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Review

Analysis of New Flexibility Market Models in Europe

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Abstract: To identify the trends in new flexibility markets, a set of market and aggregator platforms were selected and compared. The analyzed initiatives are relevant to consider alternative designs for European electricity markets. This review proposes a common methodology for analyzing these market models by comparing their description, market structure, market timing, and implementation. Furthermore, a range of policy implications and future research directions towards implementing these markets are presented. The results provide compelling evidence that the new market models represent a promising business with technical and economic justification, as they incentivize the uptake of flexibility from distributed resources by providing services to Distribution System Operators (DSOs) in coordination with Transmission System Operators (TSOs). Moreover, the interactions between these new market platforms and existing markets are of particular interest, and the contributions from aggregator platforms are also relevant to enhance the political vision of empowering the customers through their active participation in markets.

Keywords: aggregators; electricity market; distributed energy resources; distribution system operators; flexibility; local markets; market design; power system.

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1. Introduction

The energy system is undergoing a profound transformation driven by public policies focused on reducing greenhouse gas emissions, increasing the quota of renewable energy generation, and increasing energy efficiency. This process involves a change in the final use of energy supplied by fossil fuels, replaced in a large part by electricity, assuming that electricity generation soon would be more efficiently decarbonized. In this energy transition, consumers will play a central role with more active participation in electricity markets. New technologies, such as self-generation based on renewable energy and digitalization, allowing higher monitoring and control of energy loads, would allow savings in the electricity bill by actively managing those distributed resources.

In this context, distributed energy resources (DERs) connected to distribution networks may become an important flexibility source to support the operation of a highly decarbonized electricity system based on renewables [1]. The Clean Energy Package mandates DSOs to take advantage of these flexibility resources by integrating them in both planning and operation tools using market mechanisms to select the most efficient resources [2].

In addition, in Europe, the digitalization of networks and smart metering implementations allow consumers and DSOs to know, almost in real time, the load and generation patterns. In response to this situation, new digital platforms that implement new market models are arising. Under these market models, and by using these platforms, consumers and aggregators exploiting flexible distributed resources can provide services to DSOs and TSOs, or trade energy between them [3,4]. In general, these platforms may differ widely between them in terms of the services they provide, the functions they perform, the required coordination between system operators (TSOs and DSOs), their ownership, or the interrelations with existing markets, among other factors.

A growing body of literature has examined the market models rising at the European level in the context described above. For example, in [5], the authors systematically compare local markets for flexibility based on twelve projects. In [6], flexibility markets are analyzed in four pioneering European projects within a six-question framework that considers aspects such as the level of integration into the existing sequence of markets, roles of the market operator, reservation payments, and cooperation between the market TSOs and DSOs. Similarly, the authors in [7] analyzed a set of relevant initiatives and projects that provide important inputs related to flexibility needs, services and products, market organizations, and tools to integrate the existing flexibility into the planning and operation of the DSO.

In addition, preliminary studies have defined the concepts, designs, and technical aspects of flexibility markets. For example, in [8], the authors reviewed local flexibility markets and summarized the potential designs, formulations, and clearing methods. Furthermore, [9] provides a review of the flexibility products and market mechanisms and classifies the different approaches according to the purposes of the flexibility products.

This paper aims to go beyond the existing reviews in the literature, seeking to address how the European electricity markets could adapt to the new trends in flexibility markets by opening current models to new participants or innovating in the formulation of new platforms. The arguments for allowing more decentralized and flexible resources to participate in the required services of a more decarbonized renewable-based power system are of particular interest.

The contributions of this paper are summarized as follows: (1) identify an appropriate set of new flexibility markets whose proposals could be decisive in defining future designs for European electricity markets. These markets have been implemented since 2014 and most of them are completed or in full operation. However, this analysis also considers some initiatives that are still at the development stage because of their relevant approaches; (2) propose a common methodology that allows comparison between several flexibility markets focused on three aspects: market description, market structure, and market timing and implementation; and (3) provide insights into new trends in flexibility markets and explore the potential impacts of these markets in future deployments, policy implications, and future research directions.

This paper is organized as follows. Section 2 introduces the identified initiatives and projects. Section 3 proposes a common methodology to evaluate the selected flexibility markets. Sections 4 and 5 apply the methodology to market and aggregator platforms, respectively. Section 6 highlights a range of policy implications and future research directions in implementing these initiatives, and Section 7 discusses the main findings of the analysis.

2. New Flexibility Market Models in Europe

In this study, the selected flexibility market models developed in recent years in Europe are analyzed in detail. They are divided into two categories, namely, market platforms and aggregator platforms. The former is understood as marketplaces in which DER and/or aggregators can offer their flexibility and DSOs and/or TSOs can procure it. The latter refers to platforms where DER can provide flexibility through an independent aggregator or a supplier acting as an aggregator. Their names or acronyms are included in Figure 1.

Under market platforms, we identified eighteen European initiatives. Among these, Cornwall Local Energy Market (LEM) [10], Enera [11], GOPACS [12], NODES [13], and Piclo Flex [14] are quite recent initiatives developed in the last four years. These platforms share the same objective: enabling flexible resources connected to distribution networks to act as Flexibility Service Providers (FSPs). In general, these flexibility markets are promoted by DSOs that require those resources to solve network congestions (e.g., thermal or voltage violations). Given the locational characteristics of these constraints, information on the location of FSPs is required by DSOs when activating local flexibility. This information is not usually available in existing energy markets, day-ahead (DA), intraday (ID), nor in balancing markets managed by TSOs, and therefore specific local flexibility mechanisms are required.

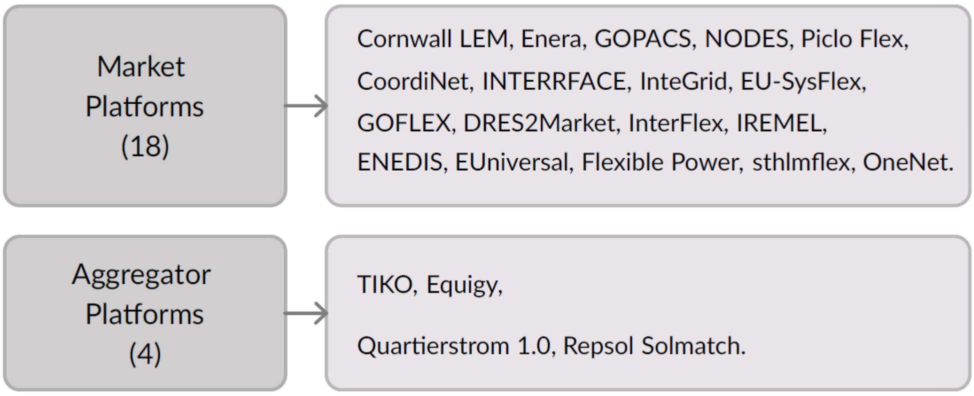

Figure 1. New flexibility market models in Europe.

Moreover, several research projects financed by the European Research Program H2020, which focus on how DSOs and TSOs can procure flexibility from distributed resources, are analyzed. For example, CoordiNet [15] and INTERRFACE [16] are two recent projects initiated in 2019, devoted to intensifying the coordination between TSO and DSOs when procuring flexibility for solving network congestion or running balancing markets. InteGrid [17] is a project finished in 2020 and mainly focused on how DSOs may procure flexibility from distributed resources to perform a more active operation of their networks following the new Electricity Directive and Regulation directions.

Similarly, since 2017, different solutions have been proposed to support effective use of distributed resources focused on the provision of services for grid operators in EU-SysFlex [18] and GOFLEX [19], the participation of Distributed Generation (DG) based on renewables in electricity markets in DRES2Market [20], and the implementation of local markets in InterFlex [21] and IREMEL [22]. In these projects, the aim is to demonstrate in large-scale pilots the potential alternatives for standardization of products and services and implement solutions through platforms, often using innovative technologies such as Blockchain, which allow for market-based procurement of these services.

In this paper, four initiatives classified as aggregator platforms are analyzed. These platforms are TIKO [23], Equigy [24], Quartierstrom 1.0 [25], and Repsol Solmatch [26]. TIKO and Equigy can be understood as aggregator platforms specially devoted to cluster small flexible resources connected behind-the-meter, but not only, and offer this flexibility to TSO markets of ancillary services. Quartierstrom 1.0 and Solmatch aim to create new supplier business opportunities in the retail market by promoting peer-to-peer (P2P) transactions, taking advantage of solar photovoltaic (PV) installations located at prosumer premises.

Finally, five new initiatives, included in Figure 1, are not analyzed in Sections 3 and 4 because the information available at the time of the analysis was not sufficient. They are ENEDIS [27], EUniversal [28], Flexible Power [29], sthlmflex [30], and OneNet [31].

3. Market Analysis Methodology

The selected new flexibility market mechanisms are classified and analyzed under the methodology illustrated in Figure 2. Three main dimensions are analyzed, namely

Market Description, Market Structure, and Market Timing and Implementation. Sections 4 and 5 present the key information of each of these dimensions, followed by a summary and discussion on the main findings.

