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Economic feasibility of distributed generation for Brazilian households: influence of the new legal framework

Viabilidade econômica da geração distribuída para residências brasileiras: a influência do novo marco legal

Daniel Leal Sousa[1], *Osvaldo Augusto Vasconcelos de Oliveira Lopes da Silva*[2], *Fabrício Higo Monturil de Morais*[2], *Marcos Antonio Tavares Lira*[3], *Albemerc Moura de Moraes*[3], *Dionatas Rayron da Silva Alves*[3]

ABSTRACT

The number of distributed generation systems has grown exponentially in Brazil since its first regulation. However, with the approval of a new legal framework, consumers began to pay for using the electricity distribution system, resulting in a direct impact on the electricity market. Thus, the objective of this work is to evaluate the influence of such a new regulation on the economic feasibility of distributed generation systems for residential facilities, which are the most representative consumers. For this purpose, the approved energy tariffs for the utilities are analyzed in detail, as well as the impact on the cash flow of systems installed in the vacancy period of the law. Five distinct scenarios are assessed, considering econometric parameters and a thorough comparison with traditional fixed-income investments available in Brazil. The study shows that there is no common pattern for the adoption of electricity tariffs, while the new regulation varies according to the tariff type in the regions most impacted in the country. Even with the decrease in attractiveness, one can state that the systems are still viable in all the analyzed scenarios, even without a smooth transition between the regulations. Finally, it is strongly recommended that new systems are installed as soon as possible associated with proper energy management in consumer units, while prioritizing energy consumption during peak generation periods.

Keywords: renewable energy; Law 14,300; energy management.

RESUMO

O número de sistemas de Geração Distribuída cresce de forma exponencial no Brasil desde a sua primeira regulamentação. Entretanto, com a aprovação do seu novo marco legal, os consumidores passaram a pagar pelo uso do sistema de distribuição de energia elétrica, impactando o mercado. Assim, é objetivo deste artigo avaliar a influência desta nova regulamentação na viabilidade econômica dos sistemas para consumidores residenciais, tipos de sistemas de maior representatividade no setor. Para tanto, analisaram-se as tarifas de energia homologadas para as concessionárias, bem como o impacto no fluxo de caixa de sistemas instalados no período de vacância da lei, caso eles fossem instalados sob a vigência da nova regulamentação em cinco cenários de análise, por meio de parâmetros econométricos e da comparação com investimentos de renda fixa tradicionais no Brasil. Pôde-se constatar que não existe um padrão para as tarifas de energia elétrica e que o impacto da nova regulamentação varia em função da componente tarifária da remuneração do uso do sistema de distribuição, identificando-se as regiões do país mais impactadas. Constatou-se que, mesmo com a diminuição da atratividade, em todos os cenários analisados os sistemas são viáveis, mesmo não havendo uma transição suave para as novas regras. Por fim, recomendou-se fortemente a instalação dos novos sistemas com a maior brevidade possível, além da gestão energética nas unidades consumidoras, com a priorização da utilização de energia nos horários de maior geração.

Palavras-chave: energia renovável; Lei 14.300; gestão energética.

[1]Instituto Federal de Educação, Ciência e Tecnologia do Piauí – Picos (PI), Brazil.

[2]Instituto Federal de Educação, Ciência e Tecnologia do Piauí – Teresina (PI), Brazil.

[3]Universidade Federal do Piauí – Teresina (PI), Brazil.

Correspondence address: Daniel Leal Sousa – Instituto Federal de Educação, Ciência e Tecnologia do Piauí – Rua Marechal Dutra, 4.300, Bloco 9, Apt. 204 – Lourival Parente – CEP: 64022-250 – Teresina (PI), Brazil.

E-mail: daniel.sousa@ifpi.edu.br

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Introduction

Global energy demand has increased over time, especially in emerging markets, producing negative environmental impacts, mainly in the long term, contributing to climate change (Barros et al., 2021). Overall, it is reasonable to state that energy is the basis of contemporary society. This is an essential structural aspect that influences sustainability considerably, both in environmental and economic terms. In this way, renewable energy sources should be encouraged worldwide (Villela et al., 2017; Mele et al., 2021) owing to reduced socio-environmental impacts and minimized greenhouse gas emissions associated with human mobility (Dinçer, 2011). Since electricity generation in such conditions may occur close to consumer centers, it will also contribute significantly to mitigate the use of thermal plants (Lira et al., 2019).

The electricity in Brazilian homes is generated by large power plants and transported over long distances by huge lines until reaching the local distribution system. It is also worth mentioning that 98% of the Brazilian generating units are part of the National Interconnected System (SIN). However, the approval of Normative Resolution No. 482/2012 by the Brazilian Electricity Regulatory Agency (ANEEL) caused a paradigm shift in the energy policy, definitively incorporating distributed generation (DG) into the energy matrix in the form of individuals and legal entities that were formerly energy consumers only (Costa et al., 2022).

DG systems are characterized by consumer units that install small generation systems close to the loads, which remain connected to the distribution network. Thus, when energy generation is greater than consumption, the systems behave like small plants by injecting the energy surplus into the network (Morais et al., 2021). While the penetration of this type of generation increases, the costs associated with generation and transmission decrease. They become a potential alternative to the increase in demand and to replace fossil fuels (Arnawan et al. 2021; Gimenes et al. 2022).

DG systems have increased significantly in recent years, mainly due to high energy demand and limitations of primary energy resources, as well as environmental degradation (Barbosa Filho et al., 2015). However, since their regulation, there has been a significant growth in the number of installed systems as shown in Figure 1. In this context, it is imperative that a clear and favorable legislation is developed, capable of ensuring not only the reduction of electricity costs but also the contribution to the Brazilian energy matrix and environmental preservation (Iglesias and Vilaça, 2022).

However, according to Zanetti Neto et al. (2014), the former legislation had numerous flaws that brought difficulties to the implementation of such systems. Despite the challenges, the increase in the number of DG systems enabled ANEEL to identify possibilities for improvements, which led to the publication of Resolution RN No. 687/2015. This new regulation presented a series of advances and, as a result, there was an exponential increase in the number of installed systems in Brazil (Figure 1), also considering the commitment to review the legislation by December 31, 2019 (ANEEL, 2015; Maestri, 2021).

Since then, the approval process for Ordinary Law No. 14,300/2022 began. It states the legal regime of DG systems, creating a new form of compensation system for the energy injected into the power grid while establishing the New Legal Framework for Distributed Generation (NLFDG) (Iglesias and Vilaça, 2022). However, although this federal law has brought legal safety to the sector, it has changed the rules for tariffing the energy surplus injected into the utility grid with a direct impact on the cash flow of DG systems since its publication (Brasil, 2021).

