CLEAN ENERGY MINISTERIAL

iea-isgan.org

ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

Power Transmission & Distribution Systems

Active System Management by DSOs

Discussion paper

Kris Kessels, Gwen Willeghems, Janka Vanschoenwinkel, Reinhilde D'Hulst, Annelies Delnooz, Helena Gerard (VITO/EnergyVille)

Jose Pablo Chavez (Comillas Pontifical University), Nima Mirzaei Alavijeh (Chalmers University of Technology), Gregor Taljan (Energienetze Steiermark GmbH), Alexander Fuchs (ETH Zürich), Santiago Gallego (Iberdrola), Sabine Lengkeek (Rijksdient voor ondernemend Nederland), and Nicole Kerkhof (Rijksdient voor ondernemend Nederland)

ISGAN Working Group 6 - Power Transmission & Distribution Systems

January 2025

About ISGAN Discussion Papers

ISGAN discussion papers are meant as input documents to the global discussion about smart grids. Each is a statement by the author(s) regarding a topic of international interest. They reflect works in progress in the development of smart grids in the different regions of the world. Their aim is not to communicate a final outcome, but rather to lay the groundwork for further research and analysis.

Disclaimer

Acknowledgments

This discussion paper has been prepared by:

Annelies Delnooz	EnergyVille/VITO	Belgium
Reinhilde D'Hulst	EnergyVille/VITO	Belgium
Janka Vanschoenwinkel	EnergyVille/VITO	Belgium
Kris Kessels	EnergyVille/VITO	Belgium
Gwen Willeghems	EnergyVille/VITO	Belgium
Helena Gerard	EnergyVille/VITO	Belgium
Jose Pablo Chaves	Comillas Pontifical University	Spain
Nima Mirzaei Alavijeh	Chalmers University of Technology	Sweden
Gregor Taljan	Energienetze Steiermark GmbH	Austria
Alexander Fuchs	Research Center for Energy Networks (FEN), ETH Zürich	Switzerland
Santiago Gallego	Iberdrola	Spain
Sabine Lengkeek	Rijksdienst voor ondernemend Nederland	The Netherlands
Nicole Kerkhof	Rijksdienst voor ondernemend Nederland	The Netherlands

Additionally, the authors would like to thank the reviewers for their final input to this document:

Wickie Lassen Agdal	Danish Energy Agency	Denmark
Susanne Ackeby	RISE Research Institutes of Sweden	Sweden
Susanne Windischberger	AIT Austrian Institute of Technology	Austria

Finally, the authors are grateful to all the ISGAN workshop participants of ISGAN Working Group 6 and the Bridge EU project's representatives for their active participation and interesting contributions to the workshop series.

List of Acronyms

ANM	Active Network Management
ASM	Active System Management
BRP	Balance Responsible Party
CBA	Cost-Benefit Analysis
CL	Capacity Limitation
DER	Distributed Energy Resources
DR	Demand Response
DSF	Demand-Side Flexibility
DSO	Distribution System Operator
EV	Electric Vehicle
FGDR	Framework Guidelines on Demand Response
FSP	Flexibility Service Provider
GCM	Grid Capacity Management
GDPR	General Data Protection Regulation
HP	Heat Pump
HV	High Voltage
LV	Low Voltage
MBMA	Meter-Before-Meter-After
MO	Market Operator
MV	Medium Voltage
NCDR	Network Code on Demand Response
NRA	National Regulatory Authority
PQ	Prequalification
RDP	Rapid Development Platform
RES	Renewable Energy Sources
SO	System Operator
TSO	Transmission System Operator

Executive Summary

The energy transition aims to reduce greenhouse gas emissions, enhance energy efficiency, and increase the share of renewables in the energy mix. Since much of this renewable energy is expected to come from wind and solar, the power grid will face new complexities in its planning and operation due to the uncertain and highly variable generation patterns of these sources. Further compounding the challenge, the ongoing electrification of industries, transport and heating will add additional loads to already stressed grids.

Distribution System Operators (DSOs), due to their proximity to end-users and their role in managing the growing number of distributed energy resources (such as solar PV and electric vehicles), are central to addressing these challenges. To maintain system stability, accommodate local peaks, ensure voltage regulation, and manage congestion, DSOs will need to implement a more active approach to local system management.

This paper aims to provide insights into how DSOs can leverage active system management to cost-efficiently and securely manage their grids. These insights stem from a series of interactive workshops held with members of the International Smart Grid Action Network (ISGAN), complemented by case studies from literature, findings from research projects, and real-world experiences shared by ISGAN members.

The paper discusses three key topics in detail:

1. **Market-Based Flexibility Procurement by DSOs:**
   The design of flexibility procurement faces several challenges, particularly for low-voltage flexibility. One of these challenges is the lack of adequate prequalification processes. There is a need for further analysis to evaluate the implications of ex-post versus ex-ante product prequalification. Additionally, innovative baseline methodologies are required to cater to new flexibility services and products, as well as to new types of flexibility service providers and flexible resources. Finally, aggregation models should be put in place, tailored to market frameworks, the types of products and services offered, and the types of FSPs (Flexibility Service Providers) and flexible resources involved.

2. **Supporting Grid Tools for Active System Management:**
   It is evident that solutions for medium- and high-voltage grids cannot be directly applied to low-voltage (LV) grids, which often require simpler and more scalable approaches. To improve LV grid management, DSOs need increased visibility of LV grid needs and improved monitoring capabilities, including digital meters for all LV flexibility users. Enhanced modeling and estimation of flexibility impacts, improved congestion forecasting capabilities, and more detailed data on the specifications of connected flexibility sources are essential to address these needs.

3. **Applicability of Flexibility Mechanisms and their trade-off with Investments:**
   While grid investment needs are substantial, the effective use of flexibility mechanisms can significantly reduce these requirements. DSOs must select the most suitable flexibility mechanisms based on economic and operational efficiency. There is no "one-size-fits-all" solution; multiple, complementary mechanisms will be necessary to address diverse DSO needs and facilitate the energy transition.

By addressing these conclusions, DSOs can better navigate the challenges associated with flexibility. Overall, we can conclude that the challenge of integrating flexibility in the DSO sphere is complex, necessitating additional guidance and research on how to correctly trade-off between different flexibility mechanisms and grid investments. This includes developing appropriate criteria, methodologies, and quantification methods. Key factors to be considered in this assessment are the economic viability, encompassing the costs and benefits of the solutions, which calls for a societal cost-benefit analysis. This analysis should account for the opportunity cost of alternatives to flexibility. Additionally, the reliability and availability of flexibility (including market liquidity) are crucial factors. Moreover, compatibility with current and future regulatory contexts should also be considered. Furthermore, the methodology should account for long-term economic and environmental impacts. Finally, the expected user engagement with the proposed solutions and the experience of DSOs should be factored in.

In conclusion, integrating flexibility in the DSO domain is a multifaceted challenge that will require ongoing effort to ensure an effective and sustainable energy transition.

Table of Content

1. Introduction

1.1. Background

This discussion paper was prepared within the framework of ISGAN Working Group 6. The Working Group 6 focus area, Power Transmission & Distribution Systems, promotes solutions that enable power grids to maintain and improve the security, reliability, and quality of electric power supply. The main objective of this focus area is to conduct studies on how distribution and transmission networks could interact in the future and ensure stable grid operation under high levels of renewables. Figure 1-1 positions this work in the ISGAN context.

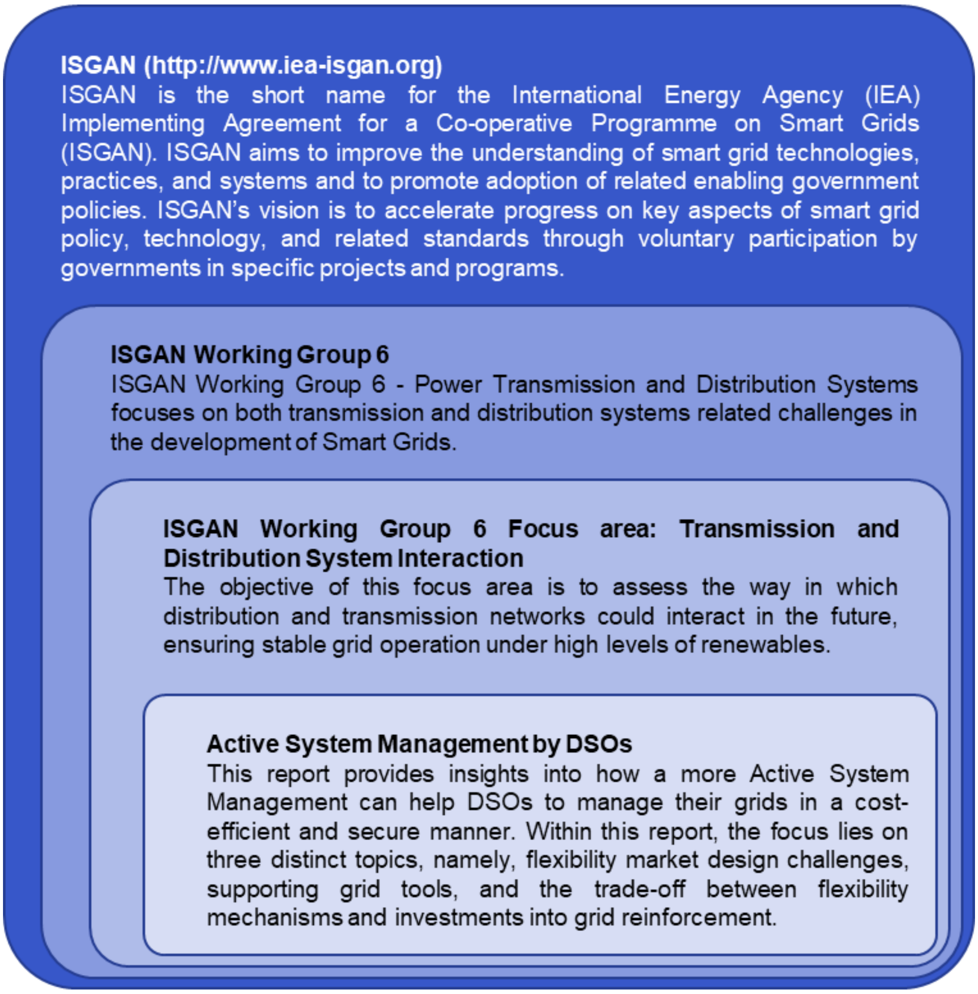

Figure 1-1: Position of this discussion paper within the ISGAN context

1.2. Purpose of the discussion paper

The objective of this discussion paper is to provide insights into how a more Active System Management (ASM) can help Distribution System Operators (DSOs) manage their grids in a cost-efficient and secure manner. The insights presented in this paper are based on a series of interactive workshops for ISGAN members, complemented with examples from literature, conclusions from research projects and experiences from ISGAN members. Before each workshop a short questionnaire was sent out to the workshop participants, the output of which was discussed during the workshops. This could be two-fold: questions to collect diverging or similar practices across ISGAN member countries, but also specific and more elaborate contributions of some of the working group (WG) members to share best practices. In addition, short polls during the workshops and on the spot discussions with workshop participants provided supplementary inputs for this discussion paper.

This paper is structured around 3 themes for DSO's ASM, namely, (i) design challenges of market-based flexibility procurement, (ii) supporting grid tools for ASM by DSOs and (iii) applicability of different flexibility mechanisms for DSOs and their trade-off with investments. The table below gives an overview of the three workshops which have been organized. It should be noted that the last workshop was a combined workshop with the Bridge WG Regulation[1]. During the different workshops, participants were present representing the following countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Greece, Ireland, Italy, Malta, the Netherlands, North Macedonia, Norway, Portugal, Slovenia, South Korea, Spain, Sweden, Switzerland, and the UK. For the third workshop, representatives of the following 12 Bridge projects were present: PARMENIDES, Beflexible, SenergyNets; HE project STREAM, Opentunity, GIFT, Euniversal, OneNet, DriVe2X, EV4EU, Communitas, XL Connect.

Table 1-1: Overview of the workshop series

Workshop		Timing
WS1	**Design challenges of market based flexibility procurement by DSOs**	13 Nov 2023 13h00-15h00 CET
WS 2	**Supporting grid tools for ASM by DSOs**	18 Dec 2023 10h00-12h00 CET
WS 3	**Applicability of different flexibility mechanisms for DSOs and their trade off with investments**	11 Jan 2024 14h00-16h00 CET

The remainder of this discussion paper is structured as follows. Chapter 2 presents the regulatory and operational context of ASM, explaining the evolution of the EU regulatory framework as well as the challenges related to harvesting low voltage (LV) flexibility. In Chapter 3, we will explore the different possibilities DSOs have at their disposal to solve their congestion and other issues, while in Chapter 4 we will look at supporting grid tools DSOs need to exploit flexibility. Then, Chapter 5 focusses on some specific challenges linked to market-based procurement by DSOs. Finally, Chapter 6 presents the main conclusions and recommendations of this paper.

[1] Bridge Working Group on Regulation. Link: https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/working-groups/regulation

2. Regulatory and operational context

2.1. European regulatory context

To achieve the European Commission's strategic goal of a climate-neutral economy by 2050, it is essential to integrate a growing share of renewable energy, including distributed energy resources (DER), into the electricity grid. Concurrently, the transition away from fossil fuels necessitates the electrification of various end-use sectors such as heating and transportation. These transitions present challenges due to increased electricity consumption and more variable generation, putting considerable strain on electricity grids. In response, the European Commission recently published its Grid Action Plan[2], highlighting the need for significant efforts at the distribution grid level, as most DER, heat pumps (HP) and electric vehicles (EV) will be connected here. However, grid investments[3] alone will not suffice and flexibility will be crucial to manage fluctuations in renewable energy generation and consumption while reducing grid investment costs. In 2022, total spending on flexibility in Europe's power system doubled from approximately 8 billion to 16 billion euros[4].

