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Review

Assessment of Demand Side Flexibility in European Electricity Markets: A Country Level Review

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Abstract: Power systems in many countries have recently undergone a significant transition towards renewable and carbon-free generation sources. Those sources pose new challenges to the grid operation due to their intermittency and uncertainty. Consequently, advanced policy strategies and technologies offering new flexibility solutions on the inelastic demand side are required to maintain the reliability of power systems. Given the diversity of situations, legislation and needs across European countries and the varying nature of distribution system operators, this article reviews the deployment of demand side flexibility at national level to identify best practices and main barriers. The analysis concerns European countries of different progress in solutions that leverage flexibility towards offering electricity grid services. The scope is to explore the operation principles of European electricity markets, to assess the participation of emerging flexible resources, and to propose new approaches that facilitate the integration of flexible assets in the distribution grid. The countries reviewed are the United Kingdom, Belgium, Italy and Greece. These countries were selected owing to their diversity in terms of generation mix and market design. Barriers for market access of flexibility resources are also identified in order to form relevant country-specific recommendations.

Keywords: demand side flexibility; demand side management; power systems; regulatory principles; flexibility services; distribution system operators

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1. Introduction

Power systems are undergoing deep transformation on the way to clean, decarbonized and more efficient energy generation and consumption mechanisms [1]. This changing environment is particularly characterized by the increasing investments in renewable generation and distributed energy resources (DERs), located both at the transmission and the distribution grids [2]. Those sources are responsible for new challenges posed to the operation of both the transmission grid, where ramping availability needs to be guaranteed by new balancing and frequency services; and the distribution grid, where new flexibility services and investments by the distribution system operators (DSOs) are required to handle reverse power flows, and new congestion and voltage issues [3,4]. Within this framework, and in order to achieve efficient usage of resources at both systems the coordination of transmission system operators (TSOs) and DSOs becomes essential. In parallel, DSOs should be inclined subsequently to long-term planning, also to short-term grid operation tasks [3,5]. To cope with these challenges, DSOs are seeking products and market mechanisms that will enable flexibility towards more active system management and control [6].

A common definition of flexibility is given as the option of adapting generation and/or consumption configurations by responding to external signals (price signals or activation) in order to provide a service towards energy system stability and security by means of cost-effectiveness [3]. Among the usual metrics of characterizing flexibility are the amount of power modulation, duration, rate of change, response time, location etc. Flexibility services were traditionally procured by the TSOs using power plants (conventional thermal and hydro power plants), grid interconnections or large consumers' demand response (DR) programs [3,7]. At present, different stakeholders are involved for flexibility procurement, such as TSOs, DSOs, balance responsible parties (BRPs) for portfolio balancing [8] consumer side agents and DERs' providers [3,9], each of whom addresses diverse operational issues either at the transmission or distribution level [10]. TSOs mainly offer flexibility products for the purposes of power balancing and frequency control, while network (voltages or congestion) management, and local network balancing is a responsibility of DSOs.

Integrating distributed generation and flexible demand requires innovative solutions and an appropriate regulatory framework. In Europe, demand side flexibility (DSF) is recognized as an instrument for the best utilization of current distribution grids and consequently to the best allocation of resources for grid investments. The need for grid flexibility procurement is outlined in the Clean Energy Package [11] for all Europeans, the recent consultation of the Council of European Energy Regulators (CEER) [12] and the TSO-DSO report published as a joint work for active system management between the European Network for Transmission System Operators for Electricity (ENTSO-E) and European associations representing DSOs [13]. A further part of the Clean Energy Package [11] seeks to establish a modern design for the European Union (EU) electricity market, adapted to the new—more flexible, more market-oriented—realities of the market. More specifically the Directive on common rules for the internal electricity market [14] embraces new rules that enable the active participation of consumers, individually or through citizen energy communities, in all markets. Distributed energy technologies and consumer empowerment have made community energy offers an inclusive option to facilitate the uptake of new technologies and consumption patterns, including smart distribution grids and DR, in an integrated manner that best offers flexibility to the network. Despite the existence of a comprehensive European energy policy framework, at national level the progress of enabling flexibility services in the distribution grid and the operation of flexibility markets varies significantly among the different European countries. This mainly depends on the national policies and regulatory frameworks.

Existing papers in the literature that review market tools to enable more active system management and control using flexibility, either focus on specific flexibility solutions (e.g., local markets [15,16], microgrids [17,18] electric vehicles [19,20], peer to peer trading [21,22] aggregators [23,24]), or on market designs that are proposed theoretically (e.g., [25–30]), although not implemented within an actual framework. For example, in [31] the authors review different concepts, mechanisms and market clearing methods to trade flexibility among distribution system operators and other participants (e.g., aggregators). However, the focus is on theoretical potential designs currently found in the literature and not in actual legislative endeavors. In addition, the study is limited on the opportunities explicitly provided within local flexibility markets and does not deal with the overall potential solutions of enhancing system flexibility. Similarly, studies [3,32–35] and [36] attempt to review and classify flexibility products and summarize the main approaches to flexibility markets designs and implementations in a theoretical perspective and based on solutions found in the literature, rather than on actual country implementations. Other papers focus explicitly on reviewing either the opportunities [37], barriers [38,39] or recommendations [10,40,41] on allowing new players within the market, covering only part of the analysis presented in this paper and do not identify targeted country specific barriers and recommendations, which is the intention of this paper. A related study is this of [38] which analyzes frequency regulation markets and mechanisms in order to identify entry barriers for aggregators and relevant options to overcome these barriers. The authors conduct a case study to highlight the situation of four major European frequency regulation markets (France, Germany, Denmark, UK) in 2016.