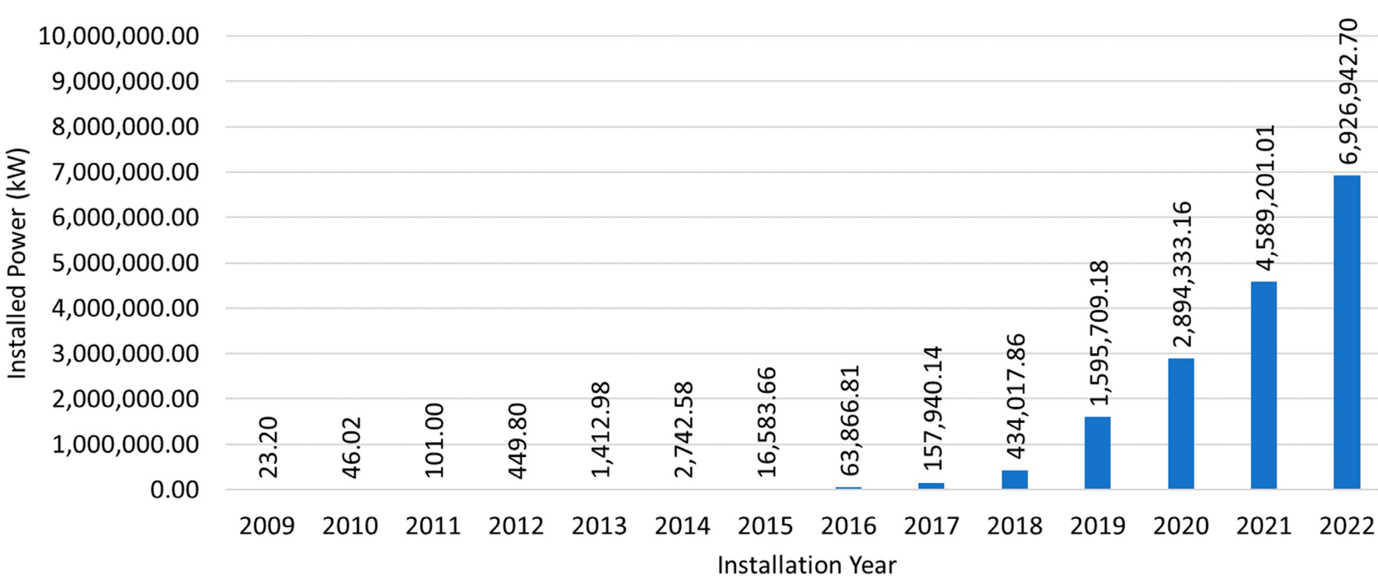


Figure 1 – Expansion of distributed generation systems in Brazil.
Source: Based on data from ANEEL (2023a).

In general, Brazilian investors have a conservative profile when dealing with their own resources and an aggressive profile when using third-party resources, with a clear preference for savings accounts associated with limited knowledge about the financial market (Borba and Reis, 2022). However, even when this last barrier is overcome, high interest rates in Brazil encourage conservative approaches like fixed-income investments since there is a positive correlation between the Brazilian's investors conservatism and the increase in these rates (Jacomassi and Oliveira, 2022). Thus, this work aims to evaluate the NLFDG influence on the economic viability of DG systems for residential consumers treated as investment enterprises.

Metodology

The approval process of Law nº 14,300/2022 published on January 6, 2022, actually started in 2019 in the form of bill PL nº 5.829/2019, formerly presented in the Chamber of Deputies on November 5, 2019. It was then forwarded to the Committee on Mines and Energy (CME), which raised several amendments. On December 8, 2019, the bill was submitted to the Committee for the Constitution of Justice and Citizenship (CCJC) and to the Committee on Finance and Taxation (CFT) after its approval under an emergency regime. On August 18, 2021, the bill was voted on by the Chamber of Deputies. Its final wording was sent to the Federal Senate, which approved it with the new amendments on December 15, 2021. The revised text was returned to the Chamber of Deputies for appreciation. The final revision was voted on and approved and, on December 17, 2021, it was sent for presidential sanction, which occurred on January 6, 2022 (Figure 2).

Even with this process completed and the legislation coming into force, on January 7, 2023, the Chamber of Deputies approved the new bill PL nº 2703/2022, which postponed the application of the proposed tariff regime for six months. Nevertheless, the proposal was not voted on in the federal Senate and the new tariff system started on January 7, 2023. The electricity tariff paid by consumers is charged in reais per kilowatt hour (R$/kWh). It consists of distinct percentages associated with generation, transmission, and distribution costs and charges. However, the electricity costs go beyond the tariffs approved by the regulatory agency, also including federal (PIS/COFINS), state (ICMS), and municipal (Public Lighting Contribution — COSIP) taxes, in addition to other sectoral charges and tariff flags, both established by specific legislation (Silva et al., 2018; Silva et al., 2021). The publication of Law No. 14,300/2022 established new rules for charging the use of the distribution system for the amount of energy generated and injected into the network.

Three periods were established for the application of the law: a vacancy period, in which generation credits are fully compensated; a transition period, during which companies' billing considers only part of the generation credits; and a period of effective application (Iglesias and Vilaça, 2022). During the latter, the consumer will be charged in full for the consumption and demand for electricity consumed from the distribution network, in addition to all tariff components not associated with energy costs. However, the energy credits associated with the DG system can be properly compensated, even though this procedure is still not regulated by ANEEEL.

Given this uncertainty, this study considered the tariff referring only to the use of the distribution system during the latter period, since DG has a negative impact on distribution, but a positive impact on generation and transmission (Arnawan et al. 2021; Gimenes et al. 2022).

