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Innovative Business Models as Drivers for Prosumers Integration - Enablers and Barriers

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ABSTRACT

In recent years, traditional power systems have undergone a significant transition, mainly related to the massive penetration of renewable generation. More specifically, the transformation of residential consumers into prosumers has been challenging the existing operation of the electricity market. This transition brings new challenges and opportunities to the power system, leading to new business models. One widely discussed change is related to a consumer-centric or prosumer-driven approach, promoting increased participation of small consumers in power systems. The present paper aims at discussing the recent business models as enablers of the increasing prosumers' role. To do so, it defines the main features of prosumers and their related regulation as well as possible market designs within power systems. In addition, it discusses enabling technologies to properly create the conditions that sustain new prosumer-driven markets. Then, it presents a comprehensive review of existing and innovative business models and a discussion on their future roles in modern power systems. Moreover, a set of recommendations for promoting these business models in the power system is provided. An important conclusion is that, even though economically possible, not all innovative business models can spread around the world due to regulatory obstacles.

1. Introduction

The current global demand for energy is mostly supplied by centralized non-renewable energy sources [1]. However, there is a strong appeal for the energy sector decarbonization [2]. The contemporary Business Model (BM) of the conventional power grid neglects the end consumer as an active participant, depending only on the interaction between distribution and transmission sectors.

A global energy transition is driven by the trend to minimize the environmental impacts of non-renewable sources, provide energy democratization, and improve the power system reliability [3]. This transformation will cause significant changes in the way which the whole society interacts with the power system, which will have to undergo a total reformulation [4].

The energy sector transformation is currently guided towards digitalization, decentralization and decarbonization [5, 6, 7, 8, 9, 10]. Guided mainly by these three factors, the electric sector is evolving from a structure in which the energy and monetary flow were unidirectional (the first always going from generation to consumers and the second taking the opposite path) to a structure in which energy, money and information flows are bidirectional. This new structure, shown in Figure 1, highlights how all the stages of the energy supply chain will interact with each other.

In addition to those aspects highlighted before, this transition also aims at reducing the costs involved in the power system and encourage the end-consumer to take a more active role and control over their own energy decisions. Strengthening the prosumer[1] concept is required, for instance [11, 12, 13], by implementing new technologies, such as smart meters [14, 15, 16]; advances in Information and Communication Technology (ICT) devices [17, 18] and the continuous integration of distributed energy resources [19, 20, 21].

With greater integration between prosumers and all of these technologies, decentralized market solutions [22] become feasible to be adopted in future power systems. Individuals and communities are gaining more control over

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[1]Prosumer is a consumer who can also produces and sell electricity. This term is better defined in section 2.1.

List of acronyms

BM	Business Model;
BRP	Balancing Responsibility Provider;
CC	Cloud Computing;
DR	Demand Response;
DSO	Distribution System Operator;
$EaaS$	Energy-as-a-Service;
EEG	Renewable Energy Act;
EMS	Energy Management System;
$ESaaS$	Energy-Storage-as-a-Service;
ESS	Energy Storage System;
EU	European Union;
EV	Electric Vehicle;
$FERC$	Federal Energy Regulatory Commission;
FiT	Feed-in Tariff;
ICT	Information and Communication Technology;
IoT	Internet-of-Things;
$P2G$	Peer-to-Grid;
$P2P$	Peer-to-Peer;
PPA	Power Purchase Agreement;
PV	Photovoltaic;
RES	Renewable Energy Resources;
SEG	Smart Export Guarantee;
SHS	Smart Home System;
SNA	Shared Network Access;
TOU	Time-of-Use;
TSO	Transmission System Operator;
UK	United Kingdom;
US	United States;

their energy generation and consumption. Such ideas benefit the emergence of concepts as local energy markets [23], energy community [24] and Peer-to-Peer (P2P) energy trading [25].

Existing BMs are not adequate to prosumers, proactive consumers, and industries, in order to give them incentives to act efficiently and have profits in the new energy landscape.

There are two generic BMs most frequently addressed in the specialized literature [26]: (i) the customer-side BM; (ii) utility-side BM.

In a study on business models for renewable energy [26], the authors focus on explaining the importance of utilities starting to develop a customer-driven BM, even without encouraging of developing the largest prosumer inclusion in these BMs and in the energy market.

On the other hand, Parag and Sovacool [27] identify promising markets for the prosumer's integration based on P2P models or prosumer communities, but without considering the required technologies or regulations. Sousa et al. [25] provide an overview of new P2P markets focused on further integration of prosumers. The authors provide a detailed study of existing P2P models and present the basic mathematical model for each proposed alternative, but without a detailed discussion on BMs and technologies to guarantee the functioning of the market strategies.

Therefore, this paper fills this gap in the literature by presenting an overview of innovative BMs for prosumers. It provides a detailed description on BMs and market designs that are currently being implemented to develop and encourage the prosumer participation in the energy market, highlighting some technologies needed to enable these new BMs and market design, such as data metering and control, cloud computing and blockchain.

The structure of this literature review has the following points:

(i) Defining the consumer main features;

(ii) Studying the current regulations in some countries related to this topic;

(iii) Overview of existing BMs for prosumers;

(iv) Future BMs trends.

The review methodology was structured according to Figure 2 and begins by gathering technical reports, scientific papers, books and laws from different fields and websites of various companies that have BMs related to the subject of

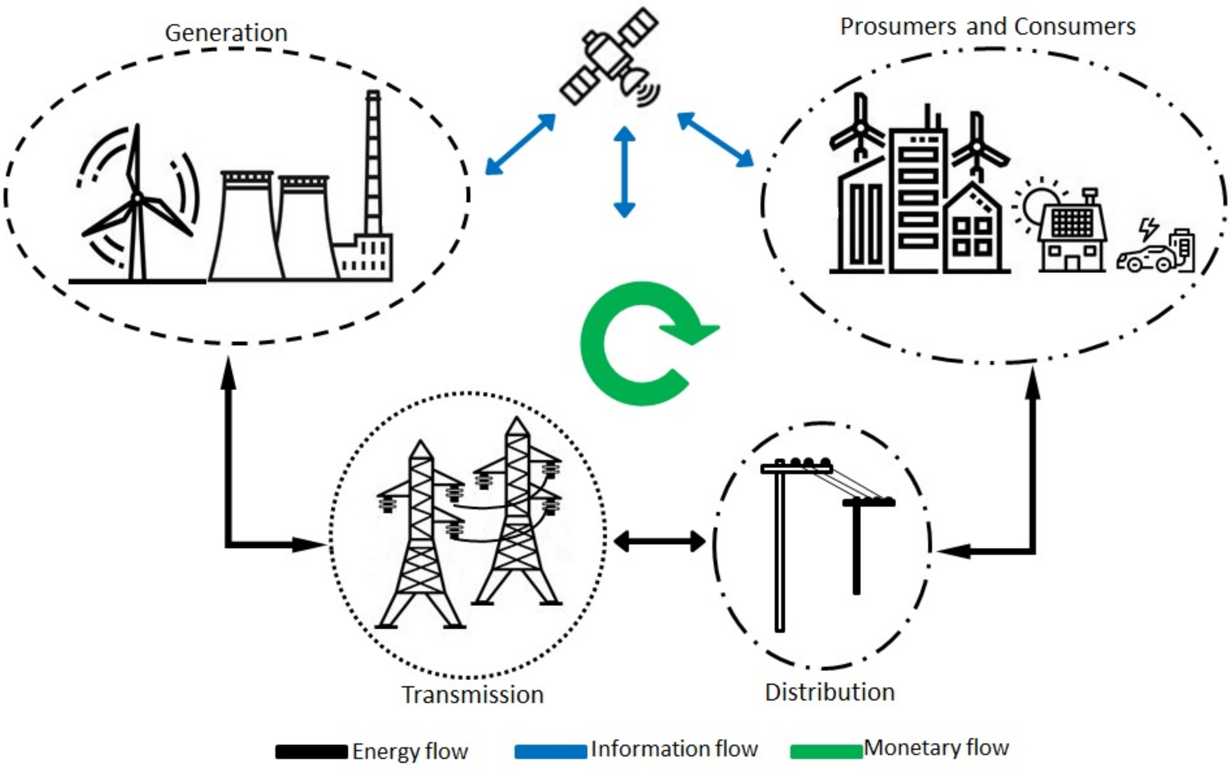

Figure 1: New energy system structure.

this paper. The research was conducted using combinations of the keywords highlighted in Figure 2. The objective was to investigate in a large and interdisciplinary review of energy prosumers integration into the power system, including the prosumer definition, traditional and innovative BMs, market design, specific regulation and enabling technologies. Literature on energy, power systems, economics, operational research, computer, social sciences, regulations, laws and decrees were included.

This search led to a total of 159 references being listed over more than 300 references evaluated. Among those selected, 67 were from journals, 16 from technical reports, 6 conference papers, 9 directives and laws and 61 websites related to the subject and companies that have their BMs focused on the prosumer. With a total of 105 publications, excluding company's websites, more than 80% of the publications was published from 2017. This reveals a growing interest from the scientific and industrial communities in increasing prosumer integration into the power system.

