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Business Model Innovations for Renewable Energy Prosumer Development in Germany

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Abstract: In Germany, the number of renewable energy prosumers has increased rapidly since 2000. However, the development of prosumers has faced and will continue to face various economic, social, and technological challenges, which have triggered the emergence of a number of innovative business models (BM). This paper enriches the empirical basis for prosumer-oriented BMs by investigating two BM innovations in Germany (P2P electricity trading and aggregation of small-size prosumers) drawing on business model and socio-technical transition theories. A mix of qualitative data collection methods, including document analysis and semi-structured expert interviews, was applied. We found that while both BMs can potentially address the challenges associated with renewable energy prosumer development in Germany, small-scale prosumers' participation in both BMs has been limited so far. We identified various internal and external drivers and barriers for scaling up these BMs for prosumer development in Germany. Despite these barriers, both aggregation and centralized P2P targeting prosumers may potentially be also taken up by incumbent market actors such as utilities. Decentralized P2P on the other hand still faces significant internal and external barriers for upscaling. Based on the analysis, the paper provides policy recommendations with respect to the identified drivers and barriers. From a theoretical perspective, our findings provide further evidence to challenge the dichotomous understanding of niche actors and incumbents, the latter of which are often theorized to be resistant to radical innovations.

Keywords: renewable energy; prosumer; business models; P2P electricity trading; aggregation

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1. Introduction

In Germany, the energy system is undergoing a paradigm shift, evolving from centralised energy generation towards an expanding network of decentralized prosumers who both produce and consume renewable energy. This development has been largely associated with the expansion of roof-top solar PV, which has surged in the past two decades. This development resulted from ambitious policy targets and their pursuit via priority grid access for renewable electricity, a purchase guarantee, and generous financial incentives provided via Feed-in-Tariff (FiT) over a 20-year period. Due to these favourable conditions, the number of prosumers increased from a few thousand to more than 900,000 between 2000 and 2016 [1], where small-scale PV systems (<10 kWp) dominated annual new installations [2]. By April 2021, almost two million PV systems (in total 54 GWp) were installed [3], with the majority being owned by private individuals, farmers or businesses [4].

However, the amended Renewable Sources Energy Act ("EEG") in 2012 introduced a steadily reduced FiT for new renewable plants. For small rooftop systems, the FiT fell from almost 60 ct/kWh in 2005 to slightly above 7 ct/kWh for plants installed in autumn 2021 [5]. In addition, since 2020, the guaranteed FiT ended after 20 years for the renewable energy plants installed in 2000 and will expire for more and more prosumers in the coming years. These changing conditions have created increasing economic challenges for prosumers, who need to decide if they are to continue running their PV plants or shut them down. On the other hand, social challenges, in particular regressive effects, have arisen from unevenly distributed opportunities to reap the benefits of prosumage (most notably between building owners and tenants) [6]. Prosumage is most likely implemented by consumers belonging to the upper income segments, who own a house with the possibility to install PVs. The distributional effects are further aggravated by the current design of grid charges. Since fixed grid costs must be spread over ever fewer customers in case of increasing prosumage, continued energy consumption-based grid charges would unfairly burden consumers that cannot become prosumers themselves. Last but not least, the increasing number of prosumers raises new technological challenges for the grid operators in maintaining system balance, as variable renewable power plants such as PV are associated with high fluctuations in electricity generation. Furthermore, as a consequence of the increase in decentralised energy sources, more generated power feeds into the distribution grids, resulting in increasing congestion at this level and bi-directional power flows between distribution grid and transmission grid (in contrast to the classical flow from the transmission grid to distribution grid). At the same time, distributed energy resources (DERs) (i.e., distributed renewable power generation, demand-side resources, and energy storage) can also be an important potential source of flexibility to address the described grid challenges [7].

These different challenges have triggered the emergence of innovative business models (BM) in Germany, which aim to explore new market opportunities through the provision of novel services addressing them. Besides Germany, globally, there are a number of pilots of BM innovations (BMIs) around peer-to-peer electricity trading (P2P) (in USA, UK, Netherlands, Colombia, Bangladesh, etc.) and aggregation of DERs (in Australia, USA, Netherlands, etc.) [8–10]. Various studies have investigated how BM and BMI promote technology innovations in the energy sector, including prosumer-centred ones. For example, ref. [11] identified and analyzed three promising prosumer-centered BMs: prosumer grid integration, P2P models, and prosumer community groups. To aggregate household flexibility capacities in Germany, an innovative business model ("Energy Supplier 2.0") was conceptualised and discussed [12]. Nine new business model archetypes of local supply in UK, which are relevant for prosumers, were analyzed [13]. Additionally, ref. [14] provided a typology of five BM archetypes that would enable viable operation after FiT expires in Germany. However, [15] claimed that many of them explored BMI design with hypothetical examples, and only a few studies presented empirical evidence of these BMI. These studies have also been primarily focused on analysing the features of specific prosumer-centered BMIs; for instance, their design framework, agorithm, and enabling technologies [16–18]. Only a few studies have taken a systematic perspective to understand how these BMIs interact with the various external factors shaping their development, such as regulatory frameworks, technological innovations, customer needs, and infrastructure [19]. Arguably, the wider interactions need to be systematically understood to assess the possibility of BMI upscaling [14,20].

Against this background, this paper aims to provide empirical evidence of prosumer-centered BMIs and systemtically analyse how the BMIs have been shaped by both internal and external factors. We focused on the recent development of the following two BMIs in Germany: P2P electricity trading and aggregation of small-size DERs. More specifically, the paper investigates the following research questions: (1) What has driven and impeded their development, especially regarding the involvement of small-scale prosumers, and (2) what are their future prospects in Germany?

The paper is organised as follows. Section 2 presents the conceptual foundation of the study and details the analytical approach and data collection methods. Sections 3 and 4 present and discuss our findings with view to the two guiding research questions. Section 4 finally draws conclusions and provides policy recommendations to support the upscaling of the investigated BMIs.

2. Conceptual Background and Methodology

2.1. Conceptual Framework

To answer the research questions, we employed the following conceptual considerations, building on BM and socio-technical transition theories:

- BMs and BMIs: Despite the increasing number of academic studies on BM and BMI, there are no common definitions of BM and BMI. In general, a BM is regarded as a device for creating and capturing value and for delivering that value to customers [21,22]. Accordingly, [23] developed a Business Model Canvas (BMC) to clearly structure business models using the following three major elements and nine building blocks:
  - Value proposition: the value from products and services that a firm provides to the customer;
  - Key activities, key partners, key resources, customer relationships, channels, and customer segment, which actually create and deliver value (i.e., value creation and delivery);
  - Cost structure and revenue stream (i.e., value capture).

In this paper, a BMI is understood either as a re-configuration of some components of a specific BM or as an entirely new means of value proposition, creation, and capture [24]. BMIs can accelerate technology adoption. Those that reconfigure the value proposition, and thus how values are created and captured, challenge the logic of the dominant system and are thus radical innovations themselves. They can emerge with or without technological innovations [25]. The two BMIs in this paper belong to this category. They represent different logics (see Section 3.1) compared to the conventional BM for prosumers, in which companies generate revenues by selling prosumers a service package consisting of PV modules and/or storage units, technical support (online inquiry, planning, maintenance), and/or residual electricity that cannot be covered by on-site generation.

