AN ALTERNATIVE PRICING OF REGULATORY COMPONENTS BASED ON ADJUSTMENTS IN THE RELATIONSHIP BETWEEN PEAK AND OFF-PEAK TARIFFS IN BRAZIL

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ABSTRACT

This paper presents a proposed tariff methodology for regulatory components of the distribution system use (TUSD) based on adjusting the ratio of peak to off-peak tariffs (POPR) in Brazil. The main objective of this study is to provide the TUSD component (and energy consumption terms) with lower prices for customers that use electricity for irrigation activities, called "irrigator customers" in southern Brazil. The respective paper is motivated by the relevance of this type of consumer in these regions, and also by the low number of methodologies present in the literature related to this theme. Thus, this article deals with a specific subject of Brazilian electricity regulation that has not been studied very much. The proposed methodology considers for the calculations of the TUSD components, market data of the irrigator customers, in addition to the adjustment in the current POPR to regulate the prices between the peak and off-peak components. The proposed tariff calculation framework considers and compares two analysis methods to define the answer to the problem: (i) TUSD off-peak constant and (ii) Constant TUSD Revenue. The results show considerable reductions in the prices of the Peak Energy TUSD component, making it possible for this method to be employed in the future by power utilities to encourage these customers to use electricity on a larger scale during peak hours.

INTRODUCTION

In rural areas of southern Brazil, electricity is largely consumed by the agricultural sector in some months of the year. Among all the agricultural activities present in these regions, the plantation process of irrigated rice stands out. Irrigation usually consists of distributing a significant amount of water captured from rivers, dams, or lakes to the rice fields (Marcolin et al. 2021). This activity is typically performed through hydraulic pumping systems and involves a large amount required of electricity (Pfitscher et al. 2012). In this region, customers who make use of electricity for irrigation activity in rice crops are commonly called "irrigator customers".

Irrigator customers have some particularities that differentiate them from other customers present in the distribution systems, such as: seasonality, showing high levels of demand (power in Watts) and energy consumption (in Watt-hours, that is, power in Watts multiplied by the time of use in hours) only during plantation process, and accentuated load variations throughout the day. During the rice harvest period, usually between the months of September and March, the pumping stations remain on almost continuously, even at dawn, with a reduction in their electricity demand in a small range of hours, usually during the peak hours of power system (6 pm to 9 pm), where the price of electricity is much higher according to Brazilian tariff structures. In some sub-regions, this interval can be modified to other times, seeking to avoid overloading the electrical systems with the instantaneous reconnection of many hydraulic pumping systems (ANEEL 2013). Besides possible operational problems in the distribution systems, this load behavior can collaborate to an inadequate process of revenue collection for the power utilities, since the methodology in force encourages energy consumption in the off-peak market with much lower prices in relation to the peak period.

In some countries, specific tariffs are proposed for irrigator customers. In Australia, Tas Networks presents a tariff modality to meet the specificities of this type of customer. In its definition, this tariff is intended for rural customers served at low voltage (below 1 kV alternating current), whose facilities are used exclusively for crop and pasture irrigation. Its tariff structure consists of two parts: (i) charges for basic services rendered and (ii) charges for energy consumption, which varies according to the time of the day (peak, off-peak and shoulder), and also throughout the hottest and coldest months of the year (Tas Network 2022). In Portugal, the regulator (Entidade Reguladora dos Serviços Energéticos (ERSE)) establishes two-part tariffs for seasonal customers,

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composed by a monthly or daily fixed charges for three levels of contracted power and an energy time-of-use tariff (peak, shoulder and off-peak periods), called tri-hourly tariff (ERSE 2020).

In the United States, specifically for the state of Arizona, there are tariffs for customers with seasonal hydraulic pumps. For this case, both the energy and demand charges are differentiated according to the time of use, being divided into "On-Peak" and "Off-Peak". Peak hours extend throughout the day, between the hours of 11am and 9pm on weekdays (APS 2017). In the state of California, Southern California Edison (SCE) provides special, exclusive rates for customers who have more than 70% of their energy used for agricultural or water pumping purposes. This rate structure is part of a program related to interruptible rates, allowing the utilities to interrupt power delivery during periods of peak energy demand in exchange for credits and bill benefits (SCE 2019).

