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Regulatory impact of photovoltaic prosumer policies in Brazil based on a financial risk analysis

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ABSTRACT

In 2018, A Regulatory Impact Analysis (RIA) was launched to review the Brazil's prosumer remuneration scheme in Brazil. Six policy alternatives that can impose different financial risks on photovoltaic prosumers, including whether or not there are complementary incentives, are considered. Policy implications are based on an analysis of the financial risk to prosumers in São Paulo state in terms of the Conditional Value at Risk of Net Present Value. The results reveal that additional financial incentives can mitigate the financial risk of some alternatives. Some alternatives impose financial risk that may discourage new prosumers in some of the São Paulo regions studied.

1. Introduction

The Brazilian electricity sector's main characteristics are the large hydropower plants' predominance and an extensive grid with 100,000 km centrally operated (Martelli et al., 2020). Although the Brazilian matrix is clean, the hydropower dependence makes the system vulnerable to thermoelectric plant activation and their high greenhouse gas emissions during drought periods (Silva et al., 2016). The long transmission lines that integrate the Brazilian electricity system also incur annual load losses above 14% (Queiroz and Forrer, 2012).

Distributed generation (DG) based on renewable sources is an alternative to mitigate these disadvantages, enabling the consumer to generate electricity on the site where it is consumed. In this aspect, DG has the following advantages: greater consumer energy security; low system losses; and lower environmental impacts (Carley, 2009). Incentive policies have been implemented in several countries to encourage DG. These include net metering/net billing to remunerate prosumers (consumers who produces part or all of their electricity demand) for the electricity surplus injected into the grid (Ramírez et al., 2017; Darghout et al., 2016; Dufo-Lopéz and Agustín-Bernal, 2015).

Brazil implemented a net metering scheme in 2012, through a normative 482/2012 published by National Electricity Regulatory Agency (ANEEL) (ANEEL, 2012). The Brazilian net metering was improved by normative 687/2015 and later by normative 786/2017 (ANEEL 2015; ANEEL, 2017) to enable new business models. The most relevant complementary policy to Brazilian net metering is Agreement 16, which establishes commercialization tax (ICMS) exemption, and the law 13.169/2015, which exempts DG from the rates of the Social Integration Program (PIS) and the Contribution to Social Financing (COFINS). In 2018, the Brazilian development bank (BNDES) created the *Climate* Fund, a loan available for projects that use clean energy generation technologies.

However, ANEEL launched the Regulatory Impact Analysis (RIA) 0004/2018 to review the remuneration schemes for prosumers (ANEEL, 2018). RIA's motivation is to evaluate the introduction of charges related to the distribution system's use since the costs not charged to prosumers are transferred to users not opting for the DG.

In the RIA process, six alternatives about different charges composition to prosumers remunerate rate will be evaluated. DG's regulatory framework includes solar photovoltaic (PV), wind, small water systems, and biomass/biogas (Faria Jr. et al., 2017). Solar PV currently corresponds to about 95% of DG power installed in Brazil (ANEEL, 2020a) and grew from 11.4 MW to 1572 MW of power installed from 2015 to 2019. Some authors explain that when considering the averages tariffs

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and solar radiation levels for Brazil or five major Brazilian regions, the impact on PV-DG's financial return is not significant (Doile et al., 2020). However, when the analysis focus becomes the financial risk in the face of catastrophic scenarios, evaluating prosumers individually in a given Brazilian state or micro-region can be raised the hypothesis that some regulatory alternatives may be a disincentive to the new prosumer's growth for PV-DG in some Brazilian places.

The additional taxes expose prosumer to more significant financial risks since the gains' remuneration tariff with energy savings and local irradiation are the main variables that impact the return on investments in PV-DG (Azevedo et al., 2020; Rocha et al., 2017). Thus, it can be investigated the hypothesis that prosumers attended by different utilities and located in cities with different solar radiation levels may present different financial risks for each regulatory alternative proposed at RIA.

Therefore, the objective of this study is to evaluate the impact of the regulatory alternatives raised on prosumer's financial risk and the importance of tax exemptions to mitigate financial risk in the context of each alternative. The evaluation is carried out for fifteen cities in São Paulo, which has seven distribution utilities operating in different state regions.

The prosumer Net Present Value (NPV) in each analyzed city is calculated to analyze the financial risk in each scenario, incorporating the uncertainties regarding the energy tariff and solar radiation level through the Monte Carlo simulation. From the NPV values obtained in the simulations, the risk analysis is performed through the *Conditional Value at Risk* (*CVaR*) to evaluate the most catastrophic results for prosumer in each simulated scenario. For each regulatory alternative, the tax exemptions impact is evaluated, and financing scenarios are simulated from the *Climate* Fund financing line of National Development Bank. The main contribution will be to identify policy implications based on the financial risks imposed by regulatory alternatives discussed in RIA April 2018 through the robust risk analysis based on Monte Carlo simulation and *CVaR*.

In addition to this introduction, this paper is structured as follows: Section 2 presents the regulatory framework and alternatives to the DG remuneration in Brazil, as well as a literature review about financial analysis of the PV-DG investments; Section 3 discusses the materials and methods used; Section 4 discusses the results and study contributions, and finally, section 5 includes the research conclusions.

2. Conceptual framework

2.1. Regulatory framework for PV-GD in Brazil

Resolution 482/2012 can be considered a regulatory framework that creates a net metering scheme in Brazil and a new generators/consumer's class represented by mini and microgeneration (Garcez, 2017; Holdermann et al., 2014). Posteriorly, some changes in resolution and complementary policy schemes are created to leverage DG in the country.

The first initiative was proposed by Minas Gerais, who granted the ICMS exemption for projects contemplated by resolution 482/2012 through law 20.824/2013 (SEF-MG, 2013). Gradually, other Brazilian states began to follow the practice of providing ICMS exemption to prosumers, culminating in the Agreement 16 launched by the National Council for Farming Policies (CONFAZ) (Gomes et al., 2018; CONFAZ, 2015).

Agreement 16 authorizes the Brazilian states to grant the ICMS exemption for DG projects included in Brazilian net metering. In July 2018, all states were already joining Agreement 16 (Andrade et al., 2020). Currently, most states offer the exemption during the entire system lifecycle, except Paraná and Santa Catarina, which only grants the exemption during only four years (CONFAZ, 2018). In 2015, law n° 13.169/2015 (article N° 8) was published, eliminating the PIS and COFINS charge for prosumers (DOU, 2015).

In 2015, a revision to resolution 482/2012 enabled new businesses and promoted more flexibility for prosumers, resulting in resolution 687/2015 (Rigo et al., 2019). The main changes introduced by this resolution 687/2015 were: the registration of new PV-DG systems started to be done from 82 days to 34 days; the electricity credits validation increased from 36 months to 60 months; and a new power range for micro-generation (up to 75 kW) and mini-generation (above 75 kW and below 5 MW) (ANEEL, 2015).

Resolution 687/2015 also resulted in three new prosumers modalities, as follows (ANEEL, 2015):

- Multiple Consumer Units: electricity uses from DG in condominiums or buildings. In this modality, each user is considered a consumer unit, and in common areas, the electricity uses in a consumer unit apart;
- Shared Generation: is a consumer gathering in the same concession area (through a consortium or cooperative composed of an individual or legal entity), a group of consumers invests in a DG system, being able to compensate for the electricity produced in a different property than where it is produced.
- Remote self-consumption: the consumer units belonging to the same individual or company with a consumer unit with DG in a different location but served by the same distribution utility. The excess electricity will be compensated by net metering.

The changes in Brazilian net metering brought by resolution 687/2015 were very beneficial to DG, and from 2015 on, the number of consumer units with DG grew exponentially, as illustrated in Fig. 1.

In 2017, a revised policy (resolution 786/2017) resulted in two changes. First, the installed power limit for microgeneration from water sources was increased from 75 kW to 5 MW (previously it was limited between 75 kW and 3 MW). Second, projects that previously classified as a commercial operation, or that have directly committed to a utility are prohibited from being classified as DG systems.

Concerning subsidized loans, the majority comes from public banks to support DG from renewable sources in Brazil (Garcez, 2017; MME, 2019). In this regard, the *Climate* Fund is the most popular finance line and with the lowest cost for DG projects in Brazil. Since 2018, it is accessible to both individuals and companies.