- Socio-technical transition

Socio-technical transition research concerns the transition of socio-technical systems, such as energy systems. The multi-level perspective (MLP) offers a heuristic framework to understand ex post how such a transition has unfolded. It depicts a transition as dynamic interactions between three levels: niches, sociotechnical regimes, and the landscape. Regimes are highly structured alignments of technologies, infrastructure, science, policies, markets, and user preference, characterized by lock-in. A regime transition means a fundamental reconfiguration of these components. Niches are "protected spaces", where radical innovations take place, and provide seeds for regime transition. The dynamics at these two levels are influenced by external landscape factors, such as climate extremes and (shifting) social values [26]. The two BMIs in this paper, being radical innovations that are not yet broadly established in the market, are located at the niche level. Thus, they are influenced by the developments at both regime (e.g., supportive regulations) and landscape level (e.g., change of climate awareness). Meanwhile, BMIs may also interact and co-evolve with other niches, such as radical technological innovations [25].

Both regime and niches are formed by a network of actors. In [27] (p. 276), socio-technical transition is perceived as "the consequences of myriad actions and interactions of actors and the alliances they form in their pursuit of systemic changes". In the context of transition, actors are commonly conceptualised as incumbent and niche actors. Incumbent actors are characterised as those who "have vested interests in maintaining the status quo" [28] (p. 148) and are thus reluctant or resistant to radical innovations from niches [29]. In the energy sector, conventional utilities are often regarded as incumbent actors [30]. Niche actors, often including entrepreneurs and start-ups, pursue radical innovations of technologies and business models [31]. Renewable energy providers and new entrants from other sectors (e.g., IT) are examples here.

2.2. Analytical Approach

To analyse the drivers and barriers for the development of each BMI and to assess the prospects of these BMIs in Germany, we drew insights from both theoretical frameworks above. The analysis took both an actor-centred and systemic perspective. First, the analysis was focused on two categories of actors, namely incumbents or niche actors of the power system who have operated these two BMIs: regional/municipal utilities (incumbents) and new entrants from other fields, e.g., battery manufacturers, service providers of energy-related software (niche actors). The drivers and barriers for incumbents and niche actors to take up these BMIs were analysed, distinguishing between internal and external ones (Figure 1). Based on the BMC concept, the following four components were used to analyse internal drivers/barriers: the value proposition of each BMI assessed against the value of the actors (i.e., company's business statement), actors' key resources, and cost structure, as well as revenue streams, of each BMI. We then investigated external drivers and barriers for the development of each BMI, using transition theory. These include key factors at the regime (policies, markets, existing technologies and infrastructure, and user preference) and landscape level, as well as other niches (in particular, technological niches).

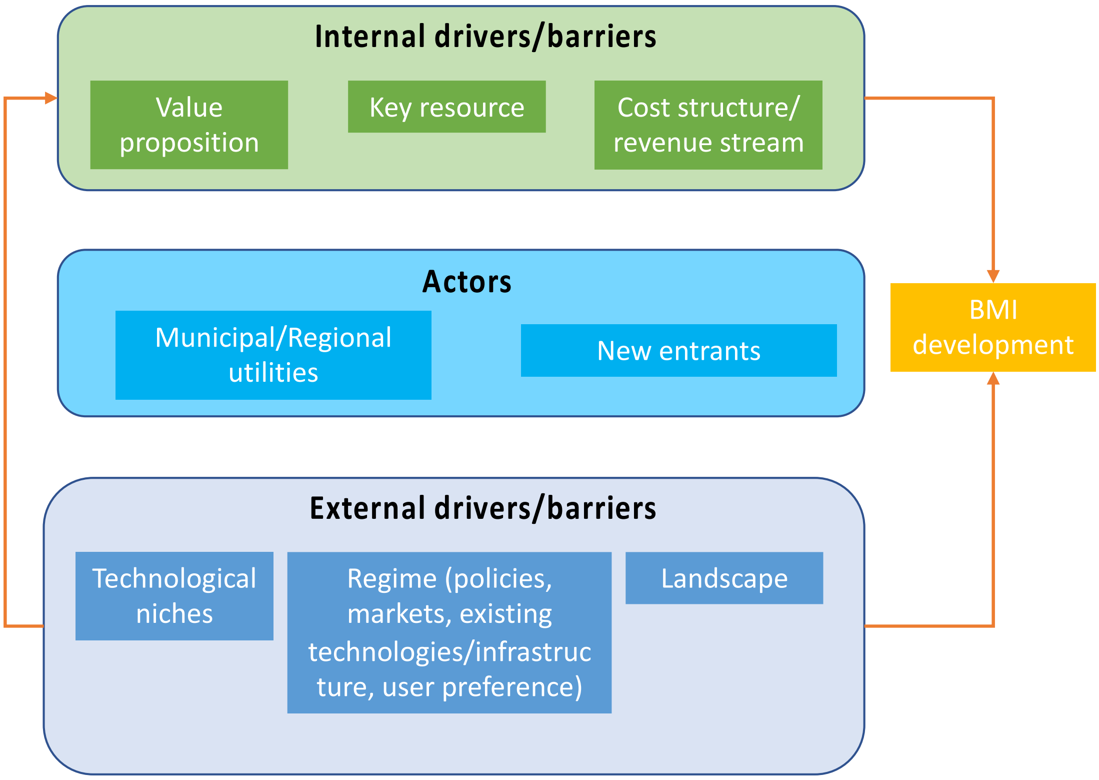

Figure 1. Analytical framework.

2.3. Data Collection

A mix of qualitative data collection methods was applied. First, a thorough literature review was conducted using a list of pertinent search terms relating to the nature and function of the BMI to deliver services to (potential) prosumers and to address the identified challenges. We conducted a systematic search using the terms of these BMIs in both German and English, such as "peer to peer","peer-to-peer", "P2P", "VPP", "virtual power plants", "aggregators", "flexibility", and "grid stabilisation". Data sources included documents gathered from the websites of companies (those who have operated or will start the BMIs) and industry associations, news from key industrial magazines, peer-reviewed papers, and books. In a second step, we conducted eight semi-structured interviews, which followed a set of pre-defined questions but with the flexibility to pursue relevant emerging lines of enquiry. These interviews were conducted in November and December 2020 and Feburary 2021. The researchers aimed to gain different perspectives, including representatives from the two actor types implementing the BMIs, other practitioners, the German consumer association, and researchers. Table 1 shows the organisations of the interviewees. The interview questions were informed by the literature review and structured based on factors in the analytical framework above. Market actors implementing the BMI were asked about details of their offer to prosumers, the relevance of the BMI for their business operation, the perceived drivers and barriers for upscaling, and their assessment of its future prospects. Likewise, those currently not implementing the BMI were asked about the reasons for this, highlighting differing perspectives and activity levels in niche markets. Interviews with non-market actors (i.e., academics and the German Consumer Association) focused on a broader societal perspective, investigating the role of these BMIs for the overall energy transition, their technical and regulatory preconditions and implications for consumers and the energy market design. The interviews took between 40 and 90 minutes and were conducted via video conferences and recorded with consent and subsequently transcribed. The interviews provided in-depth insights of each BMI, in particular, as some were operating the BMIs or closely observing their development. Additionally, the views from both companies and consumers (i.e., consumer associations) enriched understanding of the barriers and drivers. Interview results were coded according to the internal and external drivers and barriers in the analytical framework (Figure 1).

Table 1. Types and organisations of interviewees.

