



Prosumer integration into the Brazilian energy sector: An overview of innovative business models and regulatory challenges

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ABSTRACT

Considering the Brazilian energy policy's future, the perspective of a more decentralized energy system must be accounted for in the face of technological, business, and energy matrix changes. Therefore, the prosumer's figure combined with new Business Models (BM) brings opportunities and challenges for the sector. This paper aims to solidify knowledge, identify and understand the main regulatory barriers and enablers for the development of prosumers and prosumer-driven BMs in the Brazilian energy market. A comprehensive review of existing regulations provides a starting point for improving the relevant legal frameworks for prosumers' aggregation. Then, an analysis of innovative BMs in the Brazilian regulatory framework is carried out, seeking to guide the decisions for the country to develop its political and regulatory environment in the future. The paper concludes with policy recommendations to promote prosumers aggregation in the Brazilian energy sector. We conclude that the main barriers to prosumers' integration are of regulatory and technological nature, and the exploration of innovative BMs is crucial for the sector development. Redefining the role and responsibilities of utilities is a key factor, together with exploring collective self-consumption.

1. Introduction

The Brazilian electricity system traditionally presents a high share of Renewable Energy Sources (RES). Even so, an increase of RES participation in the Brazilian electrical matrix is expected until 2030, composing a primarily renewable portfolio. The RES will make up 86.6% of the total electrical energy source (EPE, 2020b). The segment is led by hydroelectric energy (58.6%), followed by wind (16.3%), biomass (7.6%), and centralized photovoltaic (4.1%), as highlighted in the Brazilian Ten-Year Energy Expansion Plan 2030 (EPE, 2020b).

In the last decades, diversification in the RES supply has started in Brazil to reduce the systemic risks related to the great dependence on hydroelectric energy, as well as to mitigate the social and environmental impacts associated with the construction of large dams. From diversification, the country has become the largest wind energy market in South

America, presenting 15.4 GW of installed capacity, together with 2.5 GW of photovoltaic (PV) in 2019 (IRENA, 2020b).

The fact that the Brazilian electric matrix is already strongly based on RES can be a great advantage for the country. In other words, the country starts in a significant advantage compared to most other countries in the world concerning the electricity sector's decarbonization goals and in the development of policy and regulation aimed at greater RES inclusion other than hydro plants.

Taking into account the current world scenario and thinking about the future of Brazilian energy policies, it should be considered the prospect of transition from a centralized energy system to a more decentralized one, accounting for social, political, economic, and technological challenges (Burke and Stephens, 2018). Such a transition must be gradual to guarantee the necessary conditions without a huge disruption in the current electricity market rules. The main advantages

Abbreviations: ACL, Free Electricity Market; ACR, Regulated Electricity Market; ANEEL, Brazilian Electricity Regulatory Agency; BM, Business Model; CEE, Chamber of Electric Energy Commercialization; DG, Distributed Generation; DR, Demand Response; DSO, Distribution System Operator; EU, European Union; FIT, Feed-in Tariff; IT, Information Technology; MME, Ministry of Mines and Energy; ONS, Brazilian ISO; P2P, Peer-to-Peer; PL, Bill; PROINFA, Brazilian Programme to Stimulate Alternative Electricity Sources; PV, Photovoltaic; RES, Renewable Energy Source; UK, United Kingdom.

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of the transition to a more decentralized environment are the capacity to reduce harmful greenhouse gas emissions (Akorede et al., 2010), mitigate inefficiencies in energy transmission and distribution reducing the need for intensive investment in network upgrades (Pepermans et al., 2005; El-Khattam and Salama, 2004), provide local energy independence (Walker and Cass, 2007), network flexibility and security (Alanne and Saari, 2006), and motivate social capital and community cohesiveness by encouraging local businesses and job creation (Walker et al., 2010; Walker and Devine-Wright, 2008). This change can introduce new roles and opportunities for consumers, who can become RES prosumers and be active energy units willing to participate in energy markets. Currently, the prosumer's phenomenon has been widely studied (Brown et al., 2019; Kuznetsova and Anjos, 2021; Campos and Marín-González, 2020; Botelho et al., 2021).

The prosumers' agent can play an important role in decarbonization, which is a worldwide trend, increasing the system's energy sustainability and resilience (Drożdż et al., 2021). They also make the system more inclusive by increasing competition in the energy offer and spreading technological innovation (Espe et al., 2018; Lavrijssen and Carrillo Parra, 2017).

Different Business Models (BM), government measures and technological solutions adopted by prosumers tend to increase the RES integration into the energy system. There is a fear that the expansion of prosumer-driven BMs could lead to the so-called "utility death spiral" (Kantamneni et al., 2016), where the income of public services decreases with the increase in the number of consumers that become prosumers (Laws et al., 2017). Thus, the overall grid costs are increased to the remaining users. In general, regulatory frameworks aim to establish the relationship between RES prosumers and the main grid (Parag and Sovacool, 2016). Regulation plays a structural role in the energy transition and can be highly complex due to the growing variety of schemes, BMs, prosumer's types, and network-related issues (Heffron and Talus, 2016). Various countries have performed subsequent reviews and updates in their laws, which indicates that RES prosumerism is a complex issue for regulators, requiring an ongoing assessment of social, economic, technological and environmental aspects (Heffron and Talus, 2016).

Following the global trend in the energy sector, the Brazilian Electricity Sector¹ is promoting changes in the regulatory, commercial, and operational framework, seeking to create conditions for more active participation of consumers in managing their energy consumption and individual choices. From April 2019, the Ministry of Mines and Energy (MME), through MME law 187/2 019 (MME, 2019a), created the working group called "GT Modernização" to seek solutions that allow the development of proposals for electric sector modernization, aiming at providing electricity to consumers in a competitive way and promoting the market opening.

Thus, the driving matter of the present work is to solidify the knowledge, identify and understand the main regulatory challenges and opportunities for the emergence and development of prosumers and prosumer-driven BMs in the Brazilian electricity market. The issue is addressed through the establishment of basic knowledge about the current electricity sector regulation. This provides a starting point to trace the policy implications for introducing and/or improving relevant legal frameworks for prosumers' aggregation in Brazil. Thus, one can support regulators, the research community, policy analysts, and decision-makers in designing a way forward that can promote prosumers' proliferation. A detailed analysis of the innovative BMs in the Brazilian regulatory scope is carried out, seeking to guide the decisions that need to be taken nowadays so that the country can develop its

¹ The Electricity Sector includes stakeholders that provide electricity generation, transmission, distribution, and marketing services for customers (industrial, commercial, public, and residential), in addition to institutions that regulate the sector.

political and regulatory environment aiming at taking advantage of all benefits that the RES prosumer adds to the energy system.