2.2. Regulatory Impact Analysis

The utilities and some non-prosumers claim that Brazil's net metering scheme, which remunerates prosumers without charges of the distribution system usage fee (TUSD) and other charges that compose retail tariffs, penalizes non-prosumers who bear the prosumers distribution costs. Thus, ANEEL launched a Regulatory Impact Analysis (RIA),

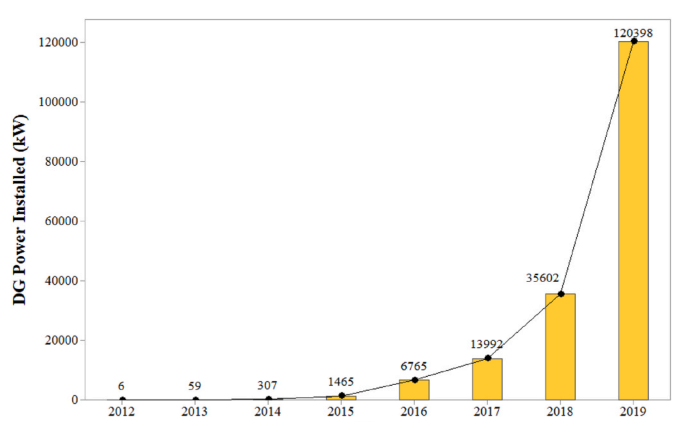

Fig. 1. DG power evolution in Brazil.
Source: ANEEL (2020a).

represented by the RIA 4/2018, to evaluate new alternatives for remuneration schemes for prosumers.

RIA promotes a regulatory review with an innovative process, encouraging social participation and scientific methods (Carvalho et al., 2020). In this way, a problem diagnosis is done and posteriorly are investigated alternatives for dealing with the problem, which will be evaluated by scientific cost-benefit and risk evaluation methods (OECD, 2008). As shown in Fig. 2, the three RIA main steps are (1) problem definition, (2) construction of regulatory alternatives, and (3) economic evaluation of the alternatives' impact on stakeholders. In all steps, social participation and scientific procedures use are encouraged.

After identifying the trade-off problems among prosumers, non-prosumers, and utilities, ANEEL constructed the regulatory alternatives. After extensive public consultation rounds with stakeholders, six regulatory alternatives were identified for analysis with the support of public consultations and scientific procedures.

Table 1 describes the regulatory alternatives under discussion. The study contribution is to analyze how each alternative proposed may affect the prosumer from the financial risk point of view. Generally, the methods used to assess the economic impact or cost-benefit of regulatory options are the cost-benefit analysis based on simple estimative of NPV; cost-effectiveness analysis; and multicriteria analysis (OECD, 2019). In this study, the proposal is a robust risk analysis from the *CVaR* to assess the worst NPV scenarios that the prosumer may experience given the possible regulatory scenarios considered. The proposed assessment method is an innovative way to assess regulatory alternatives.

Table 1
Alternatives for Prosumers' remuneration rule.

Alternative 0	It corresponds to the current remuneration scheme, with remuneration being the retail tariff without the collection of TUSD and other charges. There is no reduction in the remuneration rate.
Alternative 1	Inclusion of TUSD *Wire B* charge. This charge corresponds to the service cost provided by the utility. Reduces the remuneration tariff by 28%.
Alternative 2	TUSD *Wire A* and *Wire B* charges. The TUSD *Wire A* charge refers to electricity transmission service costs by third parties. Reduces the remuneration tariff by 34%.
Alternative 3	*Wire A*, *Wire B*, and system service charges. This last one is charges related to the distribution and transmission service. Reduces the remuneration tariff by 42%.
Alternative 4	*Wire A*, *Wire B*, system service charges, and consumption charges. Includes charges relating to technical and non-technical losses and transaction costs. Reduces the remuneration tariff by 50%.
Alternative 5	It covers TUSD components charges, in addition to the other charges embedded in the retail tariff. Reduces the remuneration tariff by 62%.

Source: ANEEL (2020b), ABSOLAR (2019).

2.3. PV-DG investment analysis

Over the decades, PV electricity has increased, and expectations are even more optimistic for the coming decades (Jäger-Waldau, 2019). This positioning has been possible due to PV technology costs, which have decreased by about 80% in the last decade (Masson and Kaizuka, 2019). In this context, it is necessary to evaluate the PV system viability from a technical, economic, and financial point of view (Zeraatpisheh et al., 2018). Concerning the decision criteria for PV investments, the methods of NPV, Internal Rate of Return (IRR), and Discounted Payback Time (DPBT) are popular and are based on discounted cash flow analysis (Talavera et al., 2019).

Prosumer's cash flows are influenced by cash inflows and outflows and financing decisions, as utilization of debt and equity is critical for the acceptance and execution of capital-intensive projects (Lomas et al., 2018). In this context, recent studies in the literature address PV-DG systems' economic viability analysis.

Schopfer et al. (2018) evaluated the viability of PV off-grid systems based on the user load profile through NPV. Haegermark et al. (2017) conducted a viability analysis of PV-DG systems in the Swedish market through NPV. Bersch et al. (2017) analyze the most profitable sizes for PV-DG systems in some different markets through IRR. In turn, Cucchiella et al. (2016) use the NPV, the DPBT, and a breakeven analysis to evaluate the impacts of energy prices and a tax subsidy on PV-DG's viability at the residential level in the Italian market.

Rodrigues et al. (2016) analyzed small-scale PV in several countries, including Australia, Brazil, China, Germany, Italy, Spain, United Kingdom, United States, among others, to identify the most viability contexts, considering the PV-DG regulation for each country. The authors' methods to assess economic viability were the NPV, IRR, DPBT, and the Profitability Index (PI). Camilo et al. (2017) also use the NPV, IRR, PI, and Payback Time (PBT), but focusing on PV-DG viability for different power scales in the Portuguese market.

Komparou et al. (2017) presented a methodology to identify the most appropriate net metering scheme for the Mediterranean region (Cyprus, Greece, Spain, Slovenia, Portugal, and France), given the regulatory policies and electricity tariffs of each location. Lee et al. (2017) explored a Monte Carlo simulation to estimate PV-DG's breakeven prices at commercial and residential scales in South Korea. Thus, the authors analyzed the uncertainties present in the projects' cash flows.

Ellabban et al. (2019) developed the Integrated Economic Adoption Model (IEAM), which can perform an economic assessment for PV-DG systems in the face of technical, environmental, economic, and financial uncertainties. The consumer can use this model to evaluate different net metering schemes offered to optimize the system's size, considering the desired economy, the grid's energy export rate, and the PBT.

Lee et al. (2018) presented a financial analysis and an impact

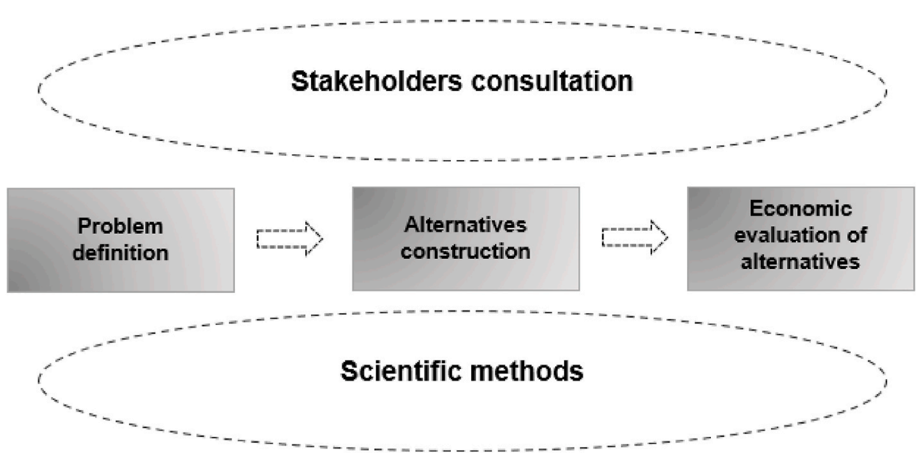

Fig. 2. RIA main steps.

analysis to residential PV-DG in the US. The authors use the NPV, PI, and PBT, estimated through the Monte Carlo simulation, considering PV-DG subsidies. The study results revealed that 18 of the 51 municipalities analyzed achieved economic viability, and in seven of them, subsidies were essential.

Concerning the Brazilian PV market, Holdermann et al. (2014) analyzed the PV-DG viability at residential and commercial scales in the 63 distribution concession areas. Miranda et al. (2015) used technical-economic simulations integrated into a geographic information system to analyze PV system feasibility. Rocha et al. (2017) compare the risk and PV systems return in four cities of different Brazilian regions in the context of resolution 482/2012 and Agreement 16, through NPV estimated from the Monte Carlo simulation. Vale et al. (2017) present a financial analysis from NPV and IRR to evaluate PV-DG systems connected to a government program's dwellings.

This study contributes to the impact evaluation of the regulatory alternatives discussed in RIA 0004/2018 on the returns and financial risks of PV-DG prosumers with the tax exemptions provided by Agreement 16 and law 13.169/2015, in addition to the BNDES loan. For risk analysis, the uncertainties will be inserted in NPV estimative by the Monte Carlo Simulation. Posteriorly, the Conditional Value at Risk (*CVaR*) will be used to identify the most catastrophic financial scenarios. The results will indicate policy implications of RIA April 2008 for prosumers in São Paulo state.

3. Materials and methods

3.1. Investment and risk analysis

3.1.1. Net Present Value and Monte Carlo simulation

Among the methods to guide decision-making about invest or not, the NPV is the most popular because it considers the investments return in monetary values (Brealey et al., 2018). NPV is based on future net cash flows, discounted to a present value by a specific discount rate. NPV formula is represented in Eq. (1).