While the electricity system has traditionally managed flexibility at the transmission level, addressing challenges in the distribution grid requires new solutions and increased flexibility at this level. The rise in DER and the electrification of end-use sectors is also a source of more flexibility within the distribution grid. Recognizing this opportunity, the European Commission emphasized demand-side flexibility as early as 2009 with the third energy package[5]. The Clean Energy Package[6] further underscored the pivotal role of end-use sectors and made consumer empowerment a central aspect of the energy union strategy[7]. Key legislative texts, such as the Electricity Market Regulation (2019/943)[8], and Electricity Market Directive (2019/944)[9], prioritize consumers in the energy transition by promoting Demand Response (DR) mechanisms and facilitating their market participation.

Article 59(1), point (e) of the Electricity Market Regulation, empowers the Commission to establish a Network Code on Demand Response (NCDR). Article 32 of the Electricity Market Directive in particular states that Member States shall provide the necessary regulatory framework to allow and provide incentives to DSOs to procure flexibility services, including

---

[2] European Commission (2023) Grids, the missing link - An EU Action Plan for Grids. Link: **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A757%3AFIN&qid=1701167355682.**

[4] Smarten and LCPDelta (2023). 2022 Market Monitor For Demand Side Flexibility. Link: **https://smarten.eu/wp-content/uploads/2023/02/DSF-Market-Monitor-2022.pdf**.

[5] European Commission (n.d.) Third Energy Package. Link: **https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/third-energy-package_en**

[6] European Commission (2019) Clean energy for all Europeans package. Link: **https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en**

[7] European Commission (2015) Energy Union. Link: **https://energy.ec.europa.eu/topics/energy-strategy/energy-union_en**

[8] European Commission (2019). Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast). Link: **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0943**

[9] European Commission (2019). Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast). Link: **https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=uriserv:OJ.L_.2019.158.01.0125.01.ENG**

congestion management in their areas, in accordance with transparent, non-discriminatory and market-based procedures unless the procurement of such services is not economically efficient or would lead to severe market distortions or higher congestion. The drafting of the new Network Code is currently ongoing and covers a lot of the topics which were discussed during the ISGAN workshops series. On the 8th of May 2024, EU DSO Entity and ENTSO-E submitted to ACER a joint proposal for the Network Code on Demand Response[10]. This discussion paper highlights some of the main challenges, but also some options Member states have to implement the provisions of the NCDR and some best practices from research and actual implementations.

2.2. Challenges for harvesting (LV) flexibility

From the regulatory context it is clear that there is clear push towards market-based solutions to realize the needed flexibility. The active participation of consumers in electricity markets and procurement of system services is however still limited due to the existence of several technical, economic, social and regulatory barriers. This is particularly the case for LV flexibility. For example, products for system services are not available for or adapted to the requirements of LV consumers. Moreover, challenges arise to ensure a secure grid operation at all voltage levels in case of procurement and activation of flexibility for system services close-to-real time[11], requiring Transmission System Operator - Distribution System Operator (TSO-DSO) and DSO-DSO coordination in addition to a well-established framework for TSO-TSO coordination.

A survey conducted as a preparation for the first workshop highlighted a number of challenges, related to the regulatory framework, (local) market design, operational processes, interoperability and ICT, the trade-off of flexibility versus investment, baselining and consumer engagement (see Figure 2-1).

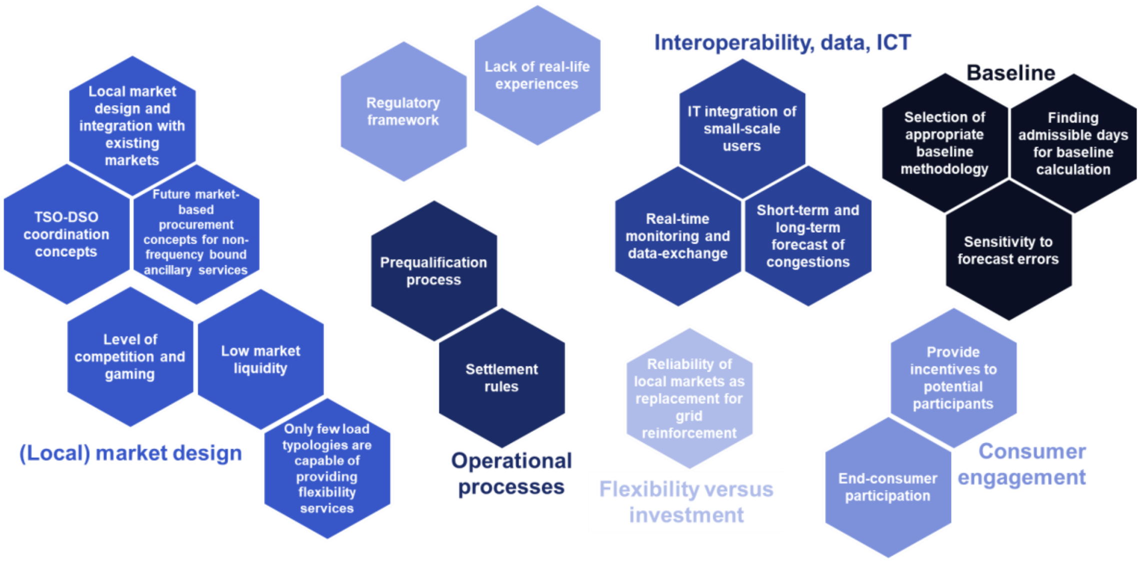

Figure 2-1: Main challenges for market-based flexibility procurement by DSOs considering the participation of demand-side flexibility (input from workshop 1)

[10] EU DSO Entity, ENTSO-E (2024). EU DSO Entity and ENTSO-E Proposal for a Network Code on Demand Response. Link: https://eudsoentity.eu/publications/download/102

[11] VITO (2021), Analysis of the legal, regulatory and regulating framework in the context of the flexibility market. Link: https://www.brugel.brussels/publication/document/notype/2022/fr/Etude-VITO.pdf.

During the first workshop, it became very apparent that there is no such thing as ‘the LV consumer’. LV consumers represent a wide variety in profiles, preferences, knowledge, behavior, etc. There is no one-size-fits-all solution and traditional solutions applied for high voltage (HV) and medium voltage (MV) cannot be easily applied to the LV level. On the other hand, with the upcoming electrification of these LV consumers (HPs, EVs, etc.) and the increased integration of RES in the distribution grid, the flexibility of LV consumers will become an important asset as explained above. Current products and markets for flexibility are however not always suited for LV participation and still need to be adapted. Concurrently, DSOs are looking for (future) solutions to solve grid issues by means of distribution-connected flexibility. In this discussion paper, we will examine different potential solutions available to DSOs for addressing grid issues, including, but not limited to, market-based solutions.

3. Complex interplay of different DSO solutions

3.1. The DSO toolbox

To operate their grids in an efficient and secure manner, DSOs can select from a comprehensive toolbox with various complementary solutions. These solutions include[12] [13] (see also Figure 3-1):

- **Technical solutions using grid assets:** all the technical solutions at the disposal of DSOs such as network reconfiguration.
- **Dynamic connection agreement**: agreements between the DSO and the grid user in which the latter agrees to have the connection curtailed in some periods.
- **Market-based mechanisms**: market-based activation of explicit flexibility which can include long-term and short-term pools in which offers are received from FSPs.
- **Dynamic distribution grid tariffs**: use of time (and locational) differentiated distribution grid tariffs which reflect the necessary temporal and spatial cost variations to trigger implicit flexibility.
- **Cost-based mechanisms**: remuneration of the flexibility provided based on the actual costs of providing the service.
- **Rule-based mechanisms**: mandatory service provision with or without renumeration.

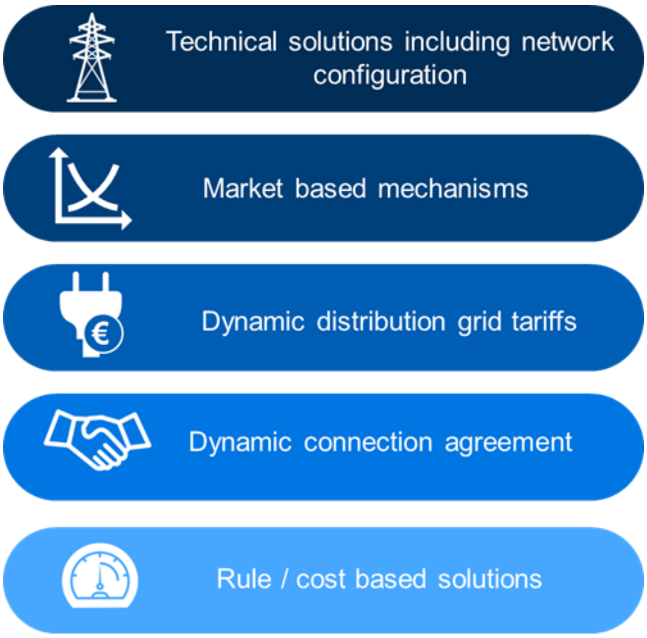

Figure 3-1: DSO toolbox of flexibility solutions

It is important to note that the applicability of the different solutions depends, among others, on the network voltage level: a solution for MV networks with industrial-type consumers is not necessarily suited for LV networks. Each method also scores differently when looking at its user impact (complexity and comfort impact for the end-user), or its effectivity or cost of

[12] H2020 EUniversal (2021). D5.1 Identification of relevant market mechanisms for the procurement of flexibility needs and grid services. Link: https://euniversal.eu/wp-content/uploads/2021/02/EUniversal_D5.1.pdf.

[13] CEDEC et al (2019). TSO–DSO Report: An integrated approach to Active System Management. Link: https://eepublicdownloads.entsoe.eu/clean-documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf.

implementation. Additionally, each method has distinct requirements regarding communication infrastructure, measurement, and computational capabilities. For example, tariff-based solutions require less communication infrastructure compared to direct control by the DSO.

Grid reinforcement, the traditional approach to addressing grid capacity issues by building larger and stronger infrastructure, will remain essential, especially as existing grid assets reach the end of their life span and as significant demands (see above), such as those from the electrification of heating and transportation, are being connect to the grid. However, reinforcement should always be evaluated alongside leveraging flexibility to determine the optimal (mix off) solution(s). For instance, infrequent congestion can maybe more efficiently be managed through the activation of flexibility, whereas prolonged or severe congestion may necessitate system reinforcement. DSOs will have to develop various solutions to ensure reliable system operations. This discussion paper will consider different solutions and will touch upon the complex interplay of these solutions and their trade-off with investments.

As a preparation to the workshop, we asked which DSO flexibility solutions were currently mostly used and studied. As can be seen in Figure 3-2, we have a clear top 3: **market-based mechanisms** and **dynamic connection agreements** had a similar scoring with a close runner up in **dynamic distribution grid tariffs**. During the workshop, we also asked for which flexibility mechanism the biggest growth could be expected. The same three mechanisms were mentioned in the following order: 1) market-based mechanisms, 2) dynamic connection agreement and 3) dynamic distribution grid tariffs. There thus seems to be a big current focus on market-based procurement by DSOs.

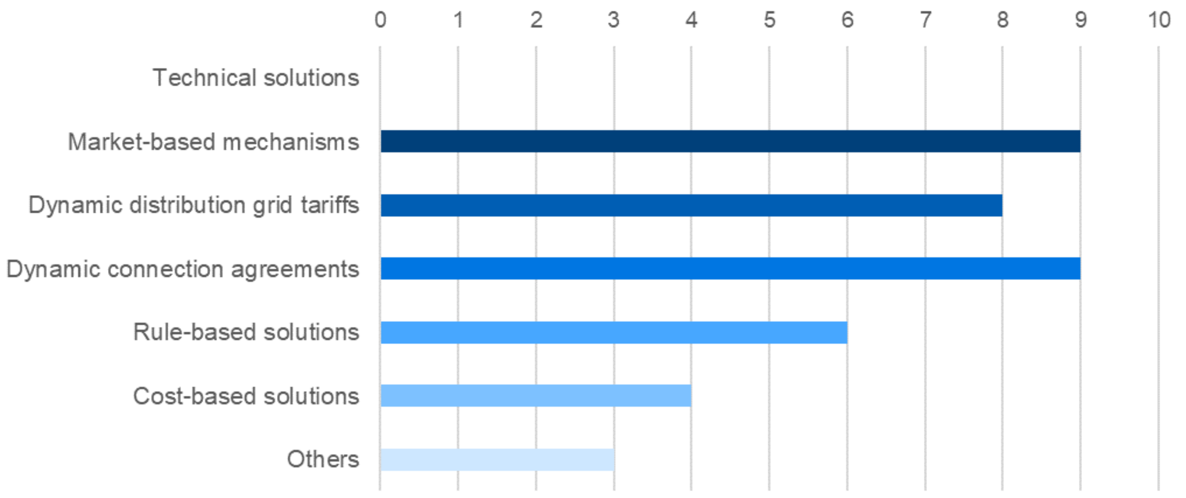

Figure 3-2: Flexibility mechanisms which are currently mostly used by DSOs in your country / studied in your project (input from workshop 3)

It should be noted that as the levels of renewable energy sources (RES) in the grids increase, it will be essential to leverage the flexibility of all types of flexible resources. The box below provides an example of how a combination of storage technologies and other flexible resources can help an Austrian DSO optimize grid operations.