In Brazil, irrigator customers have special benefits and subsidies in the composition of the tariff structure. Customers who use electricity for irrigation activity during the dawn period receive discounts ranging from 60% to 90% on regulatory components of the electricity tariff (ANEEL 2018).

The agency responsible for the regulation and supervision of the electricity sector in Brazil, Agência Nacional de Energia Elétrica (ANEEL), defines the Brazilian tariff structure should reflect the relative differentiation of the utility's regulatory costs among the different customer classes, according to the modalities and tariff periods (peak and off-peak). Brazil's electricity tariffs are composed of two components, namely Energy Tariff (translated from Portuguese as “Tarifa de Energia - TE”) and Distribution System Use Tariff (translated from Portuguese as “Tarifa de Uso do Sistema de Distribuição - TUSD”). The TE represents the price of the commodity electricity. On the other hand, TUSD indicates the price for the use of the distribution and transmission system to transmit electricity (ANEEL 2023). The TUSD is structured by four tariff components that fulfill regulatory cost functions. Figure 1 illustrates the TUSD cost functions.

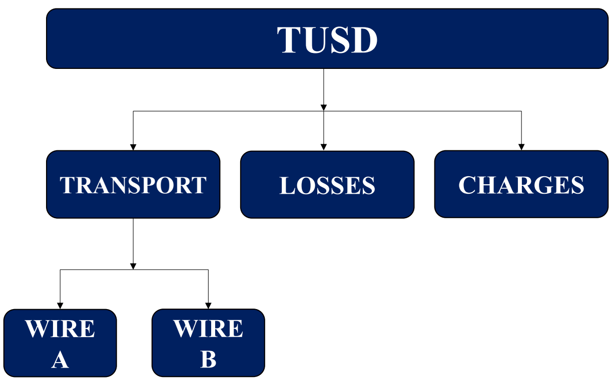

Figure 1. TUSD Cost Functions.

The TUSD cost functions are made up of the Transports, Losses and Charges. The Transport Function is decomposed in components WIRE A and WIRE B. TUSD WIRE A includes the regulatory costs related to the use of the high voltage power grid transmission systems, the use of transformers with voltage inferior to 230 kV, the use of distribution systems of other power utilities and the connection to transmission or distribution facilities. The TUSD WIRE B is formed by regulatory costs related to the company's own assets, administration, operation and maintenance (ANEEL 2023).The Charges component is responsible for recovering costs related to research and development, energy efficiency, service supervision fees, contribution to the electric system operator, incentives for alternative energy source programs, among others. The Losses component comprises the costs approved by the regulator related to technical losses, non-technical losses, transmission losses, and irrecoverable revenues (ANEEL 2023).

Cost function values are applied to irrigator customers according to their tariff modality: Blue hourly tariff modality and Green hourly tariff modality. In terms of TUSD values, both tariff modalities present tariffs with distinct prices for energy consumption and demand. Depending on the modality, differentiated prices are established for peak and off-peak periods (ANEEL 2023). Currently, irrigator customers are included in the green tariff modality. Table 1 presents a summary of the tariff structure in terms of TUSD values for demand and energy consumption.

Table 1. Tariff structure in terms of TUSD values for demand and energy consumption.

Modality	Attribute	Period	
		Peak	Off-Peak
Blue	Demand	Specific Hourly Tariff (6 pm to 9 pm)	Specific Hourly Tariff (Other Times)
	Energy Consumption	One-Time Tariff	
Green	Demand	One-Time Tariff	
	Energy Consumption	Specific Hourly Tariff (6 pm to 9 pm)	Specific Hourly Tariff (Other Times)

The peak and off-peak tariffs’ relation (POPR) is an important parameter that involves the tariff modalities and the TUSD cost functions. Currently, this relationship is established directly on the TUSD Transport component, indicating the value weight of the on-peak component over the off-peak component. This variable is important in the composition and price definitions of electricity tariffs and load modulations by the customers. Thus, a high POPR value implies much more expensive peak-hour tariffs, forcing the customer to considerably reduce demand in this interval and concentrate the load during off-peak hours.

