EUniversal
UMEI

MARKET ENABLING INTERFACE TO UNLOCK FLEXIBILITY SOLUTIONS FOR COST-EFFECTIVE MANAGEMENT OF SMARTER DISTRIBUTION GRIDS

Deliverable 5.4:

Evaluation of market mechanisms: challenges and opportunities

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Abbreviations

ADMS	Advanced Distribution Management System
aFRR	Automatic Frequency Restoration Reserves
BRP	Balancing Responsible Party
BUCs	Business Use Cases
DA	Day-Ahead
DSO	Distribution System Operator
FCR	Frequency Restoration Reserves
FMO	Flexibility Market Operator
FSP	Flexibility Service Provider
GDPR	General Data Protection Regulation
HEMS	Home Energy Management System
ID	Intra-Day
MARI	Manually Activated Reserves Initiative
mFRR	Manual Frequency Restoration Reserves
PICASSO	Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
PV	Photovoltaic
TERRE	Trans European Replacement Reserves Exchange
TSO	Transmission System Operator
UMEI	Universal Market Enabling Interface

1. Executive Summary

This deliverable aims to evaluate different implementation options of flexibility markets from a multi-stakeholder perspective and to support the flexibility market design of the EUniversal demos. To collect the information of the different stakeholders, six internal EUniversal workshops and one workshop including both partners from inside and outside the EUniversal project were organized. Chapter 2 outlines the methodology and course of the workshops, and Chapter 3 summarizes the business use cases and key characteristics of the three EUniversal demos. The discussion and findings of the workshops are categorized into eight main design challenges that were most relevant for the EUniversal demos and four other design choices that must be considered when implementing flexibility markets, of which a detailed description can be found in Chapter 4 and Chapter 5 respectively.

Chapter 4: Main design challenges of the EUniversal demos

An overview of the eight main design choices that are most relevant for the EUniversal demos and their respective section numbering can be found in Table 1. A summary of the discussion on each topic can be found in the following paragraphs.

Table 1: Overview of the eight design choices that are most relevant for the EUniversal demos and their respective section.

Chapter 4: Main design challenges of the EUniversal demos
4.1 Why and how should we use flexible resources located at the distribution level?
4.1.1 What are the possible use cases of flexibility?
4.1.2 How should flexibility be contracted?
4.2 Where do flexibility markets fit within the existing wholesale and balancing market sequence?
4.3 What is the future role of the flexibility market operator?
4.3.1 Is there a role for an independent flexibility market operator?
4.3.2 How should activities related to flexibility market operation be divided among different actors?
4.4 How is the optimal bid selected, and which information needs to be shared to achieve this?
4.4.1 What are the alternatives to flexibility procurement?
4.4.2 What is the optimal methodology to select bids in flexibility markets?
4.4.3 How is the bid selection methodology linked with information sharing?
4.5 What products should be traded in flexibility markets?
4.5.1 Should the products traded in flexibility markets be standardized?
4.5.2 What attributes should be adopted in flexibility market products?
4.6 What baseline approach should be used?
4.6.1 Should the baseline methodology be standardized?
4.6.2 What is the optimal baseline methodology for congestion management and voltage control services?
4.6.3 Which level of aggregation of baselines is appropriate during validation and settlement of flexibility?
4.7 Who should be responsible for counterbalancing the activated flexibility bids?
4.8 How to organize markets for reactive power?
4.8.1 What products and market designs are appropriate to trade reactive power?
4.8.2 How should reactive power providers be remunerated?
4.8.3 Can reactive power be aggregated?
4.8.4 What are the main barriers to reactive power markets?

First, we tried to find an answer on **why and how we should use flexible resources** that are located at distribution level. From the discussions, we identified three reasons why the contracting of flexible resources at distribution level is currently being developed: (1) driven by national and European regulation, (2) driven by the TSO while searching for balancing, reactive power and congestion relief services, and (3) driven by the DSO's need to ensure local balance and to solve congestion or voltage control issues, while also deferring network investments. Of the different use cases, there were diverging opinions on the potential for flexibility to defer network investment in the long-term. While the majority of the participants saw big potential, some indicated that there might be no potential at low voltage levels, or no potential at all, to defer network investments as investments will always be needed alongside flexibility and in order to defer network investments, flexibility solutions should be designed in such a manner that their delivery is reliable. Also, the approach to how we should contract these flexible resources is still under discussion. Therefore, a combination of both rules-based and market-based offering of flexibility services, and short-term and long-term sourcing of flexibility might arise in the coming years.

Second, we examined **where flexibility markets would fit in the existing wholesale and balancing market sequence**. We started our analysis on a more general level by developing a reference scenario for the European electricity market sequence without flexibility markets. The reference scenario consists of a series of balancing capacity markets followed by the day-ahead wholesale market, which is based on current practices of the wholesale energy markets and the ongoing harmonization of balancing markets. Next, this reference scenario was compared to the market sequence that is currently present in the three EUniversal demo countries. Several differences between the current practice and the reference scenario were identified that were further considered through the analysis. In total, four options on the timing to integrate flexibility markets in the reference scenario were evaluated by the EUniversal partners: (1) before the balancing capacity markets, (2) between the balancing capacity markets and the day-ahead wholesale market, (3) after the day-ahead wholesale market, and (4) a continuous organization of the market along the balancing capacity and day-ahead wholesale markets. For each market sequence, several benefits and disadvantages were identified. However, it was difficult to decide on one preferred market sequence. As a general conclusion, all EUniversal demos did prefer a market sequence where the flexibility market takes place after the wholesale market such that an appropriate prediction of the network congestion needs can be made.

Next, we analyzed the **future role of the flexibility market operator**. We started our analysis by examining whether there is a role for an independent flexibility market operator. From the academic literature and the workshop discussions, both arguments against and in favor of an independent market operator were identified. Arguments against a third-party market operator are the additional layer of complexity, coordination efforts and increased management costs. It was commented that through an independent market operator, the following aspects could be improved: neutrality, transparency, the possibility to have multiple buyers and know-how of market operation that might not yet fall under the competences of the DSO. Although the role of the flexibility market operator is currently taken up in practice by both the third-party market operator as well as the DSO, all EUniversal demos will further examine flexibility markets where the market operator role is adopted by a third-party. This decision created additional discussion within the EUniversal demos as a strict separation of the different roles and activities was difficult to achieve. Therefore, the different EUniversal stakeholders were asked, for each activity related to flexibility market operation, as to whom should be responsible for each specific activity in the demos. Here, we found that the different stakeholders are aligned on the registration and prequalification phase and on the delivery and monitoring phase. However, two activities in the bidding and selection (procurement) phase were under discussion: the selection of bids and the evaluation of the impact of a bid on the grid need. As it remains unclear whether these activities

should be adopted by the independent market operator or the DSO, the EUniversal demos will test different approaches.

These different approaches were discussed in more detail by examining **how to select the optimal bid** from the flexibility markets and **which information needs to be shared** for this selection. We started by examining the existing DSO alternatives to procuring flexibility during the operation of their distribution network. The three DSOs of the EUniversal demos have access to network reconfiguration tools at higher voltage levels in their distribution grid that will be used before the procurement flexibility. Besides that, all have curtailment measures in place to be used as a last resort in case the activation of flexibility is not enough to ensure the secure and reliable operation of the network. Next, we focused on how the market-based procurement of flexibility can be organized while considering both efficient market operation and secure network operation. In general, there are four ways to select the optimal bids during market-based procurement of flexibility: (1) using an economic merit order curve defined by the market prices and quantities, (2) using a techno-economic merit order curve defined by the market prices and simplified technical constraints of the network and/or flexible resources, (3) using a complex clearing algorithm deployed by the market operator considering bid prices and the impact of the bid on the network state and flexibility need, and (4) having a selection of the bids outside the market by the DSO that aims for secure and efficient operation of the grid. From the perspective of the EUniversal DSOs, only the two latter options were considered suitable to ensure a secure network operation that can be validated by the DSOs. After thorough discussions between the EUniversal stakeholders in the context of this deliverable, it was decided that these last two options will be examined by the EUniversal demos. On the one hand, a clearing algorithm will be developed and used on the N-SIDE market platform for the Portuguese demo. Here, the impact on the network will be defined using flexibility zones in which assets are grouped (no grid topology will be shared) and a final evaluation of the selected bids will be performed by the DSO after bid selection by the independent market operator. On the other hand, all three demos will test the option where the DSO is responsible for choosing the optimal bid on the NODES platform and only limited network information has to be shared between the DSO and the independent market operator. In this case, two approaches will be considered. In the Portuguese and Polish demo, the preselection of the most optimal bids will be determined by using the DSO's own network tools. In the German demo, the optimal bid will be selected by the DSO using the Optimal Bid Recommender Tool developed by N-SIDE. Finally, it must be noted that one of the main factors influencing the final bid selection methodology was the sharing of distribution network information with the market operator, as this information is sensitive to share due to data protection (GDPR) and cyber security concerns.

Besides examining the bid selection, we aimed to find an answer on **what products should be traded in flexibility markets**. We started our analysis by examining the standardization of products traded in flexibility markets. While tailored products might not be fully technology neutral and bring more complexity to the market-clearing algorithm, they might generate more innovation and benefits for flexibility services as the products are specified to the required services and needs of the flexibility market users. In contrast, generic products are resource independent, which allows for simpler clearing algorithms, leads to improved information exchange and increases interoperability under the EUniversal UMEI setting. However, generic products might be more challenging to satisfy the required services and needs of the DSOs. For all three EUniversal demos, two separate products (for active and reactive power) will be defined that are only partially standardized. However, there is an ambition to increase standardization in the future when flexibility markets mature. At least four product attributes were considered essential by all EUniversal stakeholders and will be included in the product definition of the three demos: the minimum and maximum quantity, the minimum and maximum duration of a delivery

time interval, the activation price and locational information. However, the implementation of these attributes, as well as other attributes, might be different among the EUniversal demos.

We also examined which **baseline approach should be used in flexibility markets**. We started our analysis by discussing whether baseline methodologies should be standardized over the whole flexibility market or rather freely determined by the flexibility service provider. For all three EUniversal demos, the flexibility service provider will be free to choose the baseline methodology. Here, it was mentioned that, even if baseline methodologies are not harmonized in Europe, there might be best practices, procedures and principles to be shared among Member States. These guiding principles already exist for baselining in frequency services and state that baseline methodologies should be accurate, simple, integer and effective. However, in the context of flexibility markets, additional criteria might need to be considered compared to frequency control due to the local context of congestion management and voltage control. The following four parameters were indicated as important for the EUniversal stakeholders: the local characteristics of congestion management and voltage control, the product and asset types, data availability, and the timing of the baseline submission. Further discussions on which baseline methodology is optimal for validation and settlement in the EUniversal demos were identified as outside the scope of the project. Finally, there was a discussion on whether baselines can be defined on an aggregated level or not. Three general levels of aggregation were identified: at resource level (submeter), at smart meter level (behind the meter) and at feeder or substation level (multiple connection points). The main challenge identified in this discussion is the fact that baselines should be detailed enough to capture the local characteristics of the DSO services and should be sufficiently aggregated to reduce the impact of uncertainty in the flexibility service provider's portfolio, especially during settlement. Besides that, it was mentioned that data privacy and authorization processes would play a big role in the calculation and aggregation of the baseline.

In addition, we analyzed who should carry **the responsibility for counterbalancing the activated flexibility bids** by looking at the stakeholders' perspectives and current practices. Counterbalancing is typically not considered in current demos and pilot projects as the impact of the activated flexibility is still negligible. However, when flexibility markets become more mature and the volumes traded on flexibility markets increase, counterbalancing might become more important depending on the directions of the activated flexibility bids. In theory, the counterbalancing responsibility can be adopted by three actors: (1) the DSO, who is responsible for the imbalance due to the activation of flexible resources for DSO services; (2) the flexibility service provider (through its balancing responsible party), whose portfolio is imbalanced; or (3) the TSO, who is responsible for the final balance of the network. If we look at the current practices, we find that both the flexibility service provider (through its role of a balancing responsible party) and the DSO can be responsible for counterbalancing flexibility bids. However, the opinions of stakeholders are still divided on this topic. From the TSO's point of view, one-sided activation would be difficult as it would cause an imbalance. On the other hand, the stakeholders argue that having counteractions for every flexibility activation would make the system more expensive, while the energy volumes might not be large enough to substantially impact the TSO. There is an open question of when counterbalancing is necessary and what the thresholds should be to initiate counteractions. Besides that, it was argued that if the DSO is responsible for counterbalancing, it could negate part of the cost savings from the use of flexibility, which would be embedded in the overall system management costs that are then socialized in the electricity tariffs. The complexity of the mechanism also drives the question of who would be in charge of overseeing and validating transactions.

Finally, we examined how we should organize **markets for reactive power**. We started our analysis more generally by identifying the technical solutions and mechanisms for voltage control that are currently available in the three demo countries. This analysis showed that reactive power is typically provided through mandatory services by large power plants, capacitor banks and

transformers with automated or manual tap changers. In the coming years, voltage issues in the network might increase and reactive power services might be provided by more third-party-owned resources, such as renewables, through new market-based systems. Although these markets for reactive power are still immature, the EUniversal stakeholders shared their insights on four unresolved issues. First, although reactive power products are typically treated separately from active power products due to their specific characteristics and in order to reduce complexity, the interaction between the two products remains important to consider as the reactive power output of a resource is typically dependent on its active power output and voltage control is embedded in congestion management in the distribution grids. Second, although it is still unclear how the pricing of reactive power will be organized in a market-based setting, the following cost parameters were mentioned as important: the investment cost of the installation to provide reactive power services, the operating costs due to thermal losses in the system and the opportunity cost for active power services. Third, the aggregation of reactive power is still an open issue. However, the following aspects were highlighted as important during the EUniversal workshop: the local character of reactive power services has to be considered, the location of the flexible resources has to be known, the sensitivity factors of the aggregated bids should be similar, and sensitivity factors of the aggregated bids should be the same before and after the delivery of the reactive power service due to the non-linear character of reactive power and voltage. Finally, nine market barriers and six technological barriers to the development of reactive power markets were identified by the EUniversal stakeholders.

Chapter 5: Other design choices considering flexibility markets

An overview of four other design choices that must be considered when implementing flexibility markets and their respective sections can be found in Table 2. A summary of the discussion on each topic can be found in the following paragraphs.

Table 2: Overview of the four other design choices that must be considered when implementing flexibility markets and their respective section.

Chapter 5: Other design choices considering flexibility markets
5.1 What is the role of TSO-DSO coordination in the organization of flexibility markets?
5.2 Is there a role for the meter data operator?
5.3 Is there a role for the (independent) aggregator?
5.4 Should competition between flexibility market platforms be allowed?

First, we examined the **role for TSO-DSO coordination** in the organization of flexibility markets. As the three EUniversal demos focus on the DSO needs, the interaction with the TSO is outside the scope of the project. However, an analysis of emerging flexibility platforms in Europe shows that both DSO flexibility markets, where the DSO is the single buyer, and common flexibility markets, where both the DSO and TSO are buyers, are currently being developed. In any case, for both approaches, the interactions and information sharing between the DSO and the TSO in different stages of the flexibility market process were indicated as important by all EUniversal stakeholders.

Next, we analyzed whether there is a **role for the meter data operator**, more specifically **in the context of submetering on the consumer side**. At this moment, submetering data is mainly used to stimulate innovation at the side of the flexibility service provider and for information purposes at the consumer side, rather than to deliver services for the DSO or for settlement purposes. The reason for this is that, unlike smart meters, a regulated environment for submetering on the consumer side does not yet exist. In the future, the role of the meter data operator for submeters could be taken up by the flexibility service provider or the DSO, as long as the relevant knowledge to deal with the complexity, security and data protection issues of the validation process is ensured. In the three EUniversal demos, the calculation and storage of the

volume of delivered flexibility will be determined by the independent market operator to provide neutral handling between the DSO and the flexibility service provider. Finally, it was mentioned that regardless of who takes up the meter data operator role or is responsible for calculating the flexibility volume, the consumer remains the data owner and needs to give consent for its data to be used.

Besides that, we examined the **role of the (independent) aggregator**. First, it was discussed that with the establishment of flexibility markets, the (independent) aggregator might create new competencies such as evaluating the impact of their bids on the network, optimizing the dispatch of their portfolio over different markets and handling local constraints when providing services to the DSO. Second, the participation of low voltage customers in electricity markets might bring challenges to the (independent) aggregator. The main challenge is to reduce the impact of stochasticity at low voltage level. To achieve this, the aggregator needs to smartly include a large number of resources in their portfolio and the rules of the flexibility market must be robust to cope with the impact of these uncertainties. Finally, all EUniversal stakeholders agreed that the settlement of aggregated flexibility bids should be done at the portfolio level as too many uncertainties and errors are involved at the asset level. However, as indicated before, both aggregated and individual levels might be used in the calculation of the baseline.

Finally, we aimed to answer whether **competition between flexibility platforms** in the same network area should be allowed. Although the EUniversal stakeholders agreed that allowing competition between flexibility market platforms might bring benefits (such as price reductions, better products and diversified flexibility contracts), several disadvantages and conditions were highlighted. Disadvantages include lack of liquidity, risk of gaming, coordination issues (either between more than one market platform or between the market platform and other procurement mechanisms), risk of over and under procurement by the DSO and increased complexity for the flexibility service provider. Conditions that might help the development of competition between flexibility platforms, ensure welfare maximization and provide safe grid operation are the standardization of the interfaces, the operation of the platform by a third party, the assured availability of flexible resources and coordination on the impact of the network. Finally, it was mentioned that competition might evolve in two steps. First, multiple market platforms will arise and grow based on feedback from local stakeholders and regulatory frameworks. As a second step, multiple market operators might stay or converge to one single platform that is proven to be most efficient and practical for the different stakeholders.

2. Introduction

The EUniversal project, funded by the European Union, aims to develop a universal approach for the use of flexibility by Distribution System Operators (DSO) and their interaction with the new flexibility markets, enabled through the development of the concept of the Universal Market Enabling Interface (UMEI) – a unique approach to foster interoperability across Europe.

The UMEI represents an innovative, agnostic, adaptable, modular, and evolutionary approach that will be the basis for developing new innovative services, market solutions and, above all, for implementing the real mechanisms for active consumers', prosumers', and energy communities' participation in the energy transition. In Deliverable 2.2, the three EUniversal demos described in detail the Business Use Cases (BUCs) that will be implemented within the project to test the UMEI (Vanschoenwinkel et al., 2021). Besides that, it was specified how the implementation of the different BUCs in the market would take place. After the submission of D2.2, the BUCs and the demos were further developed, and additional insights were needed to describe certain market design aspects in more detail. In this context, Deliverable 5.4 continues the work of Deliverable 2.2 by zooming in on open issues that were not yet determined at the time of writing the deliverable. Specifically, D5.4 focuses on topics that require further refinement during and after the duration of the EUniversal project, in order to implement the proposed market solutions outside the demo context. In this regard, D5.4 is written from a multi-stakeholder perspective to get a clear overview of different challenges and solutions for the discussed market design characteristics. This was achieved through the organization of six internal EUniversal workshops and also one workshop including external stakeholders. The methodology used for the organization of the workshops is explained below.

First, six internal EUniversal workshops were organized and prepared by VITO and Vlerick. The aim of these workshops was:

- to support the EUniversal demos in developing a complete flexibility market design by offering a framework and room for discussion; and
- to align the implementation of certain design choices within and outside the EUniversal project.

Figure 1 illustrates the topics addressed in each workshop. In preparation for each workshop, VITO and Vlerick created a list of questions based on a literature review and previous experiences with the topic. These preparatory questions were sent out to the DSOs (Energa, E.ON, E-REDES, Mitnetz Strom), market operators (NODES, N-SIDE) and aggregator (Centrica) participating in the EUniversal project. In this way, information regarding previous experiences, current practices of the EUniversal demos and future outlook of the topic could be collected from each stakeholder. Each workshop was organized online, had a duration of 2 hours and involved participants from Centrica, Comillas, EASE, E.DSO, Energa, E.ON, E-REDES, Mitnetz Strom, INESC-TEC, KU Leuven, NODES, N-SIDE, Vlerick and VITO. An overview of all preparatory questions and participants lists for every workshop can be found in Annex I-1 to I-6. The preparations and replies to the questionnaires served as input for the agenda and discussions of the workshop, as presented in the remainder of this deliverable.

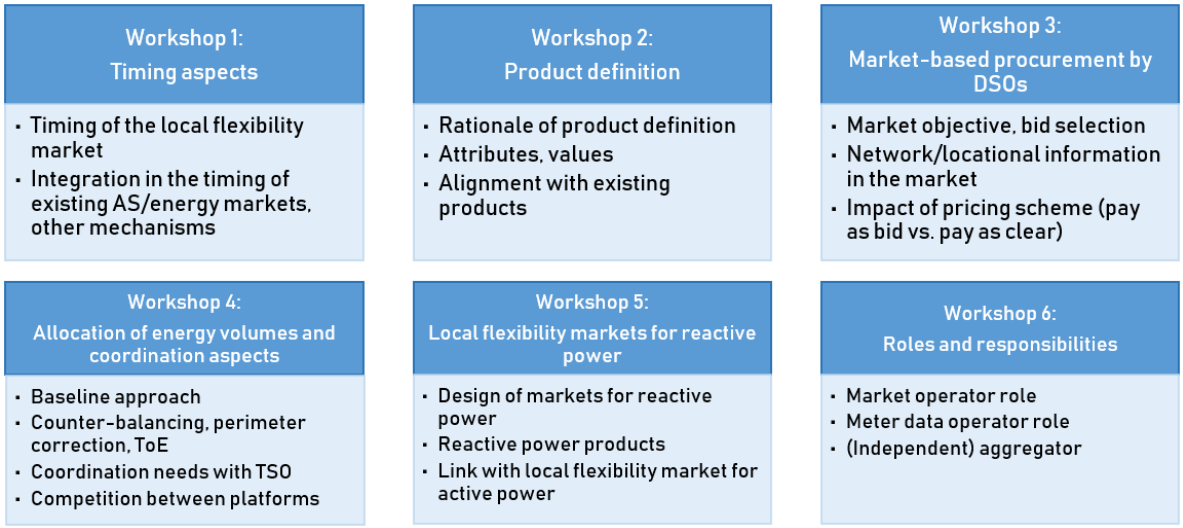

Figure 1: Overview of the topics covered in the six internal EUniversal workshops.

Second, a multi-stakeholder workshop, including both partners from inside and outside the EUniversal project, was organized in collaboration with the Vlerick DSO chair (Vlerick, 2022). This workshop aimed to build further on the discussions of the internal EUniversal workshops and bring them to a broader audience. Figure 2 illustrates the topics treated in the multi-stakeholder workshop. The workshop was an in-person event at the Vlerick Campus in Brussels and had the following participants:

- Aggregator: Centrica
- Distribution System Operators: Energa, E.ON, E-REDES, Fluvius, Mitnetz Strom, Netz-Noë, Sibelga, UK Power Networks
- Market Operators: NODES, N-SIDE
- Regulators: E-Control, VREG
- Research Institutes: Comillas, VITO, Vlerick
- Transmission System Operators: APG, Elia

Before the workshop, every participant was interviewed to understand their point of view on the discussed topics. Based on the interviews, four poll questions could be formulated that served as a basis for the flow and discussions of the workshop. An overview of the interview questions, poll questions and participants list can be found in Annex I-7, and insights of the different stakeholders on the topics will be shared in the remainder of this deliverable.

Figure 2: Overview of the topics covered in the multi-stakeholder workshop.

Finally, the outcomes of this deliverable can serve several other purposes:

- The discussions during the six internal EUniversal workshops can serve as input during the implementation of the three EUniversal demos and the continuation of the project outside the demo context.
- The discussions during the multi-stakeholder workshop can facilitate or inspire discussions on design choices on flexibility among the participants.
- The concept and preparatory questions of the six internal EUniversal workshops can serve as a basis for other research projects to facilitate open discussions between demo partners on different design aspects of market mechanisms for flexibility.
- The different stakeholder perspectives of the six internal EUniversal workshops and the multi-stakeholder workshop, including both partners from inside and outside the EUniversal project, will serve as an input for D10.5 Roadmap – strategy for the further deployment of the EUniversal solutions.
- The open issues identified on the different topics can serve as inspiration for future research and Horizon Europe projects.

3. The three EUniversal demos

This chapter consists of two parts. First, an overview of the three EUniversal demos is given based on EUniversal Deliverable 6.2 (Anderson Vazquez et al., 2021), and the two market platforms are described based on EUniversal Deliverable 7.1 (Marques et al., 2022), Deliverable 8.1 (Bockemühl et al., 2022) and Deliverable 9.1 (Matusewicz et al., 2022). Second, an overview of the general demo and key market characteristics is provided based on EUniversal Deliverable 2.2 (Vanschoenwinkel et al., 2021) and the input of the EUniversal partners. Overall, it must be noted that this summary is under the condition that the specific market designs applied in the demos will be further refined in consultation with the demo partners and depending on the needs of the specific business use cases tested.

3.1 Short summary

Figure 3 gives an overview of all Business Use Cases (BUCs) treated in the three EUniversal demos, with the focus of D5.4 indicated by the blue boxes (D6.2, Anderson Vazquez et al., 2021). In what follows, the goal and implementation of the three demos (Germany, Poland, and Portugal) and the two market platforms (NODES and N-SIDE) are summarized.

Mechanism	Service	Buyer	Product	Timeline	Aggrega-tion	Demo	Platform NODES / N-SIDE
Flexibility market	Corrective Congestion management and voltage control	DSO only	AP	Day-ahead Intraday	Yes	DE AP	✓
					No	PL AP	✓
			RP	Day-ahead Intraday	Yes	DE RP	✓
					No	PL RP	✓
	Corrective and Predictive Congestion management and voltage control	DSO only	AP/RP	Day(s)-ahead Weeks-ahead	Yes	PT 3	✓ ✓
			AP	Days-ahead Years-ahead		PT 4	✓ ✓
	Corrective Congestion management	DSO only	AP	Day(s)-ahead	Yes	PT 1	✓ ✓
	Corrective Voltage control		AP/RP			PT 2	✓ ✓
	Corrective Congestion management via flexibility of the line capacity	Producer	> RES generation than connection agreement limit	Day-ahead	No	PL DLR	✓
Bilateral contract	Corrective Voltage Control		Flexstation solutions			PL FS	

Figure 3: Overview of business use cases of the three EUniversal demos, with the focus of D5.4 indicated by the blue boxes (D6.2, Anderson Vazquez et al., 2021).

The German demo

In EUniversal D6.2 (Anderson Vazquez et al., 2021), the German demo is summarized as follows. "The German DSO is investigating the use of flexibility markets in low and medium voltage and their specific challenges. Currently, the Low Voltage (LV) grid is not monitored at all or only to a limited extent. With the increasing number of renewable generation and new flexible loads, congestion and voltage problems in the grid are becoming more frequent and observability needs to be increased. Therefore, the main objectives of the demonstrator are to increase observability and develop technical solutions for congestion management and voltage control in the LV grid with the help of flexibility markets. It is therefore important to provide accurate forecasts. The

implementation is framed by schedule-based congestion management. The calculations start day-ahead and are carried out iteratively until shortly before real-time."

The Polish demo

In EUniversal D6.2 (Anderson Vazquez et al., 2021), the Polish demo is summarized as follows. "The Polish DSO is facing specific challenges and problems in the grid area under study at all voltage levels. The key issue in the Medium Voltage (MV) grid area is congestion management and voltage control using the flexibility market. In the Polish demo, the market platform NODES will be tested with continuous trading in flexibility across distinct timeframes. The most cost-efficient solution is selected and validated by the DSO to solve the predicted grid congestion."