Regarding the structure of the paper, in addition to this introductory section, Section 2 presents a literature review about prosumer-driven BMs and prosumers aggregation policies. Section 3 comprises a Brazilian regulatory overview. Section 4 discusses the prosumers-driven BMs, considering traditional and innovative approaches. Section 5 focuses on showing how BMs integrate into the current Brazilian market context. Section 6 presents the discussions related to the present work, highlighting the challenges, opportunities, and recommendations to these topics. Finally, Section 7 gathers the most important conclusions and policy implications of this work.

2. Literature review

As the subject proposed in this paper is still incipient in Brazil, a worldwide literature review is carried out in this section to easily start the discussion for the Brazilian market and system.

Over the past five years, some studies have addressed the role of BMs and regulatory changes for a greater insertion of prosumers and RES into the world's electricity sector. The study (Burger and Luke, 2017) presents a very detailed analysis of the most common BMs for the deployment of distributed energy resources. They identify a set of BMs archetypes for different energy resources. Botelho et al. (2021) present innovative BMs as enablers of the increasing prosumers' role, defining the main features of prosumers and their related regulation, as well as possible market designs within power systems. A set of recommendations for promoting these BMs is provided. The study carried out in (Brown et al., 2019) investigates the RES prosumer phenomenon in the United Kingdom (UK) and identifies how prosumer-driven BMs can be applied in an environment without direct subsidy since BMs can be attractive for both prosumer and network operator. Ma et al. (2017) propose four BMs to allow buildings to participate in aggregated Nordic markets through flexible loads and distributed energy resources.

While the previously cited works present a world viewpoint, Ramos et al. (2020) explore some Demand Response (DR) based BMs for medium and low-voltage electricity consumers focusing on Brazil. The authors also make it clear that the Brazilian regulatory framework has been continuously adapted to better include DR mechanisms. The authors of (Vieira et al., 2016) analyze different possibilities of net metering BMs in Brazil and their insertion in the national regulatory scenario. They conclude that this type of scheme has great potential to encourage mainly small photovoltaic (PV) based prosumer in Brazil. However, some issues related to electricity taxation and the Distribution System Operators' (DSO) income must be taken into account to enable and drive the development of this market in the future.

As important as the analysis of new BMs is the development and improvement of specific regulations. For that, the authors of (Inês et al., 2020) make a comparison of the existing regulations in nine European Union (EU) countries and regions to clarify the main challenges and opportunities for a greater collective RES prosumer's inclusion in the energy system. They conclude that there is an opportunity for collective prosumers with the regulation in place at the EU level. Moura and Brito (2019) perform a detailed analysis of what they call "Prosumer Aggregation Policies", describing and categorizing the fundamental mechanisms within this concept to guide regulators, decision-makers, and the research community with a focus on Portugal's experience. On the other hand, Khan (2019) shows how the concept of prosumers evolved in a less economically developed country, Bangladesh, through a discussion of various impacts of this concept on rural communities in the country, identifying some barriers, drivers, and enablers.

Finally, an analysis of the impact of billing policy on the profitability of investment in prosumers' schemes, for Ontario's scenario, is carried out by (Kuznetsova and Anjos, 2021). The conclusion is that the technological development of storage systems can enable the energy self-sufficiency of the prosumer, even in places with high electricity

consumption and low availability of RES.

Based on the literature review, the following main points can be highlighted:

1. The prosumer aggregation policy subject is still an open field for research.
2. It is necessary to define clear and ambitious goals for RES prosumer integration and decentralized production in a near future.
3. When financial and technological barriers are overcome, it will be imperative to address policy, regulatory and organizational issues.
4. Leveraging, developing, and supporting new innovative BMs is extremely important to be considered.
5. Attention should be given to how countries around the world are responding to RES prosumer-driven regulatory challenges, taking advantage of all the accumulated knowledge as an initial step toward the Brazilian regulatory environment's development.

3. Brazilian regulatory overview

The fundamental characteristic of the Brazilian electricity sector is that it is planned in a centralized manner. The electricity market development is heavily influenced by the federal government and regulatory bodies, which determine new energy auctions and price limits, thus guiding the generation expansion in Brazil. The use of RES as the basis of the country's energy policy is due to Law 9478/1 997 (Brasil, 1997). The Brazilian medium and long-term energy policies are proposed in the Ten-Year Energy Expansion Plan (EPE, 2020b) (updated annually) and by the National Energy Plan 2050 (EPE, 2020a), respectively.

The Brazilian energy sector comprises a wholesale market composed of the regulated electricity market (ACR) and the free electricity market (ACL). The ACR is composed of utilities and captive consumers.² It is fully regulated by the Brazilian Electricity Regulatory Agency (ANEEL) and the energy is contracted through auctions. The ACL is composed of free consumers,³ generators, and trading companies. ACL participants can negotiate their energy volumes, prices, and contract terms and conditions. According to the Brazilian Energy Traders Association (ABRACEEL), the amount of energy negotiated in the free market was 36% of the total consumption in Brazil in September 2021 (Abraceel, 2021). This represents about 16 110 GWh in a single month. Although ACL participants are free to trade their energy, this market is reserved for large consumers and some conditions for participation in this market are defined throughout this section. However, this work focuses on the potential small and medium-sized prosumers and their greater integration into the energy market. In other words, the focus is on current ACR participants who may become free from future regulatory changes.

Law 10 848/2 004 (Brasil, 2004) created a regulated market for electricity companies and qualified consumers, alongside a market for free customers (defined as having an electricity demand ≥ 3 MW). This 3 MW limit was reduced to 1.5 MW in January 2021 through Ordinance 514/2 018 (MME, 2018a). This limit tends to decrease even more in the coming years, reaching 1 MW in 2022, 0.5 MW in 2023, and the full opening of this market in 2024, according to Ordinance 465/2 019 (MME, 2019b). The core of this legal instrument is an organized energy supply scheme for regulated distribution companies through short, medium, and long-term auctions of power purchase agreements. Auctions are currently the main policy instrument for expanding and

² A consumer who is only allowed to buy energy from the utility holding the concession or permission in the area where the system user's facilities are located, and who is served under regulated conditions (ANEEL, 2012).

³ Those that are served at any voltage and with demand contracted from the distributor equal to or greater than 1.5 MW (MME, 2019b). Additionally, Special free consumers, with demand greater than 0.5 MW, but must purchase from specified renewable sources.

diversifying the RES supply, covering three-quarters of the national electricity market.