Types	Organisations of Interviewees	Interview Nr.
Municipal utilities (incumbents)	WSW: municipal utilities pioneering VPP	I#1
	MVV: regional utility	I#2
New entrants (niche actors)	Buzzn: start-up operating P2P, focusing on small prosumers and consumers	I#3
	NEXT Kraftwerke: aggregator	I#4
Renewable energy providers	Lichtblick: battery providers and renewable energy supplier	I#5
	Naturstrom	I#6
Consumer association	Consumer left of North Rhine-Westphalia	I#7
Academics	Fraunhofer ISI	I#8

3. Results

3.1. How the BMIs Can Address the Challenges of Prosumer Development in Germany

This section presents the value propositions of the two BMIs and elaborates on whether they, in theory, can address the economic, technological, and social challenges of prosumer development in Germany. We assess this question by investigating how far the BMIs:

(1) Create new opportunities for prosumers to monetise DERs;
(2) Contribute to the stabilisation and optimisation of a power system with an increasing share of renewable sources by provision of flexibility, and/or;
(3) Enable the participation of a wider range of societal actors in the benefits of the energy transition.

3.1.1. Aggregators of Small-Size DERs

While DERs of individual prosumers and consumers can also be an important potential source of flexibility, their size and reliability do not fulfil the requirements of power market trading or procurement by system operators [32]. According to German regulation, the minimum size of (aggregated) loads/output to participate in the balancing power market is set at 1 MW [33]. Aggregators centrally coordinate various DERs to sell generated electricity and flexibility on the power or balancing energy market. Through advanced control systems using intelligent algorithms, aggregators aim to optimize the generation and consumption of their pooled DERs and thus the revenues of these DER clients. In return, aggregators take a share of the revenue from power or flexibility trading. Virtual power plants (VPP), as a common form of aggregation, are in full commercial operation in Germany.

3.1.2. Peer-to-Peer (P2P) Electricity Trading

P2P allows short-term electricity exchange between multiple peers such as 'prosumers', renewable energy producers, and consumers based on an interconnected online platform [34]. In Germany, commercialized P2P electricity trading can broadly be categorized according to its geographic coverage into two types: (a) those that facilitate trading between peers throughout Germany; (b) and those operated at the city and regional level. In both models, a service provider has developed an online platform as a centralized marketplace for P2P, assumes the responsibility of the balancing group management, deals with administrative process (e.g., switching providers), conducts billing and energy data management, and supports prosumers and renewable energy producers in advertising their plants. Both models offer customers the "liberty to choose and obtain direct supply of renewable energy with proof of origin" [35]. The consumers select renewable producers and prosumers and conclude contracts with the P2P service provider. Through centralized P2P trading, renewable producers and prosumers have the possibility to determine the price of their generated electricity. In some cases, the service provider guarantees them a higher purchase price than the grid operator, who is under German law the buyer of their electricity. For example, the start-up Lition claims that the producers and prosumers on their marketplace could obtain up to 23% more per kWh of electricity compared to the FiT [36]. Although centralized P2P offers a virtual marketplace for these actors, the physical flows of electricity between producers/prosumers, consumers, DSOs, and TSOs do not change, in comparison with conventional prosumer BMs [37].

Beyond this centralized P2P trading, P2P trading within close geographical proximity in a decentralized form has been investigated in a few research projects in Germany. In this BMI, through blockchain technology, prosumers can directly sell electricity to the peer prosumers and consumers in the neighborhood [38].

Considering the described features, both BMIs could address the economic challenge faced by prosumers through improving prices of prosumers' exported power (both BMIs) or generating new revenues through providing flexibility (aggregators). Thus, these BMIs potentially provide economic incentives to prosumers to continue operating their PVs after the FiT is phased out for older plants or for the operation of new plants without FiT. However, ref. [39] pointed out that, since P2P trading facilitates short-term trading, which creates high uncertainty for investors regarding revenue streams, this BMI may not incentivize new investment in PVs.

In theory, both BMIs target a wide range of societal actors, including those who do not own PV on their roof, to shape the energy transition and benefit from it. It thus partly addresses the major social challenges of prosumer development and additionally enhances the regionality and transparency of the electricity supply. However, less wealthy groups in the low and medium income segments, who are mostly tenants, are hardly targeted.

Regarding the technological challenges, the aggregator BMI can potentially address the grid challenges through enabling the provision of flexibility by DERs. Since the currently prevalent centralized P2P trading BM does not change physical flows of electricity, it can hardly address the grid challenges without additional incentives for prosumers and consumers [37]. Decentralized P2P can potentially achieve grid balance at the local level through monitoring energy flows and motivating prosumers and consumers to change their generation and consumption [40].

3.2. Drivers and Barriers for the Development of the BMIs

This section illustrates the current development of these two BMIs and summarizes what has driven and impeded their development, taking on an actor-centered and systemic perspective.

3.2.1. Company Values of Different Actors

The actor-centered analysis started with an analysis of company values of each actor, based on a review of statements by these companies and interviews with company representatives (I#1–I#6). The consistency between the company values and the BMI value propositions is one major internal factor, which influences if and how the actor takes up a specific BMI.

- Regional/municipal utilities (incumbents): They aim to supply reliable, economic, and climate-friendly energy to customers at the regional/municipal level in a centralized manner. Some of them have announced "innovation" and "digitalisation" as strategic targets in their company statements. Meanwhile, as grid operators, they are rather risk averse due to their balancing responsibilities, as underlined by I#2.
- New entrants (niche actors), e.g. battery manufacturers and providers, providers of energy-related software services: These companies are innovation-oriented and aim to enable a climate-friendly energy supply. In addition, they often put a strong emphasis on the societal benefits of their business activities. For DER manufacturers and providers, sales of their products are still their key value propositions, as described on their websites and assessed by I#7.

In the next sections, internal and external drivers and barriers of each actor to take up the P2P and aggregator BM were respectively analyzed, guided by the employed analytical framework (Figure 1).

3.2.2. Aggregators of Small-Size DERs

Except for pioneer utilities, the following two niche actors have been active in VPP operation:

- Independent VPP operators, which are not affiliated with the customer's conventional energy supplier. They are the largest player in the German VPP landscape;
- Manufacturers or providers of small-scale DERs, e.g., batteries and heat pumps, which aggregate DERs of their customers to form a VPP.

In Germany, our literature review and interviews (I#2, I#3, I#4) revealed that direct marketing has been the major business field of VPP operators, i.e., selling power produced by renewable energy plants above 100 kW in their pool on the wholesale market. Thus, currently, the average size of the DERs connected to the VPPs is relatively large. The potential of small-size DERs, such as rooftop PVs, EVs, heat pumps and home battery storages, has largely been untapped. Few pilots have been or are being implemented. For example, in a research project, the municipal utility of Iserlohn cooperated with a university to build a VPP including different small-scale DERs, ranging from prosumers and storage units to EVs [41]. Sonnen, as a battery provider, initiates a community among the owners of a PV system and Sonnen battery to share self-produced electricity with one another through a virtual energy pool. In cooperation with Germany's largest transmission system operator (TSO), TenneT, sonnen batteries were already used for redispatch [42]. Furthermore, TenneT and Germany's leading heating and cooling solution provider, Viessmann, recently launched a pilot, in which they have tested how to utilize the potential flexibility of heat pumps for grid congestion management and to form a VPP consisting of heat pumps [43]. Independent VPP operators have not yet created commercial cases, including small-size DERs. NEXT Kraftwerke, the largest independent VPP operator in Europe, has started cooperating with Sonnen, in which NEXT organizes the marketing and billing of balancing services whereas Sonnen continues to aggregate and steer the batteries of their clients [44], I#4.