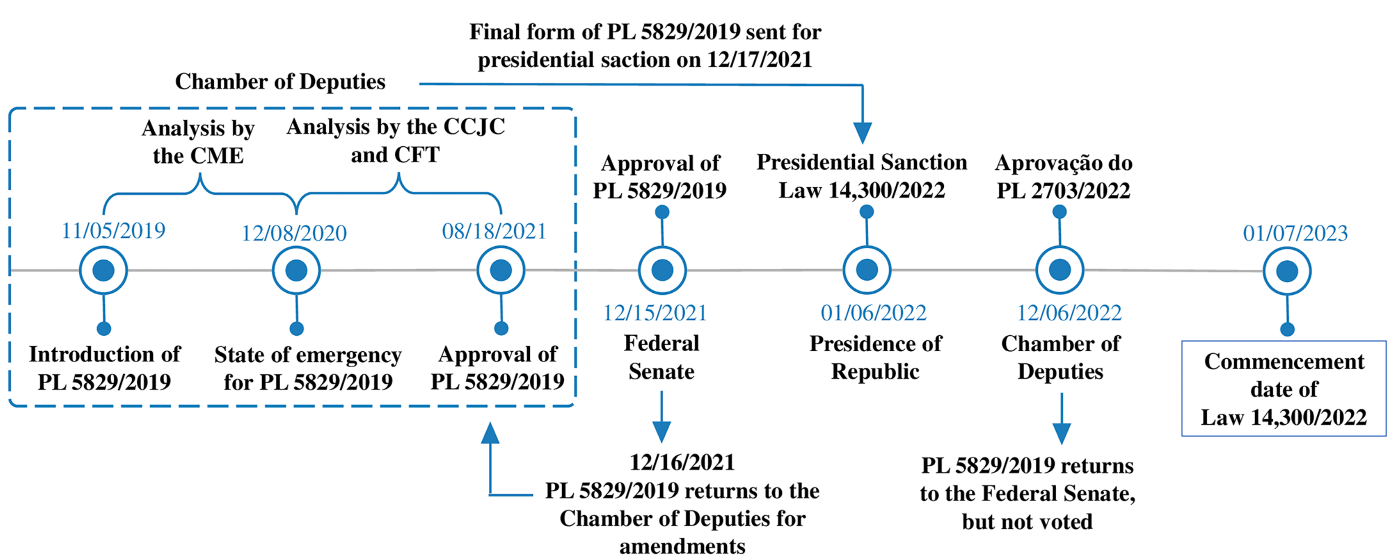


Figure 2 – Processing timeline of bill PL nº 5.829/2019 until the creation of Law nº 14,300/2022.
Source: Prepared with data from Brasil (2019; 2021).

However, there is still no consensus in the scientific community with regard to the tariff system for residential consumers, which could take into account distinct tariffs for energy consumption and demand depending on the financial balance of utilities (Martins et al., 2022). One could even consider government subsidy aimed at not charging the energy compensation system (SCEE) (Arnawan et al. 2021; Maestri and Andrade, 2022).

Thus, projects already in operation or whose request for access was filed until January 6, 2023 will maintain the full compensation regime for the energy injected into the grid until December 31, 2045. In turn, DG systems with installed capacities of up to 500 kW (as defined by the legislation) with access requests from January 7, 2023 will gradually be charged a percentage of the energy tariff corresponding to distribution (TUSD wire B). As for remote self-consumption systems with power levels greater than 500 kW and shared generation, whose consumers have 25% or more of the generation credits, in addition to paying the full value of TUSD wire B, it is also necessary to pay for transmission (TUSD wire A), the Electric Energy Services Inspection Fee (TFSEE), and the percentage related to Research and Development (R&D). Therefore, there is a smoother transition regime for small systems.

The expansion of DG is a global and national reality (Martins et al., 2022; Silva et al., 2021). It is possible to identify in the country the installation of 16.69 TWh associated with 1.58 million consumer units (CUs), with generation credits benefiting 2.07 million CUs (Table 1). Residential consumers are responsible for most of the systems in all the analyzed categories (78.65% of the installed systems, 74.18% of the CUs, and 48.46% of the installed power). Photovoltaic solar energy corresponds to the major energy source (99.96% of the installed systems, 98.77% of the CUs, and 98.56% of the installed power) (ANEEL, 2023a), thus justifying the study of such microgeneration systems.

The Northeast region holds only the third position in the country in the installation of DG systems (19.61% of the installed systems, 21.55% of the CUs, and 19.74% of the installed power) according to Table 1. However, it has the highest solar potential for energy generation, with a daily average global horizontal irradiation 5.49 kWh/m^2 (Pereira et al., 2017). For this reason, this region was chosen for this study. The fact that photovoltaic systems penetration in the Northeast region is lower than in the South and Southeast regions, which have the highest number of installed systems in all analyzed categories, corroborates the study by Costa and Santos (2020).

Table 1 – Installed distributed generation systems in Brazil.

DG Type	Total Number of Systems		Total Number of CUs		Installed Power (kW)	
	Absolute	%	Absolute	%	Absolute	%
Hydroelectric	79	0.00	18,194	0.88	77,474	0.46
Wind	92	0.01	163	0.01	17,192	0.10
Photovoltaic	1,584,684	99.96	2,048,974	98.77	16,454,723	98.56
Thermoelectric	430	0.03	7,232	0.35	145,083	0.87
Region	**Total Number of Systems**		**Total Number of CUs**		**Installed Power (kW)**	
	Absolute	**%**	**Absolute**	**%**	**Absolute**	**%**
Central-West	196,548	12.40	245,420	11.83	2,357,799	14.12
Northeast	310,861	19.61	447,037	21.55	3,295,410	19.74
North	88,478	5.58	110,240	5.31	1,041,216	6.24
Southeast	568,926	35.89	719,739	34.69	5,632,490	33.74
South	420,472	26.52	552,127	26.61	4,367,556	26.16
Consumption Class	**Total Number of Systems**		**Total Number of CUs**		**Installed Power (kW)**	
	Absolute	**%**	**Absolute**	**%**	**Absolute**	**%**
Commercial	173,625	10.95	293,133	14.13	4,807,188	28.80
Public lighting	64	0.00	92	0.00	2,217	0.01
Industrial	27,189	1.72	40,745	1.96	1,150,933	6.89
State	3,871	0.24	6,186	0.30	164,571	0.99
Residential	1,246,899	78.65	1,538,823	74.18	8,089,644	48.46
Rural	133,388	8.41	194,877	9.39	2,465,411	14.77
Public service	249	0.02	707	0.03	14,508	0.09
TOTAL	**1,585,285**	**100.00**	**2,074,563**	**100.00**	**16,694,472**	**100.00**

DG: Distributed Generation; CUs: consumer units.
Source: prepared from data obtained from ANEEL (2023a).

