D4.3: CONCLUSIONS & REGULATORY ASPECTS OF LOCAL FLEXIBILITY MARKETS

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STREAMING FLEXIBILITY TO THE POWER SYSTEM

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Abstract

This deliverable focuses on the regulatory, technical, and market aspects of local flexibility markets in electricity systems. It aims to assess how local flexibility can support grid stability, facilitate the integration of renewable energy, and enhance market efficiency. The key objective is to analyze the existing regulatory frameworks, identify barriers to flexibility adoption, propose solutions that enable more effective market-based flexibility procurement and evaluation of pilot sites in Slovenia, Finland, Italy, and Spain.

Keywords

Local flexibility markets, local flexibility regulation, EU regulation, regulatory sandboxes, Aggregator, Energy community

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EXECUTIVE SUMMARY

This document is a deliverable of the STREAM project, focusing on the **regulatory, technical, and market aspects of local flexibility markets** in electricity systems. It aims to assess how local flexibility can support grid stability, facilitate the integration of renewable energy, and enhance market efficiency. The key objective is to analyze the existing regulatory frameworks, identify barriers to flexibility adoption, and propose solutions that enable more effective market-based flexibility procurement. Through the **evaluation of pilot sites in Slovenia, Finland, Italy, and Spain**, the document explores how different mechanisms—such as demand-side response, energy storage, and distributed generation—can contribute to a more resilient and decentralized energy system.

The study presents critical findings regarding the development and implementation of local flexibility markets, emphasizing both the regulatory landscape and operational challenges. It highlights the impact of EU directives, including the **Renewable Energy Directive**, the **Electricity Directive**, and the **Electricity Regulation**, in shaping flexibility markets across different regions. The combined analysis of pilot sites reveals a range of **approaches to flexibility utilization**. In Slovenia, efforts are focused on market-based and rule-based flexibility solutions, exploring cooperation between TSOs and DSOs. Finland's pilot site examines the role of spot price optimization and frequency regulation in increasing system flexibility. In Italy, the study assesses the integration of flexibility solutions within the country's National Energy and Climate Plan, aiming to enhance grid modernization and renewable energy penetration. Spain's pilot evaluates different procurement methods for flexibility, particularly market-based solutions and non-firm connection agreements. Across all sites, common challenges include a lack of market liquidity, unclear roles for aggregators, and the need for improved regulatory alignment between TSOs and DSOs. Additionally, the concept of **value stacking** is explored as a way to maximize the economic viability of flexibility services, allowing providers to combine multiple revenue streams and enhance financial sustainability.

The document concludes that **greater regulatory harmonization across EU member states is essential to unlock the full potential of local flexibility markets**. It emphasizes the importance of establishing clear, consistent policies that enable diverse market participants to engage in flexibility trading, ensuring fair compensation for services and incentivizing investment in flexible energy solutions. Strengthening collaboration between TSOs and DSOs is critical to optimizing flexibility utilization and ensuring efficient coordination between different grid levels. Future efforts should focus on improving market accessibility, advancing digital infrastructure for real-time grid management, and refining regulatory mechanisms to support demand response and aggregator participation. By addressing these challenges, local flexibility markets can play a crucial role in balancing electricity supply and demand, mitigating grid congestion, and accelerating the transition toward a more decentralized and renewable-based energy system.

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1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This deliverable is the result of the collaboration of the STREAM project partners within the framework of the fourth work package called STREAM Ecosystem.

This deliverable outlines different options for the use of flexibility in specific local energy markets and pilot locations, including an additional review from a regulatory perspective to ensure that the developed tools and the proposed framework meet the relevant legal requirements of the energy sector in each country corresponding to the region. The results are linked to the implementation of tasks T4.3 Flexibility utilization in various markets and T4.4 Regulatory aspects of local flexibility markets. The pilot sites in Slovenia, Italy, Spain and Finland where subjected to a review of the status of local flexibility markets, options for flexibility development, value stacking, challenges, different regulatory points of view and recommendations for further legislation development.

1.2 SCOPE OF THE DOCUMENT

The deliverable D4.3 presents the conclusions and regulatory aspects of local flexibility markets. It includes an overview of the EU regulatory framework that covers local flexibility. The report also presents the overview of pilot sites in Slovenia, Italy, Finland and Spain, where it focuses on the EU regulatory, Transmission system operator (TSO), Market operator (MO), Distribution System Operator (DSO) point of view, status of development/current state of flexibility utilization in given local energy market, various options for flexibility utilization in given local energy markets, value stacking of flexibility utilization, gaps, challenges and recommendations for future legislation development.

1.3 STRUCTURE OF THE DOCUMENT

The document is structured in 6 sections that cover the main goals of the D4.3 and the results of tasks 4.3 and 4.4:

- **Section 1**: It presents the purpose, scope and structure of the document.
- **Section 2:** It presents an overview of the EU regulatory framework that addresses local flexibility.
- **Section 3:** Pilot site overview in Slovenia. Presentation of regulatory, TSO, MO, DSO points of view. Description of the status of development and current state of flexibility utilization in given local energy markets. Various options for flexibility utilization in given local energy markets within the context of the pilot sites. Presentations of local value stacking of flexibility utilization, gaps, challenges and recommendations for future legislation development.
- **Section 4:** Pilot site overview in Finland. Presentation of regulatory, TSO, MO, DSO points of view. Description of the status of development and current state of flexibility utilization in given local energy markets. Various options for flexibility utilization in given local energy markets within the context of the pilot sites. Presentations of local value stacking of flexibility utilization, gaps, challenges and recommendations for future legislation development.
- **Section 5**: Pilot site overview in Italy. Presentation of regulatory, TSO, MO, DSO points of view. Description of the status of development and current state of flexibility utilization in given local energy markets. Various options for flexibility utilization in given local energy markets within the context of the pilot sites. Presentations of local value stacking of flexibility utilization, gaps, challenges and recommendations for future legislation development.

- **Section 6**: Pilot site overview in Spain. Presentation of regulatory, TSO, MO, DSO points of view. Description of the status of development and current state of flexibility utilization in given local energy markets. Various options for flexibility utilization in given local energy markets within the context of the pilot sites. Presentations of local value stacking of flexibility utilization, gaps, challenges and recommendations for future legislation development.
- **Section 7**: Conclusions of the document, highlight the importance of regulatory harmonization, technological advancements, and market accessibility in developing effective local flexibility markets. Lessons from pilot projects emphasize the need for clear roles, collaboration among stakeholders, and standardized participation frameworks. Strategic investments in digital infrastructure and automation will be crucial for enabling real-time flexibility trading and enhancing market efficiency. Ultimately, well-structured flexibility markets will support the transition to a more sustainable, resilient, and renewable-based electricity system.
- **Section 8**: References

2 EU REGULATORY FRAMEWORK OVERVIEW OF LOCAL FLEXIBILITY

The European Union (EU) regulatory framework for local flexibility in energy markets is designed to enhance the integration of renewable energy sources, improve energy efficiency, and foster a more decentralized energy system. Local flexibility refers to the ability of local energy systems to adapt to changes in supply and demand, which is crucial for managing the increasing share of intermittent renewable energy. The EU has implemented several legislative and policy measures to support local flexibility.

2.1 CLEAN ENERGY FOR ALL EUROPEANS PACKAGE

The Clean Energy for All Europeans Package (CEP) was adopted in 2019, consisting of eight legislative acts designed to create a more integrated and competitive energy market within the EU. This package marked a significant overhaul of the EU's energy policy framework, helping to shift away from fossil fuels towards cleaner energy and to meet the EU's commitments under the Paris Agreement to reduce greenhouse gas emissions. The agreement on this new energy rulebook represents a crucial step in implementing the Energy Union strategy, first published in 2015. Based on Commission proposals from 2016, the package was finalized following a political agreement by the EU Council and the European Parliament in May 2019. The new rules under CEP will bring significant benefits to consumers, the environment, and the economy. CEP grants consumers the right to access all electricity markets and be compensated for their flexibility. However, Member States are required to implement these provisions in their national legislation. The package, aligned with the European Green Deal objectives, aims to decarbonize the EU's energy system.

The key components relevant to local flexibility within the energy market include:

- **Renewable Energy Directive**
- **Electricity Directive**
- **Electricity Regulation**
- **Energy Efficiency Directive**

The CEP package significantly impacts local flexibility by promoting renewable energy, enabling demand response, encouraging local energy communities, and supporting smart technologies. These measures collectively enhance the ability of local energy systems to adapt to changing conditions, balance supply and demand, and contribute to the EU's broader energy and climate goals.

2.1.1 Renewable Energy Directive

Directive (EU) 2018/2001 known as Renewable Energy Directive (RED II), amended by directive 2023/2413 (RED III), is a key piece of legislation from the European Union aimed at promoting the use of renewable energy sources and reducing greenhouse gas emissions. Its impact on energy system flexibility is significant and multifaceted, affecting various aspects of the energy sector. It impacts local flexibility by promoting the development of local energy communities, supporting decentralized energy production, facilitating demand response, encouraging energy storage, and driving the deployment of smart grid technologies. These measures collectively enhance the capacity of local energy systems to manage variability, balance supply and demand, and contribute to the overall stability and sustainability of the grid. The directive's emphasis on creating a supportive regulatory framework and market design ensures that local actors can actively participate in and benefit from the transition to a clean energy system. Some of the aspects of the directive that address the local flexibility are:

Higher RES Penetration: RED III sets ambitious targets for the share of renewables in the energy mix, leading to increased integration of variable renewable energy sources like wind and solar. This necessitates enhanced flexibility to manage the variability and intermittency of these sources. The directive promotes measures to better manage the grid and ensure stability, including the development of smart grids and improved grid infrastructure to accommodate fluctuating renewable generation.

Support for Energy Storage: RED III recognizes the importance of energy storage systems (ESS) for balancing supply and demand, stabilizing the grid, and providing backup power. Storage systems can offer various grid services such as frequency regulation, voltage support, and peak shaving, enhancing local flexibility. The directive encourages member states to remove barriers and incentivize the deployment of energy storage technologies.

Support for Demand Response: By encouraging demand response programs, RED III facilitates a more flexible and responsive demand side. RED III supports the integration of demand response mechanisms, allowing consumers to adjust their energy use in response to market signals. This helps balance supply and demand, consumers can shift their consumption to times of high renewable generation or lower demand, providing crucial flexibility to the grid. This contributes to enhancing consumer engagement, where consumers become active participants in the energy market, contributing to a more dynamic and responsive system.

Grid Access and Priority Dispatch: RED III aims to streamline grid access for renewable energy projects and may prioritize the dispatch of renewable energy. This requires grid operators to enhance their operational flexibility to manage priority renewable generation while maintaining grid stability.

Support for Innovation: RED III emphasizes the need for innovation in the energy sector, particularly in digital technologies that enhance flexibility. This includes the use of advanced forecasting tools, real-time data analytics, and automation to better predict and manage renewable energy generation and consumption.

Renewable Energy Communities (RECs): RED III defines RECs and outlines their roles and rights in producing, consuming, storing, and selling renewable energy. It mandates that Member States create an enabling framework to support the development of RECs, ensuring they have non-discriminatory access to energy markets and networks.

Smart Grids and Digitalization: RED III supports the deployment of smart grids and digital technologies, which are critical for managing the increased complexity of local energy systems. Smart grids can optimize energy flows by advanced monitoring and control systems that enable more efficient energy distribution and use. Facilitate renewable integration, because smart grids can better handle the variability and distributed nature of renewable energy sources. Support flexibility markets, digital platforms and smart technologies enable real-time market participation and the provision of flexibility services by small-scale producers and consumers.

Regulatory Framework and Market Design: RED III requires Member States to develop regulatory frameworks that support the integration of renewable energy and the participation of local actors in the energy market. This includes removing barriers by simplifying administrative procedures and reducing regulatory barriers for renewable energy projects. Ensuring fair market access creates conditions that allow local energy producers and consumers to participate in energy and flexibility markets on an equal footing with larger players. Providing incentives with implementing financial and policy incentives to encourage investment in renewable energy and flexibility solutions.

2.1.2 Electricity Directive

The Directive (EU) 2019/944, known as the Electricity Directive (ED), amended by directive 2024/1711, promotes consumer participation in the energy market, including through demand response and self-consumption of renewable energy. The directive aimed to create a more integrated and competitive electricity market in the European Union. One of its primary objectives is to enhance flexibility in the electricity system. Flexibility is crucial for integrating renewable energy sources and ensuring a stable and efficient power supply. It has a profound impact on local flexibility markets by promoting consumer empowerment, supporting the development of local energy communities, facilitating the integration of distributed energy resources, and ensuring a flexible and inclusive market design. By encouraging active consumer participation, enhancing the role of DSOs, and removing regulatory barriers, the directive creates a more dynamic and responsive local energy system. These measures collectively enhance the capacity of local markets to manage variability, balance supply and demand, and contribute to the overall efficiency and stability of the electricity grid. Here are some of the key takeaways on how ED impacts flexibility in more detail.

Empowerment of Consumers and Prosumers: the ED encourages active consumer participation so that consumers become "prosumers," meaning they produce and consume their own electricity. This decentralized generation contributes to local flexibility as these prosumers can feed excess energy back into the grid and help balance local supply and demand. Consumers are incentivized to participate in demand response programs, adjusting their energy use in response to price signals or grid needs, which enhances local flexibility. The ED mandates the deployment of smart meters, which provide real-time data on energy consumption. This data enables better demand-side management and more effective participation in flexibility markets. It addresses also energy management systems, consumers and local energy managers who can optimize energy usage, storage, and generation, contributing to local grid stability and flexibility.

Facilitation of Citizen Energy Communities (CECs): The ED provides a clear legal framework for the establishment and operation of CECs, which can generate, consume, store, and sell electricity. It emphasizes the right of citizens to establish and join CECs. This empowers local entities to manage their energy needs more efficiently and contributes to local flexibility. CECs can participate in local flexibility markets, offering services such as peak shaving, load balancing, and voltage control, which help stabilize the local grid.

Market Design and Regulatory Framework: ED encourages flexible market design. It promotes real-time and dynamic pricing, which reflects the actual cost of electricity at different times of the day. This pricing mechanism encourages consumers and businesses to adjust their consumption patterns to times when electricity is cheaper and more abundant, enhancing local flexibility. It recognizes the role of aggregators, who can pool the flexibility resources of multiple consumers or producers and sell these services to the grid. This aggregation can provide significant local flexibility by effectively managing small-scale resources. ED is also designed to remove administrative barriers. The ED calls for simplified administrative procedures for the deployment of small-scale renewable energy projects and DERs, reducing the time and cost involved in connecting to the grid. It’s enhancing non-discriminatory access to the grid and markets for all participants, including small-scale producers and CECs, fostering a more inclusive and flexible energy market.

Enhanced Grid Management: The ED enhances the role of Distribution System Operators (DSOs) in managing local grids. DSOs are encouraged to adopt advanced grid management technologies and practices, which are crucial for integrating high levels of DERs and managing local flexibility. DSOs are required to improve coordination with Transmission System Operators (TSOs) and share relevant data, ensuring better overall system management and enhancing the potential for local flexibility.

Priority Access and Dispatch: While promoting flexibility, the ED ensures that renewable energy sources have priority access and dispatch in the electricity grid, balancing their variability with flexible resources. It marks a significant shift in the EU's approach to integrating renewable energy sources into the electricity market. By moving away from priority access and dispatch, the directive aims to create a more competitive and efficient market while still supporting the transition to a cleaner energy system. The impact of renewable energy integration is managed through a mix of market mechanisms, technological innovation, and consumer empowerment, ensuring a balanced approach to achieving the EU's energy and climate goals.

Regulatory Adjustments to Flexibility: The ED requires member states to ensure that their regulatory frameworks do not create barriers to flexibility services. This includes revising network codes and market rules to accommodate new technologies and business models.

2.1.3 Electricity Regulation

Regulation (EU) 2019/943 known as the Electricity Regulation (ER), amended to directive 2024/1747: Establishes the framework for the operation of electricity markets, emphasizing the need for flexibility and the integration of renewable energy. It aims to create a more competitive, consumer-centric, flexible, and decarbonized electricity market in the European Union. It significantly impacts the development of local flexibility markets in the EU's electricity sector. By promoting market-based mechanisms, empowering DSOs, and encouraging consumer and aggregator participation, the regulation fosters a dynamic and resilient energy system. Regulatory adjustments are essential to facilitate these changes, ensuring that flexibility markets operate efficiently, protect consumers, and support the integration of renewable energy. These adjustments will drive innovation, enhance grid stability, and contribute to the EU's broader energy and climate goals. Here's how it impacts flexibility in the electricity sector in more detail.

Market Design and Flexibility: The ER promotes a market design that supports flexibility, enabling better integration of renewable energy sources (RES) and demand response. Key elements include Short-term Markets (encouraging intraday and balancing markets to operate closer to real-time, which enhances the ability to manage variability in supply and demand); Market Coupling (improving cross-border electricity trading to optimize resource use across the EU, thus enhancing grid flexibility and resilience); Capacity Mechanisms (ensuring these mechanisms do not hinder cross-border trade and are technology-neutral, supporting a variety of flexible resources including storage and demand-side response).

Demand Response and Consumer Participation: The ER emphasizes the role of consumers and demand response in providing flexibility. It’s facilitating the participation of demand response and distributed energy resources through aggregators in electricity markets, promoting the use of dynamic pricing contracts to incentivize consumers to shift their consumption in response to price signals and encouraging the deployment of smart meters to provide real-time consumption data, enabling more effective demand response.

Grid Management and System Operation: Mandating coordination between TSOs and DSOs to ensure efficient and secure operation of the grid, particularly in integrating variable renewable energy. Improving balancing mechanisms to allow for more flexible and efficient grid management, including the use of distributed energy resources and storage.

Renewable Energy Integration: Gradually phasing out priority dispatch for renewable energy sources, ensuring they participate fully in the market and are subject to the same balancing responsibilities as other market participants, which encourages flexibility. Minimizing curtailment and ensuring that any necessary redispatching is market-based, allowing for a more efficient integration of renewables and other flexible resources.

Technological Innovation and Infrastructure: Creating better investment signals for flexibility resources, including storage technologies, demand-side response, and advanced grid technologies. Supporting research and development in innovative flexibility solutions, such as advanced grid management systems, and encouraging their integration into the market.

Regulatory Sandboxes: They are innovative frameworks designed to foster experimentation and innovation within the energy sector. They allow companies and organizations to test new technologies, business models, or regulatory approaches in a controlled and flexible environment before full-scale implementation. Several EU countries have implemented regulatory sandboxes to test innovative energy solutions in a controlled environment. These sandboxes allow for experimentation with new business models and technologies that can enhance local flexibility.

Network Codes and Guidelines: These codes and guidelines are part of the broader regulatory framework established by the ER and are developed by ENTSO-E and other relevant bodies. They aim to enhance the flexibility, reliability, and efficiency of the electricity grid, facilitating the integration of diverse and variable energy sources. The Electricity Balancing Guideline facilitates the integration of balancing markets across the EU and promotes the participation of demand response and distributed generation.

2.1.4 Energy Efficiency Directive

The Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency also known as the Energy Efficiency Directive (EED), last amended by directive 2023/1791 establishes a framework for promoting energy efficiency across the European Union, setting binding measures to achieve energy savings and reduce energy consumption. The directive addresses flexibility in the power sector through various mechanisms aimed at enhancing overall energy efficiency while accommodating the dynamic needs of power systems. This flexibility is crucial for optimizing power generation, improving grid reliability, and integrating new technologies and renewable energy sources. Here's how the EED incorporates flexibility specifically in the context of power.

Grid Flexibility and Smart Grids: The EED supports the implementation of smart grids, which enhance the flexibility of power systems by enabling real-time monitoring and management of electricity flows. Smart grids facilitate better integration of variable renewable energy sources and improve the efficiency of electricity distribution. The directive encourages demand response mechanisms that allow for adjustments in electricity consumption based on supply conditions. This can include incentives for users to reduce or shift their electricity use during peak periods, thus enhancing grid stability and efficiency.

Efficient Power Generation and Transmission: The EED promotes improvements in the efficiency of power generation technologies. This includes encouraging the adoption of high-efficiency power plants and the retrofitting of existing plants to reduce losses and improve performance. Flexibility measures support the modernization of transmission and distribution infrastructure to reduce energy losses and enhance the efficiency of power delivery.

Integration of Renewable Energy Sources: The EED aligns with broader EU goals to increase the share of renewable energy. It supports measures that help integrate renewables into the power grid, such as investments in energy storage solutions and grid management technologies. The EED encourages the development of flexible grid management strategies to accommodate the fluctuating nature of renewable energy sources like wind and solar.

Energy Efficiency Obligation Schemes: Member states have the flexibility to design energy efficiency obligation schemes that can target specific aspects of power use. These schemes may include measures for improving the efficiency of power generation and consumption across different sectors. The EED allows for the setting of national targets that can be adjusted based on local circumstances and the evolving energy landscape, providing flexibility in how efficiency goals are met.

Financial and Incentive Mechanisms: The EED supports various financial mechanisms to promote investments in power efficiency projects. This includes funding for research and development of new technologies and incentives for adopting energy-efficient practices. Flexibility in financial support allows for the promotion of cost-effective solutions that improve power efficiency, such as subsidies for energy-efficient equipment or infrastructure improvements.

