Distributed Generation and Solar Photovoltaic Energy: The Case of Brazil

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ABSTRACT

Electricity generation worldwide is mainly based on large plants located far away from consumer centers. Although in many countries, a new the distributed generation (DG) model is emerging. In this new model, the consumer (prosumer) produces his own energy near the point of consumption, which it gives autonomy, flexibility and freedom. In Brazil, the DG has gained notoriety and has been expanding significantly. Photovoltaic energy is the technology DG predominantly used in Brazil, which undoubtedly contributes to avoid greenhouse gas emissions (GHG) emissions. However, this new model has generated a divergence of interests between energy consumers and energy distributors. In this context, the main objectives of this paper are: to present the evolution of DG in Brazil and its current legislation; and to make a critical synthesis the DG legal framework considering its scenarios, opportunities and risks in the DG market. The adopted methods ware an exploratory research, a general contextualization of DG in Brazil and a critical analysis. The results obtained showed: the growth of the DG market in Brazil; the divergence of interests between energy distribution companies and prosumers; and also showed the existence of six scenarios for DG which in five of them the current benefits of the prosumers will be reduced.

KEYWORDS

Distributed Generation. Prosumers. Photovoltaic Energy. Regulatory Framework. Opportunities and Risks. Brazil.

INTRODUCTION

Developing renewable energies is a key factor for boosting energy transition from energy sources based on fossil fuel to alternative and diversified energy sources with lower environmental impacts [1]. In 2015, during the United Nations Conference on Climate Change (COP 21) the international community signed the Paris Agreement to combat the global warming. Thus, the repercussions of international agreements and the encouragement of the use of renewable energies have accelerated the global energy transition. This signalizes the beginning of a new era of global geopolitics aimed at a low carbon economy.

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The current power generation is based on centralized generation (CG) from large power plants that use a single type of resource [1]. This is carried out through large power plants located far from urban consumer centers and large industries. A new model of decentralized generation (DG) based on renewable energy is emerging rapidly in several countries. In this context, the DG emerges technologies are potentially disruptive and able to contribute for the greenhouse gas emissions (GHG) reduction. Policy-makers are searching for evidence-based solutions for meeting contemporary challenges of energy services that are both low carbon and sustainable. Emerging trends relate to policies and regulations that incentive DG electricity generation [2]. Thus, the electricity sector worldwide is facing the rapid and dynamic advance of a new reality and there are the need of the progress and regulatory novelties indispensable to make new business models viable. The mode of decentralized generation, in which the consumer generates his own energy near the point of consumption, is called distributed generation (DG) and transforms the consumer into a "prosumer" (simultaneously consumer and producer of energy). This allows greater autonomy, flexibility and freedom of users of the electricity sector.

According to [3, 4, 5], there are spread of DG in Brazil and in several countries at different levels of development. Currently, in Brazil, the electricity sector (BES) is basically composed of government agencies, companies (generation, transmission and distribution) and consumers. There are mainly four DG technologies developed in Brazil: photovoltaic (PV) solar, wind, thermo and small hydro power. There is a predominance of DG photovoltaic (PVDG) because the solar irradiation is abundant. However, according to data of National Electricity Regulation Agency (ANEEL) [6], there is a relevant growth in the number of prosumers. It is basically due to the following factors: evolution of regulation, significant and continuous reduction of DG equipment cost, increasing of the regulated electricity tariffs, popularization and development of this new business which creating an incipient DG market. The determination of the parameters for setting the tariffs that should be charged for the use of the distribution, electricity grid to consumers who install DG (so-called prosumers) has been subject to economic and regulatory analysis.

The growing demand for electrical power and the limited capital invested to provide this power is forcing countries such as Brazil to search new alternatives for electrical power generation [7]. Continuances dropping of PV generation overall costs may come as a powerful tool for developing countries reinforce their grid and for developing countries offer their population access to electrical power in a fair price based in a sustainable way [8]. The increasing of distributed integration related to renewable energy sources, such as PV systems, requires adequate regulatory schemes in order to reach economic sustainability [4, 9]. According to [10], DG's efforts are a worldwide trend, and Brazil, although lagging behind in this process, has changed its regulation and accompanying international transformations in parallel.

The PVDG technology has good opportunities for Brazil to diversify its energy matrix with potential economic and environmental benefits. The creation of market for solar PV customers was face initial additional costs, which result in future benefits [11]. According to [12] PVDG remuneration schemes are categorized into five main categories: (i) buy-all, sell-all; (ii) net metering; (iii) real-time self-consumption at the wholesale price; (iv) real-time self-consumption at a value-based price (usually between the wholesale and retail price), whereby utilities or regulators estimate the value of PV generation based on avoided generation capacity expansions, fuel expenditures and any additional costs, and on benefits to the system or society (grid integration costs, CO_2 reduction value, capacity credits, etc.); (v) real-time self-consumption at zero remuneration. Brazil currently uses net metering.

Incentives such as feed-in tariffs and net metering are seen as key policies to achieve this objective. While the feed-in tariff scheme has been widely applied in the past, it has now become less justified mainly due to the sharp decline of the PV system costs. Consequently, the net metering scheme is being adopted in several countries, such as Brazil, where it has is in force since 2012 [9]. In the feed-in tariff scheme, the government subsidizes energy by paying consumers for energy production.

The net metering consists on the calculation of the total energy injection of PVDG on the distribution network. The entire surplus produced and not consumed is then transformed in credits that remain available to use when the PV system is not generating, for example, during following cloudy days. To make this possible, the usage of bidirectional multimeters is necessary for they are able not only to register the consumption, but also the surplus supplied to the distribution network [8]. In the net metering Brazilian scheme, the surplus energy is transferred to local distributors, and then compensated in electricity consumption of the same consumer unit or other consumer unit of the same ownership [13].

[14] demonstrated the high potential of PVDG installations in Brazil, and show that under certain conditions, grid-connected PV can be economically competitive in a developing country. Using subsidized interest rates, their analysis showed that solar PV electricity had been already competitive in Brazil in 2012, while in the country-specific risk-adjusted rate, the declining, but still high capital costs of PV make it economically unfeasible. Thus, at a mature market interest rate, PV competitiveness is largely dependent on the residential tariff and economic competitiveness was given for locations with high residential tariffs.