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+i)^t} \tag{1}$$

where: CF_t = cash flow at period *t*; *T* = investment lifetime; *i* = discount rate.

In the present study, cash inflows are represented by the loan release and the energy savings provided by PV-DG formed by multiplying the local energy tariffs and energy production. In turn, cash outflows are represented by the initial capital investment, operation and maintenance (O&M) costs, and amortized principal and interest payments on debt. In some scenarios, the ICMS charges will be considered to analyze the impact of this tax exemption on prosumer risk. Table 2 shows the cash flow of the PV-DG prosumer.

The discount rate is estimated by the Capital Asset Pricing Model (CAPM) model of Sharpe (1964), Lintner (1965), and Mossin (1966), and described in Eq. (2):

$$k_e = CAPM = r_f + \beta \times (r_m - r_f) \tag{2}$$

Table 2
Prosumer cash flow.

Cash Flow
(+) Electricity bill savings
(−) ICMS
(−) O & M costs
(+) Release of financing
(−) Investment
(−) Amortization of financing
(−) Financial expenses
(=) Cash flow balance

where: ke = cost of equity; rf = risk-free rate; β = investment risk in relation to the market; $rm - rf$ = market risk premium.

For CAPM, parameters were considered values from the end of the first half of 2020, described in Table 3. The r_f and β data were collected in the *Economatica*® software, and all parameters were discounted to inflation of 2.13% per year (IBGE, 2020).

The NPV is estimated by a stochastic method, considering uncertainties in the variables that have the greatest influence on prosumers' NPV results, which are the energy tariffs and electricity production (Rocha et al., 2017; Oliveira et al., 2020). Stochastic NPV is estimated through Monte Carlo Simulation, which is performed from the numerous calculations for a response variable, through different values for the main input variables, randomly selected from predefined probability distributions (Jiang et al., 2013).

In the present study, the only variables in which the uncertainties will be inserted are the energy tariff and solar irradiation. These variables have the most impact on the NPV results, and they are only input variables that are different in the prosumers' cash flow from different locations. For CAPEX and OPEX, the same values were considered for the prosumer at each location, since in a perfect market, their bargaining power would be comparable. Thus, it was unnecessary to perform a sensitivity analysis to select the variables in which uncertainties would be incorporated in the Monte Carlo simulation.

The probability distributions for the energy tariff and solar irradiation for the analyzed locations were estimated from an Anderson Darling goodness-of-fit for the data time series of these variables, collected from the same data source for each location analyzed. This procedure guarantees the estimation of an unbiased calculation for the NPV simulations.

3.1.2. Conditional Value at risk

After the Monte Carlo Simulation execution, the NPV results obtained in the simulations can be extracted. From them, the worst expected NPV result for PV-DG prosumer can be estimated. This estimative will be obtained from the *CVaR*, a *Value at Risk* (*VaR*) variant measure, one of the most popular statistics to estimate financial losses (Mina et al., 2001). *VaR* represents the worst expected loss for an asset, for a confidence level (Jorion, 2006). The *VaR* calculation can be described by Eq. (3):

$$1 - \alpha = \int_{-\infty}^{W^*} f(w)dw = P(w \le W^*) = p \tag{3}$$

where: α = confidence level; W^* = minimum value for *w*; *f*(*w*)d*w* = probability distribution function for *w*; *p* = degree of confidence for *CVaR* estimative.

However, the *VaR* does not present information on possible losses higher than those identified for $1 - \alpha$, which can be catastrophic in cases where returns have asymmetric distributions (Uryasev, 2000), as the investments that are affected by climatic variables. Another *VaR* limitation is the subadditivity since the *VaR* of random variables can be greater than the individual sum of each of them (Artzner et al., 1999). The *CVaR*, in turn, is characterized as a more pessimistic measure than the *VaR* and represents the conditional expected value for worst-case scenarios that exceed the *VaR* (Fig. 3) (Sawik, 2010).

In some cases, two distributions may have the same *VaR* results and

Table 3
Parameters for discount rate estimative.

Parameter	Value	Proxy
r_f	3.21%	Treasury Brazil (10y maturity)
β	0.50	Electricity companies (Brazil)
$(r_m - r_f)$	7.66%	FGV-EESP (2020)
k_e (CAPM)	6.00%	Eq. 4

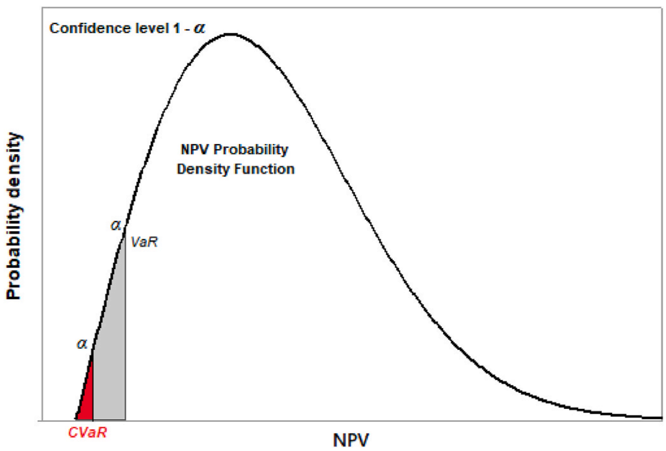

Fig. 3. Illustration of CVaR.Source: Sawik (2010).

achieve different *CVaR* for α% levels less than or equal to the *VaR*. The reason is that the *CVaR* is the expected value of the set of values that exceed the *VaR* (Charnes, 2007). Eq. (4) mathematically describes the calculation representation of the *CVaR*.

$$CVaR(w) = \int_{VaR(w)}^{\infty} z\frac{fw(z)}{1-\alpha}dz \tag{4}$$

3.2. Case study

This study analyzes the regulatory impact considered in RIA 0004/2018 for DG-PV in the context of 15 cities in São Paulo state. The different solar radiation levels and seven utilities that attend the São Paulo state, which is remunerated according to different energy tariffs, affect the financial risk for prosumers. Fig. 4 illustrates the cities and their respective utilities analyzed in this study.

In Fig. 5. the solar radiation average in São Paulo state is described. However, as there are seasonality and uncertainties related to radiation levels, the uncertainties concerning each city's monthly radiation levels are incorporated in the estimated electricity production. The uncertainties are modeled by probability distributions, which parameters are estimated from monthly solar radiation time series between 1984 and 2019, extracted from the *Power Access Data Viewer database*. (NASA, 2020).

The sum of monthly energy production over the 25 years of photovoltaic panels' lifetime cycle was considered for the factor related to annual energy production. The PV system has 157 PV with 320 W, and the technical characteristics are efficiency (η) = 19.26% and area (A) = 1.6616 m^2. Electricity production is estimated from Eq. (5) and is considered a loss equals 25% due to shading, dust, excess temperature, and technical losses (ABINEE, 2012). The monthly degradation factor of 0.02% was also considered for the PV system (Rocha et al., 2017; Jordan et al., 2016).

$$E_m = \eta \times \rho_m \times A \times (1-\gamma) \times (1-\delta)^{t-1} \tag{5}$$

where: ρ_m = monthly radiation; γ = system losses (≈25%); δ = degradation factor (0.02% at month); t = current month.

In turn, the annual electricity production E_t can be represented by Eq. (6), as the sum of electricity along the twelve months of each year.

$$E_t = \sum_{m=m}^{m+11} E_m \tag{6}$$

Annual electricity saving (*AES*) is influenced by the monthly solar radiation and monthly energy tariffs uncertainties. Thus, we can describe the electricity savings by Eq. (7).

$$AES = \sum_{m=m}^{m+11} p_m \times E_m \tag{7}$$

The PV system CAPEX is equivalent to 638.03 US$/W, whose value corresponds to industrial size systems in Brazil in the first half of 2020 (Greener, 2020) and the OPEX is 3.19 US$/W per year (0.5% of CAPEX) (Rocha et al., 2017; Edenhofer et al., 2013). About the *Climate* Fund loan premises, the conditions are the same current in the first half of 2020 (BNDES, 2020). The amortization system is constantly amortized in eight years and a waiting period for two years; the interest rate,