3 PILOT SITE OVERVIEW IN SLOVENIA

3.1 REGULATORY POINT OF VIEW

"Zakon o oskrbi z električno energijo" (ZOEE) is a key piece of Slovenian legislation that governs the electricity supply sector. This law integrates the European Union's Electricity Directive and Regulation, and it outlines essential provisions for leveraging flexibility in the distribution system, organizing a local flexibility market, and regulating aggregation activities.

Key points include:

1. **Flexibility in Distribution Networks**: The ZOEE sets out guidelines for utilizing flexibility, which involve adjusting the electricity demand or supply to ensure stability and efficiency within the distribution network. This is critical in managing fluctuating renewable energy sources and balancing supply and demand.
2. **Local Flexibility Market**: The purpose of the law is to advocate a local market for flexibility, where electricity operators and market participants can trade flexibility products. This market is vital for enabling a more decentralized and adaptable energy system.
3. **Coordination and Data Exchange**: The legislation emphasizes the need for effective coordination and data sharing between electricity operators. This is essential for managing the distribution network efficiently and ensuring that flexibility resources are optimally utilized.
4. **Flexibility Products**: The law instructs operators to develop and offer new flexibility products tailored to the evolving needs of the grid, particularly for network management and stability.

In addition to ZOEE, the Energy Agency of the Republic of Slovenia adopted a new **Act on the Methodology for Determining the Regulatory Framework for Electricity Operators**. This act includes:

- **Incentives for Flexibility**: It introduces financial or operational incentives for electricity operators to promote the use of flexibility. This encourages grid operators to invest in and adopt more flexible solutions for managing energy flows.
- **Regulatory Rules for Flexibility**: The act sets out specific rules on how flexibility can be integrated into the electricity network and market, ensuring a structured and efficient approach.

Together, these laws represent a legal basis for managing Slovenia's electricity system, focusing on flexibility, coordination, and market mechanisms to adapt to renewable energy challenges and grid modernization.

3.2 TSO, MO, DSO POINT OF VIEW

ELES is the electricity Transmission System Operator (TSO) of Slovenia. It is responsible for ensuring the reliable and safe transmission of electricity throughout the country. It manages Slovenia's high-voltage electricity transmission network, ensuring the secure and efficient operation of the system. It plays a key role in balancing supply and demand on the electricity grid in real-time.

In Slovenia, a Distribution System Operator (DSO) is responsible for the distribution of electricity from the transmission system (handled by ELES) to end consumers, including households, businesses, and industry. DSOs manage the medium- and low-voltage networks that deliver electricity to final users. The system operator of the distribution network in Slovenia till 30.9.2023 was SODO, thereafter SODO was merged with ELES. The system operator of the distribution network in Slovenia rents out the distribution infrastructure to individual electricity distribution companies (DGOs). There are several DGOs in Slovenia, as the distribution network is divided regionally, they include: Elektro Celje, Gorenjska, Ljubljana, Maribor and Primorska.

In Slovenia, the function of the TSO and the market operator (MO) are separated. Borzen performs the function of the MO in Slovenia, playing a central role in the organization, functioning, and regulation of the electricity market within the country. They are responsible for the management of the Balance Scheme and reporting daily schedules. Further on, they are responsible for running the wholesale electricity market in Slovenia. They ensure the efficient and transparent trading of electricity between producers, suppliers, and consumers. The day ahead and intraday trading of electricity in Slovenia is organized by BSP Energy Exchange which is a part of the ADEX GROUP.

The views of the Slovenian TSO, MO and DSO regarding flexibility (local markets included) are presented in a continuing manner:

ELES states in its development plan of the transmission network for the period 2023-2032 that flexibility can be implemented directly on demand (explicit flexibility) or on the basis of tariff changes (implicit flexibility), whereby explicit flexibility is important for the TSO, as the TSO directly instructs the active user to adjust their consumption or production in a certain period of time and thereby influences the operating conditions in the system or helps with development problems in the system. In practice, active users are for TSO those who are useful as balancing service providers (PSI), i.e. resources for the implementation of FCR, aFRR and mFRR. Each of the aforementioned services requires different flexibility and capacity of resources. The potential of theoretically available flexibility was studied in detail in Slovenia in 2016 as part of the FutureFlow project, where a theoretical potential of 894 MW for positive FRR and 1,440 MW for negative FRR was estimated. It should be taken into account that these are maximum theoretical potentials, available under ideal conditions. ELES determined that in reality, this is not the case, which is why the practical volumes of the reserve provided by flexible users are significantly smaller. Thus, in Slovenia, where active users in the distribution network provide a significant share of the total mFRR for a longer time, ELES observed that realistically, in order to ensure flexibility in the current price conditions, it is possible to provide around 150 MW of positive mFRR and 70 MW of negative mFRR from managed consumption and scattered production. With the electrification of transport and heating and the wider implementation of battery storage systems, they expect that the range of resources capable of providing flexibility will increase in the system. Battery storage systems are often more cost-effective than typical flexibility sources but can also provide higher quality and more expensive balancing services such as FCR and aFRR. With the current state of the art, sources on the consumption side may be more suitable for mFRR services, but in the future, advances in ICT technologies may also enable these smaller, but very numerous, sources to perform more easily in the context of other services. ELES also stated that they are seeing significant progress in resource portfolio management on the part of suppliers and aggregators, increasing the range of offerings in this segment.

In the future, for the needs of system services, especially the purchase of positive and negative mFRR energy and the purchase of energy on the daily market for balancing purposes, the TSO could also benefit from unused explicit flexibility on the part of the distribution operator. The condition for taking advantage of such flexibility is the establishment of local markets, ensuring the compatibility of products with balancing products on the ELES balancing market and the solution being supported by an appropriate trading platform with local flexibility. Since the establishment of local markets with flexibility is in the initial stage and the products and their characteristics are not yet known, a more precise estimate of the quantities thus available for the provision of system services is impossible. In general, flexibility will be able to participate in all balancing services on the ELES balancing market, as long as the products of the local flexibility market are compatible with the power leasing or power purchase products of the mFRR, the trading times of the local markets are properly coordinated with the trading deadlines of the ELES balancing market, and appropriate mechanisms for monitoring and accounting for the provision of flexibility services provided by local markets. It should be emphasized that the rules of the balancing system service on the ELES balancing market are relatively flexible and with minor modifications could support the integration of local markets with flexibility into the balancing system without any restrictions on the share of reserves from such sources.

On the basis of the ZOEE, the distribution operator prepared a proposal for new system instructions for the distribution network (SONDSEE), which, in accordance with the requirements of the ZOEE, determine the basic rules for the use of flexibility services by the DSOs. They also determine network pre-qualification procedures when TSOs benefit from flexibility services on the distribution network for their needs. Even though the SONDSEE was published on 17.5.2022, it is still in the process of being approved by the competent authorities.

SONDSEE stipulates DSOs to use the following flexibility services [1]:

- voltage regulation on the local Distribution Power Supply (DPS) section,
- management of overloads of the local DPS section,
- capacity management of the local DPS section and
- management of local island mode operations in the event of an error in the local DPS section,

whereby they will initially order flexibility services for voltage regulation and overload management for the local part of the network. For these two services, it defined standard products in the SONDSEE Instructions “NAVODILO O STORITVAH PROŽNOSTI”. Procedures related to the use of the flexibility service are also defined in more detail in SONDSEE Instructions “NAVODILO O STORITVAH PROŽNOSTI”. In the following, the products and the qualification process of resources or providers of flexibility services are introduced. It should be emphasized that the subject area has not yet been developed in Slovenia, and applications for contractors have not yet been granted, and no local flexibility market has been organized. Therefore, the procedures in SONDSEE regarding flexibility are written in such a way that it is possible to order flexibility through bilateral contracts or the flexibility market, and they will need to be supplemented when the applications in Slovenia are more precisely defined. Individual flexibility products are described with attributes. The distribution operator provided the attributes defined in Table 3-1 for standard products for distribution networks.

Table 3-1: Definition of attributes for standard flexibility products from SONDSEE

Attributes	Description
Time interval	The duration of the service
Trigger period	Months, days of the month, hours of the day
Preparation period	The period between the submission of the request by the contractual distribution operator and the beginning of the power change period.
Power change period	The time period that takes place from a certain starting point and in which the input and/or the output power is increased or decreased until the required power is reached.
Time to full activation	The period between the request for activation by the distribution operator and the corresponding full delivery of the product in question.
Min/Max Amount	The amount of power that can be changed. The power (or change in power) that is and will be offered and reached at the end of the full activation time. The smallest quantity represents the smallest power for one bid. The

	maximum quantity represents the maximum strength for one offer. In the case of an energy product, the quantity is equal to power x supply period.
Shortest and longest duration of delivery periods	The minimum/maximum length of the delivery period during which the flexibility service provider provides the full requested change in power supplied or the full requested change in power consumption from the system.
Deactivation period	The period of power change from full supply to the desired value or from full consumption back to the desired value.
Differentiation of offers	The smallest increment of the volume of the offer.
Validity period	The period during which the energy offer of the flexibility service provider can be activated, if all the characteristics of the product are taken into account. The validity period is defined by a start time and an end time.
Activation mode	The activation method of the energy flexibility product, manually or automatically, depending on whether the person initiates the service manually at the request of the distribution operator, or whether it is automatically activated in a closed-loop manner during the validity period (the distribution operator sends active/reactive power settings).
Price for power	Price for availability of flexibility (mostly expressed in € /kW /hour of availability)
Price for energy	Price for actual guaranteed flexibility: delivered energy (mostly expressed in EUR/kWh)
Divisibility	The ability of the DSO to use only a part of the energy bids or power bids offered by the flexibility service provider, either in terms of power activation or in terms of duration.
Location	This attribute determines which location data should be included in the offer. An example of location data is the measuring point (MP), GPS coordinates and the like.
Recovery period	The shortest duration between the end of the deactivation period and the next activation.
Aggregation Allowed	This attribute specifies whether aggregated supply of power or energy from multiple units through an aggregator is allowed.
Symmetric/asymmetric product	This attribute specifies whether only symmetric products or also asymmetric products are allowed. For a symmetrical product, the up-regulation volume and the down-regulation volume must be the same.
Maximum/minimum number of activations	The maximum/minimum number of activations in a certain period of time (per day, month or season).

In general, two types of products are envisaged. Namely products for active and/or reactive power and products for active energy. Products for active and/or reactive energy are oriented to a longer period of time and mean the capacity to provide power or the reservation of flexibility resources. Power energy products are used to change the transmission or production of energy in the short term (intraday or day ahead). SONDSEE defines four standard products that will be used by the distribution operator in the first phase. These products address two services:

a) Congestion management: the service includes two products namely "Congestion management with power product" and "Congestion management with energy product".

b) Voltage regulation: the service refers to the avoidance of an excessive increase or decrease in voltage in the distribution network beyond the permitted tolerances. The guideline defines two products for voltage regulation, namely "Reactive power for voltage regulation" and "Active power/energy for voltage regulation".

To ensure the use of the flexibility service, it is necessary to develop procedures for the qualification of service providers and sources, procedures for ordering services, activation of the service, measurement of the service provided and settlement, and procedures for exchanging data between stakeholders. SONDSEE assumes that DSOs can order flexibility services on the organized market or through bilateral contracts with providers, insofar as the organized market does not exist or ordering on the organized market is not economical.

SONDEE assumes that when there is an organized market service providers can apply for the tender based on the tender and technical requirements of the DSO. During the qualification process, the DSO checks whether the provider meets the general and technical requirements for offering a flexibility product. As a general rule, the provider qualifies to offer a single flexibility product. Basic qualifications are also given in SONDSEE requirements for flexibility service providers.

The SONDSEE draft is still in the process of being approved by the competent authorities. Since the area of flexibility on the distribution network has not yet been developed, the provisions of SONDSEE in this regard are written broadly enough to allow for the possibility of development of the area and different decisions regarding responsibilities and roles in the process. ZOEE stipulates that the TSO and DSOs must agree and establish the scope and method of data exchange in the flexibility process. The current provisions in this regard in SONDSEE only provide for the exchange of data, as the exchange has not yet been agreed upon. The DSO is aware that in the future it will be necessary to upgrade SONDSEE with more precise provisions regarding flexibility, but we are of the opinion that the current version corresponds to the current organization of the field of flexibility. In addition, it will be necessary to adapt the Slovenian legislation and technical regulations for the area of flexibility to the new network code for the area of flexibility. Currently, only the TSO uses flexibility resources on the distribution network. Distribution companies use flexibility only in the context of pilot projects. Also, the aggregation function has not yet started in Slovenia, as there are no defined rules/models, which is the task of the market operator. Nevertheless, aggregation functions are already offered by certain providers. Legislation imposes on various actors (electricity operators, market operator, regulatory authority) the preparation of legal bases for the organization of the field. Since individual functionalities are interconnected, we believe that individual actors should closely cooperate in the preparation of "their" provisions. We note that there is currently no organized cooperation. The consultation process carried out by the Energy Agency of Slovenia is the last joint project in the field of introducing flexibility in which all actors in Slovenia participated.

The development of local flexibility markets is closely connected to the development of different models of integration of Independent Aggregators (IA) in the electric power system of Slovenia. Slovenian MO Borzen conducted a study on the topic of the development of models of independent aggregator and their impact.

In Slovenia, the role of the aggregator in the electricity markets can be performed by the IA or taken over by the electricity supplier. Currently, in Slovenia, IA can participate in the electricity markets without nomination points (NP), and their realization is recorded in the market balance of other market participants or subjects. From the report of the Energy Agency on the situation in the field of energy in Slovenia for 2022, it can be seen that the majority of independent aggregation was observed on the day-ahead market and in the provision of balancing services, more precisely manual reserves for frequency restoration (mFRR), but was relatively small. In general, Europe is currently the most interesting market for IAs in balancing services.

In Slovenia, every balancing service provider (PSI), including IA, must be a member of the balancing group, which in practice means that it regulates its balancing responsibility with the market operator. If the PSI benefits from the PPM where the supplier is, it must be included in the balance scheme to obtain supplier status. The aforementioned arrangement in Slovenia is already in line with EU provisions, which stipulate that market participants engaged in aggregation must be financially responsible for balance deviations they cause in the electricity system. However, the current regulation in Slovenia only stipulates that they are responsible for deviations that affect their balance group.

IA's activity on the market may cause deviations in the market plan of other market participants, especially suppliers. The latter can trigger a demand for compensation from suppliers for lost income. From the review of the previous practices of regulating relations between the supplier and IA, it follows that most countries have solved the issue of supplier deviations caused by IA activities by correcting the market plan or scope (perimeter correction), while the issue of payment of possible (additional) compensation is causing more controversy.

According to the Universal Smart Energy Framework (USEF) classification, the current regulation in Slovenia is the closest to the contract model. This is a model where when providing system services, the aggregator has a closed contract with the TSO. In the event that the IA uses an asset or device that is in the supplier's balance group, then the IA always deviates by providing system services, with the direction of deviation depending on the direction of providing system services. The same applies if the aggregator were, for example, to offer flexibility in the day-ahead or intraday market. Currently, only recommendations are given regarding the actual conclusion of the contract and energy transfer, the actual implementation is left to the contracting parties, that is, the IA and the supplier. As mentioned in the provision of system services, IA (PSI) regulates the balance responsibility with the market operator. If they use the asset or device for PPM, which is in the balance group of the supplier, then IA always deviates by offering system services, and the direction of deviation depends on the direction of offering system services. The same applies if the IA offers flexibility in the day-ahead or intraday market. According to the current arrangement, both the supplier and the IA, if no agreement is reached between them, are charged for deviations at the price of the deviations. If an agreement is reached, only deviations will remain in the IA balance, which are the result of differences between the required activation and realization. In some documents, the current regulation in Slovenia, in the event that no agreement is reached between the supplier and the IA, is mistakenly treated as an uncorrected model. In the case of the latter, all deviations are borne by the supplier, and IA is not even responsible for its own deviations.

Borzen encourages the development of local flexibility markets that can provide flexibility to the electric power system of Slovenia. It supports the development of mechanisms that enable an open market development that supports participants to offer their flexibility services to support the balancing of the system.

3.3 STATUS OF DEVELOPMENT/CURRENT STATE OF FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS

ACER Report [2] outlines that Europe's 2019 clean energy package granted consumers the right to access all electricity markets and be remunerated for their flexibility, but Member States are still to implement such provisions in national legislation. Based on ACER's preparatory work, system operators are currently drafting a regulatory proposal on demand-side flexibility. The new rules aim at facilitating the market participation of demand response, storage and distributed generation. After ACER's revision, the draft of ACER’s report will be submitted to the EC in 2025.

The EC's legislative proposal on the electricity market design from March 2023, considers changes both in the market design and in the supportive framework. For example, it introduces flexibility support schemes, improves the liquidity of forward markets and strengthens short-term markets, where resources can adjust in as close to real time as possible.

One of the very important aspects that affect local flexibility is demand response which refers to residential, commercial or industrial customers changing their electricity load from normal or planned consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organized market, whether alone or through aggregation. In general, price-sensitive demand should increase in times of lower prices (variable renewable electricity - VRE excess) and decrease in times of higher prices (VRE deficit), thus balancing the system. Energy efficiency and demand response are therefore essential tools to help rebalance markets, reduce high prices and soak up low or negative prices. In general, it is more economical and less polluting to reduce or delay energy use than to activate additional supply or other flexibility resources. These benefits highlight the disproportionately impactful effect of demand response measures. Although an increasing number of countries have started piloting such projects, there are still numerous legal, technical, economic and informational barriers to activating demand response at larger scale. To realize the full potential of demand response and benefit from the more rapid decarbonization of electricity supply, policy-makers and planners need to move to a holistic development and integrated operation of the energy system. This will allow the EU to capitalize on rapid changes also under way in other sectors, such as buildings, transport and industry. With appropriate incentives and standards in place, energy system integration will facilitate harnessing flexibility from various resources, such as time-shifting and reducing the heating and cooling needs and shaving demand peaks by using domestic or industrial heat pumps and district heating.

The current situation of flexibility utilization in the context of STREAM and in general was studied through literature research in the scope of T4.3. This review serves as the cornerstone for understanding the current state-of-the-art knowledge within the field of flexibility utilization, thereby supporting the identification, creation, and enhancement of flexibility utilization strategies to be analyzed, simulated, and executed across STREAM's pilot sites.

This literature review builds upon the groundwork laid in WP2 of the STREAM project, where initial use cases for each pilot site were identified and described. Drawing from identified use cases, we tackled specific research areas of interest within technical journals, seeking out real-world applications or pilot simulations with the potential to benefit our pilot sites. In the subsequent four subsections, we offer a synthesis of the research findings—each pilot site receiving a dedicated subsection. Given the unique challenges faced by each site, as well as the differences in areas of interest, the content of each subsection varies accordingly.

The Slovenian pilot site encompasses an industrial park in the town of Ajdovščina, located in the south-western part of Slovenia. This location was selected before the official launch of the STREAM project due to its suitable power consumption characteristics. Using data gathered from metering points, project partners have pinpointed thirteen prospective companies selected based on their flexibility assets, which are deemed valuable for participation in the analysis of their contributions to flexibility utilization. Contact was established with these companies even before the official kick-off of the STREAM project. Initial project information was presented, and an invitation to sign the letter of intent was extended. Eleven companies demonstrated early commitment, while two companies, Fructal and Mlinotest respectively, signed their letters of intent later after the project had commenced. This early commitment proved crucial for project continuity, streamlining interactions as a point of contact had already been established, and these companies were well-informed about their future involvement. The fourteenth company, Knauf Insulation, was contacted later during the project's progression, owing to the positive business relationship between KOL and Knauf Insulation, established through their previous collaboration. Seven out of fourteen contacted companies have chosen to be actively engaged in STREAM, with two committing to contractual agreements for providing ancillary services.

Whilst the majority of customers are connected to the LV distribution network, several larger industrial customers are connected directly to the MV network. Hence, the focus for the Slovenian pilot includes the market-based approach, particularly pertinent to smaller consumers such as households linked to the LV grid, rule-based connection agreements, of particular relevance to larger enterprises connected to the MV grid, mFRR possibilities, etc.

Paper [3] provided a design of a local capacity market for providing system-wide and local flexibility, which consists of three stages. The first stage is related to pre-matching the bids of the DSOs and the TSO with the offers of flexible capacity sellers. At this stage, the Local flexible capacity market (LFCM) operator accepts the offers and bids aiming to maximize the social welfare of the participants. In the second stage, the DSO checks if the accepted offers and bids do not violate the security constraints of the network, and the results are sent to the third stage. Consequently, the third stage determines the accepted offers of each seller based on the results of the previous stage.

The paper considers DSO-TSO coordination in the second stage, which is also high on the priority list of the Slovenian pilot, as we see it as a very important matter. Furthermore, the paper considers maximizing social welfare, which is calculated in the paper with the following formula: utility of flexibility demand minus the costs of flexibility provided. Considering the social aspect could prove intriguing, given that within STREAM, we aim to achieve the "global" optimum.

In [4], the paper discussed two solutions for a DSO to adopt flexibility, a tariff-based approach and a market-based approach.

Drawing from the paper, we conclude that a tariff-based approach may prove efficient in grid segments where the DSO encounters voltages near limits and grid element loads. Dynamic grid tariffs incentivize customers to alleviate voltage and load concerns, thereby enhancing grid operational security. Conversely, a market-based approach could be advantageous in grid areas where the DSO faces over/under voltages and grid element overloads.