[7] highlighted the importance of the need for financial subsidy from government. It evaluates the importance of parameters such as the annual interest rate; the specific investment; the marginal cost of expanding the electrical power supply; and the government subsidy on amortization time of capital invested. [15] analysed the policy landscape of a new configuration for the electricity sector (DG) which was introduced in 2012 and regulated in Brazil by the ANEEL through a net metering regulation. The author identified the significant growth in the amount of DG units from this moment.

According to [16], in 2016, only 0.1% of Brazilian residences were ready to install PV panels. However, it reaches the impressive value of 55% of all Brazilian residences as early as 2026. The rapid introduction of PV systems, initially in the households with higher income, shows that even in places with less solar incidence may present economic potential, if the local residential tariff is high and the opportunity cost is low.

The utility regulators and policymakers are concerned about potential increases in retail rates driven distributed solar PV systems. This may adversely affect utility customers that do not invest in these technologies (consumers) more than those that do (prosumers) [17].

Currently, in addition to the search for sustainable development, there is an increased pressure for a change in consumption and production of energy patterns in Brazil. In this scenario, net metering is an important mechanism fostering dissemination of small PV solar systems. As complementary support to net metering, a tax exemption is being offered in some of the Brazilian states [18].

In Brazil, even with DG exponential advance in recent years, the possibility of the expansion is hampered by pre-existing energy policy focused in centralized production technologies [19].

In this power generation technology transition context, this article aims to be a contribution to the ongoing discussions. The structure of the paper is organized in: Methodology; Solar PV energy in the World and in Brazil; Brazilian Distributed Generation and Current Regulation Framework; Considerations about the Regulatory Framework Review; Comments and Conclusion.

METHODOLOGY

The adopted methods ware an exploratory research, a general contextualization of DG in Brazil and a critical analysis. The hypotheses presented are: (i) the existence of a great potential to be explored by DG; (ii) the current national regulations are functional, but can be improved; (iii) the existence of divergences among the interests of consumers, prosumers and distribution companies; (iv) the existence of risks related to the pressures generated by the indebtedness and judicialization of the BES associated with the distribution companies' lobby or prosumers. In this way, analyses of the Brazilian context were made and of the findings of the impact of the legislation adopted in recent years. The possible changes the future updating of Brazilian legislation are commented and critiqued.

SOLAR PV ENERGY IN THE WORLD AND IN BRAZIL

According to the International Renewable Energy Agency (IRENA) [20], total solar PV capacity in 2019 was 580,159 MW, where the regions with the greatest amount of installed capacity are: Asia with 330,131 MW (56.90 %); Europe with 138.266 MW (23.83 %); and North America with 68.276 MW (11.77 %). South America had 6.464 MW (1.11 %), with 2,485 MW (0.43 %) located in Brazil, as described in Table 1. With the PV installed capacity continuous global growth in the last decade, PV energy has had a reduction in implementation costs and an increase in competitiveness compared to others types of renewable energy.

Table 1. FV Solar Installed Capacity in: 9 Regions and World, 10 Countries, Brazil.

Year			2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	MW (%)
	N°	Names	Installed Capacity (MW)										in 2019
Regions	1°	Asia	5,494	9,609	15,979	34,487	56,208	84,459	136,256	206,351	274,274	**330,131**	**56,90%**
	2°	Europe	30,118	53,563	71,794	81,950	88,813	97,280	103,782	110,212	119,205	**138,266**	**23,83%**
	3°	North America	3,159	5,708	8,963	13,051	17,943	24,374	36,008	44,944	57,067	**68,276**	**11,77%**
	4°	Oceania	1,100	2,492	3,826	4,605	5,352	6,073	6,854	7,571	11,555	**16,233**	**2,80%**
	5°	Eurasia	6	8	13	20	47	315	935	3,727	5,651	**7,147**	**1,23%**
	6°	South America	44	64	160	194	467	909	1,548	3,426	5,246	**6,464**	**1,11%**
	7°	Africa	194	266	346	659	1,557	1,923	2,972	3,724	5,196	**6,367**	**1,10%**
	8°	Middle East	85	208	269	512	799	997	1,482	2,175	3,155	**5,134**	**0,88%**
	9°	Central America and Caribbean	78	111	161	262	333	913	1,126	1,468	1,729	**2,141**	**0,37%**
Total World			**40,277**	**72,030**	**101,511**	**135,740**	**171,519**	**217,243**	**290,961**	**383,598**	**480,078**	**580,159**	**100,00%**
Countries	1°	China and Chinese Taipei	1,044	3,226	6,941	18,140	29,008	44,380	79,033	132,569	177,754	**209,222**	**36,06%**
	2°	Japan	3,599	4,890	6,430	12,107	19,334	28,615	38,438	44,226	55,500	**61,840**	**10,66%**
	3°	United States	2,909	5,172	8,137	11,759	15,984	21,684	32,958	41,357	51,426	**60,540**	**10,44%**
	4°	Germany	18,004	25,914	34,075	36,708	37,898	39,222	40,677	42,291	45,179	**48,960**	**8,44%**
	5°	India	65	563	979	1,446	3,444	5,365	9,651	17,923	27,127	**34,831**	**6,00%**
	6°	Italy	3,592	13,131	16,785	18,185	18,594	18,901	19,283	19,682	20,108	**20,900**	**3,60%**
	7°	Australia	1,088	2,470	3,796	4,565	5,284	5,943	6,686	7,352	11,303	**15,928**	**2,75%**
	8°	United Kingdon	95	1,000	1,753	2,937	5,528	9,601	11,930	12,782	13,118	**13,398**	**2,31%**
	9°	France	1,044	3,004	4,359	5,277	6,034	7,138	7,702	8,610	9,617	**10,562**	**1,82%**
	10°	Korea Republic	650	730	1,024	1,555	2,481	3,615	4,502	5,835	7,130	**10,505**	**1,81%**
		Brazil	**2**	**2**	**3**	**6**	**16**	**27**	**84**	**1,104**	**2,078**	**2,485**	**0,43%**

According to [12], globally, DGPV capacity is significantly growing up in the last years (Table 2) and is forecast to increase the global solar PV installed capacity (Commercial, industrial and residential) from 208 GW in 2018 to 520 GW in 2024. Commercial and industrial systems are the largest growth segment because they are usually less expensive and have a relatively stable load profile during the day. That can enable larger savings on electricity bills, depending on the policy scheme in place. Of all renewable technologies, distributed PV additional growth potential is the highest because consumer adoption can be very rapid once the economics become attractive. Probably, China remains the largest growth market and will probably have a prominent position in the DG expansion. However, unlike for the residential segment, expansion in the Asia Pacific region is larger than in Europe and North America, mainly owing to strong policy incentives in Japan, Korea and India.