In this way, reducing the ratio between peak and off-peak tariffs for the TUSD component can be an interesting alternative both for irrigator customers and for power utilities. In this way, a more adequate off-peak revenue can be recovered, provided that the market is suitable for this process, in addition to encouraging on-peak consumption by these customers. The positive aspect of this alternative is that it does not require any methodological changes, only adjustments in the RPFP values of the reference tariffs made available in the tariff process of the electric power utilities, considering only the market of irrigator customers.

In this context, this paper presents a proposal for a tariff methodology based on adjusting the ratio between peak and off-peak tariffs in Brazil. It is proposed that this alternative be applied only to irrigator customers, since their capacity to modulate load allows them to avoid electricity consumption during the peak period. The methodology of this work consists of a simple tariff calculation mechanics, calculating data from energy markets and regulatory components to define the new TUSD component prices for irrigator customers for on-peak and off-peak energy consumption tariffs. The main objective of this study is to propose lower peak tariff prices to encourage irrigators to consume electricity during this period. The results obtained from this study corroborate the proposed tariff calculation mechanics, presenting lower prices in the Peak Energy TUSD.

METHODOLOGY

The tariff calculation methodology proposed in this paper aims to apply a change in the relation between peak and off-peak tariffs, in order to establish lower prices during peak hours. Currently, the regulatory components related to transmission are originally calculated in terms of demand (R$/kW) in the Blue Modality electricity tariff. The methodology considers, after applying the POPR on the TUSD Blue Modality components, their conversion to components to be charged in terms of energy (R$/MWh). Figure 2**Erro! Fonte de referência não encontrada.** illustrates the flow chart of the proposed tariff methodology.

Thus, the proposed methodology consists of five sequential steps: (i) TUSD Component Information: extraction of the regulatory component information for each tariff modality (Blue and Green) from a database of a Brazilian utility; (ii) Current RPFP: calculation of the ratio between peak and off-peak tariffs based on the information recorded in the previous step; (ii) Energy Market Data: identification of the market data for general costumers and irrigator customers; (iv) New TUSD Calculations: new prices for the Green Modality based on external parameters and (v) Methods and Results: results for the two proposed analysis methods (TUSD Off-Peak

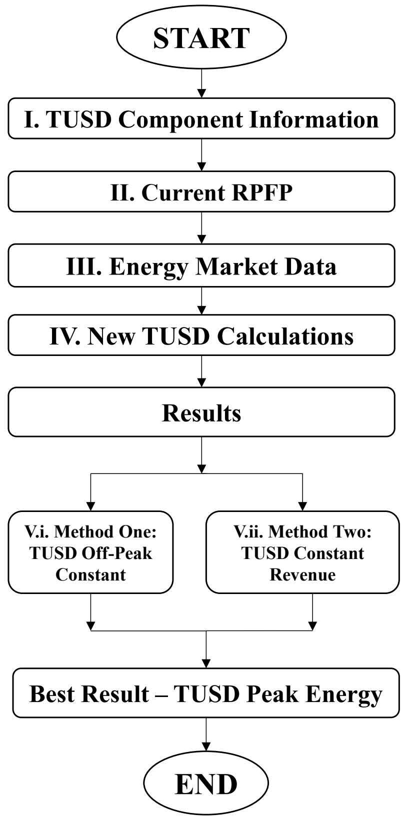

Figure 2. Stages of the proposed tariff methodology.

Constant and TUSD Constant Revenue). The method that presents the lowest TUSD Energy Peak value is considered suitable as the solution to the problem.

The following subsections detail steps (i), (ii) (iii) of the methodology. Step (v), from the methods described in (v.i) and (v.ii) is discussed in the results chapter of this paper.