"The problem in the low voltage grid is the lack of observability. The LV network is not monitored at all or only to a limited extent. With the growing number of RES and new flexible loads, congestion and voltage problems in the grid are becoming more frequent and observability and controllability should be increased. The Polish demo is based on the experience acquired partially in the UPGRID project (EU Cordis, 2022), in which solutions to increase the observability of the network were tested. Therefore, the main demo goals in the area of LV grids are to increase the observability and develop technical solutions for and control voltage using an autonomously managed intelligent secondary substation (flexstation)."

"Additionally, in the Polish demo, flexibility services offered by DSO for 110 kV lines congestion mitigation purposes on the High Voltage (HV) level will be tested. The offer is dedicated to the RES energy producers where electricity production is weather dependent. It is applicable for high voltage levels 110kV lines which load capacity is affected by excessive (above connection agreement value) renewable power generation."

The Portuguese demo

In EUniversal D6.2 (Anderson Vazquez et al., 2021), the Portuguese demo is summarized as follows. "The Portuguese DSO faces some specific challenges and problems in the grid area under study. The demo intends to analyze how the penetration of copious amounts of distributed energy resources (electric vehicles, microgeneration, distributed storage) can support the grid operation regarding congestion management and voltage control in MV and LV grids. Moreover, it is planned to analyze those problems when they arise due to a contingency. The aim is to solve grid constraints by establishing an exchange between the DSO and aggregators via a flexibility market and thus make decentralized flexibility solutions accessible for grid services."

"Specifically, for the Portuguese demo, congestion management and voltage control in MV and LV grids are the key issues to be addressed. The objective is first to anticipate the problems and then use flexibility markets to solve them. Regarding the scoping of the demo, the day-ahead market (or several days in advance for maintenance actions in the distribution grid) will be considered to solve grid problems identified through forecasting, analysis, and optimization tools. Furthermore, the medium- and long-term flexibility market will be adopted for grid planning and maintenance purposes."

"In the Portuguese demo, both the NODES and N-SIDE market platforms will be tested in parallel. The NODES platform includes ShortFlex and LongFlex markets (specific NODES terminology) with continuous trading of flexibility across distinct timeframes. The most cost-efficient solution is selected and validated by the DSO to solve the predicted grid congestion. N-SIDE's flexibility market platform aims to help solve grid problems by offering an auction-based mechanism that facilitates the matching of the DSO's expressed needs with the Flexibility Service Providers (FSPs) or aggregators' offers through an algorithm aiming to maximize social welfare. It is the intention to test each BUC with each market platform."

The NODES market platform

The NODES market platform is an open, transparent, and independent marketplace that is positioned at the center of the market framework to facilitate a coordinated exchange and interaction among the various market agents covering all market-relevant processes related to registration and prequalification, trading and post-trading processes (i.e., validation and settlement). However, it is important to note that validation and settlement will not be tested during the EUniversal demonstrations as the UMEI, the standardization of the interfaces, the operational alignment of tools and services, the asset availability, and the analytical potential of the smart grid tools are more relevant features to be tested for the success of the demo, and EUniversal as a whole.

On the NODES market platform, whose structure is shown in Figure 4, FSPs and aggregators can offer different sell orders to compete on a level playing field against each other. Hence, flexibley asset owners can stack revenues across the different market necessities and sell flexibility directly to the grid operators. System operators, in turn, can address their need for flexibility (up or down-regulation) via buy orders to solve identified existing and near-future grid constraints. The bottom-up market design by NODES allows for the purchase of flexibility services across all grid levels, including ancillary services and congestion management, facilitating the effective application of available flexibility (in terms of asset type, time, location, and price) to a specific grid problem.

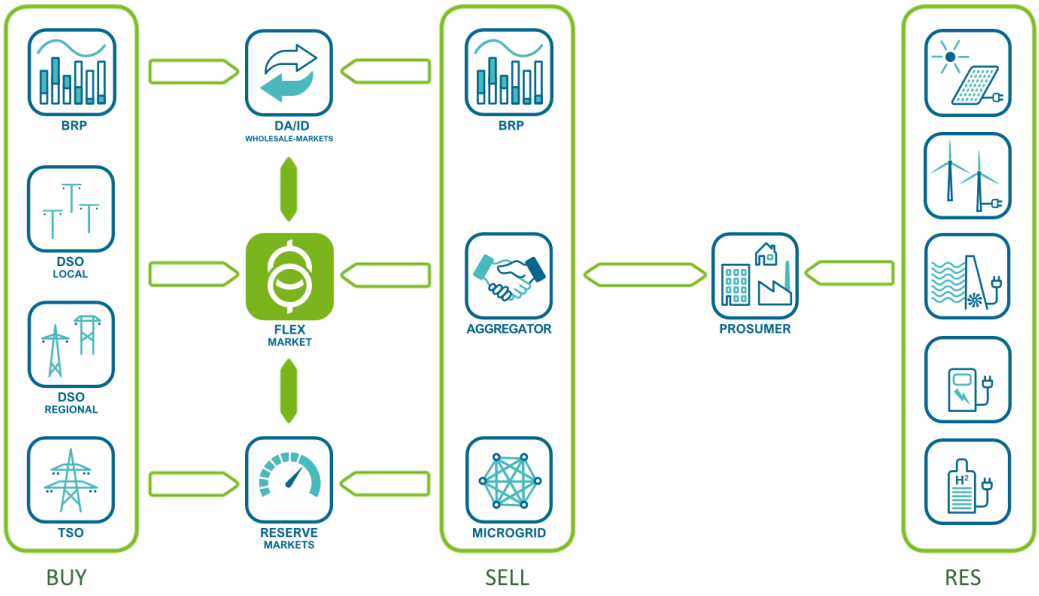

Figure 4: Interactions of different actors on the NODES market platform.

The purchase of flexibility can be performed across different market horizons, i.e., there is a short-term and long-term market, respectively named ShortFlex and LongFlex according to the NODES terminology. ShortFlex products address an immediate need for flexibility by the grid operator according to the respective short-term market characteristics that are defined in the demo-specific market design. In the ShortFlex market, NODES applies continuous market clearing (pay-as-bid) and hence, orders are matched continuously when a buy and sell order match each other's price and quantity limits. Besides that, LongFlex addresses products that can be reserved over a determined future period enabling the grid operator to activate the reserved flexibility when needed. The LongFlex procurement process on the NODES market platform is a tendering process where the DSO announces its request for LongFlex and the respective product requirements (i.e., location/grid zone, product type, time/duration/frequency,…). FSPs are then invited to submit

LongFlex offers to the DSO order, out of which the DSO can choose the most cost-efficient offer for grid management. The reservation price will be paid according to the rule book. The activation of the reserved flexibility is done via the NODES ShortFlex market, where the reserved flexibility is visible to the DSO only next to existing offers on the Shortflex market. This ensures the DSO the exclusive right to choose the best offer for the specific problem at this time.

The N-SIDE market platform

The N-SIDE flexibility market aims to facilitate the link between FSPs/aggregators and DSO bids through an auction-based mechanism that considers basic grid constraints in addition to individual operating constraints coming from market participants. To do so, the N-SIDE flexibility market uses an advanced market clearing process. With cutting-edge optimization models and algorithms, the platform can concentrate the liquidity of the market with a closed-gate mechanism before clearing it by maximizing social welfare. All this while respecting constraints shared by FSPs and system operator(s). In this way, the flexibility procurement cost of the DSO attains values close to its lowest achievable.

The timeframe for running the auction will be shared together with the flexibility needs of the DSO. The auction will run only under the condition that new needs have been shared, which allows for modularity in the clearing and ensures that no unnecessary operations are going to be performed. The flexibility needs will be defined by an internal tool of the DSO that aims to cluster the congestion and voltage issues across the various areas in an optimal way. Besides the flexibility need, the geographical area (e.g., zone or perimeter) in which the flexibility bids by FSPs/aggregators have to be situated to be effective will be shared with the market platform. To limit the amount of sensitive information, the geographical information of the flexibility need will be provided by the DSO as a list of all assets (through a unique ID) located in the flexibility zone. FSPs/aggregators can then retrieve this list from the market platform and check which of their assets can be used to place (aggregated) bids to address the flexibility need of the DSO. In this way, the geographical location of the corresponding assets is not shared on the market platform and the platform will only have visibility of the IDs assigned to a flexibility zone, preserving their privacy.

After the market clearing by N-SIDE, the accepted orders are directly accessible on the market platform by the FSP. As a result, the FSP can perform a disaggregation of the offer and obtain the individual setpoints for the assets providing the accepted flexibility offer. These disaggregated results will be sent from the FSP to the DSO such that the DSO can perform a final power flow simulation to evaluate that the foreseen flexibility activations will not introduce unforeseen constraints in their network. This data flow will be performed through email exchange. The process will end with the meter readings, which will go directly from DSO to the FSP without passing the market platform, following the Data Model of the UMEI.

3.2 General demo and key market characteristics

Table 3 and Table 4 summarize the general and key market characteristics of the EUniversal demos. The characteristics of this list were inspired by EUniversal D2.2 (Vanschoenwinkel et al., 2021) and Schittekatte & Meeus (2020). Here it must be noted that only the market characteristics of the markets for corrective congestion management and voltage control using active power products are given as they are the central part of this deliverable. More information on the other BUCs will be given in the remainder of the text when relevant (e.g., the markets using reactive power products will be described in Chapter 4.8).

Table 3: General characteristics of the EUniversal German, Polish and Portuguese demo on corrective congestion management and voltage control using active power products.

General demo characteristics	Specifications of the German demo	Specifications of the Polish demo	Specifications of the Portuguese demo
Analyzed business use case	DE-AP: Corrective congestion management and voltage control using active power products	PL-AP: Corrective congestion management and voltage control using active power products	PT1-PT2: Corrective congestion management and voltage control using active power products
Which EUniversal partners are involved?	• DSO: Mitnetz Strom, E.ON • Flexibility Market Operator: NODES • Flexibility Service Provider: Centrica • Technological partners: INESC-TEC, KU Leuven, VITO, N-SIDE	• DSO: ENERGA OPERATOR SA • Flexibility Market Operator: NODES • IT company, SCADA /DMS system provider: Mikronika • Research institute: IEN	• DSO: E-Redes • Flexibility Market Operator: NODES, N-SIDE • Flexibility Service Provider: Centrica • Technological partners: INESC-TEC, Engie Impact
What is the voltage level of the demonstrator?	LV (and MV) grid • LV: 400 V • MV: 10, 15 or 20 kV	LV, MV and HV grid • LV: 400 V • MV: 15 and 30 kV • HV: 110 kV	LV and MV grid • LV: 400 V • MV: 10kV, 15kV and 30kV
What are the grid area and grid topology of the demonstrator?	Rural, suburban area • LV rural area: radial • LV suburban area: more meshed but operated in a radial way • MV: meshed/ring • HV: meshed	Rural, suburban • LV: radial • MV: radial • HV: meshed	Rural, suburban and urban • LV rural area: radial • LV urban area: meshed • MV: mix of radial and meshed
Indication of typical grid users?	Residential and electric vehicle stations (possibly also commercial, industrial, agricultural)	Residential, SME, wind, solar and biogas generation	• LV: residential, commercial (urban areas) and electric vehicle stations • MV: Commercial, industrial, agricultural and solar and wind farms
What are typical flexibility providers?	Electric vehicles, PV systems, Batteries, Heat Pumps, Heat Storages, CHPs, Wall boxes	Li-Ion batteries, microgrids, distribution network flexible assets and control, Dynamic Line Rating, active power control of RES (windfarm, biogas power plant)	• LV: PV systems, storage systems , water heaters • MV: solar and wind farm generation units, HVAC

Table 4: Key market characteristics of the EUniversal German, Polish and Portuguese demo on corrective congestion management and voltage control using active power products.

Market characteristics	Specifications of the German demo	Specifications of the Polish demo	Specifications of the Portuguese demo	
What is the timeframe of the market?	Day-ahead, intraday	Day-ahead, intraday	Day(s)-ahead (Planned Maintenance) and Day-ahead	
Who is the buyer on the flexibility market?	DSO (Mitnetz Strom)	DSO (Energa)	DSO (E-REDES)	
What is the number of flexibility providers?			• LV: 46 FSPs • MV consumers: 13 FSPs • MV producers: 4 FSPs	
Who is the independent market operator?	NODES	NODES	NODES	N-SIDE
What is the pricing scheme?	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-cleared
What is the market-clearing?	Continuous market	Continuous market	Continuous market	Call-market

4. Analysis of the main design challenges of the EUniversal demos

In this chapter, we examine in more detail eight design questions that arise when implementing flexibility markets. The topics were identified as the most challenging in the different workshops organized in the context of this deliverable. Table 5 gives an overview of the topics that will be discussed in more detail in the following sections.

Table 5: Overview of the main design challenges discussed in the D5.4 workshops, with their respective section number.

Chapter 4: Main design challenges of the EUniversal demos
4.1 Why and how should we use flexible resources located at the distribution level?
4.1.1 What are the possible use cases of flexibility?
4.1.2 How should flexibility be contracted?
4.2 Where do flexibility markets fit within the existing wholesale and balancing market sequence?
4.3 What is the future role of the flexibility market operator?
4.3.1 Is there a role for an independent flexibility market operator?
4.3.2 How should activities related to flexibility market operation be divided among different actors?
4.4 How is the optimal bid selected, and which information needs to be shared to achieve this?
4.4.1 What are the alternatives to flexibility procurement?
4.4.2 What is the optimal methodology to select bids in flexibility markets?
4.4.3 How is the bid selection methodology linked with information sharing?
4.5 What products should be traded in flexibility markets?
4.5.1 Should the products traded in flexibility markets be standardized?
4.5.2 What attributes should be adopted in flexibility market products?
4.6 What baseline approach should be used?
4.6.1 Should the baseline methodology be standardized?
4.6.2 What is the optimal baseline methodology for congestion management and voltage control services?
4.6.3 Which level of aggregation of baselines is appropriate during validation and settlement of flexibility?
4.7 Who should be responsible for counterbalancing the activated flexibility bids?
4.8 How to organize markets for reactive power?
4.8.1 What products and market designs are appropriate to trade reactive power?
4.8.2 How should reactive power providers be remunerated?
4.8.3 Can reactive power be aggregated?
4.8.4 What are the main barriers to reactive power markets?

4.1 Why and how should we use flexible resources located at distribution level?

The aim of the EUniversal project is to examine and demonstrate how flexible resources at distribution level can resolve congestion management and voltage control issues of DSOs by using flexibility markets. However, this is not the only reasoning and approach on why these flexible resources might be activated. To examine this, the following two questions were discussed during the multi-stakeholder workshop. First, what are the possible use cases of flexibility? Second, how should flexibility be contracted?

4.1.1 What are the possible use cases of flexibility?

During the interviews in preparation for the workshop, DSOs suggested different reasons for the use of flexibility. The initiative may be driven by:

- national and European regulations;
- the Transmission System Operator (TSO) searching for balancing, reactive power and sometimes congestion relief services; and
- the DSO's own need to ensure local balance and to solve congestion or voltage control issues in their network.

First, all DSOs indicated that national and European regulations are important drivers in developing flexibility services in their network. For example, Article 32(1) of the Electricity Directive states that Member States "shall provide the necessary regulatory framework to allow and provide incentives to distribution system operators to procure flexibility services in order to improve efficiencies in the operation and development of the distribution system" (European Parliament and Council, 2019).

Second, the TSO might serve as the main driver for flexibility as TSOs are starting to consider flexible resources located in the distribution grid for balancing, reactive power and sometimes congestion relief services. This is the case of the Austrian project Industry 4 Redispatch, where industrial plants located in the distribution network will provide automated flexibility services to the TSO (AIT, 2022).

Finally, the DSO might experience the need for local balancing and the need to solve local congestion or voltage control issues, which serve as the main driver for a flexibility initiative. EUniversal D3.3 provides insights on the characterization of the main flexibility needs and solutions based on optimal power flow simulations in two test networks (Küpper et al., 2022). Here, the modeling results indicated that voltage issues are likely to appear earlier than congestions issues and that the identified issues are different in wind and photovoltaic (PV) dominated systems and typically appear at low voltage levels rather than at medium voltage levels due to an increasing share of electric vehicles and PV installations. Besides that, it was found that flexible loads and storage (i.e., electric vehicles) clearly favor the integration of intermittent renewables. Flexibility might also be used as a long-term solution for grid investment deferrals, helping to avoid reinforcing the network by using flexibility during critical hours. UK Power Networks estimates £400 million of load-related network investments between 2023 and 2028 through increased competition and the use of low voltage flexibility (UKPN, 2022). In another case, flexibility can also be used until the grid is reinforced with a new connection. In this case, the application of flexibility is envisioned to be more short-term. It is to be noted that even though flexibility is already in use in certain areas, not all stakeholders are convinced that it is a viable solution for all grid services, considering it only to be a good short-term solution while the grid is being reinforced. In contrast, others think that managing a grid with electric vehicles and much more renewables will require flexibility, otherwise, it will become too expensive for users.

In order to have a more detailed discussion on the potential of flexibility for DSO services, the following poll question was asked to the different participants of the multi-stakeholder workshop: 'Is there a potential for flexibility to defer network investments?'. As shown in the results of Figure 5, most participants replied that there is a potential to defer network investments in the long-term while using flexibility at all voltage levels. However, this view was not shared by all participants, as 25% of the responses indicated that there might be no potential at low voltage levels or no potential at all, to defer network investments. Here, it was mentioned that investments will always be needed alongside flexibility and that in order to defer network investments, flexibility solutions should be designed in such a manner that their delivery is reliable.

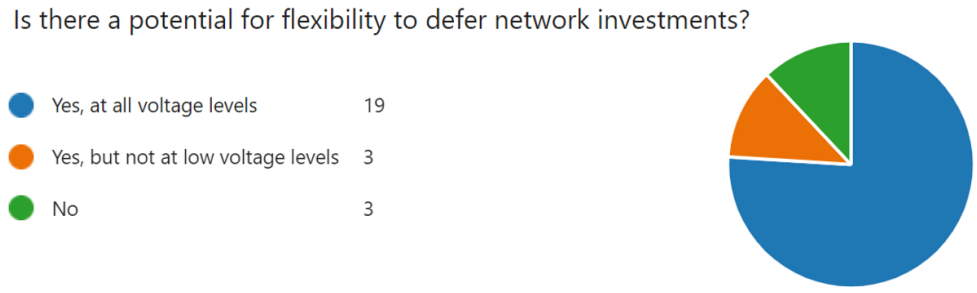

Figure 5: Answers to the first poll question posed in the multi-stakeholder workshop.

4.1.2 How should flexibility be contracted?

During the workshop, the participants were asked whether the activation of flexibility should be mandatory, voluntary, or both, and in what time frame should flexibility be contracted (short-term or long-term). The replies of the participants in Figure 6 show that most of the respondents agreed that offering flexibility should be voluntary. There are differing opinions on whether flexibility can and should be contracted in the short-term and the long-term. Some stakeholders view flexibility as being sourced in the short-term, while other stakeholders argue that flexibility should be contracted in the long-term. For example, one of the biggest barriers to using flexibility that was pointed out by the experts is that it might be uncertain, leaving the question of whether it will really be available when and in the volume that is needed. This risk may be partially hedged by entering long-term contracts for flexibility.

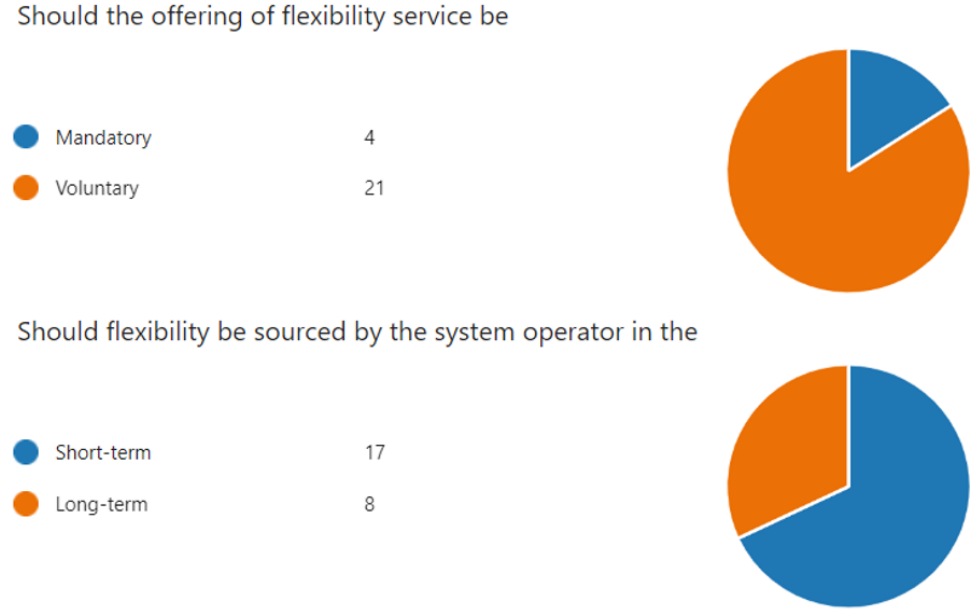

Figure 6: Answers to the second poll question posed in the multi-stakeholder workshop.

Different flexibility tools might be used for offering and sourcing flexibility, such as dynamic network tariffs, flexible connection agreements, flexibility markets, bilateral contracts and obligations. Besides giving implicit flexibility signals to grid users via dynamic network tariffs, as examined in EUniversal D5.2 (de Almeida Terça et al., 2022), system operators can contract additional flexibility in the short-term and long-term and in a mandatory or voluntary way. Table 6 maps the different flexibility tools on these two parameters.

Table 6: Mapping of the flexibility toolbox on two parameters: mandatory vs. voluntary offering of the service and short-term vs. long-term sourcing of the flexibility.

	Mandatory	Voluntary
Short-term		• Flexibility markets • Peer-to-peer
Long-term	• Obligations • Grid connection requirements (active and reactive power)	• Bilateral contracts • Peer-to-peer • Flexible connection agreements • Flexibility markets

Mandatory flexibility tools are more often used in long-term initiatives, such as obligations or grid connection rules on active and reactive power. Voluntary flexibility tools can be sourced both short-term and long-term. In flexibility markets like GOPACS and Piclo Flex, system operators can source in the short-term and flexibility service providers are typically voluntary to enter. Also peer-to-peer trading of flexibility services fall under this caterogy and are the main focus of EUniversal D5.3 (2022). During the workshop, it was argued that flexibility through connection agreements could also be categorized as short-term if the flexibility is activated in the short-term timeframe. Examples of long-term voluntary flexibility tools are bilateral contracts, peer-to-peer, flexible connection agreements and tenders for flexibility services through flexibility markets such as Piclo Flex. Here, participants agreed on the fact that flexible connection agreements should be considered as a voluntary scheme rather than a mandatory scheme as users generally have a choice (e.g., users can decide on a higher connection cost or a longer waiting period instead of entering a flexible connection agreement).

As the approach to how we should contract flexible resources is still under discussion between stakeholders, we might see a combination of flexibility tools, covering both mandatory and voluntary offering of flexibility services and short-term and long-term sourcing of flexibility, arising in the coming years. An analysis of the compatibility between flexibility tools can be found in EUniversal D5.1 (Chaves et al., 2021) and EUniversal D10.3 (Beckstedde et al., 2022).

4.1.3 Summary of the discussion

In this section, we tried to find an answer on **why and how we should use flexible resources** that are located at distribution level. From the discussions, we identified three reasons why the contracting of flexible resources at distribution level is currently being developed: (1) driven by national and European regulation, (2) driven by the TSO while searching for balancing, reactive power and congestion relief services, and (3) driven by the DSO's need to ensure local balance and to solve congestion or voltage control issues, while also deferring network investments. Of the different use cases, there were diverging opinions on the potential for flexibility to defer network investment in the long-term. While the majority of the participants saw big potential, some indicated that there might be no potential at low voltage levels, or no potential at all, to defer network investments as investments will always be needed alongside flexibility and in order to defer network investments, flexibility solutions should be designed in such a manner that their delivery is reliable. Also, the approach to how we should contract these flexible

resources is still under discussion. Therefore, a combination of both rules-based and market-based offering of flexibility services, and short-term and long-term sourcing of flexibility might arise in the coming years.

4.2 Where do flexibility markets fit in the existing wholesale and balancing market sequence?

The EUniversal project opted for a flexibility market for DSOs to procure voltage control and congestion management services from FSPs[1]. In Euniversal D2.2 (Vanschoenwinkel et al., 2021), for each of the demonstrators, BUCs were detailed, and it was described how a certain system service for the DSO is delivered through a flexibility mechanism. Nine out of ten BUCs focus on flexibility markets for DSOs. The BUC descriptions explain how the flexibility market will be realized in the different demonstrators and which interactions will be needed between the different roles. Within these BUCs, the exact timing of the flexibility markets remained, however, open. This implies that during this phase of the project, it was not yet defined how the flexibility market for DSOs would be integrated into the current sequence of electricity markets in Europe.

Proper integration of flexibility markets into the existing sequence of energy and balancing markets is important for the operation of the different market parties. However, the alignment between flexibility markets with existing markets may be challenging as they often take place in the same timeframe which that coherence between market timings, activation signals, etc., should be carefully considered. For this reason, during one of the workshops, timing aspects of the integration of flexibility markets for DSOs with existing wholesale and balancing markets were discussed.

Below we describe the findings of the workshop on the timing of local DSO flexibility markets in six parts. First, we define a reference scenario that reflects the current market sequence in Europe that does not yet consider flexibility markets. Second, we give an overview of the current market sequence in the three demo countries. Third, we evaluate four options to include flexibility markets in the reference market sequence. Next, we illustrate some of the current practices and describe the stakeholders' perspectives. Finally, we conclude with the demo preferences.

What is the reference scenario for the market sequence in Europe without flexibility markets?

For the purpose of the EUniversal project, a selection of market sequences was identified and used to guide the discussion towards key aspects that need to be taken into account, leaving further aspects for later discussion. Different market sequence options that incorporate a DSO flexibility market were considered that were created as a variation of a reference scenario.

The **reference scenario**, as shown in Figure 7, consists of the balancing capacity markets[2] followed by the day-ahead wholesale market. The choice of the reference scenario is based on current practices of the wholesale energy markets and the ongoing harmonization of balancing markets. This choice entails some assumptions with regard to the reference scenario:

- The reference scenario is based on a generalization of the current European sequence of electricity markets (following the trend of TERRE, PICASSO, MARI and FCR cooperation). Although there are some historically determined differences, all EU countries are expected to evolve towards this target model, making it a useful reference.

[1] Alternatives settings where the DSO would procure flexibility in markets together with other buyers, such as the TSO in a common market setting or where the flexibility market would be integrated with existing wholesale markets, are not considered in the EUniversal project.

[2] The 'balancing capacity markets' consist of a sequence of balancing markets with a particular order, i.e., FCR (Frequency Containment Reserves), aFRR (automatic Frequency Restoration Reserves), mFRR (manual Frequency Restoration Reserves).

- Although the different options represent a sequence of markets, there is not yet an indication of the exact clearing times of the markets. The exact timing of the EUniversal demos will be defined in their respective deliverables.
- As stated in the BUC definition in Euniversal D2.2 (Vanschoenwinkel et al., 2021), it is assumed that there is no reservation of capacity in the day-ahead (DA) and intra-day (ID) flexibility market[3]. This means that what is procured in the DA and/or ID timeframe will also be activated. A different market phase for activation is therefore not needed as it is not considered in the BUCs. Introducing forward flexibility markets (i.e., long-term capacity reservation) into the market sequence might reduce the impact of some of the disadvantages mentioned in the following sections and is considered in some of the EUniversal BUCs. This is, however, not considered in this section.

Figure 7: Overview of reference market sequence without flexibility markets.

What is the current market sequence in the EUniversal demo countries?

