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Case Study of the Impact of New Brazilian Legislation in the Year 2023 on the Economic Feasibility of Photovoltaic Microgeneration: Homes in the City of Fortaleza

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Abstract: More than two-thirds of the installed solar power in Brazil comes from distributed mini-generation and microgeneration (DMMG), mostly residential and for local self-consumption of solar PV. DMMG had its legal framework approved in 2022, gradually introduces charges for distribution network use, previously exempt. To understand these implications, this article compiles recent legislative and normative changes, particularly for solar PV DMMG projects. In addition, the present study focuses on the use of DMMG systems in the city of Fortaleza in the Northeast Region. The study includes an analysis of the integration of photovoltaic plants in homes in Fortaleza and their economic viability under the new conditions established after 2020. Two residential photovoltaic systems, with varying power levels common in the residential sector of Fortaleza, were studied. Each plant underwent three analyses: one with vested rights; another with 100% taxation of FIO Bl and a third for the current scenario, factoring in the growing FIO B charge from 15% in 2023 to 100% in 2029. Customers who obtained the system by cash payment or financing were considered. An economic feasibility study factored in a 5.79% yearly inflation rate and an 11.35% annual tariff readjustment across the two plants, including sensitivity analysis for this variable.

Keywords: photovoltaic energy; economic analysis; residential sector; Law 14300/2022; FIO B

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1. Introduction

The increase in the demand and consumption of energy is an aspect that impacts the energy sector. Recent research highlights a noticeable uptick in energy demand, particularly attributed to the economic resurgence in developing nations. This trajectory indicates a probable shift in the upcoming years, wherein energy consumption in developing countries is poised to surpass that of developed nations, fueled by enhancements in socioeconomic indicators within these regions [1]. The drive for sustainability has led to the implementation of carbon caps and, significantly, advancing ambitious renewable energy goals. The global electricity sector is changing due to rise of renewable energy resources, and the importance of distributed generation (DG) systems, such as solar and wind systems, is growing in society, as is the importance of energy storage [2].

Solar energy has the potential to play a crucial role in energy production and cost-effectiveness of energy. Photovoltaic modules were analyzed and developed, considering new concepts of performance characteristics, longer service life and high reliability for market launch [3]. The issue of self-consumption of electricity has increased due to changes in the global energy market and government policies. The energy generated by local photovoltaic and hybrid photovoltaic–wind systems is enough to supply small to large powered systems, reducing electricity price and tariff rates [4,5].

Solar energy accounts for 2.5% of the Brazilian electricity matrix, indicating its growth over the years. Photovoltaic solar generation in Brazil encompasses medium- and large-scale plants participating in the regulated market and the free energy market, as well as distributed microgeneration and mini-generation (DMMG), from which power is injected into the distribution grid, and off-grid DMMG [6].

DMMG connected to the grid is almost entirely composed of solar panels, accounting for about 99% of installed capacity in 2022. The profile of DMMG in Brazil is predominantly residential for self-consumption. Approximately 77% of installed capacity is related to generation and consumption within the consumer's own unit, while 23% is attributed to remote self-consumption. In terms of consumption, approximately 37.4% of capacity corresponds to industrial consumption, 26.4% residential, 15.7% rural, 7.5% public, 6.8% energy sector, 5.9% agriculture and livestock and 0.3% transport [7]. Considering photovoltaic generation connected to the grid of the National Interconnected System (NIS), in May 2023, DMMG accounted for 10.8% of installed capacity in NIS, while other photovoltaic solar ventures accounted for 4.1%. Thus, the contribution of photovoltaic solar energy was approximately 15%, trailing only behind hydroelectric power. This positions solar energy as the second largest source in terms of installed capacity in NIS, with a forecast to reach around 24.6% by the end of 2027 [8].

Over time, it has been observed that the dynamics of the photovoltaic solar energy market frequently involve the introduction of various economic incentives, discounts and other benefits. These incentives may evolve, diminish, or be modified as technology advances, new projects are implemented and the market stabilizes. As presented in the work by Kılıç and Kekezoğlu [9], China is the only country in the world that has implemented all incentive models for photovoltaic solar energy. Its most successful policy is the portfolio standards incentive. The USA also stands out for effectively applying this same incentive system. Both countries are leaders in the development and implementation of photovoltaic technology in their energy matrices. This demonstrates that, although current incentives and benefits are more focused, categorized and specific, the local markets in these countries are already well established.

According to the regulations in force in Spain, as analyzed by Vargas-Salgado, Aparisi-Cerdá, Alfonso-Solar and Gómez-Navarro [10], one of the major limitations to reducing the levelized cost of energy (LCOE) for photovoltaic systems is the restriction on selling energy when revenues exceed purchases. The analysis also revealed that implementing a Net Metering system could reduce the return on investment by a third. In the study conducted by Benalcazar, Suski and Kaminski [11], which analyzed the effects of financial incentives and subsidy policies on 90 households in a subtropical rural region with an average solar irradiation of 5.75 kWh/m^2/day, it was found that these financial incentives applied to renewable energy technologies lead to a reduction in both the total life cycle costs (TLCC) and the levelized cost of energy (LCOE) of the systems.

DMMG began to gain traction in the electricity market from 2012, with ANEEL Regulatory Resolution No. 482/2012 [12], which regulated these systems in Brazil, along with rules for their connection to the National Interconnected System (NIS) and the establishment of the Net Metering System (NMS), which established conditions and rules for the subsequent compensation of electricity credits injected into the grid. Since then, several regulatory adjustments have been made, culminating in the most recent one in 2022, when PL 5829/2019 was enacted as Law No. 14.300/2022 [13], which established the legal framework for DMMG.

De Doyle et al.'s [14,15] and Costa et al.'s [16] analysis delves into the scenarios both pre- and post-regulatory changes for distributed generation (DG) proposed in 2019. They assess the financial impact and associated risks for investors at both regional and national levels. Specifically focusing on residential generation (up to 75 kW), the study targets a market segment highly susceptible to financial fluctuations due to its short-term perspective and limited resource availability. The study indicates a statistically significant reduction in the economic viability of solar DG units under the proposed new regulation. This change results in an increased payback period and a decrease in other financial indicators across all analyzed regions. Additionally, the study confirms that solar radiation is not the decisive factor in determining the economic viability of solar DG production. Iglesias and Vilaça [17], compared Law No. 14.300/2022 with the previous regulation, finding that the new law negatively impacts economic viability for prosumers. The increased payments under the Net Metering System reduce investment interest and lessen the economic impact on distribution companies. Conversely, reducing the amount paid in the Net Metering System boosts consumer interest in DG investments but leads to greater market losses for distribution companies.

Certainly, it seems that the final version of Law No. 14.300/2022 introduces new considerations that were not addressed in the article by De Doyle et al. [14,15]. Therefore, this article begins by presenting data and aspects of the global and Brazilian solar markets, aiming to contextualize and demonstrate the relevance of specific legislation for distributed microgeneration and mini-generation in a scenario of exponential growth. Subsequently, the main fiscal incentives applied to the solar market are outlined. Finally, the significant changes in the rules applied to distributed microgeneration and mini-generation are presented, from Regulatory Resolution No. 482/2012 to the publication of Law No. 14.300/2022 and ANEEL Regulatory Resolution No. 1.059/2023 [12,13,18]. In this context, the cases of photovoltaic solar energy integration in homes in Fortaleza were analyzed, and an economic analysis study was conducted for this investment, considering the acquisition of the photovoltaic solar energy system either outright or through bank financing, taking into account acquired rights, customers who adhered in 2023 (law transition period) and customers who adhere with 100% of the FIO B charge, thus demonstrating the feasibility of investing in a photovoltaic solar system for the residential sector.