Table 2. Global Distributed PV installed capacity growth by segment: 2007-2024.

Global Distributed PV capacity growth by segment: 2007–2024				
Period	2007 - 2012	2012 - 2018	Estimates	
			2019 - 2024	2019 - 2024 (Accelerated Case)
Off grid	1 GW	3 GW	5 GW	7 GW
Residential	19 GW	36 GW	85 GW	114 GW
Commercial-Industrial	44 GW	103 GW	227 GW	285 GW
TOTAL	64 GW	142 GW	227 GW	317 GW

Source: Information of [12].

BRAZILIAN DISTRIBUTED GENERATION AND REGULATION FRAMEWORK

In the energy sector, the electricity sector undergoes a significant energy transition due to the renewable energies and DG (micro-generation and mini-generation). According to [13, 21], the main existing laws [22-26] that directly and indirectly regulate the DG in the BES are described in Table 3. The main DG regulations are Normative Resolution (REN) Nº 482/2012 [24] and REN Nº 687/2015 [26]. REN Nº 482/2012 is the effective regulation to beginning of a DG evolution in Brazil. [27] commented that the DG installed capacity in Brazil was less than 0.1 % in 2015, but already projected DG consistent growth scenarios for the following years. REN Nº 687/2015 modified the Procedures for Distribution of Electrical Energy in the National Electri c System (PRODIST) again and was responsible for an increase in the deployment of new DG systems. This enabled new business models such as the solar service, such as the Power Purchase Agreement (PPA), solar stock and roof rental and solar condominiums. However, these regulatory initiatives from ANEEL do not configure policies or programs, such as those seen in the United States, the Netherlands, the United Kingdom, Canada, Germany, Spain, Australia, China, India, Malaysia and France. These nations have robust and comprehensive policies that tackle solar energy from all angles, including the regulatory (tax exemptions, subsidies, feed-in tariffs, cross-discounts, etc.), without ignoring the need for investment incentives, technological research and development stimuli, renewable energy education and operational standards for building-integrated PV (BIPV) [28].

Table 3. Main Legal Frameworks of the DG in Brazil.

Legal Frameworks of Regulation	Date	Definition
Law No. 10.848 / 2004 of the Presidency of the Republic	03/15/2004	It corresponds to the current Regulatory Framework of the Brazilian Electricity Sector (SEB) and introduced the concept of distributed generation. Provides for the sale of electric power, amends Laws No. 5,655/1971, No. 8,631/1993, No. 9,074 / 1995, No. 9,427 / 1996, No. 9,478 / 1997, No. 9,648 / 1998, No. 9,991 / 2000, No. 10,438 / , and makes other arrangements.
Decree No. 5.163 / 2004 of the Presidency of the Republic	07/30/2004	Regulates the commercialization of electric energy, the process of granting of concessions and authorizations of electric power generation, and other measures.
Normative Resolution (REN) No. 482/2012 of National Electric Energy Agency (ANEEL)	04/17/2012	It establishes the general conditions for the access of distributed microgeneration and minigeration to the systems of distribution of electric energy, the electric energy compensation system (net metering). It established: (i) general conditions for access of distributed microgeneration (up to 100.0 kW) and minigeration (between 100.0 kW and 1,000.0 kW) to electric energy distribution systems; and (ii) net metering system. According to the Ministry of Mines and Energy (MME), surplus energy is transferred to local distributor, and then compensated in electricity consumption of the same consumer unit or other consumer unit of the same ownership. Thus, the positive balance of a month would be used to lower consumption at another rate point, or at the invoice of the subsequent month.
REN Nº 517/2012 of ANEEL	12/11/2012	It amends REN No. 482/2012 and Module 3 of the Distribution Procedures (PRODIST). It defined new limits for minigeration (up to 75.0 kW) and microgeneration (between 75.0 kW and 5,000.0 kW; and up to 3,000.0 kW for small hidro plants). These mini and microgeneration modalities include individual properties, condominiums and cooperatives. It too difined "Remote self-consumption" as when generated energy amount in a given month is higher than consumed energy in that month, and consumer is left with credits, which expiration date has increased from 36 months to 60 months. Furthermore, these credits can be used to reduce consumption of consumer units owned by the same holder located elsewhere, as long as they are in the same concession area of the distributor. The concept of shared generation has been created, which consists of a consumers association within the same concession area, through a consortium or cooperative, composed of individuals or legal entities that have consumer units with micro or minigeration distributed in different places from the consumer units in which the excess energy will be compensated.
REN Nº 687/2015 of ANEEL	01/24/2015	It amends REN No. 482/2012 and Modules 1 and 3 of the Distribution Procedures (PRODIST). It modified PRODIST again and was responsible for an increase in the deployment of new DG systems. This enabled new business models such as the solar service, such as the Power Purchase Agreement (PPA), solar stock and roof rental and solar condominiums.

Source: [13, 21]. Adapted.

Distributed Generation Development

Several studies of the Energy Research Company (EPE) [28-34], an official agency linked to the Brazilian federal government, project a future of consistent growth of distributed generation in Brazil. According to [6], the evolution of DG sources in Brazil presents a relevant growth (Table 4). There is an absolute predominance of PVDG in Brazil, where it represents more than 90% of the total existing connections; the number of consumers connected in electric grid; and the installed capacity. The other technologies (wind, thermo and small hydropower) are also used, but in a minority. From 2008 to 2020, the PVDG percentage growth in Brazil has been expressed, with the installed capacity growth being residential and commercial consumers.

