Evolution, Opportunities and Risks of Distributed Generation in Brazil

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ABSTRACT

Electricity generation worldwide is still based on large plants located far away from consumer centers. However, a new the distributed generation (DG) model is emerging in several countries, where the consumer produces his own energy (prosumer) near to the point of consumption which gives autonomy, flexibility and freedom to the users of the electricity sector. In Brazil, solar photovoltaic (PV) is the DG technology predominantly used. Thus, the main objectives of this paper are to present the evolution of DG in Brazil and its current legislation and to critically comment the DG legal framework, its scenarios, opportunities and risks in the DG market. The methodology adopted was the literature review and analysis of the Brazilian DG regulatory framework. The results obtained showed the growth of the DG market in Brazil, the divergence of interests between energy distribution companies and prosumers and 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

Electricity Sector around the world is facing the rapid and dynamic advance of a new reality. The technological revolution in progress and the regulatory novelties necessary and indispensable to commercially make new business models viable are already reality. The paradigm of electric generation in the world is based on centralized generation, which is carried out through large power plants located far from urban consumer centers and large industries. However, a new model of decentralized electrical generation is emerging rapidly in several countries. This mode of decentralized generation, in which the consumer himself generates his own energy near the point of consumption, is called distributed generation (DG) and transforms it into a "prosumer", that is, a consumer and producer of energy simultaneously. This allows greater autonomy, flexibility and freedom of users of the electricity sector.

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In Brazil, solar energy is abundant, but is still underutilized. However, there is an exponential growth in the number of prosumers, basically due to the following factors: evolution of regulation, significant and continuous reduction of DG equipment cost, regulated electricity tariffs increase, popularization and development of this new business, creating an incipient market of DG.

Currently, at the international level and in Brazil, one point has been subject to economic and regulatory analysis. It is a question of determining the parameters for setting the tariffs that should be charged for the use of the distribution electricity grid of prosumers who install DG.

LITERATURE REVIEW

The prospects for the diffusion of DG on a global scale are very positive and irreversible. The growing demand for electrical power and the limited capital invested to provide this power is forcing countries like Brazil to search for new alternatives for electrical power generation [1]. Policy-makers are increasingly in search for evidence-based solutions for meeting contemporary challenges of energy services that are both low carbon and sustainable. One of the emerging trends is policies and regulations that incentive DG electricity generation [2].

Information presented by [3, 4, 5] confirm the spread of DG in Brazil and in several countries at different levels of development. Currently, at the international level and in Brazil, one point has been subject to economic and regulatory analysis. It is a question of determining the parameters for setting the tariffs that should be charged for the use of the electricity distribution grid of consumers who install DG, so-called prosumers.

Continuous dropping of PV generation overall costs may come as a powerful tool for developed countries reinforce their grid and for developing countries offer their population access to electrical power in a fair price based and in a sustainable manner [6].

[4, 7] comment with the increasing integration of distributed renewable energy sources, such as PV systems, requires adequate regulatory schemes in order to reach economic sustainability. According to [8], DG's efforts are a worldwide trend, and Brazil, although lagging behind in this process, has changing its regulation and accompanying international transformations in parallel.

Factors such as climate change resulting from global warming, the repercussions of international agreements (e.g. Paris Agreement and Agenda 2030) and the encouragement of the use of renewable energy have accelerated the global energy transition, based on fossil fuels for renewable energy. DG emerges in this context as a potentially disruptive technology.

[9] commented that PV DG technology has good opportunities for Brazil to diversify its energy matrix with potential economic and environmental benefits. They told that the creation of market for solar PV customers was face initial additional costs, which result in future benefits.

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 [7].

[10] demonstrated the high potential of PV DG 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 was 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.

[1] highlighted the importance of the need for financial subsidy from the government. It evaluates the importance of parameters such as: annual interest rate; specific investment; marginal cost of expanding the electrical power supply; and the government subsidy on amortization time of capital invested. [11] analysed the policy landscape of a new configuration for the electricity sector, DG, which was introduced in 2012 and regulated in Brazil by the National Electricity Regulation Agency (ANEEL) through a net metering regulation. She identified the significant growth in the amount of DG units from this moment.