Internal Drivers and Barriers for Taking Up the Aggregator BMI

Value proposition: Renewable-based aggregation matches municipal/regional utilities' climate ambitions and the value attached to digital innovations. However, utilities have long been focused on centralized energy supply with limited attention paid to small-size DERs and demand side management. The utilities' engagement may also be impeded by their value proposition of economic and reliable energy supply and their general risk aversion. For example, I#2 stated that "*It's still unclear at the moment: will it catch on? Who will do the business? Should we get involved? What kind of market will this be?.... As a grid operator, we are very conservative*".

For independent VPP operators, VPP operation is their core business. However, as mentioned above, their key activities have been focused on the direct marketing of renewable energy from medium- and large-size plants above 100 kW, rather than small-size DERs.

While the value proposition of the BMI is partially in line with the value of DER manufacturers, namely, facilitating energy transition and innovations, our document analysis and assessment by I#7 show that aggregation is not their key value proposition.

Key resources: Both utilities and manufacturers have small-size DERs in their existing customer base. However, according to I#2, they lack the technological knowhow of VPP software and flexibility aggregation (e.g., prequalification of DERs, settlement) as well as experience operating on the flexibility market. These are the strengths of the independent VPPs [45]. In comparison with utilities and independent VPPs, manufacturers lack experience in energy supply and trading. Thus, for example, the battery provider, Sonnen, has collaborated with NEXT Kraftwerke for VPP operation [44].

Costs and revenues: Due to the lack of knowhow, namely, VPP software, both utilities and manufacturers need to purchase the service or develop the required software to operate this BMI. In addition, I#4 pointed out that the transaction costs to include small-size DERs and utilize their flexibility are very high. In addition, since the BMI aggregating small DERs is still being investigated in research projects, the revenue streams are not yet clear. Potentially, the BM operators could take a share of the revenue from the power trading and balancing service, although this is currently rather low.

External Drivers and Barriers for Taking Up the Aggregator BMI

Regulations and market: In 2014, the amended Renewable Sources Energy Act (EEG) made direct marketing mandatory for all new renewable electricity installations above 100 kW. This resulted in a rapidly increasing number of these plants connected to a VPP. Thus, a first major business for VPP operators in Germany was to trade the power produced by these plants on the wholesale market. According to the law, those who market their electricity are required to install meters for measuring their exact generation and remote-control technology to record the electricity fed into a grid in a 15-minute interval. I#3 explained that, in the absence of a legal basis for a system below 100 kW, small-size prosumers have to invest in expensive remote control and measurement equipment in order to market their generated power. I#3, I#4, I#7, and I#8 noted that this investment represents a major barrier for prosumers to participate in the aggregator BM, given the small margins they could receive.

In addition, while prosumers' battery storage represents a potential flexibility source, it is legally defined as an end user. This implies that households need to pay taxes, levies, and fees when withdrawing electricity from the grid to their battery and feeding it back. It should be noted that exemptions are possible for storage systems that are only used for storing and feeding in electricity from the grid. Since home storage systems are usually acquired with the purpose of optimising self-consumption, these exemptions mostly do not apply to them (so-called "double burden" [46], I#4). This further explains the low demand from prosumers to participate in this BMI. In addition, [47], I#4, and I#8 highlighted that, due to the improved projection methodologies, the price for flexibility provision on the balancing power market has been decreasing, which translates to low revenue.

Furthermore, the current grid regulation imposes an individual revenue cap for distributed system operators (DSOs, often municipal utilities) [48]. The cap is calculated based on the capital costs. Increasing operational costs, e.g., optimising grid management, results in a decrease in capital costs and thus revenues for DSOs. In addition, capital-intensive grid expansion is more economically attractive and simpler for them, because they can benefit from high equity interest rates and large fixed assets [38]. Thus, the revenue structure sets few incentives for utilities to invest in procuring local flexibility and in this BMI. I#4 claimed that scarce interest from DSOs largely constrained the engagement of prosumers.

On the other hand, apart from the EEG, other regulations have also driven the growth of VPPs. For example, in Germany, VPPs are given sufficient freedom to determine the DERs in their pool, such as the number and types of DERs. They are also allowed to be active on both the wholesale power market and the balancing market. Thus, with an increasing customer base, the VPPs have expanded beyond power trading, e.g., by providing services to the DERs in their pool for participating in the balancing power market. Additionally, since July 2021, aggregators' roles, market opportunities and obligations have been legally defined in German energy law (on 16 July 2021, in the "Act to implement EU requirements and regulate pure hydrogen networks in energy law").

User preference: Our analysis identified two user-related aspects as barriers for BMI upscaling, which need to be addressed: the potential data security risks related to sharing usage data with external service providers and the acceptance of prosumers and consumers regarding remote load shifting within specific BMIs (e.g., direct control by the aggregator) [47]. When it comes to using PV-storage systems as a flexibility source, I#2 pointed out that some customers prefer to maximise self-consumption instead of marketing their generated power.

Existing technologies and infrastructure: For the aggregation BMI, smart meters are an essential technology to enable monitoring and analyzing almost real-time consumption and generation patterns. Calls for flexibility can also be sent automatically via smart meters. This is a unique requirement for the technology in Germany, which, in contrast to other European countries, considers it a core technology not only for metering but to coordinate prosumage, provide information to DSOs and in the remote control of DERs (I#7). As mentioned above, prosumers are required to install such meters to market their electricity. In Germany, due to this requirement as well as strong data protection regulations and the need to develop safe data transmission technologies, smart meter rollout started only in early 2020 and aims to be completed by 2032. Thus, I#4 and I#8 noted that most prosumers have to additionally invest in expensive technology, which represents a major barrier for them to participate. The amended EEG (2021) obligates (1) PV plants with a capacity of more than 7 kWp to install a smart meter and to communicate how much electricity they feed into the grid; and (2) PV plants with more than 25 kWp to be remotely controllable. These new rules are expected to accelerate the smart meter roll-out, which will possibly promote BMI upscaling (as confirmed by I#1, I#2, I#4). I#1 further highlighted that the smart meters can also be used for bundling existing buildings, which can support aggregation.

On the other hand, pressure on grid infrastructure, due to increasing variable renewable power generation and the phase-out of coal power plants as flexibility sources, has created incentives for system operators, as incumbents, to collaborate with new entrants (manufacturers of batteries and heat pumps) on this BMI. At least as they start considering doing so, as I#2 expressed " … *the question has been raised for a while: isn't it more sensible to use decentralised flexibilities and thus save on large investments? Isn't that cheaper*?"

Landscape: The registration of battery electric vehicles (BEVs) has grown rapidly in Germany, from 12,000 in 2015 to more than 194,000 in 2020 [49]. Additionally, heat pumps have become increasingly common in new residential buildings. In 2021, 154,000 heat pumps were sold in Germany, representing an annual growth of 28% [50]. In light of increasing fossil energy prices following the introduction of a carbon price in the residential and road transport sectors and supportive regulations, the deployment of both technologies will continue to rise (expressed by I#1, I#4, and I#5). The growth of EVs and heat pumps could however lead to increasing peak demand. These developments have already driven or will drive system operators to explore the flexibility of these small-size DERs, as the conventional approach of grid expansion becomes increasingly expensive. As stated by TenneT, "*we are preparing for a future in which we are largely dependent on consumers with their electric cars, home batteries and heat pumps to stabilise the grid reliably, sustainably and cost-effectively*" [43]. This strategic perspective was also confirmed by I#1, I#4, and I#5, which already started pilots in this field.