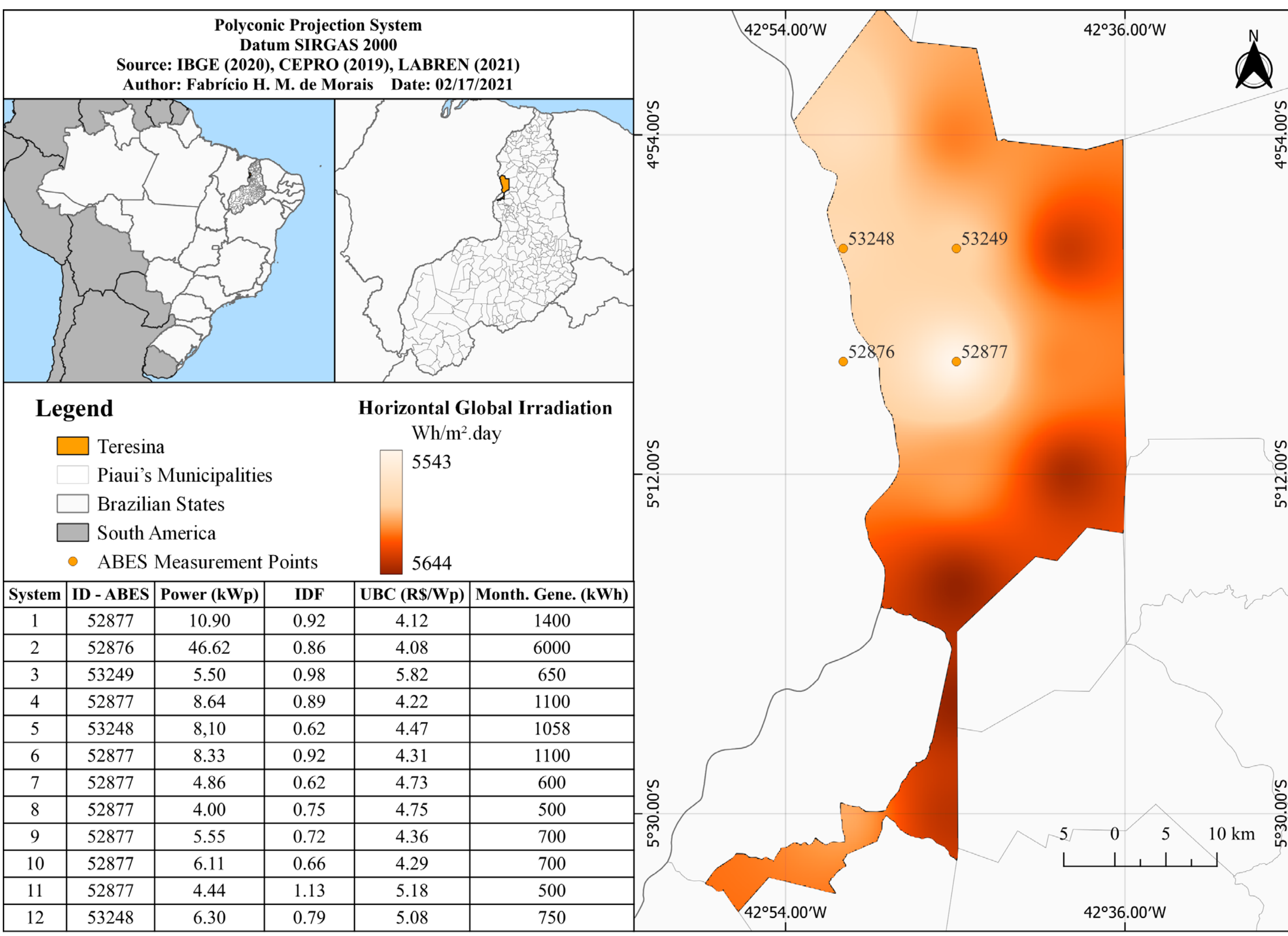
The authors showed that photovoltaic technology insertion in Brazilian homes is strongly correlated with political and socioeconomic issues, in contrast to solar resources availability.

Electric utilities must bill residential consumers for the highest value obtained from the consumption of active power or the cost of availability, equivalent to 30 kWh, 50 kWh, or 100 kWh, for single-phase, two-phase, or three-phase installations, respectively (Brasil, 2021). The tariff value and its percentage composition vary throughout the national territory according to ANEEL. In most cases, the TUSD wire B tariff is cheaper in more populous regions since the same network supplies a higher number of consumers.

In order to assess the influence of the NLFDG on the economic viability of DG systems for residential consumers, the conventional electricity tariffs approved for utilities in the country and available in ANEEL's database were initially checked (ANEEL, 2022) (Brasil, 2021). Thus, outliers were excluded (Silva et al., 2019), while maximum, minimum, and average percentages of local tariffs were evaluated. This study does not consider residential consumer units classified as "low income", who benefit from a specific public policy that offers discounts on the energy bill (which should be the subject of future studies).

A total of 12 commercial proposals for photovoltaic DG systems installed in the city of Teresina, capital of the state of Piauí (located in the Northeast region) in the year 2022 (vacancy period of the NLFDG) were selected due to data availability as shown in Figure 3. The privacy of consumers was preserved; only the reference points of each system in the Brazilian Atlas of Solar Energy were highlighted on the map (Pereira et al., 2017; Morais et al., 2019; Silva et al., 2019), which also served as reference for Costa and Santos (2020) and Silva et al. (2021). Therefore, a non-probabilistic sampling was used that does not compromise the research since the assessed scenarios allow extending the premises to other case studies.

Considering the widespread use of renewable energy sources worldwide, it is necessary to reduce costs while increasing the efficiency and resilience of conversion systems. In this context, significant technological advances have been reported on the development of photovoltaic modules (Liu et al., 2022) and inverters (Mehta and Puri, 2022).



System	ID - ABES	Power (kWp)	IDF	UBC (R$/Wp)	Month. Gene. (kWh)
1	52877	10.90	0.92	4.12	1400
2	52876	46.62	0.86	4.08	6000
3	53249	5.50	0.98	5.82	650
4	52877	8.64	0.89	4.22	1100
5	53248	8,10	0.62	4.47	1058
6	52877	8.33	0.92	4.31	1100
7	52877	4.86	0.62	4.73	600
8	52877	4.00	0.75	4.75	500
9	52877	5.55	0.72	4.36	700
10	52877	6.11	0.66	4.29	700
11	52877	4.44	1.13	5.18	500
12	53248	6.30	0.79	5.08	750

Figure 3 – Sampling space defined according to the Brazilian Atlas of Solar Energy.
Source: prepared from data obtained from Pereira et al. (2017).

Thus, for characterizing the reference systems, the initial investment, technology type, rated power, and efficiency of the modules and inverters have been analyzed aiming at calculating the basic unit cost (BUC) and the inverter sizing factor (ISF) (Pereira et al., 2017; Morais et al., 2019; Silva et al., 2019; Silva et al., 2021).

