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Local Flexibility Markets for Distribution Network Congestion-Management in Center-Western Europe: Which Design for Which Needs?

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Abstract: With the growth of decentralized resources, congestion management at the distribution level has become a growing issue in Europe. Several initiatives with local flexibility markets are being implemented, with different designs and objectives. In this paper, we provide a comparative assessment of four case studies of local flexibility markets (ENERA, GOPACS, UKPN, and ENEDIS) in different center-western Europe countries: Germany, the Netherlands, the United Kingdom, and France. We identify a number of differences across these countries that have an impact on the drivers of implementation of these local flexibility markets and their market design such as the type and depth of congestion, the organization and governance of networks operators, the current approach for congestion management, and the need for the development of additional flexibility sources. We find that the different market design choices can be explained by the local specificities and use the four case studies to generalize our findings and define a typology of possible approaches for flexibility markets depending on the electricity system local specificities, as well as the sector governance and the policy priorities.

Keywords: local flexibility market; congestion management; market-design

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1. Introduction

The ongoing evolutions of the electricity sector in Europe (renewable energy sources development, electrification of uses, early closures of coal/nuclear power, etc.) create a number of challenges for the historical network management and organization.

Among these evolutions, there is growing congestion on both the transmission and distribution networks in some countries. In the United Kingdom for example, congestion management costs increased by 74% between 2010 and 2017. These phenomena have reactivated discussions about the most appropriate market design to manage congestions, with a "revival" of the nodal vs. zonal debate [1].

Distribution networks are defined in this paper as being under 110 kV. This classification is important given the variable voltage threshold between European countries to classify networks. Distribution networks are also particularly facing transformations which could create congestion issues and conduct to evolve network management [2]. In this paper we use the term "congestion" to refer to all the constraints that may appear on the distribution network. Indeed, the significant growth of decentralized generation assets in distribution networks and increasing penetration of electric vehicles and heat pumps can create constraints on a network historically not dimensioned for these uses [3–5]. For example, in 2017, 90% of solar production in the UK and 95% of RES capacity in Germany were connected to a distribution network.

In order to deal with congestion issues, the Distribution Network Operator (DNO) historically often made the choice to reinforce the network which required potentially significant investments. These choices were made because levers traditionally used as alternatives to reinforcement (e.g., reactive power management, voltage set point management) quickly reach their technical limits in the presence of large scale decentralized production [4]. In addition, near real-time management was typically limited to a physical reconfiguration of the network, having no achievable flexibility levers in this time horizon.

One of the complements to traditional approaches for congestion management is to mobilize flexible resources at a local level. If the penetration of distributed energy resources (DER) can represent the emergence of new grid constraints, it can also be a potential flexibility resource for the network [5–10]. Various studies show that, in some power systems, the use of local flexibility sources as alternatives and/or complement to network reinforcement can lead to significant savings for the DNO [11–13]. The Distribution Network Operator should in this frame evolve from only own and develop network (network operator) to realize local energy activations as Distribution System Operator (DSO) [14,15].

An evolution of market-design is therefore needed to unleash the full potential of these new flexibility sources at the distribution level.

There are several aspects of market design that can contribute to mobilize local flexibilities and solve emerging congestion at the distribution level (as a complement to the traditional approach) including the introduction of locational price signals either in the market and/or through network pricing (through connection or usage tariffs).

In this article, we analyze one form of a market-based solution which has recently attracted attention in several Center-Western European power markets and is put forward as a promising future market development by the European Clean Energy Package: the introduction of a local flexibility market. A local flexibility market is typically used to provide services for the flexibility needs inherent to the DNO. This market model is close to the historical ancillary services markets destined to the transport system operator (TSO) but its specificities will be its location and the direct involvement of the DNO as a buyer [16]. To define flexibility exchanged on these markets we will use a definition proposed by the Smart Network Task Force, 2015: "The modification of generation injection and/or consumption patterns, on an individual or aggregated level, in reaction to an external signal (price signal/network tariff activation etc.) or in order to provide a service within the energy system or to benefit the network. The parameters used to characterize flexibility can include: the amount of (active) power modulation, the duration, the rate of change, the response delay, and the location."

This type of local flexibility market will therefore typically help DNOs to respond to voltage and current constraints appearing in cases of local energy deficit ("load" congestion) or surplus ("injection" congestion). It will participate to solve congestion by providing price signals which can be used to optimize flows into the distribution grid, while the global energy balance would still be managed by the TSO on a national level (In some case DNOs would compensate for the imbalance created by their needs of flexibility for congestion-management.). In the case of anticipated congestion, the DNO can use local flexibility to relieve local network constraints, in coordination with the TSO. For example, the network operators can ask an asset to reduce its injection or increase its load (downward flexibility) on a network node undergoing an excessive injection peak (injection congestion) Or, inversely, the network operators can ask an asset to increase its injection or reduce its load (upward flexibility) for a network node undergoing an excessive load peak (load congestion). A local flexibility market typically involves a selection of assets that can be activated to settle congestion based on a price signal.

Several industrial initiatives based in this concept of local flexibility market have recently emerged in center-western Europe, in particular:

- ENERA (Germany): Initiative launched by EPEX Spot (market operator), EWE (energy producers) and the network operators EWE NETZ, Avacon Netz and TenneT focused on the northern area of Germany [17].
- GOPACS (The Netherlands): Dutch platform launched in 2019 by 1 TSO (TenneT) & 4 DNOs (Stedin, Liander, Enexis Groep and Westland Infra) which operates on the Dutch market via the ETPA market platform [18].
- UKPN—Picloflex (United-Kingdom): Project initially launched by UKPN (a British DNO) whose first calls for tenders were made at the end of 2018 [19].
- ENEDIS (France): Project launched by ENEDIS (a French DNO) at the end of 2018, with first call for tenders launched in June 2020.

Despite the common general elements of a local flexibility market (see description above), these industrial initiatives present different organization and market designs. There is a growing body of literature that recognizes the possible diversity of local flexibility market-designs in theory [13,16,20–22]. In addition, some papers provide an initial analysis from these emerging industrial initiatives and also highlight the differences in market-designs in practice [19,23,24]. A survey like the one conducted by [23] has highlighted the different characteristics of these markets, particularly whether they are integrated within the sequences of current markets, their management via an external platforms or not, the presence or absence of capacity payment, the standardization of products in these local markets, and the issue of TSO/DNO or DNO/DNO cooperation for these markets organization.

While the existing literature describes some of these initiatives and their diversity of designs, so far, little attention has been paid to the analysis of the link between the local electricity system technical and organizational/governance specificities and the choice of design for these markets. These local specificities include the type and depth of congestion, the dynamic of development of flexibility sources, the organizational structure and governance of network operators, and the current approach for congestion management.

The objective of this paper is to provide a structured analysis of the diversity of market-designs for local flexibility markets in the light of these local specificities for the specific area defined here (center-western Europe). To proceed, we focus on four case studies in four countries which face different situations, but also where recent local flexibility market initiatives are emerging. It is important to note than we have made our analysis on local flexibility market with the information available to date.

We focus our analysis on case studies in four countries of the center-western Europe (Germany, the Netherlands, the United Kingdom, and France) to analyze how the local specificities and motivations to develop a local flexibility market led to a different market design in this area.