2. Growth of Solar Energy in Brazil

It is important to highlight that the growth of photovoltaic (PV) solar energy participation in Brazil follows a global trend and can be justified by various factors, the most notable of which is the reduction in the cost of PV solar energy projects. A study presented by IRENA [19] illustrates the exponential decrease in the average levelized cost of electricity (LCOE) of solar projects worldwide. The average LCOE varies from 0.445 USD/kW/h in 2010 to 0.049 USD/kW/h in 2022, a reduction of about 89%. In Brazil, the average price of PV modules in 2021 will be 66% lower than the average annual price in 2013, with several other countries experiencing similar price reductions over the same period [19].

In a context where energy crises occur in various countries, whether due to climatic or geopolitical reasons, resulting in increased fuel and electricity prices, photovoltaic (PV) solar power generation has been increasingly important in terms of cost competitiveness. In addition, the ongoing energy transition and the need to replace fossil fuels with renewable energy sources have spurred government action backed by popular demonstrations, and vice versa. In this sense, consumer behavior also plays a crucial role in the adoption of renewable energy technologies and may have contributed significantly to the widespread adoption of photovoltaic solar energy worldwide, including in Brazil, especially DMMG.

DMMG and other distributed energy resources (DERs) exhibit characteristics of exponential technologies (ETs). According to De Almeida, Rodrigues and Gama [20], ETs follow the 6 Ds, namely, Digitization, Deception, Disruption, Demonetization, Dematerialization, and Democratization. Digitization occurs when the ET becomes scalable; deception is when developers of ETs feel that progress falls short of expectations, usually due to initial barriers encountered in the development of any disruptive technology. Disruption occurs when the traditional market begins to be impacted and even overtaken by the ET. The next phase is demonetization, characterized by a significant reduction in prices, culminating in the democratization of the ET.

In summary, the first point is that, as highlighted by De Almeida, Rodrigues and Gama [20], the electricity industry represents a potential market for the emergence of exponential technologies due to the massive electrification of society. The second point is that in recent years, in addition to technological advances in distributed energy resources (DERs) and the reduction of equipment costs, issues such as the pursuit of energy security, a more renewable electricity matrix and societal debates on the topic have laid the groundwork for this expansion. Finally, when the traditionally monopolized Brazilian electricity market allowed consumers to also become producers through Regulatory Resolution No. 482 of April 17, 2012, ANEEL [12], the solar energy market in Brazil began to grow exponentially.

Figure 1 shows the installed capacity of distributed microgeneration and mini-generation (DMMG) in Brazil from 2013 to 2022, according to data provided by the Energy Research Company [7]. It also presents the projected expansion from 2023 to 2027, according to the National Electric System Operator [8]. To better illustrate and discuss this point, two curves were fitted to the data: the red curve represents an exponential curve, while the second curve represents a logarithmic curve. Between 2013 and 2022, the year of the approval of the legal framework of the DMMG [13], the installed capacity of the DMMG grew exponentially. From 2023, according to the ONS expansion estimates until 2027, the growth curve will be attenuated, showing a logarithmic trend, indicating a stabilization in the coming years.

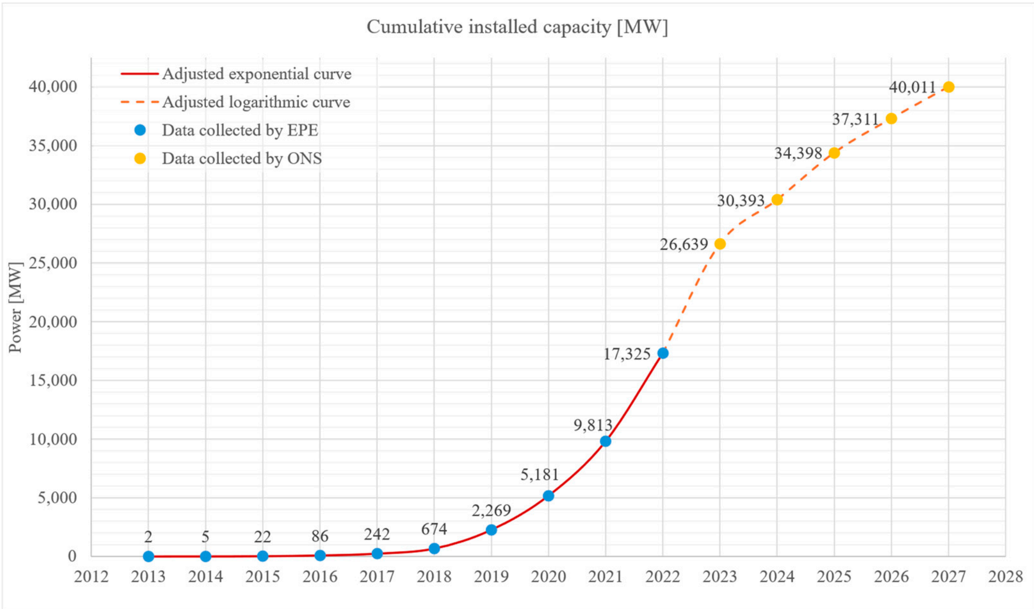

Figure 1. Evolution of cumulative installed capacity of DMMG in MW with exponential growth trend. Source: adapted from EPE [7] and ONS [8].

In summary, solar photovoltaic technologies have become a more accessible and cost-effective option for electricity generation. They are driving the global transition to renewable energy sources and transforming the consumer–producer into a new player in the electricity sector.

DMMG's exponential growth in Brazil can be attributed to several variables. These include changing consumer behavior and increased awareness of using renewable energy. In addition, economic issues such as high electricity tariffs in the country, along with government incentives for renewable energy generation and the decreasing cost of these technologies, play a significant role. DMMG, especially photovoltaic and other related technologies, have proven to be exponentially popular and effective.

3. Specific Incentives for DMMG

This section summarizes the fiscal incentives applied to distributed microgeneration and mini-generation (DMMG) based on the works of Amaral, Büttenbender and Thesing [21], Mitsuhashi and Blanchet [22] and additional readings of related legislation and resolutions. Regarding the captive market of low voltage, conventional group B, Table 1 presents the tariff composition of the electricity bill Amaral, Büttenbender and Thesing [21]. The compositions that are highlighted in green represent taxes and fees that have received or have some kind of incentive for the solar photovoltaic (PV) generation in this market.

Table 1. Tariff composition of the electricity bill for low-voltage captive consumers (group B—conventional) in 2021.

Energy Tariff (TE)	Energy	Energy
	Transport	Transport Itaipu Basic Network Itaipu
	Losses	Captive Market Basic Network
	Charges	FCUWR—Financial Compensation for the Utilization of Water Resources SSC/REC—System Service Charge/Reserve Energy Charge R&D/EE—Research and Development/Energy Efficiency Energy Development Account (EDA)
Distribution System Use Tariff (DSUT)	Transport	High Voltage Wire (FIO A) Low Voltage Wire (FIO B)
	Losses	Techniques Non-technical BN/D Losses (Basic Network/Distribution) Unrecoverable revenues
	Charges	ESSF—Electricity Services Supervision Fee ONS RD/EE—Research and Development/Energy Efficiency EDA—Energy Development Account PROINFA
Taxes	Federal	PIS/Pasep and COFINS
	State	ICMS
	Municipal	CIP

In an abstract manner, the energy bill is composed of three main components: (a) the Energy Tariff (TE), which represents payment for the energy consumed and related costs, including fees, and can be considered as the product purchased; (b) the Distribution Use Tariff (TUSD), which represents the charge for delivering or distributing energy and is related to the use of the concessionaire's distribution network; and (c) taxes, which include federal, state and local taxes. Federal and state taxes are exempt for distributed microgeneration and mini-generation (DMMG) under certain conditions, as described below.