The average daily solar irradiation was also estimated based on geographical coordinates (Santos and Oliveira, 2018). From such data, a cash flow study was performed with the average monthly energy cost for 2022 (R$ 92.29/100 kWh) to determine the following econometric parameters: the net present value (NPV), internal rate of return (IRR), payback, and cost-benefit ratio (CBR). In this analysis, a useful life of 25 years, an annual degradation rate of 0.8%, and a maintenance cost of 10% of the initial investment considering the replacement of the inverter occurring every ten years were considered. In addition, the study considered the difference between the average energy tariff adjustments of the local energy concessionaire during the last ten years and the expected values of the Special System for Settlement and Custody (Selic) rate as a discount rate (Morais et al., 2021; Duaik et al., 2022; Rediske et al., 2022).

After defining the reference scenario, the same econometric parameters were determined for five case studies of the NLFDG based on the percentage use of the SCEE. The analysis relied on a complementary parameter to the simultaneity factor, which relates the energy portion generated and consumed simultaneously to the total energy generated (Table 2) (Brasil, 2022). For this purpose, we considered the hypothetical case in which the consumers decided to make investments during the transition period and after the effective application of the NLFDG (Table 3). The gradual charging of the TUSD wire B tariff was considered during the transition period. As previously mentioned, owing to the lack of a regulation for 2029 (Brasil, 2021), the full tariff for using the distribution system was considered, that is, 100% of the tariff for the transition period.

Finally, given the profile of the Brazilian investor, who favors lower-risk investments (Borba and Reis, 2022), the reference scenario and the case studies were compared with investments in savings and the Direct Treasury (Selic Treasury 2029). This latter is a traditional investment option in Brazil, which considers a period of six years (Brasil, 2023b). Therefore, the gross return on investment after this period was analyzed to bring the discussion closer to the general population.

Table 2 – Assessed scenarios considering the percentage use of the Energy Compensation System.

Assessed Scenarios	% self-consumption and SCEE	Simultaneity Factor
Scenario 1	100% self-consumption	1.00
Scenario 2	75% self-consumption and 25% SCEE	0.75
Scenario 3	50% self-consumption and 50% SCEE	0.50
Scenario 4	25% self-consumption and 75% SCEE	0.25
Scenario 5	100% SCEE	0.00

SCEE: energy compensation system.

Results and Discussion

To assess the impact of the NLFDG on the return on investment, a survey was conducted on the amount and percentage of the TUSD wire B tariff for all utilities in Brazil based on ANEEL databases, which resulted in average values of R$ 0.69/kWh and 33.17% (Figure 4). It is observed that the South and Northeast regions present the lowest and highest impacts on the return on investment, respectively, with percentage tariffs of 31.09% and 40.71%. The Southeast, Central-West, and North regions are prone to intermediate impacts, with percentages of 32.02, 32.63, and 39.71%, respectively. It is noteworthy that the higher the percentage, the greater the impact of the new regulation.

The Federal District (DF) electric company has the second lowest TUSD wire B tariff in Brazil. COPREL in Rio Grande do Sul State holds the first position, with a 15.03% tariff. The states of Paraná and Espírito Santo have a low impact on the return on investment, with tariffs of 24.91 and 26.34%, respectively. In turn, Acre has the highest impact once the tariff corresponds to 48.12%.

Table 4 summarizes the results obtained from the economic analysis of the reference system adopted in this study. From the discount rate and the useful life of investment, one can determine the NPV in terms of capital inflows and outflows. If the NPV is positive, the system is economically viable. The IRR defines a hypothetical discount rate that nullifies the NPV to check the viability of other investments compared with the first one. In turn, the payback represents the time required for the investment to become profitable, corresponding to the period for which the NPV becomes positive (Pereira et al. 2017; Morais et al., 2019; Silva et al., 2019; Silva et al., 2021). In order to assess energy generation benefits, the electricity cost of R$ 92.29/kWh was considered, in addition to an average annual adjustment of the residential electricity tariff, and the Selic rate between 2012 and 2022 corresponding to 8.76 and 8.89%, respectively.

Table 3 – Percentage of the distribution energy tariff established by the New Legal Framework for Distributed Generation.

Implementation Period	Installation Year	Percentage of TUSD Wire B Tariff (SCEE) (%)	Percentage Tariff of SCEE (%)	SCEE Benefits* (R$/100kWh)
Vacancy	2022	0	0.0	92.29
Transition	2023	15	5.8	86.93
	2024	30	11.6	81.56
	2025	45	17.4	76.20
	2026	60	23.3	70.83
	2027	75	29.1	65.47
	2028	90	34.9	60.10
Effectiveness	≥ 2029	100	38.8	56.53

*Valid for the Equatorial Energy Piauí company for the year 2022 (tax-free tariff of R$ 74.31/100kWh and 38.75% of TUSD Wire B); TUSD: energy tariff corresponding to distribution; SCEE: Energy Compensation System.

A discount rate of 0.13% per year was adopted, thus representing the difference between the two averages (ANEEL, 2023b; Brasil, 2023a).

Considering an average cost of R$ 4.62/Wp and the aforementioned parameters (Morais et al., 2021; Duaik et al., 2022; Rediske et al., 2022), all systems are economically viable since the NPV is positive. The payback for the systems ranges from three to five years, while the systems with the lowest BUCs have the lowest payback. It is noteworthy that all case studies correspond to grid-connected photovoltaic systems. Since the manufacturers ensure a minimum efficiency of 80% of the photovoltaic modules after 25 years of operation, a useful life of 25 years was considered in the analysis. All systems present a low payback and the IRR ranges from 20.95 to 33.65%. In other words, more efficient systems must present an annual return much superior to the average basic interest rate, the Selic.

In turn, the CBR relates the NPV to the cash outflows (installation and maintenance) and inflows (energy generation). Thus, this parameter helps determine which system is more efficient from an economic perspective (Pereira et al., 2017; Morais et al., 2019; Silva et al., 2019; Silva et al., 2021). Inverters and photovoltaic modules are the most expensive system elements. The inverter design factor (IDF) corresponds to the ratio between the inverter rated power and the total peak power of the photovoltaic system. The lower the IDF the lower the inverter rated power and cost in most cases. However, it is necessary to oversize the inverters in some practical applications, especially when the consumer intends to expand the system in the future (Pinho and Galdino, 2014; Morais et al., 2021).

Table 4 – Reference scenario adopted in the present study.