According to [12] commented that only 0.1% of Brazilian residences would be ready to install photovoltaic panels in 2016. However, it reaches the impressive value of 55% of all Brazilian residences as early as 2026 e that is, in less than a decade. They affirmed with the rapid introduction of PV systems, initially in the households with higher income, shows that even places with less solar incidence may present economic potential, if the local residential tariff is high and the opportunity cost is low.

[13] comment what utility regulators and policymakers are concerned about potential increases in retail rates driven distributed solar PV systems. This may adversely affect utility customers that don´t invest in these technologies (consumers) more than those that do (prosumers).

Currently, in addition to the search for sustainable development, there is 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 currently being offered in some Brazilian states [14].

According to [15], 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.

METHODOLOGY

The methodology used in this article was a literature review, followed by a general analysis of the DG in Brazil, subsidizing its contextualization and subsequent critical evaluation. The hypotheses presented are: (i) the existence of a great expansion potential to be explored by DG; (ii) current national regulations are functional, but can be improved; (iii) the existence of divergences between the interests of consumers and prosumers and distribution companies; (iv) existence of risks related to the pressures generated by the indebtedness and “judicialization” of the Brazilian electricity sector associated with the distribution companies' lobby. In this way, analyses were made of the Brazilian context and findings of the impact of the legislation adopted in recent years. Comments and criticisms are also made about the possible changes from the updating of legislation for the year 2020 in Brazil.

SOLAR PV ENERGY IN THE WORLD AND IN BRAZIL

According to International Renewable Energy Agency (IRENA) [16], total solar PV capacity (DG and centralized generation) in 2018 was 480,357 MW, where the regions with the greatest amount of installed capacity are: Asia with 274,619 MW (57.17%); Europe with 119,380 (24.85%); and North America with 55,345 MW (11.52%). South America had 5.118 MW (1.14%), with 2,296 MW (0.48%) located in Brazil, as described in Table 1.

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

		Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	% of MW
	No		Installed Capacity Solar PV Power (MW)										in 2018
Regions	1°	Asia	3,712	5,512	9,631	16,124	35,812	60,059	89,789	139,487	210,542	274,619	57,17%
	2°	Europe	16,835	30,118	53,564	71,794	81,952	88,813	97,297	103,798	110,125	119,380	24,85%
	3°	North America	1,734	3,159	5,708	8,963	13,051	16,837	24,374	36,150	44,820	55,346	11,52%
	4°	Oceania	114	411	1 417	2,464	3,296	4,067	4,486	4,872	6,195	10,001	2,08%
	5°	Eurasia	5	6	8	13	20	49	316	936	3,687	5,662	1,18%
	6°	South America	15	41	60	156	187	469	900	1,545	3,417	5,469	1,14%
	7°	Africa	108	195	268	348	662	1,56	1,935	2,973	3,759	5,118	1,07%
	8°	Middle East	36	85	208	269	512	799	1,047	1,529	2,076	3,025	0,63%
	9°	Central America/Caribbean	48	75	109	168	267	341	924	1,151	1,485	1,737	0,36%
Total World			22,606	39,603	70,973	100,297	135,758	172,994	221,067	292,44	386,107	480,357	100,00%
Countries	1°	China/Chinese Taipei	425	1,044	3,226	6,941	18,140	29,008	44,380	79,033	132,670	177,636	36,98%
	2°	Japan	2,627	3,618	4,914	6,632	13,599	23,339	34,150	42,040	49,040	55,500	11,55%
	3°	United States	1,614	2,909	5,172	8,137	11,759	14,878	21,684	33,100	41,273	49,692	10,34%
	4°	Germany	10,565	18,005	25,915	34,075	36,709	37,898	39,243	40,714	42,337	45,930	9,56%
	5°	India	39	65	563	923	1,283	3,290	5,168	9,418	17,644	26,869	5,59%
	6°	Italy	1,264	3,592	13,131	16,785	18,185	18,594	18,901	19,283	19,682	20,120	4,19%
	7°	United Kingdom	27	95	1,000	1,753	2,937	5,528	9,601	11,912	12,776	13,108	2,73%
	8°	Australia	105	399	1,394	2,432	3,255	4,004	4,357	4,718	5,988	9,763	2,03%
	9°	France	277	1,044	3,004	4,359	5,277	6,034	7,138	7,702	8,610	9,483	1,97%
	10°	Spain	3,423	3,873	4,283	4,569	4,690	4,697	4,704	4,716	4,725	4,744	0,99%
		Brazil	0	1	1	2	5	15	23	80	1,097	2,296	0,48%

CURRENT LEGISLATION AND REGULATIONS

Within the energy sector, the electricity sector also undergoes a significant energy transition due to the new renewable energies and DG. According to [17], within the Brazilian electricity sector, the main existing laws that directly and indirectly regulate the DG in the country are described in Table 2.