The FIO B is the designation to the one of the tariff components and refers to the use of distribution network, it was exempted from charges in April 2012 by Regulatory Resolution No. 482/2022 [12] and was also the main target of amendment in Law 14.300/2022. The tariff FIO B varies according to each energy distributor and depends on the taxes charged in the concession area and population density, meaning that locations with fewer consumer units (CUs) per square kilometer (km^2) will have higher rates, due to the total cost being shared among a smaller number of CUs. A survey conducted considering the 58 most relevant electric energy distributors in Brazil in 2021, as cited by Amaral, Büttenbender and Thesing [21], found that the FIO B component represented, on average, 30.8% of the tariff. Law 14.300/2022 [13] establishes criteria and a schedule for the collection of the FIO B, and in some cases this collection has already begun in 2023.

Regarding PIS/Pasep and COFINS, Law No. 13.169, dated 6 October 2015, [23], exempts the collection of these taxes on the active electrical energy supplied by the distributor, originating from the credits generated by the consumer unit, that is, exempts these taxes from the electricity bill of consumers participating in the Net Metering System.

> *"Art. 8. The rates of the Contribution to PIS/Pasep and the Contribution for the Financing of Social Security—COFINS, applicable to the active electrical energy supplied by the distributor to the consumer unit, are reduced to zero, corresponding to the sum of the active electrical energy injected into the distribution network by the same consumer unit with the active energy credits originated in the same consumer unit in the same month, in previous months, or in another consumer unit under the same ownership, according to the Net Metering System for microgeneration and distributed mini generation, as regulated by the National Electric Energy Agency—ANEEL."* (*translated from Portuguese*)

Regarding ICMS, ICMS Agreement 16, dated 22 April 2015, [24], enabled the exemption of ICMS on the amount of active electrical energy consumed from the grid. Initially, not all states adhered to the Agreement, but in 2018, the remaining states (Amazonas, Paraná and Santa Catarina) joined. ICMS is exempt as follows:

> *"[. . .] on the electrical energy supplied by the distributor to the consumer unit, in the amount corresponding to the sum of the electrical energy injected into the distribution network by the same consumer unit with the active energy credits originated in the same consumer unit in the same month, in previous months, or in another consumer unit under the same ownership, according to the Net Metering System established by Regulatory Resolution No. 482, dated April 17, 2012."* (*translated from Portuguese*)

In summary, solar DMMG projects initiated in 2024 will already be subject to the progressive charge of the B Wire; however, they will still have exemption from ICMS, PIS/Pasep and COFINS.

4. Distributed Microgeneration and Mini-Generation (DMMG) in Brazil: What Has Changed Since 2023

Distributed microgeneration and mini-generation (DMMG) began to gain space in the electricity market starting in 2012, with the Regulatory Resolution of ANEEL, No. 482/2012 [12], which regulated microgeneration and distributed mini-generation in Brazil, as well as rules for connecting these systems to the National Electric System (SIN), and the Net Metering System (SCEE), which established conditions and rules for the subsequent compensation of credits for electricity injected into the grid.

Subsequently, Resolutions No. 517, dated 11 December 2012 [25]; No. 687, dated 24 November 2015 [26]; and No. 786, dated 17 October 2017 [27], updated and evolved some important aspects regarding DMMG. Energy credits generated by a consumer unit could be offset by another consumer unit under the same ownership or business group. Furthermore, the power limit for micro- and mini-grids was updated; a maximum deadline for credit compensation was set; and key concepts such as multiple consumer units projects, shared generation and remote self-consumption were outlined. Finally, in 2022, Bill 5829/2019 was transformed into Ordinary Law 14.300/2022 [13,28], which instituted the legal framework for DMMG.

The first change was to update the installed power limit for microgeneration, which is now 3 MW for solar PV. The 75 kW installed power limit remains for micro-generation. Another important point is that distribution companies can now contract ancillary services from DMMG consumer–producers and buy their energy credits through public tenders.

More specifically, energy credits can now be traded, besides compensating for the active energy supplied from the distributor to the consumer unit. A consumer unit with DMMG supplied at high voltage, group A, may opt for billing in group B, provided that the sum of the nominal power ratings of the transformers does not exceed 112.5 kVA.

Article 36 of Law 14.300/2022 [13] additionally offers incentives to low-income consumers via the Social Renewable Energy Program (PERS), which seeks to invest in installing photovoltaic solar systems or other renewable sources for local or remote self-consumption under the Net Metering System. Financial resources for PERS will be obtained through the Energy Efficiency Program (PEE) and complementary sources. In this case, the participating consumer unit (CU) that is also part of any housing project, in any sphere of public administration, can negotiate energy credits not only with the concessionaire but also with the government. Law 14.300/2022 [13] also provides for the valuation of distributed generation (DG) benefits, both social and environmental, which opens the possibility for consumer–generators to obtain further benefits in the future.

Finally, the most impactful and discussed change regarding the legal framework is the gradual and progressive charging of the TUSD fee, previously exempt for DG with participation in the Net Metering System (NMS). Before 2023, consumer–producers could inject surplus energy into the grid and have active energy fully compensated in the form of credits without paying for the use of the distribution network. It is worth noting that CUs with DG and participants of the NMS existing on the date of publication of Law 14.300/2022, or that submitted an access request to the distributor within 12 (twelve) months counted from the publication of said law, i.e., until 6 January 2023, will still be exempt from the TUSD fee until 31 December 2045, according to Art. 26 of Law 14.300/2022 [13]. Only from this date will they be subject to the tariff rules established by ANEEL.

Moreover, Consumer Units (CUs) that submit an access request to the distributor between the 13th (thirteenth) and the 18th (eighteenth) month counted from the publication date of this Law, i.e., between 6 January 2023 and 6 July 2023, will still be exempt from the Distribution System Usage Fee (TUSD) until the end of 2030, as established by Article 27, § 2 of Law 14.300/2022 [13]. Consumer Units (CUs) that submitted access requests after July 6, 2023, will be subject to schedule for the application of the Distribution System Usage Fee (TUSD) as shown in Table 2.

Table 2. Schedule for the application of the Distribution System Usage Fee.

Starting from Year	TUSD [%]
2023	15
2024	30
2025	45
2026	60
2027	75
2028	90
2029	100

The exception applies to CUs with DG of power from 500 kW in the modalities of compensation in the NMS remote self-consumption and shared generation, when a single holder holds 25% or more of participation in the surplus electricity. In these cases, the total incidence of the TUSD fee comes into effect from 2028, as established by Article 27, §1 of Law 14.300/2022 [13].

Table 3 was constructed based on the research conducted by Amaral, Büttenbender and Thesing [21] and by Mitsuhashi and Blanchet [22] and further complemented through the examination of relevant legislation and resolutions. It highlights the main changes in the market following the enactment of Law 14.300/2022 [13] and Regulatory Normative Resolution 1.059/2023 [18].

Table 3. Main changes in DMMG and SCEE from Law 14.300/2022 (translated from Portuguese).

Topic	Before Law No. 14.300/2022	From Law No. 14.300/2022 and ANEEL Resolution No. 1.059/2023
Installed power	Distributed generation: greater than 75 kW and less than or equal to 5 MW and utilizing qualified cogeneration or renewable sources of electric energy.	Article 2, XXIX-B [18] Distributed generation: having installed power in alternating current greater than 75 kW and less than or equal to: (a) 5 MW for dispatchable source generating plants. (b) 3 MW for other sources not classified as dispatchable source generating plants; or. (c) 5 MW for consumer units already connected on January 7, 2022, or that submit a connection request for quotation [. . .], until 7 January 2023, regardless of the classification as dispatchable source generating plants.
Net Metering System (SCEE) [21]	Full compensation of all components linked to TUSD.	Some components are no longer compensated on a staggered and gradual basis.
Compensation modalities [22]	Shared Generation: "[. . .] characterized by the gathering of consumers within the same concession or permission area, through a consortium or cooperative, composed of individuals or legal entities, who have a consumer unit with microgeneration or distributed mini generation in a location different from the consumer units where the surplus energy will be compensated."	Article 2, XXII-A [18] Shared Generation: "[. . .] characterized by the gathering of consumers, through a consortium, cooperative, voluntary civil condominium or building, or any other form of civil association established for this purpose, composed of individuals or legal entities that own a consumer unit with microgeneration or distributed mini generation."
Availability cost [21]	In practice, charged doubly	It ceases to be charged doubly and the new rule applies
Procurement of ancillary services [21]	Not covered	Article 23 [13] Allows distributors, through a public call, to contract DMMG for ancillary services.
Exclusively by the distributor, in case of non-adherence to public calls. [21,22]	Prohibited	Article 24 [13] Possible through a public call by the distributor. "The electricity distribution concessionaire or permittee must promote public calls for the accreditation of interested parties to commercialize the surplus of power generation from de projects of micro-generators and mini generators distributed, in their concession areas, for the subsequent purchase of these surplus energies, in the form of regulation by ANEEL."
Hybrid systems and storage [21]	Not covered by legal provisions	There is legal provision for such systems.