Table 4. DG Brazilian development: 2008–2020.

Distributed Generation		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total 2008-2020	%
Hydro	Connected DG systems	0	0	0	0	0	0	1	1	11	32	27	29	3	104	0,03%
	Number of Prosumers	0	0	0	0	0	0	1	4	22	6.181	2.012	253	14	8.487	1,71%
	MW	0	0	0	0	0	0,00	0,83	0,09	4,93	37,79	23,53	29,62	4,00	100,8	4,33%
Wind	Connected DG systems	0	0	0	0	0	7	10	22	8	7	4	2	8	68	0,02%
	Number of Prosumers	0	0	0	0	0	7	10	23	22	35	4	3	27	131	0,03%
	MW	0	0	0	0	0	0,02	0,05	0,06	5,04	5,12	0,03	0,04	4,62	15,0	0,64%
PV solar	Connected DG systems	1	2	9	2	7	53	296	1.443	6.728	13.931	35.470	122.366	205.444	385.752	99,88%
	Number of Prosumers	2	2	10	2	8	66	324	1.663	7.594	16.613	45.615	155.634	256.085	483.618	97,28%
	MW	0,025	0,023	0,118	0,09	0,47	1,48	2,53	9,72	49,27	127,72	397,20	1528,25	2535,72	2116,89	90,98%
Thermal	Connected DG systems	0	0	0	0	0	0	2	8	29	43	69	71	78	300	0,08%
	Number of Prosumers	0	0	0	0	0	0	2	56	84	67	355	3972	382	4.918	0,99%
	MW	0	0	0	0	0	0	0,11	2,13	10,45	12,13	15,93	26,27	27,09	94,1	4,04%
										Total of Connected DG Systems					386224,00	100%
										Total of Number of Prosumers					497154,00	100%
										Total of MW					2326,77	100%

In 03/22/2021, ANEEL [35, 36] informs that the CG installed capacity total, operating in the BES, was 215,825.9 MW and DG installed capacity total operating in Brazil was 5,231.3 MW. The PV power generation expansion contributes for a low carbon energy transition, avoiding GHG emissions and contributing to Brazil in the combat of climate change. According to [37], the solar PV generation potential considering the population in the Brazilian cities (Figure 1), points a great opportunity of DG expansion. In 2019, EPE [29] informed that carbon intensity in the BES power generation was 90.0 kg CO_2/MWh.

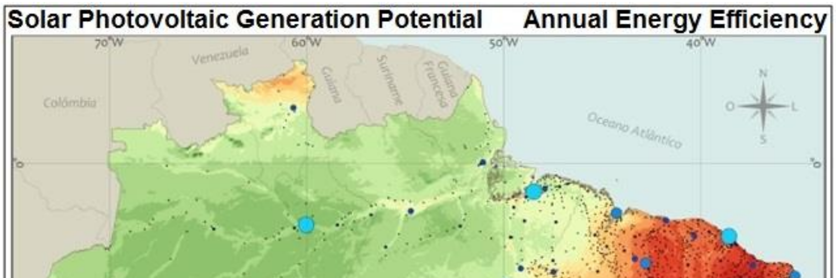

Figure 1. Solar PV generation potential Map in terms of annual energy efficiency for the whole of Brazil (measured in kWh/kWp*year in the colour profile), admitting a performance rate of 80 % for fixed PV generators and distribution of the Brazilian population in the cities. Source: [37].

According to [12], since 2015, there has been a significant increase in electricity bills due to the notorious failure of Provisional Measure (MP) No 579/2012. This REN initially aimed at the compulsory reduction of the electric energy tariff, but ended up causing widespread indebtedness of distribution companies. This has influenced the adoption of the DG by many residential consumers in order to protect them against rising energy prices. Many commercial consumers adopted DG to reduce operating costs. In the net metering system adopted in Brazil, the energy generated has the same value as the one consumed. Thus, the financial return is best for those who pay more expensive rates, which are residential and commercial low voltage consumers (B Group). In this way, the financial attractiveness of investments in DG increased, especially in these segments. Debates in public hearings and events have to create contrary pressures from the electricity distribution companies front to the Federal government in relation to the advance of the net metering model.

The investor (prosumer) is responsible for the acquisition and installation of the metering system; power injected back to the grid is limited to a fixed amount (user demand) and it results in limited expirable credits (5-year validity) to be used in electricity bill deduction. Several PV system incentives, if implemented, would bring advantages to consumers that currently connect to electric grid the sense that the levelled generation cost (e.g. minimum feasible tariff value) would be feasible with respect to values due to the distribution utility. Some of these include income tax deduction on PV equipment, special financial conditions and tax incentives on equipment, assembly and installation [38].

Distributed Generation Regulatory Framework Revision

It is important to highlight that the DG growth, participation should not be analyzed as a mere electricity matrix diversification. This interpretation tends to minimize the need for adjustments in: (i) Operating system paradigm; (ii) Regulatory framework; and (iii) Business models. In general, it is necessary to recognize that a technology transition is taking place that will affect the electricity sector in its different spheres [39].

In 2017, Ministry of Mines and Energy (MME) [40] the Brazilian government began the BES broad regulatory reform process and sent a proposal to the National Congress. However, since then the process has been under review and there is no prediction of when it will be debated and voted on in plenary.

In Brazil, according to current regulations (Table 3), the energy excess generated by prosumers is injected into the distribution electric grid. The difference between generation and its own consumption during the day will be used to discount monthly in payment of future electricity bills through net metering. Thus, the discount of the injected energy in electric grid occurs at the full rate, disregarding the electric grid costs incurred by distribution companies and the other non-energy components. Consequently, the electric grid costs will be apportioned to the other consumers who had no interest or finance conditions to install the DG systems.