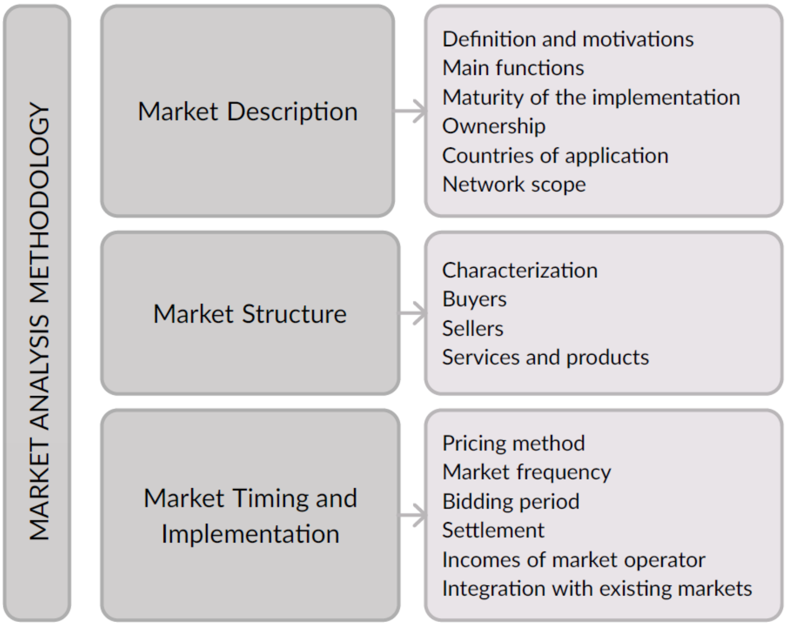

Figure 2. Market analysis methodology.

4. Market Platforms Analysis

4.1. Description of Market Platforms

Table 1 collects the main attributes that describe the selected market platforms. These market models have been implemented since 2016. Most of them are completed or in full operation, except CoordiNet, INTERRFACE, EU-Sysflex, DRES2Market, and IREMEL, which are still at a development stage. Furthermore, although the network scope varies between these alternatives, the majority of the market platforms consider resources connected both at transmission and distribution networks.

Three of the market platforms analyzed, namely, Enera, GOPACS, and NODES, are organized by market operators, EPEX SPOT, ETPA, and Nord Pool, respectively. The same platforms plus Cornwall LEM allow for the coordination between the involved DSOs with the corresponding TSOs to manage congestion at different voltage levels or include the flexibility bids also in the offer of balancing services managed by the TSOs. However, Piclo Flex is centered on flexibility services to be used by DSOs, who can book flexibility in advance through availability contracts. These contracts would support the operation of the network in peak load periods and help with specific location requirements of the grid because of faults or maintenance. Therefore, in the long term, they will help reduce the need for grid reinforcement.

On the other hand, CoordiNet and INTERRFACE are both at an initial development stage and will last until 2022. They are implementing large-scale demonstration pilots in different European countries. CoordiNet counts on three demonstration countries (Spain, Sweden, and Greece), while INTERRFACE is testing solutions in nine demonstrations. However, others are centered only on DSO services with innovative ways of procuring flexibility from small residential consumers. EU-SysFlex also focuses on providing flexibility to TSOs and DSOs, including 12 demos in Germany, Italy, Finland, and Portugal.

As highlighted in Table 1, InteGrid, InterFlex, GOFLEX, and IREMEL are focused more on providing flexibility services mainly to DSOs. They also focus on enabling the participation of DERs in existing energy markets, particularly the DRES2Market project.

InteGrid has implemented demos in Portugal, Sweden, and Slovenia to demonstrate how new tools used by DSOs are required to efficiently manage low voltage and medium voltage networks, taking advantage of the flexibility procured by small connected customers and corresponding aggregators.

InterFlex includes six different demos in five countries, namely, the Netherlands, Germany, Sweden, Czech Republic, and France, involving a wide range of resources: electric vehicles (EVs), energy storage, demand response (DR), and aggregators. GOFLEX promoted demonstrations in Cyprus, Germany, and Switzerland. The demos aim to delay grid reinforcements by reducing electricity peaks, preventing congestion, maintaining the quality of supply and reliability, and data management services for energy and flexibility trading. IREMEL is a Spanish initiative promoted by the Iberian market operator, and the DRES2Market includes Spain, Austria, France, Greece, Norway, and Poland. Both projects aim to enable the participation of DG and DR in the energy and flexibility markets.

Table 1. Description of the market platforms.

Market Platforms	Ownership	Countries of Application	Network Scope	Definitions and Motivations	Main Functions
Cornwall LEM, Pilot [1]: 2016–2020.	Centrica	The United Kingdom	ESO-DSO Level	To develop a local energy market platform to facilitate WPD (Western Power Distribution) and the National Grid ESO (Electric System Operator) in the procurement of critical flexibility services that support their business activities in the electricity industry. Hence, enabling other market participants to offer their flexibility [32].	Product enrolment, activation of flexibility, bid collection, market clearing, aggregation activities, and settlement [33].
Enera, Pilot: 2018–2020.	EPEX SPOT, EWE AG, TenneT DE (TSO), Avacon Netz and EWE NETZ (DSOs).	Germany	TSO-DSO Level	This flexibility platform coordinates flexibility demand and supply, supports DSOs with congestion management, and reduces the overall curtailment of renewable energy. ENERA continuously matches supply and demand and offers DSOs order books with specific area identifiers, such that these flexibilities can be used for network operation purposes [11].	Bid collection, market clearing, market monitoring (verification platform), settlement, developing aggregation activities (unclear if platform or external), computing network impact (by grid operators), and individual flexibility option/activation.
GOPACS, In operation [2]: 2019–to date.	Tennet (TSO), Stedin, Liander, Enexis Groep, and Westland Infra (DSOs).	The Netherlands	TSO-DSO Level	GOPACS is not a market platform itself, but it is connected to other market platforms. Currently, ETPA (Energy Trading Platform of Amsterdam) [34] is the first market platform that has joined GOPACS. It manages congestion at all voltage levels, increasing the available flexibility for re-dispatch and improving DSO/TSO coordination.	Congestion management needs are forecasted and announced via GOPACS by grid operators. The flexibility providers make offers to solve this congestion through the market platform, which acts as a gateway to GOPACS. A flexibility offer is placed as an IDCONS (Intraday Congestion Spread) if it meets specific conditions. It is also necessary to add a location tag [35].
NODES, Pilot: 2018–to date.	Nord Pool (European power exchange)	Norway and Germany	TSO-DSO Level	NODES aims to identify and give value to local flexibility [36] and link the NODES marketplace with the existing platforms that operate ID and balancing markets. Moreover, to increase value for flexibility providers and reduce costs for the DSO, flexibility not used locally could be sold to the TSO or to Balancing Responsible Parties (BRPs). It can solve imbalances in transmission.	To procure both LongFlex (Availability) and ShortFlex (Activation). Flexibility can be used for voltage control, frequency regulation, and congestion management.
Piclo Flex, In operation: 2019–to date.	Piclo	The United Kingdom	DSO Level	To develop a marketplace to standardize and facilitate DSO flexibility procurement, make more efficient use of the existing grid, and reduce the need for grid reinforcement [5].	Piclo Flex provides an independent platform to publish flexibility needs based on the demand location [37]. DSOs can see qualifying assets in the constraint management zones. The resulting map of competitors enables them to source flexibility with precise locational, technical, and temporal requirements.

CoordiNet, Under development [3]: 2019–2022	Greece: IPTO (TSO) and HEDNO (DSO). Spain: Common platform: REE (TSO). Local platform: i-DE, e-distribución (DSOs). Sweden: E.ON and Vattenfall (DSOs).	Demos in Greece, Spain, and Sweden.	TSO-DSO Level	To demonstrate how DSOs and TSOs shall act in a coordinated manner to procure and activate grid services most reliably and efficiently by implementing three large-scale demos [38]. Furthermore, to specify and develop a TSO-DSO-Consumers cooperation platform starting with the necessary building blocks for the demonstration sites.	The main functions of the Greek demo [39] are similar in the Spanish and Swedish demos: Data and information sharing between TSO and DSO, gathering of flexibility needs from both TSO and DSO, exchanging the flexibility of each FSP that can provide a specific service, gathering of market bids, performing market clearing, communicating the market results, submitting activation bids to service providers and grid operators, and performing settlement.
INTERRFACE, Under development: 2019–2022	Not specified, project in an early stage.	Demos in Bulgaria, Estonia, Finland, Greece, Hungary, Italy, Latvia, Romania, and Slovenia.	TSO-DSO Level	To design, develop and exploit an Interoperable pan-European Grid Services Architecture (IEGSA) to act as the interface between (TSO and DSO) and the customers and allow the seamless and coordinated operation of all stakeholders to procure common services [16].	IEGSA will enable TSOs, DSOs, and customers to coordinate their efforts to maximize the potential of DERs, aggregators, and grid assets. State-of-the-art digital tools based on blockchains and big data will provide new opportunities for market participation.
InteGrid, Pilot: 2017–2020	DSOs and TSOs of demonstration countries.	Demos in Portugal and Slovenia. Sweden also has demonstrations but not on flexibility procurement by DSO or TSO.	TSO-DSO Level	To demonstrate how DSOs may enable different stakeholders to participate in the energy market and develop and implement new business models, using new data management and consumer involvement approaches. Furthermore, to demonstrate scalable and replicable solutions in an integrated environment that enables DSOs to plan and operate the network with a high share of DER using flexibility inherently offered by specific technologies and interaction with different stakeholders [40].	In InteGrid, flexibility procurement is decentralized. On the DSO side, several functions were developed to aid the DSO in the evaluation, procurement, and management of flexibility: Multi-Period Optimal Power Flow (OPF), LV/MV load allocator, LV state estimator, Home energy management system. Additionally, the grid and market hub and the traffic light system promote the centralized exchange of information and the TSO/DSO coordination.
EU-SysFlex, Pilot: 2017–2021	TSOs and DSOs from the different demos. In the Finnish demo: Fingrid (TSO), Helen Electricity Network (DSO).	Demos in Germany, Italy, Finland, Portugal, France, and Estonia.	TSO-DSO Level	The project's main objective is to identify issues and solutions associated with integrating large-scale renewable energy and creating a roadmap to address future system operation complexities across Europe [18].	The functions carried out by the market operator vary according to each Business Use Case (BUC) inside each demonstrator. For example, in the Finish demo, the market operator collects offers from aggregators, collects flexibility demands from TSO and DSO, and carries out the market clearing [41].
GOFLEX, Pilot: 2017–2020	During the project time, the main actor carrying out the flexibility use cases are local energy suppliers/utilities and smaller DSOs [42].	Demos in Cyprus, Germany, and Switzerland.	TSO-DSO Level	The main objective of GOFLEX is to make a set of technology solutions for distributed flexibilities and automated dynamic pricing market-ready, enabling consumers, generators, and prosumers to aggregate and trade flexibilities. By taking a bottom-up approach (flexibility is harvested from the prosumer level and procured to higher levels in the electricity grid), GOFLEX makes DR more cost-effective and increases the level of DR available [19].	An Automatic Trading Platform (ATP) is developed as three independent core sub-systems: Flex-Offer Agent (FOA), Flex-Offer Manager (FMAN), and Flex-Offer Market (FMAR) [43]. The functionalities include Forecast grid congestions and grid needs, automatic issue of Flex-Offers depending on needs, collect Flex-Offers, market clearing, send activation signal, and settlement.