Table 3. *Cont.*

Topic	Before Law No. 14.300/2022	From Law No. 14.300/2022 and ANEEL Resolution No. 1.059/2023
Valuation of Distributed Generation Benefits [21]	There is none.	There is provision for valuing the benefits of GD, and possibly consumer–generators will have some benefits.
Opinion on access [21]	Allowed for commercialization, although the practice is not encouraged.	Article 6 [13] Prohibited the commercialization of access opinions.
Transfer of CU ownership [21]	Allowed at any time, starting from the signing of the CUSD and the CCER.	Article 5 [13] Allowed after the request for inspection of the connection point to the distributor.
Performance Bond (PB) [21]	No need to provide guarantees	Article 4 [13] Projects exceeding 500 kW and less than 1000 kW, GFC of 2.5% of the connection budget, and with 1000 kW or more, 5% of the budget. The GFC is refundable. Shared generation and EMUC modalities do not require PB.
B option [21]	Not allowed to be a B option with mini-generation.	Article 292, § 3 [18] Allows a local self-consumption mode using transformers with power up to 112.5 kVA.
Incentive for low-income consumers [21,22]	Nonexistent	Art. 36 [13] Foresees the Social Renewable Energy Program (PERS) aimed at consumers in the low-income residential subclass.
Environmental and social attributes [21]	Not valued	Art. 28 [13] It is expected that valuation will occur and that consumer–generators will have some benefit.

5. Methodology

5.1. Study Site Mapping

In Brazil, in general, the months of January and February are responsible for the highest consumption; however, each region of Brazil has particular behavior. Figure 2 shows the electricity consumption of the Northeastern residential sector from January to November of the years 2020 and 2021, according to EPE data [7], this analysis serves to verify how the public under study behaves.

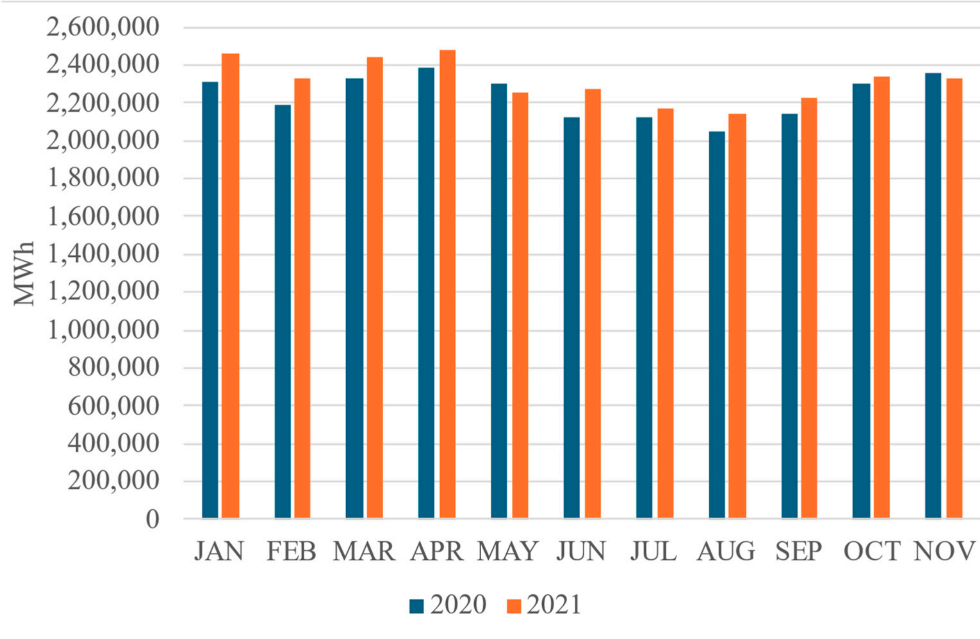

Figure 2. Monthly electricity consumption in the residential sector in the Northeast.

As can be seen in Table 3, with regard to installed power, the types of distributed generation have been reclassified to include both projects already in operation and those in the approval process and future projects. With regard to the Net Metering System, before the changes in the law all the values of the components relating to the TUSD were compensated, now some of them are not compensated in a staggered and gradual basis.

Regarding the compensation modalities, before the change it was more restrictive with regard to location and types of associations; however, after the change, it is broader and includes various forms of civil associations without restrictions on location. The availability cost will no longer be charged and will be regulated by the new rule. Procurement of ancillary services has been added and allows distributors, through a public call, to contract DMMG for ancillary services.

According to the changes in regulations, the distributor can now issue a public call to accredit those interested in selling surplus power generation under regulations by ANEEL. Hybrid systems and storage now are covered by legal provision. Valuation of DG benefits will be analyzed and possible consumer–generators have some benefits. Opinion access is now prohibited for commercialization.

Transfer of CU ownership will also be regulated, requiring a prior request for inspection of the connection point from the distributor. Finally, the rest of the changes listed Performance Bond, B option, Incentive for low-income consumers and Environmental and Social attributes that were previously unregulated or did not exist, are now governed by the different Articles specified in Table 3.

5.2. Generation of Photovoltaic Plants

The power generation of a photovoltaic generation system is monitored through the monitoring portal, made available by the manufacturer of the inverter/microinverter present in the solar plant. Normative Resolution No. 482/2012 [12] determines that consumer units (CUs) with generation along with the load, that is, the consumer unit located in the same environment where the photovoltaic system is installed, must be used to offset consumption of the generating CU, and if there is excess energy, it can be stored as credits that remain valid for up to 60 months.

ANEEL's Generation Information System (SIGA) provides all the data related to Brazil's generation capacity, allowing to access the matrix information according to the source. For the present study, it is necessary to extract data from the distributed generation of photovoltaic systems. In Figure 3, it is possible to observe the adherence of consumers from the residential class of Fortaleza who have chosen to adhere to the insertion of photovoltaic systems in their homes. This data refers to nine thousand consumers. The graph also shows the power range (kWp) that these consumers have adhered to.