Example: Grid-Supporting Multi-Use Storage Systems
In the Gasen pilot region in Steiermark, Austria, the AIT Rapid Deployment Platform (RDP) is a crucial part of the demonstrator, managing energy community flexibilities to ensure the safe operation of the power grid.

P2C-Trading and Storage Systems
The primary RDP component, Grid Capacity Management (GCM), optimizes flexibility operations while adhering to grid voltage and thermal limits. This includes managing various storage systems such as:

- Battery Storage: Short-term storage solutions that manage daily fluctuations in energy production and consumption.
- Hydrogen Storage: Storing energy over long periods, typically months, to manage seasonal variations in energy supply and demand.

E-Charging and Active Grid Support
Demand Side Management – E-Charging: GCM provides setpoints for EV charging stations, optimizing their operation to maintain grid stability. This demand-side management ensures EV charging is aligned with grid capacity.

Local and Community Storage
GCM is responsible for controlling electric and hydrogen storage, electric vehicles, and smart devices at individual consumers' homes. It generates limiting profiles at the points of common coupling of various controllable devices in the grid. These devices must maintain their active power injection and consumption within the generated limiting profiles to ensure optimum grid levels. This ensures grid limits are maintained, simulated on a test feeder, and applied to a real network model from the Gasen pilot site in Styria, Austria.

Aside from having multiple flexibility solutions at the disposal of DSOs, we also see that flexible resources are moving away from single purpose flexibility provision towards multi-service approaches, i.e., to improve their business case, owners of flexible resources are seeking ways to stack value across different services. This means that the DSO can also be in competition with other flexibility value streams.

3.2. Trade-off between different flex mechanisms

As already mentioned before, not every solution is equally suited to solve a certain DSO need and there is no “one-size-fits-all” solution for all DSOs. In the third workshop, we discussed the factors and criteria needed to a) objectively compare various flexibility solutions and b) select the most effective and efficient option or combination of options. Input from the workshop made it clear that technical, economic, regulatory, and social factors should all be considered. These are summarized in Figure 3-3 below.

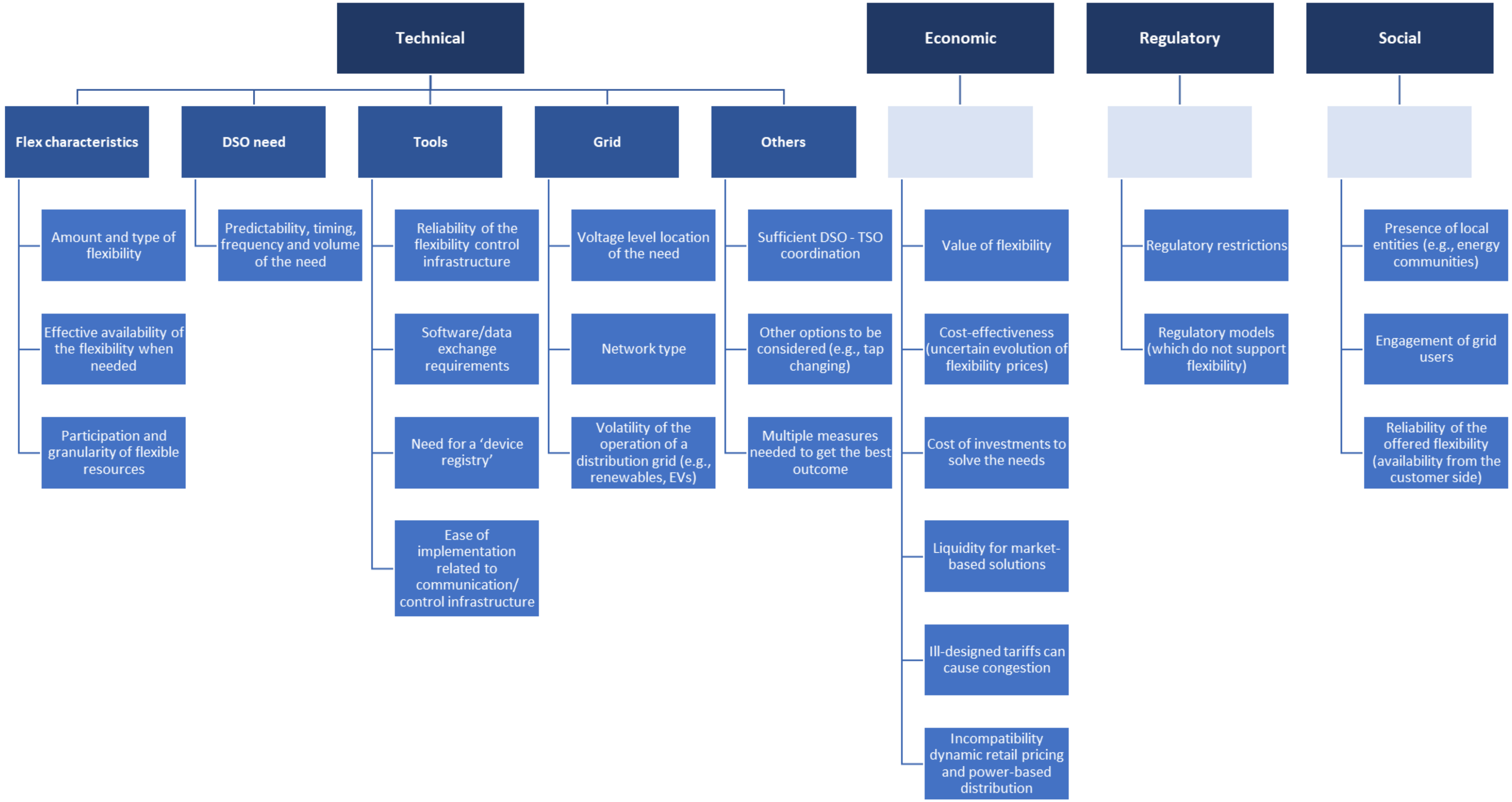

Figure 3-3: Factors which impact the usability of certain flexibility mechanisms to solve local flexibility needs (input from workshop 3)

The **technical factors** mentioned relate to the *characteristics of the flexible resources*, such as the amount and nature of available flexibility (including generation, demand response units, or storage systems) and their size, the extent to which these resources are reliably dispatchable and can respond within the required timeframes and the degree to which various flexible resources in effect participate in flexibility provision and how they are spread across the area where the grid issues occur. The *requirements of DSOs* regarding the predictability, timing, frequency, and volume of flexibility needed to manage their grids are also important factors to consider. Next, the applicability of certain solutions is also linked to the availability and reliability of certain *supporting tools*, such as the robustness of the control systems for managing flexibility. Moreover, different flexibility solutions vary in their data exchange requirements, including whether a device registry needs to be established and the functionalities it should have (e.g., only collecting information during prequalification or also having operational capabilities). They also differ in the ease of implementing the necessary communication and control infrastructure, their compatibility with existing systems, and the associated costs. The *characteristics of the grid* where the need occurs also play an important role, i.e., depending on the voltage levels where flexibility is needed, the type of network (e.g., radial or meshed) in place and the type of grid users connected to these grids (e.g., renewables, EVs) and their volatility the appropriateness of certain flexibility solutions can be different. To sum up the technical factors, other relevant technical considerations include the need for coordination between DSOs and TSOs for the different mechanisms and whether the DSO has other technical means at its disposal to solve grid issues (e.g., tap changers) and their complementarity with other flexibility means.

Another category of factors is **economic** in nature. Firstly, the economic value of flexibility needed and the cost-effectiveness of flexibility solutions to solve the considered needs are important factors. The latter should also be evaluated against the costs of investments required to address flexibility needs. The economic viability thus needs to be proven, encompassing the costs and benefits of the solutions, which necessitates a societal cost-benefit analysis (CBA)[14]. This analysis should then also account for the opportunity cost of alternatives to flexibility. Another important factor to consider when specifically targeting market-based solutions is whether enough liquidity and competitiveness could be attained. Finally, when analyzing the cost-effectiveness of different mechanisms, the compatibility with existing price and tariff schemes should be checked. In case these schemes do not support flexibility provision, they should be reviewed. This thus means that an overall approach is needed to evaluate the cost-effectiveness of the different flexibility mechanisms, also encompassing the re-evaluation of certain current practices and rules which hamper flexibility provision, some of which have been mentioned already in Figure 2-1.

The same reasoning can be applied to the **regulatory factors**. Compatibility with current and future regulatory contexts should also be considered. Certain regulatory restrictions can exist that limit optimal flexibility deployment by DSOs and certain regulatory models (e.g., on DSO remuneration) do not support flexibility. Rather than making the choice of mechanism dependent on these restrictions, regulations should be revised to enable the cost-efficient use of flexibility.

A final category of influencing factors are **social factors**. The level of engagement of different groups of consumers, the reliability / certainty of their flexibility provision and the presence of

---

[14] Various CBA tools are available, e.g., the ISGAN Smart Grid Evaluation Toolkit, an open access tool supporting decision makers in identifying the best smart grid planning options. This tool is available at **https://smartgrideval.unica.it/app/login**.

cooperative or collective initiatives that are willing to provide flexibility will influence the success of certain mechanisms.

During the workshop we discussed on one of the factors more in detail, i.e., **the type of DSO need or service that is considered**. Figure 3-4 and Figure 3-5 below present the results of a poll on which flexibility mechanisms are considered most suitable for solving congestion, respectively voltage issues in the DSO grids. The flexibility mechanisms are ranked from 1 to 5, with different colors indicating the first and last choices (corresponding to the most to least suited) made by respondents.

Market-based mechanisms and dynamic connection agreements are the most favored options for solving *congestion issues* in DSO grids, as indicated by a significant number of first-choice votes. Market-based mechanisms have slightly more first choices compared to dynamic connection agreements. On the other hand, quite some respondents also indicated market-based mechanisms as the last choice. Not all workshop participants thus supported a market approach. Rule-based mechanisms, dynamic distribution grid tariffs, and cost-based mechanisms are less preferred (in this order), with a higher proportion of respondents ranking them as one of their last choices. Cost-based mechanisms are the least favored option, with the majority of respondents selecting them as one of their last choices.

For *voltage control*, the figure looks quite different. Rule-based mechanisms are the most favored option for solving voltage issues in DSO grids, as indicated by a significant number of first-choice votes. However, it also has some last-choice votes, indicating a polarized opinion. Dynamic connection agreements are also a highly favored option, but also here there is a notable number of last-choice votes. Market-based mechanisms have a moderate level of support, with a mix of first and last-choice votes. Cost-based mechanisms are less favored, with fewer first-choice votes and a substantial number of last-choice votes. Dynamic distribution grid tariffs are the least favored option, with no first-choice votes and most respondents selecting them as one of their last choices. However, in general we see that there is also considerable variation in preferences.

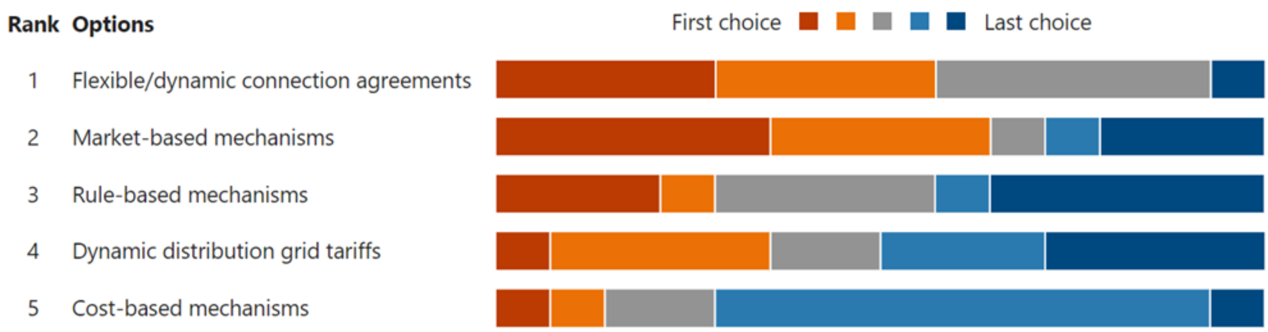

Figure 3-4: Poll answers on which flexibility mechanisms are most suited to solve *congestions* in DSO grids (input from workshop 3)

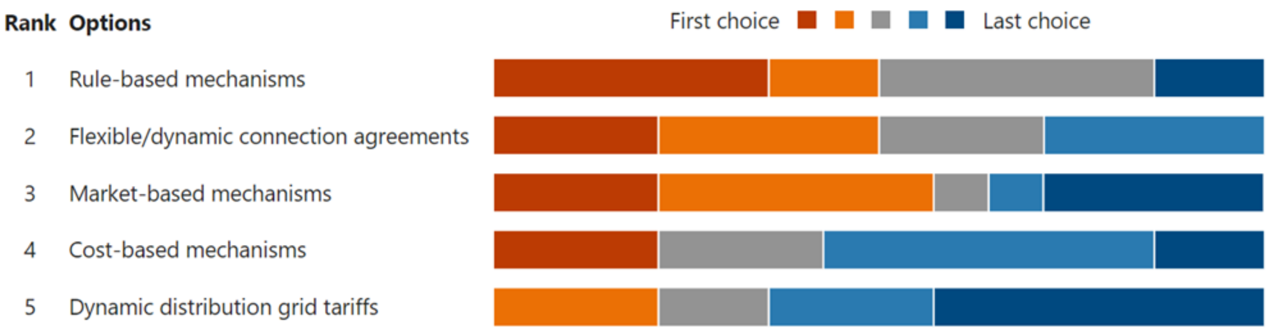

Figure 3-5: Poll answers on which flexibility mechanisms are most suited to solve *voltage issues* in DSO grids (input from workshop 3)

Another topic that has been discussed during the third workshop was that the existing designs of flexibility mechanisms present some limitations, as they are traditionally conceived to operate as independent solutions without considering their potential for integration and complementarity. This standalone approach overlooks the synergies and conflicts that may arise when different mechanisms co-exist and interact. For instance, network tariffs can provide long-term signals for infrastructure investment, while market-based solutions can address short-term operational needs. Similarly, dynamic connection agreements can provide immediate SO services that can be later managed through (local) market transactions, fostering cooperation between short-term and long-term flexibility solutions. On the other hand, designing these mechanisms without considering their interactions can lead to conflicts, such as overlapping signals to consumers, which may lead to distorted consumer behaviors. Thus, each mechanism should be designed to signal an independent cost segment separated from another mechanism.

