ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.30, n.9, e302058, 2026
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: https://doi.org/10.1590/1807-1929/agriambi.v30n9e302058 ORIGINAL ARTICLE

Economic viability of on-grid solar photovoltaic microgeneration in Brazil under Law 14,300[1]

Viabilidade econômica da microgeração solar fotovoltaica on-grid no Brasil sob a Lei 14.300

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HIGHLIGHTS:

Solar energy generation sustains its economic viability for all types of Brazilian consumers.
Tariff variation has the greatest impact on the economic viability for commercial, industrial, and rural consumers.
The installation location proved to be a critical parameter for economic viability.

ABSTRACT: Solar photovoltaic energy is growing in Brazil's electricity matrix, particularly in distributed mini and microgeneration. Law 14,300, enacted on January 6, 2022, aimed to increase investor legal security, yet its changes raised numerous questions about solar photovoltaic system economic viability. This study analyzed the economic viability of solar photovoltaic microgeneration plants for residential, commercial, industrial, and rural consumers, and assessed the influence of the simultaneity factor and geographical location on economic returns. The results reveal that, in the scenario of 100% of the Distribution System Usage Tariff - $TUSD_{Wire\ B}$ starting in 2029, the availability cost exceeded the new tariff rule in 48.22% of the cases analyzed. In the scenario of 100% TUSD starting in 2029, this percentage was 33.33%, indicating that these groups were not affected by the change in legislation. Net present value, internal rate of return, benefit-cost ratio and discounted payback period were employed as economic indicators, demonstrating that solar photovoltaic systems remain economically viable for all cases analyzed, although industrial consumers are the most affected by the legislative change. It was also observed that the simultaneity factor had less influence on the results than geographic location, which significantly affected economic viability, being identified as a critical factor. Sensitivity analysis revealed electricity consumption had the greatest impact on residential consumers, while tariff was the most impactful variable for other consumer types, in most cases.

Key words: distributed generation, net metering, regulatory framework

RESUMO: A energia solar fotovoltaica está crescendo na matriz elétrica do Brasil, particularmente na mini e microgeração distribuída. A Lei 14.300, promulgada em 6 de janeiro de 2022, visava aumentar a segurança jurídica dos investidores, mas suas alterações levantaram inúmeras questões sobre a viabilidade econômica do sistema solar fotovoltaico. Este estudo analisou a viabilidade econômica de usinas de microgeração solar fotovoltaica para consumidores residenciais, comerciais, industriais e rurais, além de avaliar a influência do fator de simultaneidade e da localização geográfica nos retornos econômicos. Os resultados revelam que, no cenário de 100% da Tarifa de Utilização do Sistema de Distribuição - $TUSD_{Fio\ B}$ a partir de 2029, o custo de disponibilidade superou a nova regra tarifária em 48,22% dos casos analisados. Já no cenário de 100% da TUSD a partir de 2029, esse percentual foi de 33,33%, indicando que esses grupos não foram afetados pela mudança na legislação. O valor presente líquido, a taxa interna de retorno, a razão benefício-custo e o payback descontado foram empregados e indicam que os sistemas solares fotovoltaicos permanecem economicamente viáveis para todos os casos analisados, embora os consumidores industriais sejam os mais afetados pela mudança legislativa. Observou-se também que o fator simultaneidade teve menos influência nos resultados do que a localização geográfica, a qual afetou significativamente a viabilidade econômica, sendo identificada como um fator crítico. A análise de sensibilidade mostrou que o consumo de eletricidade teve o maior impacto nos consumidores residenciais, enquanto o preço da tarifa foi a variável mais impactante para outros tipos de consumidores, na maioria dos casos.

Palavras-chave: geração distribuída, medição líquida, marco regulatório

Ref. 302058 – Received 20/10/2025
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• Accepted 02/06/2026 • Published 27/08/2026
Editors: Antônio Gustavo de Luna Souto & Carlos Alberto Vieira de Azevedo

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Introduction

Brazil is globally recognized for its significant share of renewable energy in its electricity matrix, primarily due to its abundant natural resources, especially hydropower (EPE, 2025). According to the 2025 National Energy Balance (BEN), based on 2024 data, 88.2% of Brazil's electricity matrix came from renewable sources, encompassing generation from the National Interconnected System (SIN), isolated systems, non-injected self-production, and net imports (EPE, 2025). However, hydropower accounts for 56% of this total, indicating a strong reliance on water resource availability and rainfall patterns, which directly affect reservoir levels (EPE, 2025). This dependence was acutely felt in 2021, when Brazil experienced its worst water crisis since 1930 (Soares & Costa, 2023). This led to increased electricity bills for consumers, necessitating greater activation of more expensive thermoelectric plants (Garcia et al., 2024).

Brazil's reliance on hydropower for electricity generation could be mitigated by diversifying its energy matrix (Silva & Carneiro Júnior, 2025). A promising alternative, given Brazil's significant generation potential, is solar photovoltaic energy (SPE) (Raimundo et al., 2025). According to Pereira et al. (2017), the Northeast region exhibits the highest average daily total horizontal global irradiance (5.49 kWh m^{-2}) and the Southern region, the lowest (4.53 kWh m^{-2}), highlighting the substantial photovoltaic generation potential of the so-called "Solar Belt", which encompasses the Northeast, the Pantanal, northern Minas Gerais, southern Bahia, and northern/northeastern São Paulo.

In 2024, SPE reached a 10% share of Brazil's electricity matrix, marking a 39.6% year-over-year increase that surpassed biomass for the first time, and despite its still moderate overall representation, it acted as the principal contributor (97%) to a 36.6% growth in distributed mini and microgeneration (EPE, 2025). This surge in distributed generation, coupled with a lack of prior regulation, led to Law 14,300, enacted on January 6, 2022 (BRASIL, 2022), and established a legal framework for the activity, the Electricity Compensation System, and the Social Renewable Energy Program. Upon publication, however, concerns arose among prospective self-generators regarding the economic viability of such investments, as the law introduced a fee on compensated active electrical energy, specifically on tariff components related to distribution service asset remuneration (BRASIL, 2022). Consequently, in February 2023, the National Electric Energy Agency (ANEEL) published Normative Resolution (REN) 1059, which among other provisions revoked REN 482/2012 and REN 687/2015, refining rules for the connection and billing of distributed micro and mini generation plants and clarifying the Electricity Compensation System (ANEEL, 2023).