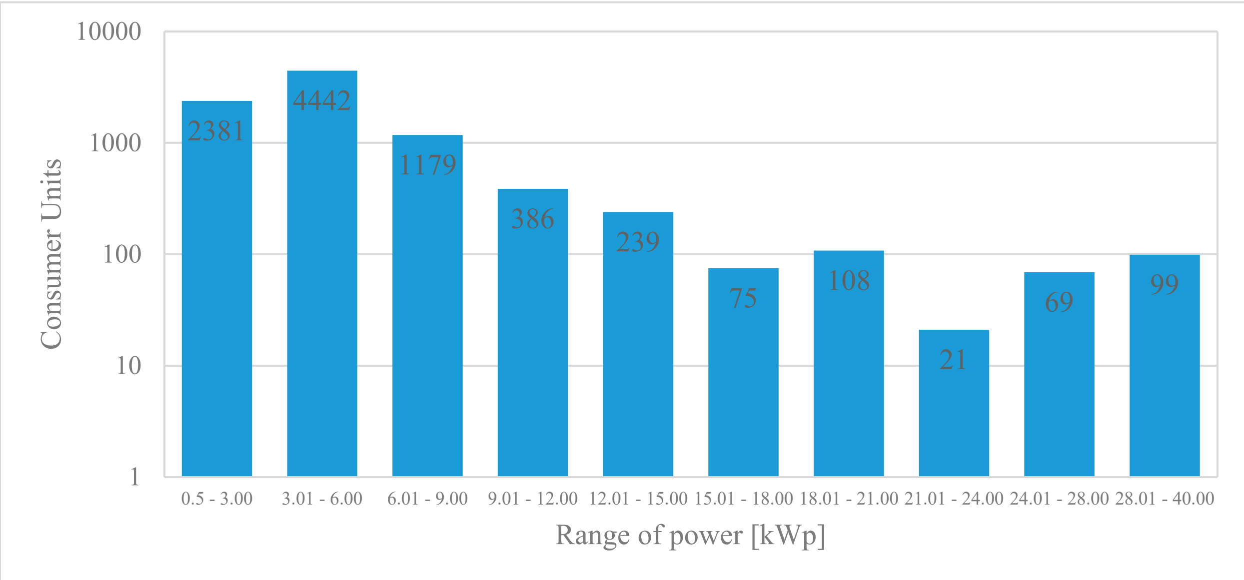

Figure 3. Residential-class consumers in Fortaleza and system power range.

In Figure 3, the separation of this number of consumers by the power range of the chosen system was adopted, with this, it can be seen that most of the public under study opted for the power range between 3.01 kWp to 6.0 kWp. With this, this range is the most common for the residential class public in Fortaleza. The study conducted was based on 3 scenarios of residential consumers with power in the range of the most consumer adherence. The first photovoltaic plant has characteristics described in Table 4. Plant 1 is a residence that needs a monthly generation of 518 kWh, consisting of 12 modules of 330 Wp and using 3 micro-inverters from the manufacturer Hoymiles; the system has a power peak of 3.96 kWp, and its price is R$20,000.00 in cash.

In Table 4 is also described Plant 2, which has an average monthly consumption of 722 kWh; this plant has ten modules of 550 Wp and 3 micro-inverters from the manufacturer DEYE, with a peak power of 5.5 kWp, and the price of the overall system is R$26,000.00 in cash. The prices of the TUSD and TE components for the residential sector, for the conventional B1 group, in which the TE is equivalent to R$0.38576/kWh and the TUSD to R$0.53994/kWh.

Table 4. Technical characteristics of the photovoltaic plants.

	Plant 1	**Plant 2**
Price	R$20,000.00	R$26,000.00
Local	Fortaleza-Ce	Fortaleza-Ce
Number of modules	12	10
Module power (Wp)	330	550
Qty. of inverters	3	3
Brand of inverters	Hoymiles	Deye
Rated power (kW)	3.6	4.8
Peak power (kWp)	3.96	5.5
Estimated monthly generation (kWh)	518	722

An economic feasibility study was carried out in the two plants under analysis, observing the behavior of these plants according to each scenario, with acquired rights (without charging the FIO B), with the taxation of FIO B (100% of this rate) and for the transition period (staggered payment of the FIO B fee until reaching 100% in 2029), and these comparisons were also made considering the payment method (cash or financing).

5.3. Economic Viability

The first step in analyzing the feasibility of an investment is to consider its economic aspects. Understand whether the investment is profitable and, if there are several possibilities, which one is the most profitable. The economic parameters of the decision are determined in this step. Two criteria to be considered are the financial and the uncertain, the financial referring to the availability of resources to carry out the investment, and the uncertain referring to the repercussions that cannot be easily converted into monetary terms [29].

Investment analysis refers to an assessment of the economic viability of investments, built in a context that encompasses a series of parameters, criteria and objectives. The biggest challenge concerns the interpretation of future occurrences. Cash flow is the primary financial statement tool, aiming to forecast all financial resource inputs and outputs for future periods. It indicates the projected cash balance for the specified period [30].

Gross revenue covers the total revenue arising from the core activities of the company, this gross revenue can be defined as all the input of resources that matches the activities for which the company was created. To understand the gross revenue formula, simply multiply the price of products and services that a company offers and multiply by the quantity of goods sold. Additionally, the investment and equity amortization over a period of 25 years, representing the average useful life of the solar energy system, must be discounted. To analyze these financial statements, the following methods will be applied: payback and net present value (NPV).

5.3.1. Payback Method

In order to analyze the economic impact of Law 14.300/2022 [13], in comparison with the current scenario, the payback of investments in both scenarios was analyzed. This indicator shows the time in which the accumulated economy exceeds the value of the initial investment. For the study, the compound payback was used, considering an annual adjustment rate of 11.35%, since this was the average value for the tariff adjustment in 2022.

Despite Law 14.300/2022 [13], having a transitional period of 6 years after its approval, in the analysis, the transition scenario was considered, as well as the time after the transition period, that is, where 100% of FIO B should be charged. With this, the extremes between the economic impacts and the current pricing model were analyzed.

Payback is the period required to recover the initial investment [31]. This methodology assesses the estimated time needed to recover the initial capital investment, aiding in the evaluation of large projects.

The Payback, in addition to indicating the time for linking resources to a given project, also presents an auxiliary indicator for liquidity and risk: the shorter the payback, the lower the risk and the greater the liquidity of the project and vice versa.

To calculate simple Payback, one can simply use Equation (1):

$$\text{Payback} = \frac{\text{Initial investment}}{\text{Cash flow with investment gain}} \tag{1}$$

The decision rule for payback is outlined as follows:

(a) If the investment is repaid within the timeframe set by the investor, the investment project is approved.
(b) If the investment is not repaid within the timeframe set by the investor, the investment project is declined.

The Cash Flow considers the annual tariff adjustment, to find out when the customer would continue paying the energy bill without using photovoltaic solar energy each year and is also used to analyze the savings of this same customer during the same period with the use of the acquisition of the photovoltaic solar system, the flow being the difference between these two situations.

5.3.2. Net Present Value (NPV)

The net present value (NPV) is calculated by summing all cash flows, discounted to their present value, including the initial investment. Known as the discounted cash flow method, NPV compares the value of the investment to the expected returns, with all values considered in terms of the current moment [30]. The objective of NPV is to estimate all relevant cash flows for a project in present value terms. This involves estimating the present value of future cash flows and subtracting the initial investment. Mathematically, NPV can be calculated using Equation (2):

$$\text{NPV} = -\text{Investiment} + \left(\sum_{n=1}^{x} \frac{\text{ATn}}{(1+\text{i})^{\text{n}}}\right). \tag{2}$$

where:

NPV = net present value
ATn = after-tax cash flow in year n
i = attractiveness rate
n = project life in years
x = total analysis period in years

The NPV method follows a basic decision rule:

(a) If NPV > 0: The investment project is viable and accepted, as the returns will exceed the invested capital.
(b) If NPV = 0: The investment is neutral, as the returns will only cover the invested capital and the minimum return required from the investor, offering no additional gain.
(c) If NPV < 0: The investment project is rejected, as the returns will not cover the invested capital and the minimum return required from the investor.

For the discount or attractiveness rate, the 2022 inflation value of 5.79% p.a. was used, according to the Extended National Consumer Price Index (IPCA, in Portuguese).

5.3.3. Internal Rate of Return (IRR)

The Internal Rate of Return, is an analysis that indicates the profitability of the investment, indicates the rate of attractiveness that causes the net present value to be zero. That is, if the profitability is lower than the attractiveness rate, the investment will be disadvantageous for the customer. The IRR can be calculated by equating the net present value equation to zero:

$$NPV = -I_0 + \sum_{n=1}^{x} \frac{F_n}{(1 + IRR)^n} = 0. \quad (3)$$

NPV = Net present value (R$)
I_0 = Investment (R$)
F_t = Cash flow in the period (R$)
n = Generator lifetime (years)
IRR = Internal rate of return (% per year)

5.4. Sensitivity Analysis

The calculations to be made will be subjected to a sensitivity analysis according to the following parameters: in which there was a variation in the monthly interest rate of the financing by ±0.5%, as well as a reduction in the financing period to 36 months and a variation of ±7% in the annual tariff adjustment. On the other hand, for the customer who purchased the system by paying in cash, the analysis was carried out only in the variation of the annual tariff adjustment.