Other typical analyses found in the literature examine opportunities of demand side flexibility within the broader scope of European level and not in a country specific basis (e.g., [7,16,42–45]). A characteristic example is the paper of [46] which elucidates the reforms arising from the implementation of the European energy policy framework, identifies fundamental barriers for consumer participation and makes several policy recommendations. Emerging innovative market designs for decentralized flexibility within the broader European perspective are also given in [12,47]. As concerns studies on specific country designs on demand side flexibility, few references can be found in some papers and reports (e.g., [48,49]), however these are limited to references in specific market segments (e.g., balancing markets [9,38] local flexibility tenders [50]) and solutions that enable demand participation (e.g., flexibility trading platforms [6,51,52], DR [53,54], residential electricity demand [55,56]), and are not presented as an integrated analysis of the whole electricity market design of the country, and thus do not provide a thorough review of the country progress. Within this framework, paper [6] provides a thorough analysis—albeit still narrow in terms of scope—of four pioneering platforms, which are the most advanced in terms of implementing flexibility markets within Europe. These projects are country specific, found in UK, Germany, the Nordics and the Netherlands, but are yet in a pilot phase and none of them is fully integrated into the existing sequence of EU electricity markets. Relevant projects on pilot market designs and commercial platforms for flexibility services are presented in [51,52]. Papers covering partially the topics addressed in this paper, presenting the situation in certain countries and during previous years, are those of [57] on a review of demand side management policy in the UK, and [58] on DR participation in the markets of Finland, Spain, UK, France and the Netherlands. Reference [50] explores market rules of local flexibility tenders for the participation of DERs and flexibility procurement by DSOs in UK and France, while [59] describes initiatives and policies on DR in UK, Italy and Spain. A more related study is found in [60] which analyzes barriers and enablers of demand participation in four European electricity markets, in Finland, France, Belgium and the UK. However, the analysis is limited to balancing markets and is tailored to demand aggregation.

Last, there exist some country level reviews tailored to other European countries [61] or globally [62,63] that do not consider the situation in the countries analyzed in the current paper. Indicatively, we refer the studies of [64,65] which review enablers and means that could increase flexibility of the Finnish energy systems, reference [66] on flexibility in the Dutch electricity system, reference [67] on DR business models in Serbia, and of [68] which presents a thorough literature review on the topics of storage demand, flexibility requirements, and resource potential in future electricity systems in Europe and especially Germany. Other relevant case studies in Germany include [69] which assesses the flexibility market approaches used in current German research projects; reference [70], which tests the implications of recently proposed local electricity market designs under the current rules in the context of the German market; reference [71] which simulates a flexibility market based congestion management in Northern Germany and also [72,73]. The studies of [74–76] give a global perspective of the challenges and opportunities of demand side management and decentralized energy technologies, particularly presenting the regulations, policies and potential capabilities in Brazil and dynamic pricing programs and DER markets in the United States respectively.

Taking into consideration that DSOs across European countries differ in terms of size and location, as well as on legislation and operational principles, this article reviews the deployment of DSF at national level to identify best practices and main barriers. European countries that have made different progress in solutions that leverage flexibility towards offering electricity grid services are examined within the scope of exploring the operation principles of European electricity markets, assessing the participation of emerging flexible resources, and proposing new approaches that facilitate the integration of flexible assets in the distribution grid. The reviewed countries are the UK, Belgium, Italy and Greece. They were selected due to their diversity in terms of generation mix and market design.

The remainder of the paper is structured as follows: Section 2 provides a review of the current status of integration of emerging flexibility services in European markets, outlining the current enablers and regulatory provisions. In Section 3, the obstacles hindering the deployment of demand-side flexibility are discussed. Section 4 presents proposals and policy recommendations to foster the integration of new flexibility services in Europe, especially in the distribution level. Concluding remarks are given in Section 5.

2. Enablers for Demand Side Flexibility in European Markets: A Country-Level Analysis

This section critically examines current European electricity markets to assess how the emerging flexible resources are incorporated into them. To have a clear and thorough picture of the situation in Europe, different electricity markets are analyzed including two of the most typical markets opened to demand participation in Europe (UK and Belgium), but also some of the less developed (Italy, Greece), highlighting principal enablers and barriers.

2.1. United Kingdom

The UK has a fully liberalized and privatized electricity system that can be considered highly reliable. Energy from renewable resources accounted 12% of gross final energy consumption in 2019 [77]. Currently the electricity system of UK is interconnected with Ireland, France, Belgium and the Netherlands [78]. The British TSO is National Grid (NG). There are currently fourteen licensed Distribution Network Operators (DNOs), having under their responsibilities distinct local zones. The main companies owning the distribution network are UK Power Networks, Western Power Distribution (WPD), Scottish Power Energy Networks (SPEN), Scottish and Southern Energy (SSNE), Northern Powergrid (NP) and Electricity North-West. Additionally, there are plenty of independent network operators (IDNOs) owning and operating a number of smaller networks [79]. The day-ahead (DA) and intra-day (ID) markets are operated by two spot platforms EPEX SPOT and Nord Pool, while a separate entity, Elexon, is in charge of balancing and settlements services. The UK has many regulative authorities. An influent non-ministerial government department also with the role of an independent National Regulatory Authority is Ofgem (Office of Gas and Electricity Markets) [80].

Demand Participation in the Market

The UK is at the forefront in the integration of energy flexibility in the system [81], considering especially three types of non-conventional sources: demand, energy storage and distributed generation. DSF, directly or via aggregation, can already earn from the participation to existing electricity markets (balancing and ancillary services, capacity market) but also providing network charges avoidance (i.e., helping large electricity users to save money reducing their network charges). It is noted that out of the total value streams for DSF of 4.5 GW, nearly 2 GW are monetised with the former (electricity markets) and 2.5 GW with the latter (network charges avoidance), combined with supply tariffs [82]. The participation is possible for large industrial and commercial customers, that represent almost 90% of the DSF capacity involved, small to medium enterprises, and aggregators, with a diverse range of technologies including also battery storage, electric vehicles, aggregators and generators (thermal and wind) [82].

In terms of DSF participation in the electricity market National Grid describes the balancing mechanism as 'the ultimate flexibility market'. Recently the Wider Access balancing mechanism [83] allowed independent aggregators to enter the balancing mechanism, under the name of virtual lead parties (VLPs) delivered through GB's participation in Project TERRE. This arrangement offers customers' generation or demand side response access, independently of the customer's electricity supplier, to a market which was traditionally the domain of large power stations. The second route for a Non-Balancing Mechanism Unit to participate in the UK balancing mechanism is through the supplier volume allocation [84].