We first identify the different characteristics of electrical systems and their organization and governance that could explain the different drivers of the implementation of a local flexibility market by realizing a comparison between these four countries (Section 2). We develop an analysis framework based on four criteria: the type and frequency of congestions, the existence and dynamic of development of enough flexibility sources adapted to the needs of the DNO; the diversity of organizational structures; and finally, the different approaches and mechanisms for the management of current congestion.

In a second step (Section 3), we identify the main market design differences through an analysis of the four case studies listed above (ENERA, GOPACS, UKPN, and ENEDIS) and emphasize how differences in local characteristics can explain differences in market-design. We analyze these different market-designs according three criteria: the timeframe of the design, the use of an external or third-party platform, and the access easiness.

Finally, in Section 4, we conclude by generalizing our findings, identifying a typology of potential approaches and analyzing the suitability of different market designs for flexibility platforms depending on the local specificities and discuss some areas for further investigation. Indeed, our approach allows us to first characterize the needs that can motivate the setting up of some local flexibility market in regions with common characteristics, and then to understand the diversity of approaches depending on the local specificities encountered and the objectives pursued by each.

2. Local Specificities Lead to Different Approaches for Congestion-Management and Define the Potential Role of Local Flexibility Markets

In this section, we introduce the relevant features characterizing an electrical system which will allow us to explain or understand the characteristics and motivations of certain local market design choices.

In this article, we consider as distribution networks all the networks having a voltage lower than 110 kV. Note that the definition of distribution network (and therefore the division of responsibilities between the TSO and the DNO) is not homogeneous in all European countries. Table 1 shows the perimeters of different network operators for each country under study. Except in the case of France, DNOs cover networks with a voltage level of less than 110 kV.

Table 1. Perimeter of network operators in Europe.

Voltage Level/Countries	Germany	The Netherlands	United-Kingdom	France
132–400 kV	TSO	TSO	TSO	TSO
110 kV–63 kV	DNO	DNO	DNO	TSO
50 kV–230 V	DNO	DNO	DNO	DNO

We use the following key distinctive features to structure our analysis of the four case studies, which we detail further below:

(1) The type and frequency of congestions;
(2) The existence of enough flexibility sources adapted to the needs of the DNO and the dynamic of new flexibility developments;
(3) The diversity of organizational structures;
(4) The different approaches and mechanisms for the management of current congestion.

We apply this framework to characterize the local situation in the cases of Germany, the Netherlands, the United Kingdom, and France and to identify local flexibility market motivations.

2.1. Type and Frequency of Congestions

- The type and the frequency of congestion in an area will differently motivate the development of a local flexibility market. Indeed, given that congestion is the “problem” that a local flexibility market is supposed to solve, understanding the type and the size (frequency and depth of congestions) of the “problem” is therefore necessary to explain motivation and design choices. Different types of constraints (summarized in Figure 1) must be managed in a network but for the sake of simplicity we divide congestions in two mains categories in this paper:
- “Injection” congestions, indicating a surplus of local energy or power (e.g., too many injections compare to physical limit of network assets with integration of RES for example)
- “Load” congestions, indicating a deficit of local energy or power (e.g., too much load compared to physical limit of network assets with electrification of uses such as electric vehicle charging, for example).

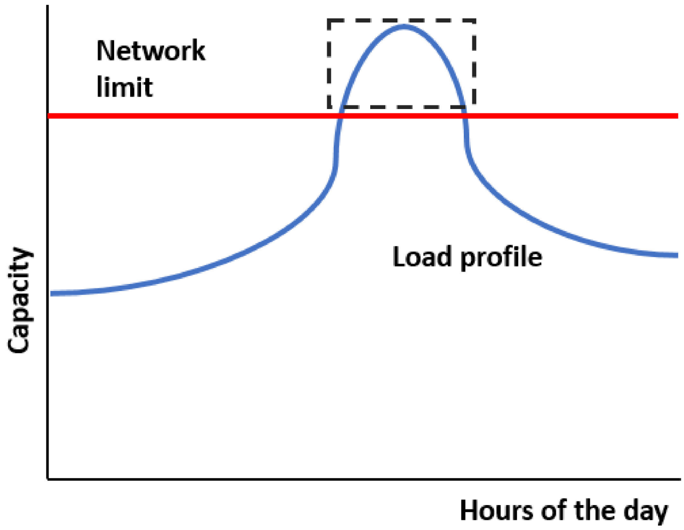

Figure 1. Congestion illustration.

Assessing the type and the frequency of congestion for a region is not an easy task. Congestions, and in particular congestions at the distribution level, strongly depend on specific state of the network at the local level and on the historical evolution of network investments and network users (classic load, RES, EV, HP, etc.). Over a large region (like a country in Europe) different congestion situations may co-exist. In this section, our objective is to give a general trend concerning congestion based on available information.

Depending on the countries, the typical patterns of congestions differ in countries: in Germany [25], in the Netherlands [26], and to a lesser extent in France [27], congestion will mainly emerge from injection problems with an increasing share of renewable energy sources (RES) directly connected to distribution network. In the United Kingdom, congestions (in the areas manage by UKPN on which we are focus) constraints will be created by both load and injection constraints [19].

The frequency of congestions will also differ depending on countries, with some already facing important amount and recurrent congestions, when others are only facing minor and infrequent congestions: In Germany [28], the United Kingdom [29] or the Netherlands to a lesser extent [26] congestion management is already a major issue entailing significant and growing costs. In Germany, even if the high cost of congestion management is mainly attributed to problems in the transmission network, [30] show that 86% of the curtailed energy would actually originate from problems on the distribution networks and especially on the interface between the distribution and transmission network. Indeed, the prospective cost of distribution network development to accommodate renewable insertion should be between 27.5 and 42.5 billion euros by 2030 [31]. In the United Kingdom, congestions in the distribution network are already significant and are expected to increase in the future [32]. The prospect of increasing congestion (both injection and load) in the UK, especially on the distribution network, can be implied by the estimation of network investment avoided thanks to the deployment of local flexibilities. The Carbon Trust and Imperial College estimate that the implementation of flexibility could avoid between 4 billion and 13 billion in investments for the distribution network by 2050 [29]. In France, on the other hand, the prospective studies on the electrical system as well as the demonstrator project currently carried out conclude with much more limited needs in terms of volume of congestion and costs than in the other countries surveyed [33].

A high level of congestion is one of the drivers to implement a local flexibility market. In an area with an important level of congestions (which appears frequently), the potential benefits brought by a market may overcome the implementation costs. Indeed, the benefits associated with the competition and direct economic comparison between different flexibility sources options to manage the congestions can help to rationalize and possibility reduce the cost of congestion management by network operators. Conversely, the implementation of a local flexibility market may not be worthwhile in a country with light and very sporadic congestions given the implementation costs.

In addition, the interest and design of a flexibility market would also differ in a zone mainly impacted by injection congestions compared to an area mostly affected by load congestions. In the first case, the main potential benefits of a local flexibility market will be the limitation and optimization of RES curtailment management, whereas in the second case the market signal will be mostly useful to ensure the development and optimization of demand response, storage or local generation.

2.2. Existence of Local Flexibility and Need for Development of New Flexibility Sources

The availability of local flexibility sources has an impact on the motivations for establishing a local flexibility market. Indeed, the existence of an already sufficient level of flexibility sources suitable to limit congestion on a cost-effective way or the necessity to develop new ones will influence the motivations and approach for developing a local flexibility market.

