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Economic Effects of Micro- and Mini-Distributed Photovoltaic Generation for the Brazilian Distribution System

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Abstract: The micro- and mini-distributed generation (MMDG) has significantly increased after the normative resolution No. 482/2012 in Brazil; the installed capacity surpassed 7 GW in 2021. In the international context, a similar event was observed, whose process generated a cross-subsidy for other consumers, in addition to other problems that affect the economic balance of concessionaires. To mitigate this issue, the National Electric Energy Agency (ANEEL) is in the process of revising current rules. Thus, this study estimates the weight of this decision, through a methodology adapted from international assessment models, based on information from the Brazilian regulatory system. In order to achieve it, this paper presents metrics to define the potential market MMDG, based on the consumption patterns of consumers. Then, through time series analysis, the MMDG demand curve is estimated under two scenarios up to 2030. Finally, the economic impact on tariff adjustments and revisions, and their effect on the electric power concessionaires are evaluated. In the distribution companies of the Enel Group alone, economic losses are estimated at USD 1.2 billion by 2030; 53% of this will be passed on to consumers' tariffs. Thus, based on international experiences, it can be concluded that the best model is the adequate grid remuneration.

Keywords: incentive regulation; grid connection; renewable energy; distributed generation; economic effects; solar energy; Brazilian regulatory system

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1. Introduction

Distributed Generation (DG) refers to electricity production carried out near or close to consumers, regardless of power, technology, and energy source. The International Council on Large Electric Systems [1] defines DG as any local generator connected to the distributor with a capacity of up to 50 MW. The Institute of Electrical and Electronics Engineers [2] defines DG as power generation with reduced capacity compared to centralized ones that can be installed anywhere in the distribution system. The International Energy Agency [3] characterizes DG as generating units on the demand side, connected to the local distribution network.

Despite the different definitions for the concept of DG, there are common points in the literature that are also subject to the classification by local regulation, such as the scale of the installed power source and the energy vector of the supply source.

Micro- and mini-distributed generation (MMDG) is currently considered to be a technological innovation in electricity markets, but it is a known concept that has already been devalued with the increasing competitiveness in centralized power generation.

More than a century ago, transmission and distribution networks were considered to be the most efficient way to transport electricity as they promoted energy security and operational stability. Electricity flowed only in one direction through the process that connected generators, transmitters, and distributors to users. Historically, the regulatory mechanisms for tariffs and metering were created to bill customers through one-way and monomial tariffs.

Amid the evolution of digital technology, the reduction in costs of decentralized renewable energy and the spread of distributed energy resources (DERs) has changed the role of consumers in the electricity market. The digital economy has broken away from the old paradigm of the consumer as a passive participant in the grid and has created the concept of a prosumer, which is a participatory consumer in decentralized production, conducting remote self-consumption and exporting surplus energy to distributors. In this new configuration, the network has developed into an interactive platform, with the insertion and consumption of energy in different time slots [4].

To follow this trend in the international scenario, MMDG was regulated in Brazil in 2012 by the National Electric Energy Agency (ANEEL) Normative Resolution (RN) No. 482/2012. This resolution granted prosumers access to the distribution system. It adopted the net metering system as an incentive policy, with complete compensation of the Distribution System Use Tariff (TUSD) [5].

The TUSD is determined by ANEEL in the tariff processes and is the value in USD/MWh charged for the use of the distribution system. It can be available that this tariff includes all expenses from generation to transmission to the final consumer, including the components of debt: part A, part B, losses, and charges [6].

Since its creation, the MMDG represented an installed capacity of only 21.9 MW until 2015 [7]. Knowing the low market adherence, ANEEL updated the regulation to signal the government's interest in expanding this technology. Among the main modifications, the following stand out [8]:

- Changing the limits of installed power of MMDG to 75 kW and 5 MW (being 3 MW for hydro sources), thus allowing the use of any renewable source and qualified cogeneration.
- Extension of the validity period for the compensation of energy credits generated from 36 to 60 months.
- Standardization of access request forms to facilitate registration in the MMDG program.
- Possibility of installing DG systems in condominiums and commercial buildings. In this modality, it is possible to share the energy generated among the condominium owners.
- The establishment of shared generation, allowing the consumer unit to be in a different location than the generating units from which the surplus energy will be compensated. However, consumers must be within the same concession area of the distributor and generating unit.
- The implementation of remote self-consumption is characterized by consumer units owned by the same legal entity or individuals with a consumer unit with MMDG in a different location from its other consumer units. The surplus energy may then be compensated for.

In 2017, two years after the revision of resolution No. 482/2012, the installed capacity of MMDG increased by more than 1000% in the country, from 21.9 to 252.1 MW [7]. The number of new connections exceeded the regulator's expectations, leading to a condition where it is interesting to review the incentives of this market.

On the one hand, distributors and some consumers allege that net metering, associated with the current price-cap regulatory model, transfers network costs to other users that do not have MMDG. On the other hand, the photovoltaic market and users interested in this decentralized generation model highlight the benefits, such as the generation of employment, the reduction of technical losses, and the mitigation of emissions. Furthermore, they claim that the current compensation system should remain until it reaches the necessary market maturity [9].

In the Brazilian MMDG market, with the announcement of the potential change of incentives, only in 2019, the installed power increased by 229%, reaching the value of 2255.2 MW compared to only 684 MW in 2018 [7]. According to the Ten-Year Energy Expansion Plan 2030 [10], framed in an optimistic scenario, MMDG presents an average rate of return of 18% p.a. In the scenario that includes regulatory changes, the rate is 10% p.a., reaching 14% in 2030. In the latest analyses of the Central Bank [11] the long-term projection for Brazilian interest rates is 6.5% p.a., indicating that the MMDG is positively characterized by a medium- to long-term return.

The Brazilian MMDG market went through an interesting transformation during the COVID-19 period. Despite the adverse effects of this pandemic on the world economy, MMDG proliferation increased to 4960.6 and 7371.9 MW in the years 2020 and 2021, respectively. These data represent a significant expansion of 49%, directed by the changes in the regulatory framework [7].

In 2022, after debates in the Brazilian electricity sector, Bill No. 14,300/2022 was approved. It maintains the current energy compensation regime for existing prosumers for 25 years. The same benefit applied to projects requested within 12 months of authorization, depending on presidential sanction. After this period, new projects will receive a transitory term of 7 years. The regulator will then charge the components that remunerate the distribution network by the TUSD in part B [12].

To maintain the compensation and tariff regime for low-voltage customers associated with the long transitional period for new entrants, the discussion about cross-subsidies and how incentives to MMDG adopters impact the tariffs of all other consumers remains valid. According to Brazilian Institute for Consumer Defense (IDEC) [13], it is worth noting that this effect is more significant on low-income families, once electricity has a five times greater impact on their budgets, on average, compared to wealthier families in Brazil.

To corroborate this statement, IDEC [14] conducted a comparative study in the cities of São Paulo/SP, Rio de Janeiro/RJ, and Belo Horizonte/MG. In São Paulo, 31% of the installed capacity is in the regions with the highest concentration of income of the city, while only 4% is in the poorest locations. For Rio de Janeiro, 26% of adopters have a high income, and 1% have a low income. In Belo Horizonte, the disparity is even more significant; 42% of the installed capacity is in rich areas and less than 1% is in regions with low-income populations.

Another relevant factor is the presence of legal entities in the MMDG business. At least 20% of the installed capacity of MMDG is produced by corporate solar farm projects belonging to companies with a share capital higher than BRL 100 million. Considering the high return rate of these projects, the number of MMDG companies financed by investment funds has consistently accelerated. This situation burdens the lower-income consumers in Brazil [14].

The problem of cost transfers between high- and low-income users has also been verified in the international scenario. As per the Edison Foundation [15], the net-metering system needs to be reformed through regulatory policies to avoid allocative distortions in the tariffs of grid users with PV panels (i.e., higher income) and of those without PV panels (i.e., lower income).

In one study [16], researchers from the Massachusetts Institute of Technology (MIT) revealed that the problem of net metering, and consequently, of cross-subsidy is in its application associated with monomial or binary tariffs that are mostly volumetric. As a solution, the researchers proposed the adoption of time-of-use tariffs and restrictions in the peak hour compensation system.

In the United States, the dissemination of photovoltaic generation has changed monomial tariffs to binomial tariffs; in some cases, mild hour-seasonal tariffs have also been adopted. It should be noted that, after changing the traditional net metering for its derivations in each state, a new specific tariff group forms that deals with the case of prosumers [17].

For the net metering situation in the European context, a feed-in tariff caused a tariff effect for other consumers and the government. This forced the German regulator to reduce the electricity grid's values compensation for new prosumers. Stone [18] verified that the benefit of feed-in tariff compared to that of conventional residential tariff decreased by 60% in Germany.

In the international scenario, countries have advanced to the second generation of smart meters and smart tariffs, while Brazil continues to follow a single tariff option, for consumption by 99% of consumers. Currently, there is no technological or regulatory framework available to indicate the tariff signals, by schedules, in the low voltage group (group B) [19].

The electricity industry needs more dynamic regulatory mechanisms to respond to new-age prosumers. These changes will require adjustments in electricity markets, aiming at higher economic efficiency and user well-being. Regulatory bodies need to understand the reality of each location in light of these new technologies, and consequently, design strategies to adapt business models, public policies, and regulatory instruments to promote solutions towards a new balance in this changing market.