Since 2018, the ANEEL [41, 42] has been conducting the public consultations on the revision of the current regulation in relation to DG for future approval. This may result in advances in relation to the DG benefits for the prosumers or in regression because of the pressure of the distribution companies lobby. Distribution companies desire reduction of the advantages of DG net metering to prosumers under the allegation of the maintenance of the economic-financial balance and in fee injustices with the no-prosumers. However, there is also pressure from public opinion, prosumers and PV solar DG companies lobby to maintain the benefits of DG PV, as they consider that there are environmental benefits (reduction of GHG emissions) and economy benefits (generation of jobs, income and business).

Tariff and Sectorial Charges in the Electricity Bill Payment. Currently, the electric energy Federal government taxes are electricity sectorial charges and Tariff of the Use of the Distribution System (TUSD). The sectorial charges are created by laws approved by the Brazilian National Congress to make feasible the implementation of government policies for the BES. Their values are contained in resolutions or ANEEL orders and are collected by distribution companies through energy bills. Their values are contained in resolutions or ANEEL orders and are collected by distribution companies through energy bills. Each of the charges is justifiable, but taken together, impact the consumer's tariff and payment capacity [43].

According to [43], the energy account percentage composition in relation to TUSD and sectorial charges is presented in Table 5. These charges are the non-manageable costs borne by the distribution concessionaires and passed on to consumers to guarantee the contractual economic-financial balance. The current sectorial charges related to this tariff process are described in Table 6. TUSD focuses on the consumers connected to the distribution concessionaires' electrical systems to remunerate the provided energy transport service (electric grid use).

Table 5. Federal Electricity Tariff Composition in Brazil.

Tariff Components	TUSD	Wire A (Transmission)	6%
		Wire B (Distribution)	28%
		Charges	8%
		Electrical Losses	8%
	TE	Energy Consumptiom	38%
		Sectorial Charges	12%
		Total	100%

Legend:
TUSD Wire A: Transportation charge of transmission of energy produced/consumed.
TUSD Wire B: Transportation charge of distribution of energy produced/consumed.
TE: Energy Tariff

Table 6. Current Sectorial Charges in Brazil.

Nº.	Sectorial Charges	Acronyms
1	Energy Development Account	CDE
2	Incentive Program for Alternative Energy Sources	PROINFA
3	Financial Compensation for the Use of Water Resources	CFURH
4	System Service Charges	ESS
5	Reserve Energy	EER
6	Inspection Fee for Electric Energy Services	TFSEE
7	Research and Development and Energy Efficiency Program	P&D and PEE
8	Contribution to the National System Operator	ONS

In addition to federal taxes, some municipalities have public lighting taxes and all States of Brazilian federation have operations tax related to the Products and Provision of Services Circulation (ICMS). There are also the tariff flags applied by the federal government. The power account cannot be zeroed because there is a minimum tax to electric grid connection. Tariff flags are a system that signals to consumers the electric power generation actual costs. The operation is simple: Flags colours (green, yellow or red) indicate whether the energy will cost more or less depending on the electricity generation conditions. With the Flags, the light bill becomes more transparent and the consumer has the best information to use the electric energy in a more conscious way. When the Flag is green, the power generation hydrological conditions are favourable and there is no addition to the accounts. If the conditions are a little less favourable, the Flag becomes yellow and there is an additional charge, proportional to consumption, at the rate of the Brazilian Real (R$) 1.00 per 100 kWh (or its fractions). Even under unfavourable conditions, the flag becomes red and the additional charge becomes proportional to the consumption in the ratio of R$ 3.00 per 100 kWh (or its fractions), for the Red flag level 1; and at the rate of R$ 5.00 per 100 kWh (or its fractions), for the Red Flag level 2. To these values, the current taxes are added [44].

Proposals for Changes to the Distributed Generation Regulatory Framework. Currently, the electricity bill discount is almost total and transfers the electrical grid costs and sectorial charges to other consumers. In this sense, sooner or later, a tariff review will have to happen to redistributing the real and socially fairer costs for net metering. In this perspective, it is worth noting that the end of subsidies can make the new business development faster. The connected batteries, installation to consumer units with DG could be one new business.

In 2018, the ANEEL [41, 42] developed six possible alternative scenarios (Table 7 and Figure 2) for updating the legislation regarding TUSD tariff charges and sector charges for DG from 2020.

Table 7. Six ANEEL alternatives in Reform of DG Regulatory Framework.

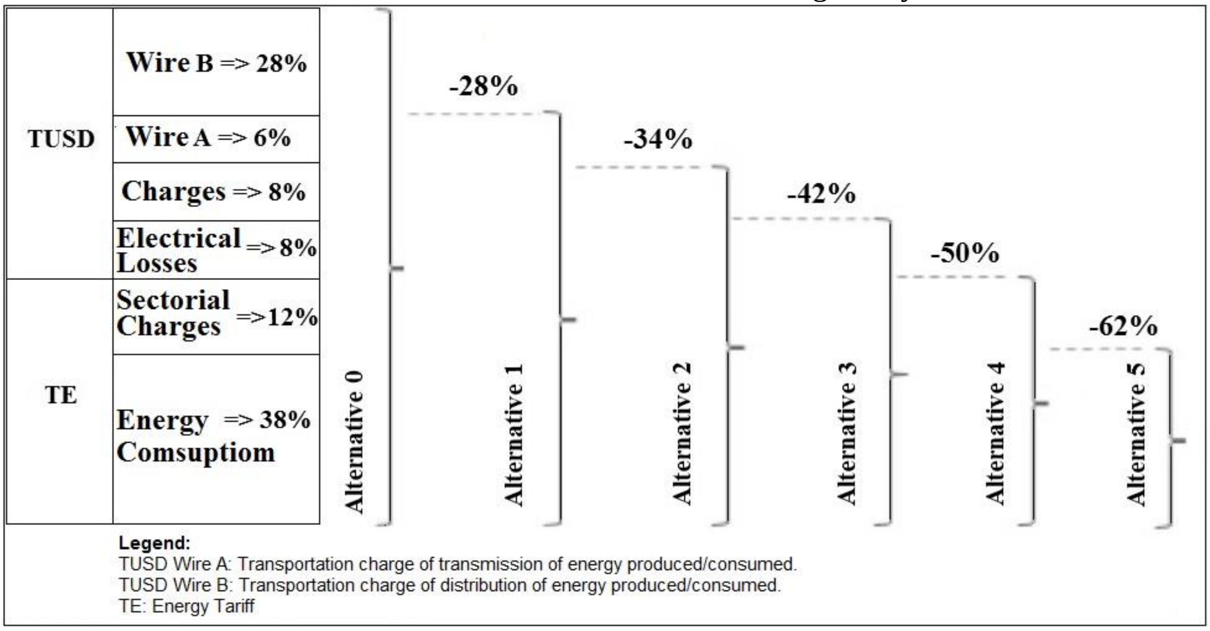

Figure 2. Six alternatives for DG Regulatory Framework Revision in Brazil.