System	NPV	IRR (%)	Payback	CBR
1	R$ 288,013.45	33.16	3	0.157
2	R$ 1,237,517.56	33.65	3	0.155
3	R$ 120,407.87	20.95	5	0.241
4	R$ 224,884.56	32.04	4	0.163
5	R$ 214,989.86	31.02	4	0.168
6	R$ 225,602.28	32.60	4	0.16
7	R$ 118,966.98	27.51	4	0.188
8	R$ 99,338.52	27.76	4	0.186
9	R$ 141,944.79	30.69	4	0.169
10	R$ 139,552.40	28.21	4	0.183
11	R$ 94,553.75	22.59	5	0.225
12	R$ 144,821.10	24.52	4	0.209

NPV: net present value; IRR: internal rate of return; CBR: cost-benefit ratio.

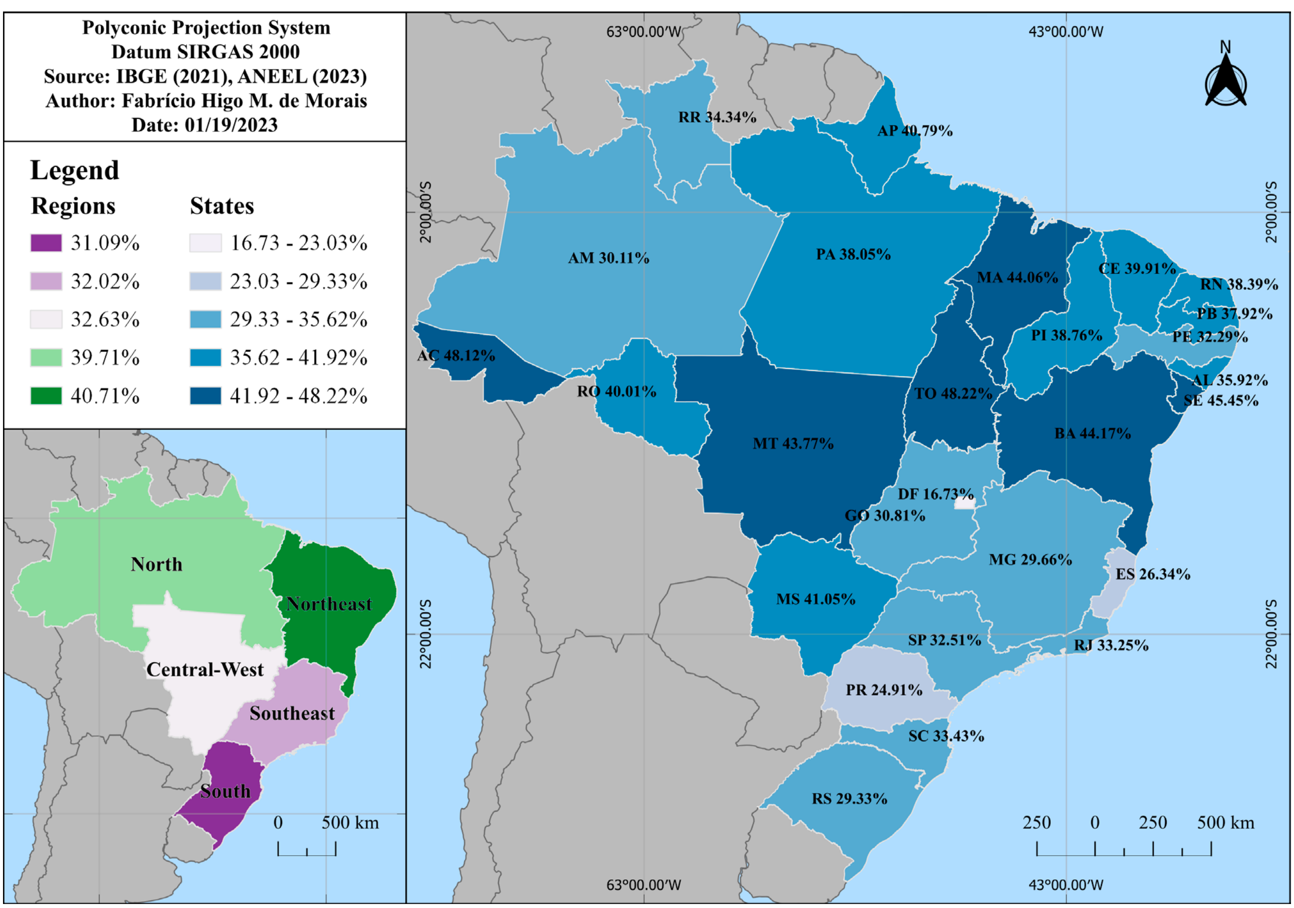


Figure 4 – Percentage of TUSD Wire B tariff for each Brazilian state.

All photovoltaic systems rely on monocrystalline modules. As expected, the systems with the lowest CBR also have the lowest ISF. System #2 is the most economically efficient, with a CBR of 0.155 and an ISF of 86%. System #11, which has an inverter with a rated power of 13%, greater than that of the photovoltaic generator, has the second highest CBR, that is, 0.225. In turn, system #3 has the highest CBR, 0.241. This is due to the fact that it is the only system that uses a more expensive and efficient technology, the microinverter, which is more effective for modules with distinct orientations (Pinho and Galdino, 2014; Morais et al., 2021). On the other hand, the implementation cost of its counterparts is lower because they employ string-based inverters instead. Since systems #2 and #3 have the lowest and highest CBR, respectively, they represent the best- and worst-case scenarios for the NLFDG impact assessment.

Figure 5 shows how the NPV of system #3 varies as a function of the percentage use of the SCEE, that is, the complementary parameter of the simultaneity factor, as well as the installation year. The percentage NPV compared with the reference system is also represented above the bars. The higher the percentage used the highest the impact of the NLFDG on generation. Since the NPV is positive, all assessed scenarios are economically viable.

However, if the assessed systems were installed only in 2023, that is, the year of the transition period with the lowest impact, consumer losses could vary from 40.1% to 44.6 considering systems #2 and #3 as a reference, respectively. Similarly, if they were installed only in 2029, the year for which the regulation will present the greatest impact, such losses could vary from 45.9 to 53.1%. However, in the specific case when the consumer is not part of the SCEE, that is, when all generated energy is consumed and not injected into the grid, thus corresponding to a simultaneity factor of 100%, there would be no loss in the context of the NLFDG, regardless of the year of installation.