The balance of this system is necessary, although achieving this is a challenge. The introduction of the prosumer, reductions in storage costs, and the future possibility of disconnection from the grid may threaten the sustainability of distributors in the long term.

Thus, as a first step in the regulatory transition, it is essential to assess the economic effects of new technologies and the regulatory barriers that need to be removed, in order to mitigate sectoral conflicts of interest, and maintain financial sustainability and social equity for access to the grid. To make it possible, it is necessary to define a regulatory framework with prices and charges that correctly signals the value of distributed resources. Only from these conditions will all the economic and technical potential of the distributed resources be developed in the world electrical markets [16].

Considering the demand, there are many contributions to analyze the effects of the expansion of MMDG in international markets. However, the diffusion process of distributed technologies is specific to each country, mainly in the economic evaluation of incentives in the regulatory environment, in order to ensure their sustainability and competition with centralized resources in the long term [20,21].

From the economic perspective, with more and more DERs in energy planning, changes are already being observed in the business models of regulated distributors around the world, through changes in revenue flows, cost structure, changes in customer profiles, and tariffs [16].

In parallel, in the Brazilian market, numerous studies point to a growing demand for MMDG in distributors, as is the case of works by EPE [22], ANEEL [7], and Hallack and Vazquez [23]. Therefore, it is already a fact that the future of the country's distribution networks will be more integrated with the consumer through new technologies.

The Brazilian electricity sector needs new models that assess the economic effects of these technologies, which support agents in the planning of distribution networks.

This paper's main contribution is to present a financial and regulatory model for evaluating the economic effects of MMDG, specific to the Brazilian distribution market, as it considers the regulatory and tariff guidelines of the sector. To achieve this, the study details how this effect is inserted in the tariff structure, through the processing of public data, considering the peculiarities of the tariff review process in Brazil.

In order to achieve the main objective of this study, it was necessary to develop secondary contributions, which are crucial for a better understanding of the evolution of this technology in utilities.

First, a methodology was developed to define the potential demand for MMDG at the distributor through the evaluation of the consumption pattern of users and microeconomic explanatory variables on the households of the families.

Subsequently, through time series analysis, the MMDG demand curve is estimated until 2030, in two scenarios for the distribution sector. The first scenario is called "reference" and considers the recent passage of Bill No. 14,300/2022. In the second "binomial" scenario, the introduction of binomial pricing is considered to correct the distortion caused by net metering, as applied in the United States and other countries with cross-subsidy problems [16]. Finally, the economic effect of tariff readjustments and revisions is evaluated, in both scenarios, from the perspective of the consumer and the electricity concessionaire.

It was also possible to estimate in which year, on the distributor's demand curve, the MMDG technology will reach the total potential market and the representative dimension in the concessionaire's regulated market. This helps to understand the specifics of each concession area and, consequently, the regional impacts of the technology.

In order to transform this theoretical knowledge into a tool for practical use, this work developed the proposal for a financial and regulatory model, through a case study applied in the distributors of the Enel Brasil group. Recently, Enel has become the largest electricity distribution company in Brazil and supports technological development in its concession area, which makes it relevant for this study [24].

Regarding the technology used, the photovoltaic MMDG with a net metering system was chosen in this evaluation. This is the most used and encouraged technology in Brazil among the available DERs [19]. Thus, this work will contribute to the application of its methodology as a reference in the evaluation of other DERs, considering the Brazilian regulatory environment.

In this way, this work does not aim only to forecast the future but to add knowledge and build tools that stimulate the planning of the electricity sector, through the identification of existing barriers in the Brazilian economic regulation.

2. Materials and Methods

To this end, this methodology is divided into two parts: demand projection and economic effects in the distributor's concession area.

Firstly, from the demand perspective, the article considered the calculation of the potential demand of MMDG in the concession area, with the definition of the potential market, projection, and scenarios for the installed capacity and electricity generation.

Secondly, from an economic standpoint, the article presented the methodology used to calculate the economic effects of MMDG in the concession area, in the tariff adjustment and review processes, and the impacts on the concessionaire.

Enel has recently become the largest electricity distributor in Brazil, making it an appropriate example to assess the effects of MMDG within concession areas. Therefore, the three companies within the Enel group were used as an applied case study for this review.

2.1. Demand Analysis

In the Brazilian electricity sector, there are existing models used to predict the dynamics of the MMDG market. Usually, these models adopt regressions by time series to predict the future, as is the case of the works of Empresa de Pesquisa Energética 'Energy research company' (EPE) [22] and Kong et al. [25].

Based on these studies [22,25], it is clear that the use of statistical predictive models for demand alone is not a sufficient condition to indicate the ideal planning of the distributor market with a greater share of MMDG.

This statement is in line with the MIT [16], which states that the electricity sector should abandon the paradigm of planning energy resources with "top-down" models and use a new standard in distributors, through a more "bottom-up" analysis, valuing technical and microeconomic aspects of the users that make up the networks, mainly through the information available from the most distributed technologies.

Knowing this, this article elaborated a methodology whose approach is within this perspective. From an analysis guided by the bottom-up model, the total potential demand for MMDG in the distributor was defined, through the evaluation of the behavior of electricity consumption and microeconomic variables.

The following two steps were performed to define the potential MMDG market of the distributor. The total market considered is clarified in Appendix A.

The first step is based on National Distribution Register (CND) or Market Information Monitoring System for Economic Regulation (SAMP) information. MMDG customers were identified for each utility until 2021. One of the variables used in decision-making is the consumption pattern in the 12 months prior to the project to conduct an economic feasibility study for this type of investment.

Using this variable, it was possible to map the average consumption of each prosumer, in two levels of openness, by tariff group (i.e., A and B) and consumption class (i.e., residential, commercial, industrial, and rural). This information can be used by concessionaires to identify the customer profile most likely to migrate to the MMDG modality. Table 1 presents the methodology of clarifying the consumption pattern.

Table 1. Average consumption pattern by sector and tariff group in MWh in the 12 months prior to migrating to MMDG in the Enel group distributors.

Sectors	Enel Goiás		Enel Ceará		Enel Rio	
	Group A	Group B	Group A	Group B	Group A	Group B
Residential	5.89	0.69	5.04	0.81	2.22	0.56
Commercial	8.54	1.83	14.45	1.82	7.78	1.63
Industrial	9.60	1.77	15.43	1.44	9.29	1.51
Rural	10.45	1.53	4.22	1.24	3.05	1.01
Total	8.62	1.46	9.78	1.33	5.59	1.17

A sample cut-off is defined in the distributor's total customer market with the information in Table 1. At Enel Goiás, for example, residential and tariff group B users, whose consumption is equal to or greater than 0.69 MWh, are candidates to join the MMDG. The total customer market can be checked in Appendix A.

The second step aims to delimit the potential market model in the microeconomic aspects that affect new accessors for MMDG.

According to ANEEL data [7], more than 97% of projects use solar photovoltaic energy, with 41% in the residential sector and 36% in the commercial sector.

Photovoltaic projects have restrictions on the area available for installation. Once you take it into account, it is fundamental to evaluate the housing situation in the distributor's concession area, using information from the Brazilian Institute of Geography and Statistics (IBGE) through the National Household Sample Survey (PNAD), as presented in Table 2.

Table 2. Microeconomic market variables for low voltage residential group [26].

Residential Sector	Enel Goiás	Enel Ceará	Enel Rio
Type of dwelling	100%	100%	100%
% homes	94.5%	89.8%	73.8%
% apartments	5.5%	10.2%	26.2%
Housing situation	100%	100%	100%
% rented	42.6%	30.9%	29.2%
% own	57.4%	69.1%	70.8%

The first variable in Table 2 is the percentage of households by housing type. This indicator reflects the space available for installing MMDG. Although customers living in apartments can invest in the technology through remote or shared generation, these cases represent only 20% of photovoltaic installations. In comparison, the generation in the consumer unit itself is equivalent to 80% of the installations [7].

The second variable is the percentage of households by housing situation. This indicator assumes that customers who live in rented houses are less likely to invest in MMDG as it is a high investment with a long-term return.

This provides a preliminary definition of the potential MMDG market in the distribution area, which can allow us to evaluate the volume of MMDG and compare it to the concessionaire's market.

Two scenarios are then projected for MMDG in the concession area through time series analysis. The first scenario refers to the proposal of Bill No. 14,300/2022 [12] of the new Brazilian regulatory framework, while the second scenario, the binomial, consists of applying a binomial tariff from 2023.

The maturity of the MMDG market in each concessionaire can be estimated using these two scenarios, clarifying the trends of the distributor's expansion curve and the period in which it will reach its total market potential in each scenario.

The application of the variables presented in steps 1 and 2 on the distributor's market can define the potential market for MMDG in the distributor's concession area.

After defining the potential market, it is necessary to estimate, in the time horizon, when the MMDG will reach the maximum number of consumers. In order to accomplish it, the demand curve projection methodology was defined based on the ANEEL database [7], using the information on installed capacity.

In 2021, photovoltaic MMDG represented 97% of the total accumulated capacity. Once it is acknowledged, the projection only considered the evolution of photovoltaic technology, keeping other sources static on the horizon until 2030 [7].