DRES2Market, Pilot: 2020–2023	To be defined	Demos in Austria, France, Greece, Norway, Poland, and Spain.	DSO Level	To develop a comprehensive and affordable approach to facilitate the effective participation of DG based on renewable energies in the electricity markets and provide balancing and reserve services according to market criteria [20].	The project will be validated at two levels: (1) simulating the impact of the promising solutions considering the evolution and variability of market prices with an increase in the share of renewables, (2) simulating an electricity market and system to identify technical and regulatory solutions, effective grid codes and market rules.
InterFlex, Pilot: 2017–2019	In both Dutch and French demos, the market platform is operated by the DSOs.	Demos in Czech Republic, France, Germany, Netherlands, and Sweden	DSO Level	The project investigated the potential of local flexibility to relieve grid constraints at a local and regional level. Therefore, the project contributed to enhance the development of new distributed energy resources and prepare the electric system for new uses. InterFlex mainly focuses on the interactions between DSO and market players.	In the Dutch and French demos (flexibility markets between DSO and aggregators), the flex markets were tested with the following functions: Forecast grid congestions and grid need, collect flexibility offers, market clearing, send activation signal, and settlement.
IREMEL, Pilot: 2019–to date	OMIE (Iberian Electricity Market Operator)	Spain	DSO Level	To facilitate the participation of RES and consumption connected to distribution networks in the markets, promoting the proper management of their discharged and consumed energy allows them to benefit from better market prices due to their flexibility and management [22].	IREMEL proposes to the DSO market mechanisms to solve eventual problems of congestion or supply. The market operator can activate local products to solve congestions.

[1] Pilot means that a proof of the concept was tested with limited impacts (in terms of agents participating, network scope, or functionalities). Although products are delivered, there may not be economic consequences. Pilots are trials that aim to test certain functionalities before the market starts operating. [2] In operation means that the market is fully operational. This means that already the products are traded, bids are submitted, cleared, and economically settled. [3] Under development means that the initiative is in an initial phase where the market concept has been defined and preliminary developments are implemented.

4.2. Market Structure

Table 2 presents the main features of the structure of the analyzed market platforms together with the market participants acting as buyers and sellers. On the one hand, buyers are DSOs and corresponding TSOs if the platform allows for coordination between them. On the other hand, sellers are FSPs that residential and business customers can form, and other asset owners, such as EV charging points or generators, municipalities, or communities, which can be aggregated by specialized operators acting as aggregators. Furthermore, in NODES, the role of BRPs in the interaction of the activation of flexibility bids with the existing energy and balancing markets is clearly identified.

Table 2. Market structure of the market platforms.

Market Platforms	Characterization	Buyer	Seller
Cornwall LEM	Two-sided market.	ESO [1] and DSO.	Aggregators, residential, and businesses.
Enera	Two-sided market.	TSO and DSO.	Aggregators and asset owners.
GOPACS	Two-sided market.	TSO and DSO.	FSPs: Residential, commercial, industry, and energy companies.
NODES	Two-sided market.	TSO, DSO, and BRP.	FSPs: BRP, microgrid, and aggregators (prosumers, active demand-supply).
Piclo Flex	Auction single buyer.	DSO	Aggregators, asset owners, consumers, community and municipality, EVs, and generators.
CoordiNet	One-sided markets and P2P markets are being tested depending on the coordination scheme and the services and products to be traded [38].	TSO, DSO, Commercial party, and Peers.	FSPs, aggregators, and generation asset owners.
INTERRFACE	Nine possible market options can be adopted for the implementation of the services of congestion management and balancing, details in [44]	TSO, DSO, and Peers.	Aggregators, FSPs: consumers, EVs, generation asset owners, and storage.
InteGrid	Decentralized single-buyer markets. Both DSO and TSO have their own markets. The grid and market hub act as a centralized data platform.	TSO and DSO.	Virtual Power Plant (VPP), LV Consumers (using the Home Energy Management System).
EU-SysFlex	Single-buyer market. In some cases, there is no market, and the service provision is mandatory (e.g., BUCs for the German demonstrator).	TSO and DSO.	Aggregators and generation assets.
GOFLEX	Single-buyer market.	DSO	Aggregators, batteries, generation asset owners, microgrids, and prosumers.
DRES2Market	Not defined yet, but the project is focused on the participation of DG in the wholesale and ancillary services market.		DG is based on renewable energy.
InterFlex	Single-buyer market (Dutch and French demos).	DSO	Aggregators, consumers, EVs, DG, and storage.
IREMEL	Two-sided market: 4 different market models are considered using global and local approaches.	TSO and DSO.	Aggregators, consumers, and generation asset owners.

[1] Electricity System Operator in the UK: National Grid ESO.

As reported in Table 2, the market characterization of each initiative varies according to the demos and the countries where they are implemented. The majority corresponds to a one-sided market where FSPs compete to fulfill the service requirements or needs set by the DSOs or/and TSOs. The exceptions are Cornwall LEM, Enera, GOPACS, NODES, and IREMEL that have been designed as a two-sided market. Here, market participants (buyers and sellers, directly or through intermediaries) determine the demand and supply sides in a market exchange, and through a market-clearing, determine the cleared prices and quantities. For instance, in GOPACS, flexibility bids are matched when they are adequately located in the network to solve the selected congestion, and the DSO or TSO pays the price difference between the matched buyer and seller offers.

Furthermore, in the Swedish demo of CoordiNet, the flexibility market for congestion is day-ahead but is run before the Nord-Pool day-ahead energy market. In this way, BRPs participating in the CoordiNet congestion market may adjust their consumption/production in the Nord-Pool market. The buyers of flexibility services in CoordiNet, EU-SysFlex, and INTERRFACE are both TSOs and DSOs, with different coordination structures for clearing the markets and flexibility activation. In InteGrid, the buyer of services is mainly the DSO acting in a separate platform from the one of the TSO. Therefore, it is a decentralized decision-making process. The sellers of flexibility are FSPs, aggregators, and asset operators. The applications demonstrated in InteGrid and EU-SysFlex are based on the concept of virtual power plants and low voltage customers with home energy management systems acting as sellers of flexibility.

With regards to P2P markets, some are being tested in demonstrations of CoordiNet and INTERRFACE. Part of the Swedish demo in CoordiNet aims to enable a P2P market to handle temporary congestions among peers when production is curtailed. The purpose of using a P2P market is to give flexibility for producers to either sell their capacity or to buy capacity during the curtailment period [45].

Regarding market structure, another important feature is what the services and products to be traded are. According to Table 3, the type of services and products vary depending on the projects and demos. The services identified include balancing, improving network congestion management, voltage control, controlled islanding, restoration support, among others. This summary is illustrated for the two groups analyzed in this study,the market and aggregator platforms.

Table 3. Services and products in the new flexibility market models.