Table 2. Main Legal Frameworks of the DG in Brazil [17]. Adapted.

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 system of compensation of electric energy, and gives other measures.
REN Nº 517/2012 of ANEEL	12/11/2012	It amends REN No. 482/2012 and Module 3 of the Distribution Procedures (PRODIST).
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).

Law Nº 10,848/2004

Brazilian Electricity Sector was reorganized in 2004, through Law Nº 10,848/2004 [17]. In this regulation, auctions were established for the contracting of centralized generation (CG), which are large plants, and the concept of DG in Brazil was also defined.

Decree Nº 5,163/2004

Decree Nº 5,163/2004 completed the reorganization of the Electric Sector by regulating the commercialization of electric energy, procedures and granting among other procedures. Complementary legislation has also emerged, such as REN Nº 77/2004 and REN Nº 414/2010. REN Nº 77/2004 established procedures related to the reduction of tariffs for the use of transmission and distribution systems for distributed solar generation, among other sources. REN Nº 414/2010 updated and consolidated the general conditions of electricity supply.

Normative Resolution Nº 482/2012

In 2012, ANEEL published the Normative Resolution (REN) Nº 482/2012 [19], which established: general conditions for access at distributed micro-generation (up to 100 kW) and mini-generation (between 100 kW and 1,000 kW) for electricity distribution systems; and the net metering system. According to [17], the surplus energy is transferred to the local distribution company. After this, there is compensation in the electric energy consumption of the same consumer unit or other consumer unit of the same property by the same Individual Taxpayer's Registry (CPF) or National Person Registry Legal (CNPJ).

[8, 20] commented on the importance of REN Nº 482/2012, which can be considered the initial regulatory framework for DG in Brazil. According to [21], net metering for DG established by REN Nº 482/2012 opened new possibilities for consumers in the country. [6] commented that there are technical and financial effects to be considered in the relations between the utility and the prosumer. With net metering, the distribution grid itself functions equivalent to a battery for the prosumers, compensating for the two-way meter installed by distribution companies. However, [19] critic the inability of existing regulation to encourage via significant financial such as the use of "avoided cost" or the possibility of energy selling, and not just compensation, are points that inhibit the free trade expansion of distributed generation in the country.

Normative Resolution Nº 517/2012

Still in 2012, ANEEL published REN Nº 517/2012 [22] to supplement REN Nº 482/2012, where a positive balance of one month's electric energy would be used to reduce consumption elsewhere in the prosumer or in the invoice for the subsequent month. The energy credits generated will be valid for 36 months and a consumer could use these credits in another consumer unit. That units have must are in the same concession area of the distributor and are owned by the same CPF or CNPJ. This process only promotes energy compensation (in kWh) between a prosumer and the distributor, not involving any kind of remuneration. The adopted net metering system implied in updates to the determinations existing in module 3 of the Procedures of Distribution of Electric Energy in the National Electrical System (PRODIST) [23].

Normative Resolution Nº 687/2015

In 2015, ANEEL issued REN No 687/2015 [24] defined new rules for DG. The limits were changed for mini-generation (up to 75 kW) and micro-generation (between 75 kW and 5,000 kW, and up to 3,000 kW for small hydro plants). These mini-generation and micro-generation types include individual properties, condominiums and cooperatives. When the amount of energy generated in a given month is greater than the energy consumed in that month, and the consumer gets credits, whose expiration date has increased from 36 months to 60 months. In addition, these credits may be used to reduce the consumption of consumer units owned by the same CPF or CNPJ holder. These consumer units can be located in different another location, provided they are in the same concession area of the distributor. This is called remote self-consumption. It was also created the possibility of shared generation. This generation type consists of an association of consumers within the same concession area, through a condominium, consortium or cooperative. This association is composed of individuals (CPF) or legal (CNPJ) entities that have micro-generation or mini-generation consumer units distributed in different locations of consumer unit.

[25] commented that the DG installed capacity in Brazil was less than 0.1% in 2015, but already projected scenarios of DG consistent growth for the following years. REN Nº 687/2015 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.