Thus, the projection model adopted in this work is the time series one, using a 12-month moving average (MM) estimator. As suggested by the "bottom-up" models [16], the estimator was defined by variables disaggregated into 3 levels: DG modality by type of location: remote and local (level 1); tariff groups A and B (level 2), and by economic class: residential, commercial, industrial, rural, and others (level 3) (see Equation (1)):

$$MMGD \sum_{Group}^{Class} P_{t+1} = MM_t = \frac{(VR_t + VR_{t-1} + VR_{t-2} + \cdots + VR_{t-n+1})}{n}, \quad (1)$$

where P_{t+1} stands for the projection for the next period $t + 1$, by DG modality, tariff group, and economic class, in MW; MM_t stands for the moving average in period t, by DG modality, tariff group, and economic class, in MW; VR_t stands for the realized and observed value in period t, by DG modality, tariff group, and economic class, in MW; and n stands for the number of periods considered in the moving average in months.

The projection by MM estimators is frequently adopted in time series models, aiming at smoothing fluctuations and highlighting long-term behaviors. As examples of its applicability, we highlight the financial market analyses, which evaluate the trend of stock prices, and recently, the prognosis and contagion of COVID-19 in the population of the countries [27,28]. In the Brazilian case, the installed capacity of photovoltaic MMDG presents variations over the year, indicating adherence to the proposed methodology.

According to the projection of installed capacity (Equation (1)), this information is used to calculate energy generation, as indicated in Equation (2). The adopted capacity factor referred to the Ten-Year Expansion Plan of EPE [10]:

$$E_{MMGD_{(n)}} = \sum_{i \in Dx}^{n} (Pot_{ni} \times FC_{reg,\ source,modal} \times \Delta t_{i,n}), \quad (2)$$

where $E_{MMGD_{(n)}}$ stands for the MMDG energy generation per month n, in MWh; Pot_{ni} stands for the installed capacity of the MMDG system in month n, in MW; $FC_{reg,\ source,modal}$ stands for the capacity factor of the nth generation system, considering specificities of the region in which the system is installed, as well as its source and modality, and $\Delta t_{i,n}$ stands for the time interval (in hours) between the MMDG system connection date and end of the reference month.

With the projection methodology for installed capacity and energy generation, it is possible to state that the dynamics of MMDG market growth present new challenges for the Brazilian regulator, and because of this, scenario analysis is vital for evaluating economic effects. This work built two scenarios that supported distributor planning: "reference" and "binomial" to make it possible.

In the first scenario, called "reference", the current regulation of MMDG by Bill No. 14,300/2022 and its expansion until 2030 in Brazil were considered.

In the second scenario, called "binomial", the introduction of the binomial tariff in 2023 was evaluated. This scenario is suggested based on international experiences [16] that imply that the binomial tariff is one of the possible solutions to maintain the economic and financial balance in the distribution sector. The payback was relevant to determine the binomial tariff scenario. It was adopted to measure the payback time of an investment in MMDG. As the binomial tariff increases the payback, the payback factor of the distributor's concession area was calculated using Equation (3) [22]:

$$PF = \left[1 - \left(\left({}^{P_b}/_{P_m}\right) - 1\right)\right], \tag{3}$$

where PF stands for the payback factor (in %), P_b stands for the binomial payback in years, and P_m stands for the monomial payback in years.

This factor found by the variation of the payback from the current monomial to the new binomial charging system is applied to the curve of the reference scenario starting in 2023. Information on initial investment and estimated cash flow was used in each scenario by the MMDG PV project to determine the payback. The data used from EPE's model [22] and GREENER [29] supports Equation (4).

$$\mathrm{P} = \left[\frac{I}{CF}\right], \tag{4}$$

where P stands for the payback (in years), I stands for the initial investment (in BRL/year), and CF stands for the cash flow (in BRL/year).

The payback component is suitable for the model as the initial investment alongside cash flow variables can capture the price reduction of the technology over the years and the cost of electricity [22,29].

2.2. Economic Effects

In order to develop this methodology, the studies of GESEL [30], MIT [16], Doyle et al. [31], Vieira [32], Picciariello [33], and Simshauser [34] were made use as reference. These studies present methods of technical and economic feasibility of MMDG technology in Brazil, and also point out the main economic effects on the market in other countries.

Based on these papers, there is a need to build a financial and regulatory model to assess the economic effects of MMDG. The model proposed in this work considers the principles of economic regulation, through tariff readjustments and revisions, specific to the Brazilian distribution market. To achieve this, the demand model of Section 2.1 was used, and it contains information segmented by economic class and tariff group to enable an application of demand in the regulatory and financial model proposed in this paper.

The data periodically disclosed by ANEEL in the distributors' market in the SAMP [35] was also used as well as the values of the tariffs and partial market in the tariff processes disclosed in the SPARTA file (i.e., the System for Automated Annual Tariff Review/Readjustment Processes) [36].

Furthermore, the development of the economic effects methodology follows the premises of the regulatory tripod: tariff, market, and revenue [37].

a. Tariff [37]

Tariffs are adjusted annually, on the anniversary date established in the concession contract, except in the years when a Periodic Tariff Review (RTP) is carried out. The electricity tariff is divided into two components:

- Energy Tariff (TE): the amount of energy consumed monthly in a home, determined by ANEEL in USD/MWh, and used to relate the monthly billing to energy consumption.
- Distribution System Use Tariff (TUSD): the usual value determined by ANEEL, in USD/MWh, used to relate the monthly billing to the electricity distribution system. This tariff covers the costs of the facilities, equipment, and components of the distribution network used to transmit energy.

In the case of this study, the economic effect methodology refers to the impact on the TUSD, which comprises the following tariff structures: part A, part B, losses, and charges.

Part A involves costs related to electricity generation and transmission activities. These are costs whose amounts and prices, to a certain extent, are beyond the distributor's will or management. A clear example is the purchase of electricity according to the market demands as well as the connection and use of electricity transmission facilities.

Part B comprises costs directly manageable by the distributor. These are costs of the distribution activity that are under the control or influence of the management practices adopted by the company. In this scenario, the margin is monetarily readjusted by the X-Factor and the inflationary restatement in the Annual Tariff Readjustment process (RTA). The economic and financial balance is recalculated periodically in time intervals of 4 or 5 years, during the RTP of the distributor. This study did not consider the X-Factor; only the inflationary repositioning of tariffs included in the model.

The tariff for losses corresponds to the costs incurred because of electricity regulatory losses in energy distribution. The value above the regulatory limit is a cost that only penalizes the distributor's margin. In addition, losses are divided into technical, which is responsible for the energy dissipated during transmission, and non-technical, referring to the loss because of energy theft. In this study, the only loss left out is the non-technical one.

The sectorial charges centralize several subsidies that are given to agents of the electricity sector as per legislation, such as the Financial Compensation for the Use of Hydric Resources—CFURH for electricity generation; Supervision Tax of Electric Energy Services—TFSEE; Account for Energy Development—CDE; Incentive Program for Alternative Sources of Electric Energy—PROINFA; System Services Charge—ESS; Reserve Energy Charge—EER; Contribution to the National Electric System Operator—ONS; Research and Development—R & D; Energy Efficiency Program—PEE.

Thus, the tariffs are adjusted annually by the inflationary indicator of each concession contract.

b. Market [37]

The market comprises the amounts of electricity, power demand, and use of the distribution system invoiced in the reference period by users who use connection points to import or inject electricity. It is crucial to point out that the amounts invoiced for any month of the Reference Period are recorded in the SAMP. With the distributor market segmented by consumption class per year, it is possible to determine the growth rate of each sector over the years. Thus, the annual market projection considers the reduction of MMDG as per Section 2.1, and the average growth of each one in the sector in the last 5 years, before the COVID-19 period.

c. Revenue [37]

The tariff aims to ensure that concessionaires receive sufficient revenue to cover operating costs, compensate investments required for network expansion, and ensure service and quality to users. The costs and investments are passed on to tariffs and calculated by the regulator, and between RTP years, they may be higher or lower than the costs imposed by companies.

As part B is responsible for the distributor remuneration, the revenue from this tariff component was used as a reference indicator to assess the economic impact of MMDG.

The market and tariff projections were applied to calculate the so-called Value of Part B in the period (VPB 0). The VPB 0 was used in the regulatory models to assess the distributor performance only with the inflationary component before applying the X-Factor.

After understanding the application of the regulatory tripod tariff, market, and revenue, the effect on the electricity sector was divided into two categories: the impact on the tariff adjustment and revision, by tariff pass-through to the consumer, and the impact on the distribution concessionaire by reductions in revenue.

2.2.1. Effect on the Consumer

The effect of the market reduction by MMDG to the consumer occurs in the tariff readjustment and tariff revising processes. The economic and regulatory model will present the results considering the principles established in the Brazilian tariff processes.

Regarding the impact on the RTA, there are two basic principles in the Brazilian regulation: providing tariff coverage for the items in part A and charges, whose values and prices, to some extent, are not manageable by the concessionaire, and maintaining the purchasing power of the concessionaire revenue through part B of the tariff.

The RTP is one of the mechanisms that define the amount paid by the consumer for energy. It is carried out every five years, on average, according to the concession contract signed between companies and the granting authority. This revising process redefines the efficiency level of operating costs and the tariff remuneration from investments by part B and losses.