In a proposal for a coordinated flexibility mechanism design presented as part of BeFlexible project activities[15], network tariffs, flexible connection agreements, and local markets are delineated by their design dimension and options established according to their impact on increasing economic efficiency. The design dimensions represent variables that collectively describe each acquisition mechanism, and the options correspond to the potential implementation values for one particular dimension. Furthermore, comparative analyses considering pairwise scenarios across these design dimensions and options are conducted. These analyses categorize conditions to determine if the acquisition mechanisms can be applied simultaneously without compromising the overall economic efficiency, or if there are significant inefficiencies or potential interaction conflicts.

3.3. Trade-off between flexibility and investments

The EU Grid action plan[16] aims to make sure our electricity grids will operate more efficiently and will be rolled out further and faster. Some of the priorities of the Grid Action Plan include long term grid planning towards 2050, regulatory incentives for forward looking grid build-out, smarter grid utilization including the use of smart grid technologies and need for network tariffs to evolve with ongoing market developments. The Proposal for a Network Code on Demand

[15] Comillas (2024). Unlocking Flexibility from Third-Party Resources: Decoding the Interaction between Mechanisms for Acquiring Distribution System Operator Services. Link: https://link.springer.com/article/10.1007/s40518-024-00236-7

[16] European Commission (2023) Grids, the missing link - An EU Action Plan for Grids. Link: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A757%3AFIN&qid=1701167355682.

Response[17] further stresses that SOs shall choose the most effective and efficient options of the different tools at its disposal, which can include grid investments. A methodology thus needs to be developed to weigh network investments versus flexibility. Figure 3-6 summarizes some of the current practices to do this assessment collected as part of the third workshop. From the answers it seems that most countries do not have a methodology yet, or the methodology is very simplified or still under development. We can thus conclude that a commonly accepted methodology is currently lacking. It is therefore important to guide policy makers and DSOs on how to develop a sound methodology to do this assessment.

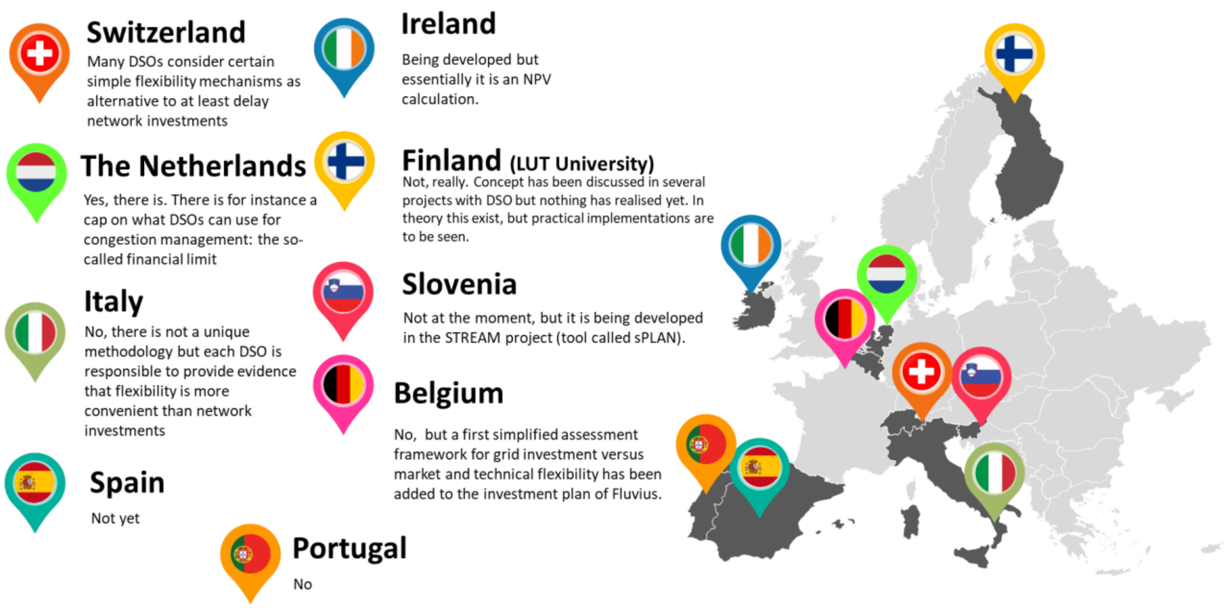

Figure 3-6: Standard methodology to weigh network investments vis-à-vis flexibility (input from workshop 3) [18]

The box below gives a practical example of the trade-off of grid investment and the use of flexibility for a rural grid Swiss distribution grids facing congestion and voltage issues.

Example: Trade-off between flexibility and investments for different Swiss distribution grids

ETH Zurich has performed several projects with Swiss utilities and industry organizations concerning the future distribution grid planning facing a high penetration of renewables. The main objective was to assess the technical capability and reliability of flexibility in a Swiss context. To quantify the grid impact and potential congestions relief using flexibility, simulations of real distribution grids modeled from high- and medium voltage down to the household level were carried out. The evaluation also included the required infrastructure and data, as well as the value of flexibility in contrast with grid upgrades.

[17] EU DSO Entity, ENTSO-E (2024). EU DSO Entity and ENTSO-E Proposal for a Network Code on Demand Response. Link: https://eudsoentity.eu/publications/download/102.
[18] It should be noted that not all EU countries were represented in the workshop.

An example of a rural grid Swiss distribution grid is shown in Figure 3-7. High midday PV production may cause overloading of lines, cables and transformers, that can be solved with flexibility or grid investments, depending on the respective annualized costs.

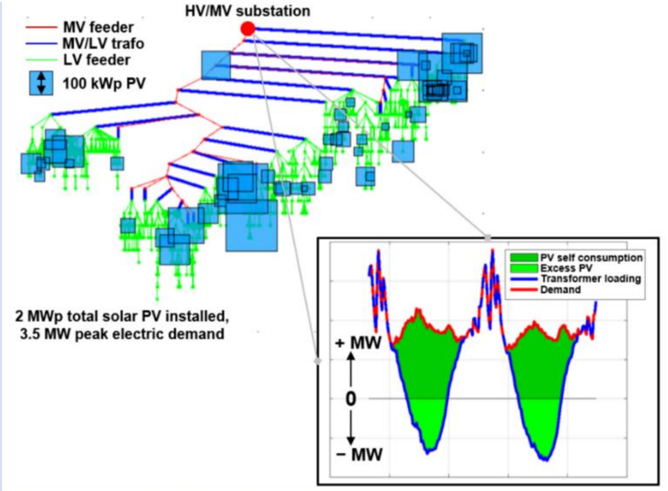

Figure 3-7: Rural grid Swiss distribution grid with high infeed from renewables and potential overloading of lines, cables and transformers

Using **only traditional grid upgrade** to solve the overloading of components due to current and voltage limits leads to new investments across all network levels. The breakup of additional grid investments for a typical Swiss distribution grid without the use of flexibility is shown in Figure 3-8 for all distribution grid voltage levels and according to the cause of grid upgrade.

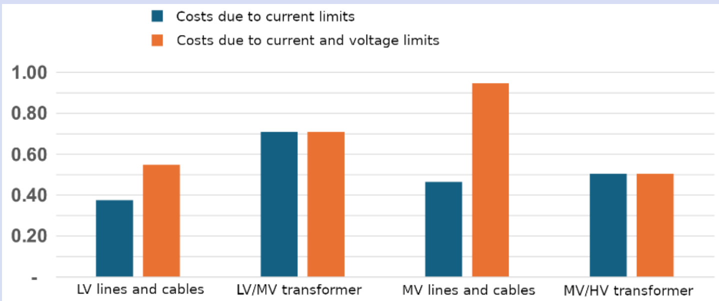

Figure 3-8: Break up of additional grid investments for a typical Swiss distribution grid without the use of flexibility across the grid voltage levels and according to the cause of grid upgrade.

Generally, the grid expansion is driven by PV injections and roughly evenly split between transformers and lines or cables. The voltage limits are driving the investments, since they still require new investments, even if all current limits are resolved. Depending on the planning criteria, investments can be shifted between the LV and MV network level, since voltage problems in the MV grid are also indirectly solved using tighter limits in the LV grid (leading to less investments in MV, but higher investments in LV).

To maximize the social acceptability of the solution, the grid planners consider a **combination of traditional grid upgrade and the use of flexibility**. The flexibility considered has minimum customer impact, leading only to certain opportunity costs, for example due to curtailed PV. The flexibility options considered include reactive power support from PV generation, also known as Q(U)-control, on-load tap changer in transformers (OLTC), and PV curtailment during peak hours up to 30% of the peak power, limited to less than 3% of the annual energy. The potential flexibility usage also includes a small time-shift of BESS schedules towards the peak hours, maintaining the level of self-consumption, spreading the EV-charging and heat pump schedule across an acceptable interval (e.g., EV charging during the night). All methods focused on a simple rule-based flexibility activation based on a schedule or local measurements, that do not require a centralized real-time coordination.

The result is shown in Figure 3-9. A reduction of the additional required grid investments by up to two thirds is possible using reactive power support from PV and the curtailment of PV, dominating OLTC support. This observation is true for a wide range of network types and serves as a planning paradigm for many Swiss distribution grid operators.

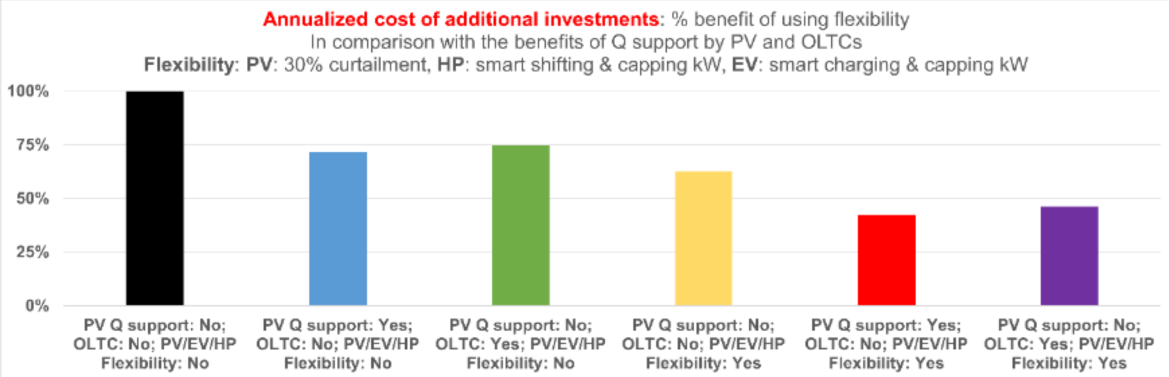

Figure 3-9: Additional grid investments required for a rural Swiss distribution grid. The reference value with no use of flexibility is on the left (black). The costs can be reduced by almost two thirds using reactive power support from PV generation and PV curtailment during peak hours (red bar on the right).

During the workshop, the notion of **anticipatory investments** has also been discussed. Anticipatory investments reinforce the grid based on anticipated potential future needs, which go beyond confirmed generation and demand needs. This proactive approach can ensure that power grids are prepared for the rapid integration of RES, thereby preventing connection delays due to slower grid capacity expansion. However, anticipatory investments carry the risk of being underutilized in case of excessive investments. During the third workshop we discussed which use cases are most relevant to consider anticipatory investments (see Figure 3-10). Areas with high untapped RES potential is indicated as the most relevant one, followed by grid development to accommodate EV charging. During the discussion, it was clear that all four use cases were deemed relevant.

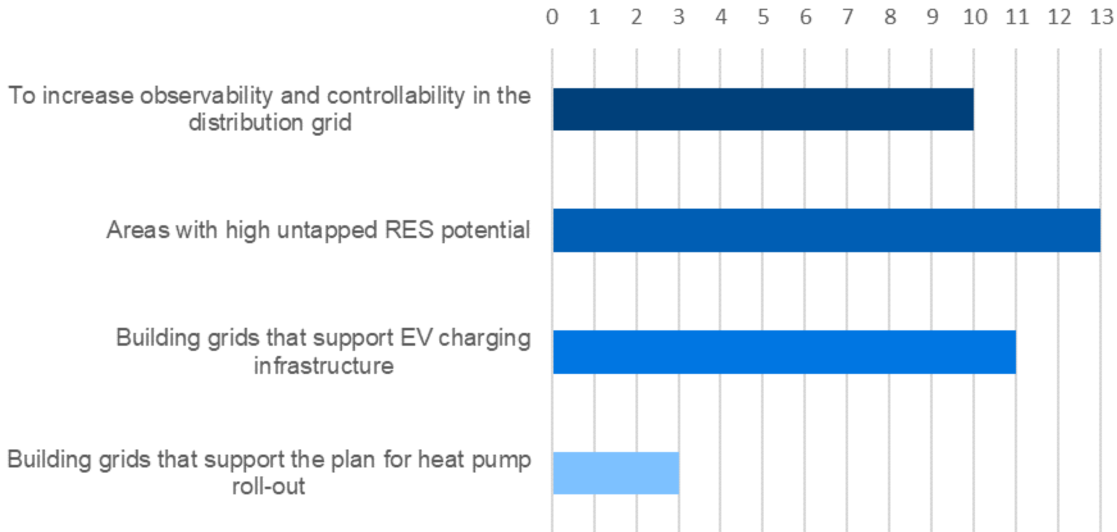

Figure 3-10: Answer on poll regarding use cases for anticipatory investments (input from workshop 3).