Below, the timing of the existing day-ahead market (DAM) and balancing capacity markets (FCR, aFRR, mFRR) in the three EUniversal demos is summarized in Table 7 based on their own inputs. In the case of **Germany**, the gate closures of the markets for ancillary services are followed by the day-ahead wholesale market and TSO redispatch markets. In **Poland**, the day-ahead wholesale market closes before the FCR and aFRR markets. Here it must be noted that currently, no mFRR market is in place and that this sequence could change in the following years with the ongoing balancing market reform in Poland. In the case of **Portugal**, balancing is still partly mandatory, but the existing markets for aFRR and mFRR occur after the day-ahead wholesale market clearing. In the remainder of this chapter, the local characteristics of the market sequences of the different demo sites will be considered.

Table 7: Timing of the existing day-ahead and balancing capacity markets in Germany, Poland and Portugal.

	Germany	**Poland**	**Portugal**
(D-45)	Gate opening DAM	Gate opening DAM	Continuous DAM until gate closure
(D-14)11:00 CET	Gate opening FCR	-	-
(D-7) 10:00 CET	Gate opening aFRR Gate opening mFRR	-	-
(D-1) 08:00 CET	Gate closure FCR	-	-
(D-1) 08:30 CET	Publication results FCR	-	-

[3] In some of the BUC considered in the Portuguese demo, the reservation of capacity is considered weeks ahead or even year(s) ahead.

(D-1) 09:00 CET	Gate closure aFRR	-	-
(D-1) 09:30 CET	Publication results aFRR	Gate opening FCR and aFRR	-
(D-1) 10:00 CET	Gate closure mFRR	-	-
(D-1) 10:30 CET	-	-	-
(D-1) 11:00 CET	Publication results mFRR	-	-
(D-1) 11:30 CET	-	-	-
(D-1) 12:00 CET	Gate closure DAM	Gate closure DAM	Gate closure DAM
(D-1) 12:30 CET	-	-	-
(D-1) 13:00 CET	Publication of results DAM (12:57 CET)	-	-
(D-1) 13:30 CET		-	-
(D-1) 14:00 CET	-	-	-
(D-1) 14:30 CET	Start iterative redispatch process up to real time	Gate closure FCR and aFRR Publication of results DAM	Publication of final results DAM (14:45 CET)
(D-1) 19:00 CET	-	-	Gate opening mFRR
(D-1) 20:00 CET	-	-	Gate opening aFRR
(D-1) 20:45 CET	-	-	Gate closure aFRR
(D-1) 21:00 CET	-	-	Gate closure mFRR Publication of results aFRR and mFRR

What are the options considered to include flexibility markets in the market sequence, and what are their pros and cons?

In what follows, we describe different options to add a local DSO flexibility market to the sequence as proposed in the reference scenario. We discuss four alternative market sequences with such a flexibility market, of which an overview is given in Figure 8.

Figure 8: Overview of the four market sequence options analyzed during the workshop.

Market sequence option 1

In the first market sequence, the DSO flexibility market takes place before the balancing capacity markets and DA wholesale market.

Integrating the DSO flexibility market at the beginning of the market sequence can bring the following **benefits** to different stakeholders:

- Flexibility Service Providers (FSPs) might benefit from the fact that they can participate in multiple sequential markets while considering the outcome of previous markets.
- FSPs are able to adjust their bids in the wholesale markets at the end of the market sequence. This argument was stated as one of the main reasons in favor of this market sequence option in the CoordiNet Swedish demo (CoordiNet D2.1, Stevens et al., 2021).
- Balancing Responsible Parties (BRPs) are able to adapt their portfolios in the DA wholesale markets, considering the trades in the TSO and DSO markets.
- DSOs might experience implicit priority access to flexibility, as the DSO flexibility market occurs at the beginning of the market sequence.

Besides that, the following **disadvantages** can be identified for market sequence option 1:

- After the flexibility market, there might be activation of bids in later markets that may create additional DSO congestion that was not anticipated in the DSO flexibility market.
- DSOs must be able to predict their network congestion needs DA, before the outcome of the wholesale market. These predictions might be inaccurate as important information on the power flow is still missing at this stage in time. As a result, there is a higher chance of needing non-market-based remedial actions or overestimating DSO flexibility needs, which may lead to over-procurement by DSOs and thus higher congestion management costs or inefficient flexibility use. It must be noted that the impact of this disadvantage also depends on the type of flexibility need that is served. The earlier the gate closure time, the more forecast errors will increase and the more difficult it becomes to make a proper assessment.

Market sequence option 2

In the second market sequence option, the DSO flexibility market takes place between the balancing capacity markets and the DA wholesale market.

The **benefits** of placing the flexibility market in the middle of the existing market sequence are similar to market sequence option 1:

- FSPs might benefit from the fact that they can participate in multiple sequential markets while considering the outcome of previous markets.[4]
- FSPs are able to adjust their bids in the wholesale markets at the end of the market sequence.
- BRPs are able to adapt their portfolios close to real-time, considering the trades in the TSO and DSO markets.

As the flexibility market still occurs before the wholesale market clearing in market sequence option 2, the same concern on the estimation of flexibility needs can be raised here. Besides that, two additional **disadvantages** were identified. An overview can be found here:

[4] As pointed out in the D1.2, the EUniversal project opted for local flexibility markets (Gouveia et al., 2021). In case integrated markets were chosen, there could be an increase in efficiency, increase in liquidity and less market fragmentation. Whether or not this is beneficial for FSPs also depends on the market and product requirements of integrated markets.

- After the flexibility market, there might be activation of bids in later markets that may create additional DSO congestion that was not anticipated in the DSO flexibility market.
- DSOs must be able to predict their network congestion needs DA, before the outcome of the wholesale market. These predictions might be inaccurate as important information on the power flow is missing at this stage in time. As a result, there is a higher chance for the activation of non-market-based remedial actions or the overestimation of DSO flexibility needs, which may lead to over-procurement by DSOs and thus higher congestion management costs and inefficient use of flexibility. It must be noted that the impact of this disadvantage also depends on the type of flexibility need that is served.
- There might be implicit priority access to flexibility at distribution level for the TSO, which might create decreased availability of local flexibility for the DSO and liquidity issues in the DSO flexibility market.
- There might be a limited time span between the balancing capacity markets and gate closure time of the DA wholesale market to organize the flexibility market. It must be noted that the importance of this disadvantage depends on the local characteristics of the market sequence and timings in every country.

Market sequence option 3

In market sequence option 3, the DSO flexibility market takes place after the balancing capacity markets and DA wholesale market. For this option, additional design choices can be made. The flexibility market can be organized as a continuous market or a series of call markets (or closed gate auctions)[5] in different timeframes (spanning the day-ahead and/or intraday timeframe).

Integrating the flexibility market at the end of the market sequence can bring the following **benefits** to different stakeholders:

- FSPs might benefit from the fact that they can participate in multiple sequential markets while considering the outcome of previous markets.
- DSOs can acquire flexibility closer to the delivery time and rely on the DA wholesale market outcome to make better network congestion predictions. In addition, aside from the DA market outcome, they have a better view of their needs due to better forecasts of weather, demand, generation and thus grid state.

Besides that, market sequence option 3 can come with the following three **disadvantages**, whose impact might be reduced by combining this option with forward flexibility markets.

- BRPs risk an imbalance in their portfolio due to activations in the DSO flexibility market. This issue is more apparent in the case of independent aggregation[6].
- There might be a risk of decreased availability of local flexibility for the DSO flexibility market, as the market occurs at the end of the market sequence.
- There is a risk that the late closing time of the flexibility market might lock out flexibility services with long start-up times, such as chemical production plants.

[5] In EUniversal D5.1, the following definition was given: "In the closed gate auction model, there are specific and predefined gate opening and closure times, corresponding to the time interval in which the market participants are allowed to trade. Following the gate closure, an auction clearing process is executed to match the buy and sell. The continuous auction model enables continuous trading by the market participants. Orders can be submitted and matched up to a specific time, defined as a duration before the service can be delivered (lead time or delivery horizon). Continuous trading is based on the first-come-first-served principle and the pricing rule is pay-as-bid." (Chaves et al., 2021).

[6] Different alternative models are possible to account for such imbalances or to counter-activate a bid to keep the balance unaltered. This topic will be further discussed in Section 4.7.

Market sequence option 4

In the last market sequence option, the DSO flexibility market overlaps at least partially with (one of) the other market segments of the reference case. Again, two additional design choices must be made: the timeframe (day-ahead or intraday) and the type of flexibility market (continuous or series of call markets).

The following **benefits** could be identified for different stakeholders:

- DSOs have the freedom to acquire flexibility at any/multiple times, based on updated information in their network.
- In addition, depending on the implementation choice of market sequence option 4, other benefits from previous options might also apply.

So far, the following **disadvantages** have been identified:

- Due to the overlap between markets, FSPs are exposed to more uncertainty and risk due to overlapping time frames, which can lead to less liquidity in the flexibility market.
- In addition, depending on the implementation choice of market sequence option 4, other disadvantages from previous options might also apply.

Looking back at the assumptions that we previously discussed in the reference scenario, some further clarifications are added below:

- As indicated, it is possible to make further alternative 'hybrid' options. Further research has to be done in this regard, yet this is out of scope for this deliverable.
- Although the different options represent a sequence of markets, there is not yet an indication of the exact clearing times of the markets. The exact timings of the EUniversal demos will be defined in their respective deliverables. It is assumed that the markets are sequential in options 1 to 3, meaning that the market outcome of an anterior market is communicated to market participants well in advance, before the gate closure of the next market. In this way, market participants can update their orders in the following markets based on the results of the preceding markets. In option 4, the DSO flexibility market runs at least partially in parallel with the balancing capacity and/or the DA wholesale markets.
- The ID wholesale market is not depicted in the four options for reasons of simplicity. The intraday wholesale market would typically open after the DA wholesale market and would thus mainly impact the sub-options to be considered under options 3 and 4.
- For similar reasons as the case of the ID market, the balancing energy market is not considered in the market sequence options. It should be noted that reserved balancing capacity cannot participate in subsequent markets.

External examples

An example of the first option is the CoordiNet Swedish demo (D2.1, Stevens et al., 2021). In the CoordiNet project, a distinction is made between local and regional DSOs, but both markets occur in day-ahead, at the beginning of the market sequence. Currently, this demo is being continued as a real-life flexibility market: the switch platform by Svenska Kraftnät and E.ON (E.ON, 2021)[7]. With regard to the second option, we are currently not aware of an existing real-life example. A first reason might be the limited time span between the balancing capacity market and the gate closure time of the DA wholesale market. A second reason might be the fact that in the market sequence of some countries, the balancing capacity market does not take place before but after the DA wholesale market clearing. Examples of this are Italy, Poland, Portugal, Spain and Sweden.

[7] Note that the Swedish example differs from our reference scenario as the balancing capacity markets occur after the national day-ahead wholesale market.

An example of the third option is one of the analyzed market options in the INTERRFACE project, which is a variation of market sequence option 3, in which the flexibility market is a continuous market in the intraday timeframe (Interrface, 2020). An example of market sequence option 4 is the NODES platform. However, it must be noted that depending on design choices, other market sequences can also be chosen for the NODES platform.

Stakeholder perspectives

In this section, we summarize the perspective of the EUniversal market operators (N-SIDE & NODES) and the DSOs of the EUniversal demos (E-REDES, Energa, E.ON & Mitnetz) to get their view on the above-described market sequence options.

From the **perspective of market operators**, there is not a strong preference for one of the options. The timing of the DSO flexibility market depends on the requirements of their customers who use their platform to procure flexibility, i.e., the DSO. Furthermore, some requirements might also be influenced by national regulations. In addition, from the perspective of the market operator, the most important aspect to be taken into account is the duration between the gate closure time, the publication time of the market results and the physical delivery of the flexibility. The following three guidelines were given for this:

- The timeslot should be sufficiently long such that an optimal solution of the market clearing algorithm can be found. How much time is 'sufficient' highly depends on the complexity of the products and details of the network constraints (see Section 4.4.2) integrated into the flexibility market.
- The timeslot should allow enough time for the FSPs to schedule the dispatch of the assets and possibly for the BRPs to rebalance their portfolio.
- The gate closure should be close enough towards delivery time to have a good estimation of the operating conditions of the distribution level.

From **the aggregator's point of view**, it was highlighted that compared to the sequential market options (option 1-3), the parallel market sequence (option 4) gives more freedom to the FSP as they can choose in which market they can participate, depending on the available type of flexibility. It would give them more options to maximize their benefit by bidding into the market(s), which ends in more revenue for FSPs.

The benefits and disadvantages of the different market sequence options summarized in the previous subsections were all confirmed **from a DSO perspective**. However, the DSOs indicated some additional disadvantages that are important to consider. For instance, in market sequence options 1 and 2, the prediction of the distribution network congestion needs to happen before the outcome of the wholesale markets. From the DSO perspective, this is unpractical as they need the outcome of the wholesale markets for their power flow predictions, which serve as a basis for the flexibility need. Without it, flexibility need estimations might be inaccurate, which increases the risk for DSOs to receive penalties that might be implemented for inefficient use of flexibility. This is especially the case for the German demo, where regulation demands cost-efficient grid management.

With respect to market sequence option 1, the Portuguese DSO pointed out that this option is not compatible with their current internal systems as the estimations of congestion are available at 3 PM, such that the congestion forecasts are as accurate as possible. As this timing comes after the DA wholesale market clearing, sequencing option 1 is less feasible to implement in practice.

Specifically for market sequence option 2, it was emphasized by the demo DSOs that the risk of having a limited time span between the balancing capacity market and the DA wholesale market should be taken into account. In the case of Germany, for example, timing is an issue as only one hour is available between the publication of the results for mFRR and the gate closure of the

wholesale market.[8] In Portugal and Poland, this disadvantage is currently seen as less important, as the balancing capacity market does not occur at the beginning of the market sequence. It was highlighted that different (voltage) levels of DSOs might have to be considered in the flexibility market (for instance, in Germany), increasing the complexity and the time needed to operate the market. This is especially complex in case the time span is limited between markets.

For market sequence option 3, it was highlighted by the EUniversal DSOs that there is a risk of decreased availability of local flexibility for the DSO flexibility market, as the market occurs at the end of the market sequence. This risk could be reduced by introducing reservation of capacity within the flexibility markets, which will be tested out in the Portuguese demo. The German demo emphasizes that this is an important route to examine as it might be the dominant option in the end. The combination with forward flexibility markets could remedy some important disadvantages. In addition, it is indicated that the DSO should take into account the timing constraints of FSPs if they want to receive a sufficient number of bids. The demos give an example of a chemical production site where, due to the internal processes, some of the decisions are made until 6 PM the day before. These points also need to be taken into account in the market timing.

Finally, with regards to market sequence option 4, the demo DSOs are concerned that FSPs might be able to bid their flexibility in multiple markets at the same time. This might create severe security issues for the distribution network, and FSPs should not be allowed to sell their flexibility twice to different parallel markets. DSOs need to be assured that if they buy flexibility, it will be delivered at the correct time and volume. This is an important design aspect to bear in mind when option 4 would be considered. For instance, market rules and market monitoring could be put in place to rule out participation in multiple simultaneous markets.

Demo preference

When asking the different demo sites after their preferred market sequence option, the following responses were given.

- For the **German demo**, it is planned to align the flexibility market with the current German redispatch mechanism involving the TSO and DSO, called Redispatch 2.0. From the previous options, market sequence option 3 with a continuous market setting and both DA and ID trading sessions (following the timing of the Redispatch 2.0 mechanism) fits best these requirements. As a result, German DSOs must make a trade-off between waiting for better congestion predictions (which is done more precisely closer to real-time) and securing sufficient flexibility in time (which might be harder closer to real-time).
- The **Portuguese demo** wants to fix the timing of the flexibility market at 3 PM CET DA as this is when they have the best estimation of the network power flow. This implies that if the balancing capacity markets are reorganized and placed before the wholesale market clearing, market sequence option 3 would be in place.
- For the **Polish demo**, it is difficult to pick a preferable market sequence as the current balancing market reform brings a lot of uncertainty and creates a lack of information on the reference scenario of existing electricity markets in Poland. The balancing reform is expected to be finalized by 2023.

[8] In the German case, this timing is dependent on the considered type of ancillary services. Respectively 3h30, 2h30 and 1h is available between the publications of the results for FCR, aFRR and mFRR, and the gate closure of the wholesale market

4.2.1 Summary of the discussion

In this section, we examined **where flexibility markets would fit in the existing wholesale and balancing market sequence**. We started our analysis on a more general level by developing a reference scenario for the European electricity market sequence without flexibility markets. The reference scenario consists of a series of balancing capacity markets followed by the day-ahead wholesale market, which is based on current practices of the wholesale energy markets and the ongoing harmonization of balancing markets. Next, this reference scenario was compared to the market sequence that is currently present in the three EUniversal demo countries. Several differences between the current practice and the reference scenario were identified that were further considered through the analysis. In total, four options on the timing to integrate flexibility markets in the reference scenario were evaluated by the EUniversal partners: (1) before the balancing capacity markets, (2) between the balancing capacity markets and the day-ahead wholesale market, (3) after the day-ahead wholesale market, and (4) a continuous organization of the market along the balancing capacity and day-ahead wholesale markets. For each market sequence, several benefits and disadvantages were identified, as summarized in Table 8 and Table 9. However, it was difficult to decide on one preferred market sequence. As a general conclusion, all EUniversal demos did prefer a market sequence where the flexibility market takes place after the wholesale market such that an appropriate prediction of the network congestion needs can be made.

Table 8: Benefits of the different market sequence options.

Benefits	Option 1	Option 2	Option 3	Option 4
Implicit priority access to flexibility for the DSO	x			depends
FSPs can participate in multiple sequential markets, considering the outcome of the previous markets	x	x	x	depends
FSPs can still adjust their bids in the wholesale market, considering the trades in the TSO/DSO markets	x	x		depends
BRPs can still adapt their portfolios in the wholesale market, considering the trades in the TSO/DSO markets	x	x		depends
DSO can acquire flexibility closer to the delivery time and rely on the DA wholesale market outcome to make better congestion predictions			x	depends
DSOs have more freedom to acquire flexibility at any/multiple times			depends	x

Table 9: Disadvantages of the different market sequence options.

Disadvantage	Option 1	Option 2	Option 3	Option 4
Higher change of needing non-market based remedial actions or overestimating DSO flexibility needs as the DSO must be able to predict their needs day-ahead	x	x		depends
Activation of bids in later markets can cause additional DSO congestion that was not anticipated	x	x		depends
Implicit priority access to flexibility for the TSO, which might decrease the availability of flexibility for the DSO		x		depends
Limited time span between balancing capacity markets and gate closure time of the DA wholesale market		x		depends
Risk of decreased availability of flexibility as the DSO flexibility market is at the end of the market sequence			x	depends
Risk of portfolio imbalance for BRPs (after nomination) due to activation by the DSO			x	depends
The late closing time of the flexibility market might lock out flexibility services with long start-up times			x	depends

4.3 What is the future role of the flexibility market operator?

One of the internal EUniversal workshops covered the topic of the future role of the Flexibility Market Operator (FMO). Although the role of the FMO is adopted by independent market operators in the EUniversal project (i.e.., NODES and N-SIDE), this topic was still considered relevant for two reasons. First, emerging market platforms do not always consider a third party as flexibility market operator, which makes it important to keep this discussion open. Second, in case of an independent market operator, discussions on how the responsibilities and activities related to market operation should be divided among different actors might arise, which we wanted to facilitate in the workshop.

This section will present the findings of the workshop preparations and the discussions during the workshop in three parts:

- the definition of the flexibility market operator;
- the role of the independent market operator and division of activities; and
- the responsibilities of the flexibility market operator.

What do we mean by flexibility market operator?

In order to define how different market parties interact in the setting of a flexibility market, a role model was set up in EUniversal D2.2 (Vanschoenwinkel et al., 2021). This led to the creation of the role of the flexibility market operator or FMO, which is described as "a neutral party that transparently provides a central service between buyers and sellers to facilitate the communication and coordination of all processes related to the procurement of capacity and/or energy bids, i.e., grid or asset registration, on its marketplace, matching of bids, validation (through market monitoring) and settlement."

4.3.1 Is there a role for an independent flexibility market operator?

In theory, a role is a unique combination of responsibilities and activities that cannot be shared between different actors (D2.2, Vanschoenwinkel et al., 2021). This implies that it must be decided whether the role of the flexibility market operator should be fully taken up by a third-party market operator, the DSO or another actor.

Certain advantages and disadvantages might arise when a third party takes up the role of flexibility market operator. Table 10 shows the results of a literature review based on the input of the participants of the internal EUniversal workshop and the previous work of INTERRFACE D3.2 (2020), EUniversal D2.1 (Falcão et al., 2021), Ofgem (2019), Standley et al. (2019) and Schittekatte and Meeus (2020). Here, it must be noted that some of the advantages of Table 10 will be considered no matter who takes up the role of the FMO, but they can be improved if an independent market operator takes up this role.

Table 10: Summary of the advantages and disadvantages of having an independent flexibility market operator based on INTERRFACE D3.2 (2020), EUniversal D2.1 (2021), Ofgem (2019), Standley et al. (2019), and Schittekatte and Meeus (2020).

Advantages	Disadvantages
• Improved neutrality/reduced conflicts of interest for balancing and redispatch • Improved transparency in bid matching • Improved communication and coordination between market players • Increased possibility of having multiple TSOs and DSOs as buyers • Increased competition and easier access for customers • Improved interoperability with other market platforms • Improved clearing algorithms, data security and encryption possibilities due to the knowledge of the market operator	• Higher coordination efforts required • Need for interface management between the DSO and the flexibility market • Sensitive data of different market parties might need to be shared with an additional actor (e.g., metering data) • Challenges regarding governance and regulation, since the responsibility for safe and efficient system operation is divided among actors • Possibly enhanced data security and GDPR complexity

Stakeholder perspectives

During the multi-stakeholder workshop, the participants were asked 'Is there a role for a third-party market operator?'. As shown in the results of Figure 9, the opinions were divided on this topic, and the participants commented that it is not a yes or no question. There is a grey area between completely externalizing the market platform to a third party and the DSO contracting a third party as a platform/algorithm provider. The division of responsibility and decisions that must be made needs to be agreed upon if there would be a third-party operator. Most participants agreed that the DSO must keep the network estimation task under their domain, as grid supervision, grid control, network operation and maintaining network security are core DSO responsibilities. However, a more detailed discussion on this will follow in the next section. Arguments against a third-party operator were that it adds a layer of complexity and cost to an already complex environment. Besides that, it was mentioned that there might not be a need for a third-party operator specified in flexibility markets as it is still a question of whether flexibility should be traded on a dedicated market or should be part of the existing markets. Arguments for a third-party operator appear in areas where there are multiple DSO interconnections, where the current stakeholders do not yet have the capabilities nor are allowed to run such a market.

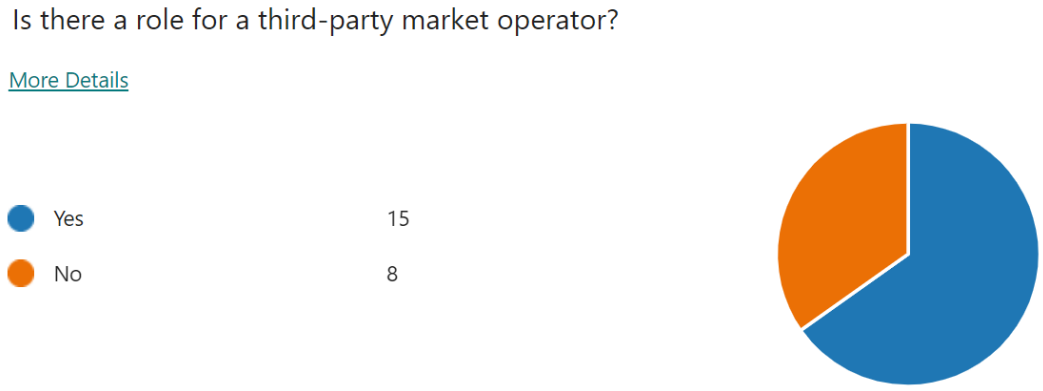

Figure 9: Answers to the third poll question posed in the multi-stakeholder workshop.

Current practices

The overview of emerging flexibility platforms in Europe, shown in Figure 10 (ENTSO-E, 2021), implies that the role of the FMO is currently adopted by both the system operator and by a third party/independent market operator (indicated by the lightbulb). Besides that, a comparison of the emerging independent marker operators can be found in Schittekatte & Meeus (2020).

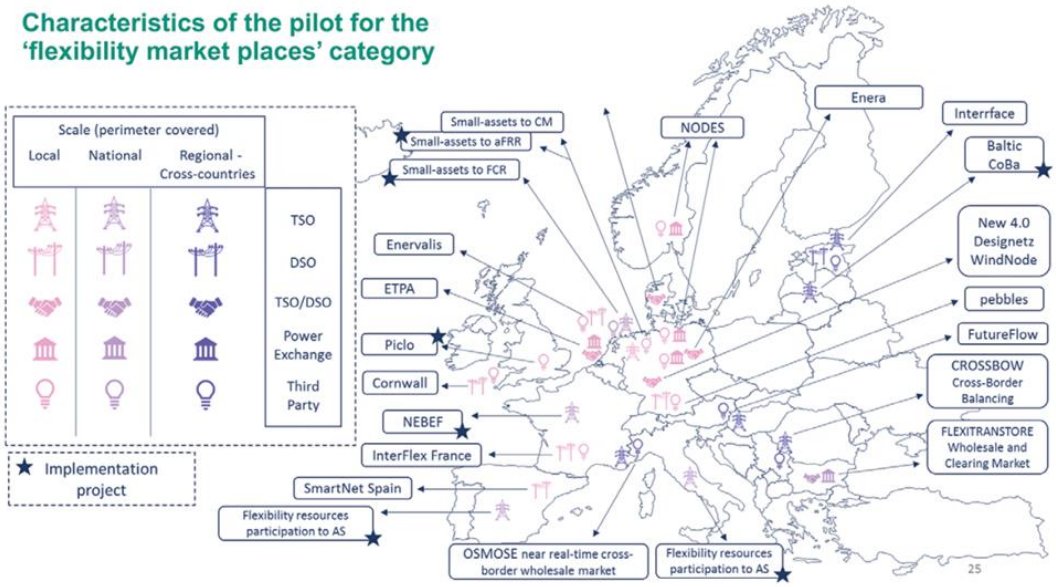

Figure 10: Emergence of flexibility platforms across EU member states (ENTSO-E, 2021).

Demo preferences

As previously discussed, the role of the flexibility market operator is adopted by the independent market operators NODES and N-SIDE in the EUniversal project.

4.3.2 How should activities related to flexibility market operation be divided among different actors?

Although the role of the FMO was described as a unique combination of responsibilities and activities that cannot be shared between different actors in EUniversal D2.2 (Vanschoenwinkel et al., 2021), in practice, a strict separation of the different roles and activities was difficult to achieve in the EUniversal demos as many activities exist and responsibilities are often shared between multiple parties. Therefore, a more detailed discussion on how the different responsibilities and activities related to flexibility market operation are divided among the different market actors was required. This section will present the stakeholder perspectives and demo preferences on this topic.

Stakeholder perspectives

Based on the existing literature and internal EUniversal workshop discussions, we found that there are at least three approaches to dividing the role of the FMO between the DSO and independent market operator:

- Identifying core activities of the DSO.
- Considering the interlinkage between market operation, network and system operation.
- Making a distinction between competitive and regulated activities.