Once you have the structure of the tariff components of the RTA and RTP, the economic effects of this work are presented in part A, part B, losses, and charges, whose sum makes up the total value of the TUSD. The dynamics of the economic effects listed in this paper occur through the market reduction that results from the migration of users to MMDG up to the year 2030.

In a time of tariff readjustment, this reduction in the MMDG market is perceived by the distributor, through the drop-in collection and revenue on items part A and charges, which will be passed on to the tariff of other consumers in the period recorded, in order to balance these accounts. The only exception occurs in concessionaires with old contracts, such as Enel Ceará. In this case, there is no neutrality for part A, being considered a market risk for the distributor.

The item losses dealt within this paper refer to a commercial loss which is considered a market risk for the distributor and which show no possibility of passing it on to other users.

Regarding part B of the tariff, it remunerates the distributor and is considered the manageable component of the business. Therefore, the distributor does not recover this component in the years of tariff readjustment, but only during the tariff review process. During the RTP, ANEEL adjusts the tariff to make up for lost revenue caused by the migration of users to MMDG in recent years. It helps to ensure the economic and financial balance of the distribution market.

Table 3 shows the variables applied in the tariff readjustment and revision processes, which are passed on to other users and calculated by Equation (5).

Table 3. TUSD components for calculating the impact of MMDG on the utility readjustment and tariff review, based on data from ANEEL [7].

Distributors	TUSD Components
Enel Goiás	Part B + Part A + Charges
Enel Ceará	Part B + Charges
Enel Rio	Part B + Part A + Charges

Equation (5) is responsible for defining the concessionaire's revenue reduction, through variable $Effect_{MMDG_n}$. This model applies the tariffs of distributors by tariff group and economy class in the market reduction per MMDG in Section 2.1.

$$Effect_{MMDG_n} = [\sum_B^A part\ A_n + \sum_B^A part\ B_n + \sum_B^A losses_n + \sum_B^A charges_n] \times \sum_B^A MMDG_n, \quad (5)$$

where $Effect_{MMDG_n}$ stands for the financial reduction of the MMDG for the distributor in year n, passed on to the consumer in the tariff adjustment and revision, in USD; $\sum_B^A part\ A_n$ stands for the value of the fixed TUSD A in year n, in each tariff group (A and B), in USD/MWh; $\sum_B^A part\ B_n$ stands for the value of the fixed B TUSD in year n, in each tariff group (A and B), in USD/MWh; $\sum_B^A losses_n$ stands for the value of TUSD *losses* in year n, in each tariff group (A and B), in USD/MWh; $\sum_B^A charges_n$ stands for the value of TUSD *charges* in year n, in each tariff group (A and B), in USD/MWh, and $\sum_B^A MMDG_n$ stands for the market reduction per MMDG in year n, in MWh, for each tariff group (A and B).

Equation (5) also uses the tariff information from the SPARTA ANEEL file [36]. The data of the used and projected tariffs are provided in Appendix B. For tariff projection, the future macroeconomic assumption of the Focus bulletin, and information from the Brazilian Central Bank on the inflation indices IGP-M (Enel Ceará) and IPCA (Enel Rio and Enel Goiás) were used [11].

When only the tariff components in Table 3 are used, the effect on the tariff readjustment and revision passed on to other consumers is determined. When applying the tariff components in Table 4, the reduction in revenue that affects the concessionaire is found.

Table 4. TUSD components for calculating the impact of MMDG on the concessionaire, based on data from ANEEL [7].

Distributors	TUSD Components
Enel Rio	Part B + Losses
Enel Ceará	Part A + Part B + Losses
Enel Goiás	Part B + Losses

In addition to the economic effect in USD defined by Equation (5), it is important to assess the magnitude of this impact on consumer tariffs. Thus, through Equation (6), it was possible to determine the percentage of revenue reduction per MMDG, which will be allocated to tariffs during the tariff revision and readjustment processes of other users. In this regard, it is worth noting that Equation (6) is a simplified estimate only to assess MMDG, and the total value of the readjustment and revision of tariffs in the coming years are conditioned to other factors outside the scope of this paper.

$$MMGD_{Tarn} = \left[\frac{Effect_{MMDG(1)_n}}{VPB(0)_n} / txM_n \right], \tag{6}$$

where $MMDG_{Tarn}$ stands for the estimated tariff pass-through in year n, in %; $Effect_{MMGD(1)_n}$ stands for the reduction in MMDG revenue passed on to other consumers in year n, in USD; $VPB\ (0)_n$ stands for the revenue value of part B for the distributor in year n, in USD, and txM_n stands for the growth rate of the distributor's MMDG market in year n, in %.

The growth rate of the distributor's MMDG market is available in Appendix A. The $Effect_{MMDG(1)_n}$ is obtained from Equation (5) and the *VPB* (0) is calculated using the realized market data in ANEEL's SPARTA file [36]. In addition, the projection of the *VPB* (0) can be performed using Equations (7) and (8):

$$VPB\ (0)_n = [(Market_n - MMGD_n) \times Part\ B_n], \tag{7}$$

$$VPB\ (0)_n = \left[\left((Market_{n-1} + (Market_{n-1} \times tx)) - MMDG_n \right) \times Part\ B_n \right], \tag{8}$$

where $Market_n$ stands for the total market per consumption class in MWh in year n; $Market_{n-1}$ stands for the total market by consumption class in MWh in year $n-1$; tx stands for the average market growth rate by consumption class in the last 5 years prior to the COVID-19 pandemic in %; $MMDG_n$ stands for the MMDG market by consumption class in MWh in year n, and $Part\ B_n$ stands for the value of the tariff *part B* in year n, for each tariff group (i.e., A and B), in USD/MWh.

Part B tariff represents the distributor's remuneration. Equations (7) and (8) present the tariff revenue of part B, which is called VPB (0). In Equation (7), the *VPB* (0) verified and available in the ANEEL database are cited. In Equation (8), there is the projected *VPB* (0), and this component considers the market reduction per MMDG until 2030. The market and the tariffs used for this calculation are available in Appendix B.

2.2.2. Effect on the Utility

The MMDG effect on the concessionaire is the reduction of revenue, which cannot be transferred through adjustments and tariff revisions to the consumer. The method for calculating this effect is the same used in Equation (5). The tariff variables adopted to apply in Equation (5) are shown in Table 4 above for each distributor in the Enel group.

The components of part B and part A are redefined with each RTP process. In the period between each RTP, the market reduction per MMDG is the concessionaire's risk and determinates financial loss in part B. In the year of the RTP, ANEEL rebalances the revenue necessary for the maintenance and operation of the business via tariff transfer to other users. In this way, the distributor's market loss is passed on to users of the regulated market in the coming years, until a new RTP occurs. Equally, losses are the distributor's market risk.

From the concessionaire's view, Equation (9) in this work represents the percentage of reduction in VPB (0) regulatory revenue with the insertion of MMDG in the concession area:

$$i\ (\%)_n = \frac{Effect_{MMDG(2)_n}}{VPB\ (0)_n} - 1, \tag{9}$$

where $i\ (\%)_n$ stands for the percentage impact on the concessionaire in year n, in %; $VPB\ (0)_n$ stands for the revenue value of part B for the distributor in year n, in USD, and $Effect_{MMDG(2)_n}$ stands for the MMDG revenue reduction passed on to the concessionaire in year n, in USD.

The data used to calculate the VPB (0) are defined by Equations (7) and (8), the effect of MMDG on the concessionaire is calculated through Equation (5), and the tariff variables in Table 4. The data used are available in Appendix B.

3. Results and Discussion

The results of this paper are demonstrated through the case study of the Enel group distributors. The exercise carried out consists of applying theoretical knowledge of Brazilian economic regulation, associated with the behavior of the demand curve for MMDG in concessionaires.

The Results and Discussions are presented on the same topics that the methodology was addressed. First, the demand analysis indicates the results for the potential market for MMDG in each utility as well as the projection for installed capacity and power generation. Then, the economic effects are detailed through the effects on the consumer and the electric energy distributor.

3.1. Demand Analysis

The demand analysis is important to apply its results in the financial and regulatory model proposed in this work. Initially, the total potential market of MMDG for each concessionaire was calculated.

The analysis of the consumption behavior of users with MMDG in the last 12 months before the installation of photovoltaic projects determined an average cut in the distributors' market base—see Table 1. Microeconomic variables were also applied in relation to the situation of households that affect the decision-making process to install a photovoltaic project—see Table 2. The interaction of these variables and analyses defined the results presented in Table 5.

Table 5 shows the potential market of each distributor by economic class and tariff group.

The greatest potential for consumption is in Enel Goiás (2.4 TWh), followed by Enel Ceará (1.9 TWh), and lastly, Enel Rio (1.4 TWh). The potential is concentrated in the low voltage group (group B) for all distributors on the commercial sector, followed by the residential, rural, and industrial sectors.

Table 5 reveals a low potential of the Brazilian industrial sector for MMDG. This result is coherent because the industrial sector already has many assets in the free market.

Participants in this segment cannot opt for the MMDG modality; only users in the regulated environment can make this choice.

The results in Table 5 are used in the projection of the demand curve and thus it will be possible to estimate, over the horizon until 2030, when the potential market for MMDG will be reached in the concession area, and also its representation in the regulated market.