According to Almeida Neto et al. (2023), the Brazilian net metering system shares similarities with those of other countries, and international policies targeting the sector are generally undergoing changes in how subsidies are applied, generating uncertainty in the market, as observed in Spain (Tomasi et al., 2022). However, the search for renewable energy sources is imperative, as they provide abundant power with low environmental impact. This shift is reinforced by Sustainable Development Goal 7, which ensures access to affordable, reliable, sustainable, and modern energy for all. As global energy demand is projected to grow at a steady rate of 1.7% per year from 2000 to 2030, the increasing requirement for clean sources has paved the way for renewables to become the primary energy matrix (Aljaghoub et al., 2022).

Having noted this increase in demand, accompanied by investor uncertainty and the need to increase the use of renewable sources, this research aimed to analyze the economic viability of implementing SPE microgeneration in residential, commercial, industrial, and rural installations, in compliance with Law 14,300 and REN 1059/2023, in Brazil. Furthermore, it investigated the impacts of the simultaneity factor (SF) and analyzed 30, 50, and 70% simultaneous consumption with generation and the influence of geographical location on project economic return.

Material and Methods

This study analyzed grid-connected SPE systems installed from 2025 onwards, assuming a 25-year lifespan, for consumers with an installed load of 75 kW or less, categorized into four subgroups: residential, commercial, industrial, and rural consumers. Rural consumers included aquacultural and irrigational users, all hereafter referred to as rural consumers. The analysis was conducted by considering average solar incidence values in regions both within and outside the Solar Belt.

According to REN 1000/2021 (ANEEL, 2021), consumer units (CU) connected to low voltage (below 2.3 kV) are classified under Group B. Furthermore, REN 1059/2023 (ANEEL, 2023) designates a renewable energy generation plant within this installed power range and connected to the distribution grid as distributed microgeneration. This research focuses on Group B consumers in Brazil, who are served exclusively by local distributors with tariffs set by ANEEL.

An economic analysis was performed to determine the financial viability of the SPE investments for each case. The following economic indicators were used: Net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR), and discounted payback period (DPP). These indicators were calculated using equations and analysis criteria from Guo et al. (2025) and Tufail et al. (2026).

The calculation of NPV, IRR, and BCR employs the Minimum Acceptable Rate of Return (MARR), which is the lowest return rate that would incentivize an investor, considering only financial gains (Jesus et al., 2023). For this research, the Brazilian basic interest rate (SELIC), set by the Monetary Policy Committee and used by the Central Bank for inflation control, was adopted as the MARR. Thus, the current Selic target of 12.25% per year in January 2025 was used as the reference value.

A service life of 25 years was adopted for the solar photovoltaic systems. This period typically coincides with the

linear performance warranty offered by most photovoltaic module manufacturers. Studies in the field assume this value as the temporal reference for financial analyses (Iglesias & Vilaça, 2022; Matos et al., 2025; Souza et al., 2026).

Conversely, string inverter manufacturers in the Brazilian market typically offer a 10-year warranty. Some authors suggest that the lifetime of a string inverter ranges from 7 to 15 years (Branker et al., 2011; Gautam et al., 2021; Soler et al., 2025). An alternative with a longer lifespan is the microinverter, which is now available on the market with a 25-year warranty, similar to photovoltaic modules (Hayibo & Pearce, 2022; Ruchira et al., 2022).

According to Sangwongwanich et al. (2018), the lifetime of a photovoltaic inverter can vary depending on the installation location and the degradation rate of the photovoltaic modules, a process often accelerated by local irradiance and temperature conditions. For the feasibility analysis of this study, a system lifespan of 25 years is assumed, in line with the common linear production warranty of photovoltaic modules. However, the possibility of additional costs for replacing components after the manufacturer's warranty expires is acknowledged.

ANEEL, via Module 7 of its Tariff Regulation Procedures, stipulates the distribution concessionaires' tariff structure. Generally, electricity tariffs comprise the Energy Tariff (TE), reflecting energy consumption, and the Distribution System Usage Tariff (TUSD), for distribution system use (Gomes et al., 2025; Pires et al., 2025). Both are defined by ANEEL in R$ MWh^{-1}.

Additionally, the analysis considers the current tariff, which signals the real costs of electricity generation based on varying generation conditions (Garcia et al., 2024), alongside the Public Lighting Contribution (CIP), whose collection methods are determined by individual municipal councils (Drumond Junior et al., 2021). Finally, the calculation includes the Tax on Goods and Services (ICMS), as well as the federal taxes for the Social Integration Program (PIS) and the Contribution to Social Security Financing (COFINS) (Maestri & Andrade, 2022; Pinto et al., 2025). This research evaluated scenarios under the green tariff flag, which has been the most prevalent, indicating favorable generation conditions and no surcharge on the bill, and used tariff data including taxes available in the ANEEL database (ANEEL, 2025).

Based on Law 14,300 (2022), Regulatory Resolution 3169/2022, microgeneration projects, for connections requested from January 8, 2023, are classified as GD II (Gomes et al., 2025). Therefore, all cases analyzed in this research fall under this classification and had the portion of the electricity bill related to compensated energy transport cost calculated based on a scaled charge of the Distribution System Usage Tariff Wire B ($TUSD_{Wire\ B}$) on the entire compensated energy amount. The electrical energy distributor tariff database, provided by ANEEL, shows a national average TUSD of R$ 0.50 kWh^{-1}, while the $TUSD_{Wire\ B}$ component is R$ 0.29 kWh^{-1} (ANEEL, 2025). This charge will increase annually in a scaled and corrected manner, factoring in the Independent Fiscal Institution's base scenario inflation projection (IFI, 2023). The monetary value for this tariff was estimated as by Table 1.