Paper [5] proposes frameworks for i) classifying flexibility resources and flexibility enablers in grid operation and planning, and ii) classifying and understanding barriers to utilizing them in terms of a flexibility value chain. The paper also conveyed a study with Norwegian DSOs and got initial responses on how flexibility is used at the moment and how they could imagine using it for planning/operation in the future.

The paper provides a holistic overview of categories for enabling DSO’s access to flexibility. The conclusions of the study with Norwegian DSOs showed that one of the key enablers of flexibility will be conditional connection agreements, which are also of high interest in the scope of Slovenian pilot sites.

In [6], the authors mainly focused on the relationship between energy communities (EnCs) and local flexibility markets (LFMs). They argue that these markets should be accessible to local players such as businesses and EnCs, not just existing incumbents. For this to be feasible, the entry threshold should be sufficiently low, utilizing inexpensive internet-enabled hardware and standard domestic smart meters to enable small-scale flexibility. The report highlights that due to expected low margins, revenue stacking from other flexibility markets and activities will be crucial for the commercial viability of aggregators.

In [7] the authors identify six overarching principles necessary for establishing LFMs: transparency for market parties, data visibility, coordination with neighboring system operators, value stacking, incentives, and a technology-neutral approach. It outlines the steps for procuring distributed flexibility, from product definition and prequalification to measurement, validation, and settlement. The report also showcases some existing solutions like Piclo and GOPACS and categorizes market products into long-term and short-term, discussing their respective advantages and disadvantages.

Paper [8] presents the results of a questionnaire involving four projects related to LFMs: Piclo Flex, Enera, GOPACS, and NODES. The questions addressed various aspects of LFMs, such as the role of the market operator, reservation payments, and TSO-DSO coordination. Based on this paper and other reports, Piclo and NODES were identified as the two most developed and active projects, warranting a deeper study.

Regarding NODES, two white papers [9], [10] outline its market design and product definitions (LongFlex and ShortFlex) and present findings from the NorFlex project, which demonstrated the operation of a local flexibility market. These descriptions and demonstration results significantly contributed to defining market-based solutions as a flexibility utilization option for the Slovenian pilot site.

In the Eurelectric report from 2018 [11], three solutions are proposed for addressing distribution grid issues: connection agreement solutions (also known as variable network access or flexible network connection agreements), rules-based solutions, and market-based solutions, each with its own pros and cons. The report identifies the connection agreement solution as key for reducing network investments, emphasizing that limitations must be transparent and predictable for users. It calls for close cooperation between DSOs and regulators to define this framework and suggests revising DSO remuneration to benefit both connected users and operators. To complement the connection agreement and market-based solutions, the rules-based solution grants DSOs full control in critical network states.

3.4 VARIOUS OPTIONS FOR FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS WITHIN THE CONTEXT OF THE PILOT SITES

The literature review on flexibility utilization provided valuable insights across various dimensions, including social welfare, TSO-DSO coordination, optimal planning, operational aspects and others. These insights catalyzed our discussions when formulating diverse flexibility utilization solutions, as each aspect contributes to the stacking of flexibility value, a concept that will be extensively described in the next chapter. The Slovenian partners–EPR, UL, and KOL–engaged in multiple meetings and fruitful discussions to propose four primary options for flexibility utilization:

- **Connection Agreement Solution**
- **Market-Based Solution**
- **Rules-Based Solution**
- **Manual frequency Restoration Reserve (mFRR)**

Although only market-based solution and mFRR are set to be utilized in a practical use case and undergo simulation and demonstration within the Slovenian pilot, it's crucial to note that both the connection agreement and rules-based solutions, while not estimated for demonstration, hold equal significance. The latter solutions play pivotal roles in enabling flexibility utilization while simultaneously safeguarding the power system.

3.4.1 Connection agreement solution

Connection agreement solution, often referred to as "variable network access”, involves a departure from the traditional approach of planning the grid to ensure a constant physical connection at all times. Alternatively, contractual agreements could be instituted to facilitate flexible network access, custom-tailored for instances where grid operators are unable to accommodate the requested connection power. In such cases, grid customers could be afforded the opportunity for monetization, compensating for occasions when full physical connection cannot be guaranteed. This approach on the one hand enables grid operators to defer or even abandon lengthy and complex investments in the grid and on the other hand, enables grid customers to get quick grid access, which would traditionally be postponed or in some cases even declined. Therefore, if the right conditions are applied, connection agreement arrangements can help reduce or delay grid investments and create a win-win situation between grid customers and grid operators.

Figure 3-1 overviews the concept of the connection agreement solution, where a grid customer plans to install a new electric device/s and a grid operator cannot guarantee the requested power at all times, due to various operational reasons (for example, not being able to guarantee n-1 condition).

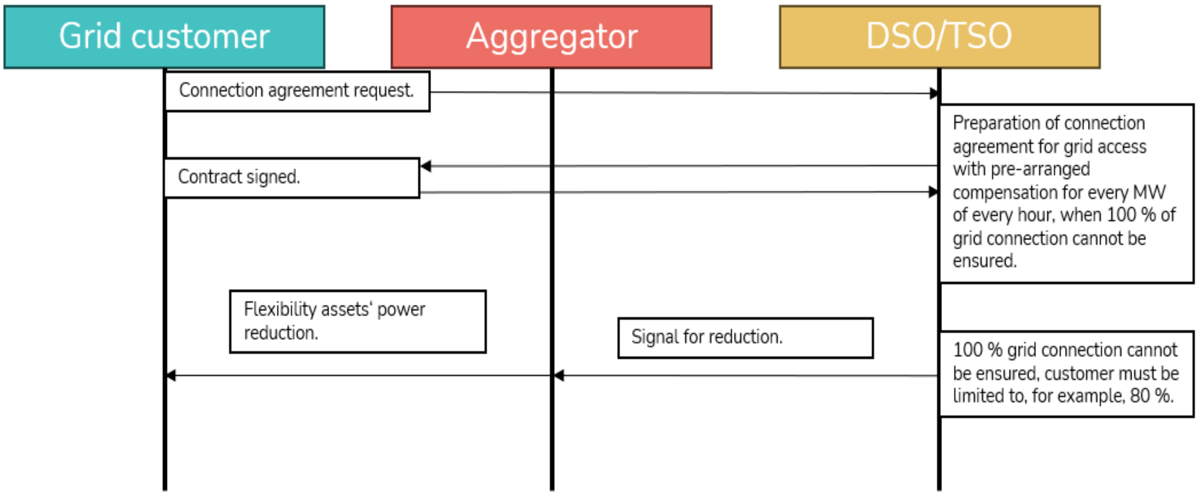

Figure 3-1: Slovenian pilot - connection agreement solution schema.

Rather than rejecting or delaying the requested connection agreement, a grid operator could offer compensation to the grid customer for each megawatt-hour when full grid connection cannot be guaranteed, due to grid enhancements. This compensation would be calculated based on the costs saved if grid enhancements were not undertaken, factoring in the time element of the investment. The grid customers would then have the option to consider the variable network access agreement, including compensation, and decide whether it aligns with their requirements. If customers agree to the connection agreement, they get a signal for power reduction every time, when the grid operator is not able to guarantee the full power consumption. Ideally, the initial contract would contain the maximal number of annual interruptions alongside their durations.

While the connection agreement solution won't be demonstrated in the Slovenian pilot, it holds potential as a facilitator for flexibility markets at large. By securing such agreements, DSOs can, in the event of operational challenges, conduct auctions to procure the requested power at a lower price than stipulated in the connection agreement/s. If the required power or required power for a lower price cannot be secured through market channels, DSOs can still use a backup scenario in the form of connection agreements. Thus, connection agreements would help unlocking the market-based solution, which is not viable at the moment, and simultaneously provide both, improved planning of the grid and security of supply in the case of operational challenges.

Depending on the national circumstances, DSOs should work with the regulators to establish general criteria that the DSOs should follow when designing and implementing such connection agreements in order to make the process transparent, objective and non-discriminatory.

3.4.2 Market-based solution

A market mechanism creates good conditions for multiple stakeholders to offer the most efficient flexibility solutions to grid operators. This, of course, is contingent upon the presence of a sufficient number of local players to facilitate healthy competition. This approach also has large potential to trigger innovation and to benefit from standards established in existing energy markets.

The market-based solution schema is presented in Figure 3-2.

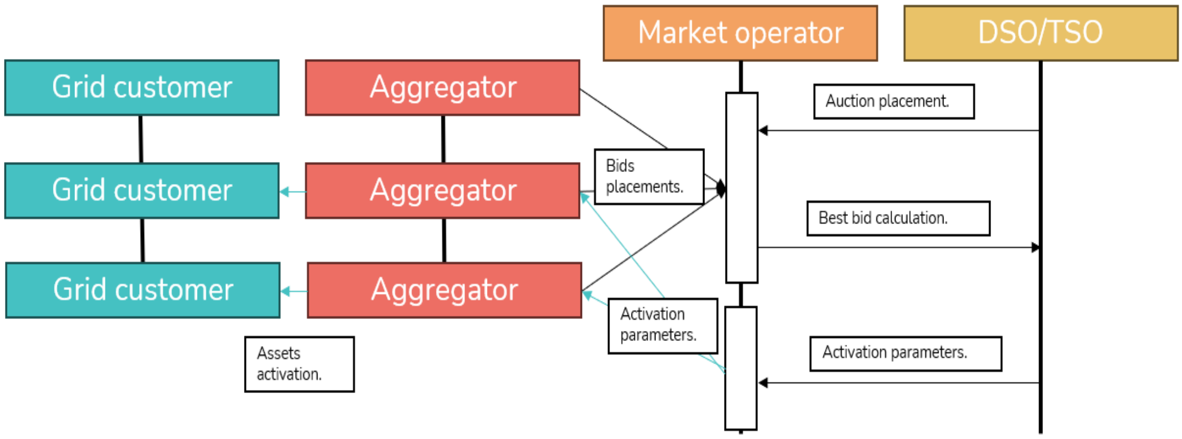

Figure 3-2: Slovenian pilot – market-based solution schema.

When grid operators foresee a potential grid issue, they may initiate a market auction for the needed power. Multiple aggregators can then submit their bids. The DSO proceeds with a best bid calculation, considering various preferences such as the most economical or technically feasible solution, or a combination of both. In the event of a grid disturbance, the DSO collaborates with the market operator to begin the activation process. Subsequently, the market operator communicates activation parameters to the best bidding aggregators, facilitating the activation of flexibility assets within their portfolio.

While the market-based solution is already well established for procuring capacity to maintain the frequency in the ancillary services market on the transmission level, the "game rules" in the local markets will have to be established through the collaboration of the DSOs with the regulators. Market-based solutions therefore require a clear product definition and preferably sufficient liquidity. The challenge of liquidity can be partially overcome with the combination of the connection agreement and market-based solutions.

3.4.2.1 Connection agreement and market-based solutions

As outlined in section 3.4.1, the market-based solution can be unlocked or enabled through the implementation of the connection agreement solution. Presently, DSOs hesitate to engage with flexibility utilization, as they would need real grid challenges to prompt action. Traditionally, grid planning entails ensuring that all grid connections remain physically feasible at all times, thereby negating the immediate necessity for flexibility solutions.

Observing Figure 3-3, our proposal advocates for a market-based solution that expands upon the principles of the connection agreement solution. Assuming the DSO has established contractual agreements with at least one grid customer, it anticipates encountering local grid issues at some point in time. When the DSO foresees an impending grid problem, it initiates auction within the market.

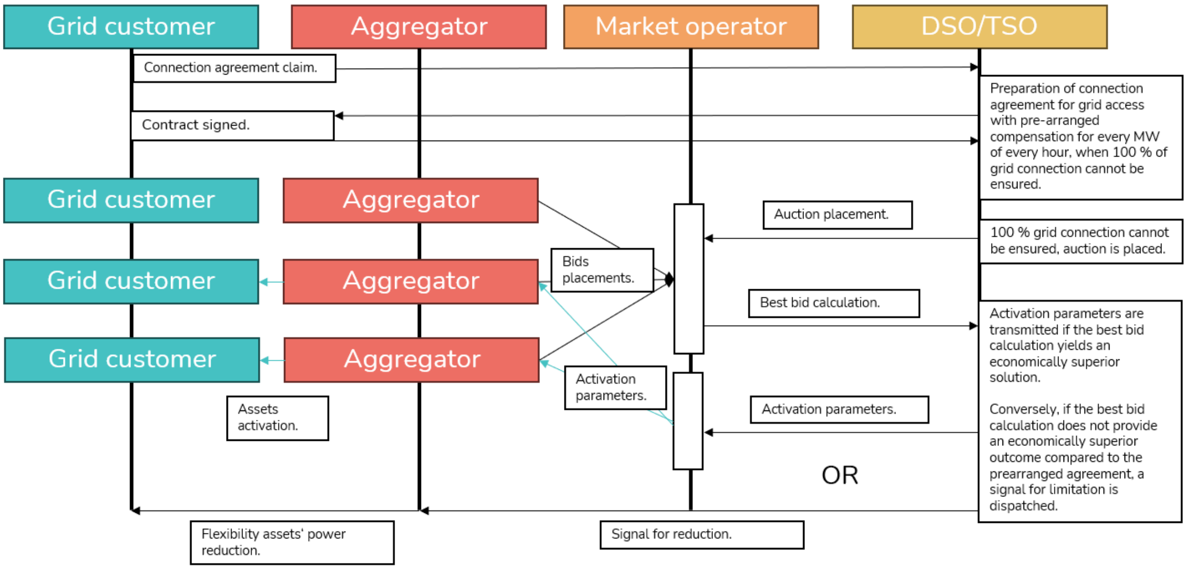

Figure 3-3: Slovenian pilot - connection agreement and market-based solutions schema.

The primary objective of these market auctions is to procure the necessary power to stabilize the grid at a cost lower than that stipulated in the connection agreement(s). Should the bids submitted on the market surpass the terms of the prearranged connection agreement, the market operator communicates activation parameters to the aggregators, prompting the activation of the most favorable bids. Conversely, a signal is sent to activate the power outlined in the prearranged connection agreement.

The described concept presents grid operators with the opportunity to embrace flexibility utilization by offering connection agreements instead of outright rejections or lengthy grid investments when the physical connection at all times cannot be ensured. This approach allows DSOs to defer or even abandon grid investments while also facilitating the flexibility market, wherein various grid customers can leverage their flexibility assets during operational grid challenges. Importantly, the security of supply remains assured, as the DSO maintains a backup scenario within the initial connection agreement solution.

3.4.3 Rules-based solution

Another technique for enabling DSOs to access flexibility may be through rules-based solutions. By rules-based solution we refer to compulsory rules in network codes and regulation to impose flexibility technical requirements. An example could be that PV power plant infeed is curtailed if certain technical limits, for example, overvoltage in the grid, are reached. A rules-based solution can also be the result of a market failure and therefore should be seen as an exception. Such an approach can be justified when there are not enough voluntary offers to prevent a blackout. However, rules-based solutions can under no circumstances be used where a market approach is possible. Rules-based solution would therefore resemble the red light in the traffic light system, described in the Deliverable D4.1 The schema for rules-based solution in the Slovenian pilot is presented in Figure 3-4.

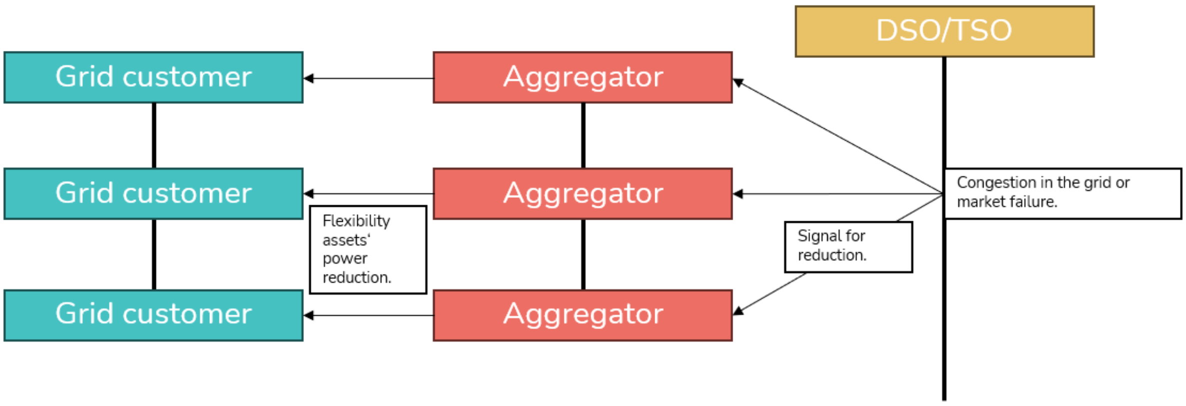

Figure 3-4: Slovenian pilot - rules-based solution schema.

In the event of an unforeseen grid congestion or market failure, it becomes imperative for the grid operator to uphold the uninterrupted operation of the grid and its underlying assets. In such scenarios, the grid operator must have the capability to dispatch signals for reduction to aggregators, who subsequently relay these signals to the flexibility assets within their portfolio.

While the proposed sequence of actions is already established for TSOs in case of emergency in the transmission grid, DSOs will need to prioritize rules-based solutions in the future to ensure the security of the power supply in a rapidly evolving landscape. Moreover, the regulatory role must be emphasized as a potential compensation mechanism for the loss of revenue and opportunity costs need to be evaluated when reductions are imposed on the grid customers. Without such considerations, grid customers may be reluctant to participate in the flexibility market, fearing the possibility of having their power curtailed to maintain operational grid limits without being compensated for it. Additionally, a significant challenge lies in determining the sequence of reduction—deciding which flexibility assets should be curtailed first.

3.4.4 Manual Frequency Restoration Reserve (mFRR)

Within the scope of STERAM, the Slovenian partners will also demonstrate mFRR. While mFRR is similar to the market-based approach, it is specifically designed for Transmission System Operators (TSOs). The fundamentals and processes of mFRR have already been detailed in D2.1 [12], so we will not delve into those specifics. However, value stacking will also be addressed for this aspect.

3.5 VALUE STACKING OF FLEXIBILITY UTILIZATION

This subchapter explores the complexities of energy systems and the critical role of flexibility in maximizing value across the entire value chain and its stakeholders, including grid customers, aggregators, market operators, and system operators. Flexibility value stacking is not a "one size fits all" solution; it is based on principles of scalability and replicability, tailored to the specific market it serves. At a high level, flexibility value stacking should enhance the overall energy efficiency of the power network, optimizing grid operation and investment. It should also provide added value to grid customers and aggregators at a more granular level, enabling them to generate new revenue streams while supporting system operators with improved operational efficiency. The flexibility value stacking for specific utilizations of flexibility within the Slovenian pilot of STREAM is described in the following sections. For each of the proposed utilizations, a review table with pros and cons (or challenges) has been developed. The pros and cons are described qualitatively and numerically - value between 1 and 5 with 5 being the best value - to assess the benefit for grid customers, aggregators, market operators and system operators.

3.5.1 Connection agreement solution

Table 3-2 depicts the value stacking of the connection agreement solution. From the table, we can conclude that the connection agreement solution best fits the DSO, scoring a value of 4. The primary benefits include the ability to defer or even reduce grid investments while increasing customer satisfaction by allowing connections under specific conditions that are currently not possible. However, the DSO faces challenges, such as the increased operational effort required and the need for transparent cost-benefit calculations. This transparency is essential for the DSO to justify its decision to either enter into contractual agreements with customers or investing in grid enhancements.

For grid customers, the connection agreement solution offers quick access to the grid without additional grid-related costs, along with the potential for passive revenue during periods of restriction. However, the risk of interruptions could lead to unforeseen costs, making this solution less appealing.

For aggregators, the connection agreement solution is less attractive due to the potential for customers to establish direct communication with the DSO (e.g., signalling when certain loads need to be reduced). Direct communication links within the connection agreement solution are not governed by standards, as they are for services like mFRR. Therefore, they allow for a more customer-friendly implementation.

The role of the market operator does not apply to this solution, resulting in an overall value of 3,3 for the entire value chain.

Table 3-2: Slovenian pilot - value stacking of connection agreement solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Connection agreement for a customer without additional costs for grid enhancement. • Additional monetization opportunity. • Faster grid access.	• Interruptions of the customers‘ operation. • Unforeseen costs due to not forecasted power limitations.	3
Aggregator	• Possible income by creating a „link“ between a customer and DSO/TSO. • Possibility to analyse and consequently utilize the contracted flexibility assets in other markets.	• Aggregator is not necessarily needed. Customers can establish their own „link“ to the DSO.	3
Market operator	• N/A	• N/A	N/A
DSO	• Postponement /reduction of the investments into the grid.	• Increase of operational effort.	4

	• Creating satisfaction in grid customers.	• Transparency of costs/benefits challenges.	

3.5.2 Market-based solution

Pros and cons of individual stakeholders within market-based solution is visualized in Table 3-3. The total value across the entire chain is 4, a 20% increase over the connection agreement solution, suggesting that this flexibility utilization better serves the majority of stakeholders.

The largest improvement over the connection agreement solution is for aggregators. As shown in the table, the market-based solution exclusively benefits this stakeholder, allowing them to monetize the flexibility of one or multiple assets in the market and possibility to analyze the participation in additional energy markets with the same assets. Grid customers also see improvements: they can connect to the grid even in a congested state of the grid, with market participation being optional. However, penalties for undelivered power or energy remain a concern for this group.

The role of the market operator, previously irrelevant under the connection agreement solution, becomes crucial with the market solution. Key challenges will include evaluating flexibility bids and managing the complexity of the assessment of topological and price factors.