In 2002, Brazil launched the Program to Stimulate Alternative Electricity Sources (PROINFA), through Law 10 438/2002 (Brasil, 2002). PROINFA was a hybrid scheme to develop a total RES generation capacity of 3300 MW, equally distributed among wind, biomass, and small hydroelectric projects. Resolution 482/2 012 (ANEEL, 2012), later updated through Resolution 687/2 015 (ANEEL, 2015b), provided net metering for small producers (< 1 MW) of PV, wind, hydro, and biomass energy. This scheme provided the generation of credits in case of production surplus, which can be used for future consumption in up to 60 months.

Another program called INOVA ENERGIA (BNDES, 2013) (2013) provided subsidies of up to 90% of the project costs for Research & Development (R&D) related to smart grids, renewable energy, hybrid vehicles, and energy efficiency in transport. In addition, the National Program for Distributed Generation (DG), called ProGD (MME, 2018b), was launched through Ministerial Decree 538 of the Brazilian government and created a working group to evaluate new measures to promote DG development (Lima, 2010).

It is important to highlight that, so far, all regulatory and policy development in the Brazilian electricity sector is mainly focused on large renewable generators, thus the wholesale market, according to the aforementioned laws and resolutions. The only current regulation that encompasses the small prosumer is based on net-metering (Poullikkas et al., 2013).

In November 2017, the ANEEL established the criteria and conditions for a DR program through Normative Resolution 792 (ANEEL, 2017b). The basic concepts on the topic are defined, as well as the requirements for consumers to participate in the program.

The number of prosumers in Brazil is increasing due to some factors, such as the reduction in the DG equipment cost, the increase in regulated electricity tariffs, and the rules for credit sharing, introduced in Brazilian regulation by Normative Resolution 687/2 015 (ANEEL, 2015b), from March 1, 2016. In early February 2021, the Federal Senate approved the Senate Bill (PL) 232/16 (Federal, 2021), which intends to modernize the commercial model of the electricity sector and the concessions for electric power generation in the country. This bill represents important advances in the sector, mainly due to the inclusion of access to the so-called free contracting environment for low-voltage consumers.

PL 616/2 020 (Federal, 2020) which proposes the regulatory framework for the prosumer, is in progress in the Brazilian national congress. According to PL 616/2 020, a consumer registered with ANEEL or with the local energy utility, capable of producing electricity at his own risk, is considered a prosumer. It also elucidates the concept of local and remote prosumer, where "local" is when the generating source is electrically close to the load and "remote" is when the generating source is electrically separated from the load, regardless of the voltage level and the distribution utility.

Fig. 1 presents a timeline with the main legislation in the Brazilian electricity sector to summarize the advances in the regulation within the context of the present work.

4. Prosumer-driven business models

The basis used to categorize traditional and innovative BMs is from Botelho et al. (2021). An analysis of these different BMs in a Brazilian energy context is carried out, followed by a discussion about the possible paths to be followed by decision-makers so that these BMs become feasible in the future. Briefly, the analyzed BMs are divided into two main groups (Botelho et al., 2021): Traditional and Innovative. Notice that the existing BMs in the literature can, to a certain extent, be categorized into one of the nine BMs from (Botelho et al., 2021).



Fig. 1. Timeline of the Brazilian electricity sector's regulation.

4.1. Traditional BMs

Traditional BMs are based on the first incentive forms for the prosumer to be included in the market, as highlighted hereinafter.

- **Feed-in Tariffs (FiT)** (Winter and Schlesewsky, 2019): a prosumer is guaranteed to receive a price above the market for the RES they deliver to the network.
- **Self-consumption** (Vieira et al., 2017): a prosumer generates his energy by installing a generation system in his consumption unit.
- **Net metering** (Vieira et al., 2016): a prosumer performs self-consumption and the electricity surplus is injected into the utility's network to which the prosumer is linked. The surplus energy

is converted into credits that can be used in the form of reduction of the following monthly bills.

- **Leasing** (Liu et al., 2014): customers hire a company to install an RE system in their unit and pay rent for the company or a fixed price for the generated energy.

4.2. Innovative BMs

Innovative BMs depend on developments in new technologies and new market-oriented regulations and are defined hereinafter. A detailed explanation and contextualization of the BMs are presented in reference (Botelho et al., 2021).

- **Aggregators** (Verhaegen and Dierckxsens, 2016): a legal entity is responsible for optimizing, technically and economically, the energy consumption and production of a small group of prosumers.
- **Energy-as-a-service** (Vella, 2019): the prosumer can explore the possibility of selling a full range of electricity-related services, that is, not just the electricity itself.
- **Demand response** (McPherson and Stoll, 2020): prosumers/consumers can reduce or change their electricity usage profile during peak consumption periods, in response to time-based fees or other financial incentives forms.
- **P2P trading platforms** (Sousa et al., 2019): The P2P-based BM works as an online marketplace where consumers, producers, and prosumers come together to trade electrical energy directly with each other, without the need of an intermediary. This type of market design has been extensively studied in the specialized literature in recent years. References (Sousa et al., 2019; Tushar et al., 2020) present complete and detailed reviews on the topic explaining the main concepts.
- **Collective services:** This BM cluster contains several collective BMs, such as collective self-consumption, (Brassar et al., 2019), energy condominiums (Ramos et al., 2020), energy cooperatives (Capellán-Pérez et al., 2018), and crowdsourcing debenture (Al, 2021).

4.3. Business models structure

A basic structure containing the key activities, value proposition, and revenue mechanism of the BMs presented in sections 4.1 and 4.2 is shown in Table 1.

5. Outlook for the Brazilian market

First, an analysis of traditional BMs (subsections 5.1 to 5.3), which are already applied in Brazil or which could be applied without a significant update in the current regulatory context of the country, is presented. Subsequently (subsections 5.4 to 5.8), innovative BMs that are emerging in a decentralized and RES scenario from technological developments and spreading of smart energy systems are addressed.

5.1. Feed-in tariffs

Brazil adopted the FiT scheme only in the first half of the 2000s (first phase of PROINFA), focused mainly on the implementation of large RES generating facilities, but due to the lack of process transparency, the country switched to an auction system (Dutra and Szklo, 2008; Kissel and Krauter, 2006). Currently, FiTs are politically not feasible in Brazil. There is no regulation on the issue and, therefore, the FiTs are not applied.

FiT programs can provide benefits (Grover and Daniels, 2017), but they also bring challenges to be faced (Bakhtyar et al., 2013). The basic idea behind FiT programs is to ensure a market for RES electricity, motivating investors to expand new technologies more safely. Pyrgou et al. (2016) discuss the advantages and disadvantages of different remuneration schemes based on existing FiTs.

Nevertheless, FiT schemes usually end after a certain period, as has been happening in recent years (Government U.K., 2018). With this global trend of ending FiT policies, it is more advantageous for policy-makers in Brazil to think ahead, about a post FiT era. Rövekamp et al. (2021) perform an analysis covering five RES BM archetypes for the post FiT era. The authors emphasize that it is necessary to develop other BMs to encourage greater integration of the prosumer and RES in the system.