Services	Products	Market Platforms	Aggregator Platforms
Balancing	FCR	EU-SysFlex, INTERRFACE	TIKO
	aFRR	EU-SysFlex, INTERRFACE	Equigy, TIKO
	mFRR	CoordiNet, EU-SysFlex InteGrid, INTERRFACE, NODES	
	RR	CoordiNet, EU-SysFlex InteGrid, NODES	
Congestion Management	Capacity	CoordiNet, Cornwall LEM, EU-SysFlex, Enera, InteGrid, InterFlex, INTERRFACE, NODES, Piclo Flex.	
	Activation	CoordiNet, Cornwall LEM, EU-SysFlex, GOFLEX, GOPACS, InteGRid, InterFlex, INTERRFACE, Piclo Flex	Quartierstrom 1.0 Repsol Solmatch
Voltage Control	Steady-state reactive power	CoordiNet, EU-SysFlex	
	Dynamic reactive power	CoordiNet	
	Active power	CoordiNet, EU-SysFlex, InteGrid, Piclo Flex	
Controlling Islanding		CoordiNet	
Restoration Support		Cornwall LEM	
Relation with ID Market		Enera, GOPACS	

4.3. Market Timing and Implementation

Table 4 describes the main attributes of the market platforms regarding pricing methods, market frequency, bidding periods, settlement, and integration with existing energy markets. In addition, the market operator incomes are specified.

Starting with the commercial platforms, we can observe that the NODES, GOPACS, and Enera markets are synchronized with existing intraday continuous markets in Nord Pool, ETPA, and EPEX SPOT, respectively, with trading intervals of 15 min blocks in Enera. However, Cornwall LEM and Piclo Flex are based on auctions that can be called according to the needs of DSOs. In the case of Cornwall LEM, market sessions typically take place on a daily basis for flexibility reserve and utilization. In contrast, in the case of Piclo Flex, auctions are organized much more in advance, with a lead-time of at least six months for booking long-term flexibility contracts.

In general, the pricing method is pay-as-bid in line with continuous trading and selecting bids that are solving local congestions located in their respective order books. The only exception to this rule is Cornwall LEM that organizes auctions separated from the functioning of the UK existing markets, and the winners are paid-as-cleared.

As a rule, the settlement of the market is always made through the corresponding platform. Moreover, the market operator incomes in the commercial platforms are mainly paid by DSOs. In Cornwall LEM, buyers are invoiced by LEM for the aggregated service, and sellers have contracts with LEM to use the platform. In Enera, research funds are used to maintain the platform in service at this pilot stage.

Concerning research and innovation projects, it was observed that market timing attributes are dependent on the demo characteristics, and in general, there is a great variety in the experiments and designs. Nevertheless, research projects do aim to integrate flexibility markets into existing electricity markets. For instance, in the CoordiNet and INTERRFACE demos, the platforms exchange information with parallel existing day-ahead, intraday, and balancing markets. In this way, market participants or BRPs are aware of their position, resulting in each flexibility market, and they can adjust that position in the following energy or balancing market. In InteGrid, the integration between the DSO congestion and voltage control market and the TSO balancing market is achieved by a traffic light system and exchanging the information through a data hub. In EU-SysFlex, two market operators are identified for TSO and DSO services, and these market operators run in parallel to the day-ahead and intraday markets. For IREMEL and DRES2Market, the market operator who runs the day-ahead and intraday energy market also manages the flexibility market.

Finally, regarding the market operator incomes, we can highlight that in CoordiNet, the flexibility platforms will be operated by the network operators TSO and DSOs. Furthermore, in InteGrid, InterFlex, and GOFLEX, the market hub is considered a market facilitator, which must presumably be remunerated by its users.

Table 4. Market timing of the market platforms.

Market Platforms	Pricing Method	Market Frequency	Bidding Period	Settlement	Incomes of Market Operator	Integration with existing markets
Cornwall LEM	Pay-as-clear	Regularly scheduled closed-gate auctions for reserve and utilization [33].	Before the closed gate of the auction.	Utilization payments (delivery percentage), Reserve payments (reconciled monthly).	The legal relationship for flex service delivery exists between buyer and seller directly, but LEM invoices buyers for the aggregated service, and sellers have contracts with LEM to use the platform [33].	No integration, but auctions run Day-ahead: Utilization. Intraday: Reserve and Utilization.
Enera	Pay-as-bid	Clearing period: ID trade interval (15 min), Gate closer: 5 min before delivery, Delivery period analog to ID: 15 or 60 min.	Continuous process, then bids are matched by the platform.	Dispatch payment: By the end of each month, all produced trades are collected and billed to respective market participants.	Research funds.	Enera is based on ID timeframe and operated with "local order books" shared by the local impact on the network. Enera is not an energy market, and the requirements for participation are much higher than those in the ID market.
GOPACS	Pay-as-bid	Continuous market. Congestion forecasts are launched when needed by the grid operators.	Before intraday gate closure time.	Carried out by the market platform.	FSPs participating in ETPA are charged with an entry fee, a monthly fee, and a fee per interchanged MWh. Grid operators owe a fee to the market platform for the use of IDCONS [35].	Fully integrated with the ETPA (continuous trading platform in the Netherlands).
NODES	Pay-as-bid	The timeframe will be configurable per region and markets, and it will be compatible with imbalance settlement in existing markets [5].	All orders are automatically matched or picked from an order book, will be activated by the buyer.	Settlement takes place monthly. The FSP submits the baseline for its asset.	Mainly contracts with the DSOs, also TSO has availability	NODES is not linked to the wholesale market yet, but it is testing with different providers and the TSO operating procedures.
Piclo Flex	Pay-as-bid	Auction based.	Tenders are organized with a lead-time of 6 months or more. Contract durations can go from a few months to 4 years [46].	Remuneration: Dispatch payment, availability payment, dispatch, and availability payment [5].	Signed commercial agreements with DSOs. The agreements will allow DSOs to use Piclo's flexibility marketplace to procure flex and other 'smart' energy services.	Separate platform from the existing sequence of electricity markets.

CoordiNet	Pay-as-clear and pay-as-bid are used. It depends on each BUC, details in [45].	It depends on each BUC details in [45]: ES-1a (once per day and every day for DA, whenever needed for real-time), SE-1a (once per day, 5 days a week), GR-2a (once per day for DA and ID, every 15 min for real-time), etc.	It depends on each BUC, before gate closure time, for example, ES-1a: before 13:15 in the DA.	It depends on each BUC, e.g., ES-1a: After real-time, the CoordiNet platform performs the settlement of congestion management services with the FSP. The FSP will perform the individual settlement with the resources [47].	For practical reasons, the platforms will be located on the TSO and DSO premises. Thus, network operators operate the market platform for flexibility procurement.	CoordiNet platforms achieve flexibility integration to participate in the day-ahead, intraday, and/or balancing market.
IN-TERRFACE	Pay-as-bid	This project is at an early stage. There are pre-agreed tariffs in some demos [48].	There are different timeframe markets: day-ahead, intraday, real-time, long-term.	To be defined.	To be defined.	The integration with the existing markets will depend on the market design of each demo. For the market models 1A and 2B, the congestion management and balancing markets are completely separated, so [48] proposes a time-sequential integration for these markets where the opening and closing of markets are coordinated based on the needs of the market participants.
InteGrid	In principle, pay-as-bid [7]. It depends on the System Operator.	Possibly day-ahead and/or intraday. Open for definition by the DSO [7].	Open for definition by the DSO [7].	Not tested [7].	The market operators are also the SOs. Nevertheless, the gm-hub acts as a market facilitator and should be remunerated [49].	The grid and market hub and the traffic light system act to promote the integration of DSO (congestion management and voltage control) and TSO (balancing) markets.
EU-SysFlex	Diverse pricing mechanism (market or regulated fee, pay-as-bid or pay-as-clear, remunerated quantities), details in [41].	It depends on each BUC, details in [41]. For example, once per day for DA in the FI-AP1 Finnish demo BUC.	It depends on each BUC, details in [41]. For instance, in the FI-AP1 Finnish demo, BUC bids are sent to the market operator before 18.00 (D-1).	It depends on each BUC [41]. FI-AP1 BUC: (1) Aggregator sends the invoicing data to the TSO, (2) Payments: capacity fee and energy fee based on market-clearing.	Not in the scope of the research project	The Finish, Italian and Portuguese VPP BUCs active power ancillary services markets are fully integrated with the existing TSO ancillary services markets. On the other hand, in the case of the Finish and Portuguese reactive power markets, those innovative markets were designed by EU-Sysflex and are not integrated with existing markets.
GOFLEX	The price formation mechanism depends on the market purpose and is different for each demonstrator.	ATP supports trading in so-called delegated and direct trading modes. These two general trading modes will be provided for use in the GOFLEX demonstration cases. In [43], a description of the flex-offer generation, negotiation,		Delegated trading: Periodically, e.g., every month. Aggregators receive revenues from parties that bought adaptation	In most demos, the DSO is implementing the market. Apart from direct fees from market participants, other sources of income are associated with the	Markets tested at GOFLEX are not directly integrated with other existing markets. However, Flex-Offers issued at GOFLEX markets may compete with offers issued in other mar-

		planning, control, and settlement phases of these trading modes is presented.		capacity on the market. Direct trading acts similarly [43].	markets, such as hardware sales, balance energy cost reduction, peak power reduction, etc.	kets as the DSO has the option to procure flexibility from existing markets or GOFLEX markets.
InterFlex	Pay-as-bid. There is another component of the price called 'Sanctioning Price.' In the FlexOffer, the aggregators decide their sanction and price, which should be between zero and the maximum sanction price [50].	Continuous auctions.	DA trading is done before the DA gate closure time. ID trading before the ID gate closure time.	In the French demo: fixed price; aggregators committed to activating in D-N are remunerated for their future availability (€/kW) and pay penalties if they do not bid in D-1, or if their flexibility is not available.	Not in the scope of the research project.	It is decided to align the trading of flexibility with the trading in the wholesale markets [50]. Commercial aggregators participating in the InterFlex market try to maximize their profit; thus, they participate in other wholesale markets. But the DSO platform is not integrated with either the wholesale or the TSO markets.
IREMEL	Pay-as-clear (ID auctions) or pay-as-bid; (continuous ID market).	The activation horizon is DA and ID. In the local market, the activation horizon may depend on procurement processes, not necessarily day or intraday.	Periodically closed gate auction (DA and ID auctions).	To be defined.	To be defined by the global/local market.	The possibility of integrating the different global and flexibility markets into the same system will be considered, using the same billing cycle and collections and payments and optimizing the management of the payment guarantees necessary to cover possible default risks.