Regarding the structure of the article, Section 2 presents the main characteristics of prosumers, with a discussion on the main barriers and a regulatory overview about integrating them into the electricity market as an active player. Section 3 discusses the prosumers-driven BMs, considering traditional and innovative approaches. Section 4 focuses on the technologies needed to support those prosumers, including data, metering infrastructure, control, and prosumer-oriented market design. Section 5 presents the discussions related to the present work, highlighting the barriers, enablers, opportunities and recommendations to these topics. Finally, section 6 gathers the most important conclusions of this work.

2. The Prosumer

2.1. Generic definition

According to Eureletric [28], "*prosumer is a customer who produces electricity primarily for his own needs but can also sell the excess electricity*". It is primarily connected to the distribution network with small or medium installed capacity. The figure of prosumer has gained prominence in the power system, which has been facilitated by affordable ICT devices and the development of smart grids and affordable distributed energy resources technologies

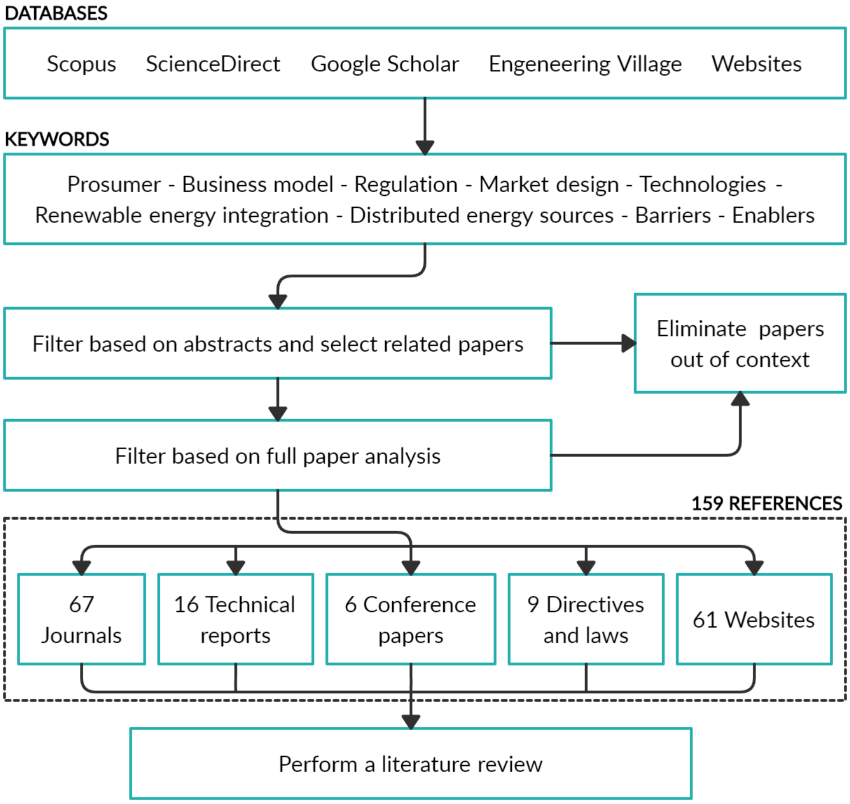

Figure 2: Literature review process.

like Photovoltaic (PV) and batteries. The possibility of selling the surplus electricity produced in combination with broader service packages has been encouraging consumers to become prosumers [28]. Lampropoulos et al. [29] were the first to make an article mentioning the concept of prosumer in the specialized literature.

2.2. Main barriers

In general, the energy from prosumers comes from Renewable Energy Sources (RES), most of them are intermittent (or stochastic) resources [30]. The proper management of those generation sources requires investments in ICT devices, smart grids, and a more flexible power distribution mechanism. This can also mean less reinforcement of the electric network with new lines and substations [31].

Distribution System Operators (DSOs) are expected to balance demand and supply, which will be more volatile in the best possible way. For that, they will have to modernize their grids with new layers of ICT, as the energy flows will become bidirectional. Further integration of prosumers also involves a new regulatory framework as well as an electricity sector restructuring.

As noted in Richter [26], prosumer-BMs will now supply a wide range of products and not just electricity or heat/cold. Energy services such as consulting, greater interaction with customers, rental of goods and services, new communication channels, and help with financing, should be provided. Companies will need to collaborate with local suppliers and installation companies to serve the customer locally and also have the ability to handle a large number of small-scale assets.

According to the study [3], the problems caused by the increasing number of variables RES inserted in the system are properly handled by current government policies. This continues harming the traditional energy BMs viability. Only questions about system reliability and security remain as the focus of most current actions, and few of them pay attention to the fact that innovative BMs are needed to deal with the changes that are taking place in the energy market. It is rarely considered the impact on BMs that the increases of variable RES may cause. To achieve the ideal transition to a more sustainable energy sector, energy policies and BMs are needed to support the complete integration of renewable energy into the grid.

Despite all technological progress in ICT, there are still barriers related to technology. In particular, we are far from the point of mass roll-out of infrastructure for real-time data (e.g., smart meters). Additionally, privacy concerns regarding data is the main obstacles for end-user acceptance of digitalization in the power system.

2.3. Regulatory overview

Although the term is widespread nowadays in the European Union (EU), for example, there is still no exact definition of who fits the prosumer concept. The lack of a clear definition makes the rights and obligations of prosumers unclear, varying across EU member states. The 2016 winter package [32], a document providing an analysis of EU member states' economic and social situation, brings a prosumer definition at EU level for the first time. However, it uses the term active client instead of prosumer [33].

More recently, given the growing importance of self-consumption, the EU Directive 2018/2001 [34], approved in December 2018, brought the definitions of "renewables self-consumer", "jointly acting renewables self-consumers" and "renewable energy community", as seen in articles 21 and 22. Knowing this directive points to a trend towards encouraging self-consumption, it is important to highlight that self-consumption is profitable for consumers only if the costs of local renewable generation is lower than retail electricity prices. This means that when there is a parity between the retail electricity market cost and self-consumption, Feed-in Tariffs (FiTs) can be eliminated.

Frieden et al. [35] present a review to understand and compare the emerging regulatory frameworks with those already in place in EU member states. According to the authors, while a few countries have already made significant progress in the transition process to the EU framework, most are still only at the beginning of these changes. For example, The German system is based on regulatory incentives for domestic microgeneration, self-consumption, and specific laws for the renewable energy-based generator connection as a way to stimulate energy prosumers.

~~Since 1990, t~~ In a short overview, the German government has adopted a unique PV generation subsidy program since 1990, as a way to test the practical functionality of these small, decentralized, grid-connected PV systems. Another important mark was the Renewable Energy Act (EEG) adoption in 2000 and last updated in 2017 [36]. The basic provisions of this law include a scheme to support renewable sources, a purchase obligation for network operators, and the solidarity principle to bear the costs of implementing RES. The EEG offered a high degree of planning certainty to investors. Traditionally, owners of PV generators are instigated to consume the electricity produced with a premium paid for each kWh consumed by themselves. This scheme was replaced by a simpler self-consumption scheme. This new scheme drives a large part of the PV market. The surplus of PV electricity is remunerated through the "market integration model": a feed-in premium on top of electricity market prices. A minimum requirement of 10% of self-consumption is demanded for installations between 10 kW and 1 MW [37]. ~~In 2017, t~~ The German government approved a law in 2017 for a plant operator in a multifamily house, to sell locally produced electricity to nearby tenants. The established precondition is that the PV plant is installed in a residential building and has a maximum capacity of 100 kW. To receive support, the plant operator can sell the electricity to the building's tenants or apartment owners in the building [38]. Prosumer was never defined as an official term in Germany but it is a driver of changes in terms of RES support and integrative legislation.

In the United Kingdom (UK), the support and multiplication of domestic PV and other microgeneration from renewable sources were massive between 2010-2015. Different incentives and policy initiatives (like FiT) have enabled the rapid growth of domestic PV prosumer [39]. Self-consumption, for systems below 30 kW, has been encouraged through a generation tariff and an export tariff, applicable to the electricity fed into the grid. The prosumer gets the generation tariff for all PV generated electricity, and an export tariff is also applied to the energy fed into the grid [37]. However, the UK's FiT scheme for small-scale renewable sources was officially closed on 31 March 2019 [40]. For almost 9 months there was uncertainty about the new scheme and finally the British government launched the Smart Export Guarantee (SEG) [41, 42] on January 1st, 2020.~~What will come next from the FiT scheme is still uncertain. One of the British government's proposals as a replacement for FiTs is the Smart Export Guarantee (SEG) [41, 42]. The SEG came into effect on January 1st, 2020.~~ To receive a payment, guaranteed by the SEG, for the surplus energy they inject into the network, prosumers must sign a so-called "SEG tariff" with one of the companies participating in the program, companies like EOn [43], Octopus Energy [44], Bulb [45], EDF Energy [46], OVO Energy [47], Shell Energy [48], Scottish Power [49] and others. The main difference of this new program in relation to FiTs, is that the SEG pays only for the excess electricity that is exported to the grid, and not for all the electricity generated. So, the SEG is paid by energy companies who buy the power and not by the government. To define the term prosumer, UK policies use terms such as "microgeneration" or "decentralized power generation" [50]. Renewable sources and the search for a more sustainable economy with a focus on mitigating climate change guided the support for prosumers in the UK.