These regulatory initiatives from ANEEL, however, 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, for example. These nations have robust and comprehensive policies that tackle solar energy from all angles, including the regulatory (e.g. tax exemptions, subsidies, feed-in tariffs (FIT), cross-discounts), without ignoring the need for investment incentives, technological research and development stimuli, renewable energy education and operational standards for building-integrated photovoltaics (BIPV) [25].

DISTRIBUTED GENERATION DEVELOPMENT IN 2012–2018

According to ANEEL [26], in 04/26/2019, the total installed capacity of the Brazilian electric sector was 164,121.1 MW with: 104,585.5 MW (63.7%) of hydropower plants; 42,391.8 MW (25.8%) of thermal power plants; 15,063 MW (9.2%) of wind farms; 2,080 MW (1.3%) of solar PV power plants. Looking at exclusively PV solar installed capacity, about 65% was CG (1,352 MW) and 35% was DG (728 MW). Thus, renewable energies predominate in the Brazilian electricity matrix and PV DG represent about 0.42% of total installed capacity.

Several studies of the Energy Research Company (EPE) [27, 28, 29, 30], an official agency linked to the Brazilian federal government; project a future of consistent growth of distributed generation in Brazil. According to ANEEL [31], the evolution of DG sources in Brazil is described in Table 3. It presents the absolute predominance of DG photovoltaic in Brazil, where it represents 99.53% of total existing connections (54,919 connections), 89.29% of the number of consumers (67,179 prosumers) with net metering and 84% of installed capacity (563,3 MW). The other technologies (wind power, thermoelectric and small hydroelectric) are also used, but in a minority. From 2012 to 2018, the percentage growth of PV DG in Brazil has been expressive according to Table 4, with the growth of installed capacity being residential and commercial consumers.

Table 3. DG Development in Brazil 2012–2018.

Generation	DG	2012	2013	2014	2015	2016	2017	2018	Totals	%
Photovoltaic Solar	Total Installed Connections	5	52	286	1,436	6,664	13,732	32,744	54,919	99,53%
	Quantity of consumer units with DG that received the credits	5	66	314	1,662	7,521	16,288	41,323	67,179	89,29%
	Installed Capacity (kW)	423.9	1,394.8	2,437.0	9,588.5	48,918.7	123,113.6	377,435.7	563,312.2	84,00%
Wind Power	Total Installed Connections	0	7	10	21	8	7	4	57	0,10%
	Quantity of consumer units with DG that received the credits	0	7	10	22	22	35	4	100	0,13%
	Installed Capacity (kW)	0.0	20.4	48.7	61.6	5,037.4	5,117.5	28.8	10,314.4	1,54%
Thermoeletric	Total Installed Connections	0	0	2	8	29	39	58	136	0,25%
	Quantity of consumer units with DG that received the credits	0	0	2	56	84	63	329	534	0,71%
	Installed Capacity (kW)	0.0	0.0	110,0	2,133.7	10,240.8	11,532.4	14,034.5	38,051.3	5,67%
Hydroeletric	Total Installed Connections	0	0	1	1	9	29	25	65	0,12%
	Quantity of consumer units with DG that received the credits	0	0	1	4	20	6,165	1,236	7,426	9,87%
	Installed Capacity (kW)	0.0	0.0	825.0	9.0	4,621.5	36,079.2	17,379.4	58,914.1	8,79%
					General Total of Connections				55,177.0	100,00%
					General Total of Prosumers				75,239.0	100,00%
					Total Installed Capacity (kW)				670,592.0	100,00%

Table 4. Photovoltaic DG Development in Brazil 2012–2018.

Increase% of GD Photovoltaic	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018
Total Installed Connections	940.0%	450.0%	402.1%	364.1%	106.1%	138.5%
Quantity of consumer units with DG that received the credits	1220.0%	375.8%	429.3%	352.5%	116.6%	153.7%
Installed Capacity (kW)	229.0%	74.7%	293.5%	410.2%	151.7%	206.6%

According to [32] since 2015, there has been a significant increase in electricity tariffs due to the notorious failure of Provisional Measure (MP) N^{o} 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 themselves against rising energy prices. Many commercial consumers too 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, financial return is best for those who pay more expensive rates, which are residential and commercial low voltage consumers. In this way, the financial attractiveness of investments in DG increased, especially in these segments. However, this pioneer and greater autonomy of the consumer in front of the energy distribution companies has generated reactions. Debates in public hearings and events have to create contrary pressures from the distribution companies front to the Federal government in relation to advance of the net metering model.