6. Results

The results reflect variations from the sensitivity analysis conducted, where key variables in the economic viability of the plants were adjusted. The interest rate varied by ±0.5% per month, the financing period was reduced to 36 months and the annual tariff adjustment varied by ±7% for both system types.

6.1. Variation of ±0.5% of the Interest Rate per Month of the Financing

All two plants were analyzed, only for consumers who subscribed to the system through financing, making this variation of ±0.5% in the monthly interest rate to verify the impact that this has on the investment payback period, or that is, if it is still a viable and attractive investment.

The value of the installment for plant 1, which is from the R$20,000.00 system, is R$655.33 per month, through the Santander bank platform, for an interest of 1.61% per month, with a variation of 0.5% both for more and for less, one can observe the certain results that can be seen in Table 5. The installment with interest of 2.11% p.m., results in an installment of R$755.33/month, already for the rate of interest referring to 1.11% p.m., results in an installment of 555.33/month.

It can be observed, as already expected, that in the analysis of 100% of the payment of FIO B by the consumer, it would be in the case that the payback period would have a greater increase. It is possible to notice that there was an average increase of one year for more or less. At Plant 1, with the usual interest rate of 1.61% p.m., a payback time of 7 years and 5 months was obtained for the acquired right, with the variation in interest at ±0.5% resulting in a payback of 8 years and 4 months and 6 years and 6 months, an average of 1 year of difference both for plus and minus.

The value of the installment for plant 2, which is from the R$26,000.00 system, is R$851.93 per month, for an interest of 1.61% per month, with the variation of 0.5% both for more and for less, one can observe the certain results that can be seen in Table 5. The installment with interest of 2.11% per month, results in an installment of R$981.93/month, already for the interest rate referring to 1.11% a.m., results in an installment of 721.93/month.

Table 5 presents the results for these variations made in the monthly interest rate, in plant 2, which has a peak power of 5.5 kWp, this presented in all analyses, whether acquired right, 100% of Wire B, or even the transition period, an average increase of 1 year more or less. It is the plant with the fastest payback time, in all analyses carried out, since the higher the energy bill, the faster it will be possible to obtain a return on investment.

Table 5. Interest rate changes in 5 years of credit.

	Plant 1		Plant 2	
Interest rate variation	+0.5%	−0.5%	+0.5%	−0.5%
		Vested Right		
Payback	8 years and 4 months	6 years and 6 months	7 years and 6 months	5 years and 10 months
IRR	28.59%	41.86%	32.95%	51.93%
NPV from the project	149,538.97	159,706.66	227,504.28	240,722.28
		100% FIO B		
Payback	11 years and 9 months	9 years and 3 months	9 years and 5 months	7 years and 4 months
IRR	18.88%	25.08%	24.55%	34.15%
NPV from the project	83,065.77	93,233.46	160,206.62	173,424.62
		Transition period		
Payback	9 years and 4 months	7 years and 3 months	8 years and 4 months	6 years and 5 months
IRR	25.11%	34.95%	28.92%	42.34%
NPV from the project	130,640.98	140,808.68	202,349.11	215,567.10

6.2. Reduction of the Financing Period to 3 Years

All two plants were analyzed, only for consumers who joined the system through financing, reducing the financing to 3 years, in order to analyze the impact that this provides on the return-on-investment period, that is, if it still remains a viable and attractive investment.

The value of the installment for plant 1, which is from the system of R$20,000.00 is R$877.55 per month, for an interest of 1.61% per month, making a decrease to 36 months in the financing period, it can be observed in the results on Table 6, and conclude that the results of the reduction of the financing period resulted in a decrease in the average time of return of the plant 1 in 1 year.

Table 6. Three years in financial credit.

	Plant 1	Plant 2
	Vested Right	
Payback	6 years and 6 months	5 years and 10 months
IRR	33.01%	37.72%
NPV from the project	159,680.63	240,688.34
	100% FIO B	
Payback	9 years and 3 months	7 years and 4 months
IRR	22.34%	28.59%
NPV from the project	93,207.44	173,390.67
	Transition period	
Payback	7 years and 3 months	6 years and 5 months
IRR	29.14%	33.32%
NPV from the project	140,782.65	215,533.16

Figure 4 shows, in a more didactic way, the turnaround time for plant 1 for the analysis of 100% of FIO B, that is, the assessment of the full value referring to this cost that makes up the TUSD. Through the figure, it is clear that there is a peak in expenses with the payment of energy plus the financing portion in the third year and that after the third year ends, costs already reduce; after that, it is already possible to verify the return on the investment made.

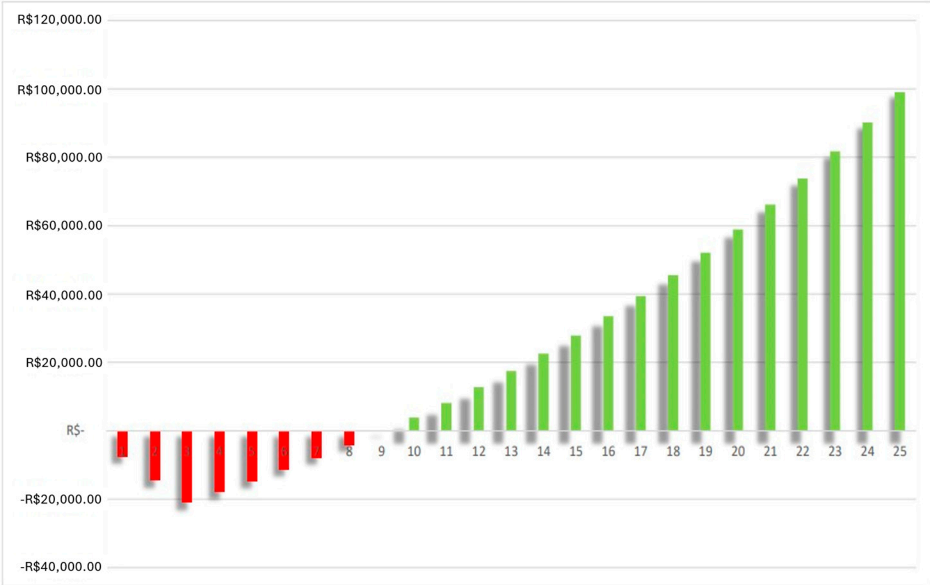

Figure 4. Plant 1 with 100% of FIO B and 3 years of financing.

The value of the installment for plant 2, which is from the system of R$26,000.00 is R$1140.82 per month, for an interest of 1.61% per month, making a decrease to 36 months in the financing period, it can be if we observe the certain results that can be seen in Table 6, and it is concluded that the results of the reduction of the financing period resulted in a decrease in the average time of return of the plant 1 in 1 year.

6.3. Variation of ±7% in the Annual Tariff Adjustment

All two plants were analyzed, for consumers who joined the system through the two payment methods that would be cash and financing, making this variation of ±7% in the annual tariff readjustment to verify the impact that this provides in the period return on investment, that is, if it is still a viable and attractive investment.

This variation was carried out in all analyses, in each plant, which would be for Vested Right, 100% of FIO B and transition period, and from these analyses we were able to verify what this variable represents for changes in the return time of the system. It is known that it is a fundamental variable with regard to payback, since cash flow is based on the value of savings, which would be the difference between what the customer would pay without solar energy for the amount that the customer would pay with solar energy, considering this annual data, so the tariff adjustment is necessary in this calculation.