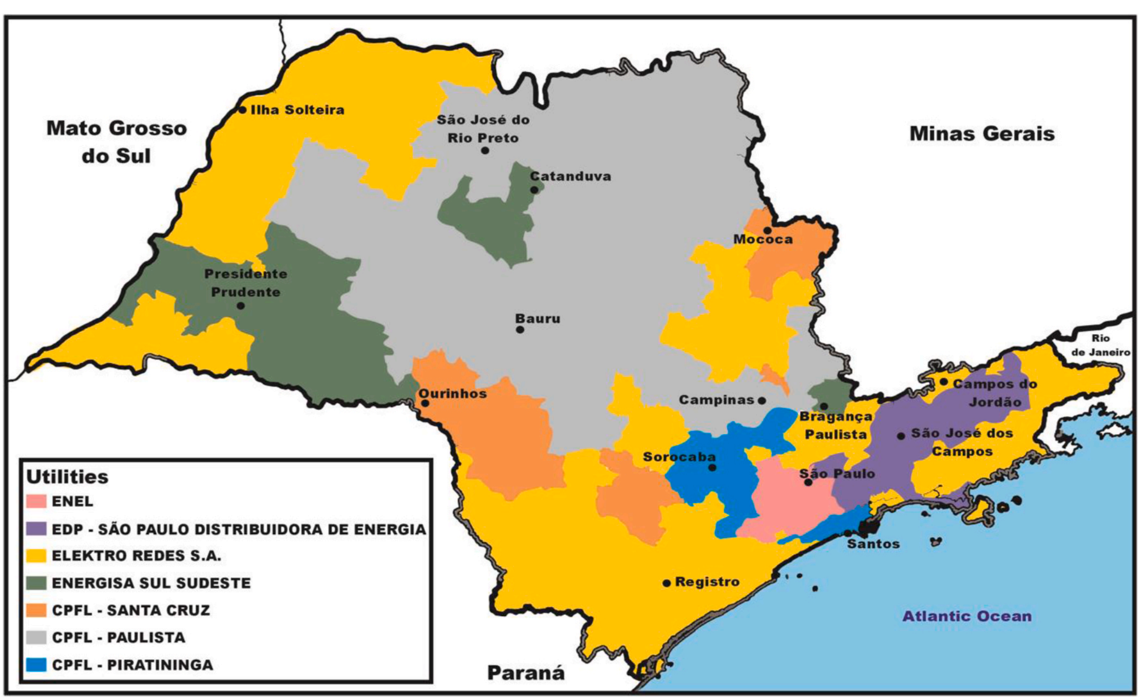

Fig. 4. Utilities in each city.

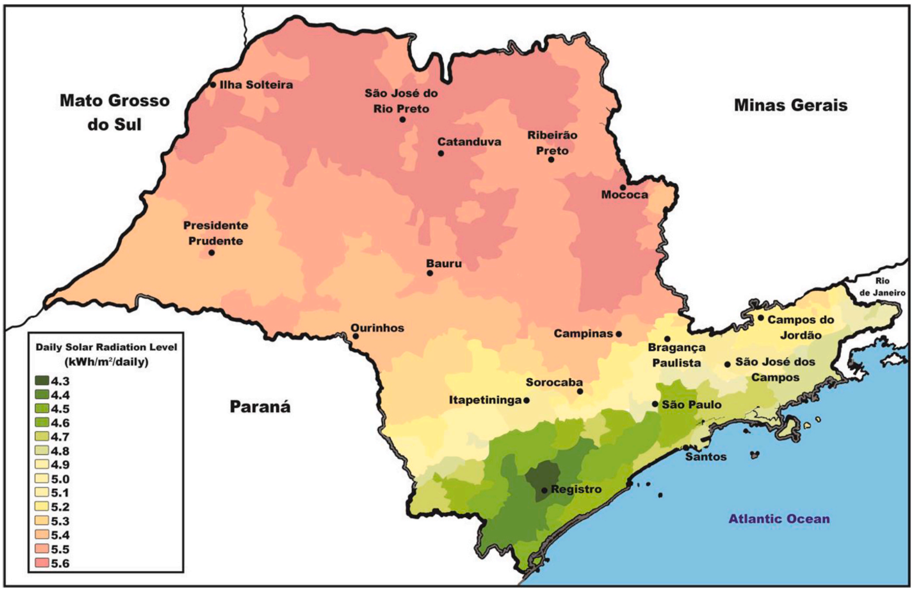

Fig. 5. Solar radiation level in São Paulo state.

discounted inflation, is 4.03% a year; besides, up to 80% of the initial investment can be amortized.

The seven utilities' tariffs were extracted from the consumption and distribution revenue reports on the ANEEL database (ANEEL, 2020c). The average monthly tariffs with and without ICMS, and PIS/COFINS taxes from 2003 to 2019 were collected. In energy savings estimative, uncertainties will also be incorporated into these tariffs' values through probability distributions.

4. Results and discussions

4.1. Results for scenarios with ICMS and PIS/COFINS exemptions

Initially, the uncertainties were inserted in the energy tariffs and solar radiation variables. The tables in Annexes A and B provide the probability distributions modeled for each of these variables from the *Crystal Ball*® software.

It is noteworthy that Energisa Sul-Sudeste attends Bragança Paulista, Presidente Prudente, and Catanduva since September 2018. The same occurred with Mococa, where the distributor CPFL –Santa Cruz attends this city since 2019 (ANEEL, 2020c). Thus, the energy tariffs probability distributions for these cities differ from other cities that are attended by the same utilities. Additionally, a uniform distribution was inserted with the range values from 0% to 80% to represent the uncertainties about CAPEX percentage financed by the Climate Fund loan.

After incorporating uncertainties in these variables were executed 5000 Monte Carlo simulation iterations. Posteriorly, the *CVaR* was with a confidence level of 99.9% was estimated for each alternative. Table 4 presents the *CVaR* results for prosumer in each regulatory alternative, considering the ICMS and PIS/COFINS exemptions guaranteed by Agreement 16 and law 13,169/2015.

According to the results reported in Table 4, only for Alternative 5 appear negative *CVaR* results for PV-DG prosumers in some cities (Catanduva, Presidente Prudente, Registro, Santos, São José dos Campos, São Paulo, and Sorocaba). In scenarios with ICMS exemption, Alternative 5 is the only one that can impose considerable financial losses to the prosumer of these cities. Thus, the uncertainties associated with tariffs and solar radiation in these cities, added to TUSD and TE charges (taxes that directly incur on TE), may discourage new prosumers.

São Paulo city, attended by ENEL, and São José dos Campos, attended by EDP, are localities where the highest financial risk to prosumer is observed if Alternative 5 is chosen in RIA April 2018 process even with the ICMS and PIS/COFINS exemptions for prosumers. After São Paulo

Table 4
CVaR results in scenarios with ICMS and PIS/COFINS exemptions (in USD thousands).

Cities	%					
	Alternative 0	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Bauru	106,245	61,893	52,417	39,565	26,659	6695
Bragança Paulista	93,465	52,994	42,795	31,672	20,427	2448
Campinas	106,116	61,413	51,757	39,640	26,563	6809
Campos do Jordão	91,723	50,503	41,937	30,334	18,585	1382
Catanduva	81,185	43,440	35,663	24,517	13,565	- 2740
Ilha Solteira	99,251	56,208	46,616	34,564	22,481	3842
Mococa	110,805	64,310	54,957	41,938	28,591	8515
Ourinhos	95,552	53,227	44,078	33,246	20,877	3059
Presidente Prudente	76,027	39,827	32,021	21,269	11,148	- 4581
Registro	70,053	34,835	27,529	17,870	7662	- 6808
Santos	70,950	35,747	27,956	18,094	8193	- 6645
São José do Rio Preto	113,188	66,654	56,918	43,156	28,899	9977
São José dos Campos	69,298	34,534	27,301	17,792	7743	- 7262
São Paulo	64,232	31,251	23,840	14,556	5241	- 9370
Sorocaba	75,217	39,102	31,392	20,790	10,863	- 5176

and São José dos Campos, the worst financial risk result is observed in the Registro. Although São Paulo and São José dos Campos have greater solar potential than Registro, the low energy tariffs in these cities are sufficient to impose greater financial risk for prosumers.

Registro is attended by the Elektro utility, which also attends Ilha Solteira and Campos do Jordão. In Ilha Solteira, the worst expected *CVaR* result for Alternative 5 is a positive NPV. In Campos do Jordão, the *CVaR* result is positive for Alternative 5, but approximately 65% lower than that observed in Ilha Solteira. However, among Elektro's cities, the most significant risk observed for Alternative 5 is in Registro due to the lower solar potential in this city.

In Santos and Sorocaba, attends by CPFL Piratininga, is also observed *CVaR* with negative results. The remuneration level proposed by Alternative 5 indicates the financial risk for PV-DG investments in these cities. In turn, in Ourinhos and Mococa, attended by CPFL Santa Cruz, Alternative 5, with the support of the ICMS and PIS/COFINS exemptions, does not impose financial risks to the PV-DG prosumer.

In the cities attended by Energisa Sul-Sudeste, Alternative 5 imposes a high financial risk for the cities of Presidente Prudente and Catanduva, but not for Bragança Paulista. Until 2018, the average energy tariffs were higher than in Presidente Prudente and Catanduva, which influenced the probability distributions modeling of the monthly energy tariffs. Besides, Fig. 5. shows that the solar potential in Bragança Paulista is lower than Presidente Prudente and Catanduva, which corroborates the hypothesis that tariff differentiation of Bragança Paulista favored the prosumer in this city. However, this tariff differentiation was maintained because the possibility of its return cannot be precluded.