4. Supporting grid tools for ASM by DSOs

Improving the capability of forecasting and detecting problems in the networks managed by the DSO (MV and LV grids) is key for enabling the use of flexibility of resources connected to this network. Forecasting and detecting problems in the DSO networks are often not that easy, especially not in LV networks, while a large share of flexibility resources is expected to be connected there in the future. In contrast with HV/MV networks, the LV network consists of many small assets. The investment policy has always been with a fit-and-forget philosophy in mind, taking into account a low 'simultaneity factor' of the different connections, and assuming a large margin for dimensioning the assets. Where MV/HV networks connect a few large industrial customers with largely predictable electricity offtake profiles, the LV network connects mainly residential customers with a highly stochastic behavior. The main interest of these residential customers is keeping their comfort, and they require easy interfaces to interact with the electricity system. General Data Protection Regulation (GDPR) rules, consent and user rights are also not to be neglected when dealing with residential customers.

On top of that, the LV system, as compared to the HV or MV networks, is largely undermeasured, and up till today, only limited monitoring and communication infrastructure is being installed. It should be noted that the level of monitoring capabilities diverges significantly between countries. Moreover, in many areas, the LV system topology is often not accurately characterized: exact cable connectivity, and house-to-cable connection information is often wrongly registered, while information on the phase connectivity of (single-phase) consumers is simply not registered in many cases.

As the MV/HV network is very different from the LV system, MV/HV solutions ASM cannot be easily copied and applied to LV. The solutions for LV grids will have to be more scalable, and inherently take into account the limitations the LV network environment brings.

This section outlines the data and measurements available within the DSO network and introduces several supporting tools that could assist DSOs in their active system management.

4.1. Data and measurements availability

In terms of data and availability of measurements for the DSO, every country and region is different. This is illustrated by the answers to the question on which data and measurements are available to the DSO in the different countries, visualized in Figure 4-1. Generally speaking, the LV grid is much less measured compared to the higher voltage levels. At the LV level, the roll-out of smart meters does not happen in every country at the same pace while the technology and specifications of smart meters evolve with generational jumps. Also, the functionality of smart meters that are rolled-out in a particular region are defined in function of the needs within that region. This results in a high variability in technology and capabilities of smart meters installed across different countries. Next to technical limitations, limitations on data availability may occur due to regulations on data privacy, which means that DSOs do not always have access to measurements from smart meters.

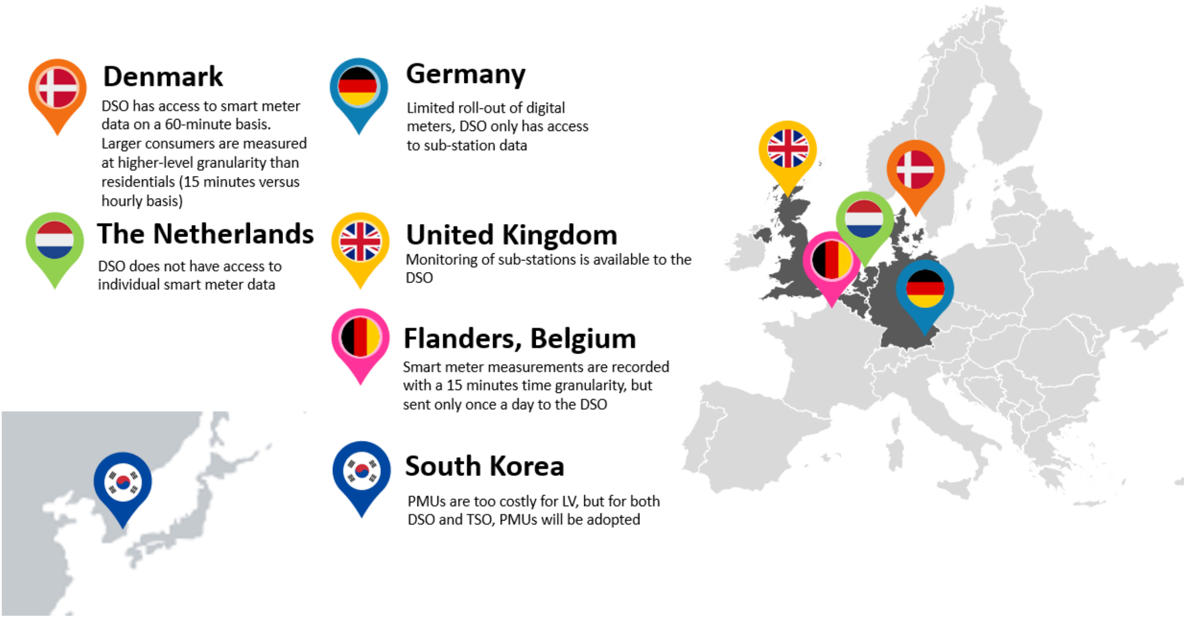

Figure 4-1. Questionnaire responses on the question which data and measurements are available in your country or region (input from workshop 2)[19].

Other types of measurements on the LV system are sometimes also available to the DSO. For example, in some countries, LV-MV substation transformers are equipped with measurements. However, also here, the temporal granularity of measurements can differ from region to region. Since the roll-out of such metering systems also does not happen at the same pace in every region, such measurements are not necessarily available for the full region. This implies that DSO tools for active system management need to be designed with the consideration of limited data availability. The varying availability of data across different voltage levels necessitates the development of distinct DSO tools for different voltage levels. Since the type of measurements and availability differs from region to region, a standardization of tools across different regions and countries will be hard to achieve.

4.2. DSO tools supporting ASM in LV networks

As previously mentioned, the LV network is anticipated to host many flexible resources in the future. However, it currently has the fewest tools available to assist the DSO in leveraging this flexibility. This section is therefore focused on tools designed for the LV grid. Different types of tools are discussed:

- **LV network monitoring** implies keeping track of the network state (i.e., network voltages and currents) in real-time. As the availability of real-time measurements in the LV grid is often very low, specific tooling to monitor the state of the network is required. When a large historical pool of smart meter data is available to the DSO, advanced data-driven techniques can be used to reduce LV real-time monitoring requirements. A data-drive state estimation technique was developed and tested during the H2020 EUniversal project[20] that provides an accurate estimate of voltages and active power injections, for a LV grid where full grid observability is not a requirement, as neither topological information nor the electrical characteristics of the grid elements

[19] It should be noted that not all EU countries were represented in the workshop.
[20] EUniversal Project, https://euniversal.eu/

are required. The state estimation only requires a limited number of meters with real-time communication capabilities.

- To be able to assess the impact of flexibility on the network, a **congestion forecasting tool** is required that estimates the risk of congestion (e.g., voltage issues, current congestion) beforehand. During the H2020 EUniversal project[21] an LV congestion forecasting tool was showcased that is able to produce an accurate congestion forecast, with limited data availability. Statistical behavior of residential end-consumers, and uncertainties in the data availability is inherently taken into account when producing congestion risk results. The tool only assumes the availability of a pool of historical offtake/injection profiles of a representative set of consumers.
- Many tools for DSOs for active system management rely on the fact that an accurate digitized version of the grid is available. This is however not true on many occasions. For example, a change in network topology can be incorrectly registered. Also, some information was never registered because it did not seem necessary in the past, such as the phase connection of single-phase small consumers. However now, within a context of harvesting flexibility from the LV network, it becomes increasingly important to be informed of the (un)balanced usage of the network. A relatively new set of tools which fit under the umbrella of **LV network mapping**, addresses this problem by trying to find the correct network topology that fits the measurements from smart meters. Many research papers have been published recently with different proposed methods to tackle this problem, such as [22] [23] [24] [25].

The EUniversal Project[26] has developed and demonstrated a new generation of tools for future distribution networks that enable effective integration of innovative flexibility market-based services and improve network resilience. The tools developed implement a predictive and coordinated management, extend network observability from HV substations to the LV consumers, distribute control capabilities, while adapted to the local characteristics of MV and LV networks. The characteristics of the developed tools are shown in Figure 4-2 and tools as well as characteristics are discussed in more detail in the project's roadmap[27].

---

[21] EUniversal Project, **https://euniversal.eu/**

[22] Yang Weng, Yizheng Liao, and Ram Rajagopal. "Distributed Energy Resources Topology Identification via Graphical Modeling". In: IEEE Transactions on Power Systems 32 (4 July 2017), pp. 2682–2694. issn: 08858950. doi: 10.1109/TPWRS.2016.2628876.

[23] Jiafan Yu, Yang Weng, and Ram Rajagopal. "PaToPa: A Data-Driven Parameter and Topology Joint Estimation Framework in Distribution Grids". In: IEEE Transactions on Power Systems 33 (4 July 2018), pp. 4335–4347. issn: 08858950. doi: 10.1109/TPWRS. 2017.2778194.

[24] Jiafan Yu, Yang Weng, and Ram Rajagopal. "Patopaem: A data-driven parameter and topology joint estimation framework for time-varying system in distribution grids". In: IEEE Transactions on Power Systems 34 (3 May 2019), pp. 1682–1692. issn: 08858950. doi: 10.1109/TPWRS.2018.2888619.

[25] J. Zhao et al. "Full-Scale Distribution System Topology Identification Using Markov Random Field". In: IEEE Trans. Smart Grid (2021).

[26] EUniversal Project, **https://euniversal.eu/**

[27] EUniversal Project (2023), Deliverable D10.5: Exploitation and roadmap. Available at **Final-deliverable-10.5-EUniversal.pdf**.

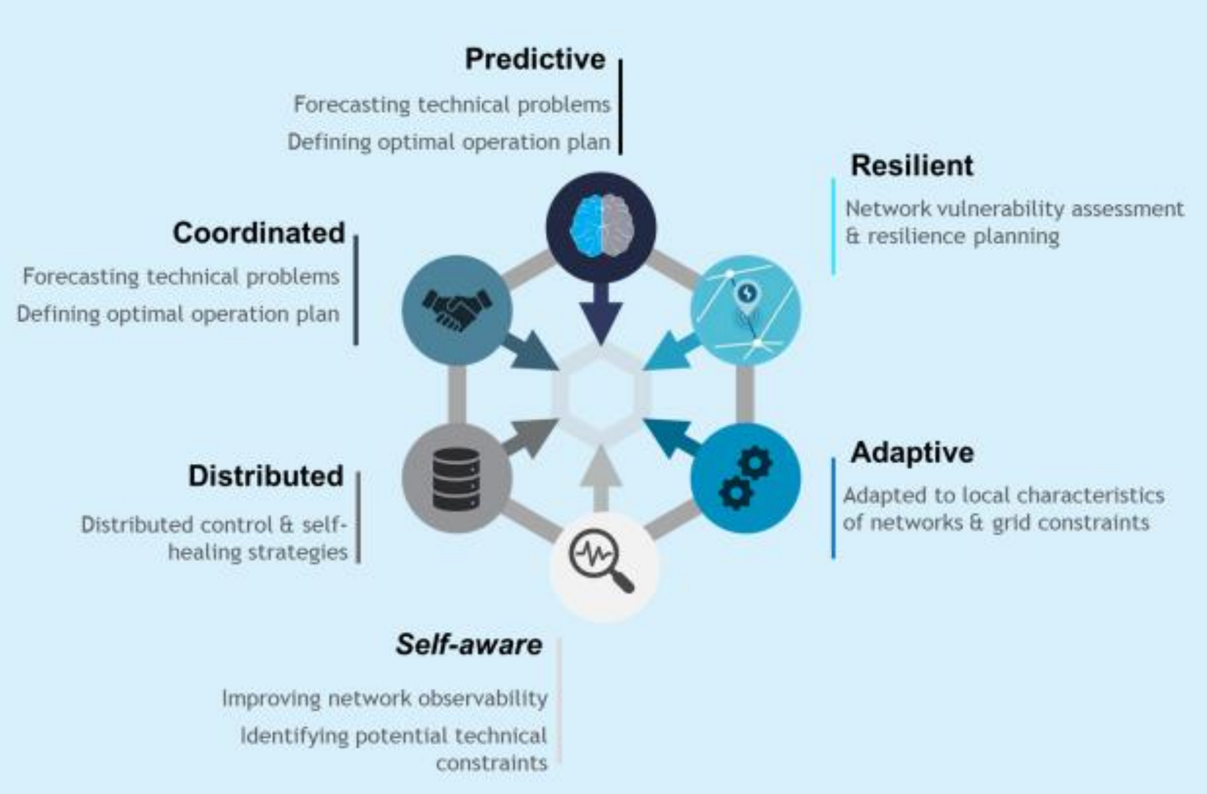

Figure 4-2: EUniversal's DSO tools' characteristics

This kind of capabilities are used in several projects to perform optimal integration of flexibility solutions, considering their optimal sizing and geographical spreads. The next two boxes show two examples of how DSOs are developing solutions to assist them in evaluating the effect of flexibility solutions on present grid issues.