~~On July 25th, 2018, t~~ The Council of Ministers of Portugal proposed on July 25th, 2018, a decree aimed at promoting the self-consumption of renewable energy. This new decree allows to facilitate connection of self-consumption facilities, regulates the mode of collective self-consumption and the creation of the Renewable Energy Communities Scheme. This decree was in public consultation until August 2018 and has not been approved yet.

In Spain, the self-consumption of electricity for grid-connected users is regulated by two Royal Decrees 15/2018 [51] and 244/2019 [52]. The first one deals with the urgent energy transition and consumer protection measures. The second decree regulates the technical, economical and organizational aspects of the electricity self-consumption. The Royal Decree-Law 15/2018 guide the energy transition towards a renewable energy-based model. The “solar tax” [53] is extinct, shared self-consumption is recognized by law and greater dissemination of Electric Vehicles (EVs) is encouraged. To complement the previous decree on self-consumption, Royal Decree-Law 244/2019 was published. Among other actions, this decree defines the different types of self-consumption, recognizes the collective self-consumption, and defines the idea of "production facility close to those of consumption and associated with them". This last one authorizes the self-consumption for generation facilities in the same house or other facilities nearby.

The French government is also an example of passing laws and regulations in the last few years to increase the consumer-side decisions [54, 55, 56]. These laws define self-consumption [54], which can be total or partial, individual or collective, on the scale of a construction, a co-ownership, or a district. The electricity sharing [55] is also regulated. The concept of "*collective self-consumption*" allows geographically close prosumers to share energy. Amends to the regulatory framework were approved in the law [56], in which the conditions for the purchase of PV generated energy up to 100 kW were defined.

Italy started using the net-metering mechanism in 2009. The systems included in this change were, initially, those below 200 kW. However, in 2015 this limit became 500 kW. This change can be seen as a proposal that mixes self-consumption with net billing features. After the end of the FiT law, net billing is the only scheme left. Above the 500 kW limit, a pure self-consumption scheme is used [37].

In Denmark, prosumers may apply to sell their surplus electricity back to the system through the DSO permission [57]. The net-metering scheme used in Denmark is similar to the others previously explained. In Denmark, collective self-consumption is allowed on building scale. For this purpose, the generation plant and also all consumers must have a utility meter in common, connecting everyone in a private network. Hourly net metering and instant net metering are in effect nowadays. The building owner, using each tenant’s meters, can perform internal billing. Therefore, the building owner is responsible for meter administration [38].

2.3.1. Regulatory summary through a timeline

After the literature survey prepared in the previous section, it is possible to summarize the main policies and regulations that have been implemented and adopted by different countries in order to benefit, encourage and allow greater participation by the prosumer in the energy market. Figure 3 shows a timeline comparing what was the focus of these regulations and policies in the past, what is prioritized today and what may happen as a future trend.

FiT policies played a prominent role in encouraging distributed generation though the deployment of prosumers worldwide. This incentive worked because it allowed a fixed and secure return on investments made by prosumers in the equipment and technologies necessary for the implementation of their generation systems, giving them the certainty of investing in technology that was still uncertain. However, now the technology is already tested and well known. Thus, in recent years, many countries have begun to move away from FiTs, replacing them by more market-driven mechanisms to encourage greater inclusion of prosumers. The UK, Germany, Denmark and Spain are examples of countries that are moving away from the FiTs and looking for new alternatives.

The net metering scheme increases the system flexibility, encouraging self-consumption of energy by the prosumers. Like FiTs, it tends to lose space for market-driven alternatives. One of these alternatives is Net Billing [58], which is a mechanism in which the prosumer’s compensation is based on the real market value of the kWh consumed or injected into the grid. Another innovative trend is an arrangement where it is possible to apply this mechanism, even if generation and consumption are located in different physical locations (also known as virtual net billing) [59].

Self-consumption policies are the current global trend, more specifically policies and regulations that deal with collective self-consumption, for example, the EU Directive 2018/2001 [34]. Collective self-consumption legislation still needs to move forward [38]. Currently, the promotion of self-consumption policies follows the trend of 3D’s, seeking

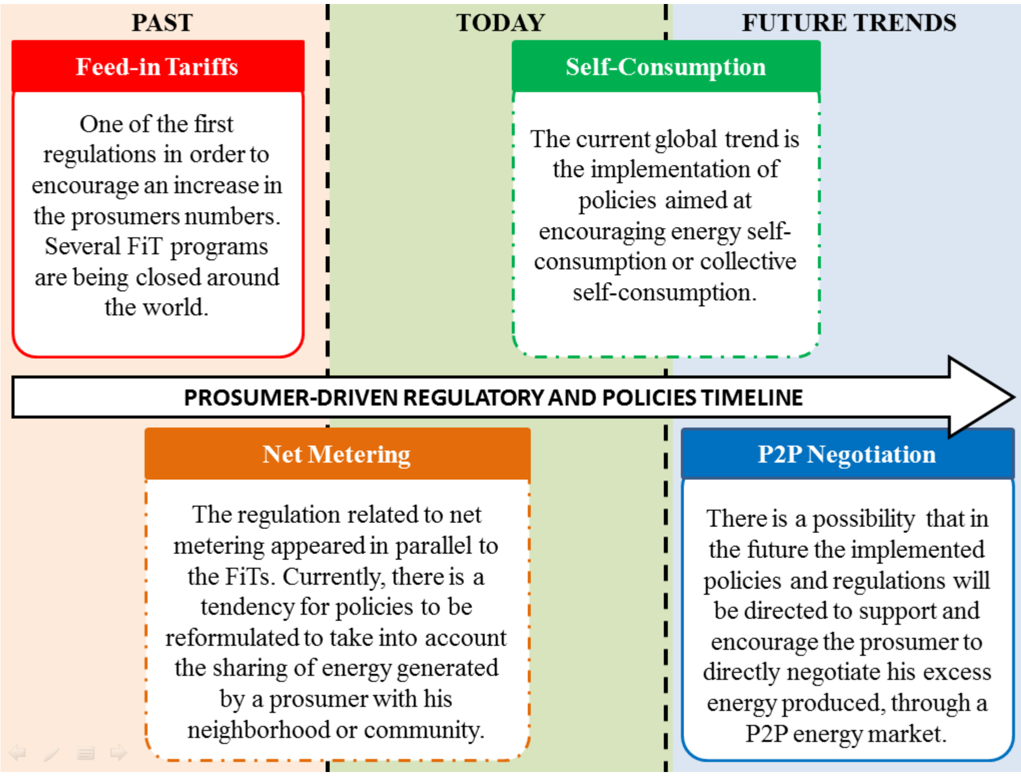

Figure 3: Regulatory timeline for prosumers proliferation in the power system.

more energy security and minimizing the environmental impacts of the sector. Existing collective self-consumption laws are still insufficient to provide a solid regulatory framework for the prosumer or the prosumer communities. As it is very likely that new BMs and financial models will emerge, the new laws and regulations that are created must take into account the potential for existing innovation and allow some level of experimentation. To this end, they must have legal provisions that allow periodic monitoring and evaluations to facilitate specific changes, guaranteeing the necessary future improvements in the legislation [38].

Possibly, the evolution of the P2P energy markets will contribute strongly to the development and implementation of policies and regulations, in order to legally support and encourage prosumers to negotiate their excess energy directly with other players in the energy market. The success of this new market model is directly linked to the type of regulatory and energy policy that will be adopted worldwide. P2P electricity trade is a novelty, therefore, several fundamental regulatory questions still need to be studied in detail and answered. The regulations and laws that emerge must be able to clearly establish the role of each participant in a P2P energy market, be it a prosumer who has scaled his generation for self-consumption and only sells any excesses or the prosumer who purposely oversized his generation to benefit from the opportunities in this type of market.

3. Business models

The reformulation of government policies and regulatory framework are essential to promote greater participation of prosumers in the electricity market. This new paradigm can lead to innovative BMs that will be crucial for prosumers to profit from investing in renewable sources [60].

Many new BMs are reshaping the way renewable energy projects are conducted. Some of these models are completely innovative when they bring a new concept or technology to improve the business. On the other hand, there are also some BMs already used in diverse areas but consisting of new applications to the energy sector.

Moura and Brito [61], claim that policies for integrating prosumers with the energy market increase the market potential of distributed generation and helps to improve traditional self-consumption policies.

Although the adoption of new policies aimed at aggregating prosumer leads to new BMs, these are not necessarily essential. In many cases, new legislation is not necessary for prosumers to be able to participate in the electricity market. SOM Energia [62], Sonnen [63], and Powerpeers [64] are good examples of projects that make it possible to integrate the prosumer without changing existing regulations.

SOM Energia, a Spanish company, has been developing some renewable energy projects. The company provides its customers/members with the opportunity to supply all their electricity consumption through 100% renewable sources, all at a price very similar to that paid for conventional energy. There is a fixed contribution to become a member. This ammount is paid only once, with no annual fee and is refundable if the member leaves the community.