A decline in value is noted for grid operators. Although they gain the ability to incorporate flexibility into grid planning, they face new challenges, such as optimizing bid selection, increased operational demands, and forecasting grid loads accurately.

Overall, the market solution offers better conditions for the stakeholders' value chain compared to the grid connection agreement solution.

Table 3-3: Slovenian pilot - value stacking of market-based solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Easier connection agreement approval, including in a possible congested state of the grid. • Monetization opportunity. • Faster grid access.	• Potential penalties for power/energy not delivered. • Potential warranty problems with electric devices manufacturers.	4
Aggregator	• Monetization for aggregation of one or more flexibility assets. • Possibility to analyse and consequently utilize the flexibility assets in other markets.	• /	5
Market operator	• Facilitation of trading (market platform development, etc.).	• Challenge of assessing flexibility bids, including considering topological	4

	• Facilitation of regulatory compliance. • Non - discriminatory access to the market for all market participants.	and price aspects of the flexibility asset). • Market liquidity challenge.	
DSO	• Postponement /reduction of the investments into the grid. • Creating satisfaction in grid customers. • Enabling grid planning based on flexibility. • Possibility to solve different operational issues.	• Substantial increase in operational effort. • Need for higher bandwidth of IT/OT networks. • Cybersecurity risks. • Grid load forecasting challenge. • Best-bid calculation challenge. • Data management challenge.	3

3.5.2.1 Connection agreement and market-based solution

The pros and cons of the combination of connection agreement and market-based solutions are presented in Table 3-4. In terms of combined flexibility utilization, the primary advantage over the sole market solution lies with the grid operator. In the combined solution, the DSO can rely on a contractual agreement to activate in the event of a grid disturbance. This means that even if challenges arise, such as in best-bid calculation or data management, the DSO can still fall back on the connection agreement to activate customers and maintain safe grid operations. The overall value of the proposed solution lies at 4.24, which is 6% higher than in the case of only a market solution and 28% higher than in the case of only a connection agreement solution.

Table 3-4: Slovenian pilot - value stacking of connection agreement and market-based solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Easier connection agreement approval, including in a possible congested state of the grid. • Monetization opportunity. • Faster grid access. • Connection agreement approval without additional costs.	• Interruptions of the customers' operation. • Unforeseen costs due to not forecasted power limitations. • Potential penalties for power/energy not delivered. • Potential warranty problems with electric device manufacturers.	4
Aggregator	• Monetization for aggregation of one or more flexibility assets.	• /	5

	• Possibility to utilize the flexibility assets in other markets.		
Market operator	• Facilitation of trading (market platform development, etc.). • Facilitation of regulatory compliance. • Non-discriminatory access to the market for all market participants.	• Challenge of assessing flexibility bids, including considering topological and price aspects of the flexibility asset). • Market liquidity challenge.	4
DSO	• Postponement /reduction of the investments into the grid. • Creating satisfaction in grid customers. • Enabling grid planning based on flexibility. • Possibility to solve different operational issues. • Contractual agreement as backup solutions always possible. Grid operation undisturbed.	• Substantial increase in operational effort. • Need for higher bandwidth of IT/OT networks. • Cybersecurity risks. • Grid load forecasting challenge. • Best-bid calculation challenge. • Data management challenge. • Transparency of costs/benefits challenges.	4

3.5.3 Rules-based solution

The rules-based solution and its benefits and challenges are overviewed in Table 3-5. The rules-based solution ranks lowest in value among all Slovenian pilot flexibility utilizations, with an overall score of 2.5. This low ranking suggests that the "stick method" is not particularly effective, especially for stakeholders who are negatively impacted by it, such as grid customers.

While customers do experience increased security of supply, they also face operational disruptions and consequently unexpected costs. Additionally, the aggregator's role in this model resembles that of the connection agreement solution, as customers have the option to establish a direct link to the DSO, bypassing the aggregator. The highest value in this framework is found with the DSO, who can address various operational issues with only a minor increase in operational effort.

Table 3-5: Slovenian pilot - value stacking of rules-based solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Increase of security of supply.	• Interruptions of the customers' operation.	1

		• Unforeseen costs due to not forecasted power limitations.	
Aggregator	• Possible income by creating a „link“ between grid customer and DSO/TSO.	• Aggregator is not needed. Customers can establish their own „link“ to the DSO.	2
Market operator	• /	• Question of costs compensation. • Technical requirements. • Cannot be retroactive.	3
DSO	• Possibility to solve different operational issues. • Increase in grid security and availability. • Contractual agreement as backup solutions always possible. Grid operation undisturbed.	• Minor increase in operational effort. • Transparency of costs/benefits challenges. • Creating dissatisfaction in grid customers. • Transparency of costs/benefits challenges.	4

3.5.4 Manual Frequency Restoration Reserve

Table 3-6 depicts the value stacking for the already established flexibility utilization mFRR. The overall value of the solution is 4.5, the highest among Slovenian pilot flexibility utilizations. This strong value reflects mFRR's established effectiveness and the benefits it provides across the stakeholder value chain.

However, some challenges remain. For grid customers, with a value of 4, issues include penalties for undelivered energy and potential warranty concerns for flexibility devices. Similarly, the market operator’s value, also at 4, is impacted by challenges related to market liquidity and the handling of deviations when assets are activated. These issues are well known, as mFRR operates daily.

Table 3-6: Slovenian pilot - value stacking of mFRR.

Stakeholder	Pros	Cons	Value
Grid customer	• Additional monetization opportunity. • Unlocking more connection possibilities.	• Potential penalties for power/energy not delivered. • Potential warranty problems with electric device manufacturers.	4
Aggregator	• Monetization for aggregation of one or more flexibility assets. • Possibility to analyse and consequently utilize	• /	5

	the flexibility assets in other markets.		
Market operator	• Facilitation of regulatory compliance.	• Market liquidity challenge. • Challenge of defining the deviations when assets are activated (concerning TSO and supplier).	4
TSO	• Possibility to solve different operational issues. • Efficient grid management. • Better supply reliability.	• Unavailability of flexible resources to solve DSO congestions.	5

3.6 GAPS, CHALLENGES AND RECOMMENDATIONS FOR FUTURE LEGISLATION DEVELOPMENT

The Slovenian pilot highlights several gaps and challenges that need to be addressed for the successful development of local flexibility markets. A key issue is the lack of a fully developed regulatory framework for flexibility services, which creates uncertainty for market participants. While Slovenian legislation, particularly the ZOEE, has begun to define flexibility provisions, there are still unresolved aspects regarding the roles and responsibilities of key actors such as TSOs, DSOs, and independent aggregators. The lack of a structured market for flexibility means that DSOs currently rely on bilateral agreements rather than competitive market-based solutions, which can limit efficiency and transparency. Additionally, coordination between TSOs and DSOs remains a challenge, as their respective roles in procuring and utilizing flexibility services are not clearly defined. Without improved cooperation and data exchange mechanisms, the integration of flexibility resources into the broader energy system will be limited.

Another major challenge is the absence of clear rules and incentives for independent aggregators, who play a crucial role in enabling small-scale flexibility providers to participate in the market. Currently, aggregators in Slovenia face regulatory and technical barriers that make it difficult for them to operate effectively. Market liquidity is another issue, as the flexibility market lacks sufficient participation from both demand-side and supply-side actors. Without an adequate number of participants, price signals may not accurately reflect the value of flexibility services, reducing the overall efficiency of the market. Moreover, the technical infrastructure required for flexibility trading, such as smart metering and automated control systems, is not yet fully developed, which hinders real-time market participation and responsiveness. The limited availability of digital tools for monitoring and verifying flexibility services also creates challenges in ensuring compliance and market transparency.

To address these issues, the document recommends several legislative and regulatory improvements. First, Slovenia needs a comprehensive legal framework that explicitly defines the roles of TSOs, DSOs, and aggregators in flexibility markets. This should include clear guidelines for market participation, compensation mechanisms, and data-sharing protocols. Second, a structured flexibility market should be established to replace the current reliance on bilateral agreements, ensuring that flexibility services are procured in a competitive and transparent manner. This would encourage more participation and drive efficiency. Third, incentives should be introduced to encourage aggregators and smaller flexibility providers to enter the market, either through financial support mechanisms or streamlined administrative procedures. Strengthening collaboration between TSOs and DSOs is also critical, requiring improved communication channels and joint planning efforts. Finally, investments in smart grid infrastructure, digital platforms, and automation technologies should be prioritized to enable real-time flexibility trading and ensure that the market can operate efficiently. By implementing these recommendations, Slovenia can create a well-functioning local flexibility market that supports the energy transition and enhances grid stability.

4 PILOT SITE OVERVIEW IN FINLAND

4.1 REGULATORY POINT OF VIEW

Finland has implemented several legislative and market-based measures to promote flexibility in its electricity distribution system. The Finnish Electricity Market Act (497/2023) includes provisions for aggregation, defining it as the consolidation of multiple end-user loads or electricity production for participation in the electricity market. Notably, the Act allows independent aggregators to operate without needing approval from the end-user's electricity supplier. This measure fosters fair and non-discriminatory participation, supporting the development of a more competitive and flexible electricity market.

Electricity Market Act (sähkömarkkinalaki) provides the overarching legal framework for the operation of electricity markets in Finland. The implementation of the Electricity Market Act is supervised by the Finnish Energy Authority (Energiavirasto). The Electricity Market Act enables DSOs to acquire flexibility services from local markets, for example, to relieve grid congestions. Concretely, these were put into practice through an order in 2021 and through the changes in the Energy Authority's monitoring methods, which came into effect in 2022 by the Finnish Energy Authority. The Electricity Market Act is in line with related EU directives, such as the Clean Energy Package to foster the use of renewable energies.

While local flexibility markets in Finland are still under preparation, there are already regulatory incentives that can support them indirectly. **Flexibility incentive** (joustokannustin) encourages DSOs to buy flexibility services from the consumers. The impact of the flexibility incentive is calculated so that the reasonable costs of implementing the flexibility incentive are at most 1 per cent of the network operator's revenue from network operations during the regulatory period. **Innovation incentive** (innovaatiokannustin) encourages DSOs to actively develop and use innovative technical and operational solutions as part of their network operations. The impact of the innovation incentive is calculated so that the reasonable research and development costs are considered to be at most 0.5 per cent of the network operator's revenue from network operations during the regulatory period.

DSOs adapt to regulatory changes that impact their operations. For instance, the Finnish Energy Authority's updates to the regulatory framework, including adjustments to the weighted average cost of capital (WACC) and methodologies for valuing the regulated asset base (RAB), influence how DSOs plan and implement flexibility measures.

Independent aggregators are permitted to operate in various reserve market products, including Fast Frequency Reserve (FFR), Frequency Containment Reserve for Disturbances (FCR-D), and Frequency Containment Reserve for Normal operation (FCR-N). They can pool flexible resources across different balance responsibilities, adhering to the specific terms of each reserve market product.

The Finnish government may issue further decrees concerning the verification of demand-side flexibility offered by independent aggregators, its accounting in imbalance settlement, and the management of financial compensation. Additionally, the EU is preparing a Network Code for Demand Response, expected to provide detailed guidelines on independent aggregation models and market access by spring 2025.

In summary, Finland's regulatory framework for independent aggregators is evolving, with established legislation and ongoing initiatives to integrate these entities into the electricity market, thereby promoting flexibility and efficiency.

4.2 TSO, MO, DSO POINT OF VIEW

Fingrid is the electricity transmission system operator (TSO) of Finland, it includes also the responsibilities of a market operator. It is responsible for managing Finland's high-voltage electricity transmission network and ensuring secure and efficient operation of the system. Fingrid plays a major role in maintaining balance between the production and consumption of electricity. Fingrid uses balancing reserves, which are pre-contracted resources that can be activated to increase or decrease electricity production or consumption. These reserves include both automatic and manual reserves. Fingrid is responsible for the safe and reliable transmission of electricity from large production facilities to industrial customers and distribution networks.

Fingrid's Datahub is a centralized information exchange system designed to enhance the efficiency and transparency of Finland's electricity retail market. Launched in February 2022, it consolidates data from approximately 3.8 million electricity consumption points into a single platform. Datahub stores comprehensive information on electricity consumption and production, facilitating efficient data exchange among market participants, including distribution system operators (DSOs), electricity suppliers, and consumers. By providing a unified platform, Datahub accelerates information exchange, reduces errors in market processes, and simplifies tasks such as switching electricity suppliers. This streamlining promotes a more competitive and dynamic market environment.

Datahub is instrumental in implementing significant electricity market reforms. For example, it enables the formation of energy communities, allowing housing associations to collectively utilize renewable energy sources like solar power. Additionally, it supports the transition to a 15-minute balance settlement period, aligning with European standards to enhance the accuracy of electricity pricing and promote sustainable energy practices.

Through the Datahub customer portal, consumers can access their electricity usage data, enabling them to make informed decisions about their energy consumption and engage more actively in the electricity market. Fingrid's Datahub is a foundational component in modernizing Finland's electricity market, fostering transparency, efficiency, and consumer engagement, while supporting the integration of renewable energy sources and the development of new market models.

Distribution System Operators (DSOs) in Finland are responsible for the distribution of electricity to end consumers. The DSO also has the responsibility of connecting electricity consumers and producers to the grid and maintaining voltage quality. There are 77 DSOs in Finland that manage low-voltage and medium-voltage networks below 110 kV, and there are 9 high-voltage DSOs in Finland that solely manage 110 kV networks.

4.3 STATUS OF DEVELOPMENT/CURRENT STATE OF FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS

In Finland, there are currently no local flexibility markets. Fingrid and Helen Electricity Network, a Finnish DSO, are currently piloting a new marketplace that enables the trading of flexible resources for congestion management. The flexibility market will cover flexibilities both at the transmission and distribution levels. In the pilot, the flexibilities at the transmission system level can be offered anywhere in Finland. At the distribution level, the flexibility offers are limited to the area of Helen Electricity Network, that is the area of Helsinki. The goal is to start trading in the local flexibility market at the beginning of 2025. At the end of 2024, Fingrid and Helen informed that Norwegian market platform for local flexibilities, NODES, was chosen for the pilot [13].

The technical requirements for the planned flexibility marketplace will be less strict than those for Fingrid's frequency support reserve markets. In transmission management, even resources that activate, for example within a few hours, are beneficial to the power system. The goal of Fingrid is to attract flexible resources, especially those that cannot meet the technical requirements of the frequency reserve markets in order to resolve national-level bottleneck situations as part of other transmission management methods. Helen Electricity Network, on the other hand, will use the new marketplace to address local congestion issues within its distribution network area. In the pilot, only active power will be traded. Currently (November 2024) Fingrid is gathering potential market participants to join the flexibility market piloting. Detailed product specifications will be available early 2025. Since the idea is to pilot a new flexibility market, the most suitable technical solutions will be found during the project and possibly various alternatives will be tested.

In current practice, there is the possibility for demand-side flexibility to participate in all available markets. The amount of demand-side flexibility participation in Finnish markets as of 9/2024 is the following: day-ahead market is 1500-2500 MW, intraday market is 0-300 MW, mFRR up is 15-470 MW, mFRR down is 0-140 MW, FCR-D up is 416 MW, FCR-D down in 107 MW, FCR-N is 9 MW, FFR is 81 MW, and aFRR up and down combined is 84 MW.

Mikkonen (2021) made a case study on the feasibility of a smart grid business model application, specifically focusing on a residential demand response control unit. The study, conducted in 2021, aims to describe business models of demand response enabled by the smart grid and observe their ability to generate cash flow using a case example. The main actors in this study are the aggregator and household(s). The findings indicate that most of the Finnish electricity markets are theoretically applicable to demand response utilization. However, some markets require quick activation times, and certain markets like FCR-N require loads to be adjustable both upwards and downwards. Additionally, trading is low or seasonal in some markets, and the offered capacity in the yearly markets must be available throughout the year, which constrains the usage of end user's direct heating loads and water heating loads. The study also highlights that the economic potential of the balancing market is significantly higher than the day-ahead market (DAM), with the balancing market being up to 7 times more economically viable and FCR-D up to 17 times more economically viable than the DAM. The study focuses on FCR-N and mFRR markets and provides good simulation examples for consideration in the STREAM project [14].

A paper by Rautiainen et al. titled "Demand Response: A Nordic Perspective" investigates demand response (DR) markets and stakeholders in Northern Europe. It presents a case study analyzing the feasibility of DR in the day-ahead market. The main actors in this study are consumers and retailers. The findings highlight that controllability and verifiability are crucial for a flexible resource to participate in DR. An aggregator can have market responsibilities but can also just enable or facilitate DR. The most interesting DR resources for today's small electricity consumers are resistive electric heating, air conditioning devices, and electric storage water heaters. The consumption of heating and cooling loads strongly depends on the outdoor temperature. For small consumers, it is estimated that there are roughly about 1800 MW of loads currently connected to control relays of AMI meters in households, which is roughly 12% of the peak load in Finland. The study also mentions that SPOT price volatility is the highest in Finland among Nordic countries and is expected to grow, creating greater opportunities for day-ahead DR [15].

Final report of a project titled "Prosumer Centric Energy Communities towards Energy Ecosystem (ProCemPlus)" explores the structure and possibilities of energy communities (ECs) to act as business-oriented energy ecosystems. The project, conducted in 2021, had several research themes including consumer/client as part of the energy community, business models and regulations, digitalization and ICT platforms, and energy technologies and assets and their control strategies. The study included several pilot cases used as platforms for the research. The main actors in this study are end users/clients, energy retailers, DSO, BMS companies and building owners. As findings the study identified six typologies for energy communities, gaps in national rules and regulations, roles, motivation, and communication needs of stakeholders in setting up the ECs. It also discussed business models and value creation for stakeholders based on different functionalities at ECs, needs of new DSO tariff structures suitable for ECs, electricity network planning, technical functionalities in buildings, and requirements for automation and ICT in case of ECs. The study highlighted the increased need for communication and data exchange between parties in ECs and the need for rules between parties. Three pilot cases were used to show functionalities of ECs: DR at Huurre Areena ice rink, Marjamäki LEMENE microgrid studies, and Kampusareena visualized the data for users and studied DR and quality issues [16].

A research paper by Koskela and Järventausta (2022) titled "Demand Response with Electrical Heating in Detached Houses in Finland and Comparison with BESS for Increasing PV Self-Consumption" presents a method for evaluating the demand response (DR) potential of electric heating in households. The main actors in this study are consumers (households) and service providers (aggregators, utilities, etc.). The findings highlight that customers who heat their buildings using electric heaters are good targets for DR operations because their heating can be controlled with limited changes in indoor temperature. The DR potential of a building can be defined by using customer load profiles and knowledge of the outdoor temperature, without requiring any other information. The novel method proposed for determining the DR potential of small-scale customers can also be used to estimate the flexibility of a large customer group. The study also notes that small-scale customers together can provide significant flexible capacity when their electrical heating is centrally controlled. DR operations are effective for increasing distributed PV penetration. The study also mentions that many people do not notice an indoor temperature change of 0.5°C over the course of an hour, but a 2°C change can affect the comfort of most people. Additionally, the law sets limits on how long an electrical heater can be switched off when controlled by an aggregator [17].

Deliverable D4.3 titled “Regulation and policy analysis report" from a project SENDER (2020-2025) funded by European Commission focused with regulatory and energy policy aspects of the SENDER project, similar to STREAM [18].

The main points addressed in the Deliverable are:

- Identification of short-, medium-, and long-term EU policy goals to foster consumer engagement and demand response in EU energy markets.
- Conducting a gap analysis between the regulatory framework at the EU level (3rd Energy Package, Clean Energy for all Europeans Package) and the identified policy goals.
- Analyzing the national regulatory framework for energy at the demonstration sites to ensure legally compliant implementation of the SENDER use cases.
- Identifying potential obstacles to implementing the SENDER use cases and deriving recommendations for actions of national regulatory authorities (NRAs).

The findings highlight that the current procurement of balancing services for the transmission system is designed to allow for the participation of market participants (aggregators) engaged in demand response. Owners of flexible loads can participate in reserve markets by agreeing to participate with the TSO, provided they comply with the technical requirements of the market. Loads can be aggregated to fulfill the technical requirements when combined, even if they would not be sufficient individually. Aggregation is possible in frequency reserves (FCR-N, FCR-D, and FFR) from the balances of different balance responsible parties. Currently, there are no direct incentives for the utilization of demand response in Finnish energy regulation. However, certain requirements have been defined to increase the demand for flexible services, such as DSOs assessing the possibility of using flexibility services instead of grid reinforcements in their long-term network development. Additionally, new obligations are to be included in the amendment of the Energy Market Act, requiring DSOs to procure necessary flexibility services from competitive markets whenever they are economically efficient [19].

4.4 VARIOUS OPTIONS FOR FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS WITHIN THE CONTEXT OF THE PILOT SITES

Based on thorough research into local flexibility utilization from the demand side in Finland, the Finnish pilot partners, Optiwatti and VTT, have decided to concentrate on specific use cases. These use cases were selected for their novelty, potential significant impact on the Finnish power system, and the particular interests and suitability of Optiwatti's customer base. Optiwatti's customers are uniquely positioned as they already have access to spot price optimization services.

In this project, the scope of these existing services is expanded to include participation in two relevant ancillary services: frequency support and scheduled flexibility. Among these, only frequency support is being piloted as part of the project. This choice is driven by its regulatory feasibility and technical challenges, making it a compelling area of focus. On the other hand, scheduled flexibility simulates a local flexibility market use case, which, while intriguing, is not yet practically possible in Finland.