Table 5. Potential market for MMDG for each distributor, in GWh.

Sectors	Enel Goiás			Enel Ceará			Enel Rio		
	Group A	Group B	Total	Group A	Group B	Total	Group A	Group B	Total
Residential	3.4	622.4	625.8	1.2	416.8	417.9	5.0	447.8	452.8
Commercial	350.4	530.0	880.4	494.9	427.4	922.3	419.7	430.1	849.8
Industrial	193.4	38.8	232.1	263.3	20.5	283.8	67.1	23.1	90.2
Rural	209.7	554.7	764.4	131.5	272.0	403.5	4.4	48.4	52.8
Total	711.9	1745.9	2457.8	844.2	1136.6	1980.8	476.9	949.4	1426.3

This information is relevant from the perspective of the regulator. ANEEL [9] points that economic distortions can occur in the Brazilian MMDG market, as this modality represents, on average, 10% of the distributor's captive market.

In Tables 6–8, the results of the demand projection are highlighted by the variables installed capacity (MW), electricity generation (GWh), and captive market (GWh). The percentage evolution of MMDG's expansion curve over the distributors' captive and potential markets is also evaluated. The estimated average payback for photovoltaic projects was also defined.

Table 6. MMDG expansion by Enel Goiás.

Reference Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Payback (years)	4.6	4.5	4.4	4.2	4.1	4.0	3.9	3.8	3.7	3.6	3.5
Generation (GWh)	303	544	784	1023	1266	1502	1742	1982	2227	2461	2700
Installed Power (MW)	262	417	572	727	883	1038	1193	1348	1503	1659	1814
Captive Market (GWh)	14,194	14,540	14,666	14,803	14,948	15,110	15,281	15,463	15,651	15,865	16,085
% Captive Market	2.1%	3.7%	5.3%	6.9%	8.5%	9.9%	11.4%	12.8%	14.2%	15.5%	16.8%
% Potential Market	12.3%	22.2%	31.9%	41.6%	51.5%	61.1%	70.9%	80.6%	90.6%	100.0%	100.0%
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Payback (years)	5.7	5.5	5.4	5.3	5.1	5.0	4.8	4.7	4.6	4.5	4.4
Generation (GWh)	303	544	784	966	1150	1332	1514	1696	1882	2060	2242
Installed Power (MW)	262	417	572	690	808	927	1045	1163	1281	1399	1517
Captive Market (GWh)	14,194	14,540	14,666	14,864	15,072	15,296	15,530	15,778	16,035	16,314	16,603
% Captive Market	2.1%	3.7%	5.3%	6.5%	7.6%	8.7%	9.7%	10.7%	11.7%	12.6%	13.5%
% Potential Market	12.3%	22.2%	31.9%	39.3%	46.8%	54.2%	61.6%	69.0%	76.6%	83.8%	91.2%

The data is projected in two scenarios and used in the analysis of the financial and regulatory model. The first scenario called reference considers the current legislation for MMDG. The second binomial scenario estimates the introduction of the binomial tariff in the low voltage market in 2023.

Table 6 shows the results of the demand analysis for Enel Goiás and represents the Enel group distributor with the highest installed capacity and volume of MMDG until 2030.

In the reference scenario, the forecasted potential market is 2.4 TWh (see Table 5) in 2029, with a captive market of 15.5%. In the binomial scenario, 91.2% of the forecasted potential market is in 2030, with a captive market of 13.5%.

Table 7 shows the results of the demand analysis for Enel Ceará and represents the second Enel group distributor in installed capacity and MMDG volume until 2030.

Table 7. MMDG expansion by Enel Ceará.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Payback (years)	5.2	5.1	4.9	4.8	4.7	4.6	4.5	4.3	4.2	4.1	4.0
Generation (GWh)	217	394	599	782	968	1149	1333	1516	1704	1883	2067
Installed Power (MW)	175	281	385	451	517	583	649	716	782	849	916
Captive Market (GWh)	12,159	11,888	11,936	11,994	12,058	12,128	12,199	12,272	12,344	12,425	12,507
% Captive Market	1.8%	3.3%	5.0%	6.5%	8.0%	9.5%	10.9%	12.4%	13.8%	15.2%	16.5%
% Potential Market	10.9%	19.9%	30.2%	39.5%	48.9%	58.0%	67.3%	76.5%	86.0%	95.1%	100.0%
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Payback (years)	5.2	5.1	4.9	6.6	6.4	6.2	6.1	5.9	5.8	5.6	5.5
Generation (GWh)	217	394	599	715	833	947	1064	1181	1301	1416	1533
Installed Power (MW)	175	281	385	451	517	583	649	716	782	849	916
Captive Market (GWh)	12,159	11,888	11,936	12,050	12,183	12,322	12,464	12,608	12,754	12,908	13,065
% Captive Market	1.8%	3.3%	5.0%	5.9%	6.8%	7.7%	8.5%	9.4%	10.2%	11.0%	11.7%
% Potential Market	10.9%	19.9%	30.2%	36.1%	42.0%	47.8%	53.7%	59.6%	65.7%	71.5%	77.4%

Table 8. MMDG expansion by Enel Rio.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Payback (years)	4.2	4.0	3.9	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.2
Generation (GWh)	107	235	393	550	710	865	1022	1180	1341	1495	1652
Installed Power (MW)	109	216	328	439	551	662	774	885	997	1.108	1.220
Captive Market (GWh)	11,490	11,149	10,916	10,689	10,464	10,248	10,034	9825	9616	9419	9222
% Captive Market	0.9%	2.1%	3.6%	5.1%	6.8%	8.4%	10.2%	12.0%	13.9%	15.9%	17.9%
% Potential Market	7.5%	16.5%	27.5%	38.6%	49.8%	60.7%	71.7%	82.7%	94.0%	100.0%	100.0%
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Payback (years)	4.2	4.0	3.9	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2
Generation (GWh)	107	235	393	504	616	726	837	948	1062	1170	1281
Installed Power (MW)	109	216	328	407	485	564	643	721	800	879	957
Captive Market (GWh)	11,490	11,149	10,916	10,735	10,557	10,385	10,216	10,051	9887	9732	9577
% Captive Market	0.9%	2.1%	3.6%	4.7%	5.8%	7.0%	8.2%	9.4%	10.7%	12.0%	13.4%
% Potential Market	7.5%	16.5%	27.5%	35.3%	43.2%	50.9%	58.7%	66.5%	74.4%	82.0%	89.8%

The reference scenario reaches 100% of the forecasted potential market of 1.9 TWh (see Table 5) in 2030, with a captive market of 16.5%. The binomial scenario reaches 77.4% of the forecasted potential market in 2030, with a captive market of 11.7%.

Table 8 shows the results of the demand analysis for Enel Rio and represents the smallest captive market, which increases the relative concentration of MMDGs in this area.

The reference scenario reaches the forecasted potential market of 1.4 TWh (see Table 5) in 2029, with a captive market of 15.9%. The binomial scenario shows that it reaches 89% of the forecasted potential market in 2030, with a captive market of 13.4%.

Despite the binomial scenario showing an increase in the pay-back of photovoltaic projects, investments in MMDG continue to be attractive to consumers and they are expected to continue to expand on the horizon until 2030.

The demand analysis of this work indicates that in the horizon until 2030, the Enel group distributors will reach the total potential market for MMDG and will surpass 10% of the captive market in the concession area.

The rest of the captive market will continue to use the energy distributed by the concessionaire as well as the current Brazilian MMDG technology, which needs the network to operate efficiently to continue to exist. Therefore, in order to guide the planning of networks in a more diversified and efficient manner for all agents, this is a necessary condition to evaluate these scenarios in the specific financial and regulatory model of each country.

3.2. Economic Effects

This topic presents the results of the economic effects of MMDG by the financial and regulatory model proposed in this paper.

Based on the demand results in the two scenarios presented, this information feeds the model and is applied following ANEEL's regulatory guidelines adopted in the tariff readjustment and revision of Brazilian distributors.

The effects on electric energy distribution concessionaires are divided into market reduction per MMDG, transferred via tariff readjustment and revision for users, and reduction of revenue for concessionaires. All economic data is in USD and the amount used for the conversion is in Brazilian currency USD 1 = BRL 5.60.

3.2.1. Effect on the Consumer

This topic shows the results of the economic and regulatory model from the consumer's perspective. Tables 9–11 show the monetary amounts passed on to the consumers until 2030, relying on the TUSD tariff components used by the Brazilian economic regulation.