Resources already available to provide flexibility are observed in many different areas [29,30]. In the Netherlands or Germany, for example, it is estimated that the flexibility potential is already significant. One of the biggest sources of existing flexibility in Germany that will contribute to solving increasing injection congestions is for instance the active management of renewable sources. Other sources of flexibility already in the system have been reported. For instance, it is estimated that only on the perimeter of ENSO NETZ, a DNO in the eastern part of Saxony, the use of 16,000 water heaters at night can give 370 MW of flexibility on a perimeter with a consumption peak of 1200 MW [34].

In other areas, the need for additional flexibility is such that some countries will seek to motivate a greater development of new flexible resources. An important recent focus in the United Kingdom, for example, has been to avoid or postpone expensive network investments by using flexibility sources, in particular, by making new flexibility sources emerge. A prospective study indicates that the further development of flexibility could save between 4 and 13 billion pounds in terms of network by 2050. These figures should be compared to a scenario for which no source of flexibility is used to relief network congestions implying an additional cost of 9 billion pounds [29]. Load congestions (created for instance by increasing electricity consumption, heat pumps, EV fast charging stations) are more likely to imply the development of new source of flexibility. In France, the needs to develop new flexible sources seem less important given the already well-developed flexible sources and the focus seems rather to mobilize these flexibility sources in an efficient way. A study conducted for the Regulator in 2017 concluded that about half of future flexibility needs can be fulfilled by already present technologies (e.g., injection congestions caused by RES generators can be solved by RES curtailment, load injection can be solved by already developed demand response) [33].

Given the large diversity of situations in the countries surveyed concerning the existence of sufficient flexibility sources (or conversely the need of investments in new flexibility resources), the motivations and approach for designing a local flexibility market will differ. In areas with high level of congestion and enough flexibility resources available, the main driver of a local flexibility market is the willingness to optimize the “dispatch” of already existent local flexibility sources, by allowing a direct economic comparison between all flexibility sources available and helping the DNO to choose the most cost-effective solution. The focus here will be on proposing a transparent market mechanism and price signal based on economic merit-order remuneration to ensure an efficient dispatch of the resources.

In other areas, where the level of congestion is high and there are not enough efficient flexibility resources available so far, a local flexibility market will be mostly driven by the objective of the development of new flexibility resources. Here, the focus will be on investment incentives, long-term price signals, and the coordination of DNO flexibility need and flexibility sources availability in the area [35].

2.3. Organization and Governance of Networks Operators

The organizational structure of the network operators (defined here as the number of operators, their perimeter in terms of voltage level, and the number of physical interfaces between them) is another aspect that should be analyzed to understand the motivation and design of a local flexibility market. In fact, different organizational structures will determine the level of communication and coordination needs between DNOs and TSOs to organize congestion management and to properly operate their networks and therefore the potential role of a local of flexibility market.

Distributed generation connected to the distribution grid and the development of local flexibility sources tend to modify the historical relationship between TSOs and DNOs as the need for data exchange, communication and coordination between them significantly increase [36–38]. Several examples can be mentioned to illustrate additional needs for exchange and coordination: The (local) flexibility activation by the DNOs on their own perimeters will impact the overall balance of the system managed by the TSO. Also, the use by TSOs or by intermediate DNOs of flexibility sources on the perimeter of a DNO, may create either a network imbalance or local congestion on the DNO perimeter. Finally, competition between the actors would occur if different actors (TSO or DNO) wish to use the same resource (this scenario will appear even more when DNOs work in tandem).

The organizational structure of the network operators will define the communication/coordination needs implied by decentralization as well as the potential role of a local flexibility market platform. Organization structures that feature a high number of DNOs/TSOs and with several interfaces typically correspond to cases with high communication and coordination needs and transaction costs. Figure 2 illustrates different types of possible organizational structures placed from left to right according to their need for coordination and exchange. Due to the existence of transaction and coordination costs, bilateral coordination between a high number of stakeholders could be costly [39,40]. Indeed, given the transaction costs, it could be more cost-effective for DNOs to participate to an external market platform shared with others DNOs than to construct their markets on their own and ensure bilaterally the coordination with all other network operators [41].

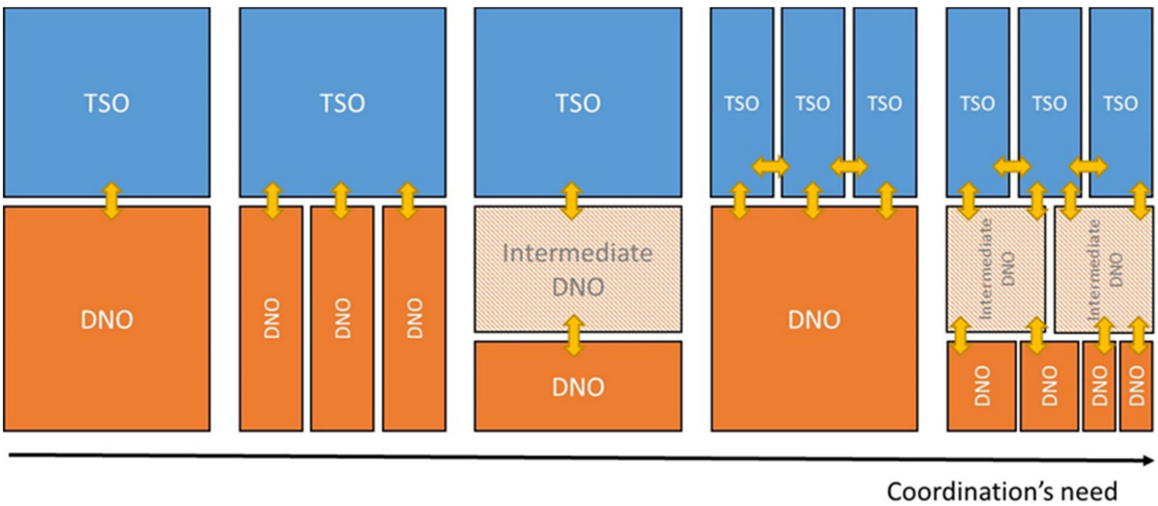

Figure 2. Types of possible organizational structures and need for coordination.

The organizational structures of network operators are very diverse in Europe. In Germany, for example, there are 4 TSOs, and around 880 DNOs [42]. Communication and coordination needs can also be observed between the different DNOs, since certain zones are managed in tandem by several DNOs that officiate at different voltage levels. In France there is only one TSO and a DNO (ENEDIS) has a very large majority and covers 95%

of consumers. In the United Kingdom and the Netherlands, there are respectively 7 and 8 DNOs.

As a local flexibility market could also have the role of platform of coordination, the motivation and design of such a market will differ depending on the organizational structure (The size of DNOs and their capabilities (resources, technical and market skills, etc.) is another aspect that can play a role that the motivation of a local flexibility market. In case of many small network operators for example it could be complex and time-consuming to build their independent market on their own. A local flexibility market may concentrate resources and benefits from economies of scale.). In case many network operators are involved, the development of a local flexibility market can be partly motivated by a need for coordination and centralization of information.

2.4. Differences in Approaches and Regulation for Congestion Management

There are several ways to manage congestion [43]: Network solutions (modification of the topology or network reinforcement), differentiated network tariffs, limiting volume of connections or using "smart" connection contracts, trade management (an institution is in charge to limit the traded electricity between geographic areas to feasible flows), and redispatching (i.e., the modification of generation and/or load schedules in order to modify the physical flows on the network). Redispatching approaches can be categorized in two types: cost-based redispatching (participants that are asked to modify generation/demand schedules are paid based on audited costs) and market-based redispatching (participants that are asked to modify generation/demand schedules are paid based on proposed bid or on a local market price). The local flexibility market belongs to this last category (market-based redispatching approach).