Identifying the core activities of the DSO

CEER (2015) proposes a general framework to categorize activities as core regulated DSO activities, activities allowed under certain conditions and competitive non-DSO activities. In theory, this framework could be applied to the different activities related to flexibility market operations to define the core activities of the DSO. During the internal EUniversal workshop, it was mentioned that this approach does not yet consider the recent changes in the core activities of the DSO due to digitalization, electrification and decarbonization. It was challenged by the EUniversal stakeholders that the idea of core activities might no longer be serving these recent changes. Instead, the role of the DSO in general should be rethought towards a more active role and a system integration approach should be taken. As a result, the workshop participants were asked how the role of the DSO might evolve in the future. Table 11 gives an overview of new activities and competencies that might be taken up by DSOs in the future.

Table 11: Overview of new activities and competencies that might be taken up by DSOs in the future based on the discussion in the sixth internal EUniversal workshop.

New activities	New competencies
• Prequalification of flexible resources • Forecast grid usage (consumption and production) and identify flexibility needs • Send activation confirmation signal of flexibility with updated forecast and grid status • Define baseline and settlement calculation methodologies and promote periodic audits	• Grid analysis considering flexibility using grid data and metering data • Advanced Distribution Management System (ADMS) integration • Network analysis in different timeframes

Interlinkage between market operation and network and system operation

Two parameters considered important by Ofgem (2019) when dividing the activities of the FMO are the importance of the activity to platform operation and the link of the activity to network and system operation. Figure 11 gives an overview of the different activities that can be considered and their relation to these parameters. Ofgem (2019) finds that, at present, there is a strong reliance between the dispatch and control activities of the FMO and the network and system operation activities of the DSO. Therefore, DSOs are currently more easily taking up these activities in flexibility markets. However, it was mentioned in Ofgem (2019) that more research is needed to find the optimal division of the FMO role such that synergies with the DSOs activities can be made while considering risks such as market power and conflict of interest. During the internal EUniversal workshop, the stakeholders agreed with this reasoning but highlighted that it is slightly different from the approach considered in the EUniversal demos. Therefore, the workshop participants referred to the methodology of the DSO Joint Task Force (2021), which is described in the next paragraph.

Distinguishing competitive and regulated activities

The last approach to define the activities of the DSO and the independent market operator was mentioned in the TSO-DSO Joint Task Force (2021) on Distributed Flexibility. Here, they started from the reasoning that the market operator typically takes up tasks in the competitive domain, while the tasks of the DSO are typically located in the regulated domain. For the EUniversal demos, this approach was considered as most relevant.

Finally, it was mentioned during the discussions of the EUniversal workshop that whatever approach was considered, it is important that the division of the roles and activities is not only working in radial grids but also in meshed grids where the activation of flexibility is more complex and reliant on grid data and network operation.

		Importance to platform operation	Link to network & system operation
Coordination	Coordinating platform tasks Facilitating data flows Harmonisation of standards and principles Alignment with external platforms and markets Conflict avoidance	High	Medium
Flexibility Procurement	Attracting flexibility providers and purchasers to the market Communicating requirements and availability Matching providers and purchasers	High	Medium
Dispatch and Control	Sending signals to dispatch assets Notification of asset dispatch Verification of asset dispatch	High	High
Platform Transaction Settlement	Verification of service against transaction Settlement of transactions	High	Low
Platforms Market Services	Credit checking Asset pre-qualification	Low	Low
Analytics and Feedback	Network analytics, response times etc. Counterparty scoring and review Identification of market faults	Low	Low

Figure 11: Overview of flexibility market platform tasks, with their respective importance for platform operation and their link to network and system operation (Ofgem, 2019).

Demo preferences

For each activity of the flexibility market operator, the different EUniversal stakeholders were asked which party should be responsible for a specific activity in the demos. Table 12 gives an overview of the answers of NODES, N-SIDE, E-REDES, Mitnetz Strom and Centrica. If multiple actors could take up the role, the different options are given and additional comments are included in the table.

Registration and prequalification

Table 12 indicates that the different activities of the registration and prequalification phase are divided among the FMO, DSO, and FSP/aggregator. This implies that during this phase, close collaboration between the different actors will be required. Overall, there is consensus that the DSO sets the product and grid prequalification requirements. As other tasks are often more administrative, different actors might be eligible to take up these activities, and for some of the activities in Table 12, multiple stakeholders were indicated by the EUniversal partners. Here it is important to mention that these diverging answers are not controversial topics that still require further discussion but are rather arrangements that have to be made during the demo operations.

Bidding and selection (procurement)

From the results of Table 12 and previous discussions within the EUniversal project, the bidding and selection (procurement) phase was identified as the most disputable market phase, which consists of different activities that have to be divided between the DSO and independent market operator. This discussion is particularly relevant for flexibility markets, where issues like system security, access to local network information, possible conflicts of interest and transparency, among others, must be considered.

For this reason, the EUniversal German demo will test a new DSO tool approach called the Optimal Bid Recommender. The Optimal Bid Recommender, which is designed by N-SIDE, takes the offers present in the independent flexibility market, performs an optimization to minimize activation costs and will inform the DSO about the optimal bids in the market to serve the flexibility needs. Next, the DSO can select these bids on the market platform, where the matching happens. In this way, the bid selection is made by the system operator, which allows for global optimization of the

market while using multiple congestion management approaches or platforms and assuring a secure network operation.

Besides the DSO tool approach, a different set-up is tested in the Portuguese demo, in which the independent market operator is responsible for the procurement of activities and receives (limited) grid information from the DSO for this purpose. Here, it was mentioned during the workshop that three challenges might arise from this approach: the possibility of allowing LV customers to participate, how to deal with forecasting, and sharing simplified information in meshed grids. A more detailed discussion of the two approaches can be found in Section 4.4.

Delivery and monitoring

On the different tasks of the delivery and monitoring phase, the Euniversal stakeholders are aligned for each activity. For each activity of the delivery and monitoring phase in Table 12, a clear majority is reached on which actor should take up the responsibility. This implies that for the EUniversal demos, the activation signal will be sent by the FSP/aggregator, and the metering data will be provided by the DSO, who takes up the role of the meter data operator. Besides that, the calculation of the amount of flexibility delivered and the remuneration will be performed by the FMO.

4.3.3 Summary of the discussion

In this section, we analyzed the **future role of the flexibility market operator**. We started our analysis by examining whether there is a role for an independent flexibility market operator. From the academic literature and the workshop discussions, both arguments against and in favor of an independent market operator were identified. Arguments against a third-party market operator are the additional layer of complexity, coordination efforts and increased management costs. It was commented that through an independent market operator, the following aspects could be improved: neutrality, transparency, the possibility to have multiple buyers and know-how of market operation that might not yet fall under the competences of the DSO. Although the role of the flexibility market operator is currently taken up in practice by both the third-party market operator as well as the DSO, all EUniversal demos will further examine flexibility markets where the market operator role is adopted by a third-party. This decision created additional discussion within the EUniversal demos as a strict separation of the different roles and activities was difficult to achieve. Therefore, the different EUniversal stakeholders were asked, for each activity related to flexibility market operation, as to whom should be responsible for each specific activity in the demos. Here, we found that the different stakeholders are aligned on the registration and prequalification phase and on the delivery and monitoring phase. However, two activities in the bidding and selection (procurement) phase were under discussion: the selection of bids and the evaluation of the impact of a bid on the grid need. As it remains unclear whether these activities should be adopted by the independent market operator or the DSO, the EUniversal demos will test different approaches, which are discussed in more detail in the next section.

Table 12: Stakeholder responses to the preparatory question of the internal EUniversal workshop 'For each of the following activities related to market operation, who is in general responsible for this activity?'.

Activity	In general, who is responsible for this activity?				Additional comments provided
	FMO	DSO	DSO (meter data operator)	FSP/ aggregator	Color code: NODES N-SIDE E-REDES Mitnetz Strom Centrica
Registration and prequalification phase	-	-	-	-	-
Market prequalification (qualify flexibility resources for a given market, check financial requirements, communication tools…)					• NODES: Depending on the prequalification process, this task may involve all partners (e.g., NODES prequalifies by the characteristics that need to be provided, the DSO prequalifies the asset, the FSP is involved in the approval process and provides the service and associated data requirements). • E-REDES: The FMO provides the platform for registration, while the FSP/Aggregator is responsible for the registration process.
Product prequalification (check technical capability and validate technical requirements)					• NODES: Depending of the definition of the product, the FMO is responsible for developing a suitable flexibility service and tanslating it into a flexibility market product. Besides that, the FSP is responsible for the technical capability and insurance of service provision. • E-REDES: The DSO identifies and checks the grid connection point. • Mitnetz Strom: The DSO defines the minimum techinical criteria.
Product prequalification (Select baseline methodology)					• NODES: Currently, no baseline methodology is standardized and the FSP selects the baseline methodology. • E-REDES: The DSO provides historical data (production and consumption) and defines baseline methodology, the FSP/Aggregator calculates baseline. • Mitnetz Strom: The DSO defines the minimum criteria, while the FSP selects the the baseline methodology. • Centrica: The methodology is usually defined by the TSO, DSO or FSP (depending on the type of market) and approved by the regulator (EUniversal D5.1, Chaves et al., 2021).
Grid prequalification (check that the flexibility does not cause congestion and avoids constraint-related checks later during the procurement phase). Alternatively, this can be done during the procurement phase.				 *(in case of single FSP in that grid)	• NODES: The grid prequalification should be the responsibility of the party with most information and legal responsibility, here the DSO. • N-SIDE: No answer, as grid prequalification is part of the procurement phase. • Mitnetz Strom: Evaluation of technical connection requirements is responsibility of DSO, but is not part of the prequalification phase.
Registration on the platform					• Mitnetz Strom: The FSP is responsible to register the resources on the platform.
Set the grid/market area (can be fixed for a longer period or be determined in a more dynamic way)					• N-SIDE: Answer based on the DSO tool approach - Optimal bid recommender. • Mitnetz Strom: The DSO evaluates in which grid area flexibility is needed.
Determine the impact of flexible resources on the grid needs (e.g. via impact factors). Alternatively, this can be done during the procurement phase.				*(in case of single FSP in that grid)	• Mitnetz Strom: This activity is not part of prequalification phase but part of the DSO role description.

Activity	In general, who is responsible for this activity?				Additional comments provided
	FMO	DSO	DSO (meter data operator)	FSP/ aggregator	Color code: NODES N-SIDE E-REDES Mitnetz Strom Centrica
Bidding and selection (procurement) phase	-	-	-	-	-
Setting up a merit-order / list of orders					• NODES: It must be noted that no merit order is set up by NODES. • Mitnetz Strom: The list of flexibility offers is generated by the market operator, while the DSO evaluates which offers are optimal.
Determine the impact of bids on the grid needs (e.g. via power flow calculations)				 *(in case of single FSP in that grid)	• NODES: This activity should be the responsibility of the party with most information and legal responsibility (the DSO), or may be outsourced by the responsible party to external supply services. • Mitnetz Strom: This activity is part of the DSO role description. • Centrica: If grid topology is shared with the FSP, then the FSP could also calculate power flow and analyze the impact of bids on the grid needs.
Selection of bids					• N-SIDE: Answer based on the DSO tool approach - Optimal bid recommender. • Mitnetz Strom: The DSO specifies the flexibility requirements beforehand and the FMO then selects the bids based on these exact specifications.
Matching bids and orders					• NODES: Matching bids and orders should be the responsibility of a neutral party (FMO) ensuring transparency, security and anonymity. • N-SIDE: Answer based on the DSO tool approach - Optimal bid recommender. • Minetz Strom: Matching on the market platform based on DSO criteria.
Inform market participants of market outcome					• NODES: Considered as a service by the FMO.
Delivery and monitoring phase	-	-	-	-	-
Send activation signal					• NODES: Considered as a service by the FMO. • Mitnetz Strom: This activity is part of the FSP role description.
Providing metering data (monitoring)					• NODES: Responsibility of the FSP and/or DSO depending on its role and specific regulations.
Calculate the amount of flexibility delivered based on metering data and baseline (flex validation)					• NODES: This activity is part of the validation and settlement phase of NODES. • E-REDES: The settlement process and control is the responsibility of the DSO, while the calculation of the delivered flexibility is done by the FMO. • Centrica: The validation and settlement phase is out of scope of this project.
Remunerate/charge FSP and DSO					• NODES: This activity is part of the validation and settlement phase of NODES.

4.4 How is the optimal bid selected, and which information needs to be shared to achieve this?

According to article 31 of Directive 2019/944 (European Commission, 2019), DSOs "shall procure the non-frequency ancillary services needed for its system in accordance with transparent, non-discriminatory and market-based procedures […]". This implies that DSOs are looking into ways to procure flexibility through a market-based approach. However, "DSOs should still challenge the best solutions from a cost efficiency system point of view starting from a zero-cost solution (e.g., grid reconfiguration, etc.)" (Eurelectric, 2021). As pointed out by (Eurelectric, 2021), there are different solutions for solving DSO needs. For instance, in case of congestion scenarios, DSOs can rely on solutions such as:

- DSO implemented solutions (such as grid reconfiguration)
- Traditional reinforcement (i.e., networks and substations)
- Dynamic network tariffs
- Flexible connection agreements
- Flexibility procurement

All of them should be considered, and even a combination of options is possible (CEDEC et al., 2019; EDSO, 2014; EURELECTRIC, 2021). During the EUniversal project, the focus is on market-based flexibility procurement. However, beyond the project, it is important to compare flexibility procurement on an equal footing with alternative solutions to solve DSO needs. DSO needs are very specific and can differ a lot from each other. As such, it is important that after the identification of all DSO needs and relevant solutions, an economic assessment is done to objectively compare the different solutions.

In addition, also within a market, it is important to properly compare different bids in the market in order to select the most economically efficient bids that can solve the DSO needs. As a result, this chapter will challenge the interpretation given to 'market-based' procurement and how this will be considered by the different demos.

To support the demos beyond the project, a workshop was organized to challenge the demos with respect to alternatives between which the DSOs can choose to answer their needs (both inside and outside the market) and how they should choose between these alternatives.

4.4.1 What are alternatives to flexibility procurement?

<u>Current demo practices</u>

In D2.2 (Vanschoenwinkel et al., 2021), it is mentioned that "in terms of medium to long-term grid planning, flexibility can improve efficiency in the development of the network as it can be used as a complement or alternative to traditional grid investments." During the workshop and the EUniversal project, this medium to long-term grid planning was not looked into in detail because this topic is still new. However, a long-term market will be tested with a timeframe of weeks instead of years to fit the Portuguese demo duration.

In real-time, the situation is different as DSOs have other network management tools available that can be used to (partially) solve congestion and voltage issues in the distribution network. As such, they can be used as an alternative to procuring flexibility. For the three DSOs of the EUniversal project, the following measures are currently in place. All demos thus have alternatives available for flexibility procurement which they currently prioritize before moving to procurement.

- The **Portuguese DSO** E-REDES can use network reconfigurations such as switching options (available at MV and LV) and changing tap positions of transformers (available at HV/MV and MV/LV). Besides that, curtailment options for producers exist in case of planned maintenance and outages. The timing and amount of curtailment are usually agreed on in a bilateral contract. Typically, the curtailment is free of charge.

- The **Polish DSO** Energa can also use network reconfigurations in areas with a meshed network topology, which are typically situated at the HV level of their network. Besides that, Energa can rely upon curtailment of producers in case of planned maintenance or outages. This mechanism is supported by the Polish Energy Law, which states that producers such as wind farms can be curtailed free of charge.
- Finally, the **German DSO** Mitnetz Strom can only use network reconfigurations at HV level (>100kV) due to the meshed network topology at high voltage levels and the limited automation at lower voltage levels. Furthermore, preventive and curative redispatch and curtailment at HV level can be exercised when deviations from the network forecasts occur in the day-ahead and intraday timeframe. It should be noted this is part of a designated regulatory scheme and is not to be confused with planned outages, which are treated with a separate emergency scheme. If plant operators were unable to feed electricity into the grid due to measures pursuant to redispatch measures, the system operator in whose grid the cause for the necessity of the measures lay is obliged to provide financial compensation. The main component of the financial compensation is the compensation for the lost energy, i.e., the electricity that could not be fed into the grid solely due to the redispatch measures. To determine the financial compensation of RES plants, the lost revenues depending on the marketing form for the lost energy of all quarter hours of the redispatch measure are added, as well as the incurred additional expenses and the saved expenses are deducted. For the other generation facilities, the financial compensation may include the following components: generation expenses, pro-rata value consumption, opportunities and operational readiness expenses.

Finally, for the three EUniversal demos, current alternatives to the use of flexibility for congestion management and voltage control in the operational timeframe are typically situated at higher voltage levels. Given the focus on MV and LV levels within the EUniversal project, no alternatives to flexibility procurement will be considered in the EUniversal demos.

4.4.2 What is the optimal methodology to select bids in flexibility markets?

From the previous discussion, it became clear that there are alternative ways to solve flexibility needs. In case one opts for a flexibility market, there are many market design options that can be chosen. One of the design aspects is the market clearing procedure. That is: how does the market clearing itself take place? Market clearing is "the process that collects flexibility offers and flexibility requests, and determines trading results (i.e., price and quantity of flexibility to be traded)" (Jin, Wu, and Jia, 2020). From a market point of view, rules for selecting and validating bids should be clearly defined and made transparent to market parties. However, from a system point of view, the DSO needs to be able to validate that the procured flexibility complies with the distribution grid constraints while ensuring network security, as well as determine the contribution of flexibilities towards the need. Figure 12 illustrates these two drivers (i.e., the market and system point of view) of the market clearing procedure.

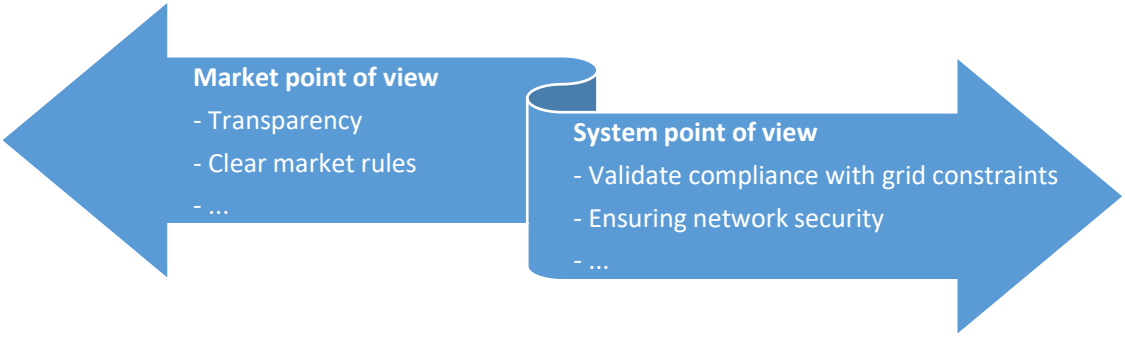

Figure 12: Drivers of the market clearing procedure.

The two drivers behind the market clearing procedure imply that proper selection of bids can be a very complicated process. For instance, in order to validate compliance with grid constraints, it is necessary to have sufficient network information to select the appropriate bids for congestion management and voltage control. This network information is not always (publicly) available to all market parties but is often only visible to the DSO. Therefore, it is possible or even needed in some cases that the DSO is also involved in the selection of flexibility to be procured. This is also indicated in EUniversal D5.1 (Chaves et al., 2021), where it is pointed out that the DSO should be in charge of the optimization process in the cases in which, to achieve the most efficient results, the market-clearing depends on comprehensive grid data that cannot be shared outside of the DSO boundaries for regulatory reasons. Therefore, for the purpose of the EUniversal project, we introduce the terminology of "bid selection". More details about this phase can be found in D5.1 (Chaves et al., 2021).

What do we mean by bid selection methodologies?

Generally speaking, there are 3 different methodologies to select bids: (1) using merit order curves defined in the market, (2) using complex clearing algorithms by the independent market operator, and (3) having an internal selection of the optimal bid by the DSO.

First, the method most used is **the merit order**. In a merit order, bids are ordered according to some parameters. Bids are selected/prioritized in order: first the first bid is selected, then the second, etc. There are different types of merit orders, depending on the parameters used to order the bids:

- The economic merit order orders all bids based on their marginal price.
- The technical merit order takes into account technical aspects, such as the geographical location of the provider that should be considered in the bid selection, to ensure grid and system security (CEDEC et al. 2019).
- The techno-economic merit order is a combination of the previous two merit orders, which takes into account both marginal price and technical aspects.
- The socio-political merit order takes into account other considerations such as environmental impacts, perceived risks and trust, legislation, employment, and implementation hassle.

Which merit order is the most appropriate depends on the needs and services considered. In case of activation for balancing purposes, bid selection follows the well-established economic principle (economic merit order). If bids are activated for congestion management purposes, bids cannot be chosen based on their price tag only, since the sensitivity to the occurring congestion might differ. More information is needed, and therefore a technical merit order would be more appropriate.

Second, there is the option of a **clearing algorithm** that takes into account additional information and which is run by the (independent) market operator (the algorithm does the matching in the market based on the available information).

Third, the **DSO does an internal optimization** by taking into account the necessary information and, as such, selects the bids itself outside the market.

What bid selection methodologies are relevant for flexibility markets, and what are their benefits and disadvantages?

From the bid selection methodologies discussed in the previous paragraphs, we can evaluate which methodologies are most relevant for flexibility markets. Here it must be noted that an additional division in these methods was made depending on the extent to which information on grid constraints needs to be shared. As a result, three bid selection methodologies relevant for flexibility markets were identified in preparation for this workshop based on the underlying bid

selection methodology, the type of data that needs to be considered and who has access to these data. The three options are now explained in more detail and summarized in Table 13. Furthermore, we also discuss the benefits and disadvantages of each option, which are summarized in Table 14.

Table 13: Overview and summary of the three bid selection options

Bid selection option 1	Bid selection option 2		Bid selection option 3
Economic merit order	(2a) Techno-economic merit order	(2b) Techno-eco optimization inside the market	Techno-economic DSO optimization outside the market
FSP submits bids based on which (together with reserved capacity bids from previous markets) a merit order list is made based on prices.	FSP submits bids that (together with reserved capacity bids from previous markets) are linked to additional information, which is used to create a merit order list (2a) or as input for a more advanced clearing algorithm by the market operator (2b)		FSP submits bids that (together with reserved capacity bids from previous markets) are extracted from the market by the DSO. The DSO does an internal optimization to select the bids.

Table 14: Overview of benefits and disadvantages of the three bid selection options.

Bid selection option 1	Bid selection option 2	Bid selection option 3
Benefits: • Simple calculation • Transparent for the market participants	Benefits: • Can consider multiple constraints (both FSP and network related) • The market platform has all information to do the matching, which can increase FSP trust	Benefits: • Can consider multiple constraints and alternative options at the DSO side (also info that cannot be shared with the market platform) • The final choice lies with the system operator, who is responsible for secure system operation
Disadvantages: • Does not account for dynamic constraints • The impact of flexibility on the DSO need cannot be considered, so not appropriate for congestion and voltage management	Disadvantages: • Computational complexity • Depending on the complexity, transparency for the market participants can be lower • Need to share network information	Disadvantages: • Computational complexity • Tends to be less transparent for the FSP

Bid selection option 1 represents an economic merit order in which bid selection is based only on the market prices. An example of this is the day-ahead wholesale market clearing. The benefits of this option are the simplicity of the bid selection and transparency of the market outcome for market participants. The main downside is that this option does not consider additional constraints. If this method would be applied for a flexibility market and would be defined at a local scale (e.g., at substation level), it could, in theory, be used to solve DSO needs on the condition that no additional information on the impact of the activation of certain flexible resources on the DSO needs would be needed. As explained before, this is not the case for the BUCs considered in the EUniversal project. As a result, a pure economic merit order curve is not considered a feasible solution for the BUCs tested within the demonstrator and will not be considered in the remaining of this chapter.

Within **bid selection option 2,** in addition to economic parameters, also technical constraints are considered in the bid selection. This can be achieved in two ways: (a) additional information is used to make a techno-economic merit order list, or (b) the information is used as input on the platform for a more advanced clearing algorithm of the market operator. In option 2, bid selection takes place on the market platform itself. An example of option 2b is the Cornwall project (Centrica, 2020). The Cornwall LEM platform is an auction-based flexibility market platform to procure flexibility simultaneously (by DSO/TSO) through closed-gate, pay-as-clear auctions. In the Cornwall project, the headroom[9] of network lines is considered in the N-SIDE market clearing algorithm to activate the optimal flexibility bids that maximize total welfare while solving the DSO needs. The N-SIDE market clearing algorithm manages asset and network constraints by taking into account distribution network capacity (dynamic headroom optimization) in the optimization algorithm. The result is that all contracts are compliant with any network constraints and technical constraints so that distribution network limits are not violated. In general, this would require a considerable level of data sharing from the DSO, but in the Cornwall project, all network data needed was publicly available and could be used by N-SIDE. Also, in the Portuguese demo of the EUniversal project, the N-SIDE platform will be used. Here, bid selection option 2b is realized by the creation of the FlexZone concept.

Benefits of option 2 are that additional network constraints can be considered during the bid selection (both from the network and from the FSP point of view) and that a neutral market player does the matching while taking into account the welfare of all market parties. In addition, the market platform has all information to do the matching, which can increase FSP trust as the selection can be made on the market operated by a neutral market operator. Disadvantages are the computational complexity of the market clearing, which can impact transparency for market participants compared to bid selection option 1 (certainly if one moves to option 2b). Furthermore, technical or grid constraints can only be accounted for if the necessary data can be shared. However, the DSO is the final party responsible for system security, and it is a risk for them to share crucial network information. In addition, some data cannot be shared due to legal reasons or are hard to share in the case of meshed networks where grid sensitivities are harder to determine. The latter is the reason why the German demo opted to go for an internal optimization tool to select the final bids outside the market (option 3). Also, the DSO might have additional information linked to construction sites, other technical solutions, maintenance plans, etc., which only they could account for themselves. Finally, depending on the complexity, transparency for the market participants can be lower.

Bid selection option 3 is a techno-economic optimization by the DSO, which performs an internal network optimization outside the market platform. This option will be developed in the EUniversal demos. The NODES platform will be used in all demos of the EUniversal project to collect all the different bids, while the DSO will be responsible for the bid selection. In the German demo, the DSO will use the N-SIDE Optimal Bid Recommender to identify the optimal bid, in combination with the NODES market platform, to do a virtual market clearing as an internal DSO tool. As such, the DSO can add more detailed network information within the tool that is not shared with the market.

Benefits of this third bid selection option are that network-related constraints can be considered during bid selection, including information that cannot be shared with external stakeholders, and other alternative options that the DSO has for solving the considered needs, which can be evaluated together. The final bid selection lies with the DSO, who is also responsible for secure system operation. The optimization focuses on cost minimization from the perspective of the DSO. While choosing between two different bids, the DSO will choose the most cost-efficient one if all

[9] The available capacity of a specified grid node (Centrica, 2020).

other conditions are fulfilled, meaning that the optimal bid selected by the DSO may not be the most favorable for the FSP, as it takes further into account aspects like grid resiliency and quality of service. Disadvantages are the computational complexity of the DSO optimization, which occurs outside the market platform. As a result, the bid selection might not be as transparent to other market parties (FSPs) compared to the other options.

Stakeholder perspectives

In what follows, we discuss the different options from the perspective of market operators, DSOs and the aggregator. Note that the discussion focuses mostly on bid selection options 2b and 3 as these options are considered as most relevant from the perspective of the EUniversal demos.

From a **market operator perspective**, the following insights were given on the preferred bid selection methodology in flexibility markets.

- The market operator N-SIDE gives two reasons why, from their point of view, bid selection option 2b is preferred over bid selection option 3. First, option 2b allows for a multi-buyer platform because other buyers (e.g., TSO can be integrated into the market), while this is more difficult to achieve under option 3[10]. Second, when N-SIDE is responsible for bid selection under option 2b, the costs and benefits of both FSPs and DSOs can be included, and total welfare can be maximized in the market clearing (under option 3, the DSO only does a maximization from its own perspective). The market outcome might be different from the bid selection under option 3, where the DSO is responsible for the market clearing and the FSP perspective might be less considered. Given the fact that FSPs do not receive all information, they might make a less optimal bid offering. The size of this problem and the actual impact of the market clearing agent on the final market outcome was identified as an interesting topic for future research during the workshop.
- In addition, N-SIDE emphasizes that if option 2b is selected, further important market design choices such as product definition, pricing scheme and auction type must be made to guarantee an efficient market outcome. Most of these design choices are covered in the different workshops of this deliverable.