5. Aggregator Platforms Analysis

5.1. Description of Aggregator Platforms

Table 5 presents the descriptive attributes for all four selected platforms. On the one hand, TIKO and Equigy can be distinguished by their different level of maturity. While TIKO started in 2014 and is fully operational, Equigy started recently as a pilot project involving three European TSOs. In TIKO, behind-the-meter assets in households are clustered to provide primary and secondary regulation to the Swiss TSO. TIKO is also operating as a technology provider for these types of applications in Austria, France, Belgium, and Germany. Equigy is a blockchain platform that aggregates small consumer-based resources to participate in TSO balancing markets with a European standard design covering Germany, the Netherlands, Switzerland, and Italy markets.

On the other hand, Quartierstrom 1.0 and Repsol Solmatch are very recent initiatives. Quartierstrom 1.0 started first in 2019 but still operates as a pilot project, while Repsol Solmatch began in 2020 directly under commercial operation. Quartierstrom 1.0 is based in Switzerland as a blockchain platform for energy trading among prosumers with solar PV installations together with the local utility. Solmatch is a Spanish initiative promoted by the Repsol supplier to trade energy between 'roofers' (consumers with solar PV installations in their premises) and 'matchers' (consumers that belong to the same community defined by a 500-meter radius). Repsol installs and maintains the PV installations and acts as a supplier of both 'roofers' and 'matchers'.

Finally, it is important to note that the network scope of these initiatives is generally focused on low voltage levels, such as in TIKO, Quartierstrom 1.0, and Repsol Solmatch.

5.2. Market Structure

The market structure behind these platforms is simpler when compared to market platforms. Table 6 collects the main attributes for the aggregator platforms. Moreover, the summary of services and products provided by these markets is included in Table 3 of Section 4.2.

TIKO and Equigy, as aggregator platforms, build the portfolio bids from small flexible resources connected to households. These bids are offered in the TSO market platforms that act as a single buyer. Both aggregator platforms interact with the flexibility providers collecting their offers and TIKO as a technology provider, supporting technology deployment that makes it possible to obtain flexibility from households. Quartierstrom 1.0 is a P2P market model for clearing transactions of buying and selling energy between all the participant prosumers, including the DSO local generation, which in Switzerland is not unbundled and acts as a supplier in the market. Repsol Solmatch is the platform used by Repsol to clear energy transactions between 'roofers' that sell energy and 'matchers' that buy this energy. The customized price combines two different energy prices: a price for solar energy and another one for the energy coming from the grid.

5.3. Market Timing and Implementation

TIKO and Equigy are focused on participation in daily TSO balancing markets. In TIKO, the settlement is made first on the TSO balancing platform, and then the TIKO platform settles the payments with the flexibility providers. The Crowd Balancing Platform at Equigy is a pilot that integrates the same settlement that is currently used in the TSO balancing markets (Germany, Netherlands, Switzerland, and Italy) and simultaneously with many small market participants through blockchain.

Table 5. Description of the aggregator platforms.

Aggregator Platforms	Ownership	Countries of Application	Network Scope	Definitions and Motivations	Main Functions
TIKO, Operation: 2014–to date	TIKO	Switzerland (Aggregator), Austria, Belgium, France, and Germany (Technology providers).	Low voltage level DSO grid.	It aims to build a solid and reliable smart grid focused on releasing all the potential behind-the-meter assets in households. In Switzerland, TIKO acts as an aggregator [51]. The flexibility of the aggregated load's main contribution to the grid operation is primary and secondary regulation.	As an aggregator: Capacity planning to create market bids, Demand management, Forward bids to the TSO market of ancillary services, Settlement, and Manage financial guarantees.
Equigy, Pilot: 2020–to date	The project was launched by TenneT (TSO in Germany and the Netherlands) in collaboration with SwissGrid (Swiss TSO) and Terna (Italian TSO).	Germany, Italy, Netherlands, and Switzerland.	All voltage levels in the grid.	A blockchain-based platform that incorporates small and distributed consumer-based resources into the electricity grid-balancing process [24]. Objectives: (1) To create European standardization of TSO-market interfaces while maintaining independence in national markets; (2) to share a common core to leverage synergies across markets; and (3) to socialize the relevant costs as much as possible between TSOs.	Collecting flexibility bids, Market clearing and sending activation signals to flexibility providers, Collecting aggregated measurements from the BSP and individual measurements for each device from Measurement Service Providers (MSPs), Correcting imbalance together with the BRP, Settlement, and Managing financial guarantees.
Quartierstrom 1.0, Pilot: 2019–2020	The project has been supported by the Swiss Federal Office of Energy in cooperation with the local utility company EW Walenstadt.	Switzerland	Low voltage level DSO grid.	Quartierstrom 1.0 creates a local P2P marketplace for locally generated solar power. The marketplace is implemented on a permissioned Blockchain governed by all prosumers. The utility participates in the market as the collector of grid usage tariffs and as a fallback-prosumer for any mismatch between market and physical power flows [52].	Collecting bids from consumers and prosumers, Market clearing, Power measurement, Settlement, and Managing financial guarantees.
Repsol Solmatch, Operation: 2020–to date	Repsol	Spain	Low voltage level in urban areas.	Initiative to create solar communities in urban areas. Solmatch's business model benefits from the new shared-self consumption regulatory frame in Spain, allowing energy sharing within a 500-meter radius [53].	Main functions [54]: (1) Feasibility study and design of the PV plants; (2) installation and maintenance of the PV plant; and (3) managing electricity supplied to households. (Solar power when available or grid power instead).

The pilot at Equigy highlights how to enlarge existing wholesale markets to enable the participation of many smaller active participants directly through adequate technology, such as Blockchain. The Quartierstrom 1.0 pilot runs a market with 15 min periods as intraday auctions. The clearing is made bilaterally between seller and buyer offers through an order book based on Blockchain. The excess bids that cannot be matched between the local offers are settled at existing tariffs with the local utility. The Repsol Solmatch commercial platform settles transactions based on agreed tariffs offered by the supplier Repsol to 'roofers' and 'matchers'. The primary incomes for the supplier come from monthly fees paid by matchers participating in the solar community and the margins obtained from the energy tariffs agreed with 'roofers' and 'matchers.'

In general, the platforms promoted by suppliers for local trading between prosumers represent business opportunities that take advantage of existing tariffs or regulations, e.g., shared self-consumption or subsidies to energy communities. This can be considered as opportunistic behavior of suppliers that profit from that. Still, at the same time, they are contributing to the policies that aim to empower consumers and put them in the center of the energy transition. Table 7 summarizes the commented market timing and implementation features.

Table 6. Market structure of the aggregator platforms.

Aggregator Platforms	Characterization	Buyer	Seller
Equigy	Single-buyer	TSO, DSO	Flexibility providers: aggregators, EVs, batteries, heat pumps, home storage systems, etc.
Quartierstrom 1.0	P2P Market	Prosumers (solar PV, batteries), and consumers (households).	Prosumers (solar PV, batteries).
Repsol Solmatch	Solmatch cannot be considered a local market. Instead, it can be seen as an innovative energy supply business model. Repsol puts prosumers that agree to install PV panels in their roof (Roofers) in touch with households willing to consume this solar energy in a 500-meter radius (Matchers) [54].	Repsol to Roofers.	Repsol to Matchers.
TIKO	TIKO participates in the Swiss ancillary services market in the role of Aggregator.	TSO from TIKO, and TIKO from flexibility resources.	TIKO to TSO, and flexibility resources to TIKO.

Table 7. Market timing of the aggregator platforms.

Market Platforms	Pricing Method	Market Frequency	Bidding Period	Settlement	Incomes of Market Operator	Integration with Existing Markets
Equigy	It depends on the product provided and the regulation from the corresponding TSO [55].			The Crowd Balancing Platform carries out the settlement.	It is not designed for commercial purposes.	Equigy's Crowd Balancing Platform integrates TSOs ancillary service markets from the Netherlands, Germany, Switzerland, and Italy.
Quartierstrom 1.0	A double auction with discriminative pricing, this means that for each trade, the price is derived as the mean between the respective buyer's and seller's price bid [56].	Bids are automatically cleared and settled every 15 min through a blockchain-based mechanism [52].	Market participants set a buy/sell price limit. Bids are sent automatically by the smart meter.	The blockchain platform carries out the settlement. Measurement data is acquired and processed by smart meters.	Quartierstrom 1.0 receives payments from each kWh traded in the grid and from the grid usage tariff.	No integration. However, the implementation integrates the local utility company in the market. Therefore, all excess bids which cannot be filled with local supply or demand are assigned to the utility provider at existing tariffs.
Repsol Solmatch	Roofers and matchers have a defined energy tariff contract with Repsol. They agree on two different prices based on the source of the energy consumed, solar or from the grid.	Not applied because Solmatch is not a market platform.		Based on agreed tariffs	Repsol primary income sources are: - Monthly fees from matchers participating in a solar community (2.99 €/month). - Payments from roofers and matchers energy tariffs.	No integration.
TIKO	Based on market rules of Swiss TSO balancing services [57].			Payments from the TSO to TIKO and then TIKO to flexibility resources.	TIKO's main incomes are revenues from services for the grid and consumer payment (equipment sale, subscription).	TIKO participates in the Swiss ancillary services market.