The hypothetical case in which the reference systems were not installed in 2022 (vacancy period) but in subsequent years (transition or effectiveness period) was also analyzed. By 2028, during the transition regime, there should be a gradual increase in the percentage of TUSD wire B tariffs. To measure this impact, one can analyze the variation in the NPV of such systems as a function of the year of installation (Figure 6). A significant impact on the benefits is immediately noticeable if the systems are installed only in 2023 (at the beginning of the transition period), which becomes even more evident in subsequent years. Thus, there is no gradual transition, and the longer the customer takes to install the system, the lower the return on investment.

As the NPV decreases with the NLFDG implementation, the IRR also decreases; in contrast, both the payback and CBR increase, making the investment even lesser attractive. In this way, the negative impact becomes more intense with the increase in SCEE use and with the delay in installing the systems. Considering an IRR of 33.65% in 2022, if system #2 were installed only in 2029, this parameter could drop to 19.83% depending on the percentage use of the SCEE. As for system #3, this reduction could be from 20.95% to 11.55% (Figure 6A).

Regarding the payback, there was a potential increase from three to five years for the first system, while for the last system, it could increase from five to eight years (Figure 6B). The CBR would increase from 0.155 to 0.253 and from 0.241 to 0.394 for systems #2 and #3, respectively. Therefore, the NLFDG implementation brings negative impacts both for the DG market and the environment since it causes a slowdown in the expansion of DG and the use of renewable energies (Costa et al., 2022).

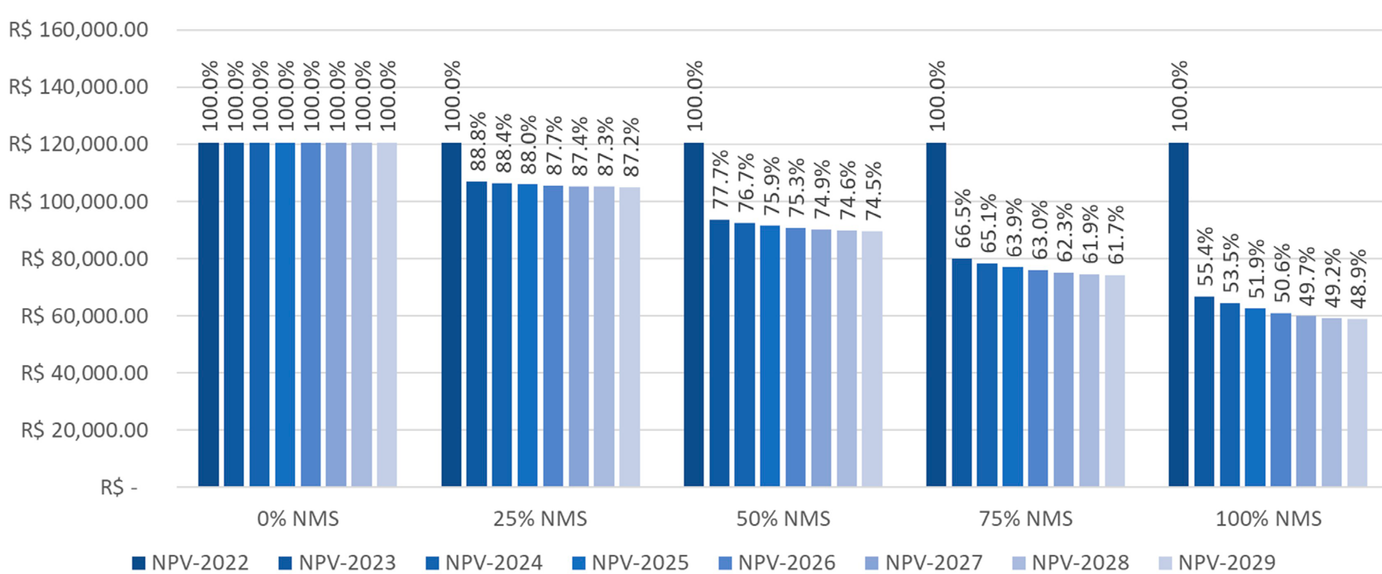


Figure 5 – Net present value as a function of the installation year and percentage use of the energy compensation system for system #3.

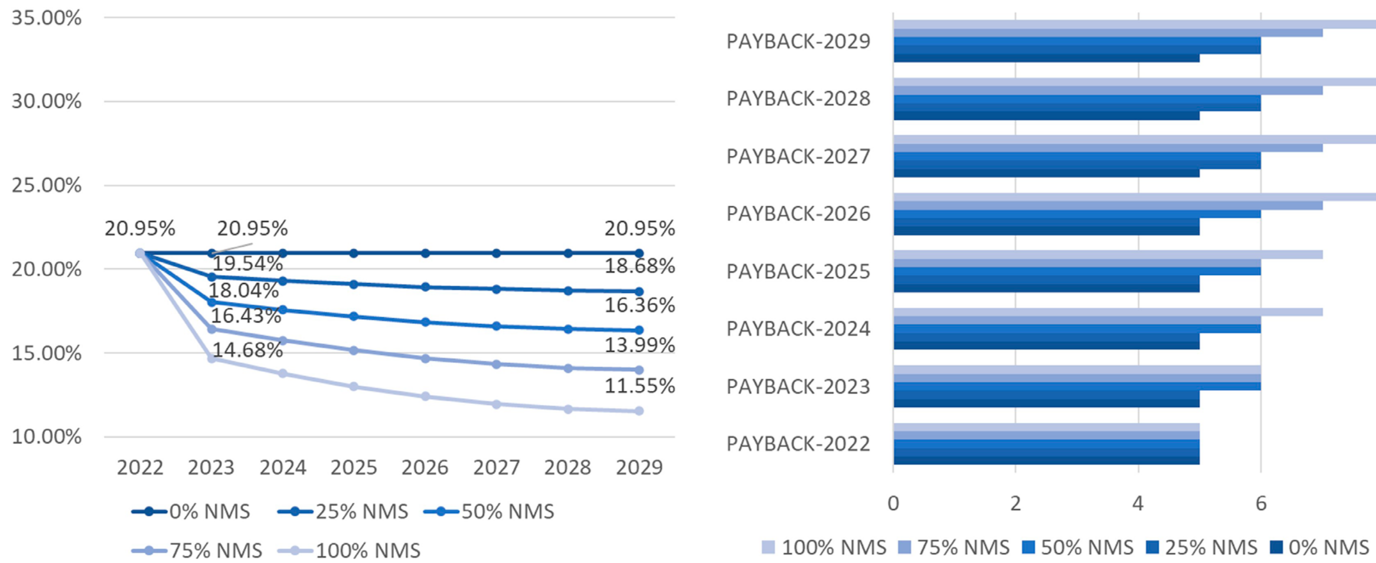


Figure 6 – Variation of the (A) internal rate of return and (B) payback for system #3.