The UK balancing services include around 20 different types of product, including reserve services, constraint management services, frequency response services, negative reserve services, reactive power and black start services. The main requirements for participants in the balancing services are:

- Firm Frequency Response—FRR: Both BM and non-BM participants can become service providers. This can include generators at transmission or distribution level, storage providers and demand. The minimum bid size in the FRR market is 1 MW [85].
- Short-Term Operating Reserve—STOR: It is open to both BM and non-BM providers. The following parameters qualify a service provider to take part in the STOR:
    - At least 3 MW of generation or steady demand reduction (allowing also aggregation);
    - ability to response within 240 min for delivery after an instruction given by the TSO National Grid;
    - being capable of an at least 2 h continuous delivery of the Contracted MW;
    - a maximum 1200 min Recovery Period following the provision of Reserve;
    - ability for a weekly minimum delivery of three times [86].
- Demand Turn Up: The demand turn up providers can be of different types: true demand, combined heat and power, energy storage, other types of generation technologies. They cannot participate at the same time in ancillary services markets [87].

In the capacity market there are three types of capacity auctions: one-year ahead, four-year ahead or transitional arrangements. The latter offers support to DR sources for two years, while preparing the providers to become ready and fully participative in the market. The capacity required as a minimum is 2 MW [88].

From Table 1 below it is possible to identify which markets allow DSF participation:

Table 1. UK's electricity market services and demand side flexibility (DSF) participation.

Service	Product	Open to DSF	Remuneration Type	Value Stacking Available	Market Participation
Adequacy	Capacity Market	Yes	Capacity based	Yes	T-4 2016 auction: 1367 MW of unproven DSF and 44 MW of proven DSF for £22.50 per kW T-4 2017 auction: 110 MW of unproven DSF and 46 MW of proven DSF with a record low contract price £8.40 per kW/year for delivery in 2020/21 T-1 2017 auction: contracts of 521 MW of unproven DSF and 93 MW of proven DSF, record low clearing price of £6.00 per kW
Wholesale	DA	Yes, through suppliers	Energy based	N/A	N/A
Balancing	ID	Yes, through suppliers	Energy based	N/A	N/A
Constraint management	Firm frequency response (or Frequency Containment Reserve—FCR)	Yes	Capacity based and Energy based	Yes across different windows. Yes across same availability windows, but subject to the product and further agreements	2341 MW (in 2018) and 773 MW (in 2017) across all tenders
	Fast Reserve (or FRR)	Yes	Energy and Capacity based	Yes (excluding Response products)	Limited participation (3 DSF providers) due to the 50 MW threshold to participate)—date from 2018

Table 1. *Cont.*

Service	Product	Open to DSF	Remuneration Type	Value Stacking Available	Market Participation
	STOR (Replacement Reserve)	Yes	Energy and Capacity based	Yes (excluding Response products)	10,192 MW (accepted tenders)—data for 2018. This number reflects all the tenders for STOR during 2018, across 3 tenders. The average DSF accepted capacity pre tender is around 3GW.
	Balancing Mechanism (Replacement Reserve)	Yes (recently open for DSF and aggregators acting as Virtual Lead Parties—VLPs)	Energy-based, according to the contracted volumes during Bids and Offers processes	Yes	Not on operation yet for DSF
	Demand Turn Up (DTU—replacement reserve, currently discontinued by NG)	Yes	Energy and Capacity based	Yes (excluding Response products)	114 MW
Constraint management	TSO level	Not open	N/A	N/A	N/A

Different types of flexibility and new market arrangement for procuring such services are also available by the UK DNOs. DNOs in the UK are designing and developing the DSF open flexibility services for distribution networks and they are already using this flexibility, even outside of innovation projects [81]. The Energy Networks Association (ENA) is supporting the Open Network Project, that aims to create a smart grid ecosystem, starting from the last mile of the energy chain, thus homes, businesses, and communities. One of the workstreams of the project is dedicated to flexibility markets and services [89], operated through online platforms. The first platform launched in the UK for DNOs flexibility procurement is Piclo Flex. Piclo, a technology company, has received governmental funding to develop and test the first GB-wide flexibility marketplace, that allows DSOs to procure flexibility from the steadily growing number of flexibility providers. The six main DNOs participated in the trial with 175 flexible providers, amounting to a total capacity of 4 GW. DNOs across the country are now extending this experience both in terms of covered network areas and in terms of providers' capacity. Another platform that provides flexibility providers with a direct path to participate in flexibility on multiple networks is "Flexible Power", operated jointly by four UK DNOs (WPD, SPEN, SSEN and NP). Up to the latest procurement cycle of DR services (second cycle of 2020) 440 MW of flexibility was contracted through Flexible Power [90].

In addition, DSF is encouraged by imposing network (both in the transmission and distribution level) and supply tariffs. The implicit tariff for DSF related to the TSO services is the so called "Triad Avoidance". The tariff is used by National Grid to determine transmission network use of systems charges and it refers to the three settlement periods of the year (from November to February) with the highest system demand. Large industrial customers are charged for the average consumption they have during these three periods; this way they are incentivised to reduce their consumption when transmission networks are already highly loaded. Apart from TSO services, there also exists a mechanism to manage constraints of the DNO. The latter can negotiate agreements with consumers connected to its network, in order to defer or avoid investments or reduce losses [88]. Specifically, through the "Distribution Use of System Charge Avoidance" tariff, DNOs are allowed to create their own mechanism to encourage the customers to consume during low demand periods and avoid peak hours, to prevent congestions in distribution networks.

The customers offering this support are not explicitly paid by the DNOs, but they receive a discount in their energy bill. DNOs also offer tariffs for "Flexible Connection". By means of the "Flexible Connection" the DNO can make a bilateral agreement with a large customer, prior to its connection to the grid. If the contracted power of the customer exceeds the peak network limits, the DNO can avoid to reinforce the grid, if the customers agrees to reduce its consumption when the network is close to its saturation threshold. In the supply side "Time of Use Tariffs" have been introduced to allow customers to adjust consumption to the off-peak hours when the price is lower. Such tariffs are available both for large and small consumers but not all the suppliers are offering them [81].

2.2. Belgium

Electricity generation in Belgium was covered for more than 40 years mainly by the nuclear industry, although during the last decade, renewable energy has considerably increased, and energy from renewable sources reached 10% of gross final energy consumption in 2019 [77]. Belgium is at the heart of the interconnected European grid and in order to meet the demand for electricity it relies on imports from the neighboring countries [91]. The electricity market is composed by the wholesale markets (DA and ID) operated by EPEX SPOT Belgium, and Nordpool and the balancing market, operated by the TSO, Elia. There is one federal regulator (CGRE—Commission for Electricity and Gas Regulation) and three regional regulators (CWaPE—Walloon Commission for Energy in Wallonia, VREG—Flemish Regulator of the Electricity and Gas Market in Flanders and BrUGEL—Brussels Gas Electricity in Bruxelles Region) [92]. There are several DSOs, most of them in Wallonia [93].