I. TUSD Component Information

The TUSD component is the sum of the regulatory components of Transport (WIRE A and WIRE B), Charges and Losses. Equation 1 describes the TUSD component.

$$TUSD = WA + WB + Los + Chs \qquad (1)$$

Where:

- *TUSD*: TUSD Component;
- *Loss*: Losses Regulatory Component;
- *Chs*: Charges Regulatory Component;
- *WA*: WIRE A Transport Regulatory Component;
- *WB*: WIRE B Transport Regulatory Component.

The information referring to each regulatory component was ascertained in the tariff review process of a power utility in southern Brazil. This company was selected for this study because it covers numerous irrigator customers. It is important to mention that these values vary according to power utility.

Table 2 presents the prices of the regulatory components of each tariff modality (Mod) and their respective TUSDs in peak (P) and off-peak (OP) periods in terms of demand (D) and energy consumption (E) for the year 2021. The blue modality is composed of peak demand (PD), off-peak demand (PDO), and one-time energy tariffs. The green modality encompasses peak energy (EP), off-peak energy (EOP) and one-time demand tariffs.

Table 2. Prices of the regulatory components and TUSDs for the year 2021.

Mod	Period	Chs	WIRE A	WIRE B	Loss	TUSD
Blue	DP	0,00	9,42	35,48	0,00	44,90
	DOP	0,00	8,94	21,07	0,00	30,01
	E	67,52	0,00	0,00	18,35	85,86
Green	D	0,00	8,94	21,07	0,00	30,01
	EP	80,21	226,58	853,32	18,35	1178,45
	EOP	67,52	0,00	0,00	18,35	85,86

The monetary value of the regulatory components and TUSD refers to the currency in effect in Brazil, Reais (R$). Demand tariffs are billed in R$ per kilowatt (R$/kW), while energy tariffs are billed in R$ per megawatt hour (R$/MWh). In Brazil, the thousands separator is a point and the decimal separator a comma.

Capturing the information in Table 2 is essential for the execution of the next steps of the methodology.

II. Current RPFP

The current POPR can be established through the ratio between the TUSD peak and off-peak components of the blue modality. Equation 2 describes the POPR.

$$POPR = \frac{TUSD\ DP_B}{TUSD\ DOP_B} \tag{2}$$

Where:

- *POPR:* Peak and off-peak tariffs' relation ;
- $TUSD\ DP_B$: TUSD Blue Peak Component of Demand;
- $TUSD\ DOP_B$: TUSD Blue Off-Peak Component of Demand.

Substituting the values of the regulatory components of the power utility (presented in Table 2) in Equation 2 gives the current POPR as 1,49.

III. Energy Market Data

The market data for all customers served by this company was obtained in the tariff review process for the period 2018-2021. Table 3 presents the accurate market for each tariff modality and period (peak and off-peak). The data covers a period of 12 months.

Table 3 presented the billing data for irrigator customers extracted from the national database of utilities that will be used in the calculation process of this methodology.

Table 3. Blue and Green Modality market data referring to all customers for the period 2018-2021.

Mod	Period	Market
Blue	DP	4.820.266,00 kW
	DOP	5.560.265,00 kW
	E	2.129.258,85 MWh
Green	D	22.413.770,00 kW
	EP	291.923,55 MWh
	EOP	4.173.921,96 MWh

Table 4 describes only the market data of the green modality, since it is the modality adopted by irrigator customers.

Table 4. Green Modality market for irrigator customers.

Mod	Period	Market
Green	D	1.470.997,30 kW
	EP	4.240,46 kW
	EOP	173.028,42 MWh

It is important to emphasize that the prices of the regulatory components of the Green TUSD are not altered by calculating the market with only irrigator customers. Capturing this information is essential for the execution of the next steps of the methodology.

IV. New TUSD Calculations

Based on the current tariff methodology structure, the TUSD Transport components (WIRE A and WIRE B) charged in terms of energy in the Green Modality is derived from the demand tariff of Blue Modality. Normally, demand tariffs (billed in R$/kW) are converted to energy tariffs (billed in R$/MWh).