The need for an evolution of the traditional approaches used for congestion management can also bring different motivations to develop a local flexibility market. In some countries, historical approaches applied to manage congestions at the distribution network level lack transparency and are often only indirectly factoring economic principles. While market-based approaches are encouraged at the European level (particularly after the Clean Energy-Package), so far only few countries in European rely on congestion management approaches based on a transparent merit order of flexibility resources. This can be partially explained by the fact that historical congestion management mechanisms have often been primarily designed by distribution operators as emergency responses in rare cases of congestion. The context has now changed in some jurisdictions and with the increasing congestions these historical approaches are increasingly questioned. In addition, historical congestion management mechanisms were often designed for traditional providers (in particular conventional generation assets). Those historical mechanisms are not featured to allow the integration of new flexibility sources with different technological characteristics (e.g., minimum requirements are often perceived as a barrier for new flexibility sources) [44].

A closer look to the situation of the four studied countries shows quite diverse congestion management approaches: some countries already have market-based redispatching mechanisms for distribution networks but with lack of transparency and not fully open for small flexibility resources.

- In France, for example, the management of the network under 110 kV is shared by both RTE since it operates on networks of 63 and 90 kV and ENEDIS, which cover networks of 20 kV and LV. The current congestion management carried out by RTE is mainly realized via a market-based redispatching mechanism. In the context of redispatching, RTE has two ways to deploy flexibility in order to solve congestion, either via the balancing mechanism or through the contractualization of assets via D-1 contracts which are bilateral contracts with producers [45]. The French balancing mechanism ranks a number of offers from flexible sources (with minimum bid of 10 MW) that can respond to the problem according to an economic merit-order of their offers with pay as bid remuneration. While the French mechanism is using a market-based approach taking into account an economic merit-order to select flexibility offers, it is also, at least as regards redispatching, not entirely transparent, since system operators do not communicate details of the activated offers or the areas concerned by congestion, and do not allow small non-aggregated assets to participate with its minimum bid size of 10 MW. ENEDIS, the main French distribution operator, does not currently have a market-based approach to manage its network constraints, but proposes specific "smart" connection contracts for renewable electricity connection ("contrats de raccordements intelligents"). These contracts allow to a certain extent for the curtailment of the RES producers in case of network constraint (i.e., injection congestions). In other countries, there is mechanism allowing to manage congestion close-to-real time but no market-based approach.

- Some other countries have relied mostly on cost-based or network solution so far. In Germany, for instance, congestion management on distribution networks is mainly carried out through network solutions or through cost-based redispatching solutions [46]. The cost-based redispatching solution system is "feed-in management", mostly used at transport level but also used by some distribution network operators. This approach manages the curtailment of renewable production (equal or over 100 kW) for network purposes and reimburses 95% of their costs (or guaranteed purchase rates as feed-in-tariff) corresponding to a management close to real time, without establishing a cost-based merit order between several available offers. Therefore, it does not allow a selection of the most economically effective flexibility offer. These costs are at the end passed through to consumers because these costs are considered as non-controllable and are outside the incentives regulation [31].
- In the United Kingdom, congestion management on the distribution network is now mainly based on network solutions and connection contracts. The regulator has introduced a new connection policy for new generation sources called "Connect and Manage", that offers a possibility of accelerated network access (new assets can start generating before the end of the complete connection/network works), making it possible to manage certain injection constraints.
- In the Netherland, to the best of our knowledge, there is no market-based mechanism to manage congestion on the distribution network. There is a cost-based dispatch solution system, with curtailment of renewable energy sources in case of congestion.

The historical approaches for congestion management at the distribution level can bring different motivations to develop a local flexibility market. In countries with no market-based approach, the development of a local flexibility market can provide market-based tools to provide an economic signal to select the least cost flexibility resources to solve congestion and optimize the dispatch of flexibility resources. In area(s) which have historically relied on some form of an economic approach, but which may include some barriers to participation and/or lack transparency, the value added of a flexibility market could be to improve the transparency and/or allow broader participation of flexibility resources by integrating some (small, new technologies) new flexibility sources. A local flexibility market can create a level-playing field between different types of flexibility resources and enhance transparency of the congestion management process at the distribution level.

2.5. Conclusions: Local Diversity and Different Potential Roles of a Local Flexibility Market

Table 2 summarizes the main local specificities of the four surveyed countries. The situation is quite contrasted across the countries. The emergence of local congestion may be important or quite limited. The organizational structure is also varied, with systems with few (and large) network operators and others with many small operators. In general, countries use congestion management approaches at the distribution level without a transparent economic merit-order, although some countries already have limited market-based mechanisms. And some countries have a sufficient number of flexibility sources meeting the characteristics they seek, while others will have to develop new ones.

Table 2. Summary of the diversity of situations in different countries.

	France	Germany	United-Kingdom	The Netherlands
Type and frequency of local congestion	Low congestion	High congestion. Injection congestion	High congestion Injection and Load congestion	Moderate congestion
Need for new resource's development.	Medium	Weak	High	High
Organizational structure	1 TSO and 1 majority DNO	4 TSOs & more than 800 DNOs (including DNO in tandem)	1 TSO and several DNOs	1 TSO & 11 DNOs (including 8 over 100,000 consumers)
Current congestion management mechanism	Market-based mechanism for 90 kV and 63 kV networks, deemed not very transparent. Connection management mechanism	No market mechanism. Cost-based mechanism.	No market mechanism. Connection management mechanism.	No market mechanism.

In summary, our case studies allow us to identify four main motivations that can drive the emergence of a local market of flexibility:

(i) As an economic tool for the DNO to efficiently use local flexibility resources in cases with important level of congestions when the historical approach does not rely on a sufficiently transparent market-based mechanism
(ii) As a market-framework to give new incentives to develop and invest on new flexibility sources;
(iii) As a tool to coordinate network operators' local flexibility activations in cases with an important level of congestion and the presence of multiple stakeholders;
(iv) As a way to cope with the inadequacy of current congestion management mechanisms which sometimes feature barriers to the participation of a broad range of flexibility resources and do not allow to integrate some new sources of flexibility for congestion management.

In the next two sections, we turn to the design choices for local flexibility markets. Through the review of the same four case studies, we identify how the local specificities of the different countries reviewed can contribute to explaining the differences in the design of flexibility markets.

3. The Existing Local Flexibility Markets Show a Broad Range of Market-Designs

In this section, we highlight the design versatility of local flexibility markets. We focus on four center-western European initiatives, which have been launched in the countries studied in Section 3. The aim of this section is to describe the main structural differences on market designs, which will allow us in the last section to understand the link between design choices and local situations. We analyze four initiatives (ENERA, GOPACS, UKPN Picloflex, Enedis). Most of these initiatives are experimental and are naturally evolving. It is important to note that our comparison is made with the information available to date.