Table 7 shows the results of all the analyses of plant 1, for Vested Right, 100% of FIO B and the transition period of Federal Law 14300/2022. These analyses are based on the variation of ±7% in the annual tariff readjustment, since the average readjustment of the electricity tariff for residential consumers in 2022 was 11.35%, according to ANEEL, the annual tariff readjustment was analyzed at 4.35% p.a. and 18.35% p.a. Table 7 presents the data based on the initial analysis of this work, it has an acquisition value of R$20,000.00, a discount rate (inflation) of 5.79% p.a., with a peak power of 3.96 kWp and for the analysis of the financing a monthly installment of R$655.33 over a period of 5 years.

Table 8 shows the results of all analyzes for Plant 2, for Vested Right, 100% of FIO B and the transition period of Federal Law 14300/2022. These analyzes are based on the variation of ±7% in the annual tariff readjustment, since the average readjustment of the electricity tariff for residential consumers in 2022 was 11.35%, according to Aneel, the annual tariff readjustment was analyzed at 4.35% p.a. and 18.35% p.a. It has the acquisition value of R$26,000.00, a discount rate (inflation) of 5.79% p.a., with a peak power of 5.5 kWp and for the analysis of the financing a monthly installment of R$851.93 over a period of 5 years.

Table 7. Plant 1 Annual tariff adjustment variation.

	In Cash		Financing	
	+7%	**−7%**	**+7%**	**−7%**
		Vested Right		
Payback	4 years and 4 months	5 years and 6 months	6 years and 5 months	9 years and 4 months
IRR	38.03%	24.20%	45.82%	21.72%
NPV from the project	476,971.06	61,008.59	463,655.10	47,692.62
		100% FIO B		
Payback	6 years and 1 month	8 years and 7 months	8 years and 7 months	14 years and 11 months
IRR	30.13%	16.52%	31.16%	11.90%
NPV from the project	301,194.37	32,356.17	287,878.41	19,040.21
		Transition period		
Payback	4 years and 10 months	6 years and 3 months	7 years	10 years and 9 months
IRR	35.47%	21.56%	40.18%	18.02%
NPV from the project	438,861.72	51,341.62	425,545.76	38,025.65

Table 8. Plant 2 annual tariff adjustment variation.

	In Cash		Financing	
	+7%	**−7%**	**+7%**	**−7%**
		Vested Right		
Payback	3 years and 11 months	4 years and 10 months	5 years and 10 months	8 years and 2 months
IRR	40.89%	27.01%	53.48%	26.36%
NPV from the project	707,599.23	93,580.08	690,288.42	76,269.27
		100% FIO B		
Payback	4 years and 11 months	6 years and 5 months	7 years and 1 month	10 years and 11 months
IRR	35%	21.23%	39.37%	17.57%
NPV from the project	529,645.39	64,572.29	512,331.58	47,261.48
		Transition period		
Payback	4 years and 4 months	5 years and 5 months	6 years and 4 months	9 years and 3 months
IRR	38.29%	24.36%	46.3%	21.98%
NPV from the project	656,759.02	80,726.79	639,448.21	63,415.99

7. Discussion

This section discusses the results for each plant after analyzing the different scenarios studied. By examining the parameters Payback, IRR and NPV, one can understand the economic viability, potential returns and overall performance of the investments in the plants.

According to the Table 5, it shows that changes in the interest rate directly affect the return time of the investment. If there were no exclusive financing for solar energy and interest rates were high, the investment could become unfeasible. However, the analyses indicate that the investment remains attractive despite these potential changes.

Through the analyses performed on the reduction of the financing time, Table 6, it was noticed that there was an average reduction of 1 year referring to the period of time of return of the study carried out for the period of 5 years. With this, it can be concluded that the financing time is also a very important variable and that it has a direct impact on the return on the investment made.

The results of Tables 7 and 8, which consider variations in the annual tariff adjustment, shows that higher adjustments make purchasing a photovoltaic solar energy system more viable due to a quicker return on investment. Conversely, an annual tariff adjustment of around 4.35% indicates that the project remains viable and that the investment is still attractive even with a moderate adjustment.

In the study carried out by De Doyle et al. [15], focusing on residential generation (up to 75 kW), where the impact of the proposed changes in DG regulations was analyzed, he obtained that before the proposed changes the IRR and NPV values for the case of the Northeast region, with a Payback of 9.88 years, were 18.03% and U$2189.27 (R$11,296.63 average exchange rate 2020) respectively. However, after the changes the IRR and NPV values decreased to 12.97% and U$1184.27 (R$6110.83 average exchange rate 2020) respectively, but the Payback increased by almost double 16.95 years, still being economically viable, but already putting investor interest in doubt.

Comparing the values after the change with the results obtained in this study, it can be seen that in the case of a +/−7% variation in the interest rate over a 5-year period, the consumer who would have the highest payback values would be 100% FIO B with a minimum of 6 years and 1 month if the payment was in cash and a maximum of 14 years and 11 months if the project was financed, this for Plant 1. However, for Plant 2, the 100% FIO B consumer obtained a minimum payback of 4 years and 11 months without financing and a maximum of 10 years and 11 months using financing.

However, in the investigation of De Doyle et al. [15], the Northeast was the region that showed the lowest economic viability due to low demand and low energy prices, but in the study presented here, for the city of Fortaleza located in the Northeast Region, under the right conditions and parameters of the project, there is economic viability and it remains interesting for people with sufficient financial means or possible investors.

In addition, comparing the value of the installments of the different scenarios analyzed with the average monthly income of people living in permanent private households in the state of Ceará, R$480.55 in the year 2021 according to the Institute of Applied Economic Research (IPEA in Portuguese) [32]. It can be inferred that due to financial limitations, investment in projects of this type would be limited to households with above-average monthly incomes.

8. Conclusions

The present study simulated three residential scenarios, with different consumptions, within the fixed of greater adequacy of the population under study in the city of Fortaleza. With this, we can verify that all scenarios are viable, since it has an attractive payback time, whether the consumer purchases the system in cash or through financing. The study, therefore, proved to be feasible in the State of Ceará, in the Northeast Region of Brazil, but precisely in the city of Fortaleza.

This work aims to demonstrate the benefits of integrating distributed generation in homes, as this class is the largest in the country. It includes a technical and economic analysis to highlight these advantages. Increased awareness and dissemination of the benefits for those choosing these actions are essential for their effectiveness. Additionally, the use of equipment and its replacement should be analyzed for their impact on demand.

In Brazil, the residential sector leads in installed photovoltaic generation capacity. Solar energy is rapidly advancing, emphasizing the need to diversify the energy matrix with alternative sources. This diversification ensures a more resilient system, not reliant on a single energy source. The focus is on expanding the energy matrix with renewable sources, thereby reducing CO_2 emissions.

As seen in the quantitative results, the changes made to the law under analysis have affected profitability by increasing the return on investment time, 14 years and 11 months with interest rate of −7% in the case of Plant 1 if a financed project. However, the sensitivity analysis shows that the variation in the interest rate is one of the parameters with the greatest influence on project profitability; as observed in Table 7, the Payback parameter could be reduced approximately 6 years if the interest rate changes from −7% to 7%, and the outlook for the future is that these interest rates will decrease. In the long term, it may be that the changes to the law will not prejudice the interest of people in investing in the implementation of DMMG photovoltaic systems.

With regard to the application of distributed generation, the importance of this study is clear, especially at a time when the world is turning to the debate on the depletion of energy sources, climate change caused by the emission of polluting gases and other issues related to the sustainability and environmental impact. In this scenario, it is emphasized that the current energy situation in Brazil is on alert, the need for studies that encourage the implementation of alternative energy sources becomes increasingly pressing.

Photovoltaic solar energy is a viable and profitable option for the residential sector in Fortaleza-CE, given its favorable geographical conditions. However, this regional advantage may also be a limitation of this study. Future research could explore case studies in cities with less solar radiation and varying average monthly incomes. In areas with lower solar radiation but higher average incomes, investing in solar energy may still be feasible. Conversely, in regions with lower average incomes compared to Fortaleza-CE, the investment may become unfeasible.