The results of the impact associated with the NLFDG were compared with the benefits of savings accounts and the Selic Treasury 2029, considering the same time interval. At the end of the first six years, with an initial investment of R$ 190,000 for system #2 and R$ 32,000 for system #3, considering a net yield of 6.55% per year for a savings account and 8.1% per year for the Selic Treasury 2029, system #2 would have yielded R$ 137,172.01 or R$ 88,357.83, and system #3 would have yielded R$ 14,881.31 or R$ 23,102.65. In all scenarios analyzed, investments in DG are more advantageous, resulting in a higher yield. However, as expected, the new regulation becomes less attractive with the increase in the percentage use of the SCEE (or decrease in the simultaneity factor) and with the delay in installing the systems, as observed both for the best- and worst-case scenarios analyzed. It is worth mentioning that high-interest rates in Brazil encourage conservative investments such as fixed-income ones (Jacomassi and Oliveira, 2022).

One could determine the profitability of investments in the first six years of operation for the first and last scenarios compared with fixed-income investments for the same period. The data labels above the bars correspond to the number of times that the yields of the scenarios analyzed are greater than the yields on investment in savings account, which is the most popular fixed-income investment in Brazil (Borba and Reis, 2022). Therefore, for the best- and worst-case scenarios, there was a reduction from 3.4 to 1.7 times and from 1.8 to 0.7 times, respectively. However, the reference scenario reflects a reality that is currently unfeasible. In view of the results of this research, it is suggested that consumers install DG systems as soon as possible and use SCEE as minimally as possible, while properly managing energy consumption so as to increase simultaneity.

Conclusion

The main advantage of the NLFDG is legal certainty, which is essential for DG expansion. In other words, one can ensure that consumers can participate in the energy compensation system, contributing with the incorporation of clean energy sources into the Brazilian electricity matrix. This reduces the environmental impacts caused by other conventional electricity generation forms that produce greenhouse gases and contribute to global warming. However, it negatively impacts the systems' economic viability.

For systems whose access request occurs after January 6, 2023, the use of transmission and distribution systems will be charged to consumers according to the system ratings. The impact on cash flow varies depending on tariffs percentage composition. An average tariff of R$ 0.69/kWh for residential consumers was found in the country, with an average percentage of distribution costs (TUSD wire B) equal to 33.17%. The tariffs of 102 distributors were analyzed, while there is no standard value for the energy tariff, nor for its percentage composition. Thus, the impact of the NLFDG increases as the TUSD wire B tariff percentage increases. The South and Northeast regions stand out as the most and least impacted in the country, with average tariffs of 40.71 and 31.09%, respectively.

The economic viability of DG systems depends on both technical (availability of the primary energy resource, the technology used for the system components, and sizing and installation aspects) and economic factors (initial investment, energy cost, tax discount, and operating and maintenance expenses). In this sense, some issues are independent of the new regulation. For instance, modules and inverters are the main components of photovoltaic systems, while ISF determines the ratio between the inverter-rated power and the peak power of the photovoltaic generator. Thus, the lower the ISF, the broader the economic viability due to the use of inverters with lower power ratings. However, the technology used is also relevant, once systems relying on string-based inverters tend to be less costly than their counterparts based on microinverters, for example.

The publication of Law 14,300/2022 negatively impacted the DG market, reducing the financial return of the projects. It tends to slow down the expansion of such systems, consequently affecting the use of renewable energies and causing negative socio-environmental impacts. Therefore, the SCEE percentage use, that is, the complementary parameter to the simultaneity factor and the year of commissioning of the system become more relevant in the economic viability analysis. In all assessed systems, regardless of the year of installation and the SCEE percentage use, the projects would remain economically viable. However, the longer the commissioning of the systems and the increasing the percentage use of SCCE, the smaller the simultaneity factor, and the less viable and less economically attractive the installation of DG systems becomes. Moreover, the transition period of the law, which should gradually reduce NPV benefits, results in a drastic decrease in the first year of installation. It could even reach a reduction of 44.6%, a loss that progressively worsens with the commissioning of systems in subsequent years.

Depending on the two aforementioned aspects, in the worst-case scenario, the NLFDG could reduce the NPV by 53.1%, decrease the IRR from 20.95 to 11.55%, increase the payback from four to eight years, and increase the CRB from 0.241 to 0.394. However, it should be noted that if the consumer does not use the SCEE, that is, all generated energy is consumed, resulting in a simultaneity factor of 100%, this new regulation is expected to cause no negative impacts.

When comparing the benefits achieved in the first six years of installation of the DG systems with the income from investments in savings accounts and Direct Treasury, which are traditional fixed-income investments in Brazil, one can state that, independently of the NLFDG, the systems are economically viable. However, as expected, with the increasing use of the SCEE (or with a lower simultaneity factor) and a delay in commissioning the systems, the economic attractiveness of DG decreases. The study demonstrated that the return on investment of a system corresponding to 180% higher than that on savings account could be reduced to only 70% depending on the percentage use of the SCEE and the year of commissioning.

It should also be noted that the favorable scenario for DG during the vacancy period of Law 14,300/2022 no longer exists since January 7, 2023. Therefore, for the economic viability of new systems, a proper energy management strategy is strongly recommended for minimizing as much as possible the percentage use of the SCEE. Thus, it is necessary to increase the simultaneity factor, whereas the higher consumption should occur during higher generation periods. In addition, consumers should install the systems as soon as possible, once the tariff for using the distribution system will increase gradually during the transition period.

Contribution of the authors:

SOUSA, D. L.: Formal Analysis; Investigation; Conceptualization; Data curation; Writing – original draft; Writing – review & editing; Resources; Software; Funding. SILVA, O. A. V. O. L.: Formal Analysis; Investigation; Methodology; Writing – original draft; Writing – review & editing; Resources; Software; Funding. MORAIS, F. H. M.: Formal Analysis; Investigation; Conceptualization; Data curation; Writing – original draft; Writing – review & editing; Resources; Software; Funding. LIRA, M. A. T.: Project administration; Supervision; Validation; Visualization; Funding. MORAES: A. M.: Supervision; Validation; Visualization; Funding. ALVES, D. R. S.: Acquisition; Data curation; Writing – review & editing; Funding.

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