4.2. Results for scenarios without ICMS and PIS/COFINS exemptions

When a scenario in which the ICMS exemptions proposed in Agreement 16 and law 13,169/2015 are withdrawn, the energy tariffs are reduced with tax charges for each alternative. Therefore, the energy tariff uncertainties are modeled already considering these rebates, and the probability distributions for energy tariffs in these scenarios are attached in Annex C.

Without ICMS and PIS/CONFIS exemptions, the prosumer's financial risk undergoes considerable changes. In this context, the PV-DG generation becomes an investment with risk investment in several cities if Alternative 3 or Alternative 4 is chosen; for Alternative 5, PV-DG becomes an investment with considerable risk for all cities analyzed. Table 5 describes the *CVaR* results in scenarios in which there are no ICMS and PIS/COFINS exemptions for each regulatory alternative.

In São Paulo, the worst expected result already reaches negative *CVaR* for Alternative 3. Without ICMS and PIS/COFINS exemptions, if Alternative 4 is chosen, in Bauru, Campinas, Catanduva, Presidente Prudente, and Sorocaba, prosumers would also have a negative *CVaR*. In Santos, the prosumer would have *CVaR* slightly lower than Sorocaba. Since CPFL Piratininga attends both, it can be inferred that the Sorocaba solar potential is a little better than Santos. Another interesting comparison is between São Paulo city and Santos. As observed in Fig. 5 and Annex I, these cities have similar solar potentials, but in São Paulo, the prosumer has a slightly higher risk. That can be explained because the Enel utility tariff is lower than CPFL Piratininga, making PV-DG in São Paulo city less financially attractive.

Another interesting result is observed for Campos do Jordão, attended by the Elektro utility. As observed in Fig. 5, Campos do Jordão has a lower solar potential than cities in the North of São Paulo, such as Catanduva and São José do Rio Preto. However, the prosumer in Campos do Jordão presents negative *CVaR* results only in Alternative 5. In Catanduva, for Alternative 4, the *CVaR* is already negative. For Alternative 4, the *CVaR* in Campos do Jordão presents results close to observed for São José do Rio Preto. These results suggest that Elektro's energy tariffs are higher than that of CPFL Paulista and Energia Sul-Sudeste, making the PV-DG in Campos do Jordão an investment with less financial risk than in cities with higher solar potential.

4.3. Policy implications

In addition to verifying that regulatory alternatives with or without the ICMS and PIS/COFINS exemptions have different consequences for the prosumer's financial risk from different locations, the results also provide important policy implications.

The first point is that risk analysis based on *CVaR* reveals that if Alternatives 3 or 4 be chosen, maintenance of Agreement 16 and law 13,169/2015 is relevant for prosumers in all cities analyzed. ICMS and PIS/COFINS guarantee a non-negative *CVaR* for prosumers in all cities. The negative *CVaR* result can be considered a bad sign for policymakers' intentions, who formulate policies and incentives to reduce the financial risk for new DG investments, aiming at the growth of new prosumers and smart grids, in addition to spillovers that can contribute to the reduced of PV technologies costs.

In the scenario where there would be no ICMS and PIS/COFINS exemptions, only Alternatives 0, 1, and 2 indicate that non-negative *CVaR* results for all cities. This result highlights the motivation of RIA 4/2018, in case any stakeholder proposes the elimination of these tax exemptions. ICMS and PIS/COFINS exemptions can be considered complementary policies capable of potentiating the effect of net metering since in prosumer energy savings alternatives are reduced; these exemptions guarantee a low financial risk. Proof is that with these exemptions, Alternative 4 already guarantees a non-negative *CVaR* in all cities, without which only Alternative 2 guarantees a non-negative *CVaR*.

Table 5
CVaR results in scenarios with ICMS and PIS/COFINS exemptions (in US thousands).

Cities	%					
	Alternative 0	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Bauru	52,598	22,712	16,158	7950	- 474.24	- 13,449
Bragança Paulista	56,087	24,569	18,182	9684	465.23	- 12,778
Campinas	52,768	21,769	16,018	7355	- 961.34	- 14,118
Campos do Jordão	56,751	25,876	19,361	10,448	1245	- 11,779
Catanduva	49,127	19,921	14,194	5897	- 2128	- 14,816
Ilha Solteira	62,964	29,730	22,687	12,968	4206	- 10,166
Mococa	69,204	35,145	27,039	16,827	7752	- 7371
Ourinhos	60,739	28,892	22,255	12,997	3832	- 10,266
Presidente Prudente	44,866	17,452	11,358	3429	- 4487	- 16,423
Registro	40,394	13,880	8457	801.19	- 6646	- 18,103
Santos	40,510	13,891	7740	724.04	- 6944	- 18,527
São José do Rio Preto	56,748	25,714	19,136	10,220	1342	- 12,320
São José dos Campos	39,895	13,429	7601	296.27	- 7071	- 18,347
São Paulo	34,387	9597	4171	- 2839	- 9820	- 20,816
Sorocaba	43,648	16,287	10,665	2508	- 5235	- 17,041

The risk analysis proposed in this study is a valuable subsidy for the RIA April 2018 process, which encourages social participation and analyses from scientific methods. The results presented in this paper search to analyze the São Paulo state prosumer point of view, where there is the highest load consumption in Brazil, and where there is a different utility presence, in addition to the different solar potential in different São Paulo state regions.

It is still worth noting that quantitative analyses that analyze financial risks under different alternatives and regulatory contexts represent a fundamental input in the regulatory decision-making process. In the RIA April 2018 case, the regulatory choice may impose a financial risk for prosumers in some localities that may inhibit PV-DG investments. This decision may discourage the DG in specific locations, increasing new users only concentrated in regions with high solar radiation potential or high energy tariffs.

5. Conclusions

This paper evaluates the prosumer's financial risk for PV-DG investments in fifteen São Paulo state cities, given the six regulatory alternatives proposed by RIA April 2018 about the review of remuneration schemes for prosumers. The prosumer's financial risk comparison in locations with different solar radiation levels and attended by utilities that charge different energy tariffs reveals that the impacts of the regulatory alternatives can differ significantly in each local.

In Campos do Jordão, the high energy tariff charged by the utility can encourage prosumer to opt for PV-DG, more than in cities where the solar potential is higher, such as the case of Catanduva. Unlike Catanduva, Alternative 4 without the ICMS and PIS/COFINS exemption does not imply a significant financial risk to prosumers in Campos do Jordão.

However, in some cases, there is the same utility attending cities in different São Paulo regions and with different solar radiation levels. Santos and Sorocaba are one case where this situation occurs. Sorocaba has a higher solar radiation level than Santos, which makes the *CVaR* result 65% higher than *CVaR* in Santos. Another case observed is when two cities are proximate and attended by different utilities. In this case, the tariff can be determinant for PV-DG investment risk to be lower in one city in comparison to another. The comparison between São Paulo and Santos, which have similar solar potential, found that higher tariff in Santos maintains Alternative 3 with low risk for prosumers in the scenario without ICMS and PIS/COFINS exemptions. However, São Paulo presents a negative *CVaR*, indicating an unfavorable outcome for prosumers.

Another important conclusion is that the ICMS and PIS/COFINS exemption are two incentives that significantly mitigate prosumer's financial risk. With ICMS and PIS/COFINS exemptions, Alternative 4, in which prosumer's remuneration is reduced by up to 50%, PV-DG is still financially attractive to prosumer, since the *CVaR* indicates that the worst scenario expected in all cities is still a positive *CVaR*. Without these exemptions, only Alternative 2 would guarantee a worse expected result with NPV still positive for all cities.

It is still worth noting that the risk analysis from the *CVaR* proposed in this study not only contributes to a more robust investment analysis for prosumers but is also a tool for analysts to contribute in public consultations during RIA processes. The *CVaR* of the NPV of the regulatory alternatives corresponds to an additional step in relation to the traditional NPV analysis of regulatory alternatives. It initially calculates a stochastic NPV from Monte Carlo Simulation, and it provides an alternative risk analysis based on monetary values from the *CVaR* of the NPV distribution values obtained in the simulations.

The risk analysis from *CVaR* indicates the monetary result for risk analysis for regulatory options and converges to the RIA proposal to encourage innovative procedures and the use of scientific methods. Future studies with the same method to evaluate the monetary risk are valuable to analyze regulatory alternatives from stakeholders affected by new regulations or review regulatory processes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ANNEX A – Probability distributions for monthly radiation levels

Table A1
Distributions for Bauru, Bragança Paulista, Campinas, Campos do Jordão and Catanduva.