Starting in 2029, the tariff rule, as per Articles 17 and 27 of Law 14,300, is to be defined by ANEEL (BRASIL, 2022). Studies assessing the technical and economic feasibility, as well as the implementation of public policies, have projected two scenarios: one maintains charges based solely on the $TUSD_{Wire\ B}$ tariff component at its full value, while the other estimates a charge encompassing the entire TUSD (including $TUSD_{Wire\ B}$ and other charges) (Campello et al., 2024; Sermarini et al., 2024; Toscan et al., 2024). However, in addition to the tariff structure, aspects such as the region where the system is installed and the impact of the availability of solar resources on the investment were also evaluated.

The economic benefit of a photovoltaic generator project stems from reduced electricity bill expenses. Photovoltaic plant design is based on the CU average monthly consumption, with module sizing aimed at minimizing the owner's bill. Therefore, investment viability considers equipment and installation costs, component lifespan, and the savings generated over that period.

Consumption for each consumer type was calculated using ANEEL data (ANEEL, 2025) for captive market consumers from November 2023 to October 2024 (residential, industrial, commercial, and rural). This period represents the most recent data available from the regulatory agency as of 2025. The provided monthly data includes cumulative consumption for all consumers within each subgroup. From this, the average total consumption and average number of consumers over the year were obtained, enabling the calculation of average monthly consumption for each consumer type, as presented in Table 2.

The electrical energy distributor tariff database, maintained by ANEEL (2025), provides average supply tariff data, including taxes, for each concessionaire. Using data from November 2023 to October 2024, it was possible to calculate the average kWh price in Brazil for each subgroup. Subsequently, the average monthly electricity bill is

Table 1. $TUSD_{Wire\ B}$ scaling in energy billing for units during the transition period

Wire B (%)	Monetary value	Period	Inflation Projection (%)
45	R$ 0.13	from 2025	4.44
60	R$ 0.18	from 2026	3.64
75	R$ 0.24	from 2027	3.00
90	R$ 0.29	from 2028	3.00
ANEEL*		from 2029	3.00

*The tariff rule to be defined by ANEEL. Source: (BRASIL, 2022; IFI, 2023; ANEEL, 2025)

Table 2. Average monthly consumption per consumer

Consumers	Consumption (MWh)	Number of consumers	AMC (kWh)
Residential	14,202,956	81,214,534	175
Commercial	4,865,718	6,129,762	794
Industrial	1,372,388	454,009	3,023
Rural	1,979,573	4,173,072	474

Source: ANEEL (2025); AMC - Average monthly consumption

determined by multiplying the average monthly consumption by the average kWh price, as shown in Table 3.

Group B consumers with microgeneration CUs can participate in the Electric Energy Compensation System (SCEE). Billing for these units differs: the distributor assesses active electrical energy consumed (EC) from the grid, active electrical energy injected into the grid by the CU, and energy surplus per billing cycle and tariff post. According to ANEEL (2023), the total value calculation depends on the specific subgroup and tariff modality, with the consumer paying for both grid energy consumption and grid energy injection. Specifically, the payable consumption portion is defined as the positive difference between the grid-consumed energy and the compensated active electrical energy, plus the transport cost associated with this compensated energy. However, the final bill must consider the higher value between the active electrical energy consumption and the Availability Cost (AC), as the AC represents the minimum tariff required for the distributor's energy supply.

Compensated energy is considered up to the point where the monetary value of consumed active energy is greater than or equal to AC, preventing duplicate billing. It is also limited to the total active electrical energy consumed by the CU in the billing cycle. Consequently, SF is a critical analysis point and measures instantaneous energy consumption at the CU, calculated as the ratio of simultaneously consumed energy to total generated energy. Generally, instantaneous consumption is derived from the difference between energy generated (recorded by the inverter) and injected energy (recorded by the energy meter).

SF magnitude depends on CU consumption characteristics and generation conditions, making it difficult to estimate a single SF for each subgroup, despite their classification by energy use (Vieira & Carpio, 2020; Dilli & Brito, 2025). Given this circumstantial dependence, this research will analyze all four consumer types with 30, 50, and 70% simultaneity values to observe their impact on economic viability.

Therefore, the tariff value paid after photovoltaic generator installation was calculated, considering two tariff scenarios for all cases and across 30, 50, and 70% simultaneity factors. Scenario 1 projects a 100% charge of the $TUSD_{Wire\,B}$ component; meaning, after the scaled transition period (Table 1), the full $TUSD_{Wire\,B}$ component would be applied in subsequent years. Scenario 2, a more pessimistic projection, assumes a 100% TUSD charge after the transition, encompassing the entire TUSD, not just one of its components.

Considering the information presented, the first step for calculating the economic viability of installing a SPE is to determine if billing will follow the new tariff structure or the AC. The AC was calculated using Eq. 1, varying per consumer type due to tariff (Table 3) and per supply type, based on minimum consumption thresholds of 50 kWh per month for three-wire bi-phase and 100 kWh per month for three-phase consumers (ANEEL, 2021). For residential and rural consumers in this study, two supply situations were considered: two-conductor bi-phase and three-phase. Commercial and industrial consumers were analyzed only under three-phase supply.

$$AC = \text{Minimum Consumption} \times \text{Cost per kWh} \quad (1)$$

Where:
AC - Availability cost.

The new tariffing applies to injected energy when it is compensated, meaning when the injected value is included in billing calculations. Thus, if generation exceeds simultaneous consumption, the energy surplus injected into the distribution grid will incur this new tariff upon compensation. This also applies if the surplus is compensated in a subsequent month; these credits would similarly be taxed upon compensation.