The investor 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 to be used in electricity bill deduction. Several PV system incentives, if implemented, would bring advantages to consumers that are currently connected to discos in the sense that the levelled generation cost (i.e. 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 financing conditions and tax incentives on equipment, assembly and installation [33].

REVISION OF THE REGULATORY FRAMEWORK OF THE GENERATION DISTRIBUTED TO 2020

It´s important to highlight that the growth of micro-generation and mini-generation participation should not be analyzed as a mere diversification of the electric matrix. 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 technological transition is taking place that will effects the electric sector in its different spheres [34].

In 2017, Federal government [35] began a process of broad regulatory reform in the Brazilian electric sector 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.

According to current regulations (Table 1), in Brazil, all the excess amount of energy injected into the distribution network by the prosumers. Thus, the difference between generation and its own consumption during the day, in a period of one month, will be used to discount in payment of future electricity bills through net metering. So the discount of the injected energy occurs at the full rate, disregarding the electric grid costs incurred by distribution companies and the other non-energy components. In the end, electric grid costs will be apportioned by the other consumers who had no interest or mainly resources to install a DG power plant.

Since 2018, ANEEL [36, 37] has been conducting a public consultation on the revision of the current regulatory framework in relation to DG for approval in 2019 and will be in force from 2020. This may result in advances in relation to the benefits of DG for the prosumers or in regression because of the pressure of distribution companies. 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.

Tariff and Sectorial Charges in Electricity Bill Payment

Currently, the Federal government taxes about electric energy are electricity sector charges and Tariff of the Use of the Distribution System (TUSD). The sector charges are created by laws approved by the National Congress to make feasible the implementation of Government policies for the electric sector. Their values are contained in resolutions or orders of ANEEL and are collected by distribution companies through the energy bill. Each of the charges is justifiable, but taken together, impact the consumer's tariff and payment capacity [38].

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 sector charges related to this tariff process are described in Table 5. TUSD is a legal charge of Brazilian electric sector. It focuses on the consumers connected to the electrical systems of the distribution concessionaires to remunerate the provided service of energy transport (use of the electric network). According to ANEEL [35], the current percentage composition of the energy account in relation to TUSD and sector charges is presented in Table 6.

Table 5. 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

Table 6. Federal Electricity Tariff Composition in Brazil.

<table>
<tr><td rowspan="6">Tariff Components</td><td rowspan="4">TUSD</td><td>Wire A (Transmission)</td><td>6%</td></tr>
<tr><td>Wire B (Distribution)</td><td>28%</td></tr>
<tr><td>Charges</td><td>8%</td></tr>
<tr><td>Electrical Losses</td><td>8%</td></tr>
<tr><td rowspan="2">TE</td><td>Energy Consumption</td><td>38%</td></tr>
<tr><td>Sectorial Charges</td><td>12%</td></tr>
<tr><td></td><td></td><td>Total</td><td>100%</td></tr>
<tr><td colspan="4">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</td></tr>
</table>

In addition to federal taxes, some Municipalities have public lighting taxes and all States of Brazilian federation have a Tax on Operations related to the Circulation of Products and Provision of Services (ICMS). There are also the tariff flags that are applied by the Federal Government. The power account can't be zeroed because there´s a minimum tax to connect to electric grid. Tariff flags are a system that signals to consumers the actual costs of electric power generation. The operation is simple: Flags colors (green, yellow or red) indicate whether the energy will cost more or less depending on the conditions of electricity generation. 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 hydrological conditions for power generation are favourable and there is no addition in the accounts. If the conditions are a little less favorable, the Flag becomes yellow and there is an additional charge, proportional to consumption, at the rate of R$ 1.00 per 100 kWh (or its fractions). Even under unfavorable 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 [39].

Proposals for Changes to the GD Regulatory Framework

Currently, the discount in the electricity bill is almost total. It 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 development of new business faster. The installation of batteries connected to consumer units with DG could be one new business.

In 2018, ANEEL [36, 37] developed 6 possible alternatives scenarios (Figure 1) for updating the legislation regarding TUSD tariff charges and sector charges for DG from 2020.