Sonnen is a battery manufacturer (sonnenBatterie), with sonnenCommunity being a community formed by sonnenBatterie owners. Every member can share the energy produced with other members. The balance between energy supply and demand for all sonnenCommunity members is achieved through central software, where everyone is monitored continuously. The company charges a monthly membership fee.

Powerpeers makes energy matching between small RES and consumers, charging a fee for the app usage. It allows consumers to choose which producer they want to buy depending on the price of energy, type of technology, geographical location, and type of business involved.

In terms of energy storage, before focusing on BMs, it is important to understand the historical regulatory framework developed according to traditional distribution grid infrastructure. Thus, the Energy Storage System (ESS) may be technically able to provide essential grid services that are used to pay off new network investments and to avoid dispatch risks or network violations. In most regulations around the world, ESSs are associated with ancillary services, network support and the reserve market. These services are connected to the transmission and distribution network (medium voltage) in most cases for large-scale service.

In the case of the battery ESS business model, there are still non-defining rules for regulating its application for small-scale services, such as for prosumers. Therefore, regulators need to address the classification of ESS services and applications on the P2P environment at two options: system support resource and prosumer asset. In the first case, the ESS can be used to improve the grid flexibility and enable dispatch of other resources for participating in the P2P market. In the second, the ESS can be a prosumer integrated to another resource, such as PV or load. In the United States (US), the largest competitive wholesale electricity markets for battery ESS, the Order 841 of the Federal Energy Regulatory Commission (FERC) established guidelines for ~~for~~ market operators to develop rules for encouraging storage units' participation in the energy, capacity, and ancillary service markets. Moreover, prosumer aggregation policies to the energy market are essential and enhance the RES market potential and traditional self-consumption policies [61].

Based on the above analysis, prosumer-driven BMs could be~~In this paper, prosumer-driven BMs were~~ categorized into traditional BMs and innovative BMs. The main BMs of each category were highlighted, as shown in Figure 4.

Essentially, traditional BMs were considered to be those based on the first forms of incentive to include the prosumer in the energy market, such as FiTs, Net metering, Self-consumption and Leasing, heavily based on government incentives and subsidies. On the other hand, innovative BMs were considered to be those that depend on the further development of new technologies, such as smart devices, Internet of Things (IoT), ICT, etc and also businesses that have a market-driven BM, such as P2P trading platforms, for example.

3.1. Traditional prosumer business models

In a review study presented by Medved et al. [65], there is an exhibition of new BMs and technologies that can enable and maximize the efficiency of the proposed business concepts for the future. Notable among these are the concepts already mentioned such as Net-metering [66] and self-consumption [67].

The self-consumption BM decreases the network load and increases its stability, contributing to a viable long-term solution. This has being encouraged by the EU, as mentioned earlier.

The self-consumption included in this section is the most common type of self-consumption, where a prosumer generates his energy by installing a PV system in his home, for example. Other types of self-consumption were classified as innovative, so they are explained in section 3.2. Traditional self-consumption is commonly associated with Net-metering or FiTs.

Net metering is a model of contract in which a consumer who owns his generation is linked to the energy utility in his region. In this contract, the prosumer performs self-consumption, and the excess electricity produced is injected into the network. The consumer receives credits as a form of payment for energy produced in excess. The customer can use the credits received in previous months to reduce the amount of his monthly invoice (the credits are generally valid for one year) [68]. Briefly, the net-metering scheme is an incentive for self-consumption of energy through a tax exemption.

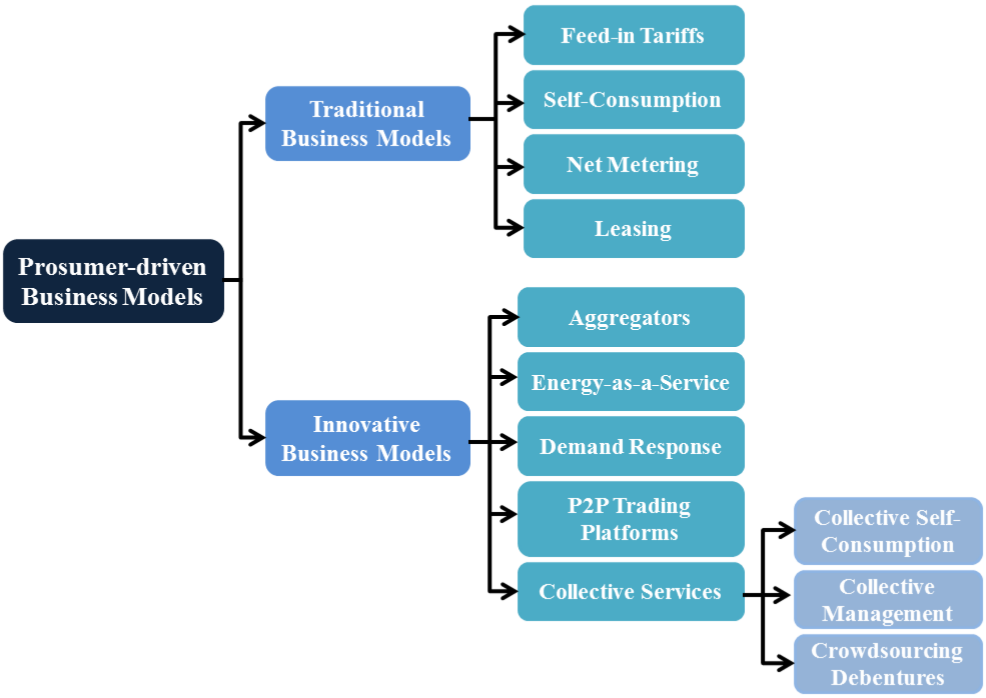

Figure 4: Business models classification.

Other models may be based on FiTs [69, 70]. The evolution of this model for PV generation generally follows the following sequence:

- Excess PV electricity gets a FiT;
- Excess PV electricity gets a Feed-in Premium above the market price;
- Excess PV electricity gets the market price through an aggregator; and
- Excess PV electricity gets the market price directly.

Another example of a growing BM is Leasing, in which customers hire a company to install a renewable energy system and pay rent for that system or a fixed price per energy generated. At the contract's end, customers can purchase the system, extend the contract, or remove the system for free. Thus, without a large initial investment, an individual can become a prosumer by renting a generation system. The leasing model employed in small-scale wind-based has the potential to modify the market and benefit prosumers [71].

Vivint Solar's [72] customers can lease a system or purchase energy based on a long-term contract, a Power Purchase Agreement (PPA). In this PPA scheme, only the amount of electricity that the PV system actually produces is converted into a fee that customers must pay. The fee is proportional to the kWh consumed. In the lease scheme, customers pay a monthly amount, which is calculated taking into account, a forecast of what will be generated by the PV system. If the leased system does not reach the agreed generation level, the company guarantees the customer a payment corresponding to the contracted system.

Sunrun Inc. [73] is a US-based residential solar electricity provider with a BM in which it offer customers either a lease or a PPA business model. In this case, homeowners pay for electricity usage, but have not purchased solar panels yet, reducing the initial capital outlay required by the homeowner. The company performs the installation and maintenance of the equipment as well as the necessary monitoring and repairs. In the leasing case, the company receives a percentage of the amount saved by the customer on the energy bill.

Like popular solar lease programs, United Wind's [74] lease program allows farmers or other landowners, at no initial cost, to power their homes or businesses through small wind turbines, producing from half to all their electricity needs, reducing total energy costs. Monthly customer payments are United Wind's primary source of revenue. The distributed wind becomes cost-competitive with power from the network, as it is qualified to obtain federal tax credits and state incentives.

3.2. Innovative business models

Increased environmental awareness among consumers means that innovative BMs are gaining more and more space. Thus, when the prosumer has no physical space available or does not have the financial means to pay for his renewable energy system, he has the opportunity to acquire the asset through models where the necessary investment is shared. Collective management of energy assets through community schemes [24] allows members of an energy community to share the benefits of a renewable energy system.

Medved et al. [65], briefly introduce energy cooperatives [75], crowdfunding [76], and the possibility of additional income for prosumers by providing ancillary services such as voltage control and power reserve provision.

The innovative BMs presented here are divided into 5 subsections for better organization and understanding, highlighting the main characteristics of BMs and also pointing out examples of companies that use them. It is worth noting that after a detailed analysis of the specialized literature and the BMs of different companies, it is observed that some companies may have a BM that fits at the same time in more than one of the subgroups highlighted below.

3.2.1. Aggregators BMs

To manage a small prosumers group and thus create capacity similar to that of a conventional power plant, aggregators appear (also called virtual plants). Aggregators use ICT-based systems to be able to virtually control distributed RES. In this way, aggregators can sell electricity or ancillary services in the wholesale energy market [77]. Some countries already have specific regulations for aggregators, like Australia, Belgium, France, Germany, Netherlands, UK, and the US [78].