A survey have described different characteristics of local flexibility markets emerging in Europe [23]. Our analysis completes their survey and introduces a structured approach to compare the design differences following three main dimensions:

- The timeframe of the design: some initiatives focus on short-term management and dispatch of flexibility sources around an intraday or close to real time timeframe, and other on long-term management and adequacy with capacity reservation payment and multi-years contracts.
- The use of an external or third-party platform: some initiatives are based on an external platform that centralize information exchanges and communication and

ensure coordination while others are based on self-organized market mechanism only managing the need of one operator without explicit coordination with others.
- The access easiness: Some initiatives focus on providing simplified access to new smallest actors, even if all of them are providing easier access than historical congestion-mechanism managed by TSO.

3.1. Timeframe of the Design

The four initiatives differ on the timeframe on which they focus on their market-design. Two of the analyzed initiatives are focused more on short-term management (day-ahead or intraday timeframe, i.e., some hours before real-time), and two initiatives are focused more on long-term needs (one or several years before real-time).

For ENERA and GOPACS, the definition of "flexibility" product is intended to respond to congestions identified in the short-term on a day-ahead (DA) or intraday (ID) vision. Network operators (DNO-TSO) identify potential network issues the day before real-time and indicate their congestion management needs at the time granularity that governs the intraday market in their area (for one day, 96-time steps of 15 min for the network in Germany and the Netherlands). For ENERA, the traded product is a downward flexibility in quarter-hour or hourly steps. It refers to the unilateral activation of an offer to buy (increase load or decrease injection) or alternatively an offer to sell from flexibility offers. For GOPACS, the traded product is named Intra-day Congestion Spread (IDCONS) [47]. It is a product that includes an offer to buy and an offer to sell outside the congested area (or vice versa) via the ID ETPA platform. Local flexibility sources in the case of ENERA and GOPACS are only paid on activation.

In the case of UKPN and ENEDIS, a long-term logic is adopted in the definition of the flexibility needs (level and frequency) and the associated products. The definition of planning needs can go up to several years (up to 7 years for UKPN). UKPN and ENEDIS may offer payment for the reservation of flexible capacity (in addition to potential payment if this capacity is activated). Reserved capacity payments are associated with an availability windows (for instance some hours of the day, some months of the year) and can be established for year or even multi-year contract. UKPN can also shortlist assets under development or planned to enable them to integrate more quickly and show in which already-developed tenders they could compete [48].

In conclusion, a local flexibility market may be designed for a short-term need to resolve congestion, focusing on dispatch close-to-real time, or for a long-term structural flexibility need, focusing on the adequacy of flexibility resources to meet the system needs and therefore on investments in flexibility resources.

3.2. The Use of an External or Third-Party Platform

Initiatives introducing flexibility markets will also differ in the coordination possibilities they propose for TSO/DNO to ensure system security and mainly to solve congestion. The organization of the local flexibility market is typically based on an external platform in the case of ENERA, GOPACS, and UKPN, but is self-organized by ENEDIS.

On the GOPACS platform, TSO/DNO coordination is central. Network operators identify locations where flexibility could be needed to solve a congestion on a part of the network and signify them to an external platform managed by a third-party (GOPACS) that centralizes the needs of network operators and manages the potential conflicts and problems in an actor's activations. The GOPACS technical platform does not receive flexibility offers; it is the link to the ETPA ("Energy Trading Platform Amsterdam") market platform and checks whether the activation of the offer(s) (previously located offers) can be used to settle congestion. If transport network operators can use resources connected to a distribution network to solve their own needs, each network operator will remain responsible of congestion-management on their grids. The matching of an offer to buy and sell on this location will be realized (via the product IDCONS) and if there is a spread in price between the two it will be compensated by the network operator.

The ENERA platform collects, as a third-party actor, flexibility needs from few DNOs and TSOs, and flexibility offers from suppliers. However, coordination between DNO and TSO to avoid unappropriated activations is done manually via a process parallel to the EPEX platform. The implementation of the EPEX market platform has revealed the need for more technical coordination. The members of the project would like to evolve in the future towards integration/centralization of the process, in order to filter the offers from one DNO perimeter that could cause a network problem on the perimeter of another TSO/DNO.

In the UKPN case, the external market platform Piclo Flex centralizes the organization of the different tenders following the needs expressed by UKPN (and the other DNOs). During the activation phase, no specific mechanism is provided to manage direct coordination with other network operators such as TSOs. UKPN warns the TSOs when it intends to activate a flexibility resource but does not request validation from them. The activation is therefore entirely in the hand of UKPN and is carried out by the flexibility provider on request of the network operator.

Finally, in the French case, local flexibility reservation tenders are directly organized by ENEDIS (no external platform). The activation is done directly at ENEDIS request, and, for the moment, there is no explicit procedure concerning the coordination with the TSO (this subject is still object of discussion and therefore possible evolution).

In conclusion, a local flexibility market may be designed to coordinate several stakeholder's actions and information (via an external platform) or to realize the autonomous management of one unique operator.

3.3. Access Easiness

The access easiness of different initiatives depends on the design of the local flexibility markets. Even if all initiatives are typically open to decentralized resources and aggregators, specific access rules may facilitate the participation of small resources and new technologies.

ENERA products are standardized on the type of offers made in intraday with minimum bids of 100 kW. For GOPACS the minimum bid size depends on each market-platform linked to GOPACS (500 kW for ETPA) and should be standardized to fit with traditional market-platform requirement. ENEDIS have imposed a minimum offer of 500 kVA, which could be considered as average accessibility (compare to UKPN for example) but it is still representing an important reduction compared to current threshold of congestion market-based solution (10 MW).

The design of the UKPN initiative has had a particular focus on the access easiness. UKPN have established different thresholds for the offers, depending on the voltage level, but with a minimum of 10 kW for low voltage call for tenders. UKPN are giving access to congestion management for many assets connected to the distribution grid which were not integrated in the historical balancing mechanism of the TSO [25]. They can also shortlist assets under development or planned [48].

The local flexibility markets therefore all strive to facilitate the participation of a broad range of flexibility resources, but with different thresholds and approaches for participation which are either in line with the historical approach at the national market level or provide the opportunity for more granular resources to participate.

3.4. Conclusions: High Diversity of the Designs of Local Flexibility Market Initiatives

A market-based solution taking the form of a local flexibility market is being implemented in several countries to respond to the increasing congestion encountered by Distribution network operators. We observe however that their design can be heterogeneous, mainly on the typical temporality (long- or short-term focus), coordination, and organization proposed on the design (the use of an external platform and more or less cooperation for TSO and DNO for example), or access easiness (establish low entry barriers for new participants). Table 3 summarizes how each initiative differs on these three mains targets.

Table 3. Summary of the main features of the different initiatives.

/Project	ENERA	GOPACS	UKPN	ENEDIS
Timeframe	Short term focus (No capacity remuneration; D-1 planning)	Short term focus (No capacity remuneration; D-1 planning)	Long term focus (for up to 7 years; capacity remuneration).	Long term focus (product up to 2 years; possible capacity remuneration.)
The use of an external or third-party platform	Average coordination (External market platform managed by a third-party actor EPEX; manual TSOs/DNOs coordination)	Strong coordination (External technical platform; TSOs/DNOs coordination within platform.)	Low coordination (No explicit coordination mechanism.)	Low coordination. (Self-manage call for tenders; coordination method with the TSO not yet established)
Access easiness	Average accessibility (Minimum offers of 100 kW)	Average accessibility (Minimum bids of each platform; 0.5 MW for ETPA)	Easy accessibility (Minimum offers of 10 kW)	Average accessibility (Minimum Offers: 500 kVA)

4. Joint-Analysis of Local Markets and Specificities: Which Design for Which Needs

This section presents the joint analysis between the local specificities of the four analyzed countries (Section 2) and the design of the local flexibility market initiatives in these countries (Section 3). Our analysis aims to untangle how the choice of design relates to the objectives and specificities of the situation regarding local congestion management in the different countries surveyed. In Section 2, we illustrated the diversity of situations in European countries and shown that the local differences can explain four main drivers to develop a local flexibility market. In Section 3, we highlighted the various market design approaches for these flexibility markets. By crossing our analysis of the local characteristics and of the design specificities, we identify four main drivers that could lead to different market-design choices which we discuss in greater details in the next subsections:

(i) The need for short-term design to optimize congestion management using existing local flexibility resources;
(ii) The need for long-term mechanisms to develop new local flexibility resources and services;
(iii) The need for an external platform to enhance communication and coordination between TSOs/DNOs;
(iv) The willingness to minimize barriers to entry of congestion management mechanisms in order to facilitate the integration of decentralized resources into the system.