The compensation tariff ($Tariff_{SCEE1}$) was calculated using Eq. 2, considering the first scenario.

$$Tariff_{SCEE1} = [EC \times (1 - SF) + \text{Compensated Energy}] \times \%TUSD_{Wire\,B} \quad (2)$$

Where:
EC - Energy consumed;
SF - Simultaneity factor; and,
$\%TUSD_{Wire\,B}$ - Percentage of the distribution system usage tariff - Wire B.

For the second scenario, the compensation tariff ($Tariff_{SCEE2}$) was calculated using Eq. 2 until 2028 and subsequently by Eq. 3 from 2029 onwards.

$$Tariff_{SCEE2} = [EC \times (1 - SF) + \text{Compensated Energy}] \times TUSD \quad (3)$$

Where:
TUSD - Distribution system usage tariff.

Using the calculated results, the values were compared to determine the higher amount, which represents the payment due to the energy utility.

Due to reduced photovoltaic module generation capacity, consumers, lacking accumulated credits, will be charged for uncompensated consumption ($Tariff_{NC}$) calculable using Eq. 4.

$$Tariff_{NC} = (EC - EG - \text{Compensated Energy}) \times \text{Cost per kWh} \quad (4)$$

Where:
EG - Energy generated.

To calculate the energy savings from the investment, it is necessary to determine the cost of the electricity bill had the generator not been installed. This value is obtained using Eq. 5.

$$Tariff = EC \times \text{Cost per kWh} \quad (5)$$

Table 3. Average electricity bill cost for each subgroup

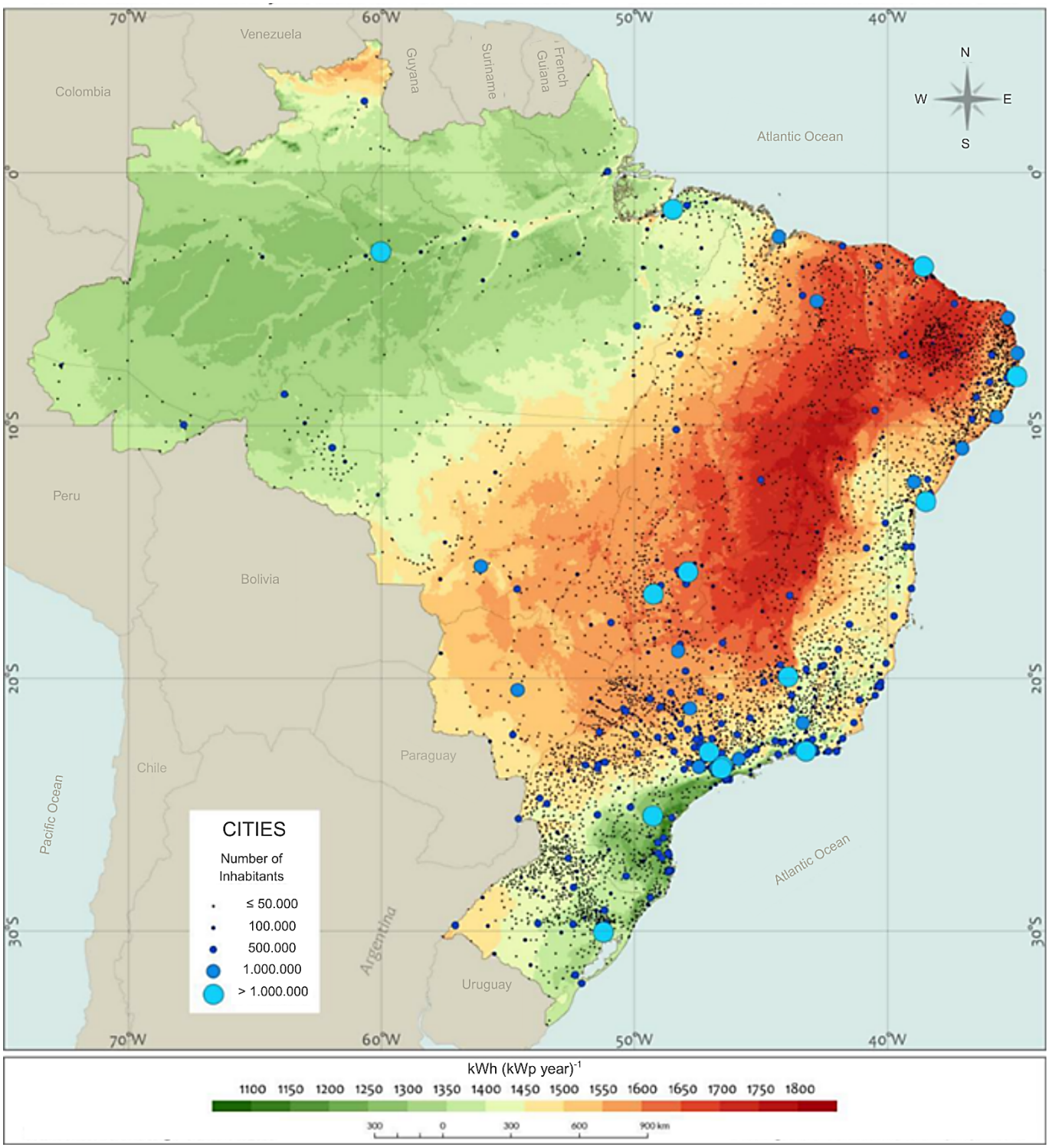
Consumers	AMC (kWh)	AEP (R$ kWh^{-1})	AMEB (R$)
Residential	175	0.89	155.75
Commercial	794	0.95	754.30
Industrial	3,023	0.84	2,539.32
Rural	474	0.60	284.40

Source: ANEEL (2025); AMC - Average monthly consumption; AEP - Average electricity price, including tax; AMEB - Average monthly electricity bill amount

The TUSD and kWh price values were adjusted for inflation, consistent with the approach for $TUSD_{Wire\ B}$. Thus, project savings are calculated by subtracting the projected cost of the electricity bill with the photovoltaic plant installed from the cost without the investment, considering both scenarios from 2029 onward.