6. Discussion on Policy Implications and Future Research Directions

As illustrated in previous sections, the implementation of the flexibility market models has many design challenges to be considered, and complex coordination with existing markets and different roles for involved agents are required. Therefore, this section highlights a range of policy implications and future research directions in implementing these market models.

6.1. Policy Implications

(1) New roles and responsibilities of DSOs*:* Several policy and regulatory barriers need to be resolved to enable the full operability of flexibility markets. For example, the role, functions, and responsibilities of the different agents involved in flexibility markets still need to be defined. Particularly, the tasks performed by DSOs may vary depending on the market design and the regulatory framework, which is still to be developed. For some traditional roles, such as determining or solving network problems, it is clear that the DSO is better placed to perform them. However, some functions in the local flexibility markets, including prequalification, settlement, market-clearing processes, etc., are not fully defined as to who will perform them. As stated in [58], DSOs have no or little experience operating a marketplace to procure grid services. Moreover, due to neutrality being required for operating a market, a neutral entity can ensure fair and equal treatment of all market participants and the correct operation of a local flexibility market. Therefore, an independent market operator can perform certain functions related to the procurement of grid services. Furthermore, there is uncertainty regarding what services the DSOs will be able to procure from the market and what they will be managing themselves as the network operator. Thus, clarification should be made regarding DSO functions to ensure a competitive marketplace.

(2) Role of Aggregator: According to [59], the two leading roles of the aggregator can be summarized as a flexibility expert and market expert. As flexibility experts, they sum up small flexibility capacities from individual DERs, so the final amount is large enough to build marketable flexibility products. On the other hand, one of the main functionalities of the aggregator as an independent market participant is to assume, develop, and excel in the role of a market expert on behalf of its aggregated portfolio, to maximize its value through time. Furthermore, FSPs, DSO, and TSO are linked to the aggregator through a communication interface, allowing it to evaluate the capability to provide power and energy services. Although there are various opportunities for aggregation business models, there are also many regulatory barriers that need to be removed for the participation of aggregators in the wholesale and ancillary services markets, especially with regards to independent aggregation [60].

(3) Regulatory barriers and sandboxes: The development of flexibility markets encounters several challenges, which vary from technical, economic, stakeholder, environmental, and regulatory barriers. As highlighted in [61], national regulations and the lack of regulation incentives are identified as the principal barrier to create local flexibility markets. Therefore, regulatory sandboxes could be used to overcome this gap. A sandbox brings an adaptive regulatory approach that facilitates regulatory analysis and provides an environment for innovation. Here actors can operate out of the conventional regulatory framework for a certain period of time, and this would allow testing new services and products that are not yet stipulated or permitted under the existing regulation. For instance, reference [62] identifies the main barriers that prevent the implementation of flexibility mechanisms by DSOs in Spain and then presents a proposal for a regulatory sandbox in this context. Furthermore, [63] examines current barriers for market access flexibility resources in five European countries, focusing on regulatory, technical, and economic aspects with the purpose of providing relevant country-specific recommendations.

(4) Flexibility remuneration mechanisms: The procurement of local flexibility requires an adaptation in the economic regulation of DSOs. In this new context, OPEX should increase by the inclusion of costs associated with flexibility procurement. By contrast, costly CAPEX on grid reinforcements are expected to be reduced, either by deferment or avoidance of investments, as local flexibility will be used to keep grids within limits [1]. Therefore, new regulatory frameworks should incorporate mechanisms that not only allow DSOs to procure system flexibility services but also to ensure the recovery of flexibility procurement costs and provide economic incentives for the use of local flexibility as an alternative for grid reinforcement.

6.2. Future Research Directions

According to the findings of this paper, further research may be accomplished in the following areas.

(1) Mechanisms for procuring grid services: The DSO has different mechanisms to procure flexibility, both market- and non-market-based alternatives. In this paper, we focus on the analysis of flexibility markets; however, more regulated mechanisms, such as access and connection agreements, dynamic network tariffs, bilateral contracts, regulated cost-based remuneration, and obligations for suppliers, are alternatives when markets cannot work correctly due to market failures or implementation costs. Each of the mechanisms has different design elements that should be carefully considered when applied in different jurisdictions to provide adequate solutions to the DSO's needs. Therefore, specific features of these mechanisms and a combination of them for acquiring grid services could be explored in future research.

(2) Flexibility markets structure: The organizational structure of the flexibility markets requires a series of functions divided into five main phases [64]: the preparation phase, forecasting phase, market operation/bid selection phase, monitoring and activation phase, and measurement and settlement phase. In this study, we have analyzed some of them; for example, in Tables 1 and 5, we listed the main functions performed by the market and aggregator platforms, respectively. Furthermore, in Tables 4 and 7, some market operation/bid selection functions and settlement phases were illustrated. Future studies should examine the selected initiatives in terms of the preparation phase (product definition, registration, and prequalification) and monitoring and activation phase to produce insights based on these functions.

(3) Services and products characteristics: This study identified services and products of the selected new flexibility market models according to Table 3. Products can be grouped into standard products and specific products, which can be described by a set of technical attributes. One of the main benefits of harmonized products is the increased standardization and, therefore, the better comparability of bids and lower entry barriers for FSPs. However, we should also consider those specific characteristics of the DSOs' needs would require specific product parameters, making product standardization not always desirable. Thus, the definition of product characteristics is a crucial aspect that should be addressed in the preparation phase of flexibility markets. This is being developed in some European research projects such as CoordiNet, where one or more standard products are defined for each of the grid services, with some commonly defined attributes [38].

(4) Additional implementation considerations: On a wider level, research is also needed to examine additional implementation aspects in flexibility markets, such as metering requirements, baseline methodologies, and TSO/DSO coordination principles. For instance, the requirements for the resolution of metering data depend on the services provided and on the settlement period. As a minimum requirement, the granularity of the metering data shall be higher than the one used for the settlement period. On the other hand, the baseline methodology is critical because payments for FSPs are directly based on the difference between the baseline and actual metered demand. Therefore, an optimal

baseline methodology is necessary to measure the effective performance of a demand resource and to compensate the FSP adequately. In general, five baseline methodologies are considered: a historical data approach, statistical sampling, maximum base load, meter before/meter after, and metering generator output [45]. Finally, it is relevant to highlight that the coordination between DSOs, TSOs, market operators, and aggregators is in the process of being defined and evaluated in current research initiatives such as CoordiNet, INTERRFACE, and OneNet [31].

7. Conclusions

We have analyzed the new flexibility markets in Europe focused on market description, market structure, and market timing and implementations. Taken together, the analysis suggests the following trends and insights.

Firstly, some market platforms are promoted and managed by actual market operators, such as Nord Pool in NODES and EPEX SPOT in Enera. They extend their functions from well-established wholesale energy markets to other network services for DSOs in coordination with TSOs. An important issue that differentiates the analyzed initiatives is how these flexibility markets for congestion management are integrated with the existing energy markets. Here, the expertise of market operators can be very relevant to make this interface simple and effective for all participating FSPs. However, FSPs participating in congestion management markets may be subject to imbalances depending on the overall market design. For this reason, the interactions between these new congestion management market platforms and existing wholesale and balancing markets are a key aspect in fostering FSP participation and creating an efficient environment for local flexibility provision. Furthermore, the involvement of DSOs and TSOs in these new models is essential as they are the users of the flexibility. Hence, it is recommended to use the experience and knowledge available to develop and implement a flexibility mechanism linking existing markets with the participation of DSOs and TSOs.

Secondly, the selected market platforms reinforce the importance of incorporating DER flexibility into the markets. They focus primarily on the new roles of DSOs when procuring flexibility for solving congestion and network problems under market-based approaches. As shown in Section 4.2, many new services and products are being demonstrated in experimental platforms by research and innovation projects. These services include balancing, congestion management, voltage control, and controlled islanding, directly affecting DSOs in coordination with TSOs. Although most pilot platforms being demonstrated are still not ready for a large-scale commercial deployment, certain market platforms have demonstrated, in some cases and for some solutions, that it is possible as of today. For instance, NODES as an independent market operator is addressing the trading of flexibility in two locations, in Norway and Germany, since 2018. Furthermore, in 2019, the Cornwall LEM enabled a DSO and the National Grid ESO of the UK to buy flexibility in a coordinated way via a local third-party platform.

Thirdly, the second group of analyzed new flexibility markets corresponds to aggregator platforms. On the one hand, TIKO and Equigy are totally aligned with the market models previously described. There is a need for specialized aggregators that cluster small DER, even at a household level, to offer services to the TSO's balancing markets. On the other hand, suppliers also have developed platforms, acting as aggregators, by promoting P2P transactions among customers. In some cases, they have a clear opportunistic justification, taking advantage of some benefits that arise from actual legislation, promoting, for instance, energy communities or shared renewable self-consumption. Nevertheless, they contribute to enhancing the political vision of empowering the customers through their active participation in electricity markets.