3.2.3. Peer-to-Peer (P2P) Electricity Trading

In Germany, centralized P2P trading has been fully commercialized. A few frontrunners among utilities have included P2P trading as an additional service to their portfolio. A well-known example is the blockchain-based "Tal.Markt" developed by the Wuppertal utility (WSW). However, so far, only a limited number of residential prosumers have been active there. More recently, WSW and three other public utilities have collaborated on a so-called "Blockwerke" platform based on WSW's platform "Tal.Markt". Each utility partner can build its business model based on the prototype of "Tal.Markt" [51]. Several start-ups, for example, Enyway, Buzzn, and Lition, have operated P2P trading throughout Germany. For both utilities and these start-ups, medium-size renewable energy producers above 100 kW rather than small-size prosumers have been their major targets. Buzzn, following their company values of promoting a decentralised, citizen-based energy system, aimed to integrate smaller plants, but pointed out that the BMIs are not economically viable under the current regulatory conditions (I#3).

Decentralized P2P trading within close geographical proximity is thus only in its infancy [35]. For example, a research project in Allgäuer Überlandwerke has developed the prototype of such a local market and tested it in a real laboratory [38].

Internal Drivers and Barriers for Taking Up P2P

Value proposition: First, centralized P2P is the core business and value proposition of those start-ups who provide platform solutions, i.e., climate-friendly and people-oriented energy transition through digitalization and innovations.

The value proposition of centralized P2P is partially consistent with utilities' value, i.e., climate-friendly and centralized energy supply. WSW, as a frontrunner, who includes this BMI as an additional service, has explained their vision: "*we need to be fit for energy transition and digitalization*" (I#1). In addition, utility may also be driven by their desire to enhance customers' loyalty, because P2P could increase the sense of "local community". This is particularly the case among those "pioneer" customers who want to actively shape the transition and are ready to pay a premium (I#1). However, similar to the aggregator BMI, the utilities' values of economic and reliable energy supply in combination with their risk aversion represent internal barriers for their engagement. These also explain why only a few utilities have been active in this BMI.

The value propostion of decentralized P2P is potentially in conflict with that of the utitlies, which seek grid stability and thus perceive the BMI to be risky (I#3 and I#5). For some new entrants and renewable energy suppliers, the idea of having a physically close (rather than platform) community is interesting, as mentioned by I#3, I#5, and I#6. For instance, I#6 stated that "*we are trying to find the most decentralised form to really develop 'communities' onsite and minimise grid challenges*".

Key resources: Start-ups like Lition and Enyway were equipped with blockchain-based software solutions, which are essential for P2P trading. However, utilities have limited technical capacity in this regard (as confirmed by I#1 and I#2). Compared to utilities, start-ups have limited experience of energy supply operations. Enyway and Lition thus cooperated with utilities for their balancing group management [52]. In addition, utilities have direct connections with their existing consumers, which puts them in a good position to operate P2P trading platforms within their balancing zone. Start-ups on the other hand use their good marketing skills to attract new customers.

Costs and revenues: If P2P trading is based on standard load profiles (it is used to forecast the daily electricity consumption of small customers), centralized P2P requires limited changes at the utilities' end. If blockchain technology is used, the utilities need to purchase the service and infrastructure, which implies a high upfront cost. For example, WSW cooperated with Swiss company Axpo who provide a blockchain solution [53]. Their revenues still stem from electricity sale. While start-ups' core competence is ICT, including blockchain technology, they also invest in infrastructure and pay for the service of balance group management. In return, they profit from the fees for the direct marketing of electricity generated by renewable energy producers and prosumers and, in some cases, an additional monthly charge.

External Drivers and Barriers for Taking Up P2P

Various external factors have influenced P2P trading:

Regulations and market: As mentioned above, the centralized P2P trading operators ultimately market renewable energy they "receive" from producers on the power market. Similar to the aggregator BMI, a major barrier for prosumers to participate in this BMI is the requirement of installing expensive metering and controlling equipment. I#3 pointed out that these additional investments as well as operational costs and the low margins make it hardly economical for small-scale prosumers to participate in this BMI. This also partly explains why those currently engaged in centralized P2P trading have mostly been producers above 100 kW, who are already equipped with meters and obligated to record 15-minute electricity generation and feed-in anyway.

The upscaling of decentralized P2P trading within close geographical proximity has been largely constrained by the current regulatory framework. First, prosumers need to invest in the above-mentioned equipment. Second, prosumers who directly sell electricity to consumers are legally considered as energy suppliers. Thus, they need to fulfill the various requirements of the classical utilities, such as balancing, billing, and numerous reporting and documentation obligations [35]. According to the EU Internal Market for Electricity Directive (Art 15 (2)(f)), these prosumers are then financially responsible for any system imbalances caused by them unless they transfer the balancing responsibility to another party. Individual prosumers can hardly bear these responsibilities. As I#1 pointed out "*with the balance group responsibility, we don't believe decentralized P2P without an intermediary could happen* . . . ", which was also confirmed by I#7. In addition, both I#3 and I#5 claimed that DSOs may impede the implementation of this BMI as it is perceived to negatively affect grid stability.

On the other hand, more recently, at the European level, the Clean Energy Package (CEP) for the first time explicitly addresses P2P trading in a Directive. Member States are now legally bound to transpose them at the national level.

User preference: The above-mentioned technical and thus investment requirements translate to little market demand for this BMI by small-scale prosumers. Additionally, users' lack of knowledge of the function of this BMI may also impede their participation. I#3 stated "*It is very difficult to get people to understand that energy flows are not being changed (though centralized P2P)* . . . ". However, as an increasing number of prosumers will stop receiving the fixed FiT in the coming years, the new revenue stream from P2P trading may enable those prosumers to continue operating their PV systems. Also, I#1 noticed the trend that consumers have an increasing demand for renewable energy and an interest in self-sufficiency with renewables at the neighborhood level.

However, I#3 claimed that social acceptance of the decentralized P2P can still represent a challenge, given the completely new manner of energy supply and lack of clarity on data use.

Existing technologies: The requirements to install metering and the slow roll-out of smart meters have impeded prosumers' participation in this BMI (I#4 and I#7). As confirmed by I#1, I#2, and I#4, the requirement of installing smart meters by the new EEG could act as a driver for this BMI.

Technology innovations: Digitalization, in particular the development of blockchain and smart contracts, enables P2P trading. The technology has been used in WSW's centralized P2P trading as well as decentralized P2P trading pilots [38]. Blockchain applications have also been included in the innovation strategies of utilities, in particular by some large incumbent players. A recent survey by the Federal Association of the Energy and Water Industries (BDEW) shows that more than 25% of German utility respondents are planning applications with blockchain [54]. The largest utilities and energy trading companies in Europe have collaborated with the software start-up PONTON on a research project of Enerchain Local, which explores software solutions of P2P trading at the local level [55].

Landscape: Due to the steep price increase for electricity and gas towards the end of 2021, a number of German energy suppliers have since gone bankrupt. By the time of the submission of this paper, the major P2P start-ups have gone into insolvency due to rocketing energy prices on the spot market (Lition and Enyway) or unanticipated supplementary grid fee charges and overall issues regarding the economical operation of their BMI within the current regulatory environment (Buzzn).

4. Discussion

4.1. Drivers and Barriers for Aggregators of Small-Size DERs and Their Future Prospects

We found that, although VPPs have been commercialized in Germany, the aggregation of small-size DERs is still in its infancy.