4.1. The Need for Short-Term Design to Optimize Congestion Management Using Existing Local Flexibility Resources

Depending on the local power system and governance characteristics, a design allowing a transparent merit-order between existing flexibility resources for the dispatch will bring potentially significant cost reductions for the short-term congestion management.

In some areas, the level of congestion is already significant and sufficient sources of flexibility are in the system, but the current congestion-management mechanism does not optimize the dispatch of these sources with a transparent economic merit-order. DNOs typically have knowledge of their network's flexibility needs, but sometimes they lack visibility on the possibility to activate and cost of the decentralized flexibility resources connected to their networks.

A flexibility market design such as the one developed by ENERA for example, which proposes a transparent short-term merit-order based on a market-based principle for flexibility resources to network operators, could allow to increase the efficiency of the dispatch and uses of flexibility resources in Germany.

4.2. The Need for Long-Term Mechanisms to Develop New Local Flexibility Resources and Services

In some areas where we observe already important or increasing congestion in the distribution networks, the number of flexibility resources could be not sufficient or not adapted to the type of congestion. In this case, it may be necessary to develop new flexibility resources to propose services for congestion management to DNOs. To provide incentives for the development of efficient flexibility sources, local flexibility market-design should focus on providing investment incentives through long-term signals such as capacity remuneration payment and/or long-term contracts.

In our case studies analysis, the design chosen by UKPN is an example of an approach geared towards the development of new flexibility resources. UKPN assesses its local flexibility needs during the network planning process. Flexibility providers can contract up to seven years and receive capacity (if available) and energy remuneration (in case of activation). New flexibility resources (not developed at the moment of the tender) can participate and get those contracts.

Because investment is needed, market-design with long-term timeframe will be privileged [49]. As described before, if competitive market will drive short-term efficiency for activating the different flexibility resources (using existent flexibility sources), a long-term oriented market design should set a level playing field and attract new investment in a range of flexibility resources which could generate efficiency gains by reducing the flexibility investment costs. Several features of such market design are important to provide a transparent and predictable investment framework, such as: the flexibility need's definition, planning and contracting for several years for example to give a better visibility and reduce risk for investors. The market design can also contribute to reducing investment risks by providing a long-term vision on future potential revenues for investors by combining a payment for reservation (capacity) and for activation (energy), thus reducing the risks for investors.

4.3. The Need for an External Platform to Manage Communication and Coordination between TSOs/DNOs

The need for coordination, communication, and data exchange are typically high in a context with high level of congestion and a large number of stakeholders involved with varied sizes and interests. In such context, local flexibility markets which are focusing on enhancing the coordination between stakeholders can play an important role in the electricity system. The alternative solution (bilateral coordination between network operators) could be less efficient given the transaction costs implied by recurrent coordination of actions for congestion management between several stakeholders.

Developing a local flexibility market provides a coordination tool between stakeholders, in particular if it is based on an external platform centralizing data and actions for several TSO/DNOs. Indeed, because networks are inter-connected, a flexibility resource could hold an interest for several actors to be used for congestion-management issues for several DNOs or participate to national balancing manage by the TSO for example. If they are not sharing a common-used platform, the hourly coordination between them would create complexity. Moreover, in case the resource use is not specific and the needs of the network operators where it is connected is not recurrent, transaction cost theory suggests than it would be suboptimal to consider an exclusive use by a network operator.

As explained in the previous section, depending on the local context the coordination benefits that different types of local market platforms bring may differ. In the cases analyzed in this article, a platform such as GOPACS which has in its operating characteristics many elements facilitating the communication between TSOs/DNOs and between DNOs, will facilitate coordination between actors in an institutional context, such as Germany, characterized by many network operators. In this context the external platform would also allow to share methods and understand potential issues created by some flexibility offers activation on the different networks. This can represent a first step towards an external platform having a potentially more extended technical role.

A local flexibility market using an external platform to centralize data and the needs of each network operator can thus bring benefits to coordinate and centralize multiple parallel bilateral processes or of parallel local markets developed by each DNO. The co-construction of a platform between TSOs and DNOs, the communication and centralization of their network constraints, and a joint monitoring of network operators on a local flexibility platform can bring benefits to organize and facilitate cooperation between TSOs and DNOs.

4.4. The Willingness to Minimize Barriers to Entry of Congestion Management Mechanisms in Order to Facilitate the Integration of Decentralized Resources into the System

In some areas, emerging flexibility sources face difficulties to participate in congestion management because of the barriers introduced by current mechanisms (as explained in Section 2). Indeed, the existing congestion management approaches may potentially be too restrictive to allow participation of a broad range of decentralized resources and the adaptation of those mechanisms (historically built for TSO's needs and conventional assets) could be difficult to implement. In this context, local flexibility market-design can bring benefits to facilitate the participation of new decentralized and small-scale resources and focus on access easiness.

From our case studies, the design chosen by ENEDIS illustrates such approach targeted on the broadening of the participation to local flexibility resources. Indeed, although French congestion needs are currently estimated in the prospective studies to be rather limited (see Section 2), the participation of decentralized resources could offer new options to the DSO to manage congestions in some specific areas. By reducing barriers to participation compared to conventional mechanisms, for example, with a minimum bid of 500 kVA (even potentially reduced), this platform allows decentralized resources to participate.

The market design of the local flexibility market should consider different aspects to facilitate access. It is possible to implement a lower minimum threshold in terms of supply volume as well as less rigid product standardization than historical congestion management mechanisms, in order to also allow actors offering different products to participate. The market should, if possible, not require an exclusivity of the resources and thus allow the flexibility resources to participate in other markets for other products as well. Finally, penalties should be proportionate in order to avoid placing too much risk on new resources.

5. Conclusions

The ongoing transformation of the electricity systems across Europe leads to a range of specific challenges and issues regarding local congestion management, which are different depending on the local power system and market specificities. Our paper leverages 4 cases studies in different countries (ENERA, GOPACS, UKPN, and ENEDIS, respectively in Germany, the Netherlands, the United Kingdom, and France) to analyze the emergence of new flexibility platforms and to identify the drivers of the implementation of these local flexibility markets and the key specific design choices depending on the local context. The main contribution of the paper is to provide a structured analysis of the diversity of market-designs for local flexibility markets in the light of these local specificities.

As a general conclusion, there is no "one size fits all" design to manage congestions: characterizing and understanding the local context and needs before implementing new market or regulatory mechanisms is a prerequisite to ensure effectiveness and efficiency. Local flexibility markets address specific needs with different designs: it is thus unlikely that unified/homogeneous design emerges among European countries, although some common design principles and guidelines could emerge.