Accurate photovoltaic project sizing is crucial for maximizing energy savings. Brazil boasts significant solar photovoltaic generation potential, detailed in the Brazilian Solar Energy Atlas (Pereira et al., 2017). The Solar Belt region exhibits annual generation values ranging from 1500 to 1800 kWh kWp^{-1}, while areas outside this region show a potential dropping to approximately 1050 kWh kWp^{-1}.

For this research, two installation sites were selected: one within the Solar Belt, assuming an intermediate annual potential of 1650 kWh kWp^{-1}, and another outside it, with an intermediate annual potential of 1275 kWh kWp^{-1}. These values are based on data from the Brazilian Solar Energy Atlas (Figure 1), which presumes an 80% average annual yield rate for fixed photovoltaic generators with properly sized and certified components (Pereira et al., 2017).



Source: Pereira et al. (2017)

Figure 1. Map of Brazil's annual solar photovoltaic generation potential per kWp installed

The peak power of photovoltaic modules was calculated assuming the average annual generation equals the average annual consumption for the first year. This design allows for surplus production, as duplicate billing is no longer enforced. This surplus provides a buffer for generation fluctuations due to atypical weather, maintenance issues, or minor increases in consumption. Furthermore, as discussed, module generation linearly degrades over the system's lifespan; this surplus can therefore mitigate impacts on generated savings. This article assumes constant average annual consumption, and thus, accumulated credits compensate for reduced module generation over time.

Photovoltaic modules experience power loss over time. Studies consider a 2% reduction in generation in the first year, followed by a gradual reduction of at least 0.40 to 0.55% annually for up to 30 years (Araújo et al., 2025; Badran & Ismail, 2025). The analysis in this research incorporated this degradation pattern.

The cost of a photovoltaic system (equipment plus labor) varies considerably. According to Greener's 2024 Strategic Study of Distributed Generation in the Photovoltaic Market (GREENER, 2025), the price of photovoltaic generator components up to 75 kWp for rooftop installations saw a 13% average reduction in January 2025 compared to January 2024, while overall system costs decreased by an average of 9%. This significant 42% average reduction in photovoltaic system prices in January 2025 (compared to January 2024) is primarily attributed to falling module costs (GREENER, 2025).

In this research, photovoltaic system prices for specific generator sizes were estimated using statistical forecasting techniques applied to the 2 to 75 kWp data from Greener's latest strategic study (GREENER, 2025). The calculated costs, based on January 2025 values, are presented in Table 4.

Table 4. Solar photovoltaic system cost per consumer class

Consumers	AAC (kWh)	SBR (kWp)	ROSB (kWp)	SBR (R$)	ROSB (R$)
Residential	1,869	1.13	1.47	3,157.08	4,102.70
Commercial	9,528	5.77	7.47	15,890.64	20,463.36
Industrial	36,276	21.99	28.45	57,496.24	72,807.86
Rural	5,688	3.45	4.46	9,570.11	12,333.09

AAC - Average annual consumption; SBR - Solar Belt Region; ROSB - Region outside the Solar Belt; SBR - Solar Belt Region; Source: (Pereira et al., 2017; Campello et al., 2024; GREENER, 2025)

To identify the most impactful variable on the economic analysis, a 5% sensitivity analysis was performed on the following variables: electricity tariff, project cost, and average consumption. In this method, each input variable was changed independently while holding all other variables constant (Dickson et al., 2025).

Results and Discussion

Based on the methods and data, the results offer a national perspective for the analyzed consumer types. However, given the aggregation of diverse consumers within subgroups (classified by activity and electricity use), consumption disparities among CUs within the same subgroup may exist.

Table 5 provides detailed information on the number of years the availability cost (AC) exceeded the new tariff for each case analyzed in both scenarios. The closer this number is to 25 years (the assumed photovoltaic system lifespan), the less influence the new tariff has on economic outcomes, as consumers would continue paying only the AC, like the period before the Distributed Generation Legal Framework. In Scenario 1, where 100% of the $TUSD_{Wire\ B}$ is charged from 2029, the AC was higher than the new tariff in 48.22% of the cases. In Scenario 2, where 100% of the TUSD is charged from 2029, this figure was 33.33% of the cases.

For residential consumers in Scenario 1, the new tariff never exceeded the AC (Table 5). In Scenario 2, however, bi-phase residential consumers with 30% SF will be impacted after the transition period, continuing to pay the AC from 2025 to 2028.

Commercial and rural consumers with three-phase supply in Scenario 1 were most influenced by SF, though at 70% SF, the AC remained the governing value. Across all cases, industrial consumers are consistently subject to the new tariff. The new tariff's incidence was higher for consumers with higher consumption and lower SFs. This directly impacts the viability of implementing an SPE generator, as it indicates that these consumers continued to pay the minimum tariff, regardless of the change in the law. Dilli & Brito (2025) also observed this and highlighted the importance of analyzing the self-consumption pattern to determine the viability of implementing a self-supply system. In their study, they observed that consumers with a daytime consumption pattern (higher SF) show greater viability for implementing this type of generator.

Table 5. Superiority of the availability cost in comparison with the new tariff

Consumers	Supply	Scenario 1			Scenario 2		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	25	25	25	4	25	25
	Three-phase	25	25	25	25	25	25
Commercial	Three-phase	2	3	25	2	3	4
Industrial	Three-phase	0	0	0	0	0	0
Rural	Two-phase	0	0	2	0	0	2
	Three-phase	2	8	25	2	4	4

SF - Simultaneity factor

Table 6 presents the NPV results. In all analyzed situations, the NPV was greater than zero, indicating economic viability by this criterion. When analyzing the research by Antoniolli et al. (2022), carried out before the implementation of Law 14,300, positive NPV values were found for residential installations on rooftops. This indicates that the change in legislation does not make the implementation of photovoltaic generators unfeasible; however, when comparing the results, a reduction in NPV is observed.