	Bauru	Bragança Paulista	Campinas	Campos do Jordão	Catanduva
Jan	Triangular (4.11; 5.78; 7.25)	Lognormal (1.64; 5.49; 0.62)	Logistic (5.57; 0.36)	Lognormal (1.74; 5.31; 0.65)	Lognormal (0.52; 5.67; 0.68)
Feb	Logistic (5.59; 0.33)	Lognormal (0.62; 5.48; 0.59)	Logistic (5.53; 0.36)	Lognormal (2.45; 5.36; 0.62)	Logistic (5.73; 0.33)
Mar	Weibull (3.14; 2.29; 6.07)	Weibull (−352.17; 357.53; 953.55)	Weibull (−358.24; 363.67; 947.97)	Student's t (4.90; 0.40; 30)	Extr Minimum (5.53; 0.36)
Apr	Lognormal (−2.26; 4.78; 0.36)	Logistic (4.81; 0.20)	Extr Maximum (0.18; 0.04)	Logistic (4.61; 0.18)	Lognormal (3.48; 5.00; 0.35)
May	Weibull (2.38; 1.75; 5.37)	Weibull (3.01; 1.13; 4.29)	Weibull (2.87; 1.26; 4.78)	Weibull (2.74; 1.32; 4.73)	Logistic (4.23; 0.16)
Jun	Logistic (3.78; 0.18)	Weibull (1.86; 2.13; 7.06)	Logistic (3.81; 0.18)	Weibull (1.80; 2.14; 7.44)	Weibull (2.61; 1.51; 5.22)
Jul	Weibull (−225.76; 229.96; 999)	Extr Minimum (4.25; 0.23)	Weibull (−44.19; 48.40; 217.74)	Extr Minimum (4.18; 0.24)	Weibull (0.00; 4.38; 19.58)
Aug	Lognormal (−2.15; 4.73; 0.45)	Extr Maximum (4.60; 0.41)	Lognormal (0.00; 4.78; 0.45)	Weibull (3.12; 1.80; 4.22)	Weibull (3.13; 1.97; 4.61)
Sep	Lognormal (−2.85; 5.10; 0.58)	Logistic (5.11; 0.28)	Logistic (5.10; 0.29)	Logistic (4.98; 0.30)	Logistic (5.29; 0.30)
Oct	Weibull (4.39; 1.46; 3.12)	Logistic (5.63; 0.28)	Lognormal (0.00; 5.67; 0.48)	Weibull (2.80; 2.76; 5.44)	Lognormal (−0.86; 0.18; 0.04)
Nov	Weibull (3.59; 2.65; 7.02)	Logistic (5.79; 0.23)	Logistic (5.92; 0.22)	Lognormal (3.38; 5.42; 0.39)	Logistic (6.00; 0.22)
Dec	Lognormal (0.00; 5.98; 0.43)	Extr Minimum (5.90; 0.30)	Logistic (5.84; 0.24)	Logistic (5.48; 0.22)	Weibull (3.79; 2.29; 6.04)

Table A2
Distributions for Ilha Solteira, Mococa, Ourinhos, Presidente Prudente and Registro.

	Ilha Solteira	Mococa	Ourinhos	Presidente Prudente	Registro
Jan	Weibull (2.57; 3.55; 6.80)	Logistic (5.61; 0.38)	Triangular (4.11; 5.78; 7.25)	Weibull (2.57; 3.55; 6.80)	Extr Maximum (4.84; 0.51)
Feb	Logistic (5.75; 0.27)	Gama (−13.21; 0.02; 999)	Logistic (5.59; 0.33)	Logistic (5.75; 0.27)	Logistic (5.04; 0.36)
Mar	Logistic (5.43; 0.23)	Extr Minimum (5.52; 0.36)	Weibull (3.14; 2.29; 6.07)	Logistic (5.43; 0.23)	Lognormal (2.84; 4.43; 0.48)
Apr	Lognormal (1.85; 4.85; 0.34)	Logistic (4.99; 0.20)	Lognormal (−2.26; 4.87; 0.36)	Lognormal (1.85; 4.85; 0.34)	Logistic (3.89; 0.22)
May	Weibull (2.19; 1.86; 5.09)	Logistic (4.24; 0.15)	Weibull (2.38; 1.75; 5.37)	Weibull (2.19; 1.86; 5.09)	Triangular (2.22; 3.47; 3.86)
Jun	Logistic (3.64; 0.18)	Weibull (2.58; 1.60; 5.46)	Logistic (3.78; 0.18)	Logistic (3.64; 0.18)	Weibull (1.24; 1.84; 6.33)
Jul	Weibull (−19.04; 23.15; 97.50)	Logistic (4.34; 0.14)	Weibull (−225.76; 229.96; 999)	Weibull (−19.04; 23.15; 97.50)	Logistic (3.09; 0.18)
Aug	Weibull (2.78; 2.04; 5.09)	Weibull (3.21; 1.93; 4.13)	Lognormal (−2.15; 4.73; 0.45)	Weibull (2.28; 2.04; 5.09)	Weibull (2.21; 1.99; 3.73)
Sep	Triangular (3.67; 5.03; 6.18)	Logistic (5.31; 0.29)	Lognormal (−2.85; 5.10; 0.58)	Lognormal (−2.71; 4.96; 0.52)	Logistic (3.73; 0.30)
Oct	Lognormal (0.00; 5.61; 0.42)	Weibull (3.79; 2.15; 4.55)	Weibull (4.39; 1.46; 3.12)	Lognormal (0.00; 5.61; 0.42)	Weibull (2.46; 1.98; 3.65)
Nov	Lognormal (−2.26; 6.16; 0.46)	Logistic (5.90; 0.23)	Weibull (3.59; 2.65; 7.02)	Lognormal (−2.26; 6.16; 0.46)	Logistic (4.93; 0.28)
Dec	Lognormal (1.99; 6.14; 0.44)	Extr Maximum (0.14; 0.004)	Lognormal (0.00; 5.98; 0.43)	Lognormal (1.99; 6.14; 0.44)	Logistic (5.22; 0.26)

Table A3
Distributions for Santos, São José do Rio Preto, São José dos Campos, São Paulo and Sorocaba.

	Santos	São José do Rio Preto	São José dos Campos	São Paulo	Sorocaba
Jan	Lognormal (0.00; 5.29; 0.66)	Lognormal (1.74; 5.78; 0.61)	Extr Maximum (5.01; 0.56)	Lognormal (0.00; 5.29; 0.66)	Lognormal (1.24; 5.44; 0.63)
Feb	Lognormal (0.15; 5.24; 0.54)	Logistic (5.85; 0.31)	Extr Maximum (4.94; 0.58)	Lognormal (0.15; 5.24; 0.54)	Logistic (5.44; 0.35)
Mar	Logistic (4.82; 0.24)	Extr Minimum (5.61; 0.39)	Weibull (2.60; 2.31; 5.35)	Logistic (4.82; 0.24)	Weibull (2.87; 2.29; 5.67)
Apr	Logistic (4.38; 0.17)	Lognormal (0.00; 5.10; 0.35)	Logistic (4.25; 0.18)	Logistic (4.38; 0.17)	Logistic (4.51; 0.19)
May	Extr Minimum (3.74; 0.25)	Logistic (4.35; 0.14)	Extr Minimum (3.66; 0.25)	Extr Minimum (3.74; 0.25)	Weibull (1.79; 2.04; 7.10)
Jun	Weibull (1.85; 1.74; 5.20)	Logistic (4.13; 0.15)	Logistic (3.35; 0.16)	Weibull (1.85; 1.74; 5.20)	Weibull (2.17; 1.47; 4.53)
Jul	Weibull (−251.27; 255.08; 948.98)	Extr Minimum (4.51; 0.19)	Logistic (3.52; 0.17)	Weibull (−251.27; 255.08; 948.98)	Weibull (−231.66; 235.57; 999)
Aug	Triangular (3.20; 4.48; 5.36)	Weibull (3.22; 1.98; 5.29)	Weibull (2.70; 1.64; 4.37)	Triangular (3.20; 4.48; 5.36)	Weibull (2.77; 1.85; 4.58)
Sep	Lognormal (−68.20; 4.48; 0.54)	Logistic (5.39; 0.29)	Logistic (4.26; 0.31)	Lognormal (−68.20; 4.48; 0.54)	Lognormal (−2.74; 4.70; 0.53)
Oct	Lognormal (0.00; 5.04; 0.56)	Weibull (4.23; 1.74; 4.58)	Lognormal (0.00; 0.18; 0.04)	Lognormal (0.00; 5.04; 0.56)	Gama (3.88; 0.20; 6.86)
Nov	Lognormal (0.00; 5.35; 0.45)	Weibull (5.59; 1.57; 4.50)	Weibull (3.94; 1.40; 3.12)	Lognormal (0.00; 5.35; 0.45)	Student's t (5.68; 0.41; 30)
Dec	Logistic (5.50; 0.21)	Weibull (3.36; 2.80; 6.36)	Logistic (5.39; 0.28)	Logistic (5.50; 0.21)	Student's t (5.77; 0.43; 30)

ANNEX B – Probability distributions for the tariff in cases with ICMS and PIS/COFINS exemption

Table B1
Distributions for Bauru, Bragança Paulista, Campinas, Campos do Jordão and Catanduva.