4.4.1 Combined SPOT price optimization and frequency regulation

This use case involves residential loads with dynamic electricity tariffs participating in the TSO's frequency reserves. It requires multi-stage optimization, starting with the creation of a baseline considering the next day's spot prices and hourly heating demand. Then, the additional flexible capacity is calculated, and bids are placed on the frequency reserve marketplace.

The key participants include grid customers (flexibility assets), the sub-aggregator (OptiWatti), a possible market aggregator, and the TSO. In the figure below, the use case is presented as a sequence diagram. In Figure 4-1, both possible aggregator roles, sub-aggregator and market aggregator, are combined under OptiWatti's responsibility.

The sequence starts with the customer communicating acceptable variations in indoor temperature to OptiWatti, which forecasts the heating demand based on weather forecasts and historical data. It creates a spot-price-optimized load curve to serve as a baseline. Additional flexible capacity is calculated and bid on Fingrid's (TSO) reserve marketplace. Accepted bids invoke frequency-following mode at the customer end, and compensation is shared between aggregators and end-users based on a pre-defined value-sharing model.

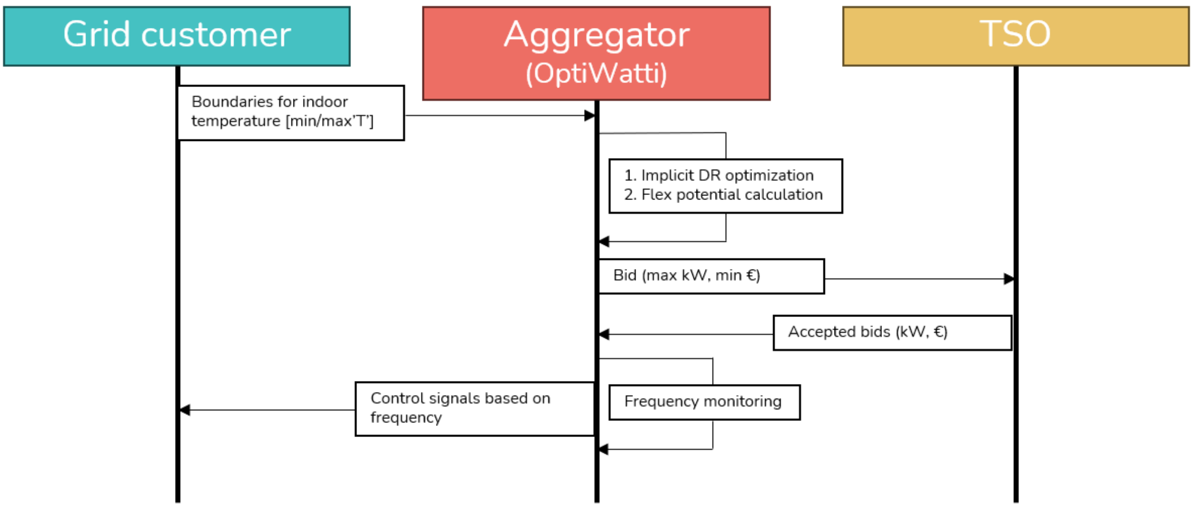

Figure 4-1: Finnish pilot - Combined SPOT price optimization and frequency regulation schema.

This use case is the primary focus of the Finnish pilot site. It will be piloted with real residential end-users across Finland.

4.4.2 Combined SPOT price optimization and scheduled flexibility

This use case involves the participation of residential loads with dynamic electricity tariffs in any explicit demand response program. It requires multi-stage optimization, starting with the creation of a baseline considering the next day's spot prices and hourly heating demand. Then, the additional flexible capacity is calculated, and bids are placed on the chosen flexibility market. In this case, it would be on a DSO's congestion management marketplace or a Balance Responsible Party's balancing service marketplace, although such markets currently do not exist in Finland.

The key participants include grid customers (flexibility assets), the sub-aggregator (OptiWatti), a possible market aggregator, and the DSO/BRP. In the figure below, the use case is presented as a sequence diagram. In Figure 4-2, both possible aggregator roles are combined under OptiWatti's responsibility.

The sequence starts with the DSO or BRP informing flexibility providers of future needs for flexibility. The customer communicates acceptable variations in indoor temperature to OptiWatti, which forecasts the heating demand based on weather forecasts and historical data. It creates a spot-price-optimized load curve to serve as a baseline. Additional flexible capacity is calculated and bid on the chosen marketplace. Accepted bids result in re-scheduling the heating load on the customer end. Compensation is shared between aggregators and end-users based on a pre-defined value-sharing model.

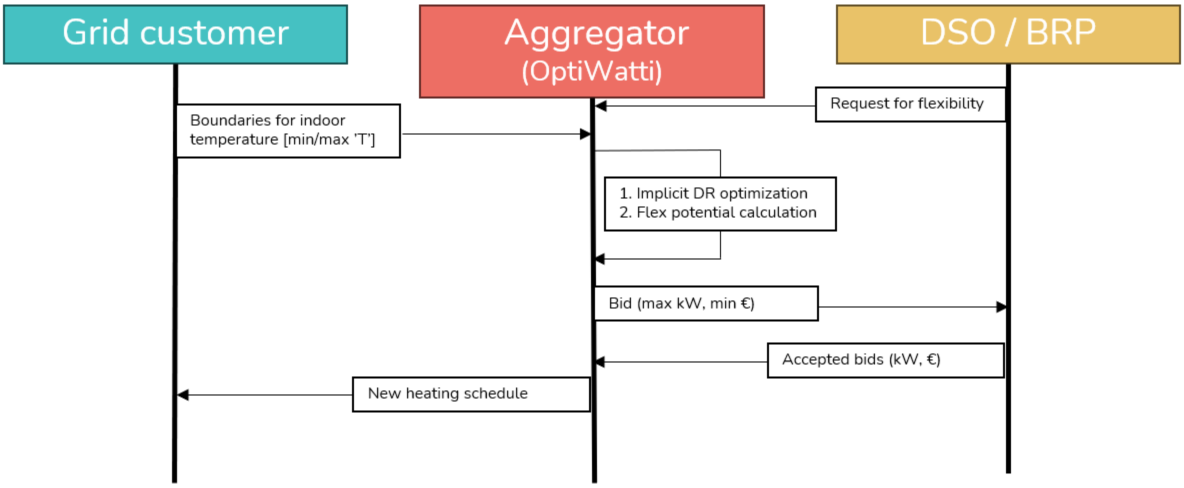

Figure 4-2: Finnish pilot - Combined SPOT price optimization and scheduled flexibility schema.

This use case will not be piloted in the Finnish pilot site as there are no such marketplaces in Finland. However, it is expected that in the following years something similar will be possible and so it is relevant to be analyzed.

4.5 VALUE STACKING OF FLEXIBILITY UTILIZATION

In this chapter, we explore different markets and the vital role of offering flexibility to many markets in maximizing value for stakeholders such as grid customers, aggregators, market operators, and system operators. Flexibility value stacking must be scalable and tailored to specific markets. At a high level, it enhances energy efficiency by optimizing grid operations and investment. On a granular level, it creates new revenue streams for customers and aggregators while improving system operator efficiency. The following sections examine flexibility applications in the Finnish STREAM pilot, with review tables assessing pros and cons qualitatively and numerically (rated 1 to 5, with 5 being the highest benefit).

4.5.1 SPOT price optimization

SPOT price optimization is possible for those grid customers who have agreed on a dynamic electricity tariff with their retailer. Currently, in Finland, the price is formed in the Nord Pool's Day Ahead (DA) marketplace for every hour, but in 2025, the price will be set in 15-min intervals. SPOT price optimization can be performed manually or automatically. However, when the dynamic price is updated four times per hour, manual optimization becomes inefficient.

Table 4-1 displays relevant stakeholders in the case of grid customer executing SPOT optimization with a service provider, or aggregator.

Table 4-1: Finnish pilot - value stacking of SPOT price optimization.

Stakeholder	Pros	Cons	Value
Grid customer	• Reducing electricity bill.	• Potential reduction in thermal comfort. • Requires automation.	4
Aggregator	• Gets a service fee for executing SPOT optimization.	• Requires semi-advanced modelling and optimization algorithms. • Must maintain thermal comfort in each room in each household.	4
BRP (retailer)	• N/A	• Experiences imbalance when customers execute spot optimization. • Challenge of forecasting the behaviour of customers in different spot price conditions.	0
DSO/TSO	• N/A	• Might create unforeseen congestion or frequency deviations during price spikes.	0

The table outlines the interplay of key stakeholders in the scenario where grid customers engage in SPOT price optimization using the services of an aggregator. The grid customer benefits significantly by reducing their electricity bill through SPOT price optimization. However, this advantage comes with a trade-off—potential discomfort from thermal adjustments and the necessity of automation to keep pace with the 15-minute price intervals. From a value perspective, the grid customer scores a 4, as the cost-saving benefit outweighs the drawbacks for those willing to adopt automated solutions.

The aggregator plays a pivotal role in enabling this optimization, receiving service fees as their main incentive. However, they face the challenge of implementing advanced modelling and optimization algorithms to deliver the service effectively. Additionally, maintaining thermal comfort across different households is a non-negotiable requirement, adding complexity to their operation. Despite these challenges, the aggregator also scores a 4, reflecting their significant role and value in the ecosystem.

The retailer, or Balance Responsible Party (BRP), experiences challenges without directly reaping benefits from SPOT optimization. The unpredictable behaviour of customers in reaction to dynamic pricing creates imbalances and complicates forecasting. This lack of advantages combined with operational difficulties gives the retailer a value score of 0.

Lastly, the Distribution System Operator (DSO) and Transmission System Operator (TSO) face similar hurdles. SPOT price optimization can lead to unexpected grid congestion and frequency deviations, particularly during price spikes. Like the BRP, they do not gain any direct benefits, resulting in a 0-value score.

4.5.2 Frequency regulation (FCR-D)

Participating in frequency regulation is not possible for residential consumers without aggregation as the minimum bid size is 0,1 MW which exceeds the levels of power used in residential sites. For some markets, such as FCR-D, the minimum bid size is even higher (1 MW). Through aggregation, however, it is possible for residential consumers to take part in the frequency markets and benefit from the additional revenue there.

Table 4-2 shows relevant stakeholders in the case of grid customers participating in frequency regulation through aggregation.

Table 4-2: Finnish pilot - value stacking of frequency regulation.

Stakeholder	Pros	Cons	Value
Grid customer	• Additional revenue opportunity.	• Potential penalties for power/energy not delivered. • Risk of decreased thermal comfort. • Risk of increased noise from activating/deactivating devices clicking.	2
Aggregator	• Gets a share of the revenue by aggregating households and bidding on the reserve market.	• Potential penalties for power/energy not delivered. • Risk of decreased customer satisfaction.	4
Market operator (TSO)	• Facilitation of regulatory compliance. • TSO benefits from additional supply capacity.	• How to prequalify and assess the performance of highly distributed DERs.	4

DSO	• N/A	• Unavailability of flexible resources to solve DSO congestions.	0

The table outlines the roles and trade-offs for stakeholders involved in residential participation in frequency regulation through aggregation. Grid customers (residential consumers) gain the potential for additional revenue by participating in frequency regulation. However, this comes with several downsides, including penalties for failing to deliver the agreed power, possible reductions in thermal comfort, and the potential annoyance of device noise during frequent activations. These cons significantly limit the grid customer's perceived value, resulting in a value score of 2, reflecting their cautious engagement in this model.

Aggregators, as intermediaries, unlock value by bundling residential resources to meet the minimum bid size of 100 kW and participating in reserve markets. They receive a share of the revenue, which makes their role profitable. However, aggregators face risks of penalties for undelivered service and the possibility of reduced customer satisfaction due to operational disruptions. Despite these challenges, the centrality of their role grants aggregators a value score of 4.

The market operator (TSO) benefits from increased supply capacity and improved regulatory compliance as aggregators enable residential participation in frequency regulation. However, managing and prequalifying distributed energy resources presents a significant challenge, requiring advanced methods to assess performance at such a granular level. Despite these operational hurdles, the TSO's role in ensuring market efficiency earns them a value score of 4.

DSOs, on the other hand, see limited benefits from this arrangement. Flexible resources prioritized for frequency regulation may be unavailable for resolving local grid congestions, leaving DSOs unable to leverage these assets for their own operational needs. With no direct gains and notable limitations, DSOs receive a value score of 0 in this framework.

4.5.3 Combined SPOT price optimization and frequency regulation

Combining the two previous use cases, SPOT price optimization and participation in frequency regulation creates more value for the flexibility providers (both asset owner and aggregator). However, also the complexity of the solution increases, posing challenges for the successful delivery of both services.

Table 4-3 shows relevant stakeholders in the case of an aggregator providing SPOT price optimization services for the grid customer and acting as an intermediary between the grid customer and the frequency regulation marketplace.

Table 4-3: Finnish pilot - value stacking of combined SPOT price optimization and frequency regulation.

Stakeholder	Pros	Cons	Value
Grid customer	• Reducing electricity bill. • Additional revenue opportunity.	• Potential reduction in thermal comfort. • Requires automation. • Potential penalties for power/energy not delivered. • Risk of increased noise from	5

		activating/deactivating devices clicking.	
Aggregator	• Gets a service fee for executing SPOT optimization. • Revenue from frequency reserve marketplace. • Opportunities for different configuration possibilities.	• Requires highly advanced modelling and optimization algorithms. • Must maintain thermal comfort in each room in each household. • Risk of decreased customer satisfaction.	5
BRP (retailer)	• N/A	• Experiences imbalance when customers execute spot optimization. • Challenge of forecasting the behaviour of customers in different spot price conditions.	0
DSO/TSO	• Facilitation of regulatory compliance. (TSO) • TSO benefits from additional supply capacity.	• Unavailability of flexible resources to solve DSO congestions. • Might create unforeseen congestions or frequency deviations during price spikes. • How to prequalify and assess the performance of highly distributed DERs.	3

The table outlines the pros and cons involved when combining SPOT price optimization with frequency regulation, showcasing the interplay of stakeholders in this complex ecosystem. Grid customers gain significant value from participating in this combination of two use cases. They benefit from reduced electricity bills through SPOT price optimization and generate additional revenue from frequency regulation markets. However, these advantages come at a cost: customers face potential reductions in thermal comfort, the need for automation, penalties for undelivered power, and the potential annoyance of relay-clicking noise during frequent activations. Despite these drawbacks, the combined financial incentives provide substantial value, reflected in a value score of 5.

Aggregator benefits from this dual case through service fees for SPOT optimization and revenue from frequency reserve markets. Additionally, the versatility of managing different configurations opens opportunities for innovation. However, this dual service demands highly advanced modelling and optimization algorithms. Aggregators also bear the burden of maintaining thermal comfort across households while managing the risk of reduced customer satisfaction. Balancing these challenges, aggregators achieve a value score of 5, indicating their central role in enabling the system.

Retailers (BRPs) face difficulties in this setup, as SPOT price optimization by customers creates imbalances and complicates forecasting. With no direct benefits, BRPs receive a value score of 0, highlighting their lack of an active role in the depicted flexibility scheme.

DSOs/TSO experience mixed impacts. The TSO benefits from increased supply capacity and enhanced regulatory compliance due to improved resource utilization. However, the unavailability of flexible resources for local DSO needs and the risk of grid congestion during price spikes pose challenges. Furthermore, assessing and prequalifying highly distributed DERs remains a technical hurdle. With a balance of pros and cons, DSOs/TSO earn a value score of 3, reflecting their significant but complex involvement in this combined use case.

4.6 GAPS, CHALLENGES AND RECOMMENDATIONS FOR FUTURE LEGISLATION DEVELOPMENT

Demand-side assets offer significant potential for providing flexibility in the electricity market, but their deployment faces several hurdles. DSOs encounter notable challenges when considering demand-side flexibility as an alternative to traditional network investments. A key issue is the uncertainty surrounding the availability of flexible resources when needed, which undermines the reliability of these assets for congestion management and grid stability.

Additionally, the lack of established markets for flexibility services makes it difficult for DSOs to predict the costs involved. With limited historical data and no standardized pricing mechanisms, forecasting expenses remains a complex task. As a result, DSOs may be reluctant to adopt demand-side flexibility solutions due to these uncertainties in resource availability and cost estimation. Lowering the minimum acceptable bid sizes for trading on flexibility markets could help reduce entry barriers and encourage broader participation.

Advanced automation has the potential to increase the use of demand-side flexibility significantly by improving the easiness of use for the consumer. However, highly optimized automation systems bring new challenges, particularly regarding consumer privacy. These systems often rely on detailed information about consumer behavior patterns and household occupancy to function effectively. Collecting and analyzing such sensitive data raises privacy and security concerns. Protecting consumer data and ensuring its responsible use are essential to maintaining trust and safeguarding individual privacy rights.

In the report, Demand side flexibility in the Nordic electricity market [20], Finnish DSOs were interviewed on their views concerning the utilization of flexibility. Finnish DSOs believed that flexibility utilization would be most beneficial in the long-term perspective, with flexibility offering the possibility of avoiding or postponing necessary grid investments. However, the Finnish DSOs had concerns due to their lack of experience with flexibility utilization raising concerns on how demand-side flexibility should be accounted for when planning the future capacity requirements. This lack of experience also contributes to concerns about the reliability of demand-side flexibility and if it would always be available when it is needed. Another factor that makes Finnish DSOs hesitant to rely on flexibility is that over-dimensioning network components is cheap. The investment decision to install extra capacity is a marginal cost in network investments, so DSOs are hesitant to forgo this practice and rely on flexibility.

DSOs were interviewed on their views regarding potential barriers to demand-side flexibility utilization in the following categories: technology, regulation, end user behavior, and the market. The DSOs believed that there is adequate technology for demand-side flexibility implementation, but robustness and experience with these technologies is lacking. Regarding regulation, the DSOs believed that tariffs that are energy focused and income regulation that is focused on Capital Expenditure (CAPEX) is a barrier to the implementation of demand-side response. End user behavior is a big challenge that DSOs believe they face with most end users being uninterested or unaware of the concept of demand-side flexibility, and currently there are weak economic incentives for demand-side flexibility. A potential belief was that the automation of demand-side response could be a potential solution to this problem rather than relying on end users reacting to price signals. Currently, DSOs do not see much need for a flexibility market as there are no real capacity restraints due to the grid being well dimensioned. However, there is a belief that the need for flexibility and a flexibility market will increase in the future.

The Finnish Ministry of Economic Affairs and Employment created the Smart Grids Working Group in 2016 to develop a shared vision of the future electricity system [21]. This vision that the working group developed emphasized the importance of having customers participating in demand-side flexibility either by themselves or with the help of a market actor. The working group recognized the importance of aggregators in the future electric system and believe aggregators should be able to operate in all marketplaces, and that aggregators should bear the responsibility of the imbalances they cause according to balancing rules.

The working group believes that the incentive for demand-side flexibility must come from the market, and the group does not support measures that reduce customers' interest in the marketplace such as the introduction of a proportional electricity tax. Additionally, they believe that regulation should encourage flexibility as an alternative to investments in the grid when it benefits both customers and society. To further progress demand-side flexibility, the working group recommends that distribution network companies should develop a platform with a standardized interface that provides demand side management services that are beneficial to customers.

Aligning Finland's demand response regulations with broader European Union energy policies facilitates cross-border energy trade and integration into the larger European energy market.

To enhance local flexibility utilization and demand side management regulation in Finland, it is essential to address several key areas. Firstly, clarifying the roles and responsibilities of all stakeholders involved in demand response initiatives is crucial. This clarity helps prevent conflicts of interest and ensures an equitable distribution of costs and benefits. Establishing a regulatory sandbox can further promote innovation by allowing companies to test new demand response solutions in a controlled environment, thereby accelerating the adoption of emerging technologies.

Active consumer engagement is another vital component. Involving consumers in the design and implementation of demand response programs ensures these initiatives are user-friendly and meet consumer needs, leading to higher participation rates. Additionally, implementing measures to guarantee equitable access for all consumer groups, including low-income households, prevents disparities and promotes widespread adoption of demand response programs.

5 PILOT SITE OVERVIEW IN ITALY

5.1 REGULATORY POINT OF VIEW

Italy has been working actively to enhance the flexibility of its energy market, aligning with the European Union's broader objectives for a sustainable, low-carbon economy. The Italian regulatory framework emphasizes integrating renewable energy, promoting energy efficiency, and modernizing its electricity grid. The Italian energy regulator, ARERA ("Autorità di Regolazione per Energia Reti e Ambiente"), supports market reforms that allow for more active participation from various resources, including small-scale renewables, storage systems, and demand response aggregators. ARERA, the Italian Regulatory Authority for Energy, Networks, and Environment, plays a fundamental role in promoting a more flexible and sustainable energy market oriented toward integrating renewable energy sources. The authority supports the active participation of a wide range of actors, including small renewable energy producers, storage systems like batteries, and demand response aggregators, which combine the demand of various consumers to participate in the energy market.