From the **aggregator perspective** of Centrica, it was mentioned that the optimization of the aggregator portfolio is less dependent on the bid selection. Information sharing is, however, considered very important as it might influence the bids that they will offer. For instance, in case of voltage issues, they can take the customers at the end of the feeder, as they would know that they are more important to the offer. Adding them to the offer would also increase their chance of being selected.

From **a DSO perspective**, the following reasons were mentioned on why, from their point of view, bid selection option 3 is preferred over option 2b.

- If the DSO is responsible for the bid selection, cost minimization of network operations can be assured as alternatives such as network reconfigurations, curtailment measures and DSO-owned flexibility can be considered in the market clearing.
- Bid selection option 3 is preferred since DSOs are legally responsible for the security and appropriate functioning of the distribution network. When the DSO is in charge of the market clearing, recent developments in the network, such as maintenance or planned outages, can easily be considered, which is not the case under bid selection option 2 since sensitive network data cannot be shared. Therefore, the bid selection of the market operator under option 2b must always be confirmed by the DSOs for security reasons, which may increase the workload.

[10] In the EUniversal demos, only a single buyer of flexibility is considered, i.e,, the DSO.

- Data sharing is an indispensable need for design choice 2, while DSOs need to ensure system security, which may impede the sharing of more sensitive data. Therefore, the possibility of sharing the needed data is an important driver in choosing between different design options. As an example, the German demo did not opt for the market-based implementation of the N-SIDE platform in their demo because it was legally questionable to share the needed data to do this.
- Option 3 might be preferred due to the fact that there is no need for double work (for instance, when it comes to data sharing or verifying whether the outcome of the market clearing is not causing additional constraints).
- It was mentioned that total welfare can still be maximized under option 3 if appropriate incentive regulation is in place.

The DSOs see an "order" in the design options ranging from only economic parameters in design choice 1 to both economic and technical parameters in design choice 2, to mostly technical parameters in design choice 3. Furthermore, the DSOs also see "hybrid" options in the sense that the Portuguese demo falls in between option 2b and option 3. That is, in the Portuguese demo, after the market optimization model has done the matching, the DSO will rerun the final solution inside their own systems to confirm that the outcome does not cause network constraints for their own grid. Furthermore, behind each design option, there are still sub-design options that need to be decided on. For instance, in design option 2, one has the option as a buyer to make an explicit bid (blind auction or not), revealing more or less information to the FSPs.

In general, it is also highlighted that while design option 2 might lead to the most socio-economic efficient outcome, within the EUniversal project, there is only one buyer. Therefore, at demo-level, this effect is not predominant.

Furthermore, the importance of the network topology for the bid selection in flexibility markets was emphasized by the DSOs (an overview of the network topology of the demo can be found in the introductory chapter). In general, two types of grid topologies appear in distribution networks:

- Radial grid topology, which is characterized by network lines that are structured in a tree shape, typically does not contain closed loops. In a radial network, DSOs can usually make a good approximation of the line limits. In a radial grid, the change of topology is really low. Also, the influence of each individual FSP is more easily determined than on a meshed network.
- Meshed grid topology, which is characterized by network nodes that are interconnected to one another, typically consists of a lot of closed network loops. In meshed networks, it can be complicated for DSOs to get a good approximation of the line limits as they are very dependent on the power flows in the network. Despite the limited network visibility, there are a lot of possibilities to change the network topology (e.g., via network reconfiguration), and the redispatch N-1 security rule can be achieved by various options.

Demo preferences

As a result, from a demo perspective, it was indispensable that the DSOs at least had a final saying in the bid selection in case the bid selection takes place in the market or that the DSO was fully responsible for the bid optimization outside the market platform. The main reason for this is linked to the fact that DSOs cannot simply share all data required for optimal bid selection. Data sharing will be discussed in more detail in the section below. Meshed grids are more difficult to manage, even though they bring a lot of benefits (more loads and renewables can be integrated).

How exactly bid selection will take place in the demos depends on the market platform to be implemented. In the EUniversal project, there are two platforms which are described below according to information in D7.1 (Marques et al., 2022), D8.1 (Bockemühl et al., 2022) and D9.1

(Matusewicz et al., 2022) and in Chapter 3 of this deliverable. Below we focus in more detail on how bid selection is taken care of in these platforms, and a summary of the demo preference can be found in Table 15.

Table 15: Overview of the bid selection methodologies in the EUniversal demos.

	PT demo NODES platform	PT demo N-SIDE platform	DE demo NODES platform	PL demo NODES platform
Responsible for bid selection	DSO	Market operator	DSO	DSO
Network topology	Rural, suburban and urban • LV rural: radial • LV urban: meshed (radial operation) • MV: mix of radial and meshed (radial operation) • HV: meshed/ring		Rural, suburban • LV rural: radial • LV suburban: more meshed but operated in a radial way • MV: meshed/ring • HV: meshed	• Rural, suburban • LV: radial • MV: radial • HV: meshed
Bid selection option	Option 3: DSO optimization outside the market platform	Option 2b: Market operator's welfare maximization algorithm cleared inside the market, final evaluation by DSO outside the market	Option 3: DSO optimization outside the market platform	Option 3: DSO optimization outside the market platform
Network representation used during bid selection?	NODES tool creates an image of the grid area by uploading geographic coordinates of the grid area or by drawing a polygon	An internal tool determines which set of FSPs can resolve a need	NODES tool creates an image of the grid area by uploading geographic coordinates of the grid area or by drawing a polygon	NODES tool creates an image of the grid by uploading geographic coordinates of the grid area or by drawing a polygon

First, **the NODES platform**. When it comes to the actual trading part, the DSO submits buy orders based on the information they have (congestion, the price they want to pay…) and specifies the respective product requirements (i.e., location/grid zone, product type, time, duration, frequency of the flexibility need as well as a reservation and the maximum activation price the DSO is willing to pay). FSPs are then invited to submit offers to the DSO order based on the information they have (the available flexibility, their assets…) out of which the DSO can choose the most cost-efficient offer for grid management purposes. The reservation price will be paid according to the rule book. The activation of the reserved flexibility is done via the NODES ShortFlex market, where the reserved flexibility is visible to the DSO next to existing offers without reservation on the Shortflex market. This ensures the DSO the exclusive right to choose the best offer for the specific problem at this time. The NODES platform, as applied in the three demos, allows for DSO optimization outside the market platform. FSPs submit bids that (together with reserved capacity bids from previous markets) are extracted from the market by the DSO. The DSO does an internal optimization to select the bids and communicates this to the market platform.

Second, **the N-SIDE platform**. On the N-SIDE platform, FSPs submit bids that (together with reserved capacity bids from previous markets) are linked to additional information (assets constraints (by FSPs/Aggregator) and network constraints (by DSO)), which is then used as input for a more advanced clearing algorithm. The auction will be run only under the condition that new DSO needs have been shared, matching the offers shared from the FSPs with the DSO orders. This allows for modularity in the clearing and ensures that no unnecessary operations are going to be performed. Iteratively, the DSO will solve through its internal tool an optimization problem

aimed at clustering the congestion and voltage issues across the various areas. The result is the flexibility need necessary to clear the congestion and a Flexibility Zone that consists of a set of FSPs in the grid area that can provide flexibility and solve this congestion. Some of these problems could be cleared, providing flexibility from different zones. In that case, an implicit sensitivity parameter is going to be provided by the DSO to adequately dispatch the assets based on the impact they would have on the congestion or voltage problem. Furthermore, to limit the sensitive information shared with the market platform, the DSO will provide a list of flexible assets (through a unique ID) contained in each zone. This information is captured directly from the market platform by the FSPs, after which the received bids are aggregated from individual assets and an aggregated bid is generated for the zone. This way, the geographical location of the corresponding assets isn't shared on the market platform, preserving their secrecy. The platform will only have visibility over an ID of the assets assigned to a flexibility zone. These aggregated orders are shared on the market platform by the FSP. After having cleared the market and having obtained the accepted orders, these are fetched from the FSP directly on the market platform to perform a disaggregation and obtain individual setpoints for the assets participating. These final disaggregated results will be sent from the FSP to the DSO to perform a final validation.

Specifically, for the Portuguese demo with the N-SIDE platform, it is only the DSO who is aware of the grid topology and therefore is the only party entitled to validate the bid selection. Grid constraints are, however, accounted for in the market clearing due to an internal DSO tool that determines 'zones' of FSPs which have different sensitivities. This information on groups of FSPs is sent to the market platform. In addition, on the DSO side, an internal power flow algorithm will run to detect constraints. This information will be mapped to the FSPs to determine which ones can help solve that specific problem. The market platform will run only with the FSPs that can solve those constraints. For the Portuguese demo, this is possible because they have a radial network operation.

4.4.3 How is the bid selection methodology linked with information sharing?

From the previous discussion on bid selection strategies, it became clear that there is a difference in terms of information sharing needs between the different options, which are linked to the underlying reasons to go for one option or the other. Especially the question of which locational information should/could be shared between different market parties, which was an important topic of discussion. The following perspectives were given by the market operators, aggregators and DSOs of the EUniversal project.

Stakeholder perspectives

From a **DSO perspective**, for security reasons and to avoid gaming, there is network information that DSOs cannot share with market operators and flexibility providers. In general, all demos agree that grid topology data cannot be shared for reasons of data protection and cyber security (GDPR) reasons. There is, however, a distinction between data that can be shared with the market operator and the FSPs. In the Portuguese demo, the FSPs cannot have access to non-participant data[11] due to GDPR. In the German demo, the FSP cannot have access to the cost of other flexibility bids and other congestion measures to ensure that there remains competition for the most efficient solution (decreasing the risk of gaming). In the Polish demo, financial data on individual auctions cannot be shared to maintain market competitiveness (decreasing the risk of gaming) and transparency. A summary of the DSO perspective is given in Table 16.

[11] With non-participant data, we refer to consumers in the network area of the demo that do not participate in the business use cases of the demo.

Table 16: Overview of information that cannot be shared with the market operator and FSP from the DSO perspective.

	PT demo NODES platform	PT demo N-SIDE platform	DE demo NODES platform	PL demo NODES platform
Which info will not be shared with the market operator and the FSP? And why?	Grid topology for data protection, cyber security and reliability reasons	Grid topology for data protection, cyber security and reliability reasons	Grid topology for data protection, cyber security and reliability reasons	Grid topology for data protection, cyber security and reliability reasons
Which additional info will not be shared with the FSP? And why?	Non-participant data due to GDPR issues regarding non-participant data	Non-participant data due to GDPR issues regarding non-participant data	Cost of other flexibility bids and other congestion measures to ensure competition for the most efficient solution	Financial data on individual auctions to maintain market competitiveness and transparency

From the **market operator's point of view**, additional information might be useful to take into account more constraints. For instance, grid information might be useful in function of checking the feasibility and relevance of the flexibility market outcome. The N-SIDE platform can integrate detailed or limited network data, depending on the use case of the flexibility market. For the EUniversal demos, two tools will be developed that require different levels of grid information. However, the N-SIDE market platform can take multiple forms depending on the information shared and the functionalities performed. This deliverable makes a distinction between N-SIDE as a market platform and N-SIDE as an Optimal Bid Recommender Tool for the DSO. However, depending on the implementation, in theory, data requirements for both implementations could be similar. In all implementations, bids need information on price, quantity, location and time.

- For the Portuguese demo (option 2b), in the case of the N-SIDE market platform, the clearing takes place on the market, implying that detailed grid information is needed. This could be data such as network connectivity data, information on topology, and data for congestion modeling. In practice, in the Portuguese demo, it was not possible to share such detailed grid information with the market platform. Instead, what will be shared is a set of FSPs and a set of parameters that will facilitate the selection process made by the FMO. Which and how this information will be provided by the DSO is part of the UMEI Flexibility Zone definition. As of writing this deliverable, it was discussed that grid constraints are accounted for in the market clearing due to an internal DSO tool that determines 'zones' of FSPs. This information on groups of FSPs is sent to the market platform. First, the DSO runs a set of grid analysis tools to detect constraints. This information will be mapped to the FSPs to determine which FSPs can help solve that specific problem. Second, the N-SIDE market platform will run the algorithm considering the different zones. The need for each zone will be met utilizing the FSPs, which can support optimally. For the Portuguese demo, this is possible because they have a radial network operation.
- In all demos, the NODES platform will be implemented. Depending on the perspective, the NODES platform might fall under option 3 or under a sub-option of option 2. When it comes to the actual trading part, the DSO submits buy orders based on the information they have (congestion, the price they want to pay…), and the FSPs submit orders based on the information they have (the available flexibility, their assets…). All FSP orders are anonymous, and the market is cleared by a set of very clear rules. They are sorted by price, and each buy order is matched with a sell order if they are equal in price, time and locality. However, the DSO buy order submission is based on an internal DSO optimization where

the DSO decides on the grid topology. This allows the DSO to create an image of its grid with the granularity chosen by itself in a way that it considers most efficient without providing sensitive data to anyone in the market and neither to NODES. This hierarchy is created before the prequalification and remains static for the demonstrations. As such, in the demos, the grid area is defined by the DSO, given by uploading the geographic coordinates of the grid area or by drawing a polygon (avoiding the need to have detailed coordinates). Finally, the DSO needs to submit the location by submitting a buy order with the needed quantity and price into an order book. In general, for the NODES platform, no sensitive information needs to be shared with the market operator. The NODES approach is based on the idea of acting as a middleman in the value chain without interfering with the different responsibilities and business responsibilities of the respective stakeholders operating on the market platform. It enables stakeholders to find a solution while only sharing a limited amount of information.

- For the German demo, N-SIDE will develop the Optimal Bid Recommender, which is a tool that helps the DSO to optimize their bid selection under option 3. More detailed information can be added as input in this tool. As this tool consists of a virtual market clearing that will be performed by the DSO, no detailed grid information has to be shared with the market operator.

Table 17 gives an overview of the solutions for the needed network information that would be required from the perspective of the market operator in order to run the tools of the EUniversal demos.

Table 17: Market operator's perspective on locational information required on the market clearing in different use cases of the EUniversal demos

PT demo N-SIDE platform	DE demo N-SIDE Optimal Bid Recommender	DE, PL, PT demo NODES platform
• No grid topology is shared with the FMO • A set of FSPs and a set of parameters that define flexibility zones is determined.	• Virtual market clearing, so no detailed information needs to be shared with the market. It remains within the DSO sphere.	• No sensitive network information needs to be shared. The grid area is defined by the DSO, given by uploading the geographic coordinates of the grid area or by drawing a polygon as an orientation (avoiding the need to have detailed coordinates).

From **the aggregator perspective**, the information on the left side of Table 18 is shared between the DSO and the FSP in an ideal scenario. Here it must be noted that with smart meter data, we mean the information measured by the smart meter at the connection point of end-users to the grid, such as cumulative consumption, injection to the grid, voltage, etc. However, we see on the right side of Table 18 that typically, not all this information is shared with the aggregator by the DSO for security and GDPR reasons.

The following two advantages of sharing more grid information with the flexibility providers were highlighted by Centrica: (1) providing more detailed grid topology might improve the bidding strategy within the aggregator's portfolio, and (2) specific information about congestion and voltage constraints might help aggregators to expand their portfolio by contacting customers at critical grid locations, therefore improving the liquidity of the flexibility markets.

Table 18: Aggregator's perspective on information sharing for flexibility markets in the ideal case and in current practice.

What kind of information would you like to receive in the ideal scenario?	Is the DSO in typically providing this information?
Grid topology	No
Foreseen location of congestion	No
Foreseen location of voltage issue	No
Minimum bid	Yes
Renumeration strategy	Yes
Approximation of the location of assets	Yes
Smart meter data	Yes

4.4.4 Summary of the discussion

In this section, we examined **how to select the optimal bid** from the flexibility markets and **which information needs to be shared** for this selection. We started by examining the existing DSO alternatives to procuring flexibility during the operation of their distribution network. The three DSOs of the EUniversal demos have access to network reconfiguration tools at higher voltage levels in their distribution grid that will be used before the procurement flexibility. Besides that, all have curtailment measures in place to be used as a last resort in case the activation of flexibility is not enough to ensure the secure and reliable operation of the network. Next, we focused on how the market-based procurement of flexibility can be organized while considering both efficient market operation and secure network operation. In general, there are four ways to select the optimal bids during market-based procurement of flexibility: (1) using an economic merit order curve defined by the market prices and quantities, (2) using a techno-economic merit order curve defined by the market prices and simplified technical constraints of the network and/or flexible resources, (3) using a complex clearing algorithm deployed by the market operator considering bid prices and the impact of the bid on the network state and flexibility need, and (4) having a selection of the bids outside the market by the DSO that aims for secure and efficient operation of the grid. From the perspective of the EUniversal DSOs, only the two latter options were considered suitable to ensure a secure network operation that can be validated by the DSOs. After thorough discussions between the EUniversal stakeholders in the context of this deliverable, it was decided that these last two options will be examined by the EUniversal demos. On the one hand, a clearing algorithm will be developed and used on the N-SIDE market platform for the Portuguese demo. Here, the impact on the network will be defined using flexibility zones in which assets are grouped (no grid topology will be shared) and a final evaluation of the selected bids will be performed by the DSO after bid selection by the independent market operator. On the other hand, all three demos will test the option where the DSO is responsible for choosing the optimal bid on the NODES platform and only limited network information has to be shared between the DSO and the independent market operator. In this case, two approaches will be considered. In the Portuguese and Polish demo, the preselection of the most optimal bids will be determined by using the DSO's own network tools. In the German demo, the optimal bid will be selected by the DSO using the Optimal Bid Recommender Tool developed by N-SIDE. Finally, it must be noted that one of the main factors influencing the final bid selection methodology was the sharing of distribution network information with the market operator, as this information is sensitive to share due to data protection (GDPR) and cyber security concerns.

4.5 What products should be traded in flexibility markets?

Another challenge identified was the definition of flexibility products that represent the parameters and constraints of the demo. Figure 13 illustrates the different steps that are required to reach an appropriate product definition, with the focus of this deliverable indicated in orange as the previous four steps were addressed in EUniversal D2.1 (Falcão et al., 2021).

Figure 13: The five-step approach to achieve appropriate product definition defined in EUniversal D2.1 (Falcão et al., 2021) with the focus of this deliverable indicated in orange.

The complexity of the specification of flexibility market products was already discussed in EUniversal D5.1 (Chaves et al., 2021): "For a local market, the flexibility deriving from an asset must comply with the requirements specified into products that reflect both the technical potential and its limitations. […] Given the heterogeneity of networks, however, the range of products may change depending on topography, population, industrial density and activity focus and the network itself. As part of the market product definition, a set of technical attributes are defined, representing the parameters and constraints attached to the offer exchanged by market participants. While some of the attributes are linked to technical dispatch characteristics of specific flexible resources, they also need to be reflected in a generic way so that they can cover a wider range of technologies (following the technological neutrality principle)." Therefore, during one of the internal EUniversal workshops, both product standardization and specification of the technical attributes were discussed.

The remainder of this chapter will present the findings of the workshop preparations and the discussions on:

- Whether flexibility market products should be standardized?
- What attributes characterize the products[12] traded on flexibility markets?

4.5.1 Should the products traded in flexibility markets be standardized?

A question raised within EUniversal is how to determine the different product attributes and whether or not they could or should be standardized. As described in EUniversal D5.1 (Chaves et al., 2021), product standardization is important to consider, as it "lowers entry barriers and helps to trade flexibility among DSOs or even with TSOs, but should not lead to an extensive exclusion of flexibility technologies."

<u>What do we mean by standardization?</u>

In the preparation of one of the internal EUniversal workshops, different levels of standardization were identified:

- On the one hand, it is possible to set or limit variations in the product attributes. Specifically, one can fix the list of attributes that need to be included in a product, one can set ranges of values for the attributes, or one can fix values for attributes. In addition, attributes can be mandatory or optional.

[12] Only active power products are considered in this section, but a similar analysis can be performed for reactive power products.

- On the other hand, one can create a variation of products over different services. Specifically, one can define multiple products for one service adapted to resources that offer the service, or one can define one product per service. Alternatively, one can define one product that covers multiple services. This product can be specific for one DSO or can be aligned between multiple DSOs. Finally, flexibility market products can also be aligned with other electricity markets, such as the wholesale market and/or markets for ancillary services.

Besides that, two types of flexibility market products were identified from EUniversal D1.2 (Gouveia et al., 2021): tailored products and generic products. Tailored products can be more adapted to specific grid problems or to the technical constraints of offering resources, creating the need for more intelligence on the side of the market clearing mechanism. Generic products tend to be more resource independent, allowing simpler clearing algorithms. An overview of the distinction between generic and tailored products can be found in Figure 14 (EUniversal D1.2, Gouveia et al., 2021).

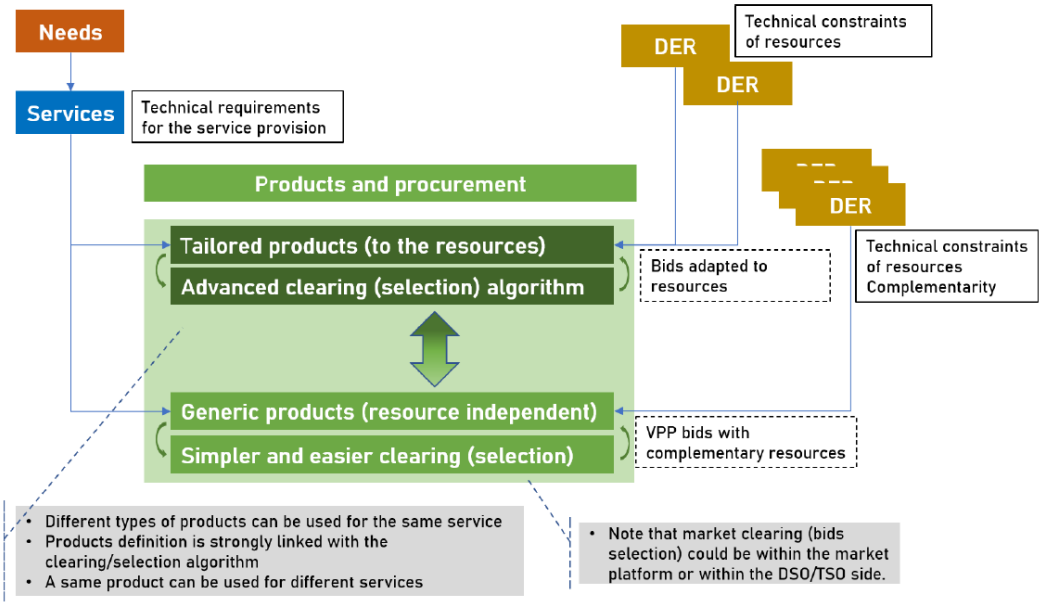

Figure 14: Overview of the distinction between generic and tailored products (EUniversal D1.2, Gouveia et al., 2021).

Stakeholder perspectives

Several publications by stakeholders have already discussed the standardization of flexibility market products. Art 32 (2) of Directive 2019/944 requires standardized market products for flexibility services, at least at a national level. CEDEC et al. (2018) encourage the use of standardized products to increase the liquidity in flexibility markets, and CEER (2018) recognizes the need to be cautious when standardizing market products on an EU-wide level due to different local characteristics and regulations.

During the workshop, four additional insights were shared by the EUniversal stakeholders:

- Tailored products might not be fully technology neutral and may bring limitations for certain flexibility providers such as aggregators and FSPs. Here, it must be noted that the impact of these limitations is dependent on the portfolio and available assets of the flexibility provider.
- Tailored products might create more complexity for the market clearing algorithm, but its impact can be anticipated and tested with simulations by the market operator. Besides

that, it must be noted that the complexity of the market clearing algorithm does not only depend on the product definition but also on other factors such as the number of bids, the market timing and the considered network constraints.
- Tailored market products might be beneficial for flexibility services as the products are specified to the required services and needs of the flexibility market. For example, the locational information shared in the product might be dependent on the use case and grid issues treated in the market.
- For the UMEI developed in the EUniversal project, generic products might be beneficial for information exchange and reducing interoperability issues, but tailored products might generate more innovation.

Current practices

Schittekatte and Meeus (2020) describe the current practices of standardization in four pioneering projects on flexibility markets and find that standardized and tailored products both occur. While NODES typically allows flexibility providers to build their offer based on a wide range of parameters, Piclo Flex, Enera and GOPACS all use standardized flexibility market products. Products in Piclo Flex are characterized by a set of standard attributes, while the products of Enera and GOPACS are aligned with the intraday market.

Demo preferences

During the workshop, the following insights on the standardization of products were shared for the different EUniversal demos.

- **The German demo** will define at least two separate products: one for active power and one for reactive power products. In the long run, standardization of these products with other markets is desired to facilitate acceptance by and communication with other DSOs and end customers. Besides that, it was indicated that the amount of standardization would also be influenced by regulation. Furthermore, the concern was raised that it might be hard to define one product that fits varying technologies on multiple voltage levels, such as for instance, large wind parks and small heat pumps.
- **The Portuguese demo** stated that at this moment in time, only a partial standardization of the market products is preferred. Currently, discussions are ongoing on which attributes fit best for the purpose. In the future, more standardization could be envisioned, with a first step to agree on attributes among the EUniversal demos to define the products.
- **The Polish demo** indicated that they are still at the beginning of developing the flexibility market. The first intention is to develop two separate products for congestion management and voltage control that would lie between tailored and generic products. Their main challenge is to translate their flexibility needs into products that can be traded on the NODES platform.

4.5.2 What attributes should be adopted in flexibility market products?

From the previous section, it is clear that each demo of the EUniversal project is planning to use its own standardized product. The different product attributes are explored in this section.

What do we mean by product attributes?

A general list of all attributes that can be used to characterize the products traded on flexibility markets can be found in Table 19 (EUniversal D5.1, Chaves et al., 2021).

Table 19: Overview of product attributes identified in EUniversal Deliverable 5.1.

Attributes	Definition
Preparation period	The period between the request by the SO and the start of the ramping period.
Ramping period	The period during which the input and/or output of power will be increased or decreased until the requested amount is reached.
Full activation time	The period between the activation request and the full delivery of the concerned product, meaning the sum of the preparation and ramping period.
Minimum/maximum quantity	The power (or change in power) which is offered and will be reached at the end of the full activation time. The minimum quantity represents the minimum amount of power for one bid. The maximum quantity represents the maximum amount of power for one bid.
Minimum/maximum duration of a delivery time interval	The minimum/maximum is a feature of the FSP and stands for the length of the delivery time interval during which the service provider delivers the full requested change of power in-feed to or the full requested withdrawals from the system. It represents a feature that characterizes the FSPs according to the measures that are used for providing grid service. This parameter is analogous to the minimum functioning time for thermal power plants and influences the participation in the mechanism for providing grid service.
Deactivation period	The period for ramping from full delivery to a set point or full withdrawal back to a set point.
Granularity	The smallest increment in volume of a bid.
Validity period	The period when the bid offered by the FSP can be activated, where all the characteristics of the product are respected. The validity period is defined by a start and end time.
Mode of activation	The mode of activation of bids, i.e., manual or automatic. Automatic activation is done automatically during the validity period (with little or no direct human control), whereas a manual activation is done at the request of the SO.
Availability price	Price for keeping the flexibility available (mostly expressed in €/MW/hour of availability)
Activation price	Price for the flexibility delivered (mostly expressed in €/MWh)
Divisibility	The possibility for a system operator to use only part of the quantity offered with bids by the service provider, either in terms of power activation or time duration. A distinction is made between divisible and indivisible bids.
Locational information included	This attribute determines whether certain locational information needs to be included in the bid (e.g., identification of Load Frequency Control area, congested area)
Recovery period	Minimum duration between the end of the deactivation period and the following activation.
Aggregation allowed	This attribute determines whether a grouped offering of power by covering several units via an aggregator is allowed.
Symmetric/ asymmetric products	This attribute determines whether only symmetric products or also asymmetric products are allowed. For a symmetric product, upward regulation volume and downward regulation volume have to be equal.