Aggregators, by definition, are legal entities whose goal is to optimize, technically and economically, the energy consumption and production. Consumers and producers can be included in the aggregated pool, which can operate both in multiple electricity markets or in only one. In order to address issues around aggregation the BestRES [79] project was initiated with Horizon 2020 [80] research funding support. The program ended on February 28, 2019. In this study, one can identify some ready-to-implement BMs, like:

- **Combined aggregator-supplier:** There is only one Balancing Responsibility Provider (BRP) at the connection point, and a package is offered for supply and aggregation;
- **Combined aggregator-BRP:** The supplier is compensated for imbalances. The independent aggregator and the supplier are on the same connection point;
- **Independent aggregator as a service provider:** The aggregator does not sell to potential buyers on its own but provides services for one of the other market actors;
- **Independent delegated aggregator:** The aggregator sells to the Transmission System Operator (TSO), the BRP or the wholesale electricity markets on its own risk; and
- **Prosumer as aggregator:** A big prosumer becomes an aggregator of his portfolio.

On the one hand, combined aggregators do not demand significant regulatory changes, and therefore, are more compatible with the existing electricity markets. On the other hand, independent aggregators can provide a greater market opening to new players as they increase competition.

The development of this type of BM requires a liberalized wholesale energy market, with clear price signals to guide the aggregators' operations, since the variation between prices is the main incentive for the aggregators BMs. Aggregators must be supported by legislation to be able to participate in both the electricity and ancillary services markets [81].

Advanced measurement and forecasting infrastructure with real-time data acquisition technologies, ICT and network digitalization are essential, as aggregators operate by optimizing supply and demand, depending on the energy price at different times or providing ancillary services when needed. Companies like Tesla [82] develop projects based on energy aggregators, like South Australia's Virtual Power Plant [83].

3.2.2. Demand response BMs

There are also other models based on Demand Response (DR) [84], driven by recent advances in information technology and control. DR has gained increasing importance at the domestic level with the maturation of the IoT. For large players in the market, DR is already a reality. However, the concept is relatively new when applied to small and medium prosumers [85, 86]. Leutgöb et al. [87] points out that despites the existence of technological solutions for DR-based programs, it is still necessary to develop appropriate BMs for small and medium prosumers.

According to the Smart Energy Demand Coalition [88] there are two ways to monetize DR. The so-called "*Explicit use of DR*" and "*Implicit use of DR*". The first, also called "*incentive-driven DR*", is defined as the flexibility that can be negotiated in the energy market and its main source of income is the sale of flexibility services to TSO, DSO or BRP. The second, also called "*price-based DR*", is defined as the prosumer/consumer's response to market price signals. The consumer can change his consumption behavior depending on the energy price at the moment and its main source of income is the savings generated by shifting loads.

Leutgöb et al. [87] categorized five types of DR-BMs:

- **Explicit DR as stand-alone service:** The DR potential of many small consumers is grouped and managed by a third party. For the success of this BM, access to switched equipment and better forecasting software is required.
- **Explicit DR combined with energy efficiency services:** This BM seeks to optimize the interaction between DR and energy efficiency in the consumer's daily life. Only a few pilot projects have been carried out in this area [89].
- **Implicit DR service for optimal use of time-of-use (TOU) contracts:** This BM is based on the variation in the price of electricity depending on the time when the energy is used. Currently, only TOU [90] contracts are an option for small and medium-sized prosumers, but it is expected in the future that prosumers will be able to opt for more market-driven options such as those based on real-time-pricing [91, 92]. The value generation of this BM depends on the difference between the highest and lowest energy price on the day.
- **Implicit DR including power supply:** Combination between DR services and the retailer's role in the energy market are the basis of this BM. It takes a step beyond TOU contracts including the active management of customers' consumption profiles. The subsidy for smart devices, the availability of software to control these devices and the training and information of small and medium prosumers are essential for this BMs success.
- **Microgrid Management:** It consists of managing the operations of all energy resources of an energy microgrid [93]. If operated in an isolated manner, the use optimization of the energy storage equipment is essential. If connected to the grid, the manager can use any of the previous BMs to generate value for all prosumers and consumers who are part of the microgrig.

Companies using one or more of the BMs presented above are highlighted below. An example of a DR-based BM is that used by the Swiss company Tiko [94]. The company is already managing more than 6,500 homes using professional DR to, for example, provide ancillary services and improve customer energy efficiency. Other models based on Batteries [95] and EVs [96] drive household self-consumption at much higher rates. Companies like Tesla [82] are already developing home battery systems to increase end-user independence on energy prices and promote self-generation and self-consumption.

Tiko Energy operates in the automated management of devices such as batteries, heat pumps, water heaters, solar panels, and electrical outlets. The company allows users to control their energy consumption according to their specific needs and energy budget, through a personalized dashboard that groups all data related to the energy consumption of the various devices that these users may have.

The control of energy production and consumption are planned and implemented through methods based on EMS. Energy cost savings and conservation, climate control, and protection are the most important objectives. Rainforest Automation [97] provides devices and services that work together to automate and optimize residential power usage.

3.2.3. P2P trading platforms BMs

Rocha et al. [98] points out that the P2P energy market is quite important in the context of "*local energy markets*". P2P BMs can generate value through energy cost savings, grid cost savings or by offering new grid services. Prosumers can trade their energy freely in the market and the peers involved in trading are protected from the volatility of retail markets. Since energy exchanges occur locally (between neighbors) there is a reduction in electrical losses in the system [99]. Additionally, by pooling resources from several small prosumers, flexibility services can be offered to TSO, DSO or BRP [100].

The large-scale implementation of P2P trading platforms, which provide a strong incentive for prosumers, still requires regulatory adaptations. Some examples of countries that already have projects in progress in this area are Bangladesh with SOLShare [101], Germany with Lumenaza [102] and sonnenCommunity [63], the Netherlands with Vandebron [103] and Powerpeers [64], and the UK with Piclo [104].

SOLshare has developed SOLbazaar, an IoT-driven trading platform which enables prosumer to trade the excess solar energy generated by Solar Home Systems (SHS). Consider the SOLbazaar as an energy marketplace where SHS users can sell their excess generation to other users. The company charges a fee for each KWh shared between neighbors.

Lumenaza connects local producers and consumers of renewable energy, using the software called "utility-in-a-box", with the intention of creating and stimulating a green, regional, community, and transparent electricity market. The system can virtually handle all the functions of an energy service provider in a modular and highly automated manner: Monitoring renewable power production, balancing supply and demand, and organize billing. This BM includes the one-time calculation of the set-up effort for a project as well as variable license fees depending on the number of customers supplied and the amount of electricity purchased.

Vandebron is a green energy company that delivers electricity and gas to individual or business customers. Although the company does not generate energy itself, it negotiates and sells electricity from independent energy producers. Producers are located on farms or are larger wind parks, and the energy is obtained from solar, wind, and biomass resources. Customers are free to choose which producer they want to buy the energy needed to supply their demand. Producers, on the other hand, determine what price they will offer the energy they generate. The company's revenue comes from a subscription fee that is paid by consumers and producers.

With Piclo, consumers and producers can buy and sell their electricity or flexibility through an online trading platform, backed with intelligent peer-matching algorithms. The company's users can choose the renewable source that will supply them and can also view every 30 minutes, the amount of generated energy during the day.

P2P electricity trading can theoretically function as a business model regardless of the existing market. However, this is generally not the case in practice. Most existing P2P platforms operate in conjunction with the traditional energy market [105].

3.2.4. Energy-as-a-Service BMs

Instead of only selling energy, the prosumer can explore selling a full range of electricity-related services. The so-called "*Energy-as-a-Service*" (EaaS) [106] operates behind-the-meter services such as demand management, energy storage, electricity exchange between local networks, energy-saving advice, and comfort and safety measures. Companies like Germany's E.on [43] are active in this area.

EaaS-BMs generally take the form of a partnership between companies and external energy specialists, where this specialist investigates all aspects of energy management and supply. It combines all this information with his energy sector knowledge to propose energy solutions that are beneficial to the company. The proposed solutions can be: ways to save energy, how to make operations more efficient or the best way to obtain the energy you use, including how to produce and store it. The best technology in terms of EMS and smart devices can be made more accessible through EaaS companies. The application of EaaS-BM for residential and community solar systems is a good example of how EaaS has been used to overcome barriers to the use of low carbon technologies. Companies like SunRun [73] and Vivint Solar [72] stand out by combining EaaS with leasing.

Xu et al. [107] categorized four types of EaaS-BM:

- **Energy Conection-as-a-service:** Companies that provide connectivity solutions with one or more networks. This BM is based on the concept of Shared Network Access (SNA) for DSOs [108]. Through SNA BM the DSO shares its access to the assets and operations of the power grid with licensed third parties, receiving a lease. This other participant receives the name of "secondary DSO" and can introduce new service offers on the market even without having the physical distribution network that remains the DSO's property.

- **Energy Supply-as-a-service:** This BM combines the existing network infrastructure with the energy supply infrastructure. Its value generation comes from the RES integration and the power quality. Companies like Senec [109] and Lichtblick [110] use this type of BM. These companies manage energy generation or storage using ICT tools to maximize the distributed RES supply.

- **Energy Data-as-a-service:** This BM is based on software and data platforms. The increasing energy sector digitalization allows a large amount of data accumulation that, together with ICT and artificial intelligence technologies, allows the development of BMs that create value from the collected data analysis, increasing network reliability and providing flexibility. An example of this BM is Fingrig's Datahub [111], a platform that provides open access to consumption data and retail electricity prices. The value creation of this BM comes from the development of new applications and intelligent energy services.