Demand Participation in the Market

Belgium was among the first countries to establish a regulatory framework suitable for DSF [94]. The wholesale electricity markets (including DA and ID) as well as the balancing market (primary and tertiary reserves, interruptible contracts program) are open to DR, which competes equally to the rest market participants and balancing service providers (BSPs). DR can be represented either individually or via aggregators [91].

To further foster demand-side participation in markets, a new market model, hereafter "transfer of energy—ToE", was adopted in 2017 with the aim to allow the final customer sidestep its energy supplier and value its flexibility by himself or by an intermediary that will be of his selection. This is advantageous also for the energy supplier to avoid any negative impact, as well as for the BRP of the respective customer and is applicable irrespective of the contract type between the final customer and his supplier. The ToE framework enables flexibility of demand to be valorized via an independent flexibility service provider (FSP), with the purpose to neutralize the impact of the activation of energy by the FSP on the calculation of the imbalance of the BRP source (namely the supplier or the BRP). In addition, FSPs and the supplier are provided with the necessary data to enable them to correctly adjust the financial impact of the activation on the supplier. This new legal framework foresees a gradual implementation of ToE to the FRR and DA/ID markets and is in place in the market of manual FRR (mFRR) since 2018. Together with the ToE, the TSO has proposed and implemented two more alternative models, the opt-out model, which foresees an agreement between the FSP, electricity supplier of the final customer and their BRPs, and lately the pass through model (only applied for specific contracts). As for the current implementation of the ToE a 15′ metering device is necessary, the model cannot be applied to low voltage consumers. Concerning the regulated prices, network or energy-related costs in Belgium are applicable to all consumer types, without exemptions, thus relevant support schemes that might affect DR are not in place currently [91].

At the distribution level, two main mechanisms are introduced that aim to transform the market. The first is a new clearing house, known as Atrias, that facilitates the exchange of data among the participants of the energy market. The second is a new market communication standard, named Market Implementation Guide - MIG6, that will best support the new market model by incorporating latest technologies with the potential of integrating smart meters and distributed production [95]. However, the smart meter roll-out in the country is still at the planning stage [96] and given the diverse regional contexts smart systems implementation will be progressive and within different timing horizons among the three regions.

In addition, in the balancing market several developments have been undertaken in order to enable the use of newly available flexibility sources:

- Price incentives to support a single-pricing balancing mechanism were established in 2012;
- From 2012 and within the following years the TSO made substantial efforts to improve balancing publications;
- In 2018, a dynamic price cap of 13.500 €/MWh was introduced in the balancing market. This increased dynamic price cap is much higher than the present ID maximum clearing price [93];
- Belgium has introduced a so-called 'alpha component' in its imbalance pricing mechanism which can be thought as an initial form of a scarcity pricing mechanism. The basis of this extra imbalance price component lays upon the increases of BRPs real-time price signals (which could back be effective to earlier time frames) in case of increases in the system imbalance of the Belgian control zone. This way, BRPs are further incentivized to avoid large and persistent imbalances. It is also noted that the alpha-component applies both to upwards and downwards flexibility.

The current market functioning rules for the compensation of quarter-hour imbalances, referred to as "Balancing Rules", entered into force on February 2020. Pursuant to the Federal Grid Code, on July 2020 a new design for the FCR and automatic FRR (aFRR) services should be implemented [97]. Under the new scheme the minimum bid size for participation in the Belgium balancing services is 1 MW. In the Table 2, a summary of the Belgian frequency-related ancillary services is presented, highlighting the evolution to a product design in which the participation and competition among all technologies and voltage levels offered by independent BSPs is equal.

For the next period specific product design adaptations and alternative metering requirement are expected to further include capacity connected on low-voltage/residential levels. In addition, focus will be given to projects (e.g., EU balancing projects) in order to further harmonize and integrate frequency-related ancillary services in a regional level [91].

Table 2. Key characteristics of Belgium ancillary services.

Key Characteristics	Frequency-Related Ancillary Service		
	FCR—R1 (Primary Reserves)	**aFRR—R2 (Secondary Reserves)**	**mFRR—R3 (Tertiary Reserves)**
Reaction time	30 s	7.5 min	15 min
Dimensioning	Contacts of a 3000 MW fixed volume for the synchronous Continental Europe area. Yearly sizing depending on data for electricity generation and consumption for each TSO control area	Volumes to be regulatory approved Yearly sizing	Daily sizing from 2020
Procurement	Daily tender and exclusively regional procurement from 2020.	Daily tender from 2020	Daily tender from 2020

Table 2. *Cont.*

Key Characteristics	Frequency-Related Ancillary Service		
	FCR—R1 (Primary Reserves)	**aFRR—R2 (Secondary Reserves)**	**mFRR—R3 (Tertiary Reserves)**
Market opening	All types of technologies (including DR & storage), all players and all voltage levels. Applicability of portfolio bidding	At present limited to large assets with a power-scheduling obligation ("CIPU assets"). Market access to all technologies, all players and all voltage levels from 2020. The new design for the aFRR services will have a merit order activation of the aFRR energy bids instead of a pro-rata activation as applied today. Portfolio bidding is allowed.	All types of technologies (including DR and storage), all players and all voltage levels. Applicability of portfolio bidding
Remuneration	Only reservation (MW) payments	Reservation (MW) and activation (MWh) payment. Move to marginal pricing for activated balancing energy envisaged as from the moment sufficient liquidity has developed	Marginal pricing for activated balancing energy from 2020

2.3. Italy

In Italy 18% of energy consumption (electrical, thermal and transportation) was covered by renewables in 2019 [77]. Because of its geographical position the country is interconnected with France, Switzerland, Austria, Slovenia, Greece and Malta [98]. The Italian electricity market is operated by GME (Gestore del Mercato Elettrico), the Electricity MO and the TSO, Terna. The market is divided in two main categories [99], the short-term market (MPE) and the forward electricity market (MTE). The short-term electricity market includes the day-ahead market (MGP), the intraday market (MI) and the daily products market (MPEG), operated by GME. It also includes the ancillary services market (MSD), operated by the TSO, Terna. The forward electricity market employs a continuous trading platform operated by GME. Currently, 126 DSOs are responsible for the electricity distribution network in Italy [98]. The regulatory authority is ARERA (Regulation Authority for Energy, Network and Environment).