5.2. Self-consumption and net metering

These two BM concepts are combined here because they are mixed in

the Brazilian regulatory environment in most cases. Self-consumption is decoupled from net metering only when the prosumer is isolated from the system, having its battery energy storage system (Divya and Østergaard, 2009).

Net metering is one of the few prosumer-driven BMs that is covered by current Brazilian regulations, allowing electric power generation from RES or qualified cogeneration,⁴ with an installed capacity of up to 5 MW⁵ in consumer units.

The prosumer having DG within the previous conditions is categorized as microgeneration (up to 75 kW) or mini-generation (from 75 kW to 5 MW), and the installation where the DG is connected is treated as a consumer unit. Compensation occurs in terms of electricity (kWh). However, for the prosumer who is connected at high voltage,⁶ the tariff varies according to the day's period when the energy is consumed: peak or off-peak. This tariff difference must be taken into account in the final energy credits valuation. According to ANEEL Normative Resolution 687 (ANEEL, 2015b), there are four possible types of net metering:

1. **Conventional net metering:** It is when the energy is generated and compensated in the same place, being the simplest type of net metering. It is important to note that even having enough energy to its own supply, the prosumer must pay the utility a minimum monthly amount, corresponding to the "network availability cost" (ANEEL, 2010).
2. **Virtual net metering:** It is known in Brazilian regulation as "Remote self-consumption" and allows the prosumer to use the surplus generation from one of his consumer units in another one. Both units must be connected to the main grid by the same utility. This BM can be interesting for prosumers who own more than one house but have no available area for installing their generation in all consumption locations.
3. **Condominium net metering:** Brazilian regulation allows DG sharing among prosumers of the same condominium. This BM is regulated in Brazil under the name of "enterprise with multiple consumer units". It is noteworthy that all the generated energy is injected directly into the network and the compensation is later carried out, since the condominium residents are not forced to participate in the DG system and, thus, compensation is made only for those who participate in the project.
4. **Community net metering:** In this BM, also known in Brazilian regulations as "shared generation", several consumers in the same concession area can be integrated into an energy community (consortium or cooperative) to invest in a generation system far from their consuming units, using the respective energy to reduce their consumption from the main grid. The techno-economic feasibility of this BM is analyzed through a case study by (Vieira et al., 2016).

A challenge for the successful dissemination of these self-consumption/net metering BMs in Brazil is the regulatory uncertainty about charging (or not charging) for grid use in the case of generation and consumption at different times or in different places. The mentioned uncertainty is related to subsidies or exemptions. For instance, under the current legislation, the micro and mini DG are exempt from network usage fees. However, since 2018, discussions have taken place between entities in the electricity sector and the government on the need to review this exemption. Another challenge is that under the rules of the Brazilian net metering, residential prosumers who adhere to the mechanism would continue to use the grid, contributing to the peak in the

⁴ Qualified cogeneration is a concept defined by ANEEL in Normative Resolution 235/2 006 (ANEEL, 2017a) that establishes a minimum total efficiency to generate electric and thermal energy from natural gas.

⁵ Except for hydro that has a 3 MW power limit.

⁶ In this study's context, it is considered high voltage when higher than 2.3 kV and low voltage when lower than this same value (ANEEL, 2010).

Table 1
Business models structure.

Business model	Key activity ^a	Value proposition ^b	Revenue mechanism ^c
Feed-in Tariffs	- Electricity generation.	- Electricity bill savings; - Ensuring value above the market for traded renewable energy.	- Sale of surplus electricity to the grid; - Savings from self-consumption; - Remuneration through feed-in tariffs. - Savings from self-consumption.
Self-consumption	- Electricity generation.	- Electricity bill savings; - Electricity self-sufficiency and independence from utilities.	- Generation of electricity credits; - Savings from self-consumption.
Net metering	- Electricity generation.	- Electricity bill savings; - Electricity self-sufficiency and independence from utilities.	- Sale of surplus electricity to the grid; - Savings from self-consumption.
Leasing	- Electricity generation.	- Electricity bill savings; - Electricity self-sufficiency and independence from utilities; - Upfront cost smoothing.	- Margin on purchasing and selling energy to prosumers/consumers.
Aggregators	- Operation, management, and maintenance of the prosumers and consumers energy portfolio; - Aggregation of customers demand flexibility.	- Supporting consumers to become electricity self-sufficient and independent from utilities; - Assistance with operational and assets management issues for customers.	- Collection of monthly and/or subscription fees.
Energy-as-a-service	- Development of energy solutions, including smart home devices and management apps; - Energy efficiency actions; - Marketing activities.	- Increasing prosumer/consumer energy efficiency and savings costs.	- Savings from implementing DR actions; - Payment from DR aggregator and other systems operators for providing demand flexibility.
Demand response	- Demand management actions.	- Demand management services; - Electricity bill savings; - Financial compensation for participation in DR programs.	- Bilateral contracts between peers.
P2P trading platforms	- Providing a direct energy trading platform between prosumers and consumers.	- Supporting consumers to become electricity self-sufficient and independent from utilities. - Democratizes freedom of choice for prosumers and consumers to select whom they want to buy/sell energy	- Sale of community's surplus electricity to the grid; - Savings from collective self-consumption; - Sale of electricity between members.
Collective services	- Local generation and supply; - Development of energy savings and sharing platforms; - New members recruitment.	- Supporting consumers to become electricity self-sufficient and independent from utilities; - Distribution of costs and responsibilities.	

^a Activities that the BM is engaged in for the primary purpose of making a profit.

^b The reason for choosing a BM instead of another. It is how the BM solves the customer's problems or meets the customer's needs.

^c Represents the ways in which the BM generates revenue.

same way they did before DG, without, however, paying for that use. As a result, consumers who do not install DG will have their electricity bill increased to subsidize the grid usage by those who installed it.

From the previous reasons, the valuation of the energy injected into the network by prosumers should be the subject of research, discussion, and reassessment by policy decision-makers to avoid the existence of cross-subsidies in tariffs (Eid et al., 2014). However, this change can lead to a reduction in the economic attractiveness of these BMs (especially, net-metering schemes) and, thus, it must be carried out with caution to guarantee the regulatory stability necessary for the market's evolution.

5.3. Leasing

This BM allows a consumer to rent a renewable generation system from a specialized company that will install the system in the consumer's unit. Thus, the lessee can use the energy that the system provides to reduce his electricity bill. The company is responsible for any maintenance and monitoring that the system requires. In turn, the consumer only needs to pay a monthly fee. The contracts last for approximately 20 years and, in the end, the lessee can choose between buying the system or removing it from his unit. Note that in the current Brazilian regulatory environment, leasing has to be combined with the self-consumption/net metering BM.