We show indeed that the power system flexibility needs and market context among the four countries are markedly different. The emergence of local congestion, the need to encourage the development of new resources, the organizational framework and the current congestion management approaches differ across the four countries. We highlight how these different local differences affect the motivations for the development of a local flexibility market, and the main contributions than a local flexibility market would have for an area, which include:

- The optimization of the activation of flexibility resources based on a transparent economic merit order;

- The willingness to send incentives to develop new flexibility sources on a specific location;
- The need for a new coordination tool between different stakeholders, such as multiple DNOs and TSOs, in a context of increasing coordination needs involving new challenges and transaction costs; and
- The willingness to integrate new types of flexibility resources, which may face entry barriers by offering products that are different from those used in the national balancing markets run by TSOs for example.

We have also identified a number of key differences in the market-design of the different local flexibility markets surveyed, mainly on three core aspects:

- The timeframe of the design corresponding to the flexibility needs (short or long-term),
- The use of an external or third-party platform and
- Their access easiness.

Our paper then analyzed the diversity of situations encountered in the different countries with the market design choices. We used the four cases studies to generalize our findings, identifying a typology of potential approaches and analyzing the suitability of different market designs for flexibility platforms depending on the local specificities:

1. When there is already a significant level of congestion and flexibility resources available, a design establishing a transparent economic merit-order can be useful to optimize the dispatch of flexibility resources and the short-term congestion management.
2. When the objective pursued by the local flexibility market is to encourage the development of flexible resources in an area, a design and product definition providing a longer-term predictability of revenues (e.g., with capacity payments) can be relevant.
3. A local flexibility market based on an external platform and with centralization of key information can be useful to facilitate communication and coordination in cases with organizational structures involving many TSOs and DNOs and a variety of stakeholders.
4. Finally, when the regulatory framework in place features barriers preventing the participation of different types of smaller flexibility resources from being exploited, a market-design which facilitates broad participation by e.g., reducing the minimum eligibility thresholds can provide new options to manage local congestion in a cost-efficient way.

6. Further Work

While this article identifies different motivations of local flexibility markets and how different market designs may address them, it does not cover a number of issues that are left for further research.

The geographical scope of the case studies presented paper is limited to four countries of Central-Western Europe, although the paper derives from these a number of general findings and recommendations. Extending the analysis to other countries with local specificities may bring new insights about how such flexibility markets could be tailored to meet the needs of different power systems. For instance, Southern European countries characterized by a significant growth of decentralized resources and challenges associated with the high solar capacity may benefit from a specific analysis of the value that flexibility platforms could bring. Other interesting case studies would include, e.g., countries in Northern and Eastern Europe where for instance decentralized/micro CHP could provide local flexibility.

Because local flexibility markets are only a subset of the potential solutions to manage local congestions, the creation of a new local flexibility markets should also be analyzed in the broader context of the possible evolution of the market design and regulatory framework. In addition to such local flexibility markets, a wholistic analysis needs to assess the possibility of extending and improving historical congestion management mechanisms, as well as other policy tools that influence congestion such as network tariffs, connections contracts, etc.

A normative economic analysis framework needs to be developed to compare different approaches to manage flexibility resources at the local level for congestion management. It will be necessary to take into account some of the possible implementation costs associated with the development of these new local flexibility markets, but also take into account the possible impact of these developments on the existing historical mechanisms [50–53].

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References

1. Verhaeghe, C.; Perekhodtsev, D.; Gérard, A.; Roques, F. *Système de Prix Nodaux: Expérience Américaine et Perspectives Pour l' Europe*; FTI COMPASS LEXECON ENERGY: Washington, DC, USA, 2018.
2. CEER. *Flexibility Use at Distribution Level*; CEER: Brussels, Belgium, 2018.
3. Commission de Régulation de l'Energie. *Les Réseaux Électriques au Service des Véhicules Électriques*; Commission de Régulation de l'Energie: Paris, France, 2018.
4. Dutrieux, H. *Méthode Pour la Planification Pluriannuelle Des Réseaux de Distribution. Application à L'Analyse Technico-Économique Des Solutions D'Intégration Des énergies Renouvelables Intermittentes*; Ecole Centrale de Lille: Villeneuve-d'Ascq, France, 2015.
5. Kempton, W.; Udo, V.; Huber, K.; Al, E. *A Test of Vehicle-to-Grid (V2G) for Energy Storage and Frequency Regulation in the PJM System*; University of Delaware: Newark, DE, USA, 2009.
6. Villar, J.; Bessa, R.; Matos, M. Flexibility products and markets: Literature review. *Electr. Power Syst. Res.* **2018**, *154*, 329–340. [CrossRef]
7. Paterakis, N.; Erdinç, O.; Catalão, J.P.S. An overview of Demand Response: Key-elements and international experience. *Renew. Sustain. Energy Rev.* **2017**, *69*, 871–891. [CrossRef]
8. Richardson, P.; Flynn, D.; Keane, A. Impact assessment of varying penetrations of electric vehicles on low voltage distribution systems. *IEEE Power Energy Soc. Gen. Meet.* **2010**, 1–6. [CrossRef]
9. Acha, S.; Green, T.; Shah, N. Effects of optimised plug-in hybrid vehicle charging strategies on electric distribution network losses. *IEEE PES T&D 2010* **2010**, 1–6. [CrossRef]
10. Wiechmann, H. *Grid Integration of Electric Mobility: 1st International ATZ Conference 2016*; Springer: Berlin/Heidelberg, Germany, 2017; p. 299.
11. Esmat, A.; Usaola, J.; Moreno, M.Á. A Decentralized Local Flexibility Market Considering the Uncertainty of Demand. *Energies* **2018**, *11*, 2078. [CrossRef]
12. Reihani, E.; Motalleb, M.; Thornton, M.; Ghorbani, R. A novel approach using flexible scheduling and aggregation to optimize demand response in the developing interactive grid market architecture. *Appl. Energy* **2016**, *183*, 445–455. [CrossRef]
13. Kotthaus, K.; Pack, S.; Hermanns, J.; Paulat, F.; Meese, J.; Zdrallek, M.; Neusel-Lange, N.; Raczka, S. Local Flexibility Markets: An Economic Solution For the Upcoming Influence of Electrical Charging Station Penetration. In Proceedings of the 25th International Conference on Electricity Distribution, Madrid, Spain, 3–6 June 2019.
14. Kufeoglu, S.; Pollitt, M.; Anaya, K. *Electric Power Distribution in the World: Today and Tomorrow*; University of Cambridge: Cambridge, UK, 2018; p. 1826.
15. Brunekreeft, G.; Buchmann, M.; Meyer, R. New developments in electricity markets following large-scale integration of renewable energy. In *The Routledge Companion to Network Industries*; Finger, M., Jaag, C., Eds.; Routledge: Oxfordshire, UK; pp. 37–51.
16. Ramos, A.; De Jonghe, C.; Gómez, V.; Belmans, R. Realizing the smart grid's potential: Defining local markets for flexibility. *Util. Policy* **2016**, *40*, 26–35. [CrossRef]
17. Tennet. *Press Release Enera Project: EWE and EPEX SPOT to Create Local Market Platform to Relieve Grid Congestions*; Tennet: Arnhem, The Netherlands, 2019.
18. Wiersma, F. Joint TSO-DSO platform for Market-Based Congestion Management. In Proceedings of the Conference CEEM-GOPACS, Paris, France, 29 May 2019.
19. Sam, D.; Ahmadi, A.; Mcdonald, L.; Mokkas, E.; Georgiopoulos, S. UK Power Network 'S Flexibility Market Offers New Revenue Stream For Customers & Enhances Active Operation of the Distribution. In Proceedings of the 25th International Conference on Electricity Distribution (CIRED 2019), Madrid, Spain, 3–6 June 2019.