Demand Participation in the Market

Among the European countries, and considering the last two years, the progress of Italy to qualify DERs for the services market is important. In 2017, the Smart Energy Demand Coalition (SEDC) described the Italian market as totally closed to distributed resources [53], while in a most recent analysis of SmartEn, the country was labelled as an active market [100]. The progress of the market opening to distributed resources mainly concerns the initial opening of the MSD market to aggregation of generation and/or consumption points and storage systems (including e-mobility charging stations). Still, participation of demand in energy markets is not supported, unlike traditional dispatching points that also participate in energy markets (e.g., large conventional power stations) [101].

The MSD services in Italy are divided in two types of services (i) ex-ante MSD and (ii) balancing market (MB). The ex-ante MSD is articulated in 6 sub-phases; the offers are submitted in the day-ahead, but the results and the actual activation of resources are undertaken during the dispatch day (day of activation). The market is used to solve technical constraints and to ensure a regulation capacity for the next day. The balancing market is also articulated in 6 sub-phases, all of them opening on the day before and closing 1 h before the first negotiable hour of that particular session. The MB is used to exchange energy for aFRR and for the real time balancing between demand and generation.

As defined in the relative Decree 300/17/R/EEL, the actors involved in the participation of distributed resources in the MSD are the following [101]:

- Dispatching Units (UdD): holders of the points of consumption/non-relevant generation;
- BSP: balance service provider, corresponds to the aggregator, it is the holder of the virtual qualified unit (UVA), and it is the actor responsible for the negotiation of services in the MSD. It does not have any contract with the BRP, because it directly interacts with the TSO. So far, more than 25 BSP have been registered and assigned to a UVA;
- BRP: the financially responsible party in case of deviations that impact the balancing of the system

The progressive inclusion of distributed resources in the MSD has started by the Italian TSO (Terna), together with ARERA, through the definition of pilot projects that will allow the organic reform of this market. The pilots of Terna and ARERA have the objective to increase immediately the amount of resources available to guarantee the safety of the electricity sector with a lower cost for the final user, through the provision of reserve and balancing services, towards the decarbonization of the national mix. A further objective is the diversification of the resources.

Through the pilot projects mentioned above ARERA decided to open the market of ancillary services to distributed resources, such as consumption units, small generation and storage. The market opening has going on since 2017. In the scope of the pilot project, the following UVAs were identified:

- UVAC (consumption virtual qualified units), since June 2017, until November 2018;
- UVAP (generation virtual qualified units), since November 2017, until November 2018;
- UVAM (mixed virtual qualified units), since November 2018 (ongoing);
- UPR (relevant generation units), since September 2017(ongoing).

The following Table 3 describes each type of virtual qualified unit (focus is given on distributed resources, thus UPRs are not considered at this stage).

Table 3. Consumption virtual qualified units (UVAC), generation virtual qualified units (UVAP) and mixed virtual qualified units (UVAM) characteristics [101].

Pilot Project	Characteristics	Minimum Power Threshold	Services	Mode	Remuneration
UVAC	Consumption points	1–10 MW	mFRR (upward) Balancing service (upward)	Reduction of consumption of at least 1 MW within 15 min from Terna's request	= to ancillary services remuneration/ Penalties + long-term contracts *
UVAP	Non-relevant generation points	1–5 MW	Congestion management mFRR (spinning and replacement) Balancing service	Increase or decrease generation of at least 1 MW within 15 min from Terna's request	= to ancillary services remuneration/ Penalties
UVAM	Consumption points Non-relevant generation points Relevant generation points Storage installations	1 MW	Congestion management mFRR (spinning and replacement) Balancing service	Increase or decrease generation of at least 1 MW within 15 min from Terna's request	= to ancillary services remuneration/ Penalties + long-term contracts *

* The inclusion of long-term contracts, as a form of remuneration, is necessary because the industries participating in the pilot must recover the high capital costs invested for the installation of the energy monitoring and control technology.

In June 2019, the total capacity of UVAs amounted to 830 MW, but the smallest loads, such as the residential ones, are still excluded from this mechanism. Each point, within the UVA, has to be equipped with a monitoring unit (UPM), to measure the injected/withdrawn energy and send this data to the concentrator (every 4 s or 60 s, depending on the type of UVA), which interfaces Terna's system. During D-1, the BSP must send to Terna the forecasted baseline (daily schedule) of the next day for the UVAM that it manages. Then, Terna, during the day, corrects this baseline considering a factor based on the measurement received from the UPM. This baseline helps the TSO verify the correct execution of the flexibility requests made to that BSP [32].

The project has achieved good results both in terms of liquidity of the market and in terms of aggregated capacity, thus the expected next steps are [102]:

- Progressive inclusion of residential loads and other smaller resources into this system;
- Encourage competition;
- Allow the participation of distributed resources in other services, such as FRR and voltage control;
- Redesign the whole system of ancillary services and network codes based on the lessons learned from pilot projects.

2.4. Greece

During the last decade, the Greek energy sector has experienced reforms which include among others the liberalization of electricity wholesale and retail markets. In addition, the electricity fuel mix has been substantially diversified, with an increase in the share of variable renewable sources in the total final energy consumption, to almost 20% in 2019 [77,103]. Another major recent development concerns the electricity market operation and relates to the transition to the new European Union target model market, with forward, DA, ID markets (operated by the Hellenic Energy Exchange) and the balancing market operated by the Independent Power Transmission Operator (IPTO-ADMIE). There is one DSO, the Hellenic Electricity Distribution Network Operator (HEDNO) and the energy market is supervised by the Regulatory Authority for Energy (RAE).

Demand Participation in the Market

The existing institutional framework has incorporated provisions for promoting DR systems. The Hellenic Distribution Network Code [104] foresees the activation of distributed DR by the DSO by establishing "Demand Control Contracts" with individual electricity consumers located in congested network areas. These contracts shall allow the Greek DSO to set limits or even to interrupt, at its own initiative, the supply to the facilities of the contracted consumers, subsequent to their notification, in the periods specified in the contracts.