Table 9. Economic effects of MMDG for Enel Goiás, in million USD.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	∑2020–2030
(1) Part A	0.0	0.6	1.6	1.0	1.3	1.4	1.4	1.5	1.6	1.8	1.8	14.0
(2) Part B	–	–	–	15.6	–	–	–	–	35.9	–	–	51.5
(3) Losses	–	–	–	–	–	–	–	–	–	–	–	–
(4) Charges	0.3	3.0	6.6	11.1	15.3	19.8	24.5	29.5	34.9	40.7	46.6	232.2
TUSD = (1) + (2) + (3) + (4)	0.3	3.5	8.3	27.6	16.6	21.2	25.9	31.1	72.4	42.5	48.5	297.7
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**∑2020–2030**
(1) Part A	0.0	0.6	1.6	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.4	11.6
(2) Part B	–	–	–	15.6	–	–	–	–	13.1	–	–	28.7
(3) Losses	–	–	–	–	–	–	–	–	–	–	–	–
(4) Charges	0.3	3.0	6.6	11.1	14.4	17.9	20.6	25.5	29.7	34.2	38.9	202.1
TUSD = (1) + (2) + (3) + (4)	0.3	3.5	8.3	27.6	15.4	19.0	21.7	26.7	44.1	35.6	40.3	242.5
ΔScenarios	–	–	–	–	1.2	2.2	4.2	4.3	28.3	6.8	8.2	55.2

Table 10. Economic effects of MMDG for Enel Ceará, in million USD.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	∑2020–2030
(1) Part A	–	–	–	–	–	–	–	–	–	–	–	–
(2) Part B	–	–	–	17.0	–	–	–	40.1	–	–	–	57.0
(3) Losses	–	–	–	–	–	–	–	–	–	–	–	–
(4) Charges	0.3	1.1	2.8	4.8	6.5	8.4	10.4	12.5	14.8	17.3	19.9	99.0
TUSD = (1) + (2) + (3) + (4)	0.3	1.1	2.8	21.7	6.5	8.4	10.4	52.6	14.8	17.3	19.9	156.0
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**∑2020–2030**
(1) Part A	–	–	–	–	–	–	–	–	–	–	–	–
(2) Part B	–	–	–	17.0	–	–	–	13.0	–	–	–	29.9
(3) Losses	–	–	–	–	–	–	–	–	–	–	–	–
(4) Charges	0.3	1.1	2.8	4.8	5.9	7.2	8.5	10.0	11.5	13.2	15.0	80.5
TUSD = (1) + (2) + (3) + (4)	0.3	1.1	2.8	21.7	5.9	7.2	8.5	22.9	11.5	13.2	15.0	110.4
ΔScenarios	–	–	–	–	0.6	1.2	1.8	29.7	3.3	4.1	5.0	45.6

The reference and binomial scenarios allow us to analyze how the binomial tariff introduction could reduce the negative impact for other users who do not have MMDG.

In the case of Enel Goiás and Enel Rio, the contractual conditions are similar to part A, and the charges are passed on retroactively during the annual tariff adjustments. Conversely, part B is only revisited in the tariff reviews every five years (i.e., next in 2023 and then in 2028).

In the case of Enel Ceará, the contractual condition is different once there is no tariff neutrality of part A. Therefore, charges are only passed on retroactively in the annual tariff readjustments. In the case of part B, it is rebalanced during the tariff reviews every four years (i.e., next in 2023 and then in 2027).

Table 11. Economic effects of MMDG for Enel Rio, in million USD.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	∑2020–2030
(1) Part A	0.2	0.5	1.5	1.8	1.8	1.9	2.0	2.2	2.3	2.5	2.6	19.3
(2) Part B	–	–	–	13.2	–	–	–	–	34.9	–	–	48.1
(3) Losses	–	–	–	–	–	–	–	–	–	–	–	–
(4) Charges	0.4	1.3	3.4	6.1	8.8	11.8	14.8	18.2	21.7	25.5	29.5	141.5
TUSD = (1) + (2) + (3) + (4)	0.5	1.8	4.9	21.1	10.6	13.7	16.9	20.3	58.9	28.0	32.0	208.9
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**∑2020–2030**
(1) Part A	0.2	0.5	1.5	1.8	1.3	1.4	1.5	1.6	1.7	1.8	1.9	15.1
(2) Part B	–	–	–	13.2	–	–	–	–	11.7	–	–	25.0
(3) Losses	–	–	–	–	–	–	–	–	–	–	–	–
(4) Charges	0.4	1.3	3.4	6.1	8.1	10.2	12.5	14.9	17.4	20.2	23.1	117.5
TUSD = (1) + (2) + (3) + (4)	0.5	1.8	4.9	21.1	9.4	11.6	13.9	16.5	30.8	22.0	24.9	157.5
ΔScenarios	–	–	–	–	1.2	2.1	2.9	3.9	28.1	6.0	7.1	51.4

Table 9 shows the economic effect on Enel Goiás' concession area. The concessionaire has the highest potential for MMDG and, consequently, the most significant economic impact that will be passed on to user tariffs until 2030.

In the reference scenario, it is expected that more than USD 297 million will be passed on tariff adjustments and revisions by 2030. However, the adoption of binomial tariffs in 2023 could avoid the reallocation of USD 55 million in consumer tariffs.

Table 10 shows the result for the concessionaire Enel Ceará. The company represents the second most significant market potential for MMDG, yet the lowest economic impacts. It happens because part A is the concessionaire's market risk.

In the reference scenario, it is expected that USD 156 million will be passed on through tariff adjustments and reviews by 2030. The adoption of binomial tariffs by 2023 may avoid the transfer of USD 45 million in consumer tariffs.

Table 11 shows the results of the distributor Enel Rio, which has the lowest potential market for MMDG and a high effect on other consumers due to its high tariffs.

In the reference scenario, it is expected that more than USD 208 million will be passed on via tariff adjustments and revisions by 2030. However, the adoption of binomial tariffs by 2023 could avoid the transfer of USD 51 million in consumer tariffs.

The tables above show that the correlation between the demand expansion for MMDG and economic effects in the concession areas is not trivial. In the case of Enel Goiás, the correlation is positive. The company has the highest potential for technology and has the most significant economic impact on tariff readjustments and revisions. However, it is not possible to have the same outcome in the case of Enel Ceará and Enel Rio. Enel Ceará has the second-largest demand curve and the lowest economic impact.

These examples show how the results of this study are guided by the rules of economic regulation and specific characteristics of the concession areas affecting the correlation between demand for technology and financial results.

Only three Enel Group distributors represent more than USD 662 million in tariff adjustments and revisions for Brazilian consumers. With the introduction of binomial tariffs, there can be an estimated reduction of USD 152 million for users.

Table 12 analyzes the transfer estimate of the economic effects of MMDG to the tariffs of other users in the tariff review and adjustment processes.

Tariff revisions for distributors Enel Goiás and Enel Rio will take place in 2023 and 2028, that is, every five years. Enel Ceará's tariff review will take place in 2023 and later in 2027, that is, every four years. In other years, tariff readjustments occur for all distributors.

In the reference scenario, the 2028 tariff revision of Enel Goiás and Enel Rio could increase tariffs by 15.6% and 12.6%, respectively. In 2027, Enel Ceará's review process is predicted to increase tariffs by 14%, simply due to the economic effects of MMDG.

In the binomial scenario, while analyzing the same tariff review periods, Enel Goiás and Enel Rio increase tariffs by 10.8% and 7.4%, respectively. Enel Ceará increases tariffs by merely 5.6%.

Table 12. Estimated transfer of the economic effects of the MMDG in the distributors' tariff adjustments and revisions (in %).

Distributor	Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Enel Goiás	Reference Binomial	0.1%	1.2%	2.6%	9.4%	2.8% 4.6%	3.5% 5.3%	4.1% 5.7%	4.9% 6.8%	15.6% 10.8%	5.9% 7.9%	6.6% 8.6%
Enel Ceará	Reference Binomial	0.1%	0.4%	0.9%	7.4%	2.0% 1.8%	2.4% 2.0%	2.9% 2.2%	14.0% 5.6%	3.8% 2.6%	3.8% 2.7%	4.1% 2.8%
Enel Rio	Reference Binomial	0.2%	0.6%	1.5%	6.5%	3.2% 2.8%	4.0% 3.3%	4.5% 3.6%	5.2% 4.1%	12.6% 7.4%	6.6% 5.0%	7.3% 5.4%

The variations between the two scenarios can be explained by the participation of the tariff components in the overall effect: part A represents 5% and part B represents 24% charging account for 71% of the transferred effects in the reference scenario. In the binomial scenario, part A, part B, and charges represent 5%, 16%, and 78%, respectively.

Thus, despite the payment of binomial tariffs, economic conflicts are persistent for the consumer as the charge component is the main problem for users who do not have MMDGs.

3.2.2. Effect on the Utility

The economic effects on each concessionaire relying on the TUSD components are called MMDG's irrecoverable portion. These values are not part of the tariff adjustments and reviews, as they are market risks passed into the concessionaire.

The distributor accumulates the negative effect of the market reduction by MMDG in the B portion components and losses until the year of tariff revision by the companies. It occurs because the distributor assumes market risks until the year of the tariff review. When this period arrives, ANEEL grants a higher or lower tariff that guarantees the economic and financial balance of the revenue necessary for the operation of the distributors in the next tariff cycle.

Table 13 shows the effect on the concessionaire at the distributor Enel Goiás until 2030.