Brazilian companies like "Wise energia inteligente" (WEI, 2021), "MRCA solar" (MRCA, 2021), "Solar 21" (S21), and "Edsun investimento solar" (EIS, 2021) are examples of companies that currently have this BM as the base of their business. The "Evolua energia" company (EE, 2021) provides plan options to its customers, without the need to invest in their unit. Customers subscribe to "Evolua" plans in a totally digital way, compensating their electricity consumption, due to the

energy injected into the distribution network by "Evolua", which becomes credits for the consumer. The company has its renewable generation park and shares the energy injected into the network with its subscriber customers.

5.4. Aggregators

An aggregator is a single entity that manages energy assets for a group of consumers, producers, and/or prosumers, and trades those assets in the energy market or directly with the system operator. Aggregators use systems with centralized information and communication technologies to remotely control distributed RES, optimizing their operation. They can provide services such as load shifting, balancing services for transmission system operators, local flexibility for DSOs, other ancillary services for system operators, and other services (IRENA, 2019). The basic aggregator's operation structure can be seen in Fig. 2.

Currently, a player that has a role close to that of an aggregator in the Brazilian regulatory framework is only in the context of the DR pilot program⁷ from the Chamber of Electric Energy Commercialization (CCEE). The entity has the function of representing and grouping consumer units that meet the criteria required by the ANEEL Normative Resolution 792/2 017 (ANEEL, 2017b). The aggregator's function is to group the consumer units' loads so that they meet the minimum requirement of the previous resolution together to participate in the program.

Currently, in Brazil, aggregators are not allowed to set up a portfolio made up of distributed RES from a mix of small prosumers. However, the

⁷ More details in section 5.6 and reference (ANEEL, 2017b).

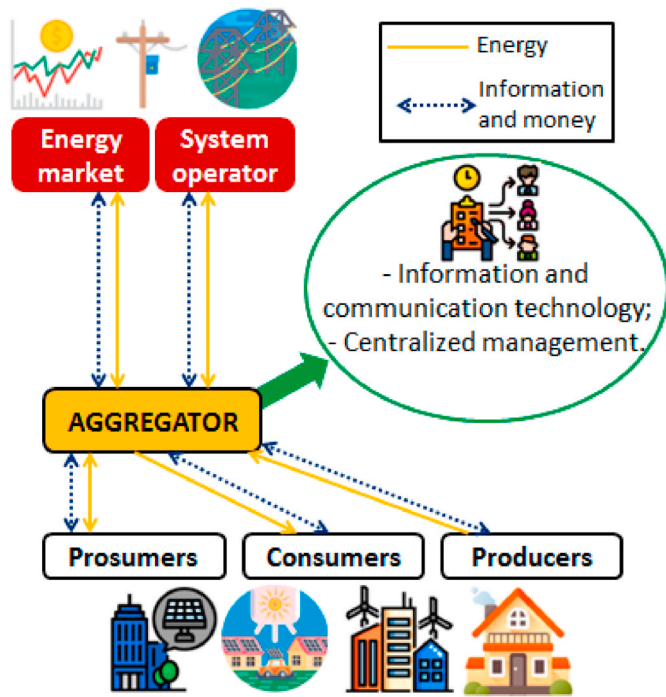


Fig. 2. Aggregators' structure.

market has been gaining an increasing level of flexibility, such as that given to micro and mini-generation through the compensation system, which paves the way for the development and elaboration of regulations that encompass the aggregators' BMs.

One possible advantage, if this BM is regulated, is that aggregators can focus their business exclusively on the purchase and sale of energy in an optimal way, without worrying about all other services inherent to the operation and maintenance of the distribution grid. This remains under responsibility of the local energy utility or the DSO.

5.5. Energy-as-a-service

Energy-as-a-service (EaaS) is a BM where a service provider offers various energy-related services, not just selling electricity (kWh). This range of services may include consulting solutions related to the energy market, technologies and regulations, assets installation, identification of new energy practices, financing, and management of consumers' energy resources, among others. An overview of the services that can be made available by an energy service provider is shown in Fig. 3.

In this BM, the client outsources the tasks of optimizing their consumption, managing their energy costs, and eventually, migrating to more sustainable generation alternatives. In turn, the electric energy company, whose revenue is essentially derived from the retaining part of the costs avoided by the consumer, becomes a provider of energy services.

In Brazil, the "EDP Smart" company (EDPS, 2021), a subsidiary from "EDP Brasil" (EDPB, 2021), has a portfolio aimed at offering solutions in the area of energy efficiency and demand response to corporate and residential consumers, providing energy management services through digital platforms. This digital platform uses artificial intelligence to identify measures to reduce consumption and meet demand.

For the increase of this BM in Brazil, a considerable investment in technologies and infrastructure is needed to acquire real-time data from energy networks. In this particular, information and communication technologies, advanced signal measurement infrastructures and intelligent devices are essential. In this sense, an ANEEL research and development project in partnership with Enel (EB, 2021) foresees the installation of 300,000 smart meters. The devices will allow consumers

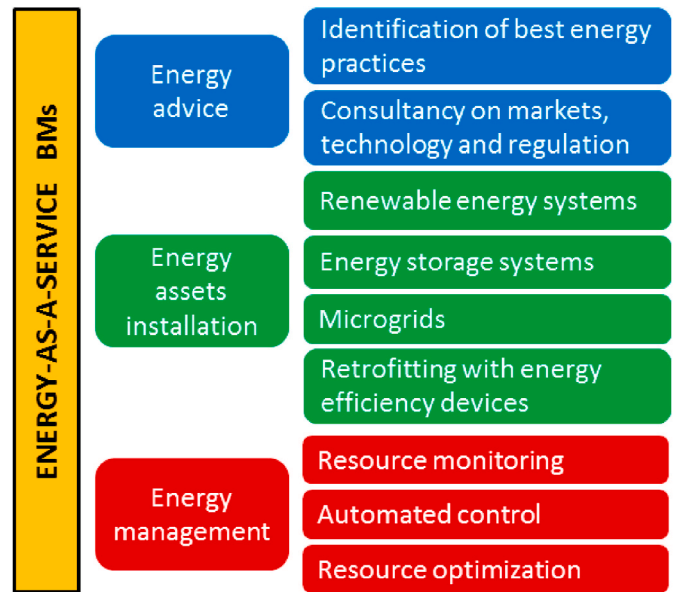


Fig. 3. Services offered by energy service providers.

to monitor and optimize electricity consumption, in addition to allowing the utility to perform some activities remotely and offer new services (Enelgroup, 2021). Another example is the installation of 23,000 smart meters carried out by Elektro (EL, 2021) in Atibaia, São Paulo. The meters will allow consumers to access system information so they can actively manage their energy consumption (Canalenergia, 2021).