In terms of internal drivers and barriers, first, we found that the value proposition of this BMI has limited consistency with that of the three actors operating VPPs in Germany. In particular, utilities' focus on the supply side and their risk aversion when facing high upfront costs act as major internal barriers to their engagement. Second, costs could also be a key internal barrier, because utilities and manufacturers need to purchase the software service and involving small-size DERs is associated with high transaction costs. In addition, for all actors, the revenue stream of this BMI is not yet clear and may be limited. Third, each of the involved actors has certain competency gaps in taking up the BMI. These gaps may be overcome through cooperation among one another.

From a regulatory perspective, the direct marketing obligation for medium-sized renewable production introduced by the EEG and supportive regulations for aggregation have driven the growth of VPPs in general in Germany. However, the requirement for prosumers to install metering and remote control and the slow rollout of smart meters have acted as key external barriers for prosumers to participate. On top of that, the fees associated with flexibility provision from battery storage, low revenues on the balancing market, and DSOs' budget structure have further impeded the development of this BMI. An additional barrier down the line for upscaling the BMI could be users' acceptance of direct control of their DERs by a third party.

On the other hand, the pressure on the grid infrastructure due to the growth of various renewables and from landscape developments (in particular, the upscaling of EVs, storages, and heat pumps) have already driven incumbents, such as TSOs, to participate in this BMI. The pressure will also impose significant challenges on the aging distributed grids and lead to grid congestion. These could drive DSOs (utilities) to operate or participate in this BMI, in the presence of proper incentive regulations [56]. The demand of DSOs (as clients) could in turn encourage DER manufacturers and large independent VPP operators to take up this BMI. Additionally, the installation obligation introduced in the EEG 2021 will accelerate smart meter rollout, which provides the infrastructure basis for the BMI. The rollout will reduce additional upfront investment in metering for prosumers. In combination with the potential revenue for prosumers, it could drive prosumers to participate in this BMI. Last but not least, in Germany, innovative market designs facilitating small-size DERs to offer their flexibility to system operators have been tested. For example, a prominent solution is the regional flexibility market, serving as an independent trading platform between DERs and DSO network operators [57]. Such a market design was also highlighted by I#4 to be essential for this BMI to achieve the engagement of prosumers.

To sum up, the further development of this BMI still faces a number of barriers. For incumbents, the pressure on the grid infrastructure and the demand of flexibility could drive them to actively participate in this BMI and accelerate experimentation and learning of this BMI. For prosumers, reduced additional upfront investment and new revenue streams due to innovative market design could make this BMI more economically attractive.

4.2. Drivers and Barriers for P2P Trading and Its Future Prospects

Centralized P2P has been commercialized in Germany and operated by several frontrunner utilities and niche actors. For niche actors, the internal barriers are limited. For most utilities, firstly, our findings revealed that their core values of economic energy supply in combination with their risk aversion represent a major internal barrier for taking up this BMI. This is particularly relevant as P2P is associated with high upfront costs when blockchain is required to operate it. On the other hand, in terms of key resources, utilities have an existing consumer basis. For them, the revenue stream thus does not fundamentally change, which can be regarded as a facilitating factor for them to take up the BMI. On top of that, a growing number of utilities include innovation and digitalization in their company values. The prototype of centralized P2P and software solutions developed by the frontrunners, e.g., the "Blockwerke" platform and R&D project of Enerchain Local, could reduce the investment costs for others. Thus, it is possible that more medium-sized and large utilities may explore centralized P2P as an additional service component to enhance their customer loyalty.

Regarding external barriers, similar to the aggregator BMI, the requirement for prosumers to install smart meters and in general their slow rollout have been major barriers for prosumers to participate. In addition, in order for centralized P2P to unlock the flexibility potential and thus address the grid challenges, separate incentives need to be introduced, for example, through variable electricity prices and grid charges for centralized P2P [37]. Last but not least, the development of centralized P2P at the national level is questionable in the near future, due to the dramatic change of landscape, i.e., the recent insolvency surge of platform start-ups.

Decentralized P2P may further develop, due to its potential to address the economic, social, and technological challenges of prosumer development, the broader roll-out of smart meters and technological innovations, and increasing interest from consumers to engage in energy transition at the neighborhood level. However, scaling up decentralized P2P direct trading between prosumers and consumers without intermediaries is unlikely, due to the above-mentioned legal and technical challenges, especially the obligation of prosumers to assume the responsibilities of energy suppliers. Decentralized P2P with intermediaries needs to be further investigated, including the technical details, business model set-up, etc. For instance, aggregators can take over the duties of energy suppliers for decentralized P2P prosumers. They can also support prosumers in providing flexibility services to grid system operators through identifying market opportunities and organising contracts between the prosumers and system operators [40]. As a result, aggregators can benefit from improved forecast accuracy due to the access to local P2P marketing [38]. For its further upscaling, since this BMI implies radical changes in energy supply and trading, legal issues need to be clarified. In particular, regulation needs to specify standardised interactions among different actors (e.g. roles and responsibilities, the allocation of taxes, levies and fees) and those between decentralized P2P markets and the conventional power market.

The EU legislation and its transposition at the national level create legal foundations for P2P trading in general, which could drive their upscaling. In addition, the acceleration of smart meter rollout and the phase-out of fixed FiT could also encourage prosumers to participate in this BMI. Additional drivers include the increasing number of blockchain applications in the energy sector and an increasing demand for renewable and regional energy from consumers.

To sum up, due to the above-mentioned regulatory drivers and technological innovations in combination with utilities' internal drivers, it is possible that more medium-sized and large utilities may explore centralized P2P as an additional service. However, centralized P2P at the national level is unclear in the near future due to the insolvency surge of major players. Despite these drivers, since a detailed legal framework is still missing, the development of decentralized P2P is difficult to predict. Thus, it is essential to monitor and evaluate the ongoing pilots and learn from the observed positive and negative impacts.

5. Conclusions

Our study enriched the empirical basis of prosumer-oriented BMIs by examining two prosumer-oriented BMIs in Germany: P2P electricity trading and the aggregation of small-size DERs. Both BMIs can potentially address the economic, social, and technological challenges associated with prosumer development. However, we found that small-scale prosumers' participation in both BMIs has been limited so far. We then conducted an extensive document analysis and interviews with different stakeholders to understand the underlying reasons, taking on an actor-centered and systemic approach. We identified various internal (value proposition, cost and revenues, and key resources of the business models) and external (policies, markets, existing technologies and infrastructure, and user preference, technological innovations, and landscape factors) drivers and barriers for scaling up these two BMs in Germany. Despite the barriers, both aggregation and centralized P2P targeting prosumers may potentially be taken up by incumbent utilities and thus be further scaled up. However, decentralized P2P trading still faces significant internal and external barriers for upscaling.

Policy makers could help to remove the above-mentioned regulatory barriers for scaling up these BMIs in Germany, such as:

- Removing fees associated with flexibility provision for prosumers;
- Reforming DSOs' budget structure and providing additional incentives to DSOs;
- Introducing variable electricity prices and grid charges to incentivize prosumers;
- Supporting intermediaries (e.g., for decentralized P2P).

Additionally, decentralized P2P and a new market design that facilitates trading flexibility from DERs should be investigated and monitored. Furthermore, the challenges for prosumer development can potentially be better addressed by combining different BMIs (also including BMs beyond this study, such as tenant electricity [19]).