Example: ORKEST: Optimal integration of network flexibility and asset intelligence[28]

The networks in the Netherlands are becoming more heavily utilized and congestion is developing in an increasing number of places. In other words, it is becoming clear that the network is a major obstacle to the speed of the energy transition. It is therefore logical that the focus is placed on the network and its capacity to accelerate the energy transition. However, simply placing a much heavier burden on the current network would lead to excessive disruptions, which actually reduces the available capacity. At the same time, capacity increases are possible (conditional and dependent on various factors), but only when the actual impact on the reliability of the grid and its components is known. What is mainly missing is actual insight into the impact on reliability of other (extreme) load patterns and how to incorporate that insight, together with various solutions such as storage, temporary overload, abandoning redundancy, etc. The project outcome is that the DSOs have gained essential insight into actual (conditional) limits, the impact on reliability of changes in grid use and have developed optimization methods that optimize both options for other grid use and the impact on reliability, an essential step in the adoption of Active Network Management (ANM). The project partners, all the Dutch DSO's, want to give this a

[28] ORKEST project, https://projecten.topsectorenergie.nl/projecten/orkest-optimal-integration-of-network-flexibiilty-and-asset-intelligence-to-increase-large-scale-integration-of-res-while-maintaining-reliability-37711

boost together and thus contribute to the development and practical application of active capacity management.

Example: NOGIZMOS: Likely battery locations to minimize undesirable PV effects

More solar and wind farms can be installed with the results of this project. The aim of the project is to develop and validate in practice an integral software system where storage at private individuals (homes) in connection with assets in the distribution network (grid management) is controlled in such a way that capacity and flexibility on higher network surfaces are increased, with the result that more solar and wind farms can be installed without reinforcement (or with less reinforcement), because the available grid capacity is used more effectively and scarcity is mitigated.

This project researches a basis of data for modelling. It creates an understanding of grid properties and load/generation potential within the system. The project developed a model of the grid where they can test different energy flow scenarios and implement models of battery systems. It observed the current (and future) situation on the MV grid. This will be important feedback for the actual implementation, testing and control of batteries and demonstrates cooperation between regional parties and a DSO.

5. Challenges of market-based flexibility procurement

In this section, we explain some of the main design challenges of market-based flexibility procurement. In this regard, during the first workshop we specifically focused on the topics of prequalification, baseline and aggregation. We will, however, first discuss some general market design topics and choices.

5.1. Market design

Different flexibility platforms can be found within and outside of Europe which aim at facilitating the participation of distribution grid-connected assets in markets for the provision of grid services. Figure 5-1 below shows some information on DSO flexibility markets initiatives across Europe collected from the workshop participants. As can be seen, the market designs of these initiatives are very divers, and they are at different stages of development.

Figure 5-1: Flexibility market initiatives across Europe (input from workshop 1)[29] [30]

Two high level design choices are (1) whether DSOs would procure their services in dedicated local flexibility markets or whether they would procure flexibility in existing markets, which can be day-ahead or intraday wholesale markets or balancing markets and (2) who would operate the market in question. Regarding the first design choice, the view of the workshop participants was divided between the two options with a small preference for dedicated local markets as can be seen in Figure 5-2. Several participants, however, noted that this depends on the specific situation and the market's maturity. Opinions also varied on which actor would be best suited to take on the role of MO (Market Operator), with a preference emerging for a third-party MO. Nonetheless, most participants indicated that this choice would ultimately depend on the context.

---

[29] It should be noted that not all EU countries were represented in the workshop.

[30] Link for Austria: https://www.e-control.at/documents/1785851/1811528/Strommarktmodell_%C3%96sterreich_030413_en.pdf/f007c31e-b6b9-48a1-83a1-53212aae5365?t=1413907916729

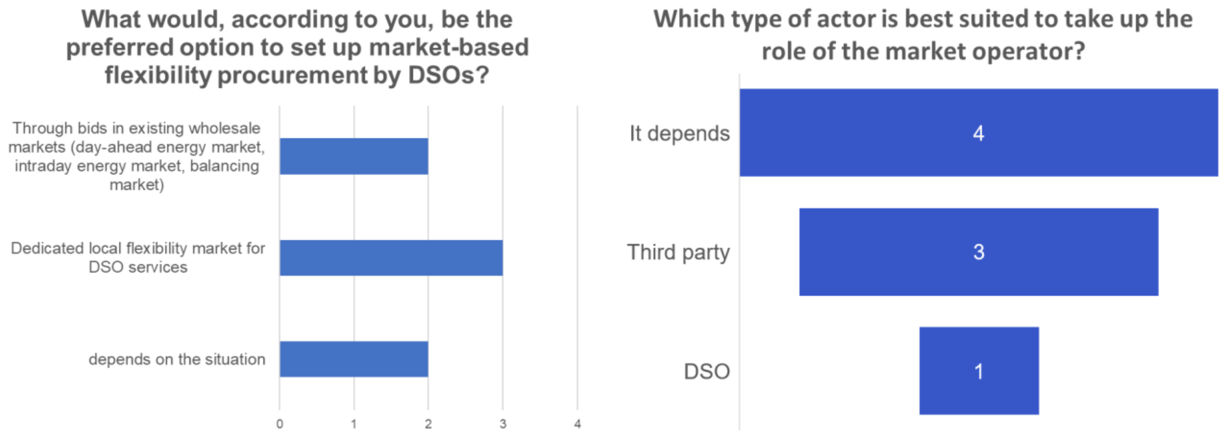

Figure 5-2: Poll results on the design of markets for DSO services (left) and the MO role (right) (input from workshop 1)

As already mentioned, different DSOs are implementing their own market-based solutions with different characteristics and design choices. All participants to the survey, which was issued before the first workshop, however indicated that there should be more regulatory intervention to come to more harmonized market designs for DSO services. Several challenges were however identified which currently hamper further harmonization, such as:

- A clear definition of "market-based procurement" and an understanding of what it entails in the context of DSOs procuring their services is currently lacking.
- DSO services and the DSO context is quite particular and market solutions which work well at transmission level or for energy trading might not be easily transposed to the distribution grid:
    - DSOs have very local needs, and the location of flexible resources very often determines the impact on these needs. Characteristics of the distribution grid therefore need to be considered during the procurement phase.
    - Flexibility might be needed during rare events, but the impact of not having enough flexibility at certain instances might be huge. DSOs need to be able to rely on the effective availability of flexibility.
    - For some DSO needs only a few resources are available which can provide the needed flexibility, which can lead to limited liquidity and market competition concerns.
    - DSOs have different solutions at their disposal called the flexibility toolbox as mentioned above (see Figure 3-1). A mixture of these solutions might be the best option, so a correct trade of needs is to be made among these solutions.

5.2. Prequalification

Prequalification (PQ) is a process used to determine, whether:

- The Flexibility Service Provider (FSP) can deliver the required service and meets the criteria for market access (Market PQ or Service Provider PQ).
- The FSP meets the communication, ICT, and technical requirements for market participation and service delivery (Product PQ).
- The FSP's participation does not compromise the reliability of grid operation (Grid PQ).

Figure 5-3 gives some more insights on the market, product and grid PQ.

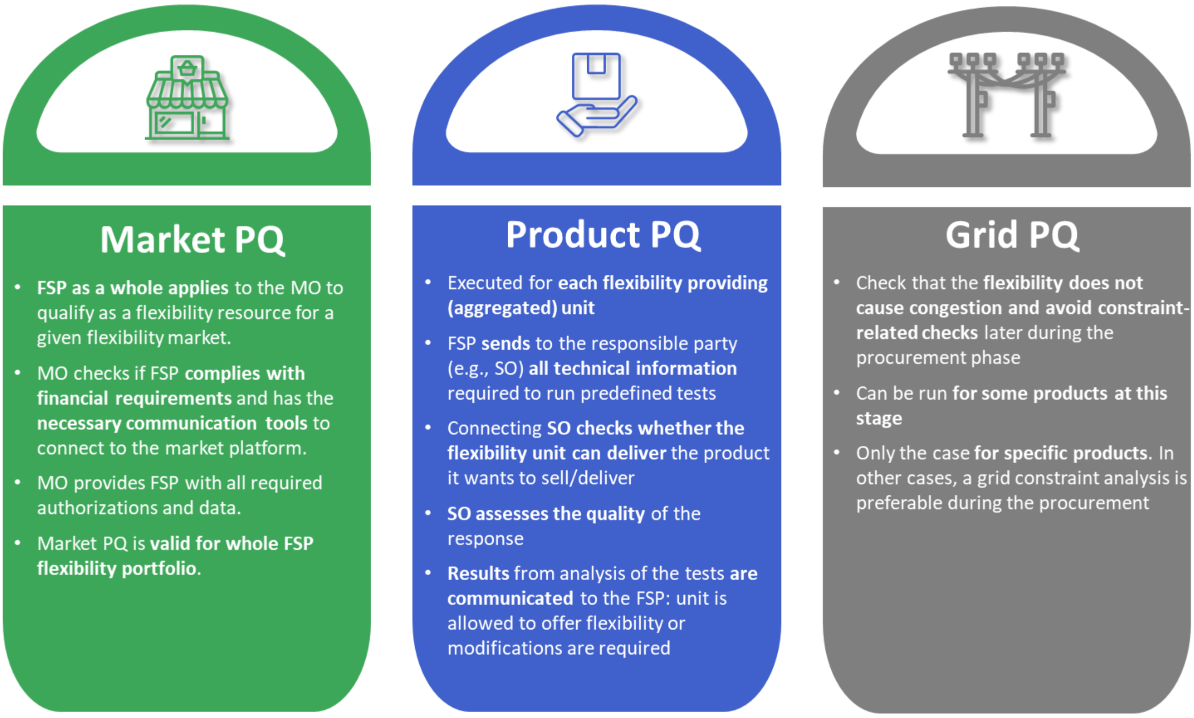

Figure 5-3: Different types of prequalification processes

During the workshop, several challenges were discussed related to the PQ process (see Figure 5-4). First of all, existing PQ processes are very often complex, individual and non-automated which makes them limitedly scalable. A lot of different approaches can be found across EU member states and between products. In general, there is an absence of uniform PQ processes and platforms and current processes very often do not allow for PQ at aggregated pool level. Very often PQ requests have to be made per flexible connection. Due to all these reasons, current PQ methods are not suited for new types of flexibility, including LV flexibility. Finally, due to a lack of experience, conservative margins are being applied during grid PQ and assessment and/or additional studies are needed when making use of LV flexibility, which adds to the barriers.

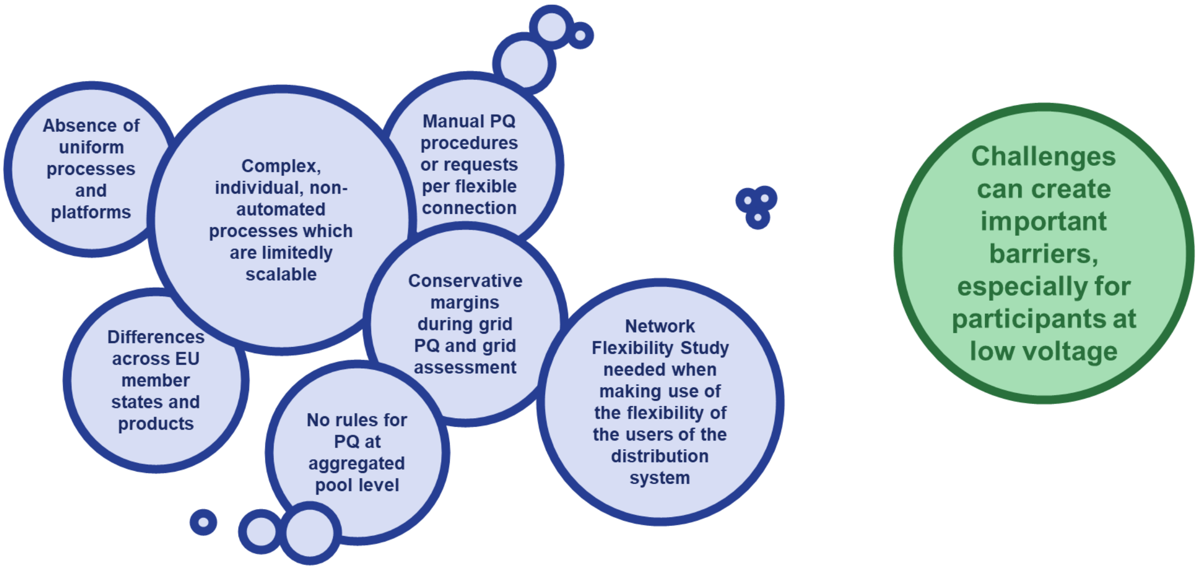

Figure 5-4: Challenges related to prequalification processes.

In the FGDR[31] and ensuing proposal for a NCDR[32], a number of solutions are proposed to harmonise and simplify the PQ process. With regard to harmonisation of the PQ process, the NCDR proposes EU-level requirements to be implemented at the national level. This degree of harmonisation is supported by the a survey during the workshop, where 67% of the participants believe that there should be some process guidelines to be followed by SOs. On the other hand, 33% believes there should be harmonization at country/region and/or at product level. No one supported SO-individualized PQ processes.

With regard to PQ process simplification, the main discussion at EU level centers around ex-ante product PQ versus ex-post product verification. The FGDR and the Proposal for a NCDR introduced product verifications as the default method for congestion management, voltage control, and specific balancing services. This approach, an alternative to product PQ, assesses compliance with service delivery after the fact (ex-post) rather than beforehand (ex-ante). All demos which were part of the OneNet project[33], considered ex-ante product PQ to be a mandatory step (i.e., no replacement by ex-post verification). The main reasons for this choice were to ensure system security and reliability and to be able to verify the ability to provide the service beforehand. Also the uncertainty regarding the upcoming EU regulation made them choose for the well-known option of ex-ante product PQ.