Curtailment of DER by the DSO is also foreseen under the following circumstances:

- When this is demanded by the TSO according to the system operation code;
- Under emergency situations;
- In case of faults or maintenance or in order to perform necessary operations on the network;
- If such an option is explicitly included in the connection agreement and/or sales agreement.

Greece to date aims to encourage demand-side participation through the application of interruptibility and long-term capacity compensation schemes [105]. Consumers connected to the electricity transmission and medium voltage network of the interconnected system can offer to the TSO the interruptible load service by participating in auctions. The TSO has then the right to temporarily decrease, up to a pre agreed value, the active power of interruptible counterparties, who are financially compensated for their services [106]. Moreover, customers connected to the medium and low voltage network of the interconnected system and in the non-interconnected islands (NIIES) can also opt for demand control contracts, provided the existence of the necessary telemetering equipment in their premises [96]. Additionally, residential customers can sign contracts offering lower tariffs for night consumption and interruptible load contracts for "agricultural customers". The latter motives are included in the commercial packages/tariff schemes of the supplies to the customers (implicit DR) and they do not concern participation in the wholesale electricity market (explicit DR).

In parallel, the option of establishing aggregators and energy communities is institutionally foreseen, giving electricity consumers the possibility to operate in the electricity market, either as consumers or as producers. To restrict the costs for consumers involved in these bodies, but also for the System, dynamic electricity tariffs are also instituted. Law 4342/2015 introduces the need of provisions within the market codes targeting to the TSO and the DSO and aiming to the equal and objective treatment of actors providing DR services, based also on their technical infrastructure and potential [107]. The law also defines for the first time the role of "aggregator." Regarding the contractual design to incorporate DR resources in the Greek electricity market, IPTO-ADMIE proposes a scheme where the load representative invoices the consumer both for the energy consumed and for the energy that was curtailed due to a DR event. In this way, potential products or financial flows between the DR aggregator and the load representative are avoided and the load representative's is settled directly for its imbalances [108]. Law 4414/2016 [109] also stipulated the obligation of all new power plants above a certain power limit to participate in the electricity market with submission of appropriate, priced supply forecast either individually or through aggregators.

However, the participation of all electricity consumers in the electricity market will not be possible until the completion of the smart meters installation project, which is expected in the following decade. To date, smart meters have been placed at medium-voltage customer sites and in few low-voltage customer locations, at a pilot phase. HEDNO has also installed two telemetering centers for the remote collection of meter readings from all medium voltage customers and RES producers, as well as from all major low voltage customers (>55 kVA) including photovoltaics [96].

Regarding the net metering and active consumer scheme there is a quantitative objective for the set up and operation of new autoproduction and net metering systems, primarily aiming to cover own needs of over 600 MW by 2030 (corresponding to in total more than 1 GW of installed capacity), and for the engagement of aggregators through the prospect of participation of energy communities and of people in energy markets. New technologies will greatly contribute to decentralize generation and for the local balancing of generation and demand.

3. Existing Obstacles

This section examines the relevant barriers that hinder further DSF proliferation. For each country, regulatory, technical, and economic barriers are discussed. It should be noted that energy and climate policy, alongside the process of sustainable transition, are highly affected by the institutional context of each country. Taking into consideration the imposed institutional complementarities and the different capacities of innovation that the institutional arrangements of the national economies offer [110,111], the multi-country analysis presented below reflects the implications of the institutional similarities and differences between the economies of the examined countries.

3.1. Regulatory Obstacles

3.1.1. UK

The capacity market presents numerous barriers to the participation of aggregators. Firstly, it is impossible for DSRs to participate in the long-term contracts (T-4), making it difficult to obtain finance easily. Moreover, despite the apparent technology agnosticism, generators are running the auction with an uneven advantage, as they have lower risks associated to their business. Finally, the capacity mechanism rewards capacity rather than reliability, as the penalization for non-delivery is capped. This issue does not represent a barrier for the aggregator but for the stability of the system as a whole [88].

Another barrier arises from the supplier's energy imbalance charges. Currently, suppliers' energy imbalance charges are affected when their customers, either directly, or through an independent aggregator, deliver balancing services to NG, meaning that suppliers could be exposed to delivery/imbalance risks due to the activity of independent aggregators. Ofgem has already shared these concerns and has suggested that the costs associated to balancing and delivery risks should be carried by the actors who produced them, thus in this case, the aggregators [81] and some relevant modifications to the Balancing and Settlement Code have been recently introduced [112].

Finally, while market uncertainties hinder wide DSF participation, the policy is proactively pushing for a wider access of these sources. Also, funding to innovation projects is having a key role in proving new technologies and market mechanisms [81].

3.1.2. Belgium

The majority of the regulatory obstacles in Belgium stem from its complex internal institutional structure and the fact that its energy policy commitments are shared by the federal government and the country's three regions. This results in lack of coordination and clarity amongst the entities responsible for energy and climate policies. The differences in regional regulators and consequently support schemes impose the need for continually changeable considerations regarding the submarkets. This fact hampers decision processes and implies higher total costs [93,96].

Moreover, DR structures, such as local energy trading between buildings or between households in the same building are not allowed in the Belgian electricity market. Some exemptions have been given for innovative projects, e.g., Energyville. Meanwhile, consumer participation in DR programs can be blocked by the DSO without the latter taking responsibility for the costs incurred by the consumer, aggregator and TSO [60].

Lastly, in case of flexible loads, the seller must be the customers' BRP, so aggregators oblige prior arrangements with the customer's supplier. Taking this into consideration, the right to use the customer's excess load for onward transaction on the power exchange has to be transferred from the supplier, which is the customer's default BRP, to the aggregator.

3.1.3. Italy

Disagreements in the cooperation scheme between the TSO and DSOs are the main deterrent factor for the slow evolution of Local Flexibility Markets.

3.1.4. Greece

In Greece, both the IPTO's Balancing Market Rulebook and the regulatory framework introduce some obstacles regarding the consumer size in balancing services provision, and the energy storage licensing and operation, respectively.

In particular, the recent update of the IPTO Balancing Market Rulebook [113] includes dispatchable load portfolios as assets to offer Balancing Services and highlights that those can be represented either by a DR aggregator or, if the portfolios include only one load, they can be represented by a consumer. However, demand management and response schemes are not yet implemented for all consumers and in principle concern only large industrial consumers. This excludes consumers' participation whether individually or through aggregators.