From a theoretical perspective, our actor-centered analysis investigated both incumbents and niche actors who operate the BMIs. Our findings show that not only niche actors but also some incumbents, such as utilities and TSOs, have been active in these BMIs. It provides additional empirical evidence to challenge the dichotomous theoretical understanding of niche actors and incumbents [29]. The latter are often theorised as resisting radical innovations [58]. However, utilities' engagement is still constrained by their company values, for example, reliable and economic energy supply and their risk aversion as grid operators.

This study took a qualitative approach with a limited number of interviewees. While the gained insights supported our analysis well, additional interviews from TSOs, large utilities, and policy makers could broaden the view and reduce bias. In addition, future research could benefit from quantitative analysis of these BMIs, such as costs and revenues for both BMI operators and for prosumers, and the contribution of these BMIs to grid challenges. In addition, since these two BMIs have been experimented within different countries to promote prosumer development, a systematic comparative analysis across different countries would further enrich understanding of how these BMIs can be designed to effectively contribute to the overall energy transition. Furthermore, since regulatory and market factors are essential for these BMs, future research can investigate the effects of different regulatory and power market framework conditions on the adoption of the BMs in a quantitative manner. Last but not least, it is suggested that future studies systematically investigate combinations of different BMs and carefully evaluate them. The neighborhood is a place where heat, power, and mobility interact with each other and thus provides a unique space for experimenting with these combinations.

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References

1. Inderberg, T.; Tews, K.; Turner, B. Is there a Prosumer Pathway? Exploring household solar energy development in Germany, Norway, and the United Kingdom. *Energy Res. Soc. Sci.* **2018**, *42*, 258–269. [CrossRef]
2. Tews, K. *Mapping the Regulatory Features Underpinning Prosumer Activities in Germany*; FFU-Report 02-2016; Forschungszentrum für Umweltpolitik, FU: Berlin, Germany, 2016.
3. Bundesnetzagentur. EEG in Zahlen. 2019. Available online: https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/ErneuerbareEnergien/ZahlenDatenInformationen/EEGinZahlen_2019.html?nn=265850 (accessed on 19 April 2020).
4. AEE. Press Release: Neue Studie Zeigt: Bürgerenergie Bleibt Zentrale Säule der Energiewende. Available online: https://www.unendlich-viel-energie.de/studie-buergerenergie-bleibt-zentrale-saeule-der-energiewende (accessed on 15 January 2021).
5. Wirth, H. *Recent Facts about Photovoltaics in Germany*; Fraunhofer ISE: Freiburg im Breisgau, Germany, 2021.
6. Bardt, H.; Growitsch, C.; Chrischilles, E.; Hagspiel, S.; Schaupp, L. Eigenerzeugung und Selbstverbrauch von Strom Stand, Potentiale und Trends. In *Interdisziplinäre Aspekte der Energiewirtschaft*; Springer Vieweg: Wiesbaden, Germany, 2014.
7. Minniti, S.; Haque, N.; Nguyen, P.; Pemen, G. Local Markets for Flexibility Trading: Key Stages and Enablers. *Energies* **2018**, *11*, 3074. [CrossRef]
8. IRENA. *Innovation Landscape Brief: Peer-to-Peer Electricity Trading*; International Renewable Energy Agency: Abu Dhabi, United Arab Emirates, 2020.
9. IRENA. *Innovation Landscape Brief: Aggregators*; International Renewable Energy Agency: Abu Dhabi, United Arab Emirates, 2019.
10. Tushar, W.; Yuen, C.; Saha, T.; Morstyn, T.; Chapman, A.; Alam, A.; Hanif, S.; Poor, H. Peer-to-peer energy systems for connected communities: A review of recent advances and emerging challenges. *Appl. Energy* **2021**, *282 Pt A*, 116131. [CrossRef]
11. Parag, Y.; Sovacool, B. Electricity market design for the prosumer era. *Nat. Energy* **2016**, *1*, 16032. [CrossRef]
12. Specht, J.; Madlener, R. Energy Supplier 2.0: A conceptual business model for energy suppliers aggregating flexible distributed assets and policy issues raised. *Energy Policy* **2019**, *135*, 110911. [CrossRef]
13. Hall, S.; Roelich, K. Business model innovation in electricity supply markets: The role of complex value in the United Kingdom. *Energy Policy* **2016**, *92*, 286–298. [CrossRef]
14. Rövekamp, P.; Schöpf, M.; Wagon, F.; Weibelzahl, M. Renewable electricity business models in a post feed-in tariff era. *Energy* **2021**, *216*, 119228. [CrossRef]
15. Brown, D.; Hall, S.; Davis, M. Prosumers in the post subsidy era: An exploration of new prosumer business models in the UK. *Energy Policy* **2019**, *135*, 110984. [CrossRef]
16. Morstyn, T.; Savelli, I.; Hepburn, C. Multi-scale design for system-wide peer-to-peer energy trading. *One Earth* **2021**, *4*, 629–638. [CrossRef]
17. Wang, N.; Xu, W.; Xu, Z.; Shao, W. Peer-to-Peer Energy Trading among Microgrids with Multidimensional Willingness. *Energies* **2018**, *11*, 3312. [CrossRef]
18. Muhsen, H.; Allahham, A.; Al-Halhouli, A.; Al-Mahmodi, M.; Alkhraibat, A.; Hamdan, M. Business Model of Peer-to-Peer Energy Trading: A Review of Literature. *Sustainability* **2022**, *14*, 1616. [CrossRef]
19. Moser, R.; Xia-Bauer, C.; Thema, J.; Vondung, F. Solar Prosumers in the German Energy Transition: A Multi-Level Perspective Analysis of the German 'Mieterstrom' Model. *Energies* **2021**, *14*, 1188. [CrossRef]
20. Bolton, R.; Hannon, M. Governing sustainability transitions through business model innovation: Towards a systems understanding. *Res. Policy* **2016**, *45*, 1731–1742. [CrossRef]
21. Chesbrough, H. Business model innovation: Opportunities and barriers. *Long Range Plan.* **2010**, *43*, 354–363. [CrossRef]
22. Teece, D.J. Business models, business strategy and innovation. *Long Range Plan.* **2010**, *43*, 172–194. [CrossRef]
23. Osterwalder, A.; Pigneur, Y. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*; John Wiley & Sons: Hoboken, NJ, USA, 2010.