	Bauru	Bragança Paulista	Campinas	Campos do Jordão	Catanduva
Jan	Extr Maximum (0.18; 0.05)	Weibull (0.02; 0.19; 3.83)	Extr Maximum (0.18; 0.05)	Weibull (0.06; 0.16; 3.35)	Weibull (−0.01; 0.20; 5.18)
Feb	Lognormal (0.00; 0.21; 0.05)	Lognormal (−0.31; 0.19; 0.05)	Lognormal (0.00; 0.21; 0.05)	Lognormal (0.00; 0.20; 0.05)	Weibull (0.03; 0.16; 4.07)
Mar	Lognormal (0.00; 0.21; 0.05)	Lognormal (0.07; 0.19; 0.05)	Lognormal (0.00; 0.21; 0.05)	Lognormal (0.00; 0.20; 0.05)	Lognormal (0.01; 0.17; 0.04)
Apr	Extr Maximum (0.18; 0.04)	Lognormal (0.06; 0.19; 0.05)	Extr Maximum (0.18; 0.04)	Lognormal (0.00; 0.20; 0.05)	Extr Maximum (0.16; 0.03)
May	Lognormal (0.08; 0.22; 0.06)	Extr Maximum (0.18; 0.04)	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Extr Maximum (0.16; 0.03)
Jun	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Lognormal (−0.01; 0.17; 0.04)
Jul	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.01; 0.20; 0.05)	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Logistic (0.17; 0.02)
Aug	Lognormal (0.08; 0.22; 0.06)	Extr Maximum (0.18; 0.04)	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Lognormal (−0.01; 0.17; 0.04)
Sep	Lognormal (0.08; 0.22; 0.07)	Lognormal (0.00; 0.21; 0.05)	Lognormal (0.08; 0.22; 0.07)	Lognormal (−0.58; 0.20; 0.04)	Lognormal (−0.33; 0.18; 0.04)
Oct	Lognormal (0.09; 0.22; 0.07)	Lognormal (0.00; 0.21; 0.05)	Lognormal (0.09; 0.22; 0.07)	Lognormal (−0.13; 0.21; 0.04)	Lognormal (−0.86; 0.18; 0.04)
Nov	Lognormal (0.09; 0.22; 0.07)	Lognormal (0.01; 0.20; 0.05)	Lognormal (0.09; 0.22; 0.07)	Lognormal (−0.10; 0.21; 0.04)	Lognormal (−0.21; 0.18; 0.04)
Dec	Lognormal (0.06; 0.22; 0.06)	Extr Maximum (0.18; 0.04)	Lognormal (0.06; 0.22; 0.06)	Lognormal (−0.09; 0.21; 0.04)	Lognormal (−0.08; 0.18; 0.04)

Table B2
Distributions for Ilha Solteira, Mococa, Ourinhos, Presidente Prudente and Registro.

	Ilha Solteira	Mococa	Ourinhos	Presidente Prudente	Registro
Jan	Weibull (0.06; 0.16; 3.35)	Weibull (−0.02; 0.26; 4.08)	Weibull (−0.03; 0.25; 4.85)	Weibull (−0.05; 0.24; 7.47)	Weibull (0.06; 0.16; 3.35)
Feb	Lognormal (0.00; 0.20; 0.05)	Weibull (0.02; 0.21; 3.47)	Lognormal (0.00; 0.19; 0.06)	Weibull (0.02; 0.17; 5.08)	Lognormal (0.00; 0.20; 0.05)
Mar	Lognormal (0.00; 0.20; 0.05)	Lognormal (0.00; 0.21; 0.07)	Lognormal (0.04; 0.20; 0.06)	Weibull (0.08; 0.10; 3.28)	Lognormal (0.00; 0.20; 0.05)
Apr	Lognormal (0.00; 0.20; 0.05)	Extr Maximum (0.19; 0.05)	Extr Maximum (0.18; 0.04)	Lognormal (0.00; 0.17; 0.03)	Lognormal (0.00; 0.20; 0.05)
May	Lognormal (0.00; 0.20; 0.05)	Extr Maximum (0.19; 0.05)	Lognormal (0.00; 0.20; 0.05)	Weibull (0.07; 0.11; 3.94)	Lognormal (0.00; 0.20; 0.05)
Jun	Lognormal (0.00; 0.20; 0.05)	Lognormal (0.00; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Weibull (0.06; 0.12; 3.19)	Lognormal (0.00; 0.20; 0.05)
Jul	Lognormal (0.00; 0.20; 0.05)	Extr Maximum (0.19; 0.05)	Extr Maximum (0.18; 0.04)	Logistic (0.17; 0.02)	Lognormal (0.00; 0.20; 0.05)
Aug	Lognormal (0.00; 0.20; 0.05)	Lognormal (0.00; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Logistic (0.17; 0.02)	Lognormal (0.00; 0.20; 0.05)

(*continued on next page*)

Table B2 (*continued*)

	Ilha Solteira	Mococa	Ourinhos	Presidente Prudente	Registro
Sep	Lognormal (−0.58; 0.20; 0.04)	Extr Maximum (0.19; 0.05)	Lognormal (0.00; 0.20; 0.05)	Weibull (0.03; 0.16; 5.08)	Lognormal (−0.58; 0.20; 0.04)
Oct	Lognormal (−0.13; 0.21; 0.04)	Lognormal (0.00; 0.22; 0.06)	Lognormal (0.00; 0.20; 0.05)	Weibull (0.02; 0.17; 5.49)	Lognormal (−0.13; 0.21; 0.04)
Nov	Lognormal (−0.10; 0.21; 0.04)	Extr Maximum (0.19; 0.05)	Lognormal (0.00; 0.20; 0.05)	Weibull (0.04; 0.15; 4.32)	Lognormal (−0.10; 0.21; 0.04)
Dec	Lognormal (−0.09; 0.21; 0.04)	Extr Maximum (0.19; 0.05)	Extr Maximum (0.18; 0.04)	Weibull (0.05; 0.14; 4.12)	Lognormal (−0.09; 0.21; 0.04)

Table B3
Distributions for Santos, São José do Rio Preto, São José dos Campos, São Paulo and Sorocaba.

	Santos	São José do Rio Preto	São José dos Campos	São Paulo	Sorocaba
Jan	Uniform (0.11; 0.25)	Extr Maximum (0.18; 0.05)	Lognormal (0.00; 0.18; 0.04)	Weibull (0.03; 0.16; 3.89)	Uniform (0.11; 0.25)
Feb	Uniform (0.11; 0.24)	Lognormal (0.00; 0.21; 0.05)	Extr Maximum (0.16; 0.03)	Uniform (0.10; 0.24)	Uniform (0.11; 0.24)
Mar	Uniform (0.11; 0.25)	Lognormal (0.00; 0.21; 0.05)	Extr Maximum (0.16; 0.03)	Lognormal (−0.01; 0.17; 0.04)	Uniform (0.11; 0.25)
Apr	Extr Maximum (0.16; 0.03)	Extr Maximum (0.18; 0.04)	Extr Maximum (0.17; 0.03)	Lognormal (−0.22; 0.17; 0.04)	Extr Maximum (0.16; 0.03)
May	Lognormal (0.00; 0.18; 0.04)	Lognormal (0.08; 0.22; 0.06)	Extr Maximum (0.17; 0.03)	Lognormal (0.00; 0.17; 0.04)	Lognormal (0.00; 0.18; 0.04)
Jun	Lognormal (0.00; 0.18; 0.04)	Lognormal (0.08; 0.22; 0.06)	Extr Maximum (0.16; 0.03)	Lognormal (−0.12; 0.17; 0.04)	Lognormal (0.00; 0.18; 0.04)
Jul	Lognormal (0.00; 0.18; 0.04)	Lognormal (0.08; 0.22; 0.06)	Extr Maximum (0.16; 0.03)	Lognormal (−0.03; 0.18; 0.04)	Lognormal (0.00; 0.18; 0.04)
Aug	Weibull (0.06; 0.13; 3.66)	Lognormal (0.08; 0.22; 0.06)	Lognormal (0.00; 0.18; 0.04)	Lognormal (0.00; 0.18; 0.03)	Weibull (0.06; 0.13; 3.66)
Sep	Weibull (0.06; 0.14; 3.77)	Lognormal (0.08; 0.22; 0.07)	Lognormal (0.00; 0.19; 0.04)	Lognormal (0.00; 0.18; 0.04)	Weibull (0.06; 0.14; 3.77)
Oct	Weibull (0.06; 0.14; 3.66)	Lognormal (0.09; 0.22; 0.07)	Lognormal (0.00; 0.18; 0.04)	Lognormal (0.02; 0.18; 0.03)	Weibull (0.06; 0.14; 3.66)
Nov	Lognormal (−1.54; 0.19; 0.03)	Lognormal (0.09; 0.22; 0.07)	Lognormal (0.00; 0.19; 0.03)	Lognormal (0.01; 0.18; 0.03)	Lognormal (−1.54; 0.19; 0.03)
Dec	Weibull (0.10; 0.10; 3.06)	Lognormal (0.06; 0.22; 0.06)	Lognormal (−0.10; 0.19; 0.03)	Lognormal (0.02; 0.18; 0.03)	Weibull (0.10; 0.10; 3.06)

ANNEX C – Probability distributions for the tariff in cases without ICMS and PIS/COFINS exemption

Table C1
Distributions for Bauru, Bragança Paulista, Campinas, Campos do Jordão and Catanduva.