During the workshop we also discussed whether ex-post verification is the preferred choice for DSO services such as congestion management and voltage control. Here we got a more nuanced view, with some participants in favor and some not, depending on the circumstances. Some arguments in favour were that ex-post verification can reduce entry barriers and might be needed to test new market concepts as it might be difficult to set stringent requirements beforehand. Additional advantages mentioned for ex-post verification are that it allows to monitor ongoing compliance and performance of qualified service providers, allows for flexibility and adaptation as the provider's capabilities evolve and provides a mechanism for continuous improvement and feedback. On the other hand, ex-post verification can reduce the reliability for the buyer and therefore increases concerns in the context of system stability (voltage and frequency). It was suggested that ex-ante PQ could be optional (at the option of the DSO) in case the market is sufficiently liquid, but as long as this is not the case, DSOs could also accept partial non-compliance of the provided services (i.e., some resources fail to deliver the flexibility according to the services requirements) and product verification could be more suited in this situation.

5.3. Baseline

The baseline refers to the profile the service providers would have had without flexibility activation. Baseline needs come from the lack of individual schedules from certain types of flexible resources such as DERs, either aggregated or individually. The table below gives an overview over some available baseline methodologies.

---

[31] ACER (2022). Framework Guideline on Demand Response. Link: **https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Framework_Guidelines/Framework%20Guidelines/FG_DemandResponse.pdf**.

[32] EU DSO Entity, ENTSO-E (2024). EU DSO Entity and ENTSO-E Proposal for a Network Code on Demand Response. Link: **https://eudsoentity.eu/publications/download/102**.

[33] OneNet Project (2023). OneNet Deliverable D3.4 - Regulatory and demo assessment of proposed integrated markets, available at **https://onenet-project.eu/wp-content/uploads/2023/09/OneNet_D3.4_V1.0.pdf**

Table 5-1: Available baseline methodologies (Source: [34])

Baseline Technique	Short description
XofY Baselines	The average of the last high, middle or low consumption X days in a Y-day list of eligible days is considered. Close-to-delivery adjustments are possible (e.g. weather differences).
Rolling average	A rolling average of the past X days of the same type. Usually considers a higher weight to days close to the activation day.
Comparable day	The FSP chooses data from the past that they consider similar to the activation day. The baseline choice is made ex-post.
Regression methods	Past data is used to build a baseline function. The baseline function can then be used on the activation day, having different input parameters (e.g. past consumption data, temperature, season, etc.).
Machine-learning techniques	Machine learning techniques are used to estimate the baseline for the activation day. A model is built from past data using a variety of techniques.
Meter-Before-Meter-After (MBMA)	A reading of the meter is performed right before activation, which serves as the baseline.
Zero baseline	The baseline is equal to zero. This method is mostly used for backup generators.
Control group	A group of non-FSP customers sharing similarities with the FSP being baselined is considered. Their average profile during the activation is used as a baseline.
Self-reported	The FSP is requested to report a profile.

No single methodology suits all purposes, as baselining approaches vary depending on the specific service, product, and resources involved[35] [36]. It is crucial to balance the principles of accuracy, simplicity, and integrity. Submetering is regarded as one method to enhance baselining, particularly in the context of combined DERs, but it is still in the early stages of implementation[37]. The proposal for the NCDR[38] anticipates and allows for various baselining methods based on the aggregation models, market design, type of service, and type of resource, with national authorities responsible for defining the general requirements for validating baselining methods. However, harmonizing these methods is anticipated in a subsequent phase, based on recommendations that should be included in the ACER's monitoring report. Figure 5-5 shows that respondents participating in the workshop consider that more guidance is needed on deciding which method can be used for baselining.

[34] CoordiNet project (2021). Deliverable D2.1 – Markets for DSO and TSO procurement of innovative grid services: Specification of the architecture, operation and clearing algorithms. CoordiNet public deliverable. Available at Documents download module (europa.eu)

[35] L. Lind, J. P. Chaves-Ávila, O. Valarezo, A. Sanjab, and L. Olmos. Baseline methods for distributed flexibility in power systems considering resource, market, and product characteristics, Utilities Policy, vol. 86, p. 101688, Feb. 2024. Link: https://doi.org/10.1016/j.jup.2023.101688.

[36] OneNet Project (2023). OneNet Deliverable D3.4 - Regulatory and demo assessment of proposed integrated markets. Link: https://onenet-project.eu/wp-content/uploads/2023/09/OneNet_D3.4_V1.0.pdf.

[37] J. P. Chaves-Avila, D. Davi-Arderius, P. Troughton, S. Cianotti, S. Gallego, and E. Faure. Submetering: Challenges and Opportunities for its Application to Flexibility Services, Curr Sustainable Renewable Energy Rep, May 2024, Link: 10.1007/s40518-024-00235-8. Link: https://link.springer.com/10.1007/s40518-024-00235-8.

[38] EU DSO Entity, ENTSO-E (2024). EU DSO Entity and ENTSO-E Proposal for a Network Code on Demand Response. Link: https://eudsoentity.eu/publications/download/102.

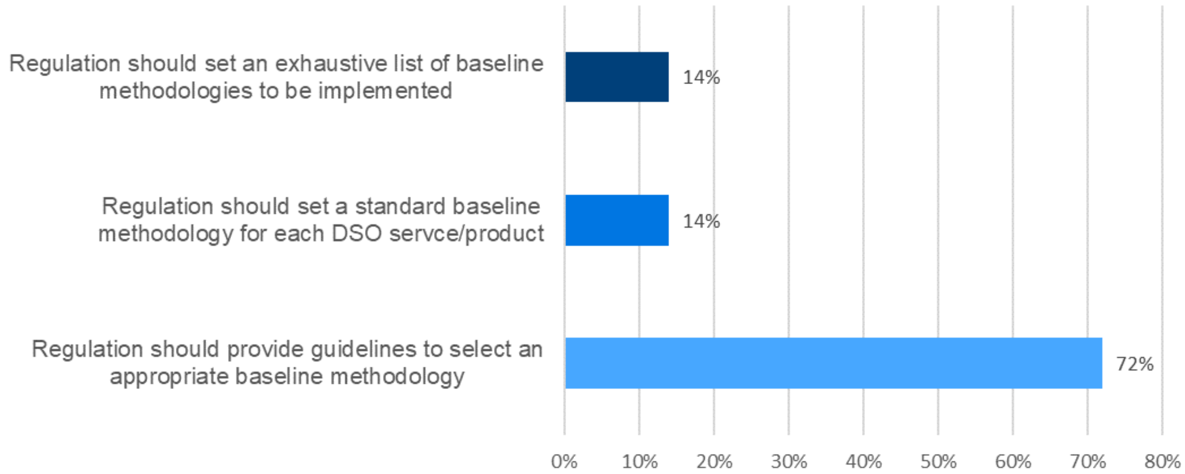

Figure 5-5: Poll results on the need for additional guidance/regulatory intervention on appropriate baseline methodology (input from workshop 1)

The workshop participants see several challenges related to the design and selection of appropriate baselining methodologies. A first challenge is that it might not always be easy to find a correct balance between the principles mentioned above. In addition, it was emphasized that realizing an ideal theoretical baseline which is representative and fair for FSPs but also for the system operator might not be realizable in practice. Another barrier that has been discussed is linked to data availability, e.g., the possible issue of not having enough representative days or data points to establish a reliable baseline. Also, the issue of differentiating between explicit versus implicit flexibility reactions has been highlighted when certain consumers and their flexible resources are exposed to different flexibility signals at the same time. This combination makes it challenging to accurately measure and account for energy usage and flexibility. Next, it should be ensured that both the capacity and the energy aspects are fairly compensated in the baselining process. The former is important to ensure that FSPs offer a capacity that they can actually deliver if activated, while the latter ensures the correct verification of service delivery upon activation notification. The need for the baselining procedure to be clear and easily understandable by all participants in the market was also raised. Setting baselines in case of aggregated pools of flexibility further adds complexity. The lack of harmonized baseline approaches for similar services across different countries has also been mentioned as a barrier. Addressing these issues requires coordinated efforts, regulatory support, and advanced technical solutions.

During the workshop, we also discussed the approaches to set baselines and the actor that would be responsible for this. The vast majority of participants to the workshop prefers to have diversified baselines at product and /or technology level with an exhaustive list being defined by a regulatory party (SO or National Regulatory Authority (NRA)), while 18% of the participants preferred harmonized baselines at product level, which would also be defined by a regulatory party (SO or NRA). The option to have self-declared abseliens defined by the FSP has not been selected by any respondents. There was thus a strong preference for having an exhaustive list of diversified baselines defined by a regulatory party, which indicates a significant inclination towards regulatory oversight and comprehensive guidelines for baselining.

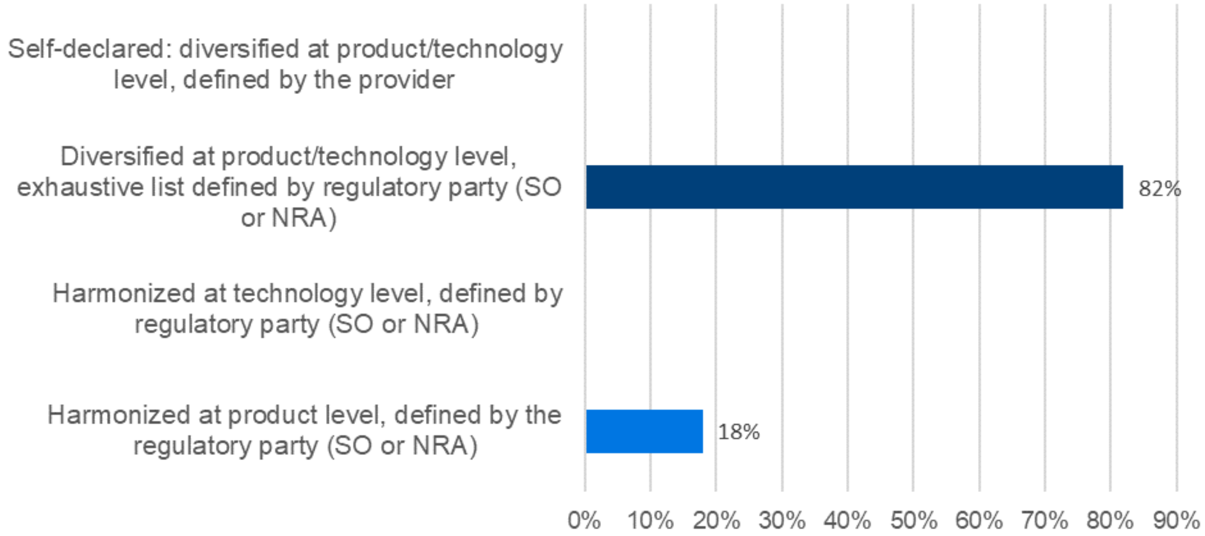

Figure 5-6: Poll results on the approach to and responsibility of defining baseline (input from workshop 1)

Figure 5-7 shows a decision framework which was developed as part of the CoordiNet project, and which can guide the selection of baseline methods considering certain factors. The framework depends on whether the resource participates individually or aggregated. Also, the presence of submeters enables the individual calculation per technology type or per cluster of resources.

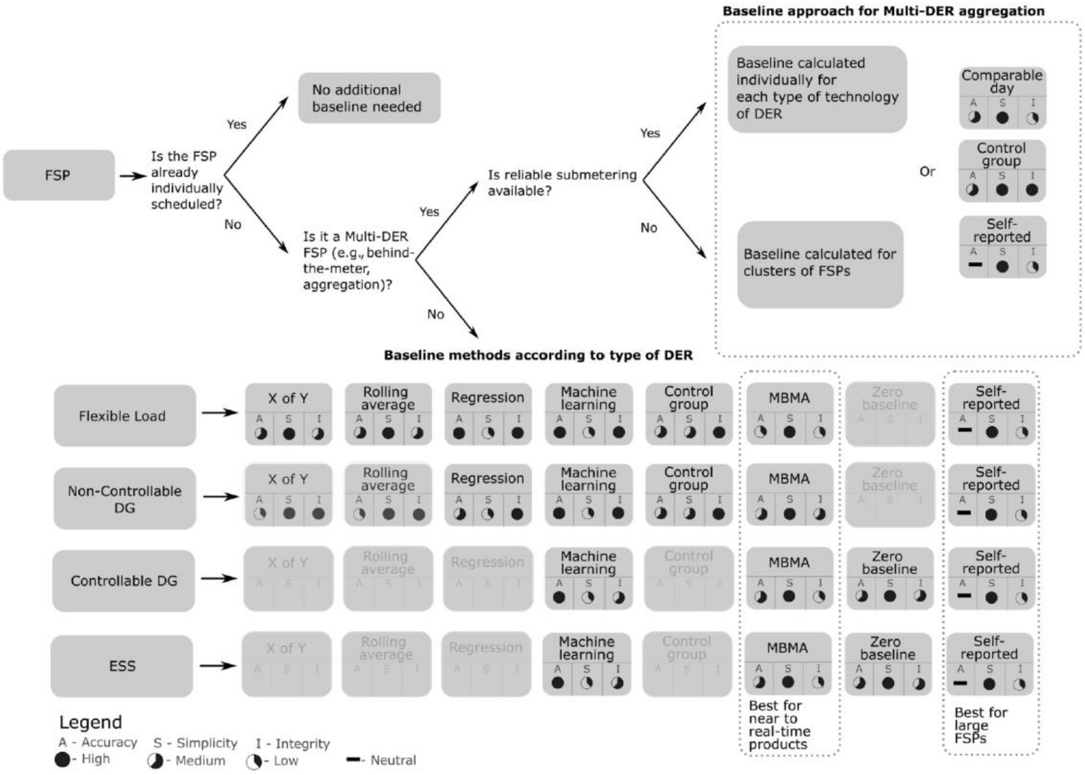

Figure 5-7: Baseline decision framework according to FSP, DER, and multi-DER presence type[39]

In the box below some alternative approach to baselining studied as part of the FlexiGrid project will be proposed.