Overall, these results provide compelling evidence that the new market models that incentivize the uptake of flexibility from small DER, even at a household level, aiming at providing services to DSOs and in coordination with TSOs, is a promising business with technical and economic justification. However, to facilitate their deployment, the policy implications discussed in Section 6 need to be addressed, where it was highlighted that regulatory sandbox frameworks could aid regulators and policymakers in testing these flexibility platforms. The sandboxes' experiences could serve as the basis for developing new regulations, enabling the implementation of these innovative market models.

In conclusion, across the new market models under analysis, congestion management at the local level/network is identified as the main priority for platform developers. However, the same DER would become active participants in existing electricity markets, namely, wholesale and balancing markets. Consequently, these markets should be adapted to incorporate the ever-growing number of resources and associated aggregators. Finally, the so-called P2P trading in local and limited scope platforms may have an opportunistic interest, but their continuity and sustainability in the long term are still to be proven.

This paper has also identified future areas that need to be studied to determine the overall impact of new flexibility market models, namely, (i) the development of mechanisms for flexibility procurement; (ii) the structure of the flexibility market; (iii) the definition of services and product characteristics; and (iv) additional considerations, such as metering requirements, TSO-DSO coordination, and baseline methodologies.

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Abbreviations

aFRR	Frequency Restoration Reserves with automatic activation
ATP	Automatic Trading Platform
BRP	Balancing Responsible Party
BUC	Business Use Case
CAPEX	Capital expenditure
DA	Day-ahead market
DER	Distributed Energy Resource
DG	Distributed Generation
DR	Demand Response
DSO	Distribution System Operator
ESO	Electric System Operator (UK)
ETPA	Energy Trading Platform of Amsterdam
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FMAN	Flex-Offer Manager
FMAR	Flex-Offer Market
FOA	Flex-Offer Agent
FSP	Flexibility Service Provider
ID	Intraday market
IDCONS	Intraday Congestion Spread
IEGSA	Interoperable pan-European Grid Services Architecture
LEM	Local Energy Market

LV	Low Voltage
mFRR	Frequency Restoration Reserves with manual activation
MV	Medium Voltage
OMIE	Iberian Electricity Market Operator (Spain)
OPEX	Operational expenditure
OPF	Optimal Power Flow
P2P	Peer-to-peer
PV	Photovoltaic
RR	Replacement Reserves
TSO	Transmission System Operator
VPP	Virtual Power Plant
WPD	Western Power Distribution (UK)

References

1. Minniti, S.; Haque, N.; Nguyen, P.; Pemen, G. Local markets for flexibility trading: Key stages and enablers. *Energies* **2018**, *11*, 3074, doi:10.3390/en11113074.
2. European Commission. Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on Common Rules for the internal market for electricity and amending Directive 2012/27/EU (Text with EEA relevance). *Off. J. Eur. Union* **2019**, *62*, 125–199.
3. Gerard, H.; Rivero Puente, E.I.; Six, D. Coordination between transmission and distribution system operators in the electricity sector: A conceptual framework. *Util. Policy* **2018**, *50*, 40–48, doi:10.1016/j.jup.2017.09.011.
4. Zhang, K.; Troitzsch, S.; Hanif, S.; Hamacher, T. Coordinated Market Design for Peer-to-Peer Energy Trade and Ancillary Services in Distribution Grids. *IEEE Trans. Smart Grid* **2020**, *11*, 2929–2941, doi:10.1109/TSG.2020.2966216.
5. Radecke, J.; Hefele, J.; Hirth, L. *Markets for Local Flexibility in Distribution Networks*; ZBW—Leibniz Information Centre for Economics: Kiel/Hamburg, Germany, 2019.
6. Schittekatte, T.; Meeus, L. Flexibility markets: Q&A with project pioneers. *Util. Policy* **2020**, *63*, 101017, doi:10.1016/j.jup.2020.101017.
7. Gouveia, C.; Alves, E.; Villar, J.; Ferreira, R.; Silva, R.; Chaves Ávila, J.P. *EUniversal—D1.2: Observatory of Research and Demonstration Initiatives on Future Electricity Grids and Markets*; 2020. Available online: https://euniversal.eu/wp-content/uploads/2021/02/EUniversal_D1.2.pdf (accessed on Jun 12, 2021).
8. Jin, X.; Wu, Q.; Jia, H. Local flexibility markets: Literature review on concepts, models and clearing methods. *Appl. Energy* **2020**, *261*, doi:10.1016/j.apenergy.2019.114387.
9. Villar, J.; Bessa, R.; Matos, M. Flexibility products and markets: Literature review. *Electr. Power Syst. Res.* **2018**, *154*, 329–340, doi:10.1016/j.epsr.2017.09.005.
10. Cornwall Local Energy Market Project Website. Available online: https://www.centrica.com/innovation/cornwall-local-energy-market (accessed on 27 April 2021).
11. Enera Project Website. Available online: https://projekt-enera.de/ (accessed on 27 April 2021).
12. GOPACS Project Website. Available online: https://en.gopacs.eu/about-gopacs/ (accessed on 27 April 2021).
13. NODES Project Website. Available online: www.nodesmarket.com (accessed on 27 April 2021).
14. Piclo Flex Project Website. Available online: https://picloflex.com/ (accessed on 27 April 2021).
15. CoordiNet Project Website. Available online: https://coordinet-project.eu/projects/coordinet (accessed on 27 April 2021).
16. INTERRFACE Project Website. Available online: http://www.interrface.eu/ (accessed on 27 April 2021).
17. InteGrid Project Website. Available online: https://integrid-h2020.eu/ (accessed on 27 April 2021).
18. EU-SysFlex Project Website. Available online: https://eu-sysflex.com/ (accessed on 27 April 2021).
19. GOFLEX Project Website. Available online: https://goflex-project.eu/ (accessed on 27 April 2021).
20. DRES2Market Project Website. Available online: https://www.dres2market.eu/ (accessed on 27 April 2021).
21. InterFlex Project Website. Available online: https://interflex-h2020.com/ (accessed on 27 April 2021).
22. IREMEL Project Website. Available online: https://www.omie.es/es/proyecto-iremel (accessed on 27 April 2021).
23. TIKO Project Website. Available online: https://tiko.energy/ (accessed on 27 April 2021).
24. Equigy Project Website. Available online: https://equigy.com/ (accessed on 27 April 2021).
25. Quartierstrom 1.0 Project Website. Available online: https://quartier-strom.ch/index.php/qs1-inkuerze/ (accessed on 27 April 2021).
26. Repsol Solmatch Project Website. Available online: https://solmatch.repsolluzygas.com/ (accessed on 27 April 2021).
27. ENEDIS Project Website Available online: https://www.enedis.fr/construct-jointly-local-flexibility-process (accessed on 31 May 2021).
28. EUniversal Project Website Available online: https://euniversal.eu/ (accessed on 31 May 2021).
29. Flexible Power Project Website Available online: https://www.flexiblepower.co.uk/ (accessed on 31 May 2021).
30. sthlmflex Project Website Available online: https://www.svk.se/sthlmflex (accessed on 31 May 2021).
31. OneNet Project Website Available online: https://onenet-project.eu/ (accessed on 31 May 2021).