Stakeholder perspectives

In preparation for the workshop, the different EUniversal partners were asked which attributes from Table 19 were considered as a requirement in the product definition of the demos. An overview of the responses can be found in Table 20. Four attributes were indicated as essential by all EUniversal demo partners: the minimum and maximum quantity of the product, the minimum and maximum duration of a delivery time interval, the activation price and locational information. For the other attributes, the opinions of the different stakeholders were more

dispersed, ranging from being important for only one of the EUniversal demo partners to most of them indicating their importance. Three reasons might explain these differences:

- Some attributes might be redundant as they are already defined in the context of the flexibility market, such as the use case or overall market design. For example, an availability price might only be considered in a reservation market.
- There might have been different interpretations of the enforceability of 'required' in the posed question by the different EUniversal partners.
- Different stakeholders might have different perspectives on the importance and restrictiveness of some of the attributes. For example, divisibility might be an important attribute from a DSO perspective and less from an aggregator perspective as it ensures that the DSO can use only part of the quantity offered by the service provider, which might influence the outcome of the flexibility market.

In the remaining of this section, we will go deeper into the different perspectives of the EUniversal stakeholders and give a more detailed explanation of why certain attributes were considered important in the product definition of the demos.

Table 20: Stakeholder responses to the preparatory question 'Which of the following attributes are required in the product definition of the EUniversal demos?'.

Attributes	Nodes	N-SIDE	Centrica	Mitnetz Strom	Energa	E-REDES	Count
Minimum/maximum quantity	x	x	x	x	x	x	6
Min/max duration of a delivery time interval	x	x	x	x	x	x	6
Activation price	x	x	x	x	x	x	6
Locational information included	x	x	x	x	x	x	6
Aggregation allowed	x		x		x	x	4
Divisibility	x			x	x		3
Full activation time			x		x	x	3
Granularity			x		x	x	3
Validity period	x			x		x	3
Availability price	x		x			x	3
Recovery period			x	x		x	3
Ramping period			x	x			2
Preparation period			x			x	2
Mode of activation			x			x	2
Deactivation period			x				1
Symmetric/asymmetric product			x				1

From a **DSO perspective**, the following insights were given on the preferred product attributes for flexibility markets.

- The German DSO Mitnetz Strom emphasized that power products rather than energy products will be most important in their demo, and an indication of the power delivered for each period will be necessary to address the flexibility needs in an appropriate way. Besides the four essential attributes (i.e., the minimum and maximum quantity of the

product, the minimum and maximum duration of a delivery time interval, the activation price and locational information), it was mentioned that the locational information included should be as precise as possible (minimum feeder level), and the responsibility of the recovery period lies with the FSP.

- The Polish DSO Energa aims to create an understandable product definition based on already existing solutions, as their experience with flexibility markets is limited to the EUniversal project. Aside from the four essential attributes mentioned before, the most important attribute defined in the Polish demo will be the full activation time. Other parameters are left open to allow all kinds of flexible resources to participate in the market.
- The Portuguese DSO E-REDES also wants to reduce the complexity by minimizing the number of attributes in order to encourage market participation and innovation. The minimum and maximum quantity, activation price and availability price were identified as the most important attributes. Besides that, the manual mode of activation will depend on the voltage level where the flexibility provider is located: a manual command will be given by the DSO to FSPs on MV level, while LV customers will be activated by the aggregator using Home Energy Management Systems (HEMS). Overall, attributes such as ramping and activation period are considered less important as the scope of the Portuguese demo is mixed rural and urban areas where flexibility will be provided by DER rather than industrial resources. However, it was mentioned that these attributes might become more important when opening the flexibility market to larger FSPs. Attributes such as activation price and minimum and maximum quantity can be chosen by the FSP but will be evaluated based on the DSO flexibility needs. Finally, in the BUCs of the Portuguese demo that consider reservation for flexibility, the availability prices should be specified beforehand, and the minimum duration of the delivery time interval should be at least 1 hour to facilitate the planning process.

From **the aggregator perspective** of Centrica, it is important to keep certain attributes as open as possible as they might bring restrictions to the aggregator's participation in flexibility markets. The following four attributes were indicated as most restrictive: the activation and deactivation ramping period, the full activation time, the recovery period, and the prices. First, setting the ramping for activation and deactivation of the flexibility market product might limit the ability to select certain assets by the aggregator; it is therefore preferred to be an optional attribute. Second, a short full activation time can create difficulties for the aggregator to find appropriate flexible resources and alternative flexibility providers when needed. Third, industrial customers might experience difficulties in complying with a predefined recovery period and might therefore prefer to keep this attribute optional. Finally, sufficiently high availability and activation prices are important for aggregators to obtain revenues and attract new customers to their portfolio.

Besides the list of attributes in Table 19, Centrica proposed another attribute that might be considered during product definition: the need to define an energy management strategy. The energy management strategy can be defined as the strategy declared by the FSP, with which proof is provided of the ability of the portfolio to deliver the service (Elia, 2020). Here, it was mentioned that an energy management strategy might be needed in the case of flexible resources with limited energy reservoirs and is preferably determined by the flexibility service providers to avoid barriers to market participation.

Current practices

In the following paragraphs, examples of flexibility market products from NODES, N-SIDE, Piclo Flex, GOPACS and Enedis are given. It is important to note here that market products are dependent on local characteristics and flexibility needs, so there is no single correct way to define

market products. Therefore, the following examples solely serve as an illustration, and the product definitions of the EUniversal demos could differ from these examples.

First, an example from N-SIDE is given. Although the N-SIDE market platform is able to support the majority of attributes listed in Table 19, often, only a selection of this list is included in the product definition based on the customers' needs. For the Cornwall project, the guiding question for defining the products was 'What is the simplest information that is required?'. Figure 15 illustrates the response to this question for the product definition of the Cornwall project in which only four attributes were mandatory from both the seller and buyer perspectives: the duration of the delivery time interval, the minimum volume, the activation price and the location. All other attributes, which differ from a buyer and seller perspective, were considered optional and could be chosen freely by the flexibility service provider (Centrica, 2020). It must be noted that the N-SIDE platform is not limited to the product definition of this example, but also more advanced products would be feasible depending on the use case considered.

Figure 15: Market product example from the N-SIDE platform (Centrica, 2020)

Second, an example from Piclo Flex and UK Power Networks (UKPN) is given. Figure 16 illustrates a market call from UKPN on the Piclo Flex website (Piclo Flex, 2021). A number of attributes from Table 19 can be identified: minimum quantity, activation and availability price, delivery time interval within the validity period and location information with required voltage level. Over the years, the market product design of UKPN enabled by Piclo Flex has been evolving based on the feedback of flexibility service providers during organized workshops called Flexibility Forums (UKPN, 2021). Some examples are the minimum (aggregated) threshold that was changed to 10 kW across all products because flexibility providers demanded lower barriers to entry, and the location information that is now shared in a shape file and postcode format because flexibility providers asked for better locational information.

Figure 16: Market product example from the Piclo Flex platform (Piclo Flex, 2020; Piclo Flex, 2021).

Third, an example from GOPACS is given. The product definition of the GOPACS platform is defined by its generic product strategy. The attributes of the flexibility products are in line with the intraday ETPA market, in which a locational tag (EAN-code) is included. Besides standardizing the products among different markets, the products are also aligned between system operators as the GOPACS platform is a TSO-DSO coordinated platform (Schittekatte & Meeus, 2020). Figure 17 illustrates what a flexibility offer to the GOPACS platform may look like. On top, the locational information, delivery time interval and quantity of an illustrative Liander market call are shown (GOPACS, 2021). At the bottom, an example from the flexibility provider manual shows how the location tag, quantity and prices can be chosen by the flexibility provider (GOPACS, 2020).

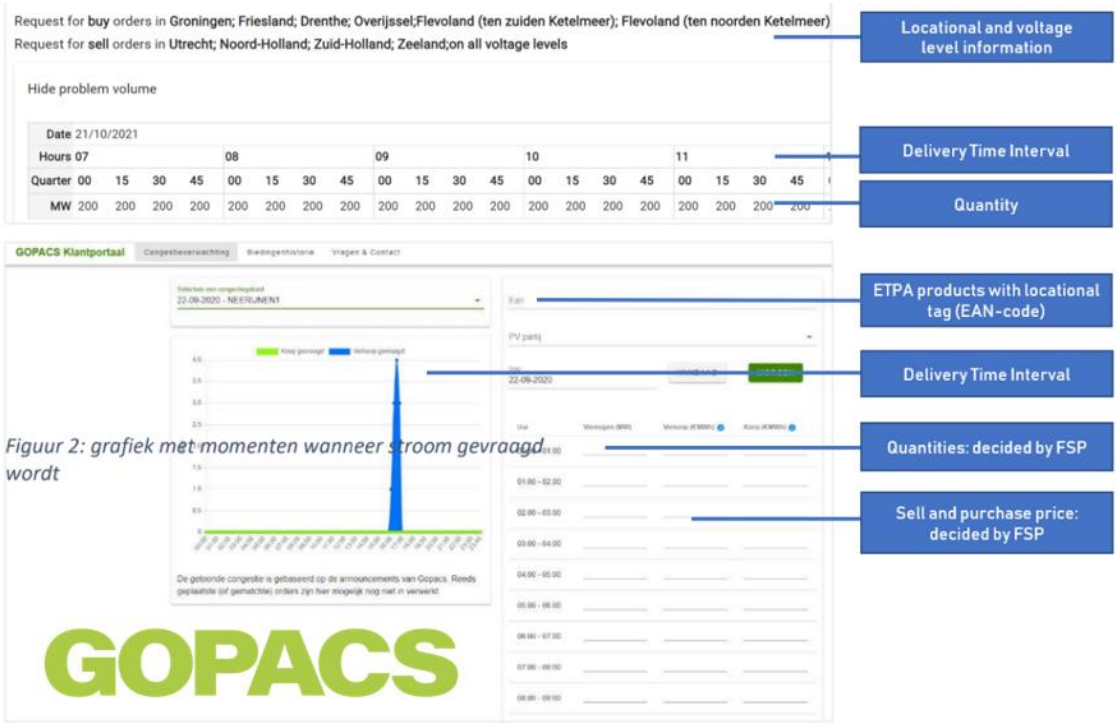

Figure 17: Market product example from the GOPACS platform (GOPACS, 2020; GOPACS 2021).

Last, an example from Enedis is given. Since 2020, Enedis has been placing flexibility tenders on its own market platform. An illustration of a typical market call on the Enedis platform is shown in Figure 18 (Enedis, 2021).

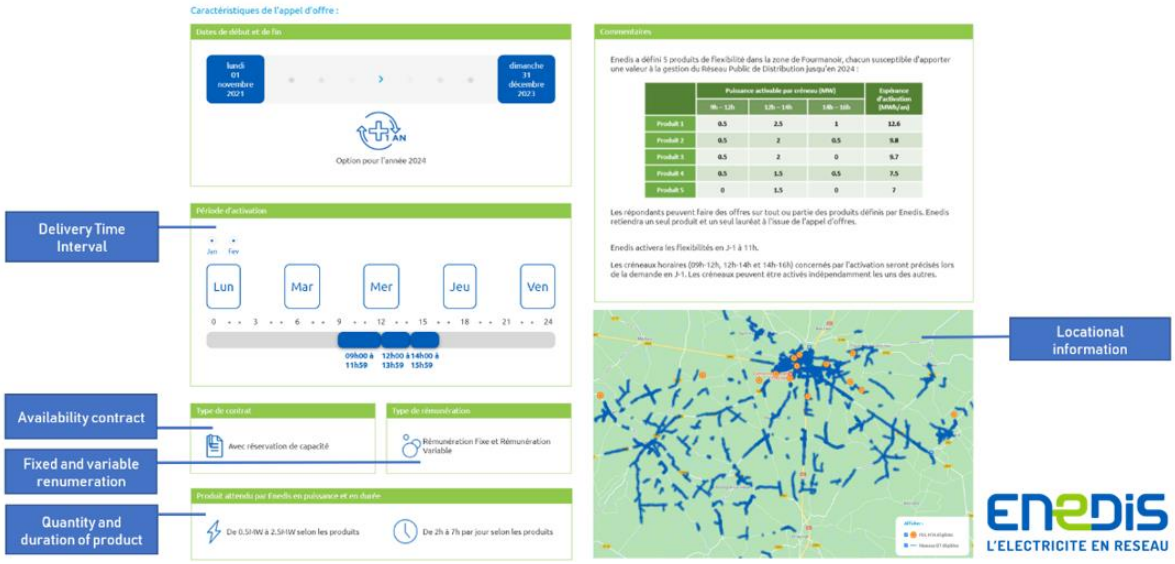

Figure 18: Market product example from the Enedis platform (Enedis, 2021).

Demo preferences

Based on the discussion of the workshop, a first design of the flexibility market products that will be traded in the EUniversal demos was defined. Table 21 gives an overview of the attributes and values that were identified for each demos during one of the EUniversal workshops. Here, it must be noted that discussions are still ongoing, and the product attributes and values will be further developed and might evolve over the course of the EUniversal demos.

Table 21: Attributes of the active power products traded on the flexibility markets of the EUniversal demos.

Attributes	German demo	Polish demo	Portuguese demo
Minimum/maximum quantity		? 50 kW - … ?	
Min/max duration of a delivery time interval	Minimum one interval of 15min	? 2h - …. ?	Min 30 minutes
Locational information included	LV Feeder level/LV grid/MV Feeder		MV: MV feeder, Grid location LV: MV feeder, Secondary Substation, LV Feeder
Aggregation allowed	Yes	No	Yes, with the publication of the disaggregated results
Granularity		1kW (for MV)	
Validity period	Products will be traded on 15-min intervals		Set of 30 min periods

4.5.3 Summary of the discussion

In this section, we aimed to find an answer on **what products should be traded in flexibility markets**. We started our analysis by examining the standardization of products traded in flexibility markets. While tailored products might not be fully technology neutral and bring more complexity to the market-clearing algorithm, they might generate more innovation and benefits for flexibility services as the products are specified to the required services and needs of the flexibility market users. In contrast, generic products are resource independent, which allows for simpler clearing algorithms, leads to improved information exchange and increases interoperability under the EUniversal UMEI setting. However, generic products might be more challenging to satisfy the required services and needs of the DSOs. For all three EUniversal demos, two separate products (for active and reactive power) will be defined that are only partially standardized. However, there is an ambition to increase standardization in the future when flexibility markets mature. At least four product attributes were considered essential by all EUniversal stakeholders and will be included in the product definition of the three demos: the minimum and maximum quantity, the minimum and maximum duration of a delivery time interval, the activation price and locational information. However, the implementation of these attributes, as well as other attributes, might be different among the EUniversal demos.

4.6 What baseline approach should be used?

Another internal workshop was organized to assist the EUniversal demos in creating an appropriate baseline methodology that can be used during validation and settlement of flexibility. Although validation and settlement are outside of the scope of the EUniversal demos, it is still important to give attention to this topic as baselining is necessary for accurate validation of the volume of flexibility delivered and a proper continuation of the demos beyond the project. Especially as several EUniversal stakeholders highlighted that baselining is still an open issue and that the most appropriate baseline methodology per product and type of asset has not been found yet.

This section will present the findings of the workshop preparations and the discussions during the workshop in two parts. First, we give a more detailed description of what we mean by baselines. Second, we go deeper into three detailed questions on baselines:

- Should the baseline methodology be standardized?
- What is the optimal baseline methodology for congestion management and voltage control services?
- Which level of aggregation of baselines is appropriate during validation and settlement of flexibility?

It must be noted that only active power products are considered in this section, even though a similar discussion can be performed for reactive power products.

What do we mean by a baseline?

Several interpretations can be given to baselines. In EUniversal D5.1 (Chaves et al., 2021), baselining was described as follows: "the baseline provides a power or energy schedule with an asset's normal behavior without flexibility activations. Its methodology is usually defined by the TSO, DSO or FSP (depending on the type of market) and approved by the regulator. Depending on the grid service to be procured, the baseline can be sent in advance by the FSP on a fixed interval (e.g., for aFRR in Belgium, 60 seconds before delivery) or can be computed afterward based on the profile before the activation (e.g., for FCR in Belgium). The granularity and window of the baseline or the application of individual or aggregated baselining, all depend on the product design." Figure 19 from Centrica (2020) illustrates this definition based on a downward flexibility event between 11:00 and 15:00. The black line in the figure represents the actual metered data at the FSP connection point. The red line represents the baseline which is an estimation of the expected energy usage when there would not have been a flexibility activation. The difference

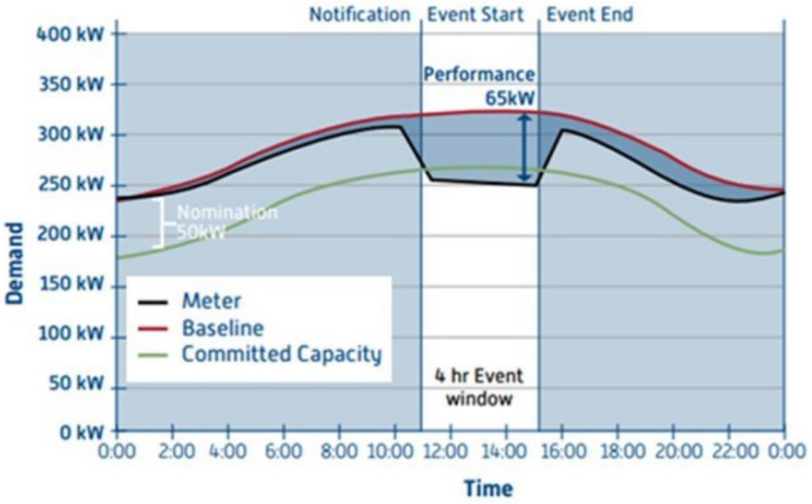

Figure 19: Illustration of the definition of the baseline (Centrica, 2020).

between the two lines illustrates the amount of flexibility activated by the flexibility service provider.

Different methodologies exist to estimate the baseline of a flexibility provider. Based on CoordiNet D2.1 (Stevens et al., 2021) and EUniversal D5.1 (Chaves et al., 2021), an overview of baseline methodologies was presented during the workshop, which is shown in Table 22.

Table 22: Overview of baseline methodologies based on CoordiNet D2.1 (Stevens et al., 2021) and EUniversal D5.1 (Chaves et al., 2021).

Baseline methodology	Description
Historical data approach, which consists of five subcategories:	This approach estimates the baseline based on historical meter data from each resource, often considering weather or calendar information. Five subcategories of the historical data approach exist:
• Averaging methods (X or Y variants)	• The method creates a baseline by averaging the demand/generation of the resource over X days in the last Y eligible days.
• Regression	• This method takes an extensive data set as input and determines the relationship between (a) dependent and independent variable(s) through a regression model.
• Comparable day	• This method identifies a representative day in the past, to be taken as a reference for the computation of the baseline, using historical meter data.
• Rolling average method	• This method uses historical meter data from many days but gives a larger weight to the most recent days.
• Statistical sampling	• This approach estimates the electricity consumption of an aggregated demand resource where interval metering is not available for the entire population.
Statistical sampling	This approach estimates the electricity consumption of an aggregated demand resource where interval metering is not available for the entire population.
Maximum base load	This approach identifies the maximum energy usage expected of each customer and sets a specific level of electricity usage that is equal to the maximum level minus the committed capacity of the customer. The maximum base load might be coincident with the system peaks or individual peak of the resource.
Meter before/meter after	This approach is usually employed for fast-response programs and reflects actual load changes in real-time, reading the meter before and after the flexibility response.
Metering generator output	This approach is used when a generation asset is located behind the demand resources' meter, in which the demand reduction values are based on the output of the generation asset.
Other	Other approaches (for example, defined by the FSP)

4.6.1 Should the baseline methodology be standardized?

Generally, there are two ways to define the baseline methodology. In the first option, the baseline is standard and one baseline methodology is chosen for the whole flexibility market or demonstrator. In the second option, the baseline methodology is changeable and can be freely determined by the FSP, which submits its baseline to the market platform.

Stakeholder perspectives

During the EUniversal workshop, it was mentioned that probably we might not harmonize baseline methodologies in Europe (e.g., through network codes), but there might be best practices, procedures and principles to be shared among Member States. Here, the connection with balancing markets was made, and best practices on baseline methodologies started appearing, but differences between countries still occur. For flexibility markets, such principles and best practices are still open and under development.

From the perspective of the aggregator, it is preferred that no fixed baseline methodology is chosen as the optimal methodology is dependent on the type of flexible resource, the available data (historical and real-time) and the timing of the baseline calculation (e.g., before or after the market clearing).

Finally, it was indicated that different baseline methodologies might be preferred in the context of flexibility markets depending on the considered use cases (e.g., congestion management, planned maintenance) and timeframes (e.g., months-ahead, day-ahead, intraday).

Demo preferences

As a result, in all three EUniversal demos, the FSP will determine the baseline methodology and submit the baseline to the DSO via the UMEI. Together with the grid forecasts of the DSO, the baselines will then be used for validation and settlements of the flexibility offers. A specific argument given by the Portuguese demo on the need for individual FSP baselines is that depending on the period considered for flexibility activation (long, medium, and short-term), different criteria shall be applied because of forecast uncertainty. This way, since the use cases of the Portuguese demo have different timeframes, different baseline methodologies might be applied.

4.6.2 What is the optimal baseline methodology for congestion management and voltage control services?

Generally, the suitability of a baseline methodology is evaluated based on four guiding principles (ENERNOC, 2009):

- How **accurate** can the methodology estimate the baseline of the resource?
- Is the methodology **simple** enough for stakeholders to understand, calculate and implement the baseline and transparent enough to be checked?
- To what extent is the methodology **integer** and does not allow the flexibility providers to game the system? For example, can the flexibility provider deliberately create congestions with its baseline that will later be solved by its own resources?
- To what extent is the methodology **effective**, and are the incentives between the baseline and the use case aligned?

Several academics (Ramos, A., 2019; CoordiNet D2.1, Stevens et al., 2021; Ziras, Heinrich & Bindner, 2021) have already evaluated the baseline methodologies of Table 22 based on these four guiding principles. Therefore, we will focus this section on what additional criteria must be considered when providing baselines for congestion management and voltage control compared to frequency services.

Stakeholder perspectives

From a **DSO perspective**, the main difference between baselines for frequency services and DSO services such as voltage control and congestion management is the local characteristic of DSO services. Therefore, portfolios of FSPs might be smaller and small changes in weather or customer behavior might have a considerable impact.

From the **market operator's perspective**, baselines are outside the scope of the market platform, and the responsibility for the quality of the baseline lies with the aggregator or asset owner. The different projects and demos show that there is a need for various validation methods and baseline methodologies based on the product and asset type and data availability.

Current practices

A guiding framework to select the optimal baseline methodology for congestion management was created in CoordiNet Deliverable 2.1 (Stevens et al., 2021) and is shown in Figure 20. The following four questions guide the decision process to select an appropriate baseline methodology:

1) Is the FSP already individually scheduled? If this is the case, the schedule of the FSP could serve as a baseline and no additional baseline would be required.
2) Is the FSP an individual unit? If this is the case, different baseline methods can be selected based on the product, unit and market characteristics.
3) Is the FSP an aggregated portfolio with the same type of distributed energy resources? If this is the case, the baseline methodology can be chosen using the same reasoning as individual units.
4) Is the FSP a virtual power plant type of an aggregated portfolio with different types of distributed energy resources? If reliable submetering is available, the baseline can be calculated per technology. Otherwise, baselines can be calculated for clusters of FSPs.

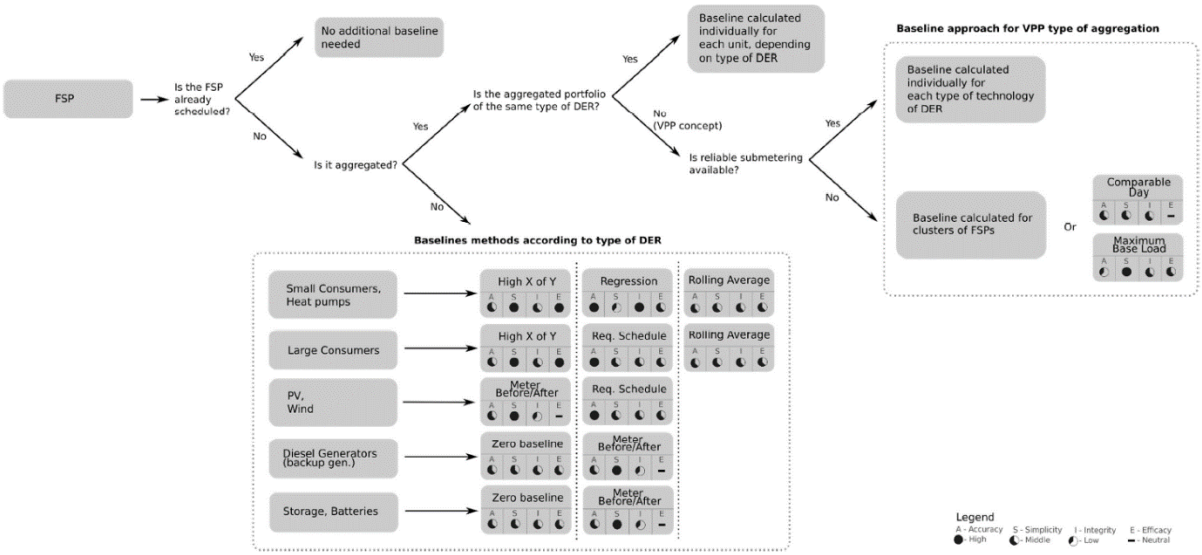

Figure 20: Guiding framework for baselining in the context of congestion management (CoordiNet D2.1, Stevens et al., 2021)

Demo preferences

In Section 4.6.1, it was mentioned that the FSP would be responsible for setting the baseline in the EUniversal demos. Therefore, there is no final selection of the optimal baseline methodology that will be used in the EUniversal demos. However, four parameters that influence the quality of the baseline and the FSP's decision were identified during the internal EUniversal workshop:

- The local characteristics of congestion management and voltage control
- The product and asset type
- Data availability
- The timing of the baseline submission

4.6.3 Which level of aggregation of baselines is appropriate during validation and settlement of flexibility?

A final discussion in the internal EUniversal workshop is whether baselines can be defined on an aggregated level or not. As validation and settlement are outside the scope of the EUniversal demos, no demo preferences could be identified. However, a definition of aggregation of baselines and the different perspectives of the EUniversal partners is shared in the following paragraphs.

What do we mean by aggregation of baselines?

Different levels of aggregation are possible depending on the installed (sub)meters. Typically, a baseline can be calculated at the following levels:

- At resource level. For example, the consumption of household devices is measured using submeters, and the production of solar panels using a separate production meter.
- Behind the meter. For example, the consumption and production of a household is measured at a single connection point of the smart meter.
- At feeder level or substation level. For example, the combination of the consumption and production of multiple households.

Here it must be noted that for different functionalities, different levels of aggregation of baselines might be used. We will now analyze from a multi-stakeholder perspective which levels of aggregation of baselines are preferred during the calculation of the baseline, the validation of the baseline and the settlement of the flexibility offer.