When compared the six scenarios, it is observed that in five and six scenarios, there would be a current benefit reduction for future prosumers. The losses in the compensation value of the produced energy vary between 28% and 62%. This would directly impact to an increase the DG project paybacks. These scenarios tend to benefit distribution companies, harming future prosumers. Prosumers who deployed their DG systems prior to changes in legislation would have the right to full compensation (Alternative 0). The ANEEL also considers maintaining alternative 0 until DG installed capacity reached 3,360 MW. The ANEEL changes in the distributed generation rules in Brazil will only apply to the new connections in Brazil. The ANEEL changes in the distributed generation rules in Brazil will only apply to the new connections in Brazil. This guarantees legal security to current contracts and respect to pioneers prosumers who believed in this technology. These actions preserve the "acquired right" legal concept of the net metering current benefits.

Study to Proposal for Binomial Tariff. In parallel to the new proposals for DG, the ANEEL [45] is also studying the possibility of changing the way of charging the electric tariff from "monomial" to "binomial" for consumers of electricity connected at low voltage (voltage below 2.3 kV), "Group B"). In the current charging model (volumetric monomial tariff) the monetary value of the electricity bill depends solely on the volume of electricity consumed The fixed costs inherent to energy management and maintenance are borne by the distribution companies and the tariff adjustments are fixed periodically by ANEEL. This may cause financial losses to the distributors. The Binomial Tariff would have two parts: a “fixed instalment”, to cover the management and maintenance of the electric grid, and other “proportional instalment” to energy consumption. The fixed portion is characterized by a lower variation with energy consumption over time, resulting in fixed revenue for distributors.

In 2018, ANEEL [46] held Public Consultation No. 002/2018 to assess the need to improve the tariff model applied to Group B (Low Voltage). To this end, Technical Note 46/2018-SGT/ANEEL [47] was made available, in which the following was discussed: (i) Review of the main theoretical concepts on pricing, (ii) Current pricing in Brazil; (iii) Current technological advances that possibility impact the electricity sector and (iv) Summary of the charging models applied in some countries. The regulatory problems related to the implementation of the binomial tariff were: Separation between product and service; Revenue from the distributor tied to the consumption of electricity; Power management; Disruptive innovations; The Granularity of Tariffs; and the Cost of Availability.

ANEEL [47], in summary, in the study embodied in this Regulatory Impact Analysis Report - AIR seeks to answer three questions: (i) What is to be considered as fixed cost? (ii) How to charge fixed costs? (iii) Should the tariff be differentiated by the quality of the service provided?

DG Projections to 2029

PDE 2029 [28] shows a shorter DG expansion than PDE 2027 DG expansion (Figure 3) because PDE 2029 considers binomial tariff and REN 482/2012 revision effects.

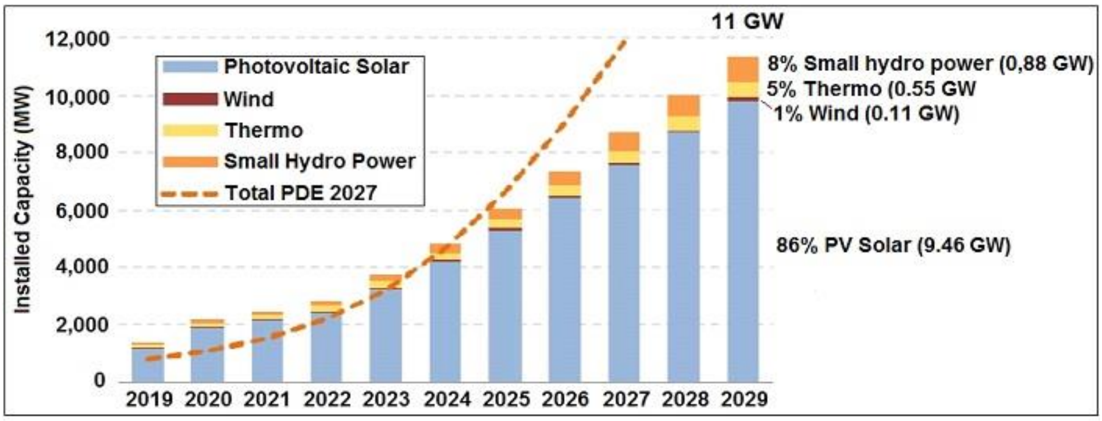

Figure 3. DG capacity installed projection of PDE 2029. Source: [28] (Adapted).

Discussions about the application of binomial tariff to consumers connected to Low Voltage (BT) and change in the energy compensation model to DG have intensified recently. Both themes are on ANEEL´s future regulatory agenda, and the result will impact the adoption of DG in the country. The changes advocated by EPE are part of the PDE 2029 reference path, but given the process uncertainties, EPE carried out some simulations with different compensation alternatives and application (Figure 4-B) or not (Figure 4-A) of binomial tariff. Results range from 9 GW to 32 GW, depending on the regulatory combination (Figure 4) [28].