Table 13. Irrecoverable portion of MMDG for Enel Goiás, in million USD.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	∑2020–2030
(1) Part A	–	–	–	–	–	–	–	–	–	–	–	–
(2) Part B	4.5	9.3	15.6	6.3	13.1	20.2	27.8	35.9	8.8	17.7	27.4	186.6
(3) Losses	0.0	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	4.0
(4) Charges	–	–	–	–	–	–	–	–	–	–	–	–
TUSD = (1) + (2) + (3) + (4)	4.5	9.6	15.9	6.7	13.5	20.6	28.2	36.3	9.2	18.2	28.0	190.7
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**∑2020–2030**
(1) Part A	–	–	–	–	–	–	–	–	–	–	–	–
(2) Part B	4.5	9.3	15.6	5.0	5.3	6.2	7.1	8.1	1.0	2.0	3.1	67.3
(3) Losses	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	2.7
(4) Charges	–	–	–	–	–	–	–	–	–	–	–	–
TUSD = (1) + (2) + (3) + (4)	4.6	9.4	15.8	5.2	5.5	6.5	7.4	8.4	1.3	2.4	3.5	70.0
Δ Scenarios	–	–	–	1.5	7.9	14.1	20.8	27.9	7.9	15.9	24.5	120.6

In the reference scenario, there is a reduction of USD 190 million in Enel Goias' revenue. With the adoption of binomial tariffs in 2023, the Enel group expects a benefit of USD 120 million.

Table 14 estimates the economic effect on the Enel Ceará distributor. At Enel Ceará, the effect is a little more significant for the concessionaire because part A is not passed on to consumers, which is a market risk for the company's shareholders.

In the reference scenario, Enel Ceará estimates the reduction in revenue at USD 223 million. With the binomial pricing, it could minimize the impact to the Enel group by USD 122 million.

Table 15 performs the same analysis for distributor Enel Rio.

Table 14. Irrecoverable portion of MMDG for Enel Ceará, in million USD.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	∑2020–2030
(1) Part A	0.1	0.4	1.0	0.9	0.9	1.1	1.1	1.2	1.3	1.4	1.5	11.0
(2) Part B	4.0	9.5	17.0	6.9	14.4	22.3	30.9	40.1	10.0	20.4	31.6	207.1
(3) Losses	0.2	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	5.0
(4) Charges	–	–	–	–	–	–	–	–	–	–	–	–
TUSD = (1) + (2) + (3) + (4)	4.2	10.3	18.4	8.2	15.8	23.9	32.5	41.8	11.9	22.4	33.7	223.1
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**∑2020–2030**
(1) Part A	0.1	0.3	0.9	1.1	0.7	0.7	0.8	0.8	0.9	1.0	1.0	8.2
(2) Part B	3.8	9.5	17.0	4.6	9.7	10.7	11.8	13.0	1.2	2.4	3.7	87.3
(3) Losses	0.3	0.4	0.5	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	4.8
(4) Charges	–	–	–	–	–	–	–	–	–	–	–	–
TUSD = (1) + (2) + (3) + (4)	4.2	10.3	18.4	6.1	10.7	11.8	13.0	14.2	2.6	3.9	5.3	100.3
ΔScenarios	–	–	–	2.2	5.1	12.0	19.5	27.6	9.3	18.5	28.5	122.8

Table 15. Irrecoverable portion of MMDG for Enel Rio, in million USD.

Reference Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	∑2020–2030
(1) Part A	–	–	–	–	–	–	–	–	–	–	–	–
(2) Part B	3.4	7.5	13.2	6.1	12.7	19.6	27.0	34.9	8.5	17.3	26.8	177.1
(3) Losses	0.4	0.7	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	12.3
(4) Charges	–	–	–	–	–	–	–	–	–	–	–	–
TUSD = (1) + (2) + (3) + (4)	3.8	8.2	14.2	7.2	13.8	20.8	28.3	36.2	10.0	18.8	28.3	189.5
Binomial Scenario	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**∑2020–2030**
(1) Part A	–	–	–	–	–	–	–	–	–	–	–	–
(2) Part B	3.4	7.5	13.2	4.5	9.3	10.1	10.9	11.7	0.9	1.8	2.7	75.9
(3) Losses	0.4	0.7	1.0	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1	9.5
(4) Charges	–	–	–	–	–	–	–	–	–	–	–	–
TUSD = (1) + (2) + (3) + (4)	3.8	8.2	14.2	5.2	10.1	10.9	11.8	12.7	1.9	2.8	3.9	85.4
ΔScenarios	–	–	–	1.9	3.8	9.9	16.5	23.5	8.1	15.9	24.5	104.1

The scenario referenced by Enel Rio accumulates a revenue reduction to the utility of USD 189 million and USD 85 million in the binomial scenario by 2030. The binomial pricing policy provides a return of USD 104 million to the distributor.

From the results of Tables 14–16, it is said that the benefit of binomial pricing to the electricity distributor depends on the proportion of part B in TUSD. On average, 95% of the negative impact on companies' results are from the part B component, so there is a higher benefit for the concessionaire with the binomial adoption.

Table 16. Projected revenue of part B—VPB (0), in million USD.

Dealership	Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Enel Goiás	Reference Binomial	289	314	279	301304	307 318	313 332	318 346	324 362	366 386	373 403	380 422
Enel Ceará	Reference Binomial	282	307	267	290294	294 303	298 316	302 330	305 345	349 373	352 389	356 406
Enel Rio	Reference Binomial	326	328	313	316317	317 321	319 324	320 328	321 331	322 335	323 338	324 342

In the reference scenario, the three group companies accumulate a negative outcome of USD 600 million. With the binomial tariff scenario in 2023, this negative effect is USD 255 million and provides a financial benefit to the Enel group of USD 347 million.

Table 16 shows the behavior of the tariff part B revenue, which is responsible for the regulatory remuneration of distributors until 2030.

Despite the reference scenario presenting more significant financial losses to the concessionaire due to market reduction, there is an increase in the distributors' revenue throughout the entire horizon. It is because not all users will migrate to this modality. As estimated by Table 6, there is a potential market that does not represent the distributor's entire captive market for MMDG technology with net metering.

Table 16 also shows that the binomial tariff recovers the revenue lost in the expansion of the MMDG market by Brazilian distributors.

With the information in Table 16, it is possible to estimate the representativeness of the economic effects of MMDG on the regulatory revenue of part B in the Enel group distributors by analyzing Table 17.

Table 17. The MMDG economic effects estimate on the regulatory revenue of part B (VPB 0) at Enel's distributors, in %.

Dealership	Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Enel Goiás	Reference	1.7%	3.1%	5.7%	2.2%	4.4%	6.6%	8.9%	11.2%	2.5%	4.9%	7.4%
	Binomial				1.7%	1.7%	1.9%	2.1%	2.3%	0.3%	0.6%	0.8%
Enel Ceará	Reference	1.5%	3.3%	6.9%	2.9%	5.4%	8.0%	10.8%	13.7%	3.5%	6.4%	9.5%
	Binomial				2.1%	3.5%	3.7%	3.9%	4.1%	0.7%	1.0%	1.3%
Enel Rio	Reference	1.2%	2.5%	4.5%	2.3%	4.4%	6.5%	8.8%	11.3%	3.1%	5.8%	8.8%
	Binomial				1.6%	3.1%	3.4%	3.6%	3.8%	0.6%	0.8%	1.1%

In the reference scenario, in 2027, Enel Goiás, Enel Ceará, and Enel Rio accumulate losses of 11.2%, 13.7%, and 11.3%, respectively. In the binomial scenario, these values are much lower and the outcome is 2.3%, 4.1%, and 3.9%, respectively.

A comparison between the results of the consumers' binomial pricing policy and concessionaire is provided in Table 18. While the consumer may enjoy a benefit of USD 152 million, the concessionaire leverages twice this benefit at a value higher than USD 347 million. The consumer is guaranteed only 31%, while the concessionaire is allocated 69% of the total benefit.

Table 18. Cumulative benefits of the binomial tariff policy, until 2030, in the distribution companies of the Enel group, in million USD.

Δ Scenarios = Reference − Binomial	Consumer	Dealer
(1) Part A	6.6	2.9
(2) Part B	73.1	340.4
(3) Losses	–	4.2
(4) Charges	72.6	–
TUSD = (1) + (2) + (3) + (4)	152.3	347.5

Considering the total economic effect of the MMDG on the consumer and the concessionaire in the reference scenario, the value was USD 1.2 billion with 53% allocated to the end-user and 47% to the distributor's shareholders. In the binomial scenario, the economic impact is USD 766 million; however, 67% of this figure is allocated to the consumer and only 33% to the concessionaire that distributes electricity. The binomial tariff should not be considered as the only solution for the economic problem in Brazil once it is known to be the death spiral of distributors in international literature.

Despite solving the problem of distributor's remuneration, the continuous transfer of burden to users in other tariff components, such as charges, continues to persist. Furthermore, for the ongoing operation of the distributed generation system itself, the grid needs to operate efficiently to guarantee operational stability and provide energy security. It makes the Brazilian tariff and regulatory modernization compulsory for the appropriate application of new technologies, as it has also been done in other countries.

4. Conclusions

According to the international literature, demand models show that the expansion of distributed energy resources is even higher and that the inclusion of prosumers in the coming years is a global reality.

When analyzing specific countries that have adopted net metering, such as the United States, it was found that the introduction of this compensation system alongside regulatory models of "price cap" or "revenue cap" enhances the effect of cross-subsidies to other consumers of the network.

In order to avoid the growth of cross-subsidies to other consumers and to equalize the balance of remuneration of distributors, the countries underwent a review of economic regulation and tariff systems.

It was found that the ideal regulatory model is the equalization of network costs for all users without generating losses for the distributed energy generation of prosumers.

One of the policies adopted is that consumers can be remunerated at an hourly rate that reflects the value of energy in the electrical system throughout the day, signaling the optimization and use of the network by users. It was also observed that the introduction of binomial pricing can solve the economic problem of network remuneration at distributors.