Stakeholder perspectives

From a **DSO perspective**, the following insights were given on the aggregation of baselines during validation and settlement of flexibility:

- The German DSO Mitnetz Strom has both submeters and meters at household level installed in their network and is considering different levels of aggregation in their demonstrator. Here, it is acknowledged that a trade-off between the DSO needs for network operation and the FSP needs for portfolio management are necessary.
- The Polish DSO Energa mentions that in the Polish demo, the baselines will be calculated at resource level. Besides that, it was mentioned that for settlement, submetering is hard to verify and therefore, data will be verified by the DSO at least at smart meter level.
- The Portuguese DSO E-REDES mentions that submetering will be performed in the demo, but only smart meter data will be used for validation and settlement. Here, it was highlighted that in the Portuguese demo, baselines should not be aggregated further than household level, both in the calculation and validation of the baseline. This is needed to assess whether the provided flexibility had the intended impact on the network issue.
- Both the Mitnetz Strom and E-REDES acknowledge that data privacy and authorization of the use of data will play a big role in the calculation and aggregation of the baseline.

From the **aggregator perspective,** the baseline can be determined either at portfolio level or at resource level. The most important part is that validation and settlement of flexibility offers are based on the baseline at portfolio level as uncertainty plays a bigger role at resource level. Due to possibly large deviations at resource level, it is better to aggregate the resources at portfolio level during settlement to avoid the uncertainty caused by deviations when all asset baselines are calculated separately.

4.6.4 Summary of the discussion

In this section, we examined which **baseline approach should be used in flexibility markets**. We started our analysis by discussing whether baseline methodologies should be standardized over the whole flexibility market or rather freely determined by the flexibility service provider.

For all three EUniversal demos, the flexibility service provider will be free to choose the baseline methodology. Here, it was mentioned that, even if baseline methodologies are not harmonized in Europe, there might be best practices, procedures and principles to be shared among Member States. These guiding principles already exist for baselining in frequency services and state that baseline methodologies should be accurate, simple, integer and effective. However, in the context of flexibility markets, additional criteria might need to be considered compared to frequency control due to the local context of congestion management and voltage control. The following four parameters were indicated as important for the EUniversal stakeholders: the local characteristics of congestion management and voltage control, the product and asset types, data availability, and the timing of the baseline submission. Further discussions on which baseline methodology is optimal for validation and settlement in the EUniversal demos were identified as outside the scope of the project. Finally, there was a discussion on whether baselines can be defined on an aggregated level or not. Three general levels of aggregation were identified: at resource level (submeter), at smart meter level (behind the meter) and at feeder or substation level (multiple connection points). The main challenge identified in this discussion is the fact that baselines should be detailed enough to capture the local characteristics of the DSO services and should be sufficiently aggregated to reduce the impact of uncertainty in the flexibility service provider's portfolio, especially during settlement. Besides that, it was mentioned that data privacy and authorization processes would play a big role in the calculation and aggregation of the baseline.

4.7 Who should be responsible for counterbalancing the activated flexibility bids?

In case flexibility is procured by DSOs for the purpose of congestion management and voltage services, the activated flexibility volumes might create imbalances at system level and these imbalances need to be counterbalanced. Depending on when flexibility is activated, no imbalance might be created (for instance, if congestion is solved before the portfolio submission for balancing). However, in Section 4.2 on the timing of flexibility market, it was discussed that the flexibility market-clearing of the EUniversal demos would occur after the balancing capacity markets and the day-ahead wholesale market. Therefore, the activation of flexibility has an impact on the system balance and depending on whether most activations are in the same or different directions, counteractions might be needed. In current demos and pilot projects with procurement of flexibility for congestion management by DSOs, the volumes are so small that this issue is typically not considered. However, this might become more relevant when flexibility markets become more mature and the volumes traded on flexibility markets increase. Therefore, we will now examine in more detail who should be responsible for counterbalancing flexibility bids during flexibility procurement. Generally, this responsibility can be assumed by three actors:

- The DSO, who caused the imbalance by activating flexible resources for DSO services.
- The FSP (through its Balancing Responsible Party (BRP)), whose portfolio is in imbalance.
- The TSO, who is responsible for the final balance of the network and might net different balancing requirements.

Stakeholder perspectives

During the multi-stakeholder workshop, the participants were asked 'what is the balancing responsibility of the DSO when activating flexibility?'. Three answers were possible:

- No responsibility
- Limited responsibility (the DSO is at least partly exposed to imbalance costs)
- The DSO is fully responsible (i.e., counter-trading).

It was mentioned during the workshop that a fourth option might exist: the TSO takes up the balancing responsibility. Figure 21 gives an overview of the responses, showing that once more, opinions were divided among the participants.

From the TSO's point of view, one-sided activation would be difficult as it would cause an imbalance. On the other hand, the stakeholders argue that having counteractions for every flexibility activation would make the system more expensive, while the energy volumes might not be large enough to substantially impact the TSO. There is an open question of when counterbalancing is necessary and what the thresholds should be to initiate counteractions. Besides that, it was argued that if the DSO is responsible for counterbalancing, it could negate part of the cost savings from the use of flexibility, which would be embedded in the overall system management costs that are then socialized in the electricity tariffs. This can be used as an argument to let counteractions be taken by the flexibility service provider or the balancing responsible party of the activated asset. The complexity of the mechanism also poses the question of who would oversee and validate transactions.

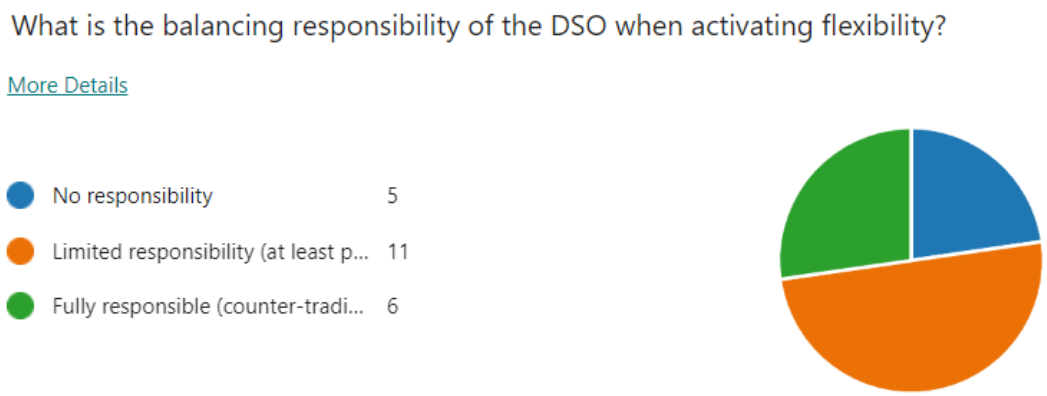

Figure 21: Answers to the fourth poll question posed in the multi-stakeholder workshop that included both partners from inside and outside the EUniversal project.

Current practices

When looking at theory and practice, we see that it can be the BRP, the flexibility service provider, and the DSO who might be responsible for counterbalancing during flexibility procurement.

In practice, the BRP is responsible for taking counteractions during the flexibility procurement of UK Power Networks and under the feed-in management regime in Germany. The latter, however, recently changed, and as of 2022, German DSOs are responsible for counterbalancing the activated flexibility bids under the Redispatch 2.0 scheme. Another example where the DSO performs counteractions when activating flexibility is the GOPACS platform in the Netherlands, where system operators are required to activate two-sided bids for congestion management. Also, in Flanders, the regulation on market-based flexibility foresees the possibility that the DSO can take up the responsibility for counterbalancing. However, it is currently still under discussion when this mechanism will come into place and how it will look like.[13]

In academic literature, both cases in which the BRP and DSO assume the counterbalancing responsibility are examined. Hadush & Meeus (2018) build further on the assumption that the imbalance will be solved by the BRP of the flexibility service provider. Besides that, Martín Utrilla et al. (2022) argue that the DSO should not make counteractions as the impact of flexibility activations may not have a significant impact on system balancing or the TSO grid. On the contrary, a shared balancing responsible model, in which the DSO is responsible for balancing the distribution grid, has been conceptually described by Gerard et al. (2018) and has been analytically examined by Le Cadre et al. (2019).

4.7.1 Summary of the discussion

In this section, we examined who should carry **the responsibility for counterbalancing the activated flexibility bids** by looking at the stakeholders' perspectives and current practices. Counterbalancing is typically not considered in current demos and pilot projects as the impact of the activated flexibility is still negligible. However, when flexibility markets become more mature and the volumes traded on flexibility markets increase, counterbalancing might become more important depending on the directions of the activated flexibility bids. In theory, the counterbalancing responsibility can be adopted by three actors: (1) the DSO, who is responsible for the imbalance due to the activation of flexible resources for DSO services; (2) the flexibility service provider (through its balancing responsible party), whose portfolio is imbalanced; or (3)

[13] The current practices in the UK, Germany and Flanders are based on interviews with experts during the preparation of the multi-stakeholder workshop.

the TSO, who is responsible for the final balance of the network. If we look at the current practices, we find that both the flexibility service provider (through its role of a balancing responsible party) and the DSO can be responsible for counterbalancing flexibility bids. However, the opinions of stakeholders are still divided on this topic. From the TSO's point of view, one-sided activation would be difficult as it would cause an imbalance. On the other hand, the stakeholders argue that having counteractions for every flexibility activation would make the system more expensive, while the energy volumes might not be large enough to substantially impact the TSO. There is an open question of when counterbalancing is necessary and what the thresholds should be to initiate counteractions. Besides that, it was argued that if the DSO is responsible for counterbalancing, it could negate part of the cost savings from the use of flexibility, which would be embedded in the overall system management costs that are then socialized in the electricity tariffs. The complexity of the mechanism also drives the question of who would be in charge of overseeing and validating transactions.

4.8 How to organize markets for reactive power?

Another internal workshop was organized to assist the EUniversal demos in developing the business use cases on reactive power markets. Within the EUniversal project, both active and reactive power will be tested. However, initially, more attention is devoted to active power products. While the project evolved, it became evident that further discussions on the specifics of reactive power (markets) were needed. As such, a workshop was set up to discuss the topic.

The remainder of this section will present the findings of the workshop preparations and the discussions during the workshop. First, we give a more detailed description of what we mean by reactive power and the scope of the EUniversal demos on reactive power markets. Second, we go deeper into four detailed questions on reactive power markets:

- What products and market designs is appropriate to trade reactive power?
- How should reactive power providers be remunerated?
- Can reactive power be aggregated?
- What are the main barriers to reactive power markets?

What do we mean with reactive power, and what is the scope of the EUniversal demos?

One of the responsibilities of DSOs is to maintain the voltages of their network within acceptable ranges. Currently, DSOs achieve this by activating non-frequency active and reactive power services that are typically delivered by conventional generators or the DSO's own network equipment. Table 23 gives an overview of the technical solutions and mechanisms that are currently available in the three demo countries.

Table 23: Technical solutions and mechanisms for voltage control that are currently available in the three demo countries

	Technical solutions	Mechanisms
Polish demo	• HV: generation units and remotely control wind farms (up to 110kV) • HV/MV: Transformers with automatic control tap changers • MV/LV: Line regulators, no possibility to activate big power plants • LV: Transformers with manual tap changers (not a common approach)	• DSO owned solutions • The control of wind farms for HV services can be treated as a mandatory action without payment or energy losses
German demo	• Coal and gas-fired power plants (2/3 units available) • Renewables with mandatory range Q(P) • TSO chokes at transformer EHV to HV • Tap changers in HV/MV transformers	• Today mandatory without payment • Market-based reactive power deployment is in preparation but currently, no additional needs
Portuguese demo	• HV/MV: automatic on-load voltage regulators in substation transformers • HV/MV: capacitor banks with on/off switch • LV: no automatic voltage regulation, yet new developments with data from smart meters	• Mandatory service: the supply and absorption of reactive power by the generator sets is a mandatory and unpaid system service defined in the Regulation of the Transmission Network • Non-mandatory delivery services: bilateral contracts with these producers

When creating an overview of the DSOs reactive power resources, it was mentioned that reactive power services are also closely related to the needs and voltage regulation of the TSO. For example, the Portuguese DSO E-REDES is required by regulation to be balanced at the TSO-DSO

network connection point but might be asked to deliver reactive power services to the TSO. In this way, E-REDES might receive instructions from the TSO to:

- activate the supply or absorption of reactive power by generators, pumping groups and synchronous compensators;
- perform maneuvers on the reactive compensation elements connected to the transmission network or connected to the tertiary windings of the transformers;
- connect or disconnect capacitor banks;
- perform transmission line maneuvers; or
- change taps on the transformers.

Besides that, it was mentioned that also in Germany, some of the DSOs might perform reactive power services to the TSO and that this service is expected to be increasingly used in the future.

In the coming year, resources that provide reactive power services will become more third-party owned as new resources for power system services arise with increasing levels of renewables, while large power plants that currently provide voltage support will become less available. To encourage the use of third-party owned resources for voltage control and to create an equal level playing field, Article 31(7) of Directive 2019/944 encourages DSOs to "procure the non-frequency ancillary services[14] needed for its system in accordance with transparent, non-discriminatory and market-based procedures". Therefore, the market-based procurement of reactive power products is being examined in Horizon Europe projects such as EUniversal and CoordiNet. We will now explain the BUCs on reactive power of the EUniversal demos in more detail.

- **The German demo** aims to test reactive power products in (radial) LV grids where voltage band violations might occur at the end of the feeders. As the problem is not yet prevalent today and only a limited amount of reactive power providers are currently present in the analyzed LV network, the demonstrator will rather be a proof of concept, where the impact of reactive power activations on voltages will be evaluated based on the sensitivities of the resources that provide the voltage service. As a result, the focus of the German demo will be on active power products and the interaction between active power and reactive power. Resources identified as potentially able to deliver the service are PV inverters, battery inverters, wind inverters, classic generators and assets owned by the system operator (chokes). It was noted that most of these technologies do not have an installation that allows automatic reactive power activation, which might be an important restriction.
- **The Polish demo** aims to test a separate reactive power market that uses similar principles as the active power services market. As the aim is to examine the required interfaces and activation requirements for reactive power from a technical point of view, abstraction will be made of the economic aspects of the market. In the future, this reactive power activation might serve as a tool to solve voltage problems that are located deep in the MV network. All MV resources that can deliver purely reactive power might be potential sources for these voltage regulation services. Therefore, the demo will focus on battery energy storage systems, wind inverters and assets owned by the DSO (such as STATCOMs).
- **The Portuguese demo** will not test reactive power markets as limitations were found while attracting and enrolling consumers. Generally, the potential need for reactive power products for voltage regulation lies in the MV network, especially in summer when

[14] Non-frequency ancillary services are defined by Recital 49 of Directive 2019/944 as "a service used by a transmission system operator or distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability."

there is a lot of local generation of solar PV. For this, the same resources mentioned in the German demo could be used, as long as automatic activation is possible.

During the interviews leading to the multi-stakeholder workshop, stakeholders from inside and outside the EUniversal projects were asked whether they see a potential for reactive power markets. Generally, four different answers were given: (1) yes for the DSO, (2) yes for the TSO, (3) yes for both, or (4) there is no potential for reactive power markets. Opinions were divided on this topic. Some argued that reactive power requirements have always been mandated, and there is no need for new mechanisms. However, it seems to depend on the situation, certain stakeholders do see voltage issues with PV that might need reactive power solutions at the DSO level. If the problem is significant and frequent enough, they might need better mechanisms to contract it.

4.8.1 What products and market designs are appropriate to trade reactive power?

As both differences and connections exist between active power and reactive power, it is an ongoing discussion on whether active and reactive power products should be traded and treated separately from active power products or not. In the remainder of this section, we will first describe the identified differences and connections between active and reactive power. Next, we will discuss how active and reactive power will be treated in the flexibility markets of the EUniversal demos. The collected information is a combination of the lessons learned from the CoordiNet Spanish demo provided by Comillas (CoordiNet D3.7, Chaves et al., 2022) and the input of the EUniversal stakeholders during the workshop.

Reactive power is different from active power as it contains the following two characteristics. First, reactive power is dependent on the R/X ratio of the network, which implies that reactive power is less effective in low and medium voltage networks. Second, the impact of reactive power on certain voltage control needs (sensitivity factors) is dependent on the network operating point, which implies that market boundaries and sensitivity factors need to be constantly updated. As a result, the effectiveness of reactive power for voltage control might be limited, depending on where the need is located and what the current network state is. Besides that, there are two reasons why there is a strong link between reactive power and active power. First, the reactive power output of a resource is generally in function of its active power output, which is often referred to as the Q(P) characteristic. Second, in LV and MV networks, voltage control is embedded in congestion management and addressed with active and reactive power support interchangeably.

EUniversal D8.1 (Bockemühl et al., 2022) states that in the EUniversal demos, active and reactive power will be considered as separate products on the market platform, but the estimation by the smart grid tools of the required amount of reactive power flexibility will include both active and reactive power. As the focus of the EUniversal demos is more on the technical aspects rather than the market aspects of reactive power markets, the market products will be simple and only minor differences (unit and location) will be made compared to active power products.

4.8.2 How should reactive power providers be remunerated?

Currently, reactive power services are often mandatory without compensation. If support is paid, the remuneration is typically based on fixed rates defined in bilateral agreements or regulated tariffs. When moving towards a market-based setting, the remuneration of providers of reactive power might change. While remuneration is outside the scope of the EUniversal demos, the most important cost parameters are listed based on the lessons learned from the CoordiNet Spanish demo provided by Comillas and the input of the EUniversal stakeholders during the workshop.

Depending on the technology of the flexibility provider and the grid need served, the pricing of reactive power might be influenced by the following cost parameters:

- The capital cost of reactive power provision, which is the investment cost for the installation that is required to provide reactive power.
- The operating cost for reactive power provision, which might consist of the internal thermal losses of the FSP due to the greater current magnitude that is circulating and/or the opportunity cost for active power services.

4.8.3 Can reactive power be aggregated?

While aggregation of active power products is already commonly performed by aggregators and other market parties, the aggregation of reactive power is currently still an open issue. Although aggregation of reactive power is outside the scope of the EUniversal demos, the most important aspects that must be considered when aggregating reactive power are listed based on the input of the EUniversal stakeholders during the workshop:

- Due to the local character of reactive power services, the area and potential for aggregation of reactive power bids might be limited.
- In order to aggregate reactive power, the location and the impact of each disaggregated unit of the grid need have to be known.
- Aggregation can be possible when units with similar sensitivity factors are clustered, which implies that the aggregated bids are located close to each other. Here it must be noted that the aggregated bid will be an approximation of the disaggregated units.
- Due to the non-linear character of reactive power and voltage, the sensitivity factor of the reactive power source on the DSO need has to be the same before and after the delivery of the reactive power. This might bring limitations to aggregation and might reduce the potential of aggregation to resources that are closely located to each other.

4.8.4 What are the main barriers to reactive power markets?

Currently, markets for reactive power are still in an early research and demonstration phase. Therefore, this section summarizes the main market and technological barriers for reactive power markets identified by the EUniversal stakeholders during the workshop.

The following nine market and regulatory barriers were identified:

- Lack of experience and knowledge of reactive power market design.
- Regulatory changes might be required before DSOs can acquire reactive power via markets.
- Different approaches, products and procurement mechanisms might be required for different network characteristics.
- Coordination between system operators and harmonization at European level might be difficult.
- Risk of limited liquidity and competition in local reactive power markets.
- Risk of strategic behavior in local reactive power markets.
- Risk of volatile market prices due to local characteristics.
- Third-party resources implicitly compete with the resources owned by the system operator, so a trade-off should be made between multiple solutions.
- From a DSO perspective, a separation is needed between mandatory reactive power services and additional reactive power services.

Finally, the following six technological barriers were identified:

- Active and reactive power provision cannot be decoupled.
- Third-party resources often need to be upgraded to enable voltage support which creates a barrier to attracting new participants.

- The lack of automatic control or schedule profiles of the resources can be a barrier to steady-state and dynamic voltage control.
- The quantification of reactive power required might be difficult to determine.
- A continuous evaluation by the system operator is required as the impact of the reactive power service provider on the DSO grid need is dependent on the current network state.
- Linearization of the optimization model used on the N-SIDE market platform is not possible, and complete nonlinear models are difficult to scale when it comes to production software deployment close to real-time.

4.8.5 Summary of the discussion

In this section, we examined how we should organize **markets for reactive power**. We started our analysis more generally by identifying the technical solutions and mechanisms for voltage control that are currently available in the three demo countries. This analysis showed that reactive power is typically provided through mandatory services by large power plants, capacitor banks and transformers with automated or manual tap changers. In the coming years, voltage issues in the network might increase and reactive power services might be provided by more third-party-owned resources, such as renewables, through new market-based systems. Although these markets for reactive power are still immature, the EUniversal stakeholders shared their insights on four unresolved issues. First, although reactive power products are typically treated separately from active power products due to their specific characteristics and in order to reduce complexity, the interaction between the two products remains important to consider as the reactive power output of a resource is typically dependent on its active power output and voltage control is embedded in congestion management in the distribution grids. Second, although it is still unclear how the pricing of reactive power will be organized in a market-based setting, the following cost parameters were mentioned as important: the investment cost of the installation to provide reactive power services, the operating costs due to thermal losses in the system and the opportunity cost for active power services. Third, the aggregation of reactive power is still an open issue. However, the following aspects were highlighted as important during the EUniversal workshop: the local character of reactive power services has to be considered, the location of the flexible resources has to be known, the sensitivity factors of the aggregated bids should be similar, and sensitivity factors of the aggregated bids should be the same before and after the delivery of the reactive power service due to the non-linear character of reactive power and voltage. Finally, nine market barriers and six technological barriers to the development of reactive power markets were identified by the EUniversal stakeholders.

5. Other design choices considering flexibility markets

Finally, we give an overview of other design choices considering flexibility markets that were treated in the different internal EUniversal workshops but were not part of an extensive discussion. This can be explained by the fact that these topics are outside the scope of the EUniversal demos and/or are still in a preliminary stage. Table 24 shows an overview of the four topics covered in this chapter, with their respective numbering.

Table 24: Overview of the other design choices identified in the D5.4 workshops, with their respective section number.

Chapter 5: Other design choices considering flexibility markets
5.1 What is the role of TSO-DSO coordination in the organization of flexibility markets?
5.2 Is there a role for the meter data operator?
5.3 Is there a role for the (independent) aggregator?
5.4 Should competition between flexibility market platforms be allowed?

5.1 What is the role of TSO-DSO coordination in the organization of flexibility markets?

Although DSOs are the sole buyers in the flexibility markets demonstrated in the EUniversal project, the design of flexibility markets might lead to coordination, interactions and information sharing with the TSO in different stages of the flexibility market process.

Currently, this discussion is outside the scope of the EUniversal demos, and the three demos focus on the DSO needs. However, when looking at other demonstrators and pilots of flexibility markets in Europe, we find that TSO-DSO coordination is important in flexibility markets where the DSO is the single buyer and also common markets, in which both the TSO and DSO are buyers, exist. For example, Valarezo et al. (2021) compare 13 initiatives of flexibility markets based on their market structure, market timing, and implementation. When looking at the network scope, Valarezo et al. (2021) identify nine projects with a scope at TSO-DSO level and four projects at DSO level. Besides that, in these nine projects, the buyer of flexibility can be both the TSO and DSO. The current development of both DSO and DSO-TSO flexibility markets in Europe shows the relevance of interactions and information sharing between system operators and implies that many more design challenges might arise when considering common markets for TSO(s) and DSO(s).

5.2 Is there a role for the meter data operator?

While the DSO is generally selected as the data manager of smart meters, the role of the meter data operator might be reconsidered for flexibility markets as the responsibilities are becoming more complex. First, additional data from submetering might become available. Besides that, (aggregated) flexibility volumes might need to be validated, and these validated volumes of the delivered flexibility have to be stored and distributed. We will now present how these three aspects might evolve in the future based on discussions in the EUniversal workshops.

First, what is the **role of submetering on the consumer side** in the context of flexibility markets, and **who will take up the meter data operator role** for these submeters? Currently, submetering data is mainly used to stimulate innovation at the FSP side to bid into the flexibility market, and for information purposes, by sharing disaggregated consumption data to the consumer, thus promoting awareness. It is only exploratively used by the DSO for settlement purposes. The main reason is that, unlike smart meters, a regulated environment for submetering on the consumer side does not exist yet. Therefore, smart meters at the connection point currently remain the main reference point to operate the grid and calculate the served flexibility,

and submetering data can only be used as a secondary data set. Here, it is important to note that network operation and flexibility procurement is performed based on validated data and determined based on regulated principles. This validation process is complex and comes with many security and personal data protection issues which require a lot of knowledge of the meter data operator to ensure one unique data set without errors. As a third-party technology provider typically installs energy management systems for the submetering of consumers, the role of the meter data operator could be taken up by other parties than the DSO. Finally, it was mentioned that whoever takes up the meter data operator role for the submeters on the consumer side, the consumer remains the data owner and needs to give consent for its data to be used.

Second, **which data will be used to determine the volume of flexibility delivered**, and **who will calculate this**? Currently, only smart meter data can be used to calculate the delivered flexibility because it is the only regulated meter. In principle, the calculation of the volume can be done by the DSO, the FSP or the FMO. In case the FSP is responsible for determining and reporting the delivered flexibility, biases towards the activity of the FSP might occur, and regulations should be defined to ensure the correct value is reported. If the DSO is responsible for calculating the delivered flexibility, the baselines submitted by the FSP should be transferred to the DSO, biases towards the activity of the DSO might occur, and regulations might be needed to ensure the correct value is reported. In case the FMO is responsible for calculating the flexibility volume, meter reading data should be transferred from the DSO to the FMO, but neutral handling between DSO & FSP can be ensured. Therefore, the FMO is the best choice for this task, and as illustrated in Table 12 of Section 4.3.2, the calculation of the amount of flexibility delivered will be performed by the FMO in the three EUniversal demos. Finally, it was mentioned that with more submetering data becoming available on the consumer side, a mismatch between the flexibility volume calculated by submetering data and smart meter data might occur. How to deal with this mismatch and who will be responsible for selecting the final value of the flexibility volume was identified as an interesting topic for further research.

Third, **who will be responsible for storing and distributing the calculated volumes** of the flexibility delivered? Here, all stakeholders agreed that this task should be the responsibility of the FMO.

5.3 Is there a role for the (independent) aggregator?

Directive 2019/994 of the Clean Energy Package touches upon the role of the independent aggregator in several ways. Art. 2 (19) defines the independent aggregator as "a market participant engaged in aggregation who is not affiliated to the customer's supplier." Besides that, the implementation of a regulatory framework for independent aggregators at Member State level is ensured by Recitals (39), Art. 3, Art. 17(3) of Directive 2019/944.

However, the creation of this new entity comes with many design challenges, such as the contractual relationship between the independent aggregator and the supplier. Based on Schittekatte et al. (2021), two open issues on the relation between the supplier and independent aggregator were discussed during one of the internal EUniversal workshops: the imbalance created in the portfolio of a supplier and the compensation for forgone revenues of the supplier due to actions of the independent aggregator. For the imbalance issue, Schittekatte et al. (2021) find that perimeter correction, in which the imbalance of the supplier is corrected by the activated volume of the independent aggregator, is the main solution adopted in different European Member States. However, for the forgone revenue issue, Schittekatte et al. (2021) find that different models are being developed, such as:

- models without compensation;
- regulated models, in which the independent aggregator pays a compensation to the supplier that is determined by a regulated methodology;

- corrected models, in which the supplier payment is realized through a correction in the consumer's electricity bill; and
- contracted models, in which the independent aggregator pays a compensation to the supplier that is contractually agreed on.

Besides having a general discussion on the relationship between the independent aggregator and the supplier based on the framework of Schittekatte et al. (2021), the EUniversal stakeholders were challenged to think about future developments of the (independent) aggregator considering flexibility markets. As a result, three new questions on aggregation emerged in one of the internal EUniversal workshops:

- How will the role and competences of the independent aggregator evolve considering the establishment of flexibility markets?
- How will the role and competences of the independent aggregator evolve considering the participation of LV customers in these markets?
- What is the aggregator's role in settling an aggregated group of flexibility?