ARERA's regulations facilitate the integration of decentralized renewable sources and encourage the adoption of storage systems, which help balance supply and demand, stabilizing the grid despite the variability of renewables. Through incentives and market reforms, battery owners and small producers can earn revenue by offering balancing services, such as frequency regulation and load shifting during peak times. Additionally, ARERA has introduced reforms in balancing and ancillary service markets, enabling the participation of small-scale resources, such as individual storage units and small renewable installations. At the same time, ARERA supports the digitalization of the grid, promoting technologies like smart meters and real-time resource management to ensure a more dynamic and adaptable network. This digitalization process, combined with reforms to allow the participation of aggregators and small producers, helps Italy build a decentralized and flexible energy system capable of responding swiftly to demand fluctuations and efficiently integrating renewable sources. Finally, ARERA implements measures to ensure transparency and consumer protection, safeguarding data privacy, guaranteeing fair prices, and making the market accessible to all. This set of interventions is essential to supporting Italy's transition to a low-carbon, resilient, and sustainable energy system.

Italy's energy market has been evolving towards greater flexibility, specifically through demand response mechanisms and balancing markets. A capacity market in 2019 to ensure reliability has been introduced while integrating renewable energy. This market rewards power plants for providing backup capacity during peak times, which helps stabilize supply and demand fluctuations due to renewable intermittency. Capacity auctions ensure that the grid has enough flexible capacity, with incentives for resources that can quickly ramp up or down based on grid needs. Italy's framework supports aggregators—companies that bundle the energy demand or generation of various small-scale participants (like homes or businesses) to participate in energy and balancing markets. This allows Italy to better manage demand response, encouraging users to reduce or shift their energy use during peak periods.

Italy supports the integration of Distributed Energy Resources (DER) such as solar panels, batteries, and electric vehicles, enabling their participation in energy markets and ancillary services to increase grid flexibility and reduce dependence on traditional plants. Smart grid technologies and digital metering systems facilitate real-time management of DER. Additionally, the country collaborates with the EU on initiatives such as Horizon Europe and the "Clean Energy for All Europeans" package, which promote innovations in flexibility and cross-border energy trading.

The Italian regulatory framework aligns with European directives, such as the Electricity Directive (EU) 2019/944, which encourages energy communities and local flexibility markets. Italy also provides incentives for renewable energy production and storage systems to support the variability of sources like solar and wind, with subsidies and tax benefits available to households and businesses investing in these technologies [22].

Finally, Italy's National Integrated Energy and Climate Plan (PNIEC) outlines the strategy for decarbonization by 2050, aiming for a high share of renewables and a flexible grid capable of managing this transition, in line with objectives for energy security, cost reduction, and emission minimization [22].

5.2 TSO, MO, DSO POINT OF VIEW

The TSO in Italy, represented by Terna, plays a pivotal role in managing the high-voltage electricity transmission network to ensure stability and security across the national grid. Terna is responsible for transporting electricity over long distances, dynamically balancing supply and demand to meet regional and national needs. The increasing penetration of renewable energy sources like solar and wind has introduced variability and unpredictability, requiring advanced solutions. To address these challenges, Terna employs smart grids, which enable real-time monitoring and control of grid operations, and energy storage systems, such as batteries and pumped hydro storage, which store excess energy during periods of high renewable generation and release it when demand exceeds supply.

Flexibility markets are another critical component managed by Terna. These markets facilitate the efficient use of storage systems, distributed energy resources (DERs), and demand response mechanisms to stabilize the grid and mitigate congestion. By promoting cross-border energy trading through international connections, Terna ensures energy availability even during surpluses or shortages in neighboring countries, enhancing overall energy security. Furthermore, Terna collaborates closely with ARERA, to implement grid management policies, optimize tariffs, and develop long-term infrastructure plans to support the transition to a low-carbon energy system.

The DSO in Italy, represented by entities such as ASM Terni S.p.A., operates at the local level, managing low- and medium-voltage networks to distribute electricity to end consumers, including households, businesses, and industrial facilities. ASM Terni focuses on maintaining and upgrading the distribution grid, ensuring its resilience and reliability. This includes handling connection requests for new renewable energy installations, such as solar panels and small wind farms, while ensuring compliance with regulatory standards.

To support the integration of distributed energy resources, ASM Terni adopts advanced grid technologies. Smart grids enable two-way communication between energy producers and consumers, allowing real-time adjustments to energy flow and more efficient fault detection and recovery. The DSO also prioritizes minimizing technical losses in the network by optimizing grid design and introducing energy-efficient solutions. Moreover, ASM Terni actively promotes demand-side management by encouraging consumers to adopt energy-saving technologies and practices, contributing to overall system efficiency.

Both Terna and ASM Terni play complementary roles in transforming Italy's energy landscape. While Terna ensures national grid stability and oversees the integration of large-scale renewable energy projects, ASM Terni focuses on local grid optimization, integrating distributed resources, and improving service quality. Together, they enable a reliable, efficient, and sustainable energy system, addressing the challenges of decarbonization and the growing demand for renewable energy.

5.3 STATUS OF DEVELOPMENT/CURRENT STATE OF FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS

A literature review was conducted to explore innovative approaches to energy flexibility management within local energy communities and water distribution systems. The first paper [23], titled "Flexibility Provisions through Local Energy Communities: A Review," examined the role that Local Energy Communities (LECs) played in supporting a sustainable energy transition and highlighted the challenges of integrating these communities into existing energy markets. It emphasized the need for

Local Flexibility Markets (LFMs) and discussed the collaboration between DSOs and aggregators in optimizing the flexibility resources provided by LECs.

The second one [24], titled "Optimal Coordination of Water Distribution Energy Flexibility with Power Systems Operation" focused on enhancing the energy flexibility of Water Distribution Systems (WDSs) in day-ahead power system operations. Through an optimization model, it demonstrated how water system operators could reduce energy costs and contribute to power system stability by adapting their demand in response to forecasted energy prices and water demand.

This literature review provided an overview of the proposed technical solutions and operational models, identified benefits and challenges, and underscored the need for further research and pilot projects to fully realize the potential of energy flexibility in both sectors.

The paper [23], "Flexibility Provisions through Local Energy Communities: A Review" examined the critical role that energy communities had played in promoting a sustainable energy transition and enhancing consumer empowerment. LECs had the potential to provide much-needed flexibility services to power grids, thereby supporting grid stability by adjusting their energy demand or supply based on system requirements. However, integrating these communities into existing energy markets had posed significant challenges due to existing market structures, tariffs, and regulatory barriers.

The review highlighted the importance of well-designed social and technical solutions that enabled LECs to offer flexibility. This included the establishment of LFMs with suitable pricing mechanisms that allowed LECs to interact with DSOs and aggregators. DSOs played a pivotal role in coordinating the local grid, while aggregators facilitated the management of flexible resources by predicting and dispatching energy adjustments based on demand response mechanisms. The study discussed both implicit and explicit demand response approaches, emphasizing how aggregators worked with Balancing Responsible Parties (BRPs) to manage flexibility effectively.

Identified barriers included limitations in peer-to-peer energy trading and strict regulatory requirements that often hindered the participation of LECs in energy markets. Overcoming these barriers, the authors argued, required a collaborative approach involving all stakeholders, from energy regulators to technology providers.

The paper concluded with recommendations for creating fairer market rules and strengthening ICT infrastructure to support LFMs. Additionally, it highlighted the need for further research and pilot projects—such as those conducted at Aalborg University's Department of Energy—to develop practical solutions for integrating LECs. This exploration, the authors noted, was essential for fully realizing the potential of LECs in achieving energy flexibility and advancing the broader goals of the energy transition.

Another paper [24] presented a model aimed at optimizing the energy flexibility of water distribution systems (WDSs) within day-ahead power system operations. In this framework, Water Distribution System Operator (WDSO) were envisioned as proactive, energy-conscious managers responsible for reducing the operational costs of local water distribution systems. By forecasting the next day's water demand and electricity prices, the model allowed WDSOs to offer flexible energy capacity to power system operators while maintaining adherence to hydraulic constraints.

The study also introduced a network-constrained unit commitment model, designed to enhance the integration and optimization of WDS energy flexibility. This model effectively minimized energy expenses for WDS operators, thereby supporting the stability of the overall power system. Moreover, the integration of WDS energy flexibility contributed to reducing peak electricity demand and smoothing load profiles, benefiting both the water system operators and the broader power grid.

The findings indicated that the proposed optimization model was highly effective in lowering energy costs and reducing peak demand. However, to meet the specific goals of a pilot site focused on scheduling water pumping based on peak demand and local renewable energy availability, further adjustments were necessary. In particular, addressing uncertainties related to wholesale energy prices, water demand forecasts, and renewable energy production forecasts would be critical for tailoring the model to the unique operational needs of the pilot site.

5.4 VARIOUS OPTIONS FOR FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS WITHIN THE CONTEXT OF THE PILOT SITES

The literature review provided a detailed description of the flexibility activation process (summarized above), covering both energy communities and integrated water-energy systems. Flexibility in energy systems involves coordinated responses to grid demands. The DSO requests flexibility, managed by an Energy Community Manager (ECM) or a WDSO, depending on the context. In energy communities, the ECM activates flexible assets like batteries and demand-side management to stabilize the grid. In integrated water-energy systems, the WDSO optimizes pump operations through load shifting, demand response, and energy storage. These strategies enhance efficiency, reduce costs, and support grid stability, demonstrating innovative approaches to flexibility in evolving energy markets.

5.4.1 Flexibility activation to the DSO's flexibility request

It has been depicted that the DSO requests flexibility to manage grid demands, coordinated by an ECM, Figure 5-1. The manager assesses and activates available flexible assets owned by end users within the community, ensuring that the grid's needs are met efficiently and promptly. The process begins with the DSO, responsible for maintaining grid stability, requesting flexibility to balance supply and demand. This request arises when there are grid imbalances, such as during high demand or low generation from renewable sources. Flexibility refers to the ability to adjust energy consumption or production in real-time to stabilize the grid.

The ECM coordinates the response to this request by assessing the available flexible assets within the community. These assets can include battery storage systems, electric vehicles, demand-side management systems, and decentralized renewable generation like solar panels. The ECM evaluates the capacity and readiness of these assets, determining how quickly they can be activated and how much flexibility they can provide to the grid.

Once the available assets are assessed, the ECM activates the necessary resources. This may involve reducing electricity consumption, increasing local generation, or dispatching stored energy to meet the grid’s needs. The goal is to ensure that the grid's demand is met efficiently and promptly. The ECM ensures the optimal activation of these assets, balancing the timing and amount of flexibility provided while minimizing costs and maintaining grid stability. The resources must be deployed quickly to respond to any unforeseen grid issues, ensuring that the grid remains stable during periods of high strain.

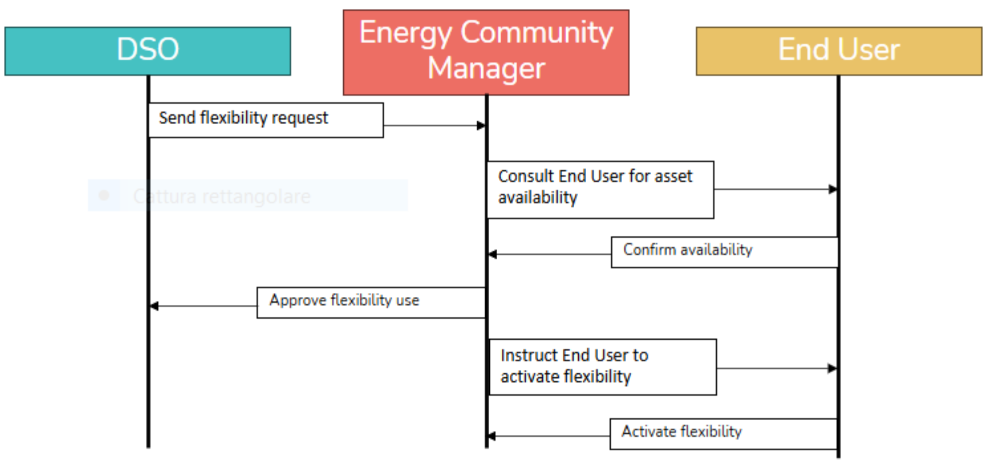

Figure 5-1: Italian pilot – Flexibility activation to the DSO’s flexibility request.

5.4.2 Water energy nexus

In pilot sites integrating water distribution networks with local energy markets, flexibility utilization focuses on optimizing water pump operations to align with grid demands, enhancing efficiency, stability, and cost-effectiveness. Load shifting is a common approach, where pump schedules are adjusted to operate during off-peak periods with lower electricity demand or surplus renewable energy, reducing grid strain and operational costs. Demand response enables pumps to modulate energy consumption based on grid signals or dynamic pricing, either by responding directly to DSO requests or adapting to high electricity costs. Another method involves energy storage integration, where water reservoirs or batteries store energy during low-demand periods, allowing pump operations to decouple from real-time grid conditions and providing stored energy for use during peak periods.

Water pumps can also participate in ancillary services, dynamically adjusting their power consumption to support grid needs such as frequency regulation or reserve capacity, while ensuring water supply requirements are met. Renewable energy integration is another key strategy, where pump operations are synchronized with local renewable generation, such as solar or wind, maximizing the use of clean energy and reducing grid dependency. Pumps can also be aggregated with other distributed energy resources into virtual power plants, enabling them to act as a single, coordinated entity in local energy markets and offering opportunities to participate in a range of grid services. In microgrid or islanded scenarios, pump operations are aligned with local renewable generation and storage to balance energy needs and improve resilience.

These strategies rely on advanced analytics, real-time IoT-enabled data collection, and robust communication systems for effective coordination. Successful implementation requires regulatory compliance, financial incentives, and strong collaboration between DSOs, water operators, and market participants. By adopting these approaches, pilot sites demonstrate innovative ways to enhance sustainability, optimize operations, and support the transition to a more flexible and resilient energy system.

As depicted in Figure 5-2, the DSO sends flexibility requirements to the WDSO in the form of operational schedules for the operation of water pumps based on advanced analytics. These schedules are then implemented to adjust pump operations, ensuring optimal energy use and maintaining system stability while meeting both water and electrical demands.

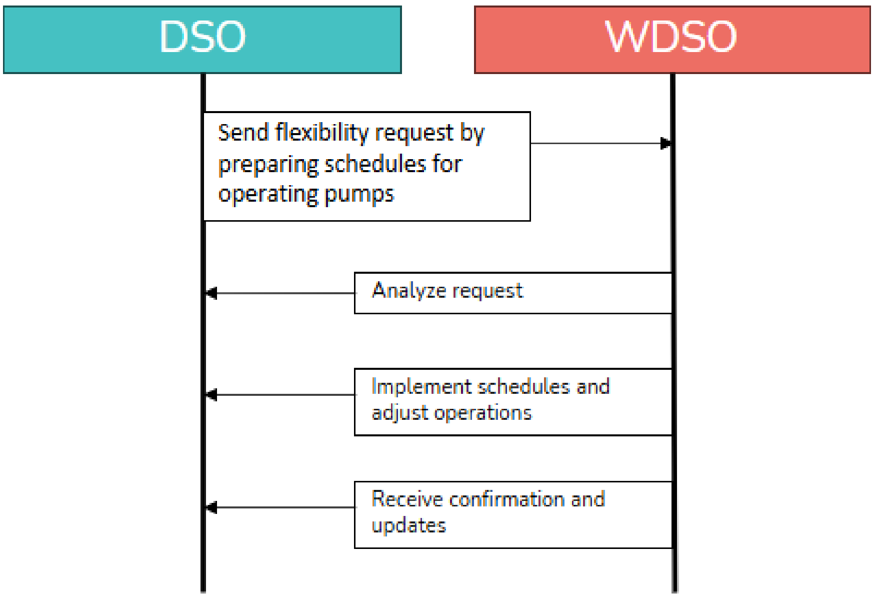

Figure 5-2: Italian pilot – Water energy nexus.

5.5 VALUE STACKING OF FLEXIBILITY UTILIZATION

The following sections outline the flexibility value stacking for specific applications of flexibility within the Italian pilot in the project. For each proposed application, a review table summarizing the pros and cons (or challenges) has been prepared, using values from 1 to 5.

5.5.1 Flexibility activation to the DSO's flexibility request

Table 5-1 depicts, with the maximum value, that participating in flexibility activation helps grid customers save on energy bills, improve reliability with backup systems, reduce their carbon footprint, and gain better control over energy use. It also highlights opportunities to earn revenue, support local grid stability, and ensure readiness for future energy regulations and technologies. The cons of participating in flexibility programs include high upfront costs for equipment and integration, potential operational disruptions, complex requirements, unpredictable financial benefits, and reliance on volatile market conditions. Other risks involve penalties for non-compliance, data security concerns, and potential negative impacts on comfort or convenience.

Depending on the point of view of the aggregator, these benefits make flexibility programs an attractive option for aggregators, offering financial, operational, and environmental value while empowering the community to play an active role in energy management. However, the relevant challenges illustrate that while flexibility programs offer opportunities, they also involve significant risks and complexities that aggregators must carefully manage to succeed.

The relevant advantages regarding the market operator are the improvement of the balance between supply and demand and support for renewable energy integration. Instead, the coordination of various resources and participants is a downside.

For DSOs, flexibility activation offers significant advantages, including improved grid stability, better management of peak demand, enhanced integration of renewable energy, cost efficiency, and alignment with regulatory requirements. However, it also presents challenges such as the need for substantial upfront investments in infrastructure, the complexity of coordinating flexibility across diverse participants, dependence on customer engagement, and potential cybersecurity risks.

Table 5-1: Italian pilot – Flexibility activation to the DSO's flexibility request.

Stakeholder	Pros	Cons	Value
Grid customer	• Additional cost savings on energy bills. • Contribute to the stability and reliability of the local grid. • More control over their energy consumption. • Potential for revenue generation. • Future energy innovations.	• Adjustments and operational interruptions. • Unforeseen circumstances or operational constraints. • Initial costs and investments. • Privacy and data security concerns. • Potential negative impact on comfort or convenience.	5

Aggregator	• Maximize the economic return on resources. • Gains greater control over the energy supply. • Greater control and influence over energy management. • Foster a sense of participation in sustainability initiatives.	• Aggregator is considered as energy community manager. • Compliance with energy regulations.	3
Market operator	• N/A	• N/A	N/A
DSO	• Maintain grid stability by balancing supply and demand.	• Regulatory for support or incentivize flexibility activations. • Barrier to adoption.	4

5.5.2 Water energy nexus

Table 5-2 depicts a summary of stakeholders in the water-energy nexus, outlining their advantages, challenges, and value assessments. Grid customers benefit from lower energy costs during off-peak times and a stable grid but face reduced control over demand response and pricing variability, with a value of 4. Aggregators gain increased flexibility opportunities and foster participation in sustainability initiatives but encounter added complexity in scheduling, with a value of 2. No information is provided for the market operator. The DSO experiences optimized energy use, enhanced grid stability, improved demand forecasting, and more dynamic response to grid conditions but must address increased coordination complexity and potential conflicts with other grid demands, with a value of 4.

Table 5-2: Italian pilot – Water energy nexus.

Stakeholder	Pros	Cons	Value
Grid customer	• Lower energy costs during off-peak times. • Stable grid.	• Reduced control over demand response. • Pricing variability.	4

Aggregator	• Increased flexibility opportunities. • Foster a sense of participation in sustainability initiatives.	• Additional Complexity in Scheduling.	2
Market operator	• N/A	• N/A	N/A
DSO	• Optimized energy use. • Enhanced Grid Stability. • Better demand forecasting. • Create a more dynamic response to grid conditions.	• Increased complexity in coordination. • Potential conflicts with other grid demands.	4

5.6 GAPS CHALLENGES AND RECOMMENDATIONS FOR FUTURE LEGISLATION DEVELOPMENT

As DSOs, market operators, and aggregators work together, flexibility markets face gaps and challenges that need addressing in future legislation. Key issues include the lack of a unified regulatory framework, unclear valuation and compensation for DERs, and inadequate consumer protection and data privacy. Coordination among stakeholders is often disrupted by conflicting priorities, while technological infrastructure and cybersecurity risks present additional hurdles. Low participation, particularly from small players, limits market liquidity, and financial unpredictability complicates market operations.

Future legislation should establish a standardized framework ensuring transparency and fair access, protect data privacy, and incentivize technological innovation. Simplifying administrative processes, improving coordination, and supporting small players will boost participation and efficiency. Revenue stability mechanisms and educational campaigns can further encourage engagement, while aligning with decarbonization goals promotes sustainability. Regular updates will keep the framework adaptive to evolving market needs.

In the context of water, the legislation should establish clear frameworks for cross-sector cooperation, promote flexible market participation, incentivize technological innovation, and provide financial support for necessary investments. This will help optimize both energy and water systems for a sustainable, efficient future. In particular to address gaps and challenges in coordinating renewable energy use between DSOs and WDNOs, future legislation should focus on several key areas. First, standardized communication protocols are needed to ensure smooth data exchange between operators. Legislation should promote flexible load participation in energy markets by creating mechanisms that reward water systems for adjusting energy use during renewable surpluses. There's also a gap in data collection on water system energy consumption, which should be addressed by encouraging the integration of detailed data across sectors.

Legislation should also foster better integration of energy and water policies, creating frameworks that promote cross-sector cooperation. Technological integration remains a challenge, so legislation should support research and development in smart grid and water technologies and encourage pilot projects. Financial support, including incentives for infrastructure investments, is crucial to reduce the cost burden on operators.

Another challenge is coordinating stakeholders with different priorities. Clear legal frameworks and conflict-resolution mechanisms should be introduced to streamline this coordination. Additionally, regulations should offer a gradual transition to new technologies, mitigating regulatory uncertainty. Lastly, to balance renewable integration with grid stability, legislation should support energy storage solutions.