The three-phase residential consumer shows the lowest NPV across all analyzed scenarios (Table 6). Notably, this consumer type was most impacted by geographical dependence, with the NPV within the Solar Belt region (indicated by warm colors in Figure 1) approximately, on average, 28% greater than outside the Solar Belt region (indicated by cool colors in Figure 1).

When comparing NPVs across analyzed regions, values are consistently higher within the Solar Belt for all cases. Furthermore, considering the tariff scenarios, the residential consumer's NPV only changes for the bi-phase case with a 30% SF; in other residential scenarios, the NPV remains unaffected by either tariff projection.

By analyzing the impact of self-consumption on the NPV, it was observed that higher SF values result in an increase of this indicator (Table 6). This was also observed in the economic analysis conducted by Chen et al. (2025), where a 50% increase in self-consumption resulted in a 69.9% increase in NPV, while total grid dependence led to a more than 5-fold reduction in NPV compared to the best-case scenario.

Table 7 presents the internal rate of return (IRR) results. Consistent with the NPV findings, all analyzed cases demonstrate project viability, as the IRR consistently exceeded the MARR.

The IRR results (Table 7) indicate that investments are more attractive in Solar Belt regions. Rocha et al. (2017) demonstrated that cities within the Solar Belt, such as Petrolina, Pernambuco state, Brazil, exhibit optimal viability for photovoltaic microgeneration, reinforcing the expectation that regions with higher solar irradiance potential yield better investment returns, due to greater availability of photovoltaic solar resource. Furthermore, the SF has little effect on the IRR value, with the largest percentage variation (2.71% in scenario 1 and 4.35% in scenario 2) occurring for the two-phase rural consumer in the Solar Belt region. This indicates that changes in self-consumption do not have a significant impact on this indicator.

The highest IRR values are observed for commercial and industrial consumers, while three-phase residential and both bi-phase and three-phase rural consumers show the lowest IRRs. Gomes et al. (2025) observed that, between 270 and 310 kWh of consumption, the IRR value calculated using the rules established by Law 14,300 can be higher than under the old legislation for residential consumers. This reinforces the need for detailed analysis, for each specific case, to make decisions regarding investment in SPE.

Table 8 presents the BCR analysis results. All cases demonstrated financial benefits exceeding initial costs.

Table 6. Net present value (NPV) results of Scenarios 1 and 2 by consumer class, geographic region, and simultaneity factor (SF)

Scenario 1 - NPV (R$)							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	9,352.45	9,352.45	9,352.45	8,406.83	8,406.83	8,406.83
	Three-phase	4,348.79	4,348.79	4,348.79	3,403.17	3,403.17	3,403.17
Commercial	Three-phase	53,446.14	57,177.42	58,062.69	48,873.42	52,604.71	53,489.98
Industrial	Three-phase	156,349.86	172,717.43	189,085.00	141,038.24	157,405.81	173,773.38
Rural	Two-phase	13,419.17	15,746.60	18,131.87	10,656.19	12,983.61	15,368.89
	Three-phase	12,962.14	15,152.16	15,417.75	10,199.16	12,389.17	12,654.77
Scenario 2 - NPV (R$)							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	8,435.34	9,352.45	9,352.45	7,489.72	8,406.83	8,406.83
	Three-phase	4,348.79	4,348.79	4,348.79	3,403.17	3,403.17	3,403.17
Commercial	Three-phase	45,208.74	51,256.21	56,783.99	40,636.03	46,683.49	52,211.28
Industrial	Three-phase	125,484.66	150,670.86	175,857.06	110,173.03	135,359.23	160,545.43
Rural	Two-phase	8,167.77	12,117.15	15,885.27	5,404.79	9,354.17	13,122.29
	Three-phase	7,949.85	11,526.61	14,803.47	5,186.86	8,763.63	12,040.49

Table 7. Internal rate of return (IRR) results of scenarios 1 and 2 by consumer class, geographic region, and simultaneity factor (SF)

Scenario 1 - IRR results							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	45.87%	45.87%	45.87%	36.01%	36.01%	36.01%
	Three-phase	28.70%	28.70%	28.70%	22.62%	22.62%	22.62%
Commercial	Three-phase	51.88%	53.19%	53.44%	40.74%	41.96%	42.21%
Industrial	Three-phase	47.10%	49.75%	52.33%	37.31%	39.52%	41.68%
Rural	Two-phase	30.01%	32.71%	34.87%	23.54%	25.73%	27.58%
	Three-phase	29.42%	31.28%	31.50%	23.12%	24.78%	24.99%
Scenario 2 – IRR results							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	44.49%	45.87%	45.87%	34.62%	36.01%	36.01%
	Three-phase	28.70%	28.70%	28.70%	22.62%	22.62%	22.62%
Commercial	Three-phase	49.89%	51.87%	53.14%	38.64%	40.57%	41.91%
Industrial	Three-phase	44.61%	48.16%	51.47%	34.68%	37.84%	40.76%
Rural	Two-phase	25.84%	30.20%	33.54%	19.46%	23.27%	26.27%
	Three-phase	25.28%	28.72%	31.12%	19.11%	22.30%	24.62%

Table 8. Benefit-cost ratio (BCR) results of Scenarios 1 and 2 by consumer class, geographic region, and simultaneity factor (SF)

Scenario 1 – BCR results							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	3.96	3.96	3.96	3.05	3.05	3.05
	Three-phase	2.38	2.38	2.38	1.83	1.83	1.83
Commercial	Three-phase	4.36	4.60	4.65	3.39	3.57	3.61
Industrial	Three-phase	3.72	4.00	4.29	2.94	3.16	3.39
Rural	Two-phase	2.40	2.65	2.89	1.86	2.05	2.25
	Three-phase	2.35	2.58	2.61	1.83	2.00	2.03
Scenario 2 – BCR results							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	3.67	3.96	3.96	2.83	3.05	3.05
	Three-phase	2.38	2.38	2.38	1.83	1.83	1.83
Commercial	Three-phase	3.84	4.23	4.57	2.99	3.28	3.55
Industrial	Three-phase	3.18	3.62	4.06	2.51	2.86	3.21
Rural	Two-phase	1.85	2.27	2.66	1.44	1.76	2.06
	Three-phase	1.83	2.20	2.55	1.42	1.71	1.98

The new tariff structure had a minimal impact on the BCR, with less than a 10% difference between the average values across both scenarios. Furthermore, both scenarios indicate that installing the photovoltaic system in the Solar Belt yields an average BCR approximately 28% higher than outside this region.