The regulatory framework for the development and operation of electromobility and energy storage is incomplete, and the procedures for their integration in electricity market are too complicated. In order to tackle energy storage licensing and operation issues, a special committee assembled by the energy ministry (FEK B' 5619/21 December 2020) to deliver a plan, by May 2021, on revising an existing framework to facilitate, and make financially beneficial, battery system installations at homes, businesses and industrial facilities. The existing framework, is particularly restrictive and, as a result, subduing related investments, limits energy storage system installations to 30 KW and permits usage to roof-mounted photovoltaic (PV) panels for self-production.

3.2. Technical Obstacles

3.2.1. UK

Obstacles stem from the large number of balancing services [114], each of whom features different specifications such as response times, duration of actions, and availability period. This highly complex market, together with the lack of transparency of the operator's website—where information is not easy to access or even unavailable—makes it difficult for participants to understand and compare the benefits and revenue streams they could achieve through each service [88].

Regarding demand aggregation in the UK, its principal barriers are: the tender period, which is yearly or seasonally, instead for example a daily resolution that would be a worthy trade-off for enabling involvement of DR, can be an obstacle in all markets; the minimum bid size of 25 MW in the aFRR service; the fact that services like the Demand Turn Up service were not active in 2019 [60].

The lack of automatic consumption readings represents an obstacle to the development of new energy markets and to the engagement of residential consumers. The roll-out of smart meters, that will alleviate this obstacle, is not completed in the UK and is expected to finish in 2024 [115].

Lastly, some ancillary services pose prequalification requirements which are hardly met by aggregators, for instance a very high minimum capacity or a very high run duration [88].

3.2.2. Belgium

Currently the full access of customer loads to the market is hindered by measurement provisions. The isolation of the volatility of local energy production or inflexible consumption at one site from the available flexible power/load potential at that same location, is currently not feasible technically, causing a large amount of the available DR potential to be inaccessible for aggregation. The full measurement of the available load could be enabled by the establishment of "meter behind meter" provisions in the settlement process [39].

3.2.3. Italy

The minimum size selected for the UVAM project is 1 MW. This decision permits small loads to be included as participants in the market and will involve residential consumers in the long run. Nevertheless, it represents a drawback when it comes to technology, as this level of capacity is more difficult to control and manage.

3.2.4. Greece

The majority of the technical obstacles in the Greek case can be attributed to the lack of the appropriate infrastructure, either technical or digital, from the involved parties.

The absence of technical infrastructure, like smart metering equipment which is still in the preliminary rollout phase causes DR schemes to unfold at a rather slow pace [96]. Moreover, there is complete lack of the appropriate infrastructure from the TSO's side to send Dispatch Instructions in real-time to dispatchable portfolios of RES aggregators and DR aggregators and/or storage operators, in order to balance the system in real-time.

Delays in the digital transformation of the Greek DSO, HEDNO, prevent it from being able to respond efficiently to the challenges of increased RES penetration, manage decentralised systems for energy generation and storage, and electricity transactions.

Finally, to assess the extent of market concentration, and to detect anti-competitive practices, mechanisms and indicators to monitor the market, and the analysis of bidding behavior through cooperation between competent bodies, where relevant [116], are needed, that are currently absent.

3.3. Economic Obstacles

3.3.1. UK

The UK is one of the few countries creating flexibility products for DNOs but, so far, the liquidity of this market has been insufficient to incentivize new investment in the technology. To overcome this situation, Ofgem's network charging and access review should include clear price signals towards the providers of this service [81].

High competition already exists in the ancillary services arena, among the different services and within the same services, making access difficult for new parties, such as aggregators [88]. Also, while price volatility in the wholesale market is high, it is not high enough for DSR providers [81].

3.3.2. Belgium

The Belgian tariff scheme is based on energy consumption, providing no incentives to consumers for a behavioral consumption change, that could potentially eliminate the burden to the grid at peak events [117]. Additionally, the network tariffs scheme, being very high and not flexible for customers, yields to marginal earnings from flexible power supply and does not offer inducements to shift consumption patterns [96].

Obstacles emerge from the performance guarantee required as a threshold for being a BRP. This performance guarantee, that amounts to 4000 EUR, constraints customers from choosing aggregators and acts as an unfair advantage towards suppliers. Participation on the aFRR-R2 market is difficult for new players offering different technologies from those the current price caps were designed for. Considering also the pro-rata activation (no merit order before July 2020), this limits competition on the R2 market and results in higher prices for the TSO and consequently for the end consumer.

Finally, real-time-pricing is not allowed in Belgium [118].

3.3.3. Italy

Remuneration for availability is necessary to recover the high up-front investment the demand side must face, in order to become an active participant in the ancillary service market, especially due to the cost of the installation for monitoring and control of flexible loads. Moreover, these stakeholders have to stop or vary the productive cycle, facing economic losses of an activity that is not part of their core-business [102]. Thus, to encourage demand-side flexibility, the capacity is highly remunerated.

On the other hand, the energy price cap that UVAM can bid in the ancillary markets are high and not restricting at all. Therefore, the consumption units risk becoming passive elements of the system, offering availability (thus profiting on the capacity), while bidding with a high energy price, in order to avoid being selected as flexibility providers.

The imbalance between the offers for availability and the offers for energy is observable also in the cashflow figures. During 2018, the ancillary service market spent 4.8 million euros to pay UVAs for capacity availability and only 0.29 million euros for the energy activation [102].

3.3.4. Greece

New financial instruments being compatible with the new market environment will contribute to the implementation of the required investments. Such instruments may concern incentives for the penetration of electromobility, the use of electricity storage systems, tax incentives and dynamic electricity tariffs to support local energy communities and consumers, the efficient implementation of research or pilot projects by all market players, with the ultimate goal of creating benefits for final consumers etc. [116].

4. Recommendations and Policy Implications

4.1. UK

To support the transition to a smarter and more flexible energy system actions in UK should focus on removing policy and regulatory barriers to smart energy solutions, as electricity storage, and enabling them to enter the market and compete fairly alongside other new or established energy technologies [119]. The use of smart solutions, including DR, in homes and businesses should be further incentivized and enabled by the roll-out of smart meters, the move towards market-wide half-hourly settlement, and the provision of a framework for smart tariffs [59,119].