The following equations describe the calculation of peak and off-peak tariffs (billed in R$/kW), considering the two external parameters to the tariff structure calculation: the adjusted POPR and the TUSD Revenue. These expressions are necessary to recalculate the Blue Modality regulatory transport components.

$$WB_{BOPad} = \frac{R_{TUSD}}{POPR_{adj} \times M_{adjP} + M_{OP}} \tag{3}$$

$$WB_{BPad} = WB_{BOPad} \times POPR_{adj} \tag{4}$$

Where:

- WB_{BOPad}: Adjusted price of the WIRE B component of off-peak demand in the Blue Modality;
- WB_{BPad}: Adjusted price of the WIRE B component of peak demand in the Blue Modality;
- $POPR_{adj}$: Adjusted POPR;
- R_{TUSD}: Total revenue of the TUSD component for irrigator customers;
- M_{adjP}: Adjusted market of peak, referring to irrigator customers;
- M_{OP}: Off-peak market, referring to irrigator customers.

The total revenues of the TUSD component for irrigator customers are obtained from the sum between the peak and off-peak portions of the multiplication between the price of the WIRE B component and the reference market for the Green Modality. In this topic, only the values for the WIRE B component were considered, since these involve attributes referring to the distribution systems. Equation 5 describes the total revenue of the TUSD component. Revenue calculation involves regulatory costs and its functions cannot be optimized.

$$R_{TUSD} = WB_{GOPE} \times M_{GOPE} + WB_{GD} \times M_{GD} \qquad (5)$$

Where:

- R_{TUSD}: Total revenue of the TUSD component for irrigator customers;
- WB_{GOPE}: Price of the WIRE B component of off-peak energy in the Green Modality.
- M_{GOPE}: Off-peak market, referring to irrigator customers;
- WB_{GD}: Price of the WIRE B demand component in the Green Modality.
- Mkt_P: Demand market, referring to irrigator customers;

The adjusted peak market is calculated by dividing the total revenue of the WIRE B peak component in the Green Modality and the price of the WIRE B peak component in the Blue Modality, presented in Equation 6.

$$M_{adjP} = \frac{RWB_{GP}}{WB_{BP}} \qquad (6)$$

Where:

- M_{adjP}: Adjusted market of peak, referring to irrigator customers;
- RWB_{GP}: Total revenue of the WIRE B peak component in the Green Modality
- WB_{BP}: Price of the WIRE B peak demand component in the Blue Modality;

The adjustment of the TUSD Transport peak components (WIRE A and WIRE B) for Green Modality billed in terms of demand (R$/kW) to terms of energy consumption (R$/MWh) is given by the following equations.

$$WA_{GPE} = \frac{WA_{BP}}{LF \times h_p} \times 1000 \qquad (7)$$

$$WB_{GPEad} = \frac{WB_{BPad}}{LF \times h_p} \times 1000 \qquad (8)$$

Where:

- WA_{GPE}: Price of the WIRE A peak energy component in the Green Modality;
- WA_{BP}: Price of the WIRE A peak demand component in the Blue Modality;
- WB_{GPEad}: Price of the WIRE B component of peak energy adjusted in the Green Modality;
- WB_{BPad}: Price of the WIRE B component of peak demand adjusted in the Blue Modality;
- LF: Load factor;
- hp: Numbers of peak hours in a month.

The adjustment in the on-peak and off-peak ratio between the TUSDs components will be applied in two different methods, and hence it will be evaluated the prices of the proposed model compared with the current methodology. The first method consists in keeping the TUSD off-peak component of the Blue Modality constant, changing only the peak component. In the second method, the TUSD revenue of irrigator customers is kept constant. For both scenarios, the POPR adjusted ($POPR_{adj}$) in 1,2 was considered. This value was adopted because it is lower than the current POPR calculated in Equation 2.

RESULTS

In the following subsections, the results obtained by the two proposed methods are presented.

V.i. Method A: TUSD Off-Peak Constant

This method keeps the TUSD off-peak component as the reference for calculating the peak component for the Blue Modality. This method does not use market data in its formulation.