- **Energy Application-as-a-service:** It is a BM that groups energy and data supplies and also provides a specific application or market for energy, data or connectivity negotiations to take place. This BM seeks to reduce the barriers between end consumers and producers, in addition to allowing greater prosumer integration in the energy market. Companies that have this BM operate, mostly, through an e-commerce software or application. Companies like Vandebron [103] use this type of BM.

Another BM that should be mentioned is the Energy Storage as a Service (ESaaS) that enables a facility, even without buying the battery system, to take advantage of an ESS through a service contract. ESS provides a set of services with a focus on improving electricity resilience, generating more revenue, and increasing savings. The operation of the ESaaS system through a service contract or even through an EMS, both based on an advanced battery storage system, can add value to the business by providing this energy reliably and economically.

3.2.5. Collective services BMs

Finally, BMs based on collective services, like self-consumption are gaining prominence. The EU promotes the principle of energy communities. A local, virtual and flexible community where every customer/user is connected to a energy point (the same low-voltage substation, for example) could join or leave this community quickly and easily, which can be achieved through collective self-consumption. Under the current regulation, only energy community where members are at the same point is allowed, but a relaxation of the regulation is expected to allow energy community in a broader sense.

The emergence of specific and multiple models of collective self-consumption through an existing legal framework or within pilot initiatives is due to the lack of a clear legal framework in the various European countries.

The Council of European Energy Regulators categorized three different BMs [112]:

- **Community owned generation assets:** This is the most common case. Renewable energy, in this case, is resold to a supplier instead of being consumed by the community members. Revenues are shared among members or re-injected into other renewable production projects. Citizens' cooperatives that have their own renewable energy generators are usually part of this structure;

- **Virtual sharing over the grid:** The community uses the public electricity grid to share all the renewable energy produced among its members. The balance between generation and consumption is carried out by a common energy supplier who is also responsible for organizing the sharing; and

- **Sharing of local production through community grids:** In this BM that has traditionally developed on disconnected energy islands, the community uses a private network to share the energy produced. However, initiatives based on this model have also emerged in regions with public networks, motivated by the desire to reduce grid tariffs and produce/consume energy locally.

An example of a local energy community is LEF [113] in Hoog Dalem district in Gorinchem, the Netherlands. An energy community is formed by a group of approximately 15 homeowners that generates its own electricity. LEF's purpose is to perform electricity self-consumption as well as, if necessary, the mutual exchange of electricity between community members. The necessary electricity can also be bought from the grid, if there is not enough self-production to serve everyone, through the use of flexibility or ancillary services.

The local energy market works based on blockchain technology. This allows local end-users to bid for electricity supply or demand. Software collects data from household appliances, matches that data to the weather, and thus allows bids to be generated. The data collected allows a more accurate forecast of energy demand and, from that, a market emerges from this game of supply and demand.

Another category included in collective services are the *energy cooperatives*. Consumer cooperatives is a company created by the union of several small and medium-sized prosumers and consumers that aims to better meet the energy

Table 1
Real examples of companies and their respective BMs.

Business Model	Electricity Service	Typical Services	Exemple
Demand Response	Large DR resources	Firm capacity, operating reserves and constraint mitigation.	Enel X [117] and Restore [118]
	Small DR resources	Firm capacity, operating reserves and constraint mitigation.	Ohmconnect [119], Encycle [120] and Lichtblick [110]
Energy Management System	EMS Providers	Non-electricity services.	Gridpoint Energy [121], Blue Pillar [122], Rainforest Automation [97] and Wiser/Schneider Electric [123]
Electricity and thermal storage for network services	Network Services	Firm Capacity, operating reserves, network constraint mitigation.	Invenerge [124], Greensmith [125], Younicos [126], AES Energy Storage [127], Ecoult [128] and Ambri [129]
Energy storage for end-user optimization	Energy Storage	Firm capacity.	Stem [130], Younicos, SolarCity\Tesla [82], Sungevity [131] and Sonnen [63]
Storage for end-user and system co-optimization	Energy Storage	Firm Capacity, operating reserves and network constraint mitigation.	Stem, Green Charge Network [132], Ice Energy [133], Advanced Microgrid Solutions [134] and Vcharge [135]
Solar-plus-storage for end-user and system co-optimization	Solar Energy and Storage	Energy, firm capacity and operating reserves.	Sunverge [136] and Solar Grid Storage/SunEdison [137]
Distributed solar PV finance and installation	Solar Energy	Energy.	SolarCityTesla, Solairedirect [138], SunRun [73] and Vivint Solar [72]
Community solar	Solar Energy	Energy.	NexAmp [139] and Mosaic [140]

needs of all its members. An example of using this type of BM is the Dutch Windcentrale [114], which allows the consumer to co-own a wind turbine. Any Dutch citizen can buy equity shares for 250-300 euros. One share equals approximately 500 kWh per year. Windcentrale manages the project only by taking a fixed fee per share (10%), so it does not own equity.

Another model is the crowdsourcing debenture, practiced by Abundance Investment [115], a UK-based online investment platform which contributes to a green economy. The company's investors share the profits from the generation and sale of low-carbon electricity. The company mainly relies on renewable energy projects in the UK in its investment portfolio.

3.3. Other real examples of prosumer-driven Business Models

Burger et al. [116] presents an empirical analysis of the most common BMs for implementing power management and DR systems, PV solar resources, and electricity or heat storage. A detailed analysis of 144 BMs is made comprising the electricity service technology, the captured revenue stream, customer segment as well as DR resource for each model. This study highlights that the current BMs for distributed energy resources are driven more by regulatory and political factors than by technological factors.

Table 1 lists some real companies that contribute to foster the prosumers integration, their BMs, and the services that are provided by them. The basic ideas for each BM presented in this table were detailed in the previous sections.

For the business viability of providing electricity services, specific regulations and policies are extremely important because they guide the formation of BMs. Thus, regulators and policymakers must adapt yourselves and contribute to the structuring and sustainability of long-term BMs. Continuous research is needed to achieve ideal policies and regulations aiming at avoiding over-reliance on these aspects. Evidence suggests that lower dependence levels are achieved through market-oriented schemes. Regulatory and political dependence is a tangible and significant risk for innovative businesses and technology.

3.4. Business models' summary

Table 2
Business models' summary.

	Characteristics					
	Business models	**Regulatory Framework**	**Market enviroment**	**Technology dependence**	**New infrastructure needs**	**Summary**
Traditional BMs	Feed-in Tariffs	+	+	+	n/a	Section 3.1 page 9
	Self-Consumption	+	+	+	n/a	Section 3.1 page 8
	Net metering	+	+	+	n/a	Section 3.1 page 8
	Leasing	+	+	n/a	n/a	Section 3.1 page 9
Innovative BMs	Aggregators	++	++	++	++	Section 3.2.1 page 10
	Energy-as-a-Service	++	+++	++	+	Section 3.2.4 pages 12 and 13
	Demand Response	+	++	+++	++	Section 3.2.2 page 11
	P2P Trading Platforms	+++	++	+++	++	Section 3.2.3 pages 11 and 12
	Collective Services	++	+	++	++	Section 3.2.5 pages 13 and 14

+++ More dependent
\+ Less dependent
n/a Not applicable

A brief summary of the different BMs characteristics detailed above is presented in Table 2. This summary presents and classifies which areas need further development for the successful implementation of the BM, i.e., the areas on which the BM is most dependent. The classification was carried out on a theoretical basis taken from the studied references.

4. Technologies

Coupled with innovative BMs are the new technologies needed to better and further develop the infrastructure that is essential for promoting full prosumer integration into the energy market.

4.1. Data metering and control

In the coming decades, energy systems tend to become increasingly connected, so digital technologies will play a key role. The energy sector digitization is imminent. Future digitized power systems will be able to supply energy at the right time and place, at the lowest possible cost, to anyone who needs [141].

Big data and artificial intelligence combined contribute enormously to the value creation of the new prosumer-oriented BMs. The paper [142] provides a review of the big data application in microgrids.

Another technology that has gained prominence in the energy sector is the IoT technologies. IoT enables real-time Internet communication between home appliances, facilitating information collection and exchange. In [143] it is presented the IoT role in integrating renewable energy resources into the electricity grid. The IoT association with smart meters for monitoring power quality and reliability is also a study subject [144].

The use of advanced infrastructure based on ICT and control for the total prosumers integration in a smart grid environment is essential since, in this environment, it is necessary to deal with bidirectional data and energy flow [13].

4.2. Database platforms

Blockchain can be an important ally in the prosumer inclusion in the energy market. With this technology, it is possible to manage all devices connected to the grid through intelligent automated contracts, so prosumers and system operators can benefit from the flexibility and real-time pricing [145].

Smart contracts would signal the system when initiating transactions. The balance between demand and supply occurs automatically under predefined rules to ensure that all energy flows involved in the process are controlled. In this way, blockchain technology could directly control network flows and storage facilities [146]. Al-Ali [147], present a service model based on prosumers applying blockchain. This allows multiple power sources, users and producers to connect more easily.

Another important feature worth mentioning is Cloud Computing (CC). Cloud-based systems allow users to access information with greater flexibility. Information and data from various systems can be obtained, stored, accessed, and analyzed by users through different electronic devices, like application [148].