Example: Alternative approach to baselines; the FlexiGrid Project

Grant agreement number 864048

Problem[40] [41]:

- Choosing a baseline depends on various business models and control algorithms of FSPs.
- Finding admissible historical days for calculating the baseline is challenging in a future where flexibility is provided often and for different purposes.
- A mistaken/manipulated baseline can lead to an inflated/deflated quantity of flexibility.
- Validation of baselines and agreement between FSPs and DSOs can be costly.

[39] L. Lind, J. P. Chaves-Ávila, O. Valarezo, A. Sanjab, and L. Olmos. Baseline methods for distributed flexibility in power systems considering resource, market, and product characteristics, Utilities Policy, vol. 86, p. 101688, feb. 2024. Link: https://doi.org/10.1016/j.jup.2023.101688.

[40] C. Ziras, C. Heinrich, and H. W. Bindner, "Why baselines are not suited for local flexibility markets," Renewable and Sustainable Energy Reviews, vol. 135, p. 110357, Jan. 2021, doi: 10.1016/j.rser.2020.110357.

[41] N. Mirzaei Alavijeh, D. Steen, A. T. Le, and S. Nyström, "Capacity limitation based local flexibility market for congestion management in distribution networks: Design and challenges," International Journal of Electrical Power & Energy Systems, vol. 156, p. 109742, Feb. 2024, doi: 10.1016/j.ijepes.2023.109742.

Proposed solution: Capacity-limitation (CL) products are proposed as an alternative to baseline-based products[42] [43]. In [44], the CL product puts a cap on the net-load during certain hours. Its quantity is calculated based on transparent values of FSP's connection capacity (Figure 5-8). A similar product, Max-usage, is tested in Effekthandel Väst in Gothenburg, Sweden[45].

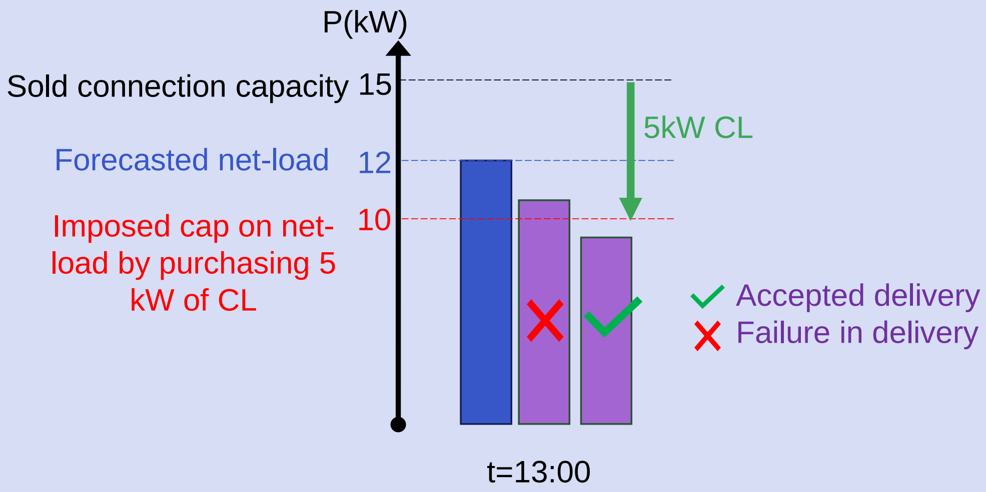

Figure 5-8: An example: Capacity-limitation product definition and delivery validation

One of the advantages of the CL product is that is not defined based on baselines, but with respect to transparent values of connection capacities/fuse level. As a result, this reduces potential conflict-of-interests in agreement on baselines, and the administrative burden of delivery validation. One potential disadvantage of the CL product is that the product is heterogeneous leading to a complex bidding and market clearing.

5.4. Aggregation

Several challenges are observed in case independent aggregation takes place, i.e., when the aggregator is not the same entity as the supplier. The aggregator offers flexibility services and is therefore responsible for the imbalances this service creates. At the same time and at the same access point there are other actors taking up necessary responsibilities, i.e., the supplier and Balance Responsible Party (BRP) role, often performed by the same stakeholder. The decision of an aggregator to use flexibility on one connection point can therefore impact the energy balance position of the BRP of the supplier, and suppliers have also requested compensation for the revenues they have foregone due to the flexibility activation. This can lead to financial risks for both stakeholders. In summary, the actions of the independent

[42] C. Heinrich, C. Ziras, T. V. Jensen, H. W. Bindner, and J. Kazempour, "A local flexibility market mechanism with capacity limitation services," Energy Policy, vol. 156, p. 112335, Sep. 2021, doi: 10.1016/j.enpol.2021.112335.

[43] N. Mirzaei Alavijeh, D. Steen, A. T. Le, and S. Nyström, "Capacity limitation based local flexibility market for congestion management in distribution networks: Design and challenges," International Journal of Electrical Power & Energy Systems, vol. 156, p. 109742, Feb. 2024, doi: 10.1016/j.ijepes.2023.109742..

[44] idem

[45] "Effekthandel Väst: Maxtak på elförbrukningen avlastade elnätet under vintern," Göteborg Energi. Accessed: Jun. 05, 2024. [Online]. Available: **https://www.goteborgenergi.se/i-var-stad/artikelbank/maxtak-pa-elforbrukningen-avlastade-elnatet-under-vintern**

aggregators lead to two specific problems: an imbalance issue and a foregone revenue issue for the energy supplier.

Finding a solution for the imbalance issue finds support form a vast majority of the workshop participants, see Figure 5-9. It is observed that the majority of countries have addressed the imbalance issue through a perimeter correction[46]. By implementing a perimeter correction, any supplier's BRP imbalance is rectified using the metered energy volume, activated by an independent FSP. The necessity of financial compensation for the loss of revenue is more questioned. This is also visible in the polling during the workshop, see Figure 5-9. There are both arguments against and in favour of such compensation mechanisms. The heart of the discussion stems from the difficult challenge of accurately quantifying the 'loss of revenue' for the BRP/supplier. Even a rough estimate faces significant hurdles, as it is heavily influenced by a wide array of parameters. These include the diverse hedging strategies adopted by suppliers, the varying sourcing costs they encounter, and the proportion of active consumers within the BRP/supplier portfolio.

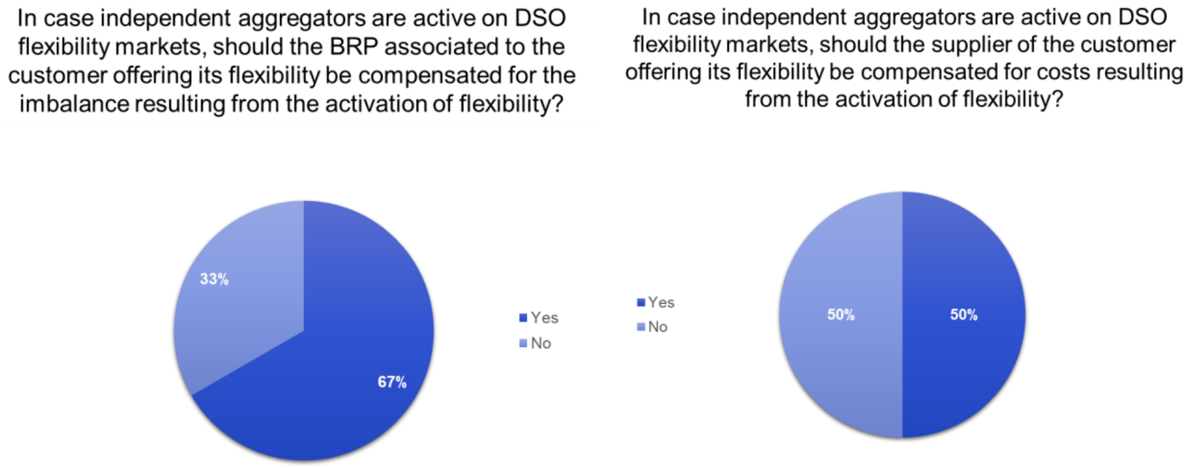

Figure 5-9: Poll results on the need for correcting for imbalances (left) and the need for financial compensations for loss of revenue (right) (input from workshop 1)

There are different methods to deal with the integration of the FSP in a market environment and to tackle the issues of imbalances and loss of revenue. A direct approach for achieving participation of independent aggregators, while isolating the flexible asset from the remainder of the load, involves adopting a so-called 'split supply model', facilitated by sub-metering[47]. In addition, Aggregator Implementation Models[48] can be used to perform corrections. Different models are possible, structured based on the manner of perimeter correction and/or the financial compensation. When examining the value transactions among market participants within various aggregation models, we find a complex interplay of economic factors and market dynamics significantly influencing economic transactions. The costs and benefits experienced by stakeholders under different aggregation models are primarily contingent on whether

[46] Tim Schittekatte, Vincent Deschamps, Leonardo Meeus (2021), The regulatory framework for independent aggregators, The Electricity Journal, Volume 34, Issue 6, 2021, 106971, https://doi.org/10.1016/j.tej.2021.106971.

[47] USEF, 2021. USEF: The framework explained

[48] USEF, 2017. USEF: work stream on aggregator implementation models. Recomm. Pract. key considerations a Regulatory Framework. Mark. Des. Explicit. Demand Response. Update. Sept. 2017 Incl. Resid. Cust. segment.

upward or downward flexibility (i.e., reduced or increased net consumption) is provided. Furthermore, these costs and benefits are directly influenced by the signs, volumes, and rankings of prices (imbalance price, service delivery price, retail price, and regulated price) relative to each other. Hence, for a given time stamp, the preferred aggregation model for a stakeholder can shift dramatically from being the most advantageous to the least advantageous.

In light of the perimeter adjustments performed by TSOs to neutralize the effect of the service provision of the involved BRPs[49], there is a strong recommendation to transition away from the uncorrected model. This shift is imperative to create a more favorable environment for FSPs, fostering increased participation and engagement. However, implementing perimeter corrections accounts for a significant portion of the negative impact on the BRP/supplier's net position. In this context, it becomes imperative to implement financial compensation, particularly from the supplier's perspective, as a necessary measure to mitigate some of the negative impact. From the consumer perspective, it is advised to maintain transparency and avoid complexities to avoid burdensome processes for the consumer. Certainly, given the current EU dynamic to lighten the burden on the consumer, aggregation models which would require additional compensations to be paid by the consumer themselves may appear less compatible.

[49] This adjustment follows from Article 49 of the Electricity Balancing Guideline (EB GL, Regulation (EU) 2017/2195), which stipulates that "Each TSO shall calculate an imbalance adjustment to be applied to the concerned BRPs for each activated balancing energy bid." This regulatory requirement forms the cornerstone of ensuring grid stability and accountability in the electricity sector.

6. Conclusions and recommendations

In this section, we summarize the main conclusions from the three workshops.

During the **first workshop "Design Challenges of Market-Based Flexibility Procurement by DSOs**, we focused on three main topics, i.e., prequalification, baselining and aggregation. From the discussions, it was clear that the current *prequalification processes*, or lack thereof, present significant barriers, particularly for LV flexibility. Moreover, there is a need for further analysis to understand the implications of ex-post versus ex-ante product prequalification. With regard to *baseline methodologies*, different and innovative approaches are required for various products and services, as well as for new types of FSPs and flexible resources. On the topic of *aggregation*, we found that different aggregation models have varying impacts. The most suitable aggregation model depends on the market framework, the types of products and services offered, and the types of FSPs and flexible resources involved.

During the **second workshop "Supporting Grid Tools for Active System Management by DSOs**, we discussed, among others, that MV and HV solutions cannot be directly applied to LV grids, which very often require more simple and scalable solutions. In addition, there is a need to increase the DSO capabilities in the LV grid, i.e., the visibility of the LV grid needs to be increased; additional monitoring is necessary including the installation of digital meters for all LV flexibility users; improved modeling and estimation of flexibility impacts are needed and more detailed information on the specifications of connected flexibility sources is to be collected and, finally, enhanced congestion forecasting capabilities are required.

The **third workshop** focused on the **"Applicability of Different Flexibility Mechanisms for DSOs and Their Trade-offs with Investments"**. During this workshop, there was consensus that investment needs in grids are substantial, but the use of flexibility can significantly reduce these requirements. DSOs should therefore select the most efficient flexibility mechanisms, both economically and operationally, to address their needs, such as congestion management and voltage control. There is no "one size fits all" solution. Various complementary flexibility mechanisms will be necessary to meet DSO needs and facilitate the energy transition.

By addressing these conclusions, DSOs can better navigate the challenges associated with flexibility. Overall, we can conclude that the **challenge of integrating flexibility in the DSO sphere is complex**, necessitating additional guidance and research on how to correctly trade-off between different flexibility mechanisms and grid investments. This includes developing appropriate criteria, methodologies, and quantification methods. Key factors to be considered in this assessment are the economic viability, encompassing the costs and benefits of the solutions, which calls for a societal CBA. This analysis should account for the opportunity cost of alternatives to flexibility. Additionally, the reliability and availability of flexibility (including market liquidity) are crucial factors. Moreover, compatibility with current and future regulatory contexts should also be considered. Furthermore, the methodology should account for long-term economic and environmental impacts. Finally, the expected user engagement with the proposed solutions and the experience of DSOs should be factored in.