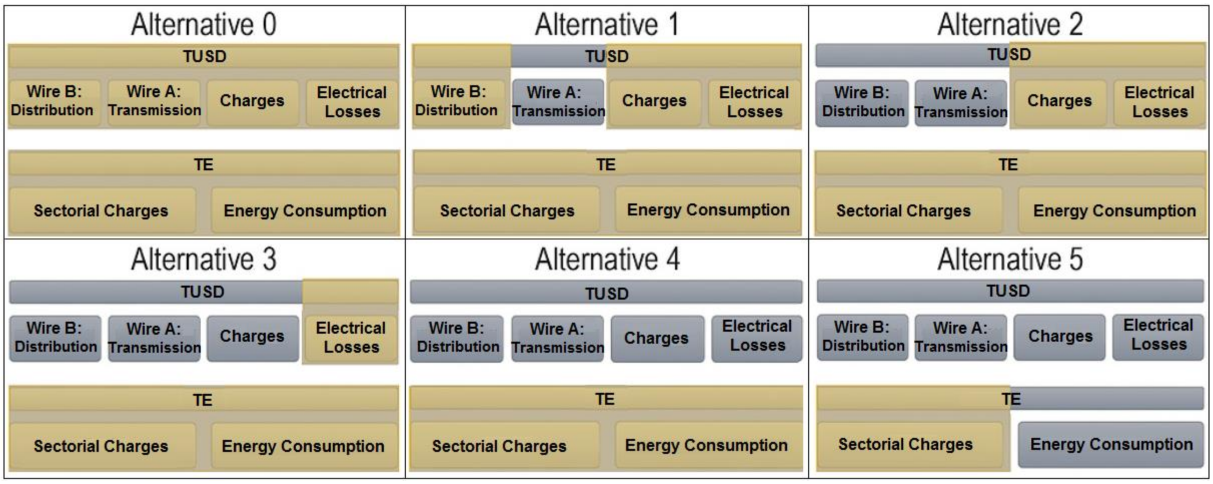

Figure 1. Six alternatives for Reform of DG Regulatory Framework in Brazil [37]. Adapted.

Alternative 0. There is the current net metering system is maintained with full rate. In this way, the equivalent of 100% of the energy produced is compensated in the electricity bill, but the bill is not even zeroed because there is a distribution grid minimum connection fee.

Alternative 1. There is a partial transfer of the TUSD to the prosumer through partial collection of the use of the wires. However, it is maintaining the exemptions related to charge and losses of the TUSD and to the sectorial charges of energy. In this way, there would be a charge for the transportation of distribution of the energy produced (TUSD Wire B), which would represent o lost on average 28% energy produced and the prosumer could compensate in electricity bill the equivalent of 72% of the energy produced. The payment of distribution grid minimum connection fee is maintained.

Alternative 2. There's a partial transfer of the TUSD to the prosumer through full collection of the use of the wires. However, it is maintaining the exemptions related to charge and losses of the TUSD and the energy sector charges. In this way, the transmission of the distribution (TUSD Wire B) and transmission (TUSD Wire A) of the energy produced would be charged, which would represent o lost on average 34% of the energy produced and the prosumer could compensate the equivalent of 66% of the energy produced in the electricity bill. The payment of distribution grid minimum connection fee is maintained.

Alternative 3. There´s a partial transfer of the TUSD to the prosumer through full collection of the use of the wires (distribution and transmission) and charges. It is maintaining the exemptions related to TUSD losses and the energy sector charges. This would represent o lost on average 42% energy produced and the prosumer could only compensate in electricity bill the equivalent of 58% of the energy produced. The payment of distribution grid minimum connection fee is maintained.

Alternative 4. There´s a total transfer of TUSD (the full charge of wire usage, sector charges and losses) to the prosumer, while maintaining exemptions from the energy sector charges. This would represent o lost on average 50% of energy produced and the prosumer could only compensate in electricity bill the equivalent of 50% of the energy produced. The payment of distribution grid minimum connection fee is maintained.

Alternative 5. There´s a total transfer of TUSD to the prosumer (full charge of wire usage, sector charges and losses) and energy sector charges. This would represent o lost on average 62% energy produced and the prosumer could only compensate in electricity bill the equivalent to 38% of the energy produced. The payment of distribution grid minimum connection fee is maintained.