The current regulatory values for the WIRE A and WIRE B components for the Blue Modality off-peak period are unchanged. The prices are presented in Table 2.

The TUSD Peak Transport component is calculated using Equation 2, by entering the values corresponding to the peak component and the adjusted POPR. The price of the TUSD Peak Transport component is R$ 36,01 per kW. The WIRE B peak Blue Modality component is obtained by the difference between the Transport and the WIRE A peak component, totaling a price of R$ 26,59 per kW. Table 5 presents the recalculated Blue Modality components.

Table 5. TUSD components of the Blue Modality recalculated.

Period	WIRE A	WIRE B	Transport
DP	9,42	26,59	36,01
DOP	8,94	21,07	30,01

After the TUSD components of the Blue Modality have been recalculated, an adjustment is made to these values in terms of energy for the composition of the Green Modality structure, considering the irrigator customers' market. For this, a load factor (LF) of 0,66 (value defined by the regulatory agency to this power utility) and 21 days with peak hours in a month were considered, totaling the number (hp) of 63 hours.

The adjustment in terms of peak energy is calculated by Equations 7 and 8, and the following prices were obtained: TUSD WIRE A component of the Green Modality, R$ 226,58 per MWh, TUSD WIRE B component of the Green Modality, R$ 639,49 per MWh, and TUSD Transport, R$ 886,07 per MWh. Table 6 presents the recalculated prices for the TUSD regulatory components of the Green Modality.

Table 6. Prices recalculated for the Green Modality.

Per.	Chs	WIRE A	WIRE B	Loss	TUSD
D	0,00	8,94	21,07	0,00	30,01
EP	80,21	226,58	639,49	18,35	964,62
EOP	67,52	0,00	0,00	18,35	85,86

Thus, we highlight the final result of this alternative by comparing the data of Table 2 with that of Table 6: TUSD demand increases from R$ 30,01 per kW to R$ 30,66 per kW; TUSD peak energy decreases from R$ 1178,45 per MWh to R$ 964,62 per MWh.

V.ii. Method B: TUSD Constant Revenue

The second method takes into account the market data of irrigator customers to adjust the TUSD components of the Blue Modality. The market data used in this topic has been presented in Table 4.

The adjusted green market value in the peak period was 101.982,89 kW, considering Equation 6. The values for the TUSD WIRE A component of the Blue Modality are not changed. The TUSD WIRE B off-peak component is calculated using Equation 3, inputting the values for adjusted POPR, revenue and market data. The price of the TUSD WIRE B off-peak component is R$ 21,73 per kW, generating an on-peak Blue Modality Transport TUSD of R$ 30,66/kW. The off-peak TUSD WIRE B component is calculated by Equation 4, and a value of R$ 26,07 per kW is obtained. Thus, the price of the TUSD component for the Blue Modality was adjusted to R$ 35,49/kW. Table 7 presents the recalculated Blue Modality components.

Table 7. TUSD components of the Blue Modality recalculated.

Period	WIRE A	WIRE B	Transport
DP	9,42	26,07	35,49
DOP	8,94	21,73	30,66

After the TUSD components of the Blue Modality were recalculated, an adjustment is made to these values in terms of energy for the composition of the Green Modality.

The adjustment in terms of peak energy is calculated by Equations 7 and 8, and the following prices were obtained: TUSD WIRE A component of the Green Modality, R$ 226,58 per MWh, TUSD WIRE B component of the Green Modality, R$ 627,02 per MWh, and TUSD Transport, R$ 853,60 per MWh. Table 8 presents the recalculated prices for the TUSD regulatory components of the Green Modality.

Table 8. Prices recalculated for the Green Modality.

Per.	Chs	WIRE A	WIRE B	Loss	TUSD
D	0,00	8,94	21,73	0,00	30,66
EP	80,21	226,58	627,02	18,35	952,15
EOP	67,52	0,00	0,00	18,35	85,86

Thus, we highlight the final result of this alternative by comparing the data of Table 2 with that of Table 8: TUSD demand increases from R$ 30,01/kW to R$ 30,66/kW; TUSD peak energy decreases from R$ 1.178,45/MWh to R$ 952,15/MWh.