5.6. Demand response

DR-based BM has been gaining worldwide prominence in recent years (Ramos et al., 2020; Siano, 2014; Müller and Möst, 2018). This BM allows the consumer to actively participate in the market and in the integration of wholesale and retail price signals. Policy-makers have shown strong support for DR in Europe (Jain et al., 2020). Currently, DR mechanisms have been the subject of debate and cause of regulatory changes in Brazil.

Depending on the signal given to the consumer, DR-based BMs can be categorized into price-based or incentive-based. The first refers to the change in the energy use profile as a result of price variation over the hours of the day. In this way, the consumer prioritizes energy use when the price is lower and reduces energy usage when the price is higher. The main variations of this program are: time-of-use tariff (Celebi and Fuller, 2012), critical peak pricing (Herter, 2007), peak time rebate (Vuelvas and Ruiz, 2017), and real-time pricing (Allcott, 2009). The second category offers consumers financial incentives to reduce demand at critical moments in the system, when supply margin is low or when there is a drop in reliability. The flexibility of these consumers must be dispatchable, as they are triggered through a dispatch order from the operator. The main variations of this second category are: direct load control (Chen et al., 2014), interruptible/curtailable service (Aalami et al., 2010), emergency demand response program (Aghaei et al., 2016), and demand-side bidding (Adika and Wang, 2014). A summary of the DR-based BM is shown in Fig. 4.

The CCEE, together with the Brazilian ISO (ONS), is carrying out the DR pilot program (which is an incentive-based program) established by ANEEL Normative Resolution 792/2 017 (ANEEL, 2017b) and Ordinance MME 460/2 020 (MME, 2020), which runs until April 30, 2022. The objective is to reduce the supply costs of the Brazilian electricity system, providing greater reliability and low tariffs to end consumers. For this purpose, options are developed by the ONS aiming at avoiding dispatching thermal plants outside the merit order. In this way,

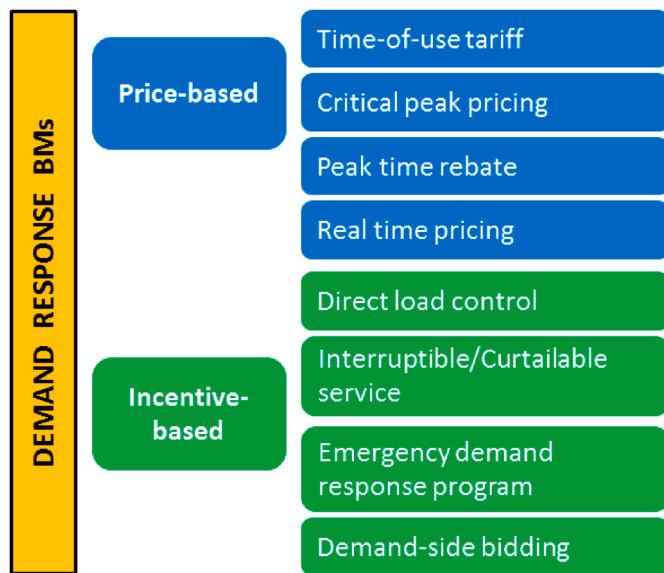


Fig. 4. Demand response business models summary.

consumers can reduce their electricity consumption and receive financial compensation.

The optimization of this service is carried out by the ONS through a cost comparison between the dispatch of thermal plants outside the merit order and the cost of activating the DR offered by consumers. Then, the lowest cost between the two options, accounting for the operating conditions, is triggered by the operator. A study carried out in (Santos et al., 2019) shows the operational savings that can be obtained through demand reduction simulations, considering the DR pilot project for 2018. Unfortunately, the program does not include small consumers.

Since January 2020, the option for the so-called “white tariff”, a price-based incentive, has been available for all consumer units connected at low voltage (ANEEL, 2015c). The white tariff signals to small consumers the variation of the energy value according to the day and time of consumption. From this new tariff, consumers can pay different amounts depending on the time and day of the week in which they consume electricity. On weekdays, the white fare has three values: peak, intermediate and off-peak. These periods are established by Utility and are different for each one (ANEEL, 2015a). Saturdays, Sundays, and holidays have a non-peak tariff throughout the whole day.

From a DR-based BM, LV consumers in a free market can negotiate small DR contracts with an aggregator, utility, DSO, or balance responsible parties.⁸

5.7. Collective services

BMs based on collective services, like collective self-consumption have gained worldwide prominence in recent years. The main example is the EU that has been promoting the principle of energy communities.

Energy cooperatives are another growing example that can be mentioned among collective services (Botelho et al., 2021). Dilger et al. (2017) provide a conceptual framework for this BM and categorize it depending on the members’ roles. Herbes et al. (2017) highlight that the main barriers faced by energy cooperatives are: risk aversion, possible environmental impacts, and the lack of competence from cooperative managers.

In 2016, the first shared distributed generation cooperative in Brazil

⁸ Entity responsible for maintaining the balance between the energy supply and the system demand through its own portfolio.

was founded. The Brazilian Renewable Energy Cooperative (Coober, 2021) has a capacity of 75 kWp and serves 18 consumer units. Other similar ventures were developed in subsequent years. The Energy Consumers Cooperative (Enercred, 2021) was created in 2017 and has two PV power plants totaling 180 kWp and serving 200 houses. Another example is the Solar Energy Cooperative (Coopsolar, 2021), which began operating in 2020, with 75 kWp and serving 15 consumer units. However, it should be noted that all these cooperatives have their BM based on net metering, the only one allowed by the current Brazilian regulation. All the energy from the RES plants owned by the cooperative is injected into the distribution network, generating electricity credits that are shared among all the cooperative members. It is necessary to improve the Brazilian regulatory framework, so that energy communities and other collective BMs can monetize with energy sales among members, and not only through net-metering schemes.

The laws needed to provide a solid regulatory framework for collectives services BMs, such as prosumer communities, still need improvements. The new laws must have mechanisms that allow the incorporation of technological advances and the emergence of new BMs (Frieden et al., 2019). Thus, with the monitoring and continuous improvement of the regulatory framework, an environment more conducive to the BMs’ success can be made viable.

5.8. Peer-to-Peer (P2P) trading platforms

In 2018, for the first time, the European Commission defined P2P trading of renewable energy through EU Directive 2018/2 001 (Commission, 2018). In contrast, in the United States, P2P trading is only possible through isolated microgrids (IRENA, 2020a). Nothing about this type of BM is mentioned in any current Brazilian regulation. However, some recent works have studied the applicability of P2P energy trading in the Brazilian context (Barbosa et al., 2020; Xavier et al., 2015). This BM can help, in the future, to develop a more decentralized energy market in Brazil.