We will now debrief the stakeholder's perspectives on these three questions based on the responses and discussion in the internal EUniversal workshops.

First, how will the **role and competences of the (independent) aggregator** evolve **considering the establishment of flexibility markets**?

- Aggregators could develop new competences to assess the impact of their flexibility bids on the grid. Access to the grid topology could be beneficial for developing these new skills. Nevertheless, the provision of these data may raise issues related to security of operations, gaming and GDPR.
- When flexibility is sold in the market, the aggregator must be able to dispatch this flexibility in the most efficient way among its portfolio. That advanced dispatch process might require new processes and competences of the aggregator.
- The flexibility market will place local constraints on the portfolio optimization of aggregators, which might require new competences.

Second, how will the role and competences of the independent aggregator evolve **considering the participation of LV customers** in these markets?

- Many resources will be required to reduce the impact of stochasticity at LV level. If the number of resources in the portfolio of the aggregator is limited, it is essential that the allowed margin for the error of the baselines is high enough to compensate for the error in the forecast algorithm. Therefore, it is important that an acceptable bandwidth of baselines is defined in the market and product rules.
- The more smaller customers will participate in this market, the more the aggregator will have to be organized in a smart way.

Finally, what is the **aggregator's role in settling an aggregated group of flexibility**? Here, all EUniversal stakeholders agreed that the settlement of aggregated flexibility bids should be at portfolio level as too many uncertainties and errors are involved at asset level (especially for LV customers). However, as indicated in Section 4.6.3, both aggregated and individual levels might be used in the calculation of the baseline.

5.4 Should competition between flexibility market platforms be allowed?

As different independent market operators are currently developing flexibility markets, we might see competition between flexibility market platforms in the same network areas in the future. This section will give an overview of the different stakeholder perspectives on the main advantages, disadvantages and conditions for DSOs procuring flexibility at multiple platforms

within the same grid area. Before going into more detail, it was noted that independent of the advantages and disadvantages mentioned in this section, competition between flexibility market platforms should only be allowed if it maximizes total welfare among all stakeholders and ensures a safe network operation.

Table 25 shows the advantages and disadvantages of allowing competition between flexibility market platforms. Besides arguments against and in favor of competition, several conditions that might help the development of competition, ensure welfare maximization and provide safe grid operation were mentioned by the EUniversal stakeholders. All conditions can be found at the bottom of Table 25.

Besides, it was mentioned that competition between platforms might evolve in two steps. First, multiple market platforms may appear and competition will grow. Since 2019, we see that more and more demos and pilots on flexibility markets are being developed, but there is still a long way to go. Here it was highlighted that market platforms are currently evolving based on the environment and feedback they get from local stakeholders and regulatory frameworks. Hence, the overall direction of the competition and respective results will depend on political and regulatory guidelines. However, many needs will become more common and an equilibrium in the number of market platforms will be reached. As a second step, multiple market operators might stay or converge to one single platform that is proven to be the most efficient and practical for the different stakeholders. Here, the link can be made with the single day-ahead market coupling trend and the common platforms for balancing services at European level.

Table 25: Overview of the advantages, disadvantages and conditions of allowing competition between flexibility market platforms.

Advantages
• Positive effect on prices • Incentivizes for better product offering towards customers • Allows to meet more diversified needs and types of contracts, which can bring opportunities for FSPs
Disadvantages
• Lack of liquidity in the different markets • Requires thorough organization and coordination (either between more than one market platform or between the market platform and other procurement mechanisms) of the assets and purchased flexibility (e.g., it must be prevented that the same flexibility product is activated twice) • Less visibility over the complete asset list might cause non-optimal prices and less optimality in the market clearing algorithm • Risk of over procurement as the DSO might demand full flex from each platform • Risk of under procurement as the DSO needs to split across the platforms • Increased risks of gaming • More advanced bidding strategies might be needed by FSPs, which can lead to competition problems
Conditions
• The platform interface should be standardized • The platform should be owned and operated by an independent market operator to assure transparency in the entire process • A flexible resource should only be participating in one market at the same time • The DSO must have the necessary tools to evaluate and validate the different market results together to ensure that no additional network constraints occur

5.5 Summary of the discussions

In this chapter, we discussed four design choices considering flexibility markets that are relevant but were not part of an extensive analysis during the EUniversal workshops as the topics were rather outside the scope of the EUniversal demos and/or still in a preliminary stage. The following paragraphs summarize the highlights of the discussions on the different topics.

Section 5.1 examines the **role for TSO-DSO coordination** in the organization of flexibility markets. As the three EUniversal demos focus on the DSO needs, the interaction with the TSO is outside the scope of the project. However, an analysis of emerging flexibility platforms in Europe shows that both DSO flexibility markets, where the DSO is the single buyer, and common flexibility markets, where both the DSO and TSO are buyers, are currently being developed. In any case, for both approaches, the interactions and information sharing between the DSO and the TSO in different stages of the flexibility market process were indicated as important by all EUniversal stakeholders.

In Section 5.2, we analyzed whether there is a **role for the meter data operator**, more specifically **in the context of submetering on the consumer side**. At this moment, submetering data is mainly used to stimulate innovation at the side of the flexibility service provider and for information purposes at the consumer side, rather than to deliver services for the DSO or for settlement purposes. The reason for this is that, unlike smart meters, a regulated environment for submetering on the consumer side does not yet exist. In the future, the role of the meter data operator for submeters could be taken up by the flexibility service provider or the DSO, as long as the relevant knowledge to deal with the complexity, security and data protection issues of the validation process is ensured. In the three EUniversal demos, the calculation and storage of the volume of delivered flexibility will be determined by the independent market operator to provide neutral handling between the DSO and the flexibility service provider. Finally, it was mentioned that regardless of who takes up the meter data operator role or is responsible for calculating the flexibility volume, the consumer remains the data owner and needs to give consent for its data to be used.

Section 5.3 examined the **role of the (independent) aggregator**. First, it was discussed that with the establishment of flexibility markets, the (independent) aggregator might create new competencies such as evaluating the impact of their bids on the network, optimizing the dispatch of their portfolio over different markets and handling local constraints when providing services to the DSO. Second, the participation of low voltage customers in electricity markets might bring challenges to the (independent) aggregator. The main challenge is to reduce the impact of stochasticity at low voltage level. To achieve this, the aggregator needs to smartly include a large number of resources in their portfolio and the rules of the flexibility market must be robust to cope with the impact of these uncertainties. Finally, all EUniversal stakeholders agreed that the settlement of aggregated flexibility bids should be done at the portfolio level as too many uncertainties and errors are involved at the asset level. However, as indicated in Section 4.6.3, both aggregated and individual levels might be used in the calculation of the baseline.

Section 5.4 aimed to answer whether **competition between flexibility platforms** in the same network area should be allowed. Although the EUniversal stakeholders agreed that allowing competition between flexibility market platforms might bring benefits (such as price reductions, better products and diversified flexibility contracts), several disadvantages and conditions were highlighted. Disadvantages include lack of liquidity, risk of gaming, coordination issues (either between more than one market platform or between the market platform and other procurement mechanisms), risk of over and under procurement by the DSO and increased complexity for the flexibility service provider. Conditions that might help the development of competition between flexibility platforms, ensure welfare maximization and provide safe grid operation are the standardization of the interfaces, the operation of the platform by a third party, the assured

availability of flexible resources and coordination on the impact of the network. Finally, it was mentioned that competition might evolve in two steps. First, multiple market platforms will arise and grow based on feedback from local stakeholders and regulatory frameworks. As a second step, multiple market operators might stay or converge to one single platform that is proven to be most efficient and practical for the different stakeholders.

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Annex I – Workshop documentation

I.1 Workshop 1: Timing aspects

The first workshop was organized online on the 30th of September 2021 and covered two parts: (1) the timing of the flexibility market, and (2) the integration in the timing of existing markets for ancillary services, energy markets and other mechanisms (e.g., redispatch).

Preparatory questions

Questions posed to DSOs (Energa, E-REDES, Mitnetz Strom):

Please fill in the following timing parameters for the energy and ancillary service markets in your country:

- Start bidding time interval (gate opening): starting moment from which buy/sell orders can be submitted by market participants.
- Order book closure (gate closure): closure of the time interval in which buy/sell orders can be submitted by market participants.
- Publication of final results: the time when results are published and participants are notified about their contracts.
- Trading procedure: how frequently does the market matching take place?
- Market time unit: the period for which the market price is established.

Please fill in the timing of the steps identified in the BUCs of the demos.

Participant

Total: 27 participants

- Centrica (2)
- Comillas (2)
- E.DSO (2)
- Energa (3)
- E.ON & Mitnetz Strom (3)
- E-REDES (6)
- INESC-TEC (2)
- KU Leuven (1)
- NODES (2)
- Vlerick (1)
- VITO (3)

I.2 Workshop 2: Product definition

The second workshop was organized online on the 25th of October 2021 and covered three parts: (1) the rationale of product definition; (2) attributes and values of flexibility market products; and (3) the alignment of the demo products with existing products.

Preparatory questions

Questions posed to DSOs (Energa, E-REDES, Mitnetz Strom):

- Are there specific attributes missing that are needed in a distribution grid context?
- Which attributes can be specifically restrictive from an FSP point of view (market liquidity)?
- Which attributes are specifically important for grid security?
- What level of standardization would you like to aim for in your demo and why?

- Fixed list of attributes with one single value set for each attribute by the DSO
- Fixed list of attributes but set a range for the attributes or give the FSPs some degree of freedom to choose the values

Questions posed to market operators (N-SIDE, NODES):

- What are your experiences with specific product definitions?
- Which type of products do you support in your market platform?
- If you look at our proposed list of attributes,
  - Which ones would you typically use in your platform, which ones can be left out and which other ones would you propose?
  - Are there certain attributes that are restrictive for you as a market operator?
- Are there other relevant points/comments that you would like to mention?

Questions posed to aggregators (Centrica):

- Which attributes can be specifically restrictive from an FSP point of view (market liquidity…)?
- Do you have certain preferences on which attributes should be used in the product definition? For which attributes should you, as an FSP, be allowed to set the value?
- Do you have concrete best or worst practices as examples?
- Are there other comments you would like to give?

Participant list

Total: 31 participants

- Centrica (2)
- Comillas (4)
- E.DSO (2)
- Energa (1)
- E.ON & Mitnetz Strom (3)
- E-REDES (11)
- INESC-TEC (2)
- KU Leuven (1)
- N-SIDE (1)
- Vlerick (1)
- VITO (3)

I.3 Workshop 3: Market-based procurement by DSOs

The third workshop was organized online on the 3rd of December 2021 and covered three parts: (1) market objective and bid selection; (2) network and locational information in the market; and (3) the impact of the pricing scheme (e.g., pay-as-bid versus pay-as-cleared).

Preparatory questions

Questions posed to DSOs (Energa, E-REDES, Mitnetz Strom):

In EUniversal D2.2 (2021), it is mentioned that “in terms of medium to long-term grid planning, flexibility can improve efficiency in the development of the network as it can be used as a complement or alternative to traditional grid investments.” Is there already a methodology in place to make the trade-off between investments and flexibility? Would you like us to zoom into this trade-off during the workshop?

The market objective of a local flexibility market typically entails the minimization of costs of the procured flexibility. Which alternatives to flexibility procurement do you consider in the operational timeframe when procuring flexibility (none, dynamic network reconfiguration, curtailment options)? What are the costs of these alternatives?

Does the bid selection take place a) on the market platform or b) outside the market (i.e., as a result of a separate DSO optimization)? Why did you choose this option (if necessary, distinguish between BUCs)?

- In case of option a):
  - Is network information considered during the market-clearing? If yes, how (via locational tag, static or dynamic impact factors, simplified network model)?
  - Which other information (price, quantity of bids, …) is used to clear the market (please also specify the origin of the information)?
- In case of option b):
  - Are certain of the above-mentioned alternatives (see question 2) to flexibility procurement considered in your optimization when selecting bids on the flexibility market? If yes, please explain how?
  - Which type of network model is included in this optimization (manual representation, representative network models, simulation of critical areas, full simulation of network)? Please explain.
  - Which other information (price, quantity of bids, …) is used to select the bids (please also specify the origin of the information)?

What kind of information cannot be shared with a) the market operator or b) the FSPs? For which reasons (e.g., certain regulation that prohibits the sharing of information)?

In EUniversal D2.2 (2021), the following pricings schemes were defined for the different demos:

- DE demo: pay-as-bid (NODES)
- PT demo: pay-as-bid (NODES) and pay-as-bid or pay-as-clear (N-SIDE)
- PL demo: pay-as-bid (NODES)
- For the PT demo, have you already decided which pricing scheme will be used on the N-SIDE platform, or will both pricing schemes be tested and compared?
- What do you consider as advantages and disadvantages of the two different pricing schemes (assuming the local flexibility market would be auction-based)?

Participant list

Total: 23 participants

- Centrica (2)
- EASE (1)
- Energa (2)
- E.ON & Mitnetz Strom (3)
- E-REDES (7)
- INESC-TEC (1)
- NODES (2)
- N-SIDE (2)
- Vlerick (1)
- VITO (2)

I.4 Workshop 4: Allocation of energy volumes and coordination aspects

The fourth workshop was organized online on the 3rd of February 2022 and covered four parts: (1) baseline approach; (2) counterbalancing, perimeter correction and transfer of energy; (3) coordination needs with the TSO; and (4) competition between platforms.

Preparatory questions

Questions posed to DSOs (Energa, E-REDES, Mitnetz Strom):

- Baselining
  - Did you already identify which flexibility resources are participating in the demo and need a baseline? If yes, please list them.
  - Will you apply a baseline on resource level and/or on portfolio level (in the case of aggregated bids)?
  - Which strategy will be followed to determine the baseline? Why do you choose this option?
    - Option 1: One baseline methodology is chosen for the whole demo / BUC (scratch what is not appropriate). Which baseline methodology will be used and why?
    - Option 2: The baseline is determined by the FSP, which submits this baseline to the market.
  - What are specific challenges of baseline methodologies with regard to congestion management and voltage control? Why would certain baseline methods used for frequency services not be applicable to congestion management and voltage control?
- Perimeter correction and counterbalancing
  - What is the legal framework and/or what are ongoing developments for perimeter correction/transfer of Energy rules for balancing services in your country?
  - Is there already a legal framework for perimeter correction for DSO-grid services, and how do you think this would evolve in the future?
  - Are there any counterbalancing measures (to counter-activate a bid to keep the system balance unaltered) that need to be considered when the DSO activates flexibility? If yes, please explain. For the German demo, please also make a specific link with the German Redispatch 2.0 mechanism if relevant.
  - What is the impact of this regulatory framework/situation on the DSO? What are the consequences/issues/responsibilities for you due to these frameworks?
- TSO-DSO coordination
  - Although local flexibility markets are targeted within EUniversal, in each phase of the BUCs, interaction, cooperation or information sharing with TSO might occur. Can you please explain the envisioned future coordination needs with the TSO during the following market phases:
    - Registration and prequalification (e.g., common procedure, information sharing)
    - Bidding and selection (e.g., bid forwarding to TSO markets after the local flexibility market clearing)
    - Delivery, monitoring and Settlement (e.g., considerations of counterbalancing and perimeter correction, common procedures)
  - Which of these interactions can be supported by the UMEI?
- Competition between platforms

- Should a DSO be allowed to procure flexibility from multiple competing platforms in the same DSO region? What would be the benefits and disadvantages of competition between platforms compared to one platform for each region?

Questions posed to market operators (N-SIDE, NODES):

- Baselining
  - With regard to baseline methodologies, what are your previous experiences/lessons learned, specifically with regard to congestion management and voltage control?
- Competition between platforms
  - Should a DSO be allowed to procure flexibility from multiple competing platforms in the same DSO region? What would be the benefits and disadvantages of competition between platforms compared to one platform for each region?
  - How do you see competition between platforms evolving in the future?

Questions posed to aggregators (Centrica):

- Baselining
  - Would you prefer (1) one fixed baseline methodology for a certain service determined beforehand, or (2) determine and submit your own baseline methodology? Please explain.
  - What are lessons learned from previous experiences, specifically with regard to congestion management and voltage control? Would you typically prefer to set a baseline on resource level or portfolio level? Please explain.
- Perimeter correction and counterbalancing
  - What could be the impact of the rules on perimeter correction and counterbalancing with regard to responsibilities/challenges for the FSP? Please clarify.
- Competition between platforms
  - Should a DSO be allowed to procure flexibility from multiple competing platforms in the same DSO region? What would be the benefits and disadvantages of competition between platforms compared to one platform for each region?

Participant list

Total: 22 participants

- Centrica (1)
- Energa (2)
- E.ON & Mitnetz Strom (4)
- E-REDES (8)
- IEN (1)
- INESC-TEC (1)
- NODES (1)
- N-SIDE (1)
- Vlerick (1)
- VITO (2)

I.5 Workshop 5: Local flexibility markets for reactive power

The fifth workshop was organized online on the 15th of March 2022 and covered three parts: (1) the design of markets for reactive power; (2) reactive power products; and (3) the link with local flexibility markets for active power.

Preparatory questions

Questions posed to DSOs (Energa, E-REDES, Mitnetz Strom):

- How is voltage support currently delivered in your grids? Please distinguish between your own DSO solutions and solutions using third-party resources, if applicable. For the latter, which type of mechanism is put in place to activate/select the voltage support (mandatory, cost-based)?
- Please describe the grid needs you want to address with reactive power in your demonstrator? Where is the need located? What is the service you are asking for from the FSPs?
- Would you estimate the need in terms of voltage or in terms of reactive power? Please explain.
- Regarding the product design of the proposed local reactive power market in your demo, how will it differ compared to the proposed products for the active power market? Do you already know how the product will be defined?
- Which flexible resources will be able to deliver the service? What are the minimum technical requirements to be able to deliver the service?
- How will the reactive power product be renumerated?
    - Will remuneration for availability and/or delivery be considered?
    - Will the remuneration be cost-based or market-based? In case of cost-based remuneration, how are these costs determined?
- Regarding the market design of the proposed local reactive power market in your demo, how will it differ compared to the proposed active power market? How will you determine the impact of the bids on your voltage need? How do you/will you describe and compute sensitivity factors (to quantify the coupling among busses in terms of voltage magnitude, the coefficient that quantifies the impact of a control action in terms of variation of active and reactive power exchange in one node to control the voltage on a target node)?
- From the BUC description, it seems you will evaluate the reactive and active power bids (together with other technical solutions) in your DSO optimization as both actions can support voltage control and influence each other. Can you please explain the process?
- To what extent can reactive power be offered in an aggregated manner? How can the sensitivity of an aggregated group to solve a voltage issue at a certain location in the grid be determined?
- Linked to the previous question, should the impact on the voltage issue be evaluated by the DSO (considering the contribution of each individual flexible resource) or the aggregator (considering the impact of aggregated resources)?
- How will you measure service delivery (e.g., measure the activation at the connection of the flexible asset or within the DSO grid where the need is located)? Will you use the active and/or reactive power delivered or a voltage magnitude target value?
- What are the main challenges for setting up a local reactive power market?

Questions posed to market operators (N-SIDE, NODES):

- Do you already have previous experience with setting up reactive power markets, or are you working on solutions for reactive power? If yes, can you share some information on the market and product design?
- For EUniversal, do you already know how the market design of the proposed local reactive power market will differ compared to the proposed active power markets? Please explain.
- What are the main challenges for setting up local reactive power markets?

Questions posed to aggregators (Centrica):

- Do you already have previous experience with participating in reactive power markets, or are you working on solutions for reactive power? If yes, can you share some information?
- To what extent can reactive power be offered in an aggregated manner? How can the potential/sensitivity of an aggregated group to solve a voltage issue at a certain location in the grid be determined?
- Which types of flexible resources will be used in the EUniversal demos to provide voltage control services? Which flexible resources in your portfolio could be used to deliver voltage control services?
- Linked to the previous question, should the impact on the voltage issue be evaluated by the DSO (considering the contribution of each individual flexible resource) or the aggregator (considering the impact of aggregated resources)?
- What are the main challenges for FSPs when participating in local reactive power markets?

Participant list

Total: 20 participants

- Comillas (2)
- E.DSO (1)
- Energa (2)
- E.ON & Mitnetz Strom (3)
- E-REDES (4)
- INESC-TEC (2)
- NODES (1)
- N-SIDE (1)
- Vlerick (1)
- VITO (3)

I.6 Workshop 6: Roles and responsibilities

The sixth workshop was organized online on the 4th of May 2022 and covered three parts: (1) the market operator role, (2) the meter data operator role, and (3) the role of the independent aggregator.

Preparatory questions

Questions posed to DSOs (Energa, E-REDES, Mitnetz Strom), market operators (N-SIDE, NODES) and aggregators (Centrica):

How do you see the role of the DSO evolving in the context of local flexibility markets? Which additional activities should the DSO take up? Which new competences need to build up for these activities?

Role of the local flexibility market operator

- How do you see the role of the local flexibility market operator evolving in the context of local flexibility markets? Which activities should the local flexibility market operator take up?
- Please fill in the table below with regard to the tasks and activities related to market operation: The viewpoint of EUniversal is to opt for an independent market operator. However, from Workshop 3 and throughout the project, it became clear that some tasks can be taken up by other actors. For the activities mentioned below,
    - Please indicate in general (not from the perspective of your demo) who would preferably take up which role/activities by putting an 'X'. You can indicate multiple answers and indicate under which conditions which actor applies.
    - Please also indicate how it is done in your demo.
- What are the advantages and disadvantages of having a neutral market operator versus a DSO as the market operator?

Role of the data operator

- Currently, the DSO is responsible for the standard meters (smart meter data and network data). However, in case new meters are used for flexibility (submetering etc.): who will take up the meter data operator role for those new devices?
- From these metered data, who will determine the volume of flexibility delivered? Is this the DSO, FSP or other? What are the advantages or disadvantages of your choice?
- Who will be responsible for the storing and distributing of the calculated volumes of the flexibility delivered?

Role of the (independent) aggregator

- How do you see the role of the aggregator evolving? Which additional activities should an aggregator take up, and which competences should the aggregator build up?
    - … considering the establishment of local flexibility markets (e.g., consider network location/impact in an aggregated bid)?
    - … considering the participation of LV customers in these markets (e.g., in case of aggregation of a large number of customers with a low value of flexibility with a high degree of stochasticity)?
- How do you see the role of the aggregator in the validation and settlement of flexibility delivery of aggregated portfolios?
    - Will the aggregator provide a baseline on portfolio level or for each flexible resource individually?
    - Will the settlement be done on an aggregated or individual level?

Participant list

Total: 28 participants

- Centrica (1)
- E.DSO (5)
- Energa (2)
- E.ON & Mitnetz Strom (4)
- E-REDES (7)
- INESC-TEC (3)
- NODES (1)
- N-SIDE (2)
- Vlerick (1)
- VITO (2)

I.7 Multi-stakeholder workshop

The multi-stakeholder workshop was organized at the Vlerick Brussels Campus in cooperation with the Vlerick DSO Chair (Vlerick, 2022) on the 28th of May 2022 and covered two parts: (1) the big picture of using flexibility to manage congestion in distribution networks; and (2) detailed flexibility market design issues that need more discussion (e.g., reactive versus active flexibility products and markets, the possible role of third party operator for flexibility markets, the balancing responsibility of the DSO,…).

Interview questions

Questions posed to DSOs and TSOs:

- Do you already have experience with using flexibility today?
- Where do you see the potential for flexibility? Under what kind of circumstances?
    - Why? Evening peaks, EVs, Renewables,…
    - Where? Feeders or transformers, rural versus cities, temporary or permanent,…
    - When? Evening, seasonal,…
    - Which voltage level? MV/LV, and what exactly do you call MV/LV?
- Do you see a potential to use flexibility to save investments in your grid, and what are the main barriers to reaching that potential?
- Do you have a methodology and grid technology to know when/where you need flexibility?
- Do you see a need and potential for reactive power markets in your area in the future? If yes, would it be traded separately from active power?
- What is the DSO's balancing responsibility when activating flexibility?
- Is there a role for third-party operators in flexibility markets? Where do you see this?
- What is the order of magnitude of the ICT costs that come with flexibility procurement? Is this lower/higher than the expected benefits?

Questions posed to market operators:

- Could you explain how your flexibility platform operates and if/how this has evolved over the years?
- Where do you see the potential for flexibility? Under what kind of circumstances?
    - Why? Evening peaks, EVs, Renewables,…
    - Where? Feeders or transformers, rural vs cities, temporary or permanent,…
    - When? Evening, seasonal,…
    - Which voltage level? MV/LV, and what exactly do you call MV/LV?
- What do you think are the main benefits your market platform can bring to the different market participants?
- What do you think are the main benefits your market platform can bring to the different market participants?
- What does the communication with the DSO and other market participants look like?
- Do you see a need and potential for reactive power markets in your area in the future? If yes, would it be traded separately from active power?
- How do you interact with the balancing market? What is the DSO's balancing responsibility when activating flexibility?
- Is there a role for third-party operators in flexibility markets? Where do you see this?
- How do you expect your business to evolve in the coming years?

Questions posed to aggregators:

- What is your current experience with flexibility markets?

- Where do you see the potential for flexibility? Under what kind of circumstances?
    - Why? Evening peaks, EVs, Renewables,…
    - Where? Feeders or transformers, rural vs cities, temporary or permanent,…
    - When? Evening, seasonal,…
    - Which voltage level? MV/LV, and what exactly do you call MV/LV?
- What do you think are the main benefits that aggregators can bring to the different market participants?
- What methodology and grid technology do you use to place flexibility offers?
- Do you see a need and potential for reactive power markets in your area in the future? If yes, would it be traded separately from active power?
- What is the DSO's balancing responsibility when activating flexibility? What is the DSO's balancing responsibility when activating flexibility?
- Is there a role for third-party operators in flexibility markets? Where do you see this?
- How do you expect your business to evolve in the coming years?

Questions posed to researchers and regulators:

- How do you think research/regulation on flexibility has been evolving over the past years?
- Where do you see the potential for flexibility? Under what kind of circumstances?
    - Why? Evening peaks, EVs, Renewables,…
    - Where? Feeders or transformers, rural vs cities, temporary or permanent,…
    - When? Evening, seasonal,…
    - Which voltage level? MV/LV, and what exactly do you call MV/LV?
- Do you see a potential to use flexibility to save investments in distribution grids, and what are the main barriers to reaching that potential?
- Which methodology and grid technology do you think is required to identify when/where flexibility is needed?
- Do you see a need and potential for reactive power markets in your area in the future? If yes, would it be traded separately from active power?
- What is the DSO's balancing responsibility when activating flexibility?
- Is there a role for third-party operators in flexibility markets? Where do you see this?

Polling questions during the workshop

Is there a potential for flexibility to defer network investments?

- Yes, at all voltage levels
- Yes, but not at low voltage levels
- No

Should the offering of flexibility service be

- Mandatory
- Voluntary
- Both

Should flexibility be sourced by the system operator in the

- Short-term
- Long-term

Is there a role for a third-party market operator?

- Yes
- No

What is the balancing responsibility of the DSO when activating flexibility?

- No responsibility
- Limited responsibility (at least partly exposed to imbalance costs)
- Fully responsible (counter-trading)

Participant list

- APG (2)
- Comillas (1)
- E-Control (1)
- Elia (1)
- Energa (1)
- E.ON (1)
- E-REDES (1)
- Fluvius (5)
- Mitnetz Strom (1)
- Netz-Noë (3)
- NODES (1)
- N-SIDE (1)
- UK Power Networks (2)
- Vlerick (4)
- VITO (2)
- VREG (2)