The highest values of BCR were observed among commercial and industrial consumers (Table 8). Driven by their substantial energy consumption, the accumulated benefit over a 25-year period is markedly higher than in the other analyzed scenarios. Conversely, for rural consumers, these values did not exceed 2.89. This finding is notably lower than the Benefit-Cost Ratio (BCR) of 4.69 reported by Souza et al. (2026) in their feasibility analysis of SPE implementation in broiler production. Furthermore, residential consumers were the ones in which the BCR indicator showed the least variation related to SF.

Table 9 presents the DPP for all cases analyzed in this study. The DPP is consistently shorter for installations within the Solar Belt. Tariff scenarios primarily affect rural consumers' DPP, which are also most sensitive to the installation's SF. Commercial and industrial consumers exhibit the shortest DPPs, all under four years.

A rural investor with a 30% SF installing outside the Solar Belt could experience a 9-year financial return period, exceeding one-third of the generator's lifespan. However, this period is still shorter than the typical warranty period for photovoltaic modules (between 10 and 25 years) (Badran & Ismail, 2025). Notably, a DPP under 10 years also falls within the typical warranty period for photovoltaic inverters, meaning this component would retain manufacturer support until after the financial return is achieved.

The DPP decreases as the SF increases, rendering the investment more attractive to rural consumers whose electricity demand is concentrated during daylight hours.

For residential consumers, the DPP ranged between 2.87 and 7.48, not being impacted by changes in the SF, nor by the type of tariff adopted after 2029. These values are higher than those reported by Dilli & Brito (2025), who observed a discounted payback period of 2 years and 7 months in their worst-case scenario. Furthermore, while those authors noted variations in the DPP resulting from changes in the SF, such fluctuations were not observed in the present study.

Leite et al. (2024) also analyzed the impacts of the new legislation on residential consumers in Brazil by means of a distinct methodology. These authors considered the scenario prior to Law No. 14,300 (100% compensation), the projections from regulatory impact study No. 003/2019 (38% compensation), and the system in force after Law No. 14,300/2022 (72% compensation). The authors found economic viability for the indicators in all analyzed cases, similar to the results of this study. The viability of implementing photovoltaic generators is also observed for other types of consumers, as found by Bonatto et al. (2025), who found that the Brazilian public sector could save US$ 95 billion over 25 years.

It is important to note that, while the results of the research represent a national average, actual outcomes may vary regionally due to differing energy tariffs, as observed by Gomes et al. (2025), who analyzed the tariff composition of 27 energy concessionaires distributed throughout Brazil and how this affects economic viability.

Table 9. Discounted payback period (DPP) results of scenarios 1 and 2 by consumer class, geographic region, and simultaneity factor (SF)

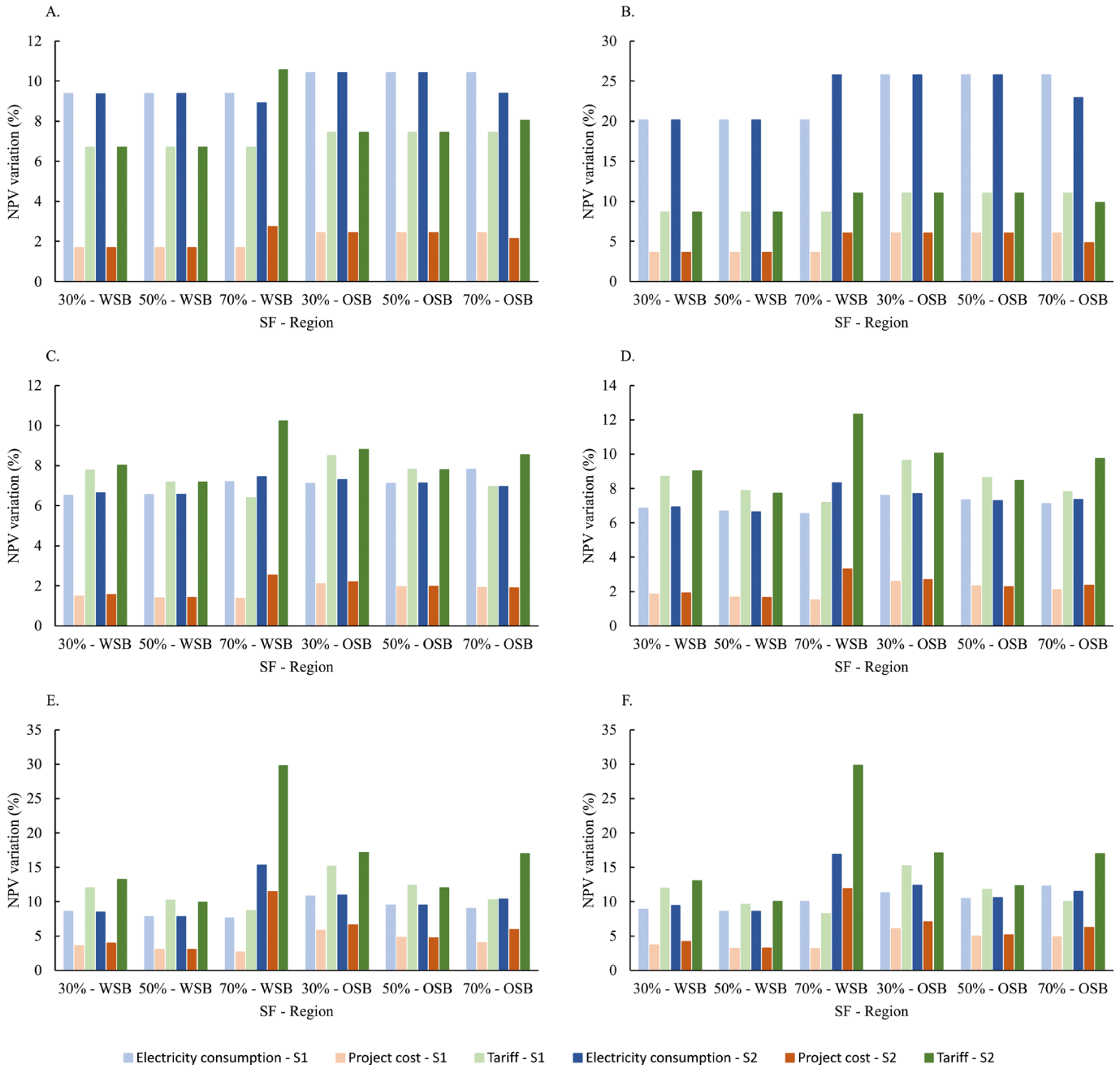
Scenario 1 - DPP (years)							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	2.87	2.87	2.87	3.88	3.88	3.88
	Three-phase	5.27	5.27	5.27	7.48	7.48	7.48
Commercial	Three-phase	2.41	2.40	2.40	3.24	3.18	3.18
Industrial	Three-phase	2.63	2.50	2.39	3.51	3.30	3.12
Rural	Two-phase	4.79	4.29	4.00	6.91	6.05	5.53
	Three-phase	4.94	4.65	4.63	7.10	6.47	6.41
Scenario 2 - DPP (years)							
Consumers		Solar Belt Region			Region Outside the Solar Belt		
		SF					
		30%	50%	70%	30%	50%	70%
Residential	Two-phase	2.87	2.87	2.87	3.88	3.88	3.88
	Three-phase	5.27	5.27	5.27	7.48	7.48	7.48
Commercial	Three-phase	2.41	2.40	2.40	3.24	3.18	3.18
Industrial	Three-phase	2.63	2.50	2.39	3.51	3.30	3.12
Rural	Two-phase	5.25	4.38	4.00	8.85	6.71	5.75
	Three-phase	5.50	4.84	4.66	9.19	7.28	6.51