5.9. Business models overview

An overview containing the BM’s deployment status, the current regulatory problems, and recommendations for regulation is presented in Table 2.

In addition, to better compare the challenges related to the implementation and/or development of those different BM schemes, an assessment including technical, social/community, environmental and regulatory criteria, including the current applicability in the Brazilian context have been considered as presented in Table 3.

The assessment was carried out guided by the following criteria:

- **Technical Challenge:** some models can be implemented with little or no technological change, such as those that can be implemented with a smart meter. At the intermediate level, are those that need more data communication or even a certain degree of control over the asset. In the extreme edge, the P2P model needs a complete restructuring of the market, regulation and in the DSO structure to properly support the BM.
- **Policy/Regulatory Challenges:** some models can exist with little effort in regulation or small political pressure, many of those models are in use all around. Under this classification, the most difficult models are those that need a complete restructuring in regulation, such as P2P or those like the FiT that is even used by many countries, nowadays it has been changed by other models.
- **Environmental Benefits:** in general, all the BMs presented are related to an increase in renewable generation. Those models that increase the participation of small consumers and more distributed resources have a greater relevance.
- **Social/Community Integration:** some models are known for the increase of interaction between consumers and prosumers,

Table 2
BM status.

Business model	Current BM's deployment status ^a	Current regulatory problems ^b	Recommendation for regulation to support the BM ^c
Feed-in Tariffs	- There is no regulation.	- Not applicable	- There are no support recommendations for this BM. Policy-makers must think ahead, developing other BMs.
Self-consumption	- Always associated with net metering BM, since surplus energy is injected into the grid, generating energy credits.	- There is no possibility to directly negotiate and sell the surplus energy.	- Policy-makers should focus on leveling a regulatory environment aimed at collective self-consumption.
Net metering	- It allows electricity generation from RES or qualified cogeneration with an installed capacity of up to 5 MW in consumer units. - Virtual, collective and individual net metering are also regulated.	- There is no possibility to directly negotiate and sell the surplus energy; - Uncertainty overcharging (or not charging) for the grid use.	- To value the electricity injected into the network by prosumers to avoid the existence of cross-subsidies in tariffs.
Leasing	- Always associated with self-consumption/net metering BM, where the consumer only needs to pay a monthly fee. - Establishment of long-term contracts.	- There is no possibility to directly negotiate and sell the excess energy.	- To allow the direct sale of the excess energy.
Aggregators	- Appears only in the context of DR programs.	- There is no possibility to set up a portfolio made up of distributed RES from a mix of small producers. - There is no broad regulation.	- To legally define the aggregator's figure so that it can focus exclusively on the purchase and sale of electricity in an optimal way. - To promote subsidy policies for investments in technologies and infrastructure for the electricity sector digitization.
Energy-as-a-service	- Some companies in the electricity sector provide consultancy based on this BM.	- Only large consumers who participate in ACL can participate in the program.	- To expand access to DR programs so that small and medium-sized consumers can participate.
Demand response	- The DR pilot program is ongoing, coordinated by CCEE together with ONS.	- Not applicable	- To establish policies that allow the prosumer to participate in energy market pools, bilateral or multilateral contracts. In addition to regulating and enabling P2P trading platforms, making possible direct energy trading between prosumers.
P2P trading platforms	- There is no regulation	- Not applicable	- Policy-makers should focus on developing a regulatory environment aimed at prosumer energy communities.
Collective services	- Energy cooperatives, communities, and condominiums are allowed but always associated with self-consumption/net metering.	- Allows only the sharing of energy credits; - There is no possibility to directly negotiate and sell excess energy.	- Policy-makers should focus on developing a regulatory environment aimed at prosumer energy communities.

^a Presents an overview of the BMs' implementation situation, highlighting how each one appears in the Brazilian market context.

^b Highlights the main current regulatory problems found in the BMs implementation.

^c Exposes the main regulatory recommendation for the BMs development in the Brazilian context.

Table 3
Comparison between different business models.

Business model	Technical Challenges ^a	Policy/Regulatory Challenges ^b	Environmental Benefits ^c	Social/Community Integration ^d	Current applicability in Brazil ^e
Feed-in Tariffs	Minor technological change	Regulatory restructure needed	Intermediate relevance	Little relevance	Underdeveloped
Self-consumption/Net metering	Minor technological change	Adaptation of existing regulations	Intermediate relevance	Little relevance	In use
Leasing	Minor technological change	Little effort needed	Intermediate relevance	Little relevance	In use
Aggregators	New IT solutions needed	Adaptation of existing regulations	Great relevance	Intermediate relevance	Initiated
Energy-as-a-service	New IT solutions needed	Little effort needed	Little relevance	Little relevance	Initiated
Demand response	New IT solutions needed	Adaptation of existing regulations	Intermediate relevance	Intermediate relevance	Initiated
P2P trading platforms	Market restructure needed	Regulatory restructure needed	Great relevance	Intermediate relevance	Underdeveloped
Collective services	New IT solutions needed	Regulatory restructure needed	Great relevance	Great relevance	Initiated

IT = Information technology.

^a Emphasizes the level of technological development necessary for the BM's successful implementation.

^b Highlights the degree of regulatory development necessary for the BMs' implementation.

^c Portrays the intrinsic BMs' environmental relevance.

^d Shows how the BM promotes the integration between consumers and prosumers within a community.

^e Highlights the current BMs' implementation status in the Brazilian context.

increasing the sense of community. A major contribution to the increased sense of community classifies the BM as "great relevance".

- **Current applicability in Brazil:** Regarding applicability, the BMs that are already in use or were used for some time in Brazil are classified as "In use". BMs that have already started, in some way, to be explored receive "Initiated", and BMs that still need many regulatory development are classified "Underdeveloped".

6. Discussion: challenges and opportunities

The main objective of the present work was to provide a basis for understanding how different BMs can help in the proliferation of prosumers and RES in the Brazilian electricity market, in a way that can benefit the country and Brazilian citizens toward a more sustainable and decentralized system.