20. Villafafila-Robles, R.; Bremdal, B.; Sumper, A.; Rajasekharan, J.; Olivella-Rosell, P.; Ottessen, S.; Munné-Collado, Í.; Lloret-Gallego, P. Local Flexibility Market Design for Aggregators Providing Multiple Flexibility Services at Distribution Network Level. *Energies* **2018**, *11*, 822. [CrossRef]
21. Zhang, C.; Ding, Y.; Ostergaard, J.; Bindner, H.W.; Nordentoft, N.C.; Hansen, L.H.; Brath, P.; Cajar, P.D. A flex-market design for flexibility services through DERs. *IEEE PES ISGT Eur.* **2013**, 1–5. [CrossRef]
22. Gerard, H.; Puente, E.I.R.; Six, D. Coordination between transmission and distribution system operators in the electricity sector: A conceptual framework. *Util. Policy* **2018**, *50*, 40–48. [CrossRef]
23. Schittekatte, T.; Meeus, L. Flexibility markets: Q&A with project pioneers. *Util. Policy* **2020**, *63*, 101017. [CrossRef]
24. Radecke, J.; Hefele, J.; Hirth, L. *Markets for Local Flexibility in Distribution Networks*; ECONSTOR: Hamburg, Germany, 2019.
25. Joos, M.; Staffell, I. Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany. *Renew. Sustain. Energy Rev.* **2018**, *86*, 45–65. [CrossRef]
26. Energieonderzoek Centrum Nederland (ECN). *The Demand for Flexibility of the Power System in The Netherlands, 2015–2050*; Energieonderzoek Centrum Nederland (ECN): Amsterdam, The Netherlands, 2016.
27. *Synthèse Appel à Contributions – Les Flexibilités Locales sur le RPD*; Enedis: Paris, France, 2019.
28. *Rapport de L ' Agence FéDérale Des Réseaux (Bundesnetzagentur) Sur la Production Minimale en 2019*; BNetzA: Bonn, Germany, 2018.
29. Carbon Trust and Imperial College. *An Analysis of Electricity System Flexibility for Great Britain*; Carbon Trust: London, UK, 2016.
30. Schermeyer, H.; Vergara, C.; Fichtner, W. Renewable energy curtailment: A case study on today's and tomorrow's congestion management. *Energy Policy* **2018**, *112*, 427–436. [CrossRef]
31. Brunekreeft, G.; Kuznir, J.; Meyer, R.; Sawabe, M.; Hattori, T. *Incentive Regulation of Electricity Networks under Large Penetration of Distributed Energy Resources—Selected Issues*; GOPACS: Arnhem, The Netherlands, 2020; p. 33.
32. UKPN. *Flexibility Roadmap*; UKPN: London, UK, 2018.
33. ECUBE. *Etude Sur Les Mécanismes de Valorisation Des Flexibilités Pour la Gestion et le Dimensionnement Des Réseaux Publics de Distribution D'électricité*; ECUBE: Chicago, IL, USA, 2017.
34. Netz, E.; Germany, G.; Schmidt, M.; Knoll, R.; Netz, E.; Germany, G.; Schegner, P.; Darda, T.; Germany, E.A.G. Providing Flexibility in the Distribution Network—Challenges and Solutions. In Proceedings of the 25th International Conference on Electricity Distribution, Madrid, Spain, 3–6 June 2019.
35. Hansen, J.-P.; Percebois, J. Microéconomie et Marchés de l'énergie: Marché et Concurence: Pratiques et Limites. In *Energie: Economie et Politiques*; De Boeck: Brussels, Belgium, 2010; pp. 62–65.
36. Hadush, S.Y.; Meeus, L. DSO-TSO cooperation issues and solutions for distribution grid congestion management. *Energy Policy* **2018**, *120*, 610–621. [CrossRef]
37. Gerard, H.; Rivero, E.; Six, D. Basic schemes for TSO-DSO coordination and ancillary services provision. *SmartNet Deliv. D* **2016**, *1*, 12.
38. Ampatzis, M.; Nguyen, P.H.; Kling, W. Local electricity market design for the coordination of distributed energy resources at district level. *IEEE PES Innov. Smart Grid Technol. Eur.* **2014**, 1–6. [CrossRef]
39. Williamson, O.E. The Economics of Organization: The Transaction Cost Approach. *Am. J. Sociol.* **1981**, *87*, 548–577. [CrossRef]
40. Arrow, K.J. The Organization of economic activites: Issues pertinent to the Choice of Market versus Nonmarket Allocation. In *The Analysis and Evaluation of Public Expenditure: The PPB System*; U.S Joint, Ed.; Government Printing Office: Washington, DC, USA, 1969; pp. 47–64.
41. Grossman, S.J.; Hart, O.D. An Analysis of the Principal-Agent Problem. *Econometrica* **1983**, *51*. [CrossRef]
42. JRC. *Distribution System Operators Observatory 2018*; European Union: Brussel, Belgium, 2019.
43. Hirth, L.; Glismann, S. *Congestion Management: From Physics to Regulatory Instruments*; Econstor: Hamburg, Germany, 2018.
44. NODES; E-Bridge; Pöyry. *Market-Based Redispatch is a Necessary Complement to the Current German Redispatch Regime*; NODES: Lysaker, Norway, 2019.
45. *Plaquette Mécanisme d'Ajustement*; RTE: Paris, France, 2010.
46. Bayer, B.; Matschoss, P.; Thomas, H.; Marian, A. The German experience with integrating photovoltaic systems into the low-voltage grids. *Renew. Energy* **2018**, *119*, 129–141. [CrossRef]
47. GOPACS. *IDCONS Product Specification*; GOPACS: Arnhem, The Netherlands, 2019.
48. Piclo. *Energy on Trial*; Piclo: London, UK, 2019.
49. Stoft, S. Power Market Fundamentals. In *Power System Economics*; IEEE: Piscataway, NJ, USA, 2009; p. 496.
50. Neon and Consentec. Cost- or Market-Based? Future Redispatch Procurement in Germany. Available online: https://www.bmwi.de/Redaktion/EN/Publikationen/Studien/future-redispatch-procurement-in-germany.pdf?__blob=publicationFile&v=3 (accessed on 6 May 2021).
51. Finon, D. Mythe du Paradigme Electrique Decentralise. *La Rev. l'Energie* **2017**, *635*, 20–34.
52. Hansen, J.-P.; Percebois, J. Microéconomie et marchés de l'énergie. In *Energie: Economie et Politiques*; De Boeck Supérieur: Louvain-la-Neuve, France, 2010; pp. 56–118.
53. Madina, C.; Riano, S.; Gomez, I.; Al, E. Cost-Benefit Analysis of TSO-DSO Coordination to Operate Flex markets. In Proceedings of the 25th International Conference on Electricity Distribution (CIRED 2019), Madrid, Spain, 3–6 June 2019.