6 PILOT SITE OVERVIEW IN SPAIN

6.1 REGULATORY POINT OF VIEW

The National Integrated Energy and Climate Plan (PNIEC) is the strategic orientation roadmap in Spain that integrates energy and climate policy with a time horizon of 2030, in accordance with national and European regulations, sending the necessary signals to provide certainty and drive the actors, providing flexibility and manageability to the energy transition and the decarbonisation of the economy [22].

This plan reinforces the country's energy self-sufficiency, promotes energy efficiency, and adopts social and territorial measures to ensure a just transition. It foresees an important advance in storage technologies and promotes self-consumption. In addition, it promotes the electrification of the economy and the use of renewable hydrogen and biogas.

Sustainable mobility is a key focus, along with the energy rehabilitation of efficiency, the process of improving the energy performance. Strategic autonomy in the industrial value chain is prioritized and measures to decarbonize industry are expanded.

In 2023, the PNIEC has been updated to reflect a renewed and more ambitious commitment to the transition to a greener economy. Aligned with the EU's new "Target 55" package and in response to the challenge of climate change, the revised PNIEC sets more robust targets, such as a 32% reduction in emissions by 2030 and an increase in the use of renewables to 48% of final energy consumption.

The PNIEC originally intended renewable electricity generation in 2030 to be 74% of the total, but in this update, it aims for 81% of the total, consistent with a trajectory towards a 100% renewable electricity sector by 2050.

Parque de generación del Escenario PNIEC 2023-2030. Potencia bruta (MW)				
Años	2019	2020	2025	2030
Eólica	25.583	26.754	36.149	62.054
Solar fotovoltaica	8.306	11.004	46.501	76.277
Solar termoeléctrica	2.300	2.300	2.304	4.804
Hidráulica	14.006	14.011	14.261	14.511
Biogás	203	210	240	440
Otras renovables	0	0	25	80
Biomasa	413	609	1009	1409
Carbón	10.159	10.159	0**	0
Ciclo combinado	26.612	26.612	26.612	26.612
Cogeneración	5.446	5.276	4.068	3.784
Fuel y Fuel/Gas (Territorios No Peninsulares)	3.660	3.660	2.847	1.830
Residuos y otros	600	609	470	342
Nuclear	7.399	7.399	7.399	3.181
Almacenamiento*	6.413	6.413	9.289	18.913
Total	111.100	115.015	151.173	214.236

Figure 6-1: Spanish pilot - PNIEC projections of renewable electricity generation in 2030

*Including solar thermal storage reaches 22.5 GW

Emission reductions are expected to increase from 23% to 32% with respect to 1990. In addition, the use of renewable energies is expected to increase from 42% to 48% of final energy consumption. Foreign energy dependence is drastically reduced, with a projected increase of 50% in primary energy from local sources. In the electricity sector, renewable energies are expected to account for 81% of generation in 2030, with an emphasis on self-consumption, which will reach 19 GW. Energy storage capacity is projected to increase to 22 GW in order to integrate this number of renewables into the electricity system.

MITECO's Sandbox

Sandboxes of the Ministry for the Ecological Transition and the Demographic Challenge (MITECO) are controlled testing environments that allow companies and financial institutions to experiment with technological innovations and new business models in the energy sector under the supervision of regulators, without the risks associated with a full market implementation. These environments provide a secure space where new solutions can be tested.

Implemented by Royal Decree 568/2022, of July 11, establishing the general framework of the regulatory testbed for the promotion of research and innovation in the electricity sector, the sandbox will seek to cope with the speed of technological changes affecting the sector and will contribute to designing a regulatory framework capable of better adapting to new needs. These projects may be developed in areas such as smart grids, demand aggregation, the provision of flexibility services and energy storage, are often complex and unprecedented, so it can be particularly challenging to identify their specific characteristics and needs [25].

The aim of the test bed is that the regulation does not represent a barrier to innovation in the energy transition, adapting it to the new flexibility needs of the electricity sector. In May 2023, Order TED/567/2023 was approved, calling for access to this regulatory test bed. In addition, through the Call for New Business Models for the Energy Transition of the Institute for Energy Diversification and Saving (IDAE), projects participating in the sandbox may receive public support [26].

6.2 TSO, MO, DSO POINT OF VIEW

In Spain, the roles of Distribution System Operators (DSOs), Transmission System Operator (TSO) and market operator (MO) are separated.

OMIE is the Iberian Peninsula's Nominated Energy Market Operator, responsible for operating the day-ahead and intraday power markets. OMIE, along with all of the NEMOs (Nominated Electricity Market Operators) chosen in each member state, is actively involved in integrating wholesale electricity markets throughout the EU. It manages several energy-related product auctions and is responsible for settling the schedules derived from the clearing processes. Additionally, OMIE exchanges real-time information on all programs with the TSO.

In Spain, Distribution System Operators (DSOs) are tasked with ensuring the efficient transmission of electricity from generation points to final consumers. DSOs manage the medium and low voltage grids that deliver electricity to end-users and ensure the quality of supply.

There are a total of 333 DSOs in Spain, all of which must be Spanish or EU trading companies with a permanent establishment in Spain. Also, they are responsible for building, maintaining and operating the distribution resources and managing the grids they operate.

This activity is regulated in articles 38 to 42 of Law 24/2013 on the Electricity Sector, in Royal Decree 1048/2013, and in articles 36 to 42 of Royal Decree 1955/2000.

In Spain, the electricity transmission system operator (TSO) is REE which is responsible for operating and managing the national electricity system, ensuring the balance between electricity generation and consumption in real time by overseeing the high voltage transmission grid.

The views of the Spanish TSO, MO and DSO in regard to flexibility are presented in a continuing manner:

OMIE as the market operator, through the PNIEC 2021-2030 and through the regulatory testbeds (Sandbox) seeks to help offer flexibility solutions to manage the distribution grid and resolve congestions through local electricity markets. These markets can optimize the operation of the electricity system as a whole, facilitate the integration of distributed energy resources and comply with the internal electricity market directive, which in Article 32 promotes the definition of flexibility services as a complementary alternative to the current management of the distribution grid based on grid reinforcements. For its implementation, it is necessary to increase the visibility that distribution grid operators have on the energy resources connected in their area of influence, as well as to improve the visibility for the holders of these resources and investors on the status of congestions, both punctual and persistent, at the distribution grid level. In this sense, both the energy communities and the figure of the independent aggregator will be relevant, which will allow the entry of consumers who would otherwise not participate in the markets individually.

The planning of the transmission grid by REE for the period 2025-2030, aims to advance in the ecological transition of Spain to strengthen existing infrastructure and promote new facilities, ensuring electricity supply and prioritizing environmental protection and economic efficiency. This plan is defined in Order TED/1375/2023 [26], which initiates the procedure to develop proposals with a 2030 horizon. This plan seeks to meet the energy and climate commitments of the PNIEC 2021-2030, maximize the use of renewable energies, improve efficiency, reduce losses and eliminate technical restrictions. It also promotes energy storage, industrial decarbonization and territorial cohesion, while respecting environmental constraints.

The DSOs through **Circular 1/2024** must ensure efficient and transparent non-discriminatory access and connection of electricity networks and establish the methodology and conditions for access and connection to the electricity transmission and distribution networks. Distributors must perform several key roles:

1. Processing of Applications: Manage and evaluate requests for access and connection, ensuring that the necessary technical and economic criteria are met.
2. Publication of Information: Maintain accessible and updated information on available capacities on their websites, promoting transparency.
3. Promote Efficiency: Promote efficiency in the access and connection process, simplifying and standardizing the required information.
4. Capacity Assessment: Conduct specific studies to determine the firm and flexible access capacity of demand facilities.
5. Project Development: Develop budgets and technical conditions for grid connection, including coordination of infrastructure projects.
6. Information Management: Use web-based platforms to manage and track permit files, facilitating communication and dispute resolution.
7. Network Optimization: Work on maximizing the use of existing networks, minimizing environmental impacts and facilitating the rational development of networks.
8. Implementation of New Regulations: Adapt and develop distribution operating procedures to make grid operation more flexible and resolve congestion.
9. Promotion of Self-consumption: Facilitate access and connection for self-consumption facilities and recharging points for electric vehicles.

6.3 STATUS OF DEVELOPMENT/CURRENT STATE OF FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS

In Spain, the development of flexibility services, including non-firm connections, has been advancing to accommodate the increasing integration of renewable energy sources and to enhance grid management. A significant regulatory milestone in this progression is the issuance of Circular 1/2024 by the Comisión Nacional de los Mercados y la Competencia (CNMC) on [i]September 27, 2024, [27].

Circular 1/2024 establishes a standardized methodology and conditions for access and connection to electricity transmission and distribution networks for demand installations. This circular introduces a framework for flexible access capacity, allowing demand installations to opt for connection agreements that do not guarantee continuous supply throughout the year. Notably, it introduces two distinct modalities of access capacity:

- **Firm access capacity**: the maximum active power that can be supplied at any time throughout the year.
- **Flexible access capacity**: This capacity refers to the power that is subject to a consumption reduction, and therefore continuous supply is not always guaranteed. The granting of flexible access capacity depends on a capacity analysis to determine its feasibility.

The introduction of flexible access capacity aligns with the broader European trend of employing alternative connection agreements to enhance system flexibility. Despite these regulatory advancements, the practical implementation of flexibility services in Spain is still in the early stages.

The alignment of Spain's Circular 1/2024 with the principles outlined in the draft EU Network Code on demand response underscores a cohesive strategy toward integrating flexibility services within the European energy market. By adopting flexible access capacities, Spain is positioning itself to effectively implement forthcoming EU-wide regulations, fostering a more resilient and adaptable energy infrastructure. However, the practical realization of these services necessitates further development in market mechanisms, technological infrastructure, and stakeholder engagement to fully harness the potential of demand-side flexibility.

A literature review was conducted to explore innovative approaches to energy flexibility management within local energy communities, aggregators and flexibility providers in low and medium-voltage networks.

The first project titled **IREMEL**: Integration of Energy Resources through Local Markets [28], aims to develop a simulation of a typical distribution network to verify different aspects of the operating model of local capacity markets for the solution of distribution congestion. For this purpose, two types of analysis will be carried out, which are explained below. Technical analysis of congestions using three network models that replicate the typical conditions found in industrial, rural and urban areas of Spain under different scenarios and in the face of changes in weather conditions. Economic analysis of the possible ways to solve congestion to find the optimal option in terms of cost-efficiency for the distributor; analysis of the economic model for the participants, evaluating the possibility of granting a fixed rent to build an attractive economic model for these technologies.

The main advantages of this model, IREMEL found, were that it placed the small generator at the centre of the energy transition and allowed it to generate ancillary revenues, making it more profitable to install. In addition, it helped the system to resolve congestion more efficiently through competition and free markets, thus saving costs and providing an alternative to infrastructure investments. The project promoted the creation of several local market prototypes covering a wide range of actors and situations, identified challenges and opportunities for the active role of the consumer and producer-consumer, and facilitated the continuous management of energy based on price signals. It also sought to demonstrate the viability of new technologies for distributed resource management and their participation in local markets, led innovation in electricity markets under new European regulations, and detected regulatory barriers that hindered the development of these markets.

The second one, titled **Futured**: Flexibility In Electrical Distribution Networks. DSOs under the current regulatory framework do not consider flexibility services provided by third parties when planning new network upgrades, as this is not covered by regulation. However, local flexibility markets are already being implemented in several European countries, such as the UK, Germany, the Netherlands, Sweden and Norway. In addition, several European H2020 research projects, such as Integrid42, EUniversal, CoordiNet, INTERRFACE, among others, are exploring different design alternatives. Some local market platforms in operation, such as Enera, GOPACS and NODES, are demonstrating the possibilities of new business models in this area.

In Spain, the current remuneration model for DSOs does not contemplate the purchase of flexibility services from third parties, nor does it offer incentives for their use as an alternative to new investments in the grid CAPEX. An aggregator could offer demand reduction services by activating customer premises backup batteries in selected regions of the grid, as in a pilot conducted in Barcelona that included six substations, and 20 cell phone base stations equipped with backup batteries that can be disconnected from the grid when needed. In this pilot, the coordination scheme “Balance Shared Responsibility Model” was considered. In this scheme, the DSO must respect a predefined schedule at each interconnection point between the distribution and transmission grids, based on the nominations of the BRPs and the historical forecasts of each interconnection point. To maintain this scheduled exchange profile and avoid congestion in the distribution network, the DSO must observe the real-time status of the network through telemetry data received from remote terminal units located at the substations.

As a conclusion, it was considered necessary to create a new role called Local Market Operator, which would allow the DSO to fulfil its responsibilities and neutrally incorporate the flexibility of aggregators and local DERs, organizing a local market in which aggregators offer their flexibility according to the requirements of the network.

6.4 VARIOUS OPTIONS FOR FLEXIBILITY UTILIZATION IN GIVEN LOCAL ENERGY MARKETS WITHIN THE CONTEXT OF THE PILOT SITES

For this pilot site, various flexibility solutions are proposed to address the specific needs of local energy ecosystems, such as integrating renewable energy sources and managing grid constraints. These solutions aim to provide a comprehensive understanding of how flexibility can be adapted to operational, economic, and regulatory conditions. While some solutions prioritize immediate operational reliability through direct agreements with DSOs, others also enable the creation of economic value by enabling stakeholder participation in energy markets.

6.4.1 Flexible connection agreement solution (non-firm solution)

The flexible/non-firm connection agreement solution, which could also be called "Flexible Supply Type" or "Flexible Access Capacity," implies a clear differentiation from the traditional approach of operating and planning the network to always guarantee the requested supply at any time. In this way, new contractual arrangements can be developed to facilitate flexible network access, designed for cases where network operators cannot permanently satisfy the requested connection power, either provisionally during the time in which the network extension or reinforcement work is carried out, or definitively, if the client, after receiving the technical-economic conditions of the flexible demand access and connection proposal, finds it convenient. This new approach allows DSOs to postpone or even reject costly investments that they had planned in order to guarantee the quality and security of supply, and at the same time, allows customers to access in a more agile manner compared to the traditional scenario, in which the connection request would be delayed or even rejected. Therefore, if appropriate flexible connection conditions are applied, connection agreements can create a win-win situation for both parties.

It is important to highlight that, in this flexible proposal, the DSO conducts a detailed capacity study in which it concludes that the installation can consume a percentage (%) of hours per year (EDD), conveying this information to the applicant, who can voluntarily decide whether to accept it or not.

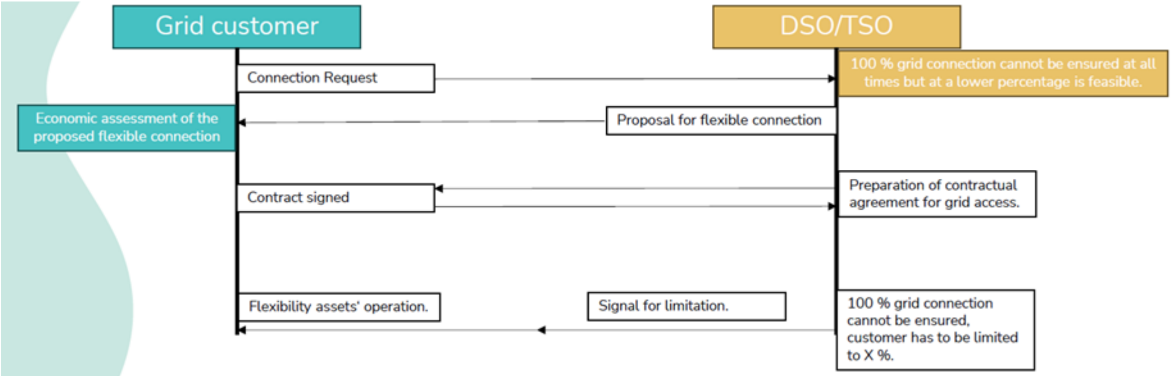

Figure 6-2: Spanish pilot - connection agreement solution schema.

This solution of the connection agreement will be demonstrated in the Spanish pilot and may provide a vision of the potential as a facilitator of flexibility markets in general, Figure 6-2. By obtaining such agreements, DSOs may, in the event of operational difficulties, conduct auctions to purchase the requested energy at a lower price than is stipulated in the connection agreement(s). If the power required at a lower price cannot be secured through market channels, DSOs can use an alternative backup scenario in the form of connection agreements. Therefore, the connection agreement would help unlock the market-based solution, which is not viable now, and at the same time provide better grid planning and security of supply in the event of operational challenges.

In addition, thanks to this solution, depending on national circumstances the DSOs should work with the market regulator to establish general criteria to follow when designing and implementing such connection agreements so that the process is transparent, objective and non-discriminatory.

6.4.2 Market-based flexibility procurement

This solution brings the participation of flexible resources in an open flexibility market which is triggered by the DSOs with the objective of providing to the DSOs a more convenient alternative for some of their planning and operation scenarios. In this manner, customers who already have assets that can add value to the flexibility market, can be of great value to the electrical system and, of course, can obtain an economic return. Typical participants in these flexibility market could be:

- A hotel that has a domestic hot water (DHW) production system with a heat pump and a water accumulation volume of several tens of cubic meters, so it has no problems heating water at different times.
- Industries with production processes where they can provide flexibility in some part of the process, for example, industrial refrigeration machines for cold storage rooms.
- Vehicle charging stations where vehicles do not find it problematic to be connected for several hours to charge their battery and even discharge at certain times.
- Small prosumers whose PV installation is already connected in a self-consumption regime with surpluses without physical storage, who see a new possibility to provide flexibility to the grid.

In this regime, two different options are proposed, long-term and short-term flexibility market mechanisms for the procurement of these services.

6.4.2.1 Long-term market-based flexibility procurement

This mechanism can be used to address frequent problems that arise in the network that require a very expensive reinforcement solution and/or whose execution is estimated in the very long term within the planned maintenance of the network. Long-term agreements with flexibility providers will be established through a market-based procurement process, in which aggregators submit their bids, and in which the DSO calculates the best bid considering various preferences, such as the most economical and/or technically feasible solution, Figure 6-3.

While there is a well-defined and established market-based solution to acquire capacity in frequency maintenance in the electricity transmission grid, the rules for DSO flexibility markets remain to be established through the collaboration of DSOs with regulators.

An example in which this solution is proposed could be a scenario in which the DSO is aware of a network issue that requires a lot of time to be solved, where market procurement can be triggered to try to limit or avoid the issue until the network reinforcement is completed. Aggregators could then submit their offers to the market, liquidity in the bids from flexibility assets is of importance for the efficient performance of these market-based solutions. The best economic solution will then be sent to the DSO to perform a technical feasibility calculation of these offers and finally, the market platform will publish the market results. During the service windows contracted, in case of activation needs, the DSO will send the activation signals to the contracted flexible assets.

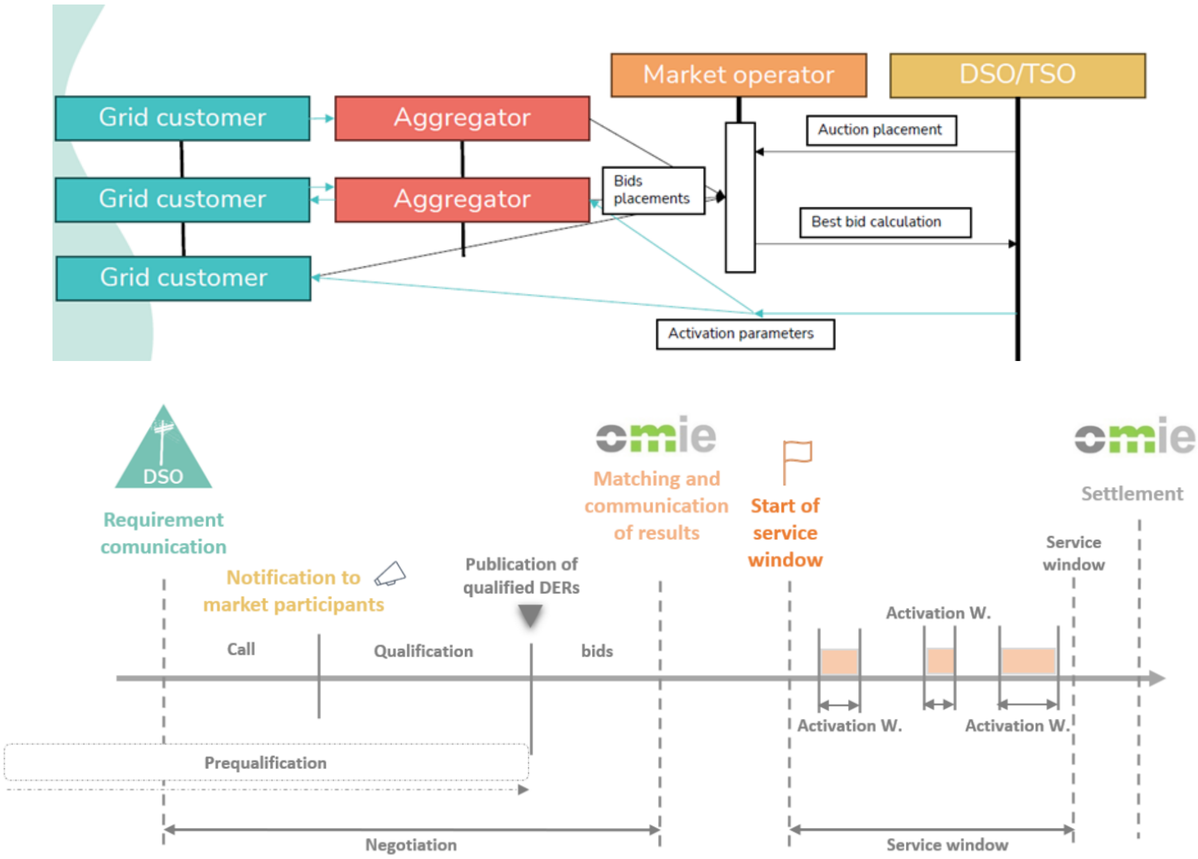

Figure 6-3: Spanish pilot – long term market-based solution schema.