Since the creation of normative Resolution 482, the expansion of demand for MMDG in Brazil has already surpassed the 7 GW mark in 2021. It is essential to assess the expansion of technology demand through economic and regulatory variables that are specific to each country. There is a lack of studies that assess this aspect within the scope of Brazilian economic regulation.

As a consequence, the financial and regulatory model of this study simulates the result for the distributors of the Enel Group and assesses the situation of the Brazilian case. As a main result, it can be stated that the part B tariff component is responsible for the maintenance and operation of the concessionaire and affects 95% of the concessionaire's revenue reduction caused by the expansion of MMDG in the country. The other consumers, on the other hand, are affected by the tariff component in 70%, which is passed on in the annual tariff readjustments.

In the reference scenario, there is a negative effect on the Enel Group's distributors of USD 1.2 billion by 2030, where 52% is passed on to other users in tariff readjustments and revisions, and the remaining 48% is a reduction in revenue of the concessionaire. In the binomial scenario, there is a reduction in this negative effect, and it reaches the value of USD 766 thousand million by 2030, in which 67% is passed on to consumers in tariff adjustments and revisions with a 33% impact on the revenue of the distributors of the Enel Brasil Group.

From the economic regulation perspective, it can be concluded that the introduction of the binomial tariff only solves the concessionaires' dilemma. Unlike other countries, Brazil has high charges in the composition of its tariff model and consequently, the solution from the consumer's point of view is associated with the review of subsidy policies that are inserted in the tariffs of the Brazilian electricity sector.

Considering the demand in the concession areas, it can be concluded that, based on the estimate of the potential market in each distributor, in the reference scenario, the potential market will represent between 15–20% of the concessionaires' captive market. In the binomial scenario, this value continues to expand but is slightly lower—between 10–15% of the captive market.

This information is relevant to correlate with the evolution of the distributor's revenue up to 2030, which even in the reference scenario will continue to expand. This indicates that a large part of consumers will remain in the regulated market of companies within the scope of this study, which makes it essential to equalize costs to other users.

The model also identified that the application of the current economic and financial regulation penalizes distributors and consumers for the same economic effect in the tariff component in part B. The market loss in the years between tariff revisions is seen as the distributor's market risk and this effect cannot be passed on to other consumers in the tariff readjustments. Concessionaires accrue part B revenue reductions up to the tariff revising year. In the year of tariff review, ANEEL restores the companies' economic and financial balance by adjusting the tariff to the necessary level to maintain the distribution service and considering the conditions of the new market. From the distributor's perspective, there is no guarantee of future recovery of lost revenue. From the consumer's perspective, regulators pass this effect on to network users. This fact implies a double economic effect due to the same tariff component for consumers and distributors.

There are many discussions about the correct incentives to the market for renewable sources in Brazil and the suggestion of the best solution needs reciprocity with economic regulation. The economic and regulatory model of this work clarifies the barriers surrounding the creation of a new legal framework for MMDG in Brazil, mainly pointing out that the problem is not in the distributed renewable source but in the current "net metering" incentive model associated with the obsolete model tariffs in the face of new technologies.

The study concludes that there is no efficiency in the billing of the Brazilian market with high insertion of MMDG through monomial rates. This type of tariff, alongside a high share of sectorial charges, does not signal the distributor's needs and does not capture the behavior of the prosumer connected to the electricity grid. It is known that this result is in line with the international scenario, and countries that invest in the technological development of the electricity sector no longer use this type of tariff.

This work provides some initial information about the capacity factors of distributors, but it does not aim to carry out this study. The study of capacity factors may be a future work and requires the development of other regulatory models and distributors' internal information, such as the assessment of the asset base, the effects of technology on technical losses and regulatory over-contracting mechanisms.

Concerning other distributed energy resources, the model proposed in this paper can be adapted and will serve as a reference in the evaluation of expansion scenarios and the economic effects of other technologies.

The COVID-19 pandemic reinforced the fact that households were transformed into multi-use locations increasing overall dependence on electricity services and connectivity to the distributor in a more interactive way. The digitization of the electricity sector allows the population access to technologies that promote energy efficiency, price predictability, energy supply options, tariff visualization, and choice of the best service. This digitization also supports efforts against climate change, as supported during the COP-26 summit. The definition of a structured public policy aimed at the effective modernization of infrastructure and regulation is, therefore, essential for the sustainability of the Brazilian electricity sector in the coming years.

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Appendix A

Table A1 shows the total market of the distributors. One can apply this information to Tables 1 and 2 in the methodology to calculate the potential market for each concessionaire.

Table A1. Total market for each distributor, in GWh.

Sectors	Enel Goiás			Enel Ceará			Enel Rio		
	Group A	Group B	Total	Group A	Group B	Total	Group A	Group B	Total
Residential	3.4	4386.4	4389.9	1.4	3687.8	3689.2	5.3	3947.1	3952.4
Commercial	370.0	917.5	1287.6	544.3	707.6	1251.9	459.7	687.9	1147.6
Industrial	208.6	60.0	268.6	283.9	30.1	314.0	71.7	32.1	103.8
Rural	216.5	970.7	1187.2	133.3	952.1	1085.4	4.5	156.4	160.9
Total	798.5	6334.7	7133.3	962.9	5377.6	6340.5	541.2	4823.6	5364.8

Table A2. The growth rate of the distributor's MMDG market.

Dealers	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Enel Rio	95.4%	99.6%	101.7%	103.9%	106.0%	108.3%	117.9%	122.1%	126.5%	131.0%	135.7%
Enel Ceará	99.6%	103.0%	106.3%	109.7%	113.1%	116.7%	120.3%	124.2%	128.2%	132.3%	136.5%
Enel Goiás	101.7%	99.5%	100.9%	105.5%	109.9%	114.8%	119.0%	119.0%	119.0%	119.0%	119.0%

Appendix B

The tables below indicate the tariffs used in the economic model and the tariff adjustment index. The tariff data from 2022 to 2030 were projected using the Brazilian Central Bank's inflation forecast from Table A3.

Table A3. Inflationary indicators passed on to tariffs in the concessionaires' readjustments.

Tariff Adjustment	Inflation	2022	2023	2024	2025	2026	2027	2028	2029	2030
Enel Goiás	IPCA	4.1%	3.7%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
Enel Ceará	IGP-M	5.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
Enel Rio	IPCA	4.1%	3.7%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%

Table A4. Distribution System Use Tariffs (TUSD) by tariff group and components for Enel Goiás, in USD/MWh.

Tariff Group	TUSD	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
B1, B2, B3	Charges	10.69	12.45	14.55	15.15	15.71	16.26	16.83	17.42	18.03	18.66	19.31	19.99
	Part A	4.55	6.80	5.96	6.20	6.43	6.66	6.89	7.13	7.38	7.64	7.91	8.18
	Part B	25.22	26.38	29.40	30.60	31.73	32.84	33.99	35.18	36.42	37.69	39.01	40.37
	Losses	1.07	1.19	1.25	1.30	1.35	1.39	1.44	1.49	1.55	1.60	1.66	1.71
A4	Charges	9.58	10.88	12.51	13.03	13.51	13.98	14.47	14.98	15.50	16.04	16.61	17.19
	Losses	0.93	1.06	1.11	1.16	1.20	1.24	1.29	1.33	1.38	1.43	1.48	1.53

Table A5. Distribution System Use Tariffs (TUSD) by tariff group and components for Enel Ceará, in USD/MWh.

Tariff Group	TUSD	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
B1, B2, B3	Charges	4.89	5.68	8.11	8.51	8.85	9.21	9.57	9.95	10.35	10.76	11.19	11.63
	Part A	3.98	4.07	6.11	6.42	6.67	6.94	7.21	7.50	7.80	8.11	8.43	8.77
	Part B	30.87	33.11	42.88	45.02	46.82	48.69	50.62	52.64	54.73	56.91	59.18	61.53
	Losses	2.06	2.15	2.43	2.55	2.65	2.76	2.87	2.98	3.10	3.22	3.35	3.49
A4	Charges	4.19	4.75	6.83	7.17	7.46	7.75	8.06	8.38	8.72	9.06	9.42	9.80
	Losses	1.44	1.58	1.90	1.99	2.07	2.16	2.24	2.33	2.42	2.52	2.62	2.72

Table A6. Distribution System Use Tariffs (TUSD) by tariff group and components for Enel Rio, in USD/MWh.

Tariff Group	TUSD	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
B1, B2, B3	Charges	11.54	13.10	15.30	15.93	16.51	17.09	17.69	18.31	18.95	19.61	20.30	21.01
	Part A	6.75	7.31	11.77	12.26	12.71	13.15	13.61	14.09	14.58	15.09	15.62	16.17
	Part B	37.04	38.15	40.01	41.65	43.19	44.70	46.27	47.89	49.56	51.30	53.09	54.95
	Losses	5.12	5.22	5.66	5.90	6.12	6.33	6.55	6.78	7.02	7.26	7.52	7.78
A4	Charges	10.22	11.25	13.02	13.55	14.05	14.54	15.05	15.58	16.13	16.69	17.27	17.88
	Losses	4.13	4.23	4.90	5.10	5.29	5.48	5.67	5.87	6.07	6.29	6.51	6.73

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