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References

1. Ferreira, A.; Kunh, S.S.; Fagnani, K.C.; De Souza, T.A.; Tonezer, C.; Dos Santos, G.R.; Coimbra-Araújo, C.H. Economic Overview of the Use and Production of Photovoltaic Solar Energy in Brazil. *Renew. Sustain. Energy Rev.* **2018**, *81*, 181–191. [CrossRef]
2. Ramos, D.S.; Del Carpio Huayllas, T.E.; Morozowski Filho, M.; Tolmasquim, M.T. New Commercial Arrangements and Business Models in Electricity Distribution Systems: The Case of Brazil. *Renew. Sustain. Energy Rev.* **2020**, *117*, 109468. [CrossRef]
3. Antoniolli, A.F.; Naspolini, H.F.; de Abreu, J.F.; Rüther, R. The Role and Benefits of Residential Rooftop Photovoltaic Prosumers in Brazil. *Renew. Energy* **2022**, *187*, 204–222. [CrossRef]
4. Rigo, P.D.; Siluk, J.C.M.; Lacerda, D.P.; Spellmeier, J.P. Competitive Business Model of Photovoltaic Solar Energy Installers in Brazil. *Renew. Energy* **2022**, *181*, 39–50. [CrossRef]
5. Rigo, P.D.; Siluk, J.C.M.; Lacerda, D.P.; Rosa, C.B.; Rediske, G. Is the Success of Small-Scale Photovoltaic Solar Energy Generation Achievable in Brazil? *J. Clean. Prod.* **2019**, *240*, 118243. [CrossRef]
6. Zuluaga, C.F.; Avila-Diaz, A.; Justino, F.B.; Martins, F.R.; Ceron, W.L. The Climate Change Perspective of Photovoltaic Power Potential in Brazil. *Renew. Energy* **2022**, *193*, 1019–1031. [CrossRef]
7. EPE. *National Energy Balance 2022: Base Year 2021*; EPE: Lagos, Nigeria, 2022.
8. ONS. *ONS Annual Report 2023*; ONS: London, UK, 2023.
9. Kılıç, U.; Kekezoğlu, B. A Review of Solar Photovoltaic Incentives and Policy: Selected Countries and Turkey. *Ain Shams Eng. J.* **2022**, *13*, 101669. [CrossRef]

10. Vargas-Salgado, C.; Aparisi-Cerdá, I.; Alfonso-Solar, D.; Gómez-Navarro, T. Can Photovoltaic Systems Be Profitable in Urban Areas? Analysis of Regulation Scenarios for Four Cases in Valencia City (Spain). *Sol. Energy* **2022**, *233*, 461–477. [CrossRef]
11. Benalcazar, P.; Suski, A.; Kaminski, J. The Effects of Capital and Energy Subsidies on the Optimal Design of Microgrid Systems. *Energies* **2020**, *13*, 955. [CrossRef]
12. ANEEL. Amends Normative Resolution No. 482, of 17 April 2012, and Modules 1 and 3 of the Distribution Procedures—PRODIST. Available online: https://www2.aneel.gov.br/cedoc/ren2012482.pdf (accessed on 12 February 2024).
13. Brazil Law No. 14.300, of 6 January 2022. Available online: https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2022/lei/l14300.htm (accessed on 12 February 2024).
14. de Doyle, G.N.D.; Rotella Junior, P.; Carneiro, P.F.G.; Peruchi, R.S.; Rocha, L.C.S.; Janda, K.; Aquila, G. Economic Feasibility of Photovoltaic Micro-Installations Connected to the Brazilian Distribution Grid in Light of Proposed Changes to Regulations. *Energies* **2021**, *14*, 1529. [CrossRef]
15. de Doyle, G.N.D.; Rotella Junior, P.; Rocha, L.C.S.; Carneiro, P.F.G.; Peruchi, R.S.; Janda, K.; Aquila, G. Impact of Regulatory Changes on Economic Feasibility of Distributed Generation Solar Units in Brazil. *Sustain. Energy Technol. Assess.* **2021**, *48*, 101660. [CrossRef]
16. Costa, V.B.F.; Capaz, R.S.; Silva, P.F.; Doyle, G.; Aquila, G.; Coelho, É.O.; de Lorenci, E.; Pereira, L.C.; Maciel, L.B.; Balestrassi, P.P.; et al. Socioeconomic and Environmental Consequences of a New Law for Regulating Distributed Generation in Brazil: A Holistic Assessment. *Energy Policy* **2022**, *169*, 113176. [CrossRef]
17. Iglesias, C.; Vilaça, P. On the Regulation of Solar Distributed Generation in Brazil: A Look at Both Sides. *Energy Policy* **2022**, *167*, 113091. [CrossRef]
18. ANEEL. Normative Resolution No. 1.059, of 7 February 2023. Available online: https://www2.aneel.gov.br/cedoc/ren20231059.pdf (accessed on 7 March 2024).
19. IRENA. *Renewable Power Generation Costs in 2021*; International Renewable Energy Agency: Abu Dhabi, UAE, 2022.
20. De Almeida Prado, F.A., Jr.; Rodrigues Da Silva, A.L.; Gama Viana, F. Tecnologias Exponenciais, Economia Comportamental e o Consumidor de Energia do Futuro. In: XXVI Seminario Nacional de Produção e Transmissão de Energia Elétrica. 2022. Available online: https://sinerconsult.com.br/ana-lucia-rodrigues-da-silva/fernando-a-de-almeida-prado-jr-ana-lucia-rodrigues-da-silva-fabiana-gama-viana-tecnologias-exponenciais-economia-comportamental-e-o-consumidor-de-energia-no-futuro/ (accessed on 8 July 2024).
21. Do Amaral, V.R.; Büttenbender, P.L.; Thesing, N.J. New Legal Framework for the Distributed Generation of Electric Energy in Brazil: An Approach to the Main Changes. *Informe GEPEC* **2024**, *28*, 440–461. [CrossRef]
22. Mitsuhashi, N.S.; Blanchet, L.A. Public Funding and Photovoltaic Solar Energy Based on Law 14.300/2022. *Prism. Jurid.* **2023**, *22*, 389–402. [CrossRef]
23. Brazil Law No. 13.169, of 6 October 2015. Available online: https://www.planalto.gov.br/ccivil_03/_ato2015-2018/2015/lei/l13169.htm (accessed on 12 February 2024).
24. Confaz Convention ICMS 16/15—National Finance Policy Council CONFAZ. Available online: https://www.confaz.fazenda.gov.br/legislacao/convenios/2015/CV016_15 (accessed on 12 February 2024).
25. ANEEL. Normative Resolution No. 517, of 11 December 2012. Available online: https://www2.aneel.gov.br/cedoc/ren2012517.pdf (accessed on 7 March 2024).
26. ANEEL. Normative Resolution No. 687 of 24 November 2015. Available online: https://www2.aneel.gov.br/cedoc/ren2015687.pdf (accessed on 7 March 2024).
27. ANEEL. Normative Resolution No. 786, of 17 October 2017. Available online: https://www2.aneel.gov.br/cedoc/ren2017786.pdf (accessed on 7 March 2024).
28. Câmara, S. Draft Law 5829/2019. Available online: https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2228151 (accessed on 27 April 2024).
29. Casarotto Filho, N.; Kopittke, B.H. *Investment Analysis-Manual for Problem Solving and Decision Making*; Atlas: São Paulo, Brazil, 2020.
30. Brom, L.G.; Balian, J.E.A. *Analysis of Investments and Working Capital*; Saraiva Educação SA: São Paulo, Brazil, 2007.
31. de Brito, R.P.; Brito, L.A.L. Competitive Advantage, Value Creation and Their Effects on Performance. *Rev. De Adm. De Empresas* **2012**, *52*, 70–84. [CrossRef]
32. IPEA Ipeadata, Per Capita Income (Atlas DH—Pnad Contínua/A). Available online: http://www.ipeadata.gov.br/Default.aspx (accessed on 18 June 2024).