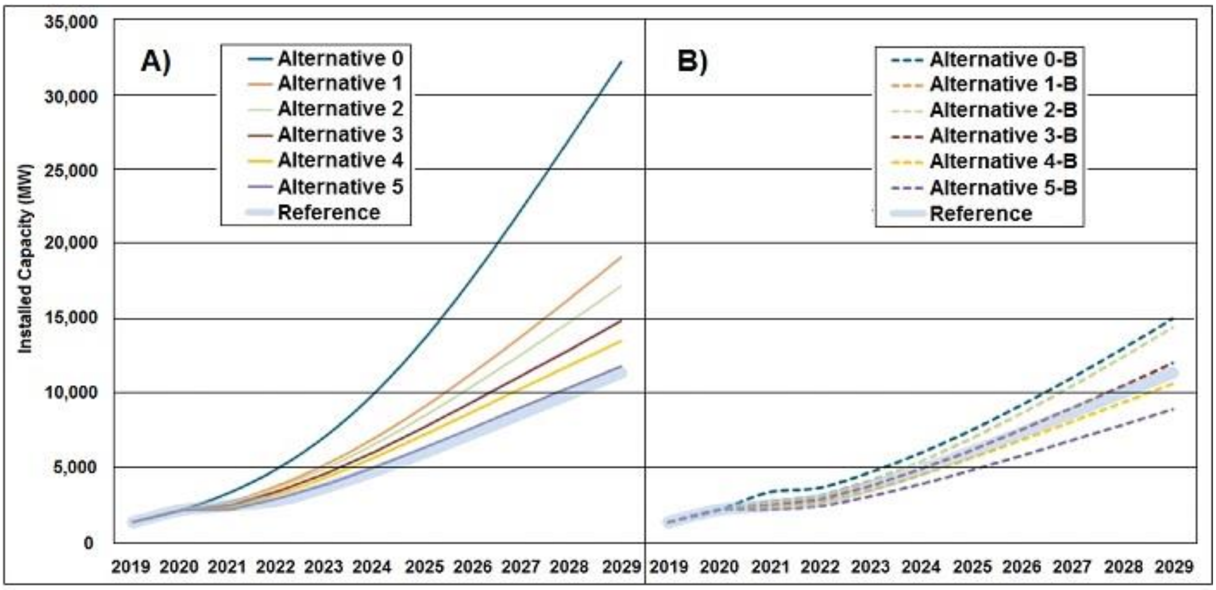

Figure 4. Regulatory Sensitivity Analyses DG Projections: A) Five alternatives without Binomial Tariff; B) Five Alternatives with Binomial Tariff. Source: [29] (Adapted).

PDE 2029 [28] projects the sensitive analysis (Figure 2), about the five DG alternatives and Binomial Tariff change effects to the REN 482/2012. However, the PDE 2029 regulatory sensitivity DG projections (Figure 2) need be revised, because the BES is impacted with Covid-19 crisis.

ANEEL Public Consultation for Regulatory Impact Analysis

In January 2019, ANEEL initiated new public consultations and publications to collect subsidies and additional information for a Regulatory Impact Analysis (AIR) of the REN No 482/2012 revision. With the publication of AIR, there was a first bottleneck of these proposals by ANEEL. For the generation by the load, it was proposed the adoption of Alternative 1. As for the remote generation, the proposal is a transition to Alternative 1 and then to the Alternative 3, in which there would be no compensation for the distribution plots, transmission ("the wire") and part of the tariff charges, together, these three elements account for about 40% of the amount paid by the consumer for each kWh consumed network. In addition, it´s important to keep in mind always two principles presented by ANEEL in its proposals in AIR [40]:

Table 8. Principles by ANEEL in AIR.

Principle 1	Changes will occur gradually and predictably. Thus, although the new resolution will be published at the end of 2019, the changes to the compensation mechanism would not happen immediately, would be activated when specific triggers, measured in accumulated power, were achieved. For the generation next to the load, the trigger initially proposed would be 3,360 MW. Already for the remote DG, two triggers were suggested: the first, of 1,250 MW, would trigger the alteration of the compensation for Alternative 1; and the second, of 2,130 MW, would trigger a change from Alternative 1 to Alternative 3 [40].
Principle 2	There will be a transition rule for these changes. Through it, the distributed micro-generation and mini-generation systems until the publication of ANEEL's new normative resolution will continue to have its electric energy credits offset. The compensation will be in accordance with the current model, for a period of 25 years, and will be subject to the new rule. Already those connected between the publication of the updated rule and the triggering of the first trigger, would compensate credits by the current model for a period of 10 years [40].

CONSIDERATIONS ABOUT THE REGULATORY FRAMEWORK REVIEW

There are divergences between the prosumers and the Brazilian PV Solar Energy Association (ABSOLAR) interests regarding to the distribution companies' interests. Currently, electricity bills are very high in relation to the Brazilian population purchasing power. DG projects prices have also fallen significantly in recent years. These factors have encouraged consumers to become prosumers. The distributing companies fear to lose the revenues of these consumers. In this way, distribution companies want to transfer part of their electricity grid costs and create a wire tariff for future prosumers, acting as a lobby. Such actions would reduce the attractiveness and DG payback in Brazil.

ANEEL regulations are periodically reviewed and updated in an attempt to induce a growth of the PV solar energy market in Brazil. Existing regulations could be improved to: (i) reduce or exempt equipment fees from PVDG as well as provide government incentives; (ii) enabling consumers to enjoy greater benefits by allowing surplus energy to be sold to the distributor or to the free market; (iii) exempt taxes for non-profit institutions; and (iv) include in the housing programs the energy efficiency requirement and the DG in new projects.

The Brazilian National Congress discusses proposals for new GD legislation. The main law is nº 5829/2019, which intends to create a legal framework. A proposed presented in March/2021 proposes a gradual transfer of costs from TUSD wire B to consumers and a 10-year transition to the tariff change in the current model. The changes would take effect 12 months after the publication of the Law. They too would guarantee the maintenance of the current rules for pioneering consumers, bringing more legal and regulatory security to consumers who generate their own renewable electric energy. ABSOLAR made criticisms regarding to the law. As a consequence, an amendment was proposed that provides a trigger for changing the rule from reaching a 10% share of distributed generation in the electrical supply of each distributor. It has also been proposed to reduce by half the remuneration for the use of electrical infrastructure compared to the original text of the substitute law project. This is because such prosumers use, on average, half of the network compared to a consumer without distributed generation. However, the bill is still under discussion.