	Bauru	Bragança Paulista	Campinas	Campos do Jordão	Catanduva
Jan	Weibull (0.03; 0.12; 3.80)	Weibull (0.03; 0.13; 3.59)	Weibull (0.03; 0.12; 3.80)	Weibull (0.05; 0.12; 3.24)	Weibull (0.01; 0.13; 4.65)
Feb	Weibull (0.04; 0.10; 3.48)	Lognormal (−0.16; 0.14; 0.03)	Weibull (0.04; 0.10; 3.48)	Lognormal (0.00; 0.15; 0.04)	Weibull (0.03; 0.11; 4.12)
Mar	Weibull (0.06; 0.09; 2.82)	Lognormal (0.06; 0.14; 0.03)	Weibull (0.06; 0.09; 2.82)	Weibull (0.05; 0.11; 2.99)	Uniform (0.09; 0.17)
Apr	Lognormal (0.04; 0.14; 0.03)	Lognormal (0.06; 0.14; 0.03)	Lognormal (0.04; 0.14; 0.03)	Lognormal (0.00; 0.15; 0.04)	Uniform (0.09; 0.17)
May	Lognormal (0.09; 0.14; 0.03)	Lognormal (0.06; 0.14; 0.03)	Lognormal (0.09; 0.14; 0.03)	Lognormal (0.00; 0.15; 0.04)	Lognormal (0.05; 0.13; 0.02)
Jun	Lognormal (0.09; 0.14; 0.03)	Lognormal (0.04; 0.15; 0.03)	Lognormal (0.09; 0.14; 0.03)	Lognormal (0.00; 0.15; 0.04)	Lognormal (0.06; 0.13; 0.03)
Jul	Lognormal (0.09; 0.14; 0.03)	Extr Maximum (0.13; 0.03)	Lognormal (0.09; 0.14; 0.03)	Lognormal (0.00; 0.15; 0.04)	Lognormal (−0.14; 0.13; 0.03)
Aug	Lognormal (0.08; 0.14; 0.03)	Extr Maximum (0.13; 0.03)	Lognormal (0.08; 0.14; 0.03)	Weibull (0.05; 0.11; 3.16)	Lognormal (0.00; 0.14; 0.03)
Sep	Lognormal (0.08; 0.14; 0.03)	Extr Maximum (0.13; 0.03)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.00; 0.16; 0.03)	Lognormal (0.00; 0.14; 0.03)
Oct	Lognormal (0.08; 0.14; 0.03)	Extr Maximum (0.13; 0.03)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.02; 0.16; 0.03)	Lognormal (0.00; 0.14; 0.03)
Nov	Lognormal (0.08; 0.14; 0.03)	Extr Maximum (0.13; 0.03)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.02; 0.16; 0.03)	Lognormal (0.00; 0.14; 0.03)
Dec	Lognormal (0.07; 0.14; 0.03)	Extr Maximum (0.13; 0.03)	Lognormal (0.07; 0.14; 0.03)	Lognormal (0.03; 0.16; 0.03)	Lognormal (0.02; 0.14; 0.03)

Table C2
Distributions for Ilha Solteira, Mococa, Ourinhos, Presidente Prudente and Registro.

	Ilha Solteira	Mococa	Ourinhos	Presidente Prudente	Registro
Jan	Weibull (0.05; 0.12; 3.24)	Weibull (−0.01; 0.19; 4.12)	Weibull (−0.01; 0.17; 4.28)	Weibull (−0.12; 0.26; 12.98)	Weibull (0.05; 0.12; 3.24)
Feb	Lognormal (0.00; 0.15; 0.04)	Lognormal (0.00; 0.16; 0.05)	Lognormal (0.00; 0.15; 0.04)	Weibull (0.02; 0.11; 5.07)	Lognormal (0.00; 0.15; 0.04)
Mar	Weibull (0.05; 0.11; 2.99)	Lognormal (0.03; 0.16; 0.05)	Lognormal (0.05; 0.15; 0.04)	Weibull (0.06; 0.07; 3.42)	Weibull (0.05; 0.11; 2.99)
Apr	Lognormal (0.00; 0.15; 0.04)	Extr Maximum (0.14; 0.04)	Lognormal (0.03; 0.15; 0.04)	Lognormal (0.00; 0.13; 0.02)	Lognormal (0.00; 0.15; 0.04)
May	Lognormal (0.00; 0.15; 0.04)	Extr Maximum (0.14; 0.04)	Lognormal (0.03; 0.15; 0.04)	Lognormal (0.00; 0.13; 0.02)	Lognormal (0.00; 0.15; 0.04)
Jun	Lognormal (0.00; 0.15; 0.04)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Lognormal (−0.17; 0.13; 0.02)	Lognormal (0.00; 0.15; 0.04)
Jul	Lognormal (0.00; 0.15; 0.04)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Weibull (0.07; 0.07; 3.27)	Lognormal (0.00; 0.15; 0.04)
Aug	Weibull (0.05; 0.11; 3.16)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Weibull (0.07; 0.07; 3.28)	Weibull (0.05; 0.11; 3.16)
Sep	Lognormal (0.00; 0.16; 0.03)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Weibull (0.05; 0.09; 4.09)	Lognormal (0.00; 0.16; 0.03)
Oct	Lognormal (0.02; 0.16; 0.03)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Weibull (0.05; 0.09; 4.01)	Lognormal (0.02; 0.16; 0.03)
Nov	Lognormal (0.02; 0.16; 0.03)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Weibull (0.05; 0.09; 4.05)	Lognormal (0.02; 0.16; 0.03)
Dec	Lognormal (0.03; 0.16; 0.03)	Extr Maximum (0.14; 0.04)	Extr Maximum (0.14; 0.03)	Weibull (0.05; 0.09; 3.88)	Lognormal (0.03; 0.16; 0.03)

Table C3
Distributions for Santos, São José do Rio Preto, São José dos Campos, São Paulo and Sorocaba.

	Santos	São José do Rio Preto	São José dos Campos	São Paulo	Sorocaba
Jan	Lognormal (0.00; 0.14; 0.03)	Weibull (0.03; 0.12; 3.80)	Uniform (0.09; 0.19)	Weibull (0.02; 0.11; 4.08)	Lognormal (0.00; 0.14; 0.03)
Feb	Uniform (0.09; 0.18)	Weibull (0.04; 0.10; 3.48)	Uniform (0.09; 0.19)	Uniform (0.08; 0.17)	Uniform (0.09; 0.18)
Mar	Uniform (0.09; 0.18)	Weibull (0.06; 0.09; 2.82)	Uniform (0.09; 0.19)	Lognormal (0.00; 0.13; 0.03)	Uniform (0.09; 0.18)
Apr	Uniform (0.09; 0.18)	Lognormal (0.04; 0.14; 0.03)	Extr Maximum (0.13; 0.02)	Weibull (0.05; 0.09; 3.20)	Uniform (0.09; 0.18)
May	Uniform (0.09; 0.18)	Lognormal (0.09; 0.14; 0.03)	Extr Maximum (0.13; 0.02)	Weibull (0.05; 0.08; 3.04)	Uniform (0.09; 0.18)
Jun	Uniform (0.09; 0.18)	Lognormal (0.09; 0.14; 0.03)	Extr Maximum (0.13; 0.02)	Lognormal (0.00; 0.13; 0.03)	Uniform (0.09; 0.18)
Jul	Uniform (0.09; 0.18)	Lognormal (0.09; 0.14; 0.03)	Extr Maximum (0.16; 0.03)	Lognormal (0.04; 0.13; 0.02)	Uniform (0.09; 0.18)
Aug	Uniform (0.09; 0.18)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.00; 0.14; 0.03)	Lognormal (0.04; 0.13; 0.02)	Uniform (0.09; 0.18)
Sep	Uniform (0.09; 0.18)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.00; 0.14; 0.03)	Lognormal (0.04; 0.13; 0.02)	Uniform (0.09; 0.18)
Oct	Uniform (0.09; 0.18)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.00; 0.14; 0.03)	Lognormal (0.04; 0.13; 0.02)	Uniform (0.09; 0.18)
Nov	Lognormal (0.02; 0.14; 0.02)	Lognormal (0.08; 0.14; 0.03)	Lognormal (0.02; 0.14; 0.02)	Lognormal (0.03; 0.13; 0.02)	Lognormal (0.02; 0.14; 0.02)
Dec	Lognormal (0.06; 0.14; 0.02)	Lognormal (0.07; 0.14; 0.03)	Extr Maximum (0.13; 0.02)	Lognormal (0.04; 0.13; 0.02)	Lognormal (0.06; 0.14; 0.02)

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