4.2. Belgium

Belgium should institute standardized processes (e.g., data exchange, volumes' assessment, a governance structure and a compensation methodology binding BRPs and aggregator/consumer relationship) to enable consumers'/aggregators' market access fully independently of the retailer. In the field of flexible tariffs, the legal system must be redesigned, with the goal to combine flexible prices with sufficient protection of consumers [96]. To facilitate the uptake of price-based DR, the rollout of smart meters with the necessary functionalities should continue. Additionally, an amendment of the scarcity pricing scheme to ensure that BRPs and BSPs are charged equal prices for their energy production/consumption is necessary [120].

4.3. Italy

In Italy the aim of the regulation should sift to reorganize the ancillary services market as well as the imbalances rules, in a manner that (a) all available resources could possibly participate at a maximum rate, with due regard for security constraints, and (b) the cost of the system is to be limited. The use of both concentrated on network service and distributed forms of energy must be supported by the establishment of storage solutions and the construction of a vast storage capacity, which is seen as necessary for the availability of sufficient flexibility sources. Moreover, it is important to enhance and upgrade the electrical transmission and distribution network, partly with a view towards smart grids, and install apparatus designed to optimally manage energy flows. In parallel to distributed generation, the encouragement of more pro-active and flexible electricity DR resources is important. For example, as regards electric vehicle recharging, it is vital to establish suitable market and technological measures and instruments so as to foster the convergence of supply and demand peaks for non-dispatchable renewable sources. With the increasing participation of distributed generation, a most suitable dispatch model for the national context will have to be investigated, with strongly standardised models, as the current central dispatch model, being avoided [98].

4.4. Greece

In Greece a more cost-effective and sustainable system functioning is required and could be achieved by the complementary functioning of different energy operators and sources, supported by an appropriate regulatory framework. Among the policy priorities of the following decade should be placed regulatory changes and measures for the energy coupling of sectors, the penetration of renewables in new sectors and uses, and the development of appropriate pilot and pioneering applications. The regulatory framework needs to change to propose incentives for the implementation of such projects. At a technical level, it is critical to develop a relevant institutional framework for storage units to facilitate their participation in the electricity market, using simplified procedures for their integration in existing or newly built RES plants and without affecting the compensation applicable to such plants. In addition, the net metering scheme should be progressively expanded, attaining higher growth rates. This could be facilitated by the digitization of networks and meters management to restructure the electricity markets and boost competition with measures such as the installation of digital, 'smart' metering devices and centralized systems to the operators' assets for the best of management and control [116].

5. Conclusions

The increased share of renewable-based distributed generation at power systems urges for an increased need for flexibility-enabling technologies in the demand side. In order to allow new resources of DSF to participate in the electricity markets it is necessary to adapt market design through new market players and define new roles (e.g., aggregators, BSPs and BRPs) or extend the roles of already existing parties (role of TSOs and particularly DSOs). Regulators and system operators are already playing a key role in market design innovation and have a substantial impact on the consolidation of emerging business models, as they can either hinder or help their evolution as a tool to increase flexibility.

The analysis of this paper shows that endeavors of fostering DSF are prominent all around Europe, however, as seen in Table 4, progress of integrating flexibility sources and relevant business models into the market is different among the European countries. At the same time, it is particularly noted that even if legally open for the DSF service, impractical requirements limit the participation of certain consumer categories, e.g., aggregators, even in more mature (concerning DSF) markets, like those reviewed for the UK and Belgium. For the UK and Belgium, and in a broader perspective for all European countries with a significant progress on DFS, the main recommendations to serve the requirements of DSF mainly concern the establishment of more standardized processes for enabling market access for consumers and aggregators, and the adaptation of new planning and operational procedures regarding the interactions among different business actors. For example, it is recommended that aggregators should be eligible to sign contracts directly with prosumers without the interaction of BRP/retailers and DSOs. At the same time, strong requirements on the bidding volume and bid duration restrict aggregators participation possibilities. Such barriers of market entry for aggregators should be reduced. Another major challenge for DSF met in all of the countries examined, but also applicable in the rest of Europe, is the delay of projects for smart meter deployment. The roll out of advanced metering technologies, in parallel with adopting a cost-reflective design for retail tariffs, is a precondition for actively stimulating end users' DR. Last, in this new environment driven by more flexible and decentralized resources connected directly to distribution networks, DSOs will play a key role. As noted within this review, the UK laid the foundation for transitioning the role of DSOs by launching the Open Networks project and online marketplaces to procure flexibility services for local requirements. A change on the regulatory framework for DSOs all through Europe by proposing new incentives for the adaptation of the distribution network operation to the new paradigm of DERs is understood as a key to the success of the energy transition.

Table 4. Summary of the characteristics of the reviewed countries.

	Internal Market Characteristics
UK	Electricity market design including DA, ID and balancing markets Electricity system with interconnections Renewables (% of gross final energy consumption, 2019): 12% Many regulatory authorities Many DSOs
Belgium	Electricity market design including DA, ID and balancing markets Electricity system with interconnections Renewables (% of gross final energy consumption, 2019): 10% One federal and three regional regulators Many DSOs

Table 4. *Cont.*

	Internal Market Characteristics
Italy	Electricity market design including DA, ID and balancing markets Electricity system with interconnections Renewables (% of gross final energy consumption, 2019): 18% Single regulatory authority Many DSOs
Greece	Electricity market design including DA, ID and balancing markets Electricity system with interconnections Renewables (% of gross final energy consumption, 2019): 20% Single regulatory authority Single DSO
Status of market opening to demand side flexibility	
UK	Markets open to demand side participation: • Primary response (FCR) • Secondary response (FCR) • Frequency Control by Demand Management (FCDM/FCR) • High-frequency response (FCR) • Enhanced frequency response (FCR) • Fast reserve (aFRR) • STOR (RR) • Demand Turn Up (RR) • Supplemental Balancing Reserve (SBR/RR)
Belgium	Markets open to demand side participation: • primary (FCR) and tertiary reserves • interruptible contracts program • strategic reserve • wholesale electricity markets (including day-ahead and intra-day)
Italy	Markets still not officially open for demand side participation. Demand side participation at the ancillary services market through the pilot project UVAM.
Greece	Markets still not officially open for demand side participation.Demand-side participation through: • long-term capacity compensation schemes • interruptibility schemes

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