Opportunities

It was verified the DG market began to grow after the edition of REN No 482/2012 and especially after REN Nº 687/2015 (Tables 2 and 3). According to [48], ABSOLAR defends the interests of companies of solar energy productive chain. According to ABSOLAR [49] there are approximately 75,000 prosumers in a universe of more than 84 million captive consumers served by distribution companies. It considers that it is still early to reduce the net metering tariff benefits since currently the prosumers do not represent even 1% of the consumers total in Brazil. In this way, there is still enormous potential for growth by consumers and the economic and financial balance of the distribution companies is still far from being threatened.

There is a need for distribution companies to reformulate their business models to adapt to the new reality imposed by DG. Then, there is an opportunity for them to start offering new smart services aggregated to DG. They too could prepare for others future demands that smart grids and the internet of things will bring. They too could prepare for others future demands that smart grids and the internet of things (IoT) will bring. In addition, the electricity distribution market is a regulated market and costs are calculated by ANEEL, and not by companies. Thus, this is also an opportunity for ANEEL to improve its working and regulation methods.

Current Brazilian electrical grid still requires many investments and improvements. DG market evolution will demand evolution of the electric grid. In addition, it is an opportunity that can favour the use of batteries in homes, smart grids and IoT. This will be a second stage of market development for prosumers and distribution companies.

Since 2020, the pandemic of covid-19 has affected Brazil and the world. This brought negative impacts on BES and the Brazilian economy as a whole. In this context, the DG market national expansion has not been harmed. DG too can also be a tool to help consumers overcome the negative impacts of this pandemic and to create jobs via DGPV companies. In addition, the DG helps the country to achieve the COP 21 targets for reducing GHG emissions, thus helping to combat climate change.

Risks

The BES has presented many problems related to the business pressures generated by indebtedness and judicialization as a result of other governmental actions. As distribution companies are part of this sector, it is possible that there will be a future judicialization if their commercial interests are frustrated. If there is an economist-financial imbalance, it is possible that they will judicially cover government compensation.

The continuous and robust DG growth impact will gradually lead to a reduction in the income of distribution companies. Federal and State governments in Brazil will tend to suffer a tax revenue reduction. However, the lowest electricity costs impact could be reversed in higher consumption of other resources. They could also be reversed in larger business investments since in both cases the economy tends to be energized.

COMMENTS AND CONCLUSION

Nowadays, less than 5% of total consumers in Brazil are prosumers. Then, there is a great DG expansion potential to be explored. The current national regulations are functional and permit the DG continuous growth. Although the regulatory framework can be improved to the DG best adaptation in the BES context. The DG market growth created divergent interests between energy distribution companies and prosumers. In addition, ANEEL proposed six scenarios for DG from 2020 (in which five scenarios the current prosumers benefits will be significantly reduced) and binomial tariff adoption for BT consumers (more expensive electricity bills). Thus, there are risks related to the pressures generated by the indebtedness and "judicialization" of the BES associated with the distribution companies' lobby or prosumers. These risks will be potentially harmful to the BES and the economic future context of Brazil.

Until 2019, there was no effective discussion about the economic context of Brazil and how DG and the electricity sector link to larger economic issues and the future of Brazil. However, issues such as pressures, international about climate change actions, the pandemic crisis and consumer pressure are spelling out the importance of these debates. The current regulations support the PV solar energy market growth in Brazil. However, the legislation review expected to happen in 2021 may lead to setbacks, loss of benefits for prosumers and prospective prosumers, and legal uncertainty. Distribution companies lobby actions and pressures act contrary to the prosumers DG benefits, so much so that in six of the six scenarios presented the trend is to reduce benefits. The public opinion and the PVDG companies lobby support the current benefits continuity.

The ANEEL regulations periodically are reviewed and updated in an attempt to induce a PV solar energy market growth in Brazil. Existing regulations could be improved to reduce or to exempt equipment fees from PVDG as well as provide government incentives; beyond that, to enabling consumers to enjoy greater benefits by allowing surplus energy to be sold to the distributor or to the free market; to exempt taxes for non-profit institutions; and to include in the housing programs the requirement of energy efficiency and the DG in projects.

There is a need for regulatory improvement aimed at cheapening further the conditions in the DG systems implementation in the residential, commercial and industrial markets. Too it is important offer greater freedom and flexibility for the consumer to effectively become a "prosumer" in the energy market. However, pressures from distribution companies may impose setbacks and reductions in the prosumers DG benefits, which may have negative effects on their expansion.

The Brazilian current national legislation needs too revision and improvements to keep pace with market trends and rapid technological developments. Public consultations are important and democratic tools to support revisions of existing legislation. However, it is valid to criticize the pressure power asymmetry on the issue of interest divergences between consumers/prosumers and distribution companies. One of the few legal provisions that ensure the current prosumers rights is the consolidated legal concept of "vested right" since the DG projects and DG contracts already in place will not be prejudiced in relation to regulation changes because there is no laws retroaction.

Potential changes in the regulatory framework may also represent new risks and opportunities for DG. In the future, there will be a need to guarantee the distribution companies economic-financial balance and the prosumers DG benefits.

National Congress initiatives can improve, expand and qualify the discussions and deliberations on the DG. In fact, it will probably create a new national regulatory framework for the DG, with regulatory definitions higher than those of ANEEL. So, the challenge is to create a future balanced regulatory solution to will be adopted. In this context, further DG studies are strategic as it will contribute to the electricity sector evolution and the electricity consumer market.

NOMENCLATURE

ABSOLAR – Brazilian Photovoltaic Solar Energy Association
ANEEL – National Electric Energy Agency
BIPV – Building-Integrated Photovoltaic
BT - Low Voltage
CDE – Energy Development Account
CFURH – Financial Compensation for the Use of Water Resources
CG – Centralized Generation
CNPJ – National Registry of Legal Entities
CPF – Register of Individuals
DG – Distributed Generation
EER – Reserve Energy
EPE – Energy Research Company
ESS – System Service Charges
ICMS – Circulation of Products and Provision of Services
IoT – Internet of Things
IRENA – International Renewable Energy Agency
MP – Provisional Measure
P&D – Research and Development
PPA – Power Purchase Agreement
PEE – Energy Efficiency Program
PRODIST – Procedures for Distribution of Electric Energy in the National Electric System

PV – Photovoltaic
REN – Normative Resolution

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