Figure 2 presents the results of the sensitivity analysis, showing which variable had the greatest impact on the NPV for each consumer, SF, region, and scenario in absolute values.

It can be observed that higher project costs reduced the NPV, while increased electricity consumption and higher tariff rates improved it (Figure 2). In most cases, the tariff is the most influential variable for commercial, industrial, and rural consumers, while electricity consumption has the greatest impact on residential consumers (Figure 2). According to Silva & Rato (2024), the growth rate of electricity tariffs can exceed inflation by 1.64 times. Therefore, the economic viability of SPE implementation is subject to greater variation among consumers whose NPV demonstrates heightened sensitivity to tariff adjustments.

Under Scenario I, the maximum NPV variance was observed among three-phase residential consumers, where a 5% growth in energy consumption corresponded to an NPV increase exceeding 20% against the reference value. Under Scenario II, rural consumers recorded a nearly 30% NPV increment in response to a 5% tariff escalation. It should be noted, however, that when the SF is 70%, a change in scenario may precipitate a shift in the impact of the variables considered within the sensitivity analysis. This occurs in cases such as two-phase residential, three-phase commercial and rural.

The sensitivity analysis also demonstrated that installations outside the Solar Belt are more susceptible to these fluctuations, regardless of the tariff scenario. Furthermore, different SFs cause minor NPV changes, except for rural consumers. Rocha et al. (2017) similarly noted that cities like Uruguaiana, outside the Solar Belt, exhibit low economic viability due to lower winter solar radiation.



NPV - Net present value; SF - Simultaneity factor; WSB - Within the Solar Belt; OSB - Outside the Solar Belt; S1 - Scenario 1; S2: Scenario 2

Figure 2. Sensitivity analysis of NPV, in absolute values, for consumers: two-phase residential (A), three-phase residential (B), commercial (C), industrial (D), two-phase rural (E), and three-phase rural (F)

Conclusions

1. This economic analysis, indicates that photovoltaic solar energy investment generally remains economically viable and acts as inflationary protection for all consumer categories (residential, commercial, industrial, and rural) in Brazil, even after the changes introduced by Law 14,300/2022. Under the established conditions, residential consumers were least affected by the new legislation's tariff changes, while industrial consumers were most affected. For rural and commercial consumers, the simultaneity factor significantly influenced the billing method.

2. The installation location proved to be a critical parameter for economic viability. The Solar Belt region consistently yielded better indicator results, with net present value showing a 9 to 53% increase simply by locating the installation within this region. Additionally, the uncertainty of the future tariff structure from 2029 affects residential consumers less than rural consumers, who are the most heavily impacted.

3. The economic viability of projects for commercial, industrial, and rural consumers proved more susceptible to variations in electricity tariff prices during the sensitivity analysis. Conversely, for residential consumers, consumption variation was the most impactful factor. However, self-consumption of 70% may alter these results. As expected, installations outside the Solar Belt were more affected in the sensitivity analysis. This suggests that installing solar photovoltaic systems in regions with higher radiation incidence also provides greater stability against fluctuations in key variables analyzed in this viability study.

Contribution of authors: Vinícius M. da Costa: investigation, data curation, methodology, writing - original draft. João V. P. Oliveira: conceptualization, methodology, resources, supervision, writing - review & editing. Kemily F. Ferreira: investigation, data curation, writing - original draft. Márcio A. Martins: formal analysis, supervision, funding acquisition, project administration, writing - review & editing.

Data Availability Statement: The authors declare that there are no data underlying the text.

Conflict of interest: The authors declare that they have no conflicts of interest.

Financing statement: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

Acknowledgments: The authors are especially grateful to UFV, CAPES and CNPq for supporting this research.

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