6.4.2.2 Short-term market-based flexibility procurement

This solution can be considered for scenarios where an immediate response is not necessary, but the response level should be situated at an intermediate point between an immediate response model and a long-term one, Figure 6-4.

An example in which it could be applied is a scenario where congestion or voltage problems appear in the network and after analysis, it could be solved with the provision of flexibility. The DSO would send a requirement to conduct short-term auctions through the market operator and send trigger signals to the contracted flexible assets.

In this modality, the whole process needs to be accelerated to achieve the expected goals, accordingly, greater agility is required in the qualification and prequalification stages of the FSP with respect to the "Long-term market-based flexibility procurement" modality, which is why in this scenario only FSPs who are already prequalified in previous processes are considered at the time of sending the request.

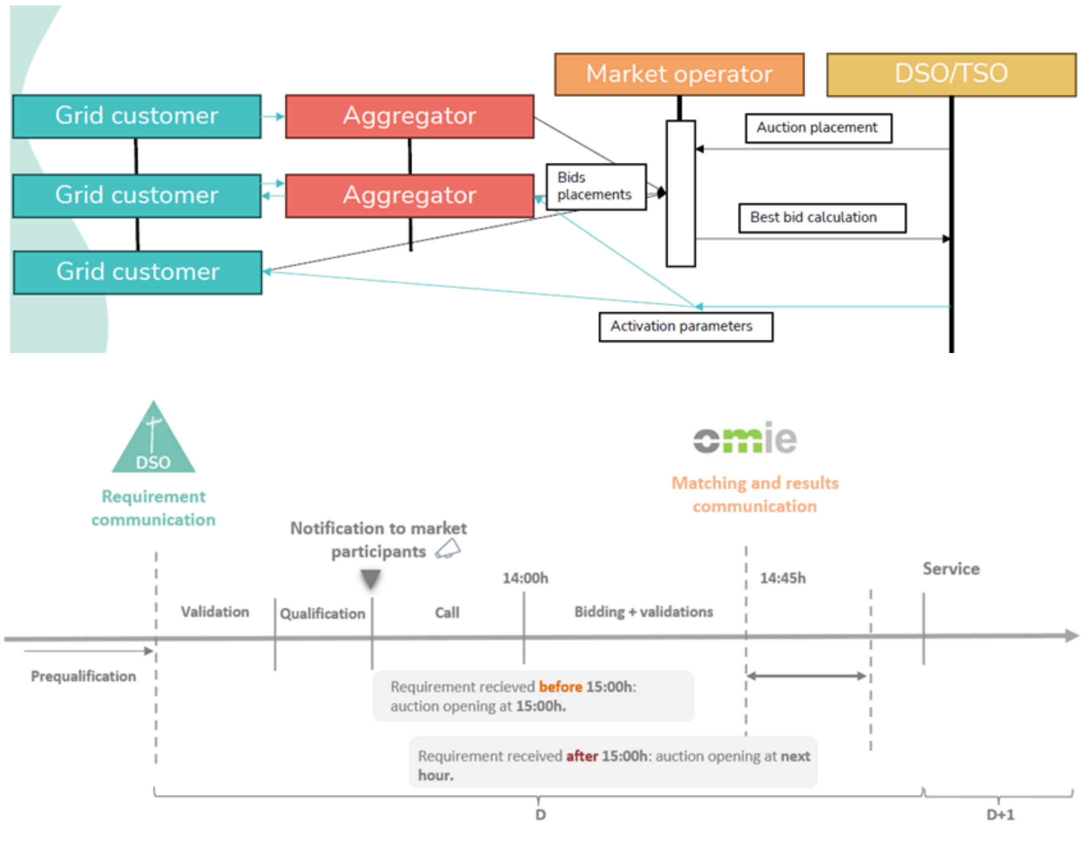

Figure 6-4: Spanish pilot – short term market-based solution schema.

6.4.3 Non-firm connection agreements with market-based solution

This solution is based on the previous section, further expanding the principles of the flexible connection agreement solution.

This proposal could be considered in the following scenario, although it is true that new scenarios may arise whose implementation may also be convenient, Figure 6-5:

- When a connection request is received, it is expected that the DSO cannot guarantee the connection 100% of the time, and accordingly, a flexible connection agreement is proposed and in place. It should be noted that there are multiple circumstances that may cause this (municipal construction licenses, administrative authorizations, construction execution, exploitation request processing including its exploitation authorization, etc.)

- The DSO foresees potential problems with the local network at some point.
- Instead of activating the flexible connection agreement to curtail or modify the current consumption or generation of the customer, a flexibility auction is triggered through the market operator. The main objective of this auction is to obtain the necessary power and energy to stabilize the network at a lower cost compared to that stipulated in the connection agreement.
- Bids are then received. If the submitted bids improve the pre-established connection agreement, the market operator communicates the activation parameters to the aggregators, triggering the activation of the most favorable bids. A signal is sent to activate the power indicated in the pre-established connection agreement.

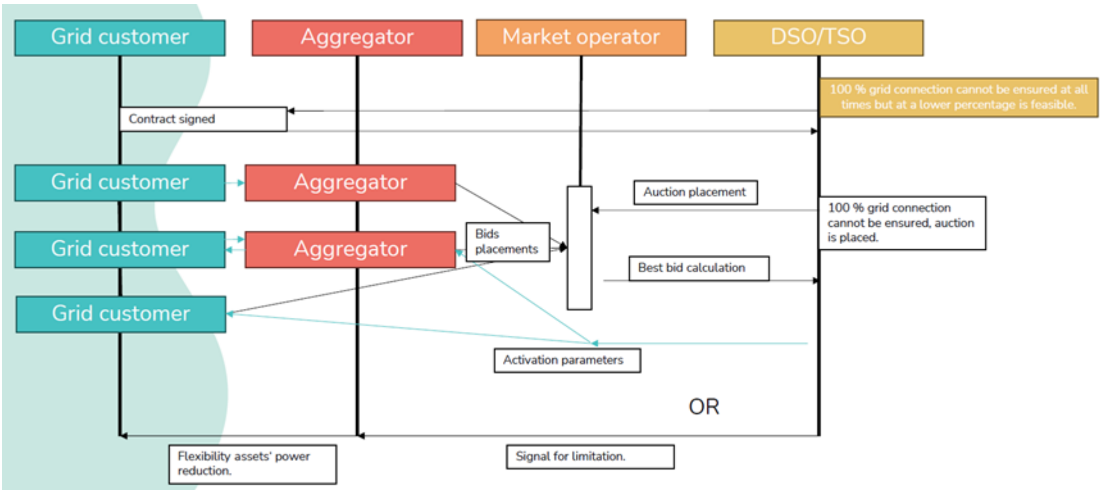

Figure 6-5: Spanish pilot – non-firm connection agreement and market-based solutions schema.

This solution offers the DSO the opportunity to take advantage of flexibility by offering connection agreements instead of directly rejecting connection requests, and additionally, it can help delay investments in the network when a physical connection cannot be always guaranteed. This approach allows network investments to be postponed or even abandonment while facilitating the flexibility market, in which network customers can leverage their flexibility assets during network operational challenges. It should be noted that the security of supply remains guaranteed in this scenario, as the DSO maintains a backup scenario within the initial connection agreement solution.

6.5 VALUE STACKING OF FLEXIBILITY UTILIZATION

Flexibility is key to maximise value across the energy value chain, benefitting diverse stakeholders. The concept of flexibility value stacking involves leveraging flexible resources to deliver multiple, simultaneous benefits across various energy market segments. However, it is not a one-size-fits-all solution; its successful implementation depends on principles of scalability and replicability, tailored to the unique characteristics of the specific market it serves.

At its core, flexibility value stacking aims to enhance the overall energy efficiency of the power grid by optimizing both grid operations and investments. Beyond system-level benefits, it also provides significant value to network customers and aggregators, enabling them to unlock new revenue streams. Simultaneously, it supports system operators by improving operational efficiency, ensuring a more resilient and adaptive energy system.

This chapter explores the stacking of flexibility values in the context of the Spanish STREAM pilot. It delves into the specific applications of flexibility within this pilot, offering a structured analysis of the associated advantages and disadvantages. Each proposed solution is evaluated through a review table that highlights qualitative and quantitative benefits for key stakeholders, including network users, aggregators, market operators, and system operators. The quantitative assessment assigns scores ranging from 1 to 5, where 5 denotes the optimal value, providing a clear and actionable evaluation framework.

By presenting these insights, the chapter aims to illustrate how tailored flexibility strategies can drive system-wide efficiency and stakeholder value while addressing the unique challenges and opportunities of the Spanish energy market.

6.5.1 Flexible connection agreement solution (non-firm solution)

This section analyses the value stacking potential of the connection agreement solution proposed, highlighting its implications for various stakeholders, including grid customers, DSOs, aggregators, and market operators. Table 6-1 summarizes the qualitative and quantitative assessments of this solution.

The connection agreement solution offers significant benefits to grid customers, achieving a high score of 4. The primary advantage lies in its ability to expedite access to the network or enable connections that were previously deemed unfeasible through traditional evaluation methods. This flexibility can accelerate project timelines and unlock economic opportunities. However, the solution comes with inherent risks, such as the potential for service interruptions. These interruptions could result in unforeseen costs, making the solution less attractive to customers who prioritize stability and reliability.

For DSOs, the connection agreement solution provides multiple strategic benefits. It allows for the deferral or even reduction of capital-intensive grid investments while enhancing customer satisfaction by enabling connections under specific conditions that were not possible before. This increased flexibility supports network optimization and is aligned with broader system efficiency goals. However, DSOs face challenges such as higher operational efforts required to manage these agreements and the critical need for robust cost-benefit analyses. These analyses are essential to determine whether forming contractual agreements with customers is more advantageous than investing in grid infrastructure upgrades.

This solution presents no applicability for aggregators and market operators, as it is typically a bilateral agreement between grid customers and the DSO.

Table 6-1: Spanish pilot - connection agreement solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Connections that were previously not feasible can now get a connection point from the DSO. • Accelerate grid access.	• Interruptions of the customer 's operation at previously agreed times. • A 100 % grid connection cannot be ensured, customers could be limited for	4

		some periods of time.	
Aggregator	• N/A	• N/A	N/A
Market operator	• N/A	• N/A	N/A
DSO	• Postponement/reduction of the investments into the grid. • Creating satisfaction in grid customers. • Accelerating grid connections.	• Increase of operational effort. • Increase in legal and contractual efforts. • Increased operational risks.	2

6.5.2 Long-term market-based solution

This section evaluates the long-term market-based solution proposed, focusing on its value stacking potential for stakeholders across the energy value chain. Table 6-2 provides a detailed assessment of the benefits and challenges for each stakeholder.

Grid customers experience notable benefits under the market-based solution. With the use of this solution by DSOs, the network can be managed in a more efficient manner, facilitating the approval of new connections for grid customers that previously were denied due to network capacity issues, providing faster and better quality of service. Additionally, it provides a great opportunity to create additional value from their energy management operations by supporting the DSOs when required. However, a potential drawback is the potential penalties for undelivered power or energy that could be imposed creating financial risks and making the solution less appealing for risk-averse users.

Aggregators emerge as one of the main beneficiaries of the long-term market-based solution. This framework allows them to monetize the flexibility of single or aggregated assets in energy markets, providing opportunities to engage with multiple consumers and participate in different market segments using the same resources. By enabling aggregators to participate in additional markets, this solution strengthens their business models and fosters innovation. As a result, this stakeholder achieves a significant improvement in value compared to the connection agreement solution. Nonetheless, the need to forecast the availability of flexibility in the long term and the potential penalties remain a potential drawback.

The role of market operators, previously irrelevant under the connection agreement solution, becomes key for the success of the long-term market-based solution. Market operators are tasked with evaluating flexibility offerings, a process that requires them to account for complex topological and pricing factors. The appearance of new markets provides them with the opportunity to create new services, new business models and therefore increasing their revenues and their significance in the energy value chain.

In contrast to aggregators and grid customers, DSOs experience a reduction in value compared to the connection agreement solution. While the market-based solution enables DSOs to integrate flexibility into grid planning and operations, it introduces significant challenges. These include the need to optimize bid selection, manage increased operational demands, and improve load forecasting capabilities based on historical data. Additionally, DSOs must develop advanced tools to simulate load flows with high accuracy, further straining their resources and operational bandwidth.

Table 6-2: Spanish pilot – long term market-based solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Easier connection agreement approval, including in a possible congested state of the grid. • Monetization opportunity. • Faster grid access. • Potential for improved service quality (reduced service interruptions).	• Potential penalties for non-delivered flexibility	5
Aggregator	• Monetization for aggregation of one or more flexibility assets.	• Long-term flexibility forecasts might be inaccurate. • Potential penalties for non-delivered flexibility.	4
Market operator	• Facilitation of trading (market platform development, etc.). • Facilitation of regulatory compliance. • Non-discriminatory access to the market for all market participants. • Increased revenues.	• Challenge of assessing flexibility bids, including considering topological and price aspects of the flexibility asset). • Market liquidity challenge.	3
DSO	• Postponement/reduction of the investments into the grid. • Satisfaction in grid customers. • Enabling optimal grid planning including flexibility. • Possibility to solve different operational issues. • Maximization of grid capacity.	• Substantial increase in grid planning and operation effort. • Need for higher bandwidth of IT/OT networks. • Cybersecurity risks. • Grid load forecasting challenge. • Calculation of feasible bids challenge. • Data management challenge. • Increased administrative burden.	3

6.5.3 Short-term market-based solution

The value provided to individual stakeholder's mirrors that of the long-term market-based solution. This indicates that the short-term approach delivers comparable utility, but with a focus on addressing immediate, time-sensitive needs.

In this case, grid customers benefit similarly to the long-term solution while aggregators can further solidify their position as key stakeholders in the flexibility ecosystem by also responding to short-term needs. One of the crucial aspects when comparing long term and short-term solution lies in the forecasting of the available flexibility, which can be done more effectively for the short-term solution. Furthermore, market operators are tasked with evaluating flexibility offerings under tight time constraints, requiring more advanced systems to manage complex processes and pricing factors efficiently, adding to the complexity of their role. The ability to incorporate short-term flexibility into operations is valuable, particularly for addressing sudden or unexpected grid constraints. However, the short-term focus heightens operational demands for DSOs, that amplifies the resource and technical challenges DSOs could face.

6.5.4 Non-firm connection agreements with market-based solution

By merging the strengths of both solutions, this combined framework offers a balanced and resilient approach to flexibility value stacking, Table 6-3.

By retaining the contractual agreements from the non-firm connection solution, DSOs gain a reliable fallback mechanism to address network disturbances or unexpected events. This ensures that even if challenges such as best offer calculation, data management, or bid optimization arise in the market-based framework, the DSO can activate customers through pre-established agreements to maintain grid stability. However, the hybrid nature of this solution introduces additional complexity, requiring DSOs to manage both contractual obligations and market interactions simultaneously. This dual responsibility necessitates advanced tools and processes to ensure efficient integration.

Grid customers and aggregators also gain flexibility and monetization opportunities, while market operators play a critical role in ensuring seamless integration.

However, the hybrid nature of this approach introduces added complexity for all stakeholders, requiring sophisticated tools, clear operational frameworks, and robust coordination. By leveraging the strengths of both solutions, the combined approach addresses both immediate and long-term flexibility needs, offering a resilient and adaptable framework for the energy system.

Table 6-3: Spanish pilot – non-firm connection agreement and market-based solution.

Stakeholder	Pros	Cons	Value
Grid customer	• Easier connection agreement approval, including in a possible congested state of the grid. • Monetization opportunity. • Faster grid access. • Connection agreement approval without additional costs.	• Interruptions of the customer ‘s operation at previously agreed times. • 100 % grid connection cannot be ensured, customers could be limited in some periods of time.	4
Aggregator	• Monetization for aggregation of one or more flexibility assets.	• Flexibility forecasts might be inaccurate.	4

	• Possibility to utilize the flexibility assets in other markets.	• Potential penalties for non-delivered flexibility.	
Market operator	• Facilitation of trading (market platform development, etc.). • Facilitation of regulatory compliance. • Non-discriminatory access to the market for all market participants. • Increased revenues.	• Challenge of assessing flexibility bids, including considering topological and price aspects of the flexibility asset). • Market liquidity challenge. • Increased administrative burden.	3
DSO	• Postponement/reduction of the investments into the grid. • Creating satisfaction in grid customers. • Enabling grid planning based on flexibility. • Possibility to solve different operational issues.	• Substantial increase in operational effort. • Need for higher bandwidth of IT/OT networks. • Cybersecurity risks. • Grid load forecasting challenge. • Best-bid calculation challenge. • Data management challenge. • Transparency of costs/benefits challenges.	3

6.6 GAPS, CHALLENGES AND RECOMMENDATIONS FOR FUTURE LEGISLATION DEVELOPMENT

At present, legislation does not sufficiently cover the flexibility markets and there is a lack of regulation in terms of roles, responsibilities and operating mechanisms in these markets. This leads to a shortage of regulatory frameworks that can incentivize the participation of distributed resources, such as storage and renewable generation. Thus, there is a lack of homogeneous criteria for coordination between local and national actors, especially between DSOs and TSOs.

In order for the flexibility markets to facilitate and manage maximum possible flexibility in the system, there are two new actors in the energy sector, the energy communities and the aggregator, which currently lack specific regulations that delimit their roles and responsibilities and a lack of regulatory framework facilitating their active participation in the energy markets.

For the development of the energy sector, the creation of a clear regulatory framework that facilitates the formation of local flexibility markets managed by DSOs is key. Flexibility markets should incentivize the participation of distributed resources by motivating them with equitable remuneration and the development of regulatory sandbox-type pilot projects that allow experimentation and adjustment of models before their massive implementation.

The figure of the aggregator should be regulated as an independent actor, ensuring its integration in all electricity sector markets. To this end, it is necessary to recognize their right to participate in the electricity markets without the need for coordination of information between the aggregator, the marketer and the customer, in order to avoid distortions or negative effects on the efficient operation of the system, without this representing a barrier to the participation of the aggregator.

As for energy communities, administrative procedures should be facilitated, and specific economic incentives should be provided to stimulate the creation and expansion of energy communities. A coordinated effort involving regulators, policy makers, market operators and the communities themselves. By developing supportive regulatory frameworks, providing financial incentives, fostering community engagement and promoting technological solutions, barriers to community energy participation in local flexibility markets can be mitigated.

7 CONCLUSIONS

The document presents a comprehensive analysis of the regulatory and operational aspects of local flexibility markets, focusing on their implementation in Slovenia, Finland, Italy, and Spain. It outlines the achievements in understanding how flexibility services can contribute to grid stability, market efficiency, and the integration of renewable energy. Key findings highlight the role of EU regulations, the different approaches taken by pilot sites, and the challenges in adopting market-based flexibility solutions. Through detailed assessments of regulatory frameworks, technical requirements, and market structures, the document provides a foundation for advancing local flexibility markets. Achievements include identifying gaps in current regulatory environments, evaluating the economic potential of flexibility services, and proposing frameworks for better market integration. The document also emphasizes the importance of value stacking, where flexibility providers can leverage multiple revenue streams to enhance financial viability.

These findings are crucial for guiding future developments in local flexibility markets. The results of the pilot projects serve as a reference for continued improvements, particularly in refining regulatory frameworks and enhancing cooperation between TSOs and DSOs. The evolution of digital infrastructure and automated flexibility trading platforms will play a significant role in supporting real-time market participation. Future policy efforts should focus on reducing market entry barriers for flexibility providers, improving price signals in flexibility markets, and ensuring that market mechanisms are accessible and transparent. Additionally, strengthening the integration of demand-side response and energy storage solutions will be essential in optimizing grid operations and maintaining system reliability. The document serves as a roadmap for ongoing legislative and market developments, highlighting the need for adaptive policies that align with evolving energy demands.

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8.2 ACRONYMS

Acronyms list	
ACER	Agency for Cooperation of Energy Regulators
BRP	Balancing Responsible Parties
CAPEX	Capital Expenditure
CEP	Europe's 2019 clean energy package
CECs	Citizen Energy Communities
CNMC	Comisión Nacional de los Mercados y la Competencia
DSO	Distribution System Operator

DPS	Distribution Power Supply
EC	European Commission
ECM	Energy Community Manager
EED	Energy Efficiency Directive
ESS	Energy Storage Systems
EU	European Union
LEC	Local Energy Communities
LFM	Local Flexibility Markets
MO	Market Operator
MP	Measuring Point
NEMO	Nominated Electricity Market Operators
NM	Nomination Point
RED III	Renewable Energy Directive
RECs	Renewable Energy Communities
RES	Renewable Energy Sources
SONDSEE	Sistemska obratovalna navodila za distribucijski sistem električne energije s prilogami, predlog dokumenta
TSO	Transmission System Operator
VRE	Variable Renewable Electricity
WDS	Water Distribution Systems
WDSO	Water Distribution Network Operator
ZOEE	Zakon o oskrbi z električno energijo