CONCLUSION

This paper presented a proposal for changing the TUSD regulatory component of Brazil's energy tariff, based on adjustments in the relationship between peak and off-peak tariffs. This methodology was calculated exclusively on the energy market of irrigation customers of a power utility in southern Brazil, and the central objective was to encourage energy consumption during peak hours through lower than current tariffs.

The results obtained with the tariff alternative proposed by this methodology can be considered good and promising. For the two methods evaluated, the adjustments to the POPR reduced the TUSD peak related energy tariff prices in the Green Modality. The TUSD off-peak price for the green mode was unchanged from the current value because this component does not involve regulatory cost functions related to transportation (WIRE A and WIRE B). Method B (TUSD Constant Revenue) showed lower prices in the TUSD Peak Energy component compared to Method A (TUSD Off-Peak Constant), so it is chosen as the solution to the problem.

As a positive point, the proposed alternative has low operational complexity, and does not require profound methodological changes. However, this calculation model cannot be generalized to other tariff modalities.

In future research, we hope to evaluate the results of this methodology individually for a given set of irrigator customers, considering load modulation and reacting to price elasticity at each client.

REFERENCES

ANEEL (2013). “Resolução Homologatória Nº 1514”. Accessed on 13 February 2023, Available online: http://www2.aneel.gov.br/cedoc/reh20131514.pdf

ANEEL (2018). “Tarifa Consumidores (Descontos)”. Accessed on 13 February 2023, Available online: https://antigo.aneel.gov.br/web/guest/alta-tensao-itens/-

/asset_publisher/zNaRBjCLDgbE/content/descontos/654800
ANEEL (2023). “Procedimentos de Regulação Tarifária – PRORET: Módulo 7 (Estrutura Tarifária das Concessionárias de Distribuição de Energia Elétrica)”. Accessed on 13 February 2023, Available online: https://www2.aneel.gov.br/cedoc/aren20231060_2_1.pdf
APS (2017). “Rate Schedule E-221 Classified Service Water Pumping Service Revision 46”. Accessed on 13 February 2023, Available online: https://www.aps.com/-/media/APS/APSCOM-PDFs/Utility/Regulatory-and Legal/Regulatory-Plan-Details-Tariffs/
ERSE (2022). “Atualização da tarifa de energia do Setor Elétrico”. Accessed on 13 February 2023, Available online: https://www.erse.pt/media/re4l30ps/atualiza%C3%A7%C3%A3o-tenergia-se-2022-t4.pdf
Marcolin, P.; Bernardon, D.P.; Souza, N.B.; Eichkoff, H.S.; Madaloz, J.; Kopp, L.M.; Chiara, L.M. and J.A. Silva. 2021. “Metodologia para Detecção de Perdas Não Técnicas de Unidades Consumidoras Irrigantes de Arroz.” In XIV Conferência Brasileira sobre Qualidade de Energia (CBQEE 2021), Online Conference, Brazil.
Pfitscher, L.L.; Bernardon, D.P.; Kopp, L.M.; Heckler, M.V. T.; Behrens, J; Montani, P.B. and B. Thomé. 2012. “Automatic control of irrigation systems aiming at high energy efficiency in rice crops.” In 2012 8th International Caribbean Conference on Devices, Circuits and Systems (ICCDCS 2012), Playa del Carmén, México.
SCE (2019). “Rate Schedule Tou-Pa-3 for Agricultural & Pumping Service Customers”. Accessed on 13 February 2023, Available online: https://www.sce.com/sites/default/files/inline-files/TOU-PA-3%20Rate%20Fact%20Sheet_WCAG.pdf
Tas Network (2022). “Irrigation Network Tariffs”. Accessed on 13 February 2023, Available online: https://www.aer.gov.au/system/files/TN-Irrigation%20Network%20Tariffs%20Fact%20Sheet.pdf

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