Bera et al. [149] show CC applications within the smart grid concept, focusing on power management, information management, and security. In [150], CC applications for smart grid are presented in terms of efficiency, security, and usability.

Projects such as Globus [151] and OpenNebula [152, 153] are examples of using CC applied for smart grid enhancement. Studies on smart cloud meters [154] are also found in the specialized literature.

4.3. Prosumer market design

Significant changes are expected to occur in the current energy market structure. Multiple players operating a decentralized power grid will likely be a reality, then policymakers and companies must be prepared for this. Therefore electricity markets need to be restructured so that all participants can benefit from the increasing inclusion of prosumers. The possible market models that integrate prosumers according to study [27] are P2P models, prosumer-to-grid (P2G) integration models, and communities.

Where:

A: P2P model, prosumers directly interconnect, buying and selling energy services;

B: P2G model, prosumers provide services to a microgrid that is connected to a larger network;

C: P2G model, prosumers provide services to an isolated and autonomous microgrid; and

D: Community model, prosumers gather resources or form a virtual power plant, i.e., a community.

Users on the demand-side of a market with a structure focused on the prosumer can actively offer services that other prosumers or system operators and energy utilities need and not just react to the price signals of the market [155]. Another market design is proposed in study [77] where the concept of the federated power plant is created, like a virtual power plant formed through P2P transactions between self-organizing prosumers. In [96], the authors implemented the P2P energy trade between EV.

As highlighted by Sousa et al. [25], recently, the P2P electricity market has emerged as a new proposal to enable prosumers to directly share their electricity and investments. Consumers can freely choose how and from whom they buy their electricity. An alternative structure that should be highlighted is the community-based market [25]. These local prosumer markets are likely to operate in a smart city environment.

Finally, Espe et al. [156], considering publications in renowned energy and technology journals from 2009 to 2018, present a literature review on the prosumer-community based smart grid.

5. Concluding remarks: enablers, barriers and opportunities ~~Opportunities and Recommendations~~

This section is divided into three items regarding the prosumers integration in the energy markets. First, enablers are presented. The second subsection shows the main barriers that must be overcome by prosumers. Finally, the opportunities and recommendations on the topic identified by the authors are exposed.

5.1. Enablers

~~In contrast to the barriers mentioned in section 5.1, t~~ There are ~~also~~ a number of issues that allow, facilitate and direct the emergence of innovative BMs, the development of prosumer-driven traditional BMs and also the greater prosumer inclusion in the energy market. As enablers, were considered characteristics that can encourage society to want a greater prosumer inclusion, encouraging the development of related prosumer-driven BMs, helping to overcome

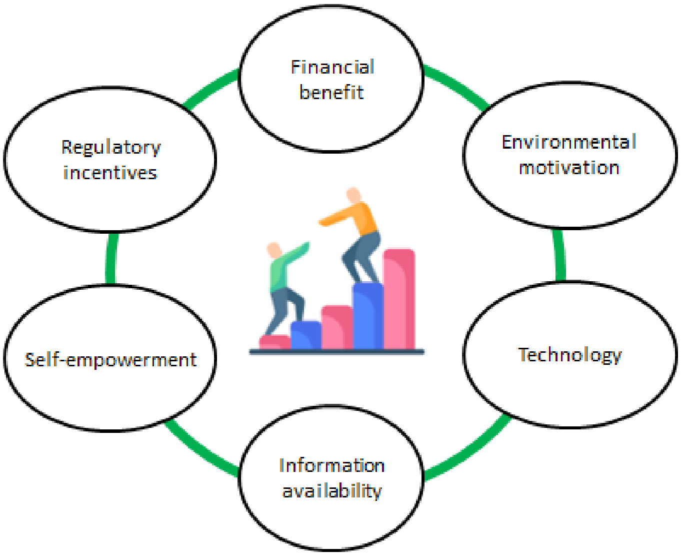

Figure 5: Enablers for the prosumer-driven BMs development.

the subsequently ~~previously~~ established barriers (see section 5.2). All issues considered relevant are shown in the Figure 5 and highlighted below.

- **Environmental motivation:** a strong motivator for the development of new energy market models with the inclusion mainly of the RES-based prosumer are the environmental issues. The ambition to make the electrical matrix increasingly green and carbon free, allied with the concern to make society less dependent on fossil fuels;
- **Self-empowerment:** the possibility of controlling its own power generation, making it less dependent on centrally generated electricity, sold by a utility. Having the feeling of greater energy security;
- **Financial benefit:** the decrease in costs related to some forms of distributed generation and the increase in prices of energy from traditional sources can make self-production more accessible and competitive. Especially for energy communities that may have a better potential for financial return;
- **Technology:** The emergence of new technologies are extremely important for the formation and development of new BMs. The ability of prosumers to interact with each other and also with the power grid is greatly benefited by advances in EMS, ICT, smart devices and IoT;
- **Regulatory incentives:** a stable regulatory framework is needed to stimulate innovation and provide an attractive business environment for the development of innovative solutions, technologies and services, enabling the emergence of innovative BMs. The regulatory framework must aim to benefit the prosumer's economic development, as well as contributing to a fair allocation of costs and benefits. Becoming a prosumer and investing resources in the development of BMs should become attractive. The regulations developed should make prosumers integrated into the market and the energy system without too many complications. Support schemes must be designed and developed in such a way that they are cost-efficient, transparent and do not cause market distortion. In many regions, states are willing to approve regulations friendly to prosumers;
- **Information availability:** Increasing prosumer participation in the energy market and the innovative BMs development is only possible if these players are well informed, trust the data and information available and have the ability to use technologies and smart devices. New ICT, IoT, blockchain technology and infrastructure such as smart grids are facilitators of the successful formation and management of prosumer groups.

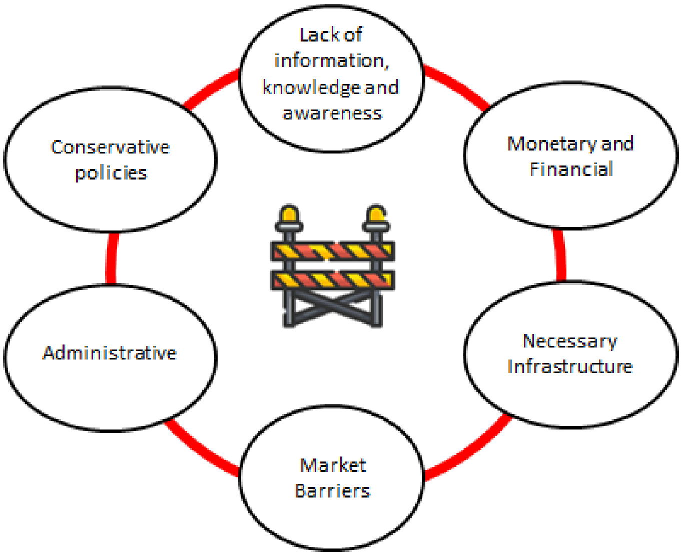

Figure 6: Remaining barriers for the prosumer-driven BMs development.

5.2. Remaining barriers

~~Some of the barriers~~ In addition to the main barriers faced by the prosumer, described in section 2.3, this section presents what the authors consider as the six key barriers points that may still delay the development of the prosumer-driven BM and its greater market inclusion are illustrated in Figure 6 and highlighted below.

- **Lack of information, knowledge and awareness:** the lack of information, knowledge and training on the characteristics of the prosumers, P2P energy markets and specific legislation can lead to delays in the development of potential BMs aimed at the greater prosumer inclusion in the energy market. This topic can also lead to insecurity regarding the privacy of personal data related to P2P energy/monetary transactions.

- **Monetary and financial:** refer to the costs and investments required for the prosumer, especially small-scale ones, to acquire the technologies and equipment necessary for the assembly, maintenance and operation of their generation systems. With the decrease in government incentives and the lack of good opportunities for financing small RES, this problem becomes worse. There may still be long payback periods and the financial risks involved may be high;

- **Necessary infrastructure:** availability of the physical and technological infrastructure necessary to efficiently incorporate the prosumer into the existing energy market can be a problem. It is necessary to advance the smart meters technology and also make them cheaper, for example. The development of BMs associated with IoT and online platforms requires a lot of innovative knowledge to increase prosumer-driven BM's viability;

- **Administrative:** the lack of institutions (public and private) and authorities dedicated to supporting and encouraging the development of the new market structure necessary for the greater prosumer integration; complicated bureaucratic procedures; difficulty in acquiring technologies and equipment; inadequate planning guidelines; and complex, slow or time-consuming permission and operation processes. Political resistance or institutional corruption can delay or even hinder undermine the development of innovative BMs;

- **Market barriers:** it can be quite difficult for the small prosumer to compete competitively with the big utilities. The decentralized energy markets development poses a threat to utilities, which currently apply a BM almost entirely focused on centralized generation, sales and electricity distribution. Some utility companies may resist the energy markets evolution, facing prosumers with their distributed energy systems as a threat;