32. Moreira, R.; Strbac, G. *Business Case for Flexibility Providers: Cornwall Local Energy Market*; 2019. Available online: https://www.centrica.com/media/4378/busines-case-for-flexibility-providers.pdf (accessed on Jun 12, 2021).
33. Woodruff, J. *Visibility Plugs and Sockets: Closedown Report*; 2020. Available online: https://www.centrica.com/media/4383/vpas-phase-1-trial-report-v10-28-10-19.pdf (accessed on Jun 12, 2021).
34. ETPA: Frequently Asked Questions. Available online: https://etpa.nl/wp-content/uploads/2018/06/Frequently_Asked_Questions-15062018.pdf (accessed on 27 April 2021).
35. STEDIN; Liander; Tennet; Enexis. *IDCONS Product Specification: GOPACS*; 2019.
36. NODES. *White Paper: A Fully Integrated Marketplace for Flexibility*; 2018. Available online: https://nodesmarket.com/download/whitepaper/ (accessed on Jun 12, 2021).
37. Piclo. *Flexibility & Visibility: Investment and Opportunity in a Flexibility Marketplace*; 2019. Available online: https://piclo.energy/publications/Piclo+Flex+-+Flexibility+and+Visibility.pdf (accessed on Jun 12, 2021).
38. Delnooz, A.; Vanschoenwinkel, J.; Rivero, E.; Madina, C. *CoordiNet Deliverable D1.3: Definition of Scenarios and Products for the Demonstration Campaigns*; WP1/T1.3; 2019. Available online: https://private.coordinet-project.eu//files/documentos/5d72415ced279Coordinet_Deliverable_1.3.pdf (accessed on Jun 12, 2021).
39. Bachoumis, T.; Dratsas, P.; Kaskouras, C.; Charilaos Sousounis, M.; Martinez Garcia, A.I.; Viachos, I.; Dimeas, A.; Trakas, D.; Botsis, A.; Sideratos, G.; et al. *CoordiNet Deliverable D5.1 Demonstrator Analysis & Planning*; WP5/T5.1; 2020. Available online: https://private.coordinet-project.eu//files/documentos/5e4c2778aea24D5_1 coordinet.pdf (accessed on Jun 12, 2021).
40. Bessa, R. *InteGrid D1.2 Uses Cases and Requirements*; WP1—Use Cases and System Architecture Use; 2017. Available online: https://integrid-h2020.eu/uploads/public_deliverables/D1.2 Read Use Cases and Requirements.pdf (accessed on Jun 12, 2021).
41. Effantin, C.; Loevenbruck, P. *EU-SysFlex D3.3: T3.3 Business Use Cases for Innovative System Services*; WP3/T3.3; 2018. Available online: http://eu-sysflex.com/wp-content/uploads/2019/03/D3.3_Business-Use-Cases-for-Innovative-System-Services.pdf (accessed on Jun 12, 2021).
42. Berlet, R.; von Jagwitz, A.; Jander, D. *GOFLEX D10.2: Demand Side Management, Opportunities and Restrictions in the European Market*; WP10; 2017. Available online: https://www.goflex-project.eu/Deliverables.html (accessed on Jun 12, 2021).
43. Šikšnys, L.; Neupane, B.; Brus, S.; Černe, G. *GOFLEX D2.1: Automatic Trading Platform Requirement & Interface Specification*; WP2; 2017. Available online: https://www.goflex-project.eu/Deliverables.html (accessed on Jun 12, 2021).
44. RSE; EMP; ENTSO; UPRC. *INTERRFACE: D3.1 Definition of New/Changing Requirements for Services*; WP3/T3.1; 2020. Available online: http://www.interrface.eu/sites/default/files/publications/INTERRFACE_D3.1_V1.0.pdf (accessed on Jun 12, 2021).
45. Stevens, N.; Merckx, K.; Cricifix, P.; Gómez, I.; Santos-Mugica, M.; Díaz, Á.; Sanjab, A.; Kessels, K.; Rivero, E.; Mou, Y.; et al. *CoordiNet Deliverable D2.1-Markets for DSO and TSO Procurement of Innovative grid Services: Specification of the Architecture , Operation and Clearing Algorithms*; 2020. Available online: https://private.coordinet-project.eu//files/documentos/6033b5fe475cdCoordiNet_WP2_D2.1_Markets for DSO and TSO procurement of innovative grid services_V1.0_20.02.2021.pdf (accessed on Jun 12, 2021).
46. UK Power Networks. *Flexibility Services Invitation to Tender—2018/19—UK Power Networks (Operations) Limited*; 2018. Available online: https://www.ukpowernetworks.co.uk/internet/asset/9ed338e5-b879-4642-8470-8b90e0a730bJ/Invitation+to+Tender+-+PE1-0074-2018+Flexibility+Services.pdf (accessed on Jun 12, 2021).
47. Chaves-Ávila, J.P.; Gómez San Román, T.; Lind, L.; Sánchez Fornié, M.Á.; Olmos Camacho, L. *CoordiNet Deliverable D3.1: Report of Functionalities and Services of the Spanish Demo*; WP3/T3.1; 2020. Available online: https://private.coordinet-project.eu//files/documentos/5e4c274e8190dD3.1 Coordinet.pdf (accessed on Jun 12, 2021).
48. ENTSO-E; UPRC; EMP; BME; RTU; TUT; RSE; EUI. *INTERRFACE: D3.2 Definition of New/Changing Requirements for Market Designs*; WP3/T3.2; 2020. Available online: http://www.interrface.eu/sites/default/files/publications/INTERRFACE_D3.2_v1.0.pdf (accessed on Jun 12, 2021).
49. Cossent, R.; Lind, L.; Simons, L.; Frías, P.; Valor, C.; Correa, M. *InteGrid D7.5 Business Models to Support the Developed Concepts*; WP7—CBA, Regulatory Analysis and Business Models Business; 2020. Available online: https://integrid-h2020.eu/uploads/public_deliverables/D7.5_Business Models.pdf (accessed on Jun 12, 2021).
50. Van Cuijk, T.; Fonteijn, R.; Geelen, D.; Laarakkers, J.; Rademakers, P. *InterFlex D7.3 Innovative Solutions to be Tested in the Use Cases, Version 1.0*; WP07; 2018. Available online: https://interflex-h2020.com/wp-content/uploads/2020/02/D7.3-Enexis-DEMO-innovative-solutions-to-be-tested-in-the-use-cases_Enexis_InterFlex.pdf (accessed on Jun 12, 2021).
51. Schweren, K. *Tiko—Delivering Value as Virtual Power Plant & Home Energy Management System*; 2020. Available online: https://ec.europa.eu/energy/sites/default/files/documents/session_2_-_5_katrinschweren_tiko.pdf (accessed on Jun 12, 2021).
52. Brenzikofer, A.; Meuw, A.; Schopfer, S.; Wörner, A.; Dürr, C. QUARTIERSTROM: A decentralized local P2P energy market pilot on a self-governed blockchain. In *Proceedings of the 25th International Conference on Electricity Distribution*; CIRED: Madrid, Spain, 2019.
53. Zannini, A. Blockchain Technology as the Digital Enabler to Scale up Renewable Energy Communities and Cooperatives in Spain. Master's Thesis, Utrecht University, Utrecht, The Netherlands, 2020.
54. Repsol External Relations—Management Division. *REPSOL Launches SOLMATCH, the First Large Solar Community in Spain*; Madrid, Spain, 2020. Available online: https://www.repsol.com/imagenes/global/en/PR30042020_Solmatch_tcm14-176594.pdf (accessed on Jun 12, 2021).
55. Equigy Webinar 2020. Available online: https://www.youtube.com/watch?v=pCUEznpO394&feature=youtu.be&ab_channel=TenneT (accessed on 27 April 2021).

56. Ableitner, L.; Meeuw, A.; Schopfer, S.; Tiefenbeck, V.; Wortmann, F.; Wörner, A. Quartierstrom: Implementation of a Real World Prosumer Centric Local Energy Market in Walenstadt, Switzerland. Available online: http://arxiv.org/abs/1905.07242 (accessed on 27 April 2021).
57. Nousios, D.; Aebi, S. *Swissgrid: Principles of Ancillary Services Products—Products Description*; 2020. Available online: https://www.swissgrid.ch/dam/swissgrid/customers/topics/ancillary-services/as-documents/D201223-AS-Products-V16-en.pdf (accessed on Jun 12, 2021).
58. Chaves-Ávila, J.P.; Troncia, M.; Herding, L.; Morell, N.; Valarezo, O.; Kessels, K.; Delnooz, A.; Vanschoenwinkel, J.; Villar, J.; Budke, J.; et al. *EUniversal: D5.1 Identification of Relevant Market Mechanisms for the Procurement of Flexibility Needs and Grid Services*; 2021. Available online: https://euniversal.eu/wp-content/uploads/2021/02/EUniversal_D5.1.pdf (accessed on Jun 12, 2021).
59. Jimeno, J.; Merino, J.; Cortes, A.; Santos, M.; Sanchez, E.; Camargo, J.; Manna, C.; Verbeeck, J.; Ziu, D.; Marroquin, M. *CoordiNet: D2.3—Aggregation of Large-Scale and Small-Scale Assets Connected to the Electricity Network*; WP2; 2021. Available online: https://private.coordinet-project.eu//files/documentos/6026502c9cb56CoordiNet_WP2_D2.3_Aggregation of large-scale and small-scale assets connected to the electricity network_V1.0_10.02.2021_.pdf (accessed on Jun 12, 2021).
60. Poplavskaya, K.; De Vries, L. A (not so) independent aggregator in the balancing market theory, policy and reality check. In Proceedings of the 15th International Conference on the European Energy Market (EEM), Lodz, Poland, 27–29 June 2018.
61. Valarezo, O.; Chaves-Ávila, J.P.; Rossi, J.; Hillberg, E.; Baron, M. Survey Results on Local Markets to Enable Societal Value. In Proceedings of the 14th IEEE PowerTech Conference, Madrid, Spain, 28 June–2 July 2021. Available online: https://www.iit.comillas.edu/publicacion/mostrar_publicacion_conferencia.php.en?id=11976 (accessed on Jun 12, 2021).
62. Correa, M.; Gomez, T.; Cossent, R. Local Flexibility Mechanisms for Electricity Distribution Through Regulatory Sandboxes : International Review and a Proposal for Spain. In Proceedings of the 14th IEEE PowerTech Conference, Madrid, Spain, 28 June–2 July 2021. Available online: https://www.iit.comillas.edu/publicacion/mostrar_publicacion_conferencia.php.en?id=11975 (accessed on Jun 12, 2021).
63. Forouli, A.; Bakirtzis, E.A.; Papazoglou, G.; Oureilidis, K.; Gkountis, V.; Candido, L.; Ferrer, E.D.; Biskas, P. Assessment of Demand Side Flexibility in European Electricity Markets: A Country Level Review. Energies 2021, 14, 2324. https://doi.org/10.3390/en14082324
64. CEDEC; E.DSO; ENTSO-E; EUROELECTRIC. GEODE TSO-DSO Report: An Integrated Approach to Active System Management Available online: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Position papers and reports/TSO-DSO_ASM_2019_190416.pdf. (accessed on 28 May 2021).