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 revision of REN N^{o} 482/2012.

With the publication of AIR, there was a first bottleneck of these proposals by ANEEL. For the generation by the load, it was proposed initially 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]:

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 kW. Already for the remote DG, two triggers were suggested: the first, of 1,250 kW, would trigger the alteration of the compensation for Alternative 1; and the second, of 2,130 kW, 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 REVIEW REGULATORY FRAMEWORK

It´s observed that in 5 of the 6 scenarios there would be a reduction of the current benefits for future prosumers from 2020, and the losses in the compensation value of the produced energy vary between 28% and 63%. This would directly impact the reduction of the pay-backs of the DG projects. 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). ANEEL also considers maintaining alternative 0 until installed capacity of DG reaches 3,360 kW. The ANEEL changes in the rules of distributed generation 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 legal concept of "acquired right" to the current benefits of net metering.

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

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

Opportunities

It was verified that the DG market began to grow after the edition of REN Nº 482/2012, but it emerged consistently after REN Nº 687/2015 (Tables 2 and 3). ABSOLAR [40] defends the interests of the companies of solar energy productive chain. According to ABSOLAR [41] 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 too early to reduce the tariff benefits of net metering, since currently the prosumers don´t represent even 1% of the total consumers of 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. So there is an opportunity for them to start offering new smart services aggregated to DG and to prepare for others future demands that smart grids and the internet of things will bring.

Current Brazilian electrical grid still requires many investments and improvements and the evolution of DG market is an opportunity that can favor the use of batteries in homes, smart grids and internet of things (IoT). This will be a second stage of market development for prosumers and distribution companies.

Risks

Currently, the Brazilian electricity sector 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 economic-financial imbalance, it is possible that they will judicially cover government compensation.

The impact of the continuous and robust growth of DG will gradually lead to a reduction in the income of distribution companies. Federal and state governments will tend to suffer a reduction in tax revenues. However, the impact of lower electricity costs 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.

CONCLUSION

The results obtained in this paper confirms the growth of the DG market in Brazil, the divergence of interests between energy distribution companies and prosumers and the existence of 6 scenarios for the DG from 2020, in which 5 scenarios the current benefits of the prosumers are reduced.

The current regulations support the growth of the PV solar energy market in Brazil. However, the review of legislation expected to happen in 2020 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 DG's benefits for prosumers, so much so that in 5 of the 6 scenarios presented the trend is to reduce benefits.

ANEEL regulations periodically are reviewed and updated in an attempt to induce a growth of the photovoltaic solar energy market in Brazil. Existing regulations could be improved to: reduce or exempt equipment fees from solar photovoltaic DG as well as provide government incentives; enabling consumers to enjoy greater benefits by allowing surplus energy to be sold to the distributor or to the free market; exempt taxes for non-profit institutions; and 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 and better financing conditions in the implementation of DG systems in the residential, commercial and industrial markets, as well as 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 on the DG's benefits to prosumers, which may have negative effects on their expansion.

Current national legislation needs revisions 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 asymmetry of power of pressure on the issue of divergence of interests between consumers / prosumers and distribution companies. One of the few legal provisions that ensure the rights of current prosumers is the consolidated legal concept of "acquired right", since the projects and contracts of DG already in place will not be prejudiced in relation to regulation changes because there is no retroaction of laws. Potential changes in the regulatory framework may also represent new risks and opportunities for GD mechanics.

In this context, further studies in the area of DG are a strategic action, as it will contribute to the evolution of the electricity sector and the electricity consumer market.

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NOMENCLATURE

ABSOLAR – Brazilian Photovoltaic Solar Energy Association
ANEEL – National Electric Energy Agency

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
FIT – Feed-in Tariffs
ICMS – Imposto sobre Circulação de Mercadorias e Prestação de Serviços
IoT – Internet of Things
IRENA – International Renewable Energy Agency
MME – Ministry of Mines and Energy
MP – Provisional Measure
ONS – National System Operator
P&D – Research and Development
PEE – Energy Efficiency Program
PPA – Power Purchase Agreement
PROINFA – Incentive Program for Alternative Energy Sources
PRODIST – Procedures for Distribution of Electric Energy in the National Electric System
PV – Photovoltaic
REN – Normative Resolution
TFSEE – Inspection Fee for Electric Energy Services
TUSD – Distribution System Use Tariff

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