24. Massa, L.; Tucci, C.L.; Afuah, A. A critical assessment of business model research. *Acad. Manag. Ann.* **2017**, *11*, 73–104. [CrossRef]
25. Bidmon, C.; Knab, S. The three roles of business models in societal transitions: New linkages between business model and transition research. *J. Clean. Prod.* **2018**, *178*, 903–916; [CrossRef]
26. Geels, F. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case study. *Res. Policy* **2002**, *31*, 1257–1274. [CrossRef]
27. Haan, F.; Rotmans, J. A proposed theoretical framework for actors in transformative change. *Technol. Forecast. Soc. Chang.* **2018**, *128*, 275–286. [CrossRef]
28. Johnstone, P.; Stirling, A.; Sovacool, B. Policy mixes for incumbency: Exploring the destructive recreation of renewable energy, shale gas 'fracking,' and nuclear power in the United Kingdom. *Energy Res. Soc. Sci.* **2017**, *33*, 147–162. [CrossRef]
29. Ruggiero, S.; Kangas, H.-L.; Annala, S.; Lazarevic, D. Business model innovation in demand response firms: Beyond the niche-regime dichotomy. *Environ. Innov. Soc. Transit.* **2021**, *39*, 1–17. [CrossRef]
30. Richter, M. Business model innovation for sustainable energy: German utilities and renewable energy. *Energy Policy* **2013**, *62*, 1226–1237. [CrossRef]
31. Geels, F.W.; Schot, J. Typology of sociotechnical transition pathways. *Res. Policy* **2007**, *36*, 399–417. [CrossRef]
32. Eid, C. Towards the Design of Flexibility Management in Smart Grids: A Techno-Institutional Perspective. Ph.D. Thesis, Delft University of Technology, Delft, The Netherlands, 2017.
33. Available online: www.regelleistung.net (accessed on 15 March 2021).
34. Wilkinson, S.; Hojckova, K.; Eon, C.; Morrison, G.M.; Sandén, B. Is peer-to-peer electricity trading empowering users? Evidence on motivations and roles in a prosumer business model trial in Australia. *Energy Res. Soc. Sci.* **2020**, *66*, 101500. [CrossRef]
35. Loebbe, S.; Hackbarth, A.; Stillahn, T.; Pfeiffer, T.; Rohbogner, G. Customer participation in P2P trading: A German energy community case study. In *Behind and Beyond the Meter*; Sioshansi, F., Ed.; Academic Press: Cambridge, MA, USA, 2020; pp. 83–103.
36. Uhr, P. Lition Guided Tour: Berlin Energy Dialogue. 2021. Available online: https://2021.energydialogue.berlin/ (accessed on 15 March 2021).
37. Ninomiya, Y.; Sasakawa, A.; Schröder, J.; Thomas, S. *Peer-to-Peer (P2P) Electricity Trading and Power Purchasing Agreements (PPAs). GJETC Study on Digitalization and the Energy Transition*; Wuppertal Institute for Climate, Environment and Energy: Wuppertal, Germany, 2020.
38. Smart Service Welt (SSW). *Begleitforschung Energierevolution Getrieben Durch Blockchain*; Institut fuür Innovation und Technik (iit) in der VDI/VDE Innovation + Technik GmbH: Berlin, Germany, 2020.
39. Bauknecht, D.; Heinemann, C.; Seebach, D.; Vogel, M. Behind and beyond the meter: What's in it for the system? In *Behind and Beyond the Meter*; Sioshansi, F., Ed.; Academic Press: Cambridge, MA, USA, 2020; pp. 179–192.
40. Morstyn, T.; Farrell, N.; Darby, S.J.; McCulloch, M.D. Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. *Nat. Energy* **2018**, *3*, 94–101. [CrossRef]
41. Leitmarkt Agentur NRW. Available online: https://www.leitmarktagentur.nrw/klimaschutz/virtuellekraftwerke (accessed on 28 November 2021).
42. TENNET. Blockchain Pilot Reveals Potential of Decentralised Home Storage Systems for Tomorrow's Energy Infrastructure. Available online: https://www.tennet.eu/news/detail/blockchain-pilot-reveals-potential-of-decentralised-home-storage-systems-for-tomorrows-energy-infra/ (accessed on 18 May 2019).
43. TENNET. Equigy Platform Gives European Consumers Access to Tomorrow's Sustainable Energy Market. Available online: https://www.tennet.eu/news/detail/equigy-platform-gives-european-consumers-access-to-tomorrows-sustainable-energy-market/ (accessed on 23 April 2020).
44. NEXT. Sonnen und Next Kraftwerke Kooperieren Bei Lieferung von Primärregelleistung. Available online: https://www.next-kraftwerke.de/neues/kooperation-sonnen-next-kraftwerke-primarregelleistung-batteriespeicher (accessed on 21 September 2021).
45. Valarezo, O.; G mez, T.; Chaves-Avila, J.P.; Lind, L.; Correa, M.; Ulrich Ziegler, D.; Escobar, R. Analysis of New Flexibility Market Models in Europe. *Energies* **2021**, *14*, 3521. [CrossRef]
46. Schönfisch, M.; Lilienkamp, A.; Titze, D. Aggregation von Haushalten in (Regionalen) Virtuellen Kraftwerken. Regulatorische Rahmenbedingungen und Hürden. VISE Policy Brief Nr. 9 | Q1/2020. Available online: https://www.ewi.uni-koeln.de/en/publications/vise-policy-brief-no-9-aggregation-of-households-in-regional-virtual-power-plants-regulatory-framework-and-hurdles/ (accessed on 1 April 2020).
47. Wohlfarth, K.; Klobasa, M. Setting course for demand response in the service sector. *Energy Effic.* **2019**, *12*, 327–341. [CrossRef]
48. Matschoss, P.; Bayer, B.; Thomas, H.; Marian, A. The German incentive regulation and its practical impact on the grid integration of renewable energy systems. *Renew. Energy* **2019**, *134*, 727–738. [CrossRef]
49. IEA. Electric Car Registrations and Market Share in Selected Countries, 2015–2020, IEA, Paris. Available online: https://www.iea.org/data-and-statistics/charts/electric-car-registrations-and-market-share-in-selected-countries-2015-2020 (accessed on 29 April 2021).
50. BWP. Starkes Wachstum im Wärmepumpenmarkt. Available online: https://www.waermepumpe.de/presse/news/details/starkes-wachstum-im-waermepumpenmarkt/#content (accessed on 20 January 2022).
51. IWR. Stadtwerke Bauen Blockchain-Angebot Aus. Available online: https://www.iwr.de/news/stadtwerke-bauen-blockchain-angebot-aus-news35789 (accessed on 5 February 2019).

52. Zfk. Handeln ohne Mittelsmann. Available online: https://www.zfk.de/digitalisierung/smart-city-energy/handeln-ohne-mittelsmann (accessed on 11 December 2019).
53. Wuppertaler Stadtwerke Starten Ersten Blockchain-Handelsplatz für Ökostrom. Available online: https://www.wsw-online.de/unternehmen/presse-medien/presseinformationen/pressemeldung/meldung/wuppertaler-stadtwerke-starten-ersten-blockchain-handelsplatz-fuer-oekostrom/ (accessed on 20 November 2017).
54. BDEW. Digital@EVU 2020—Wo Steht Die Digitale Energiewirtschaft in Deutschland, Österreich und der Schweiz? Available online: https://www.bdew.de/service/publikationen/digitalevu-2020-unternehmen-planen-hoehere-investitionen-in-digitalisierung/ (accessed on 3 October 2020).
55. Ponton. Blockchain Based Solution Enables p2p Trading of Electricity between Prosumers. Available online: https://www.ponton.de/launch-of-enerchainlocal/ (accessed on 8 November 2019).
56. Stanley, R.; Johnston, J.; Sioshansi, F.P. Platforms to support nonwire alternatives and DSO flexibility trading. In *Consumer, Prosumer, Prosumager: How Service Innovations Will Disrupt the Utility Business Model*; Sioshansi, F.P., Ed.; Academic Press: Cambridge, MA, USA, 2019; pp. 111–126.
57. Heilmann, E.; Klempp, N.; Wetzel, H. Design of regional flexibility markets for electricity: A product classification framework for and application to German pilot projects. *Util. Policy* **2020**, *67*, 101–133. [CrossRef]
58. Berggren, C.; Magnusson, T.; Sushandoyo, D. Transition pathways revisited: Established firms as multi-level actors in the heavy vehicle industry. *Res. Policy* **2015**, *44*, 1017–1028. [CrossRef]