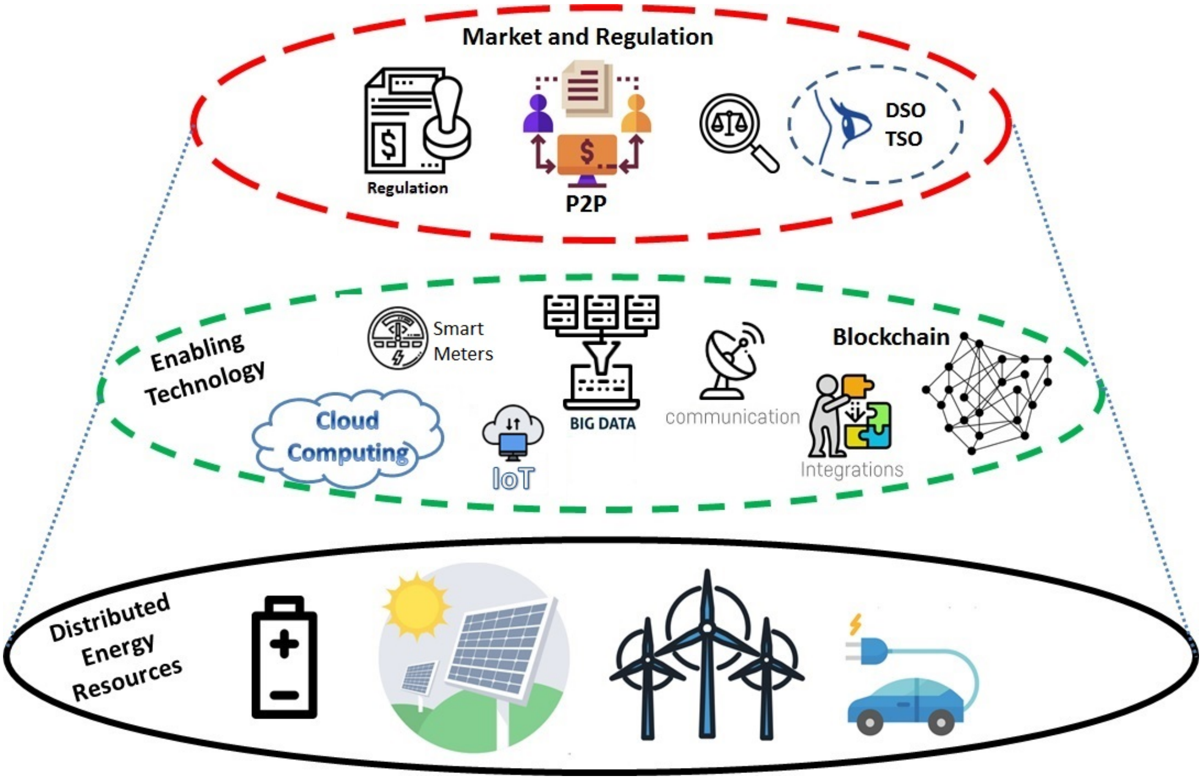

Figure 7: Innovative Business Models Structure.

- **Conservative policies:** include inadequate policies, some policies discontinuation, unfavorable or inconsistent policies and lack of transparency can be an issue. Political uncertainties significantly hinder the expansion and development of new BMs and the greater inclusion of the prosumer.

5.3. Opportunities and recommendations

In a general view, there is a global trend to reduce or even extinguish governmental incentives primarily related to renewable generation sources, such as FiT [157]. So, to keep the increase of those carbon-free sources, the prosumers need to monetize their investments somehow.

The present work shows that prosumers integration in the electricity market depends on different aspects, as shown in Figure 7. To start with, the integration of those layers would benefit the feasibility of the market for small scale players.

In the base of those developments are the distributed RES, which in the case of the small scale players are presently related to the rooftop solar, and an increasing number of EV. Although, there is also an expectation for the deployment of battery storage in the near future.

From the increase of the distributed RES and the possibility to exchange energy, information, and money, some technological developments play an important role in the measurement, control, communication, and security of the distributed market. This layer is represented by the big data, CC, IoT, and Blockchain, among others.

In another layer, there is the need to rethink the market design and related regulation to properly allow and encourage prosumer participation. This must be done considering different aspects and points of view, i.e., not only the consumers' benefits but also the grid operators' challenges, and their possible benefits must be accounted for. This layer includes the development of P2P and community market designs as an example.

In practice, the development and implementation of such markets strongly depends on the regulatory framework imposed by each country, which depends on the law decision-makers and also on the willingness of system operators to operate and manage more locally. Changes in the last 2 years in regulation in most European countries encourages self-consumption of energy as a way to slowly integrate prosumers into the system without significantly impacting grid operation. In this case, new BMs (e.g., combining PV generation and storage devices) may emerge and grow in the coming years, providing an opportunity to decentralize the system. Still, energy exchange among prosumers would be the ultimate goal to streamline the current way of trading energy and managing the system.

The aforementioned points raise important questions, such as the viability of the distribution systems and the possibility of the utility death spiral. For instance, in the case of distributed energy resources and storage devices, the need for network usage is lower in most of the time, thus increasing the cost for the rest of the consumers that still need the distribution network [158, 159]. Considering the evolution of the DSOs, their future main role seems to be to provide the distribution service through a regulated tariff, a role similar to what TSOs currently play in present deregulated markets. Even though this evaluation is beyond the main objective of this paper, this problem is also addressed by properly regulatory development, which could also allow distribution companies to participate in some type of BMs.

Simultaneously, the role of the energy communities is initially stated, leaving the door open for emerging new BMs tailored to small local energy communities. For instance, a group of prosumers could aggregate their demand or generation surplus and negotiate as a collective with retailers. A clear picture of the role and responsibilities of the energy community agent has not yet been defined in a regulatory environment, which is crucial for the smooth integration of these energy communities.

In the present work, it is shown that there is room for some BMs, even considering the present laws and regulations. Although, the proper change in those regulatory aspects, including more active participation of prosumers, DSO, and TSO in the discussion of those new models, is of importance to foster the development of the energy sector.

To sum up, these identified opportunities and recommendations follow the 3Ds paradigm for modern power systems, which are the decarbonization, decentralization and digitalization of the system.

6. Conclusions

Today, energy entities and governments are promoting the integration of innovative prosumers' BMs into the power system to achieve higher levels of economic and environmental sustainability. This paper contributes for this discussion through a detailed review of prosumers BMs, pointing out the main identified barriers and enablers for their smooth integration into the power system in the coming years.

From this literature review, one can conclude that for the smooth and successful integration of prosumers in the power system, three aspects are essential: (*i*) the proliferation of RES and ESS through consumers, enabling self-consumption and supplying surplus energy to other consumers; (*ii*) technological developments for safe and controlled energy exchange; and (*iii*) update and improve the market design and regulatory framework. The ultimate combination of these aspects will motivate the design and development of appropriate BMs that will encourage conventional consumers to engage and participate in the system. Innovative business models can enable faster integration of prosumers in the system by combining the economic, environmental, and social aspects and characteristics of consumers. From the BMs gathered in this review, some of the BMs that better fit all these three aspects are the collective services as BMs. The main enabler for these BMs is the proximity and trust between the energy manager and the prosumers. On the other hand, the regulatory framework is the main obstacle for the success of such BMs, as the current regulation in many countries neglects such options. Therefore, the applicability of such BMs is often dependent of the lobby made by the community with the government agencies, network operators and retailers.

Furthermore, this review shows that innovative BMs are emerging that the primary focus is the prosumer preference. A very promising BM, if supported by appropriate regulations (third aspect), are those based on the prosumer-centric energy markets. Although there has been extensive research on this type of market in the past two years with multiple initiatives and trading options around the world, further research needs to be conducted to harmonize technologies and regulations in such a way that eases the adoption of such solutions. P2P-BMs can easily receive greater support from society, as they follow the global trend of collaborative economy.

The main barriers to the development of innovative BMs for prosumers observed in this review are, in addition to the already mentioned lack of regulation, the high price of the necessary equipment and technologies in many countries/regions, the low levels of information and technical knowledge, unavailability of support from local/district/national authorities and lack of well-established IoT and ICT technologies. Nevertheless, almost all BMs identified under this review have the ultimate goal of integrating prosumers into the power system. Hence, prosumers have a more active role in the power system, turning them into key players in the energy markets, not just selling electricity but also providing energy services.

This work focuses on the review of the most innovative BMs in the field, discussing the main barriers and enablers for prosumer integration in the system. Thus, a broad view including, the characteristics of those consumers, regulation aspects involved in their role, and the market structures that encourage their participation, are discussed. Even more, it presents a review of existing business models and evaluates the necessity to give proper incentives to those consumers to take a more proactive role in the near future. An important conclusion from this work is that, even though innovative BMs encourage cost-effective and sustainable prosumers integration, they do not always have a successful implementation, as the regulatory framework and inertia of system entities take time to change, and must present a holistic approach to obtain the desired results, which depends on the regulatory history and the preferences of each country or region.

For the successful implementation of the innovative BMs, further directions must be considered. For instance, a comprehensive study of the evolution of recent regulations related to small consumers and prosumers in different countries, including possible future outcomes and providing some hints on regulatory paths. In addition, the evolution of the roles of electricity market players and the simulation of their impact on BMs, such as changes in the role of the distribution companies in future market design.

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