To provide the necessary environment for prosumers, a set of changes must be taken, considering the regulatory context. Among the

required changes, it can be highlighted:

1. One of the main challenges to be overcome is the integration between prosumers and the utilities responsible for managing the network in Brazil, thus reshaping their current role. Therefore, utilities tend to become DSO, that is, an active system manager. Such a change may lead to an increase in DSO costs arising from the planning, development, operation, and balancing of their networks (Picciariello et al., 2015), which will require a restructuring of the DSOs' tasks and remuneration. If this transition is not done in a systematic and well-structured way, it can lead to the utility death spiral.
2. Regarding the BMs covered in the present work, a potential market for self-consumption BMs, mainly collective ones, should be better explored and developed, making it accessible even for those who do not have the appropriate local conditions (Feldman et al., 2015). A consumer who is unable to accommodate a renewable generation system in his own consumption unit may buy energy from closer prosumers or in a "beyond-the-meter scheme"⁹. Policies aimed at exploring the "beyond-the-meter" market and not exclusively "behind-the-meter"¹⁰, can bring economic benefits and technical potential, such as economy of scale and reduction of peak generation surplus.
3. Facilitating market access for emerging participants is crucial for prosumer aggregation policies. In this context, the aggregator's figure associated with a less rigorous set of rules for a player to enter the market can be a promising solution (Verhaegen and Dierckxens, 2016; Hancher and WINTERS, 2017). The aggregator BM can be beneficial to both prosumers and network operator. The management of different prosumers, with different demand profiles and generation portfolios, can provide a more accurate balance between local generation and consumption (Vergados et al., 2016). Combining heterogeneous prosumers' demand and generation profiles can help ensure network balance (Da Silva et al., 2013). Recently, regulations were created to expand the electricity market towards smaller consumers. The creation of the retailer (CCEE, 2021), which in Brazil represents the aggregation of these small consumers, is the first step in this direction. In addition, the possibility for these consumers to participate in the market has been gradually expanded. According to the Brazilian Electricity Market modernization plan, it is expected that in 2023, consumers with a load of 500 kW will be allowed. Further studies may reduce this limit even more by 2024. Nevertheless, it is necessary to expand the legal definition of these new agents to clearly establish their responsibilities, rights, and duties.
4. Despite the existence of the DR pilot program, small consumers do not have the means to trade directly in the energy market, nor the equipment needed to manage their energy resources. This can be a barrier and discourage the adoption of these new technologies by consumers. DR-based BMs can provide significant benefits to utilities and consumers by reducing energy consumption during peak hours. Ramos et al. (2020) highlight that an efficient pricing system, capable of signaling an adequate use of resources, can be the main driver for the success of this BM in Brazil. Incentive policies, training courses, and advertisements to disseminate information about DR programs' functioning should be explored to attract more commercial and residential customers. Residential, industrial, and commercial buildings can play an important role in this type of program by providing system flexibility.
5. Small prosumers must have access to electricity market pools, bilateral or multilateral contracts. In this context, a market structure

based on P2P is very promising. This BM brings greater energy democratization. According to (Sousa et al., 2019), the retail market, in general, lacks competition, and the P2P market can be a solution to this problem. For this BM, the prosumer must have a management system capable of collecting, analyzing, and optimizing demand and generation data, as well as information on current market conditions (Tushar et al., 2018). From this, the prosumer can decide whether to participate in the P2P market or not. Prosumers face some challenges in this market design, including a reduction in the energy cost, increase and maintenance of sustainable RES use, and improvement in their social engagement. However, the DSO must preferably have a participatory and non-invasive oversight role to ensure reliable operation of the power system, although in the worst case this may imply the imposition of strong constraints by the DSO. Thus, policies and methodologies that integrate prosumers and DSO are essential for the success of P2P-based BM.

To all these changes can take place, some auxiliary reforms are needed. The shift from the "business-as-usual" for key players in the energy sector is essential for implementing prosumers' aggregation policies (Sioshansi, 2014).

The reformulation of the current regulation will be imperative for the greater integration of prosumers into the system while ensuring compliance with network standards (Burger and Luke, 2017). Interconnection regulations and equipment certification to allow online measurement of prosumers must be provided. Such measures tend to boost the energy sector digitization and promote the implementation of technologies such as smart meters. These advances lead to the issue of who should be responsible for the required financing and investment, as well as to information security issues (Zafar et al., 2018). To ensure the required investments, an essential step is the faster smart metering infrastructure deployment, enabling the electrical network management at the prosumer level. This has been done in Brazil for many customers by the distribution companies. As an example, Copel has recently installed 50,000 smart meters, in a plan to massively deploy smart meters benefiting 4.5 million people (Copel, 2021).

National policies that can subsidize the access to renewable generation technologies for small and medium-sized consumers, as well as campaigns to encourage energy efficiency throughout the entire electricity supply chain (from generation to final use) are fundamental. Another measure is to establish partnerships with developed countries to promote a solid technology transfer structure, preserving intellectual property rights.

In summary, it is extremely important to plan, think and develop regulations considering the needs of both the prosumers and the power system. The entities responsible for the operation and maintenance of the electrical infrastructure must be fairly remunerated while providing quality services at competitive prices to consumers. The democratization of access to electricity markets should be the ultimate goal of the prosumers' aggregation policies.

7. Conclusion and policy implications

In the present paper, a description of how innovative BMs can help prosumers further integrate into the Brazilian electricity market is presented. A comprehensive review of the current specific regulation was carried out, as well as an analysis of how innovative BMs fit into the Brazilian context. Incorporating new BMs into the market offers new ways for prosumers to monetize, generate new income sources, besides potentially helping the network.

Taking into account the topics presented in the discussion section and the current policy and regulatory environment in Brazil, the main policy recommendations that can help to overcome barriers for greater integration of prosumers into the electricity market and for prosumer-driven BMs are:

⁹ Refers to power equipment located off-site. Outside the consumer's property.

¹⁰ Refers to power equipment located on-site, on consumer's property.

To redefine the utilities' role and responsibilities, recognizing them as an active DSO in network management;
 To make access to DR programs more flexible, allowing small and medium prosumers to participate under the management of an energy community or an aggregator;
 To accelerate the market opening for small and medium consumers, reducing the requirements to participate in the wholesale market, in addition to focusing on creating a community-level retail market;
 To allow energy communities to be autonomous, thus being able to manage their energy resources independently, as an aggregator;
 To allow the access of electricity market pools, bilateral or multi-lateral contracts to small and medium-sized prosumer.

A great opportunity lies before Brazil's policy-makers. Counting on the experience of other countries with an electricity market that already incorporates small size prosumers, Brazil can adopt more corrective measures for the development of its regulatory environment in the future. Regulatory barriers, technical and cultural challenges still need to be overcome for the success of prosumers aggregation policies and the prosumers themselves.

CRedit authorship contribution statement

D.F. Botelho: Conceptualization, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. **L.W. de Oliveira:** Conceptualization, Formal analysis, Investigation, Visualization, Writing – review & editing, Supervision. **B.H. Dias:** Conceptualization, Formal analysis, Investigation, Visualization, Writing – review & editing, Supervision. **T.A. Soares:** Conceptualization, Formal analysis, Investigation, Visualization, Writing – review & editing, Supervision. **C.A. Moraes:** Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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