

ANALYSIS OF PRICE- DEMAND ELASTICITY OF ELECTRIC ENERGY IN SMART ELECTRICAL GRIDS

Bruno Rodrigues Kawagoe

All content in this magazine is licensed under a Creative Commons Attribution License. Attribution-Non-Commercial-Non-Derivatives 4.0 International (CC BY-NC-ND 4.0).



Abstract: The goal of this work was to study the fluctuation of energy demand as a function of its price, in order to analyze the feasibility of migrating from the conventional energy tariff to the white tariff. To predict certain scenarios, the concepts of price-demand elasticity were used. The estimates of the price-demand oscillation were carried out after collecting energy consumption data in homes in different neighborhoods, therefore, different social classes, so a load curve was set up to analyze the consumption from time to time. The model's goodness of fit was evaluated through dispersion calculations and the correlation between observed values in each unit and the estimates was verified. Considering that the correlation of price-demand elasticity in this case is unitary, therefore, the value oscillates proportionally to the demand, it was possible to conclude with this present study that, for certain social classes, it will be of little advantage to abandon the conventional tariff, as it is necessary that there is a drastic reduction in electricity consumption at peak hours. On the other hand, for other social classes, which naturally consume more energy, it is advantageous after a certain point to migrate from the conventional tariff to the white tariff.

Keywords: White tariff, Conventional tariff, Tariff elasticity.

INTRODUCTION

The Electric Energy Service is essential in the daily life of society, whether in homes or in the various segments of the economy. For the use of this good, it is necessary to apply tariffs that remunerate the service in an adequate way, which enables the structure to maintain the service with quality and that creates incentives for efficiency. Following these precepts, ANEEL develops tariff calculation methodologies for segments of the electricity sector (generation, transmission, distribution

and commercialization), considering factors such as generation, transmission and distribution infrastructure (ANEEL, 2016).

In line with this, we have some tariff modalities for electricity, according to REN No. 414/2010 (2010) tariff modalities are a set of tariffs applicable to the consumption of electricity and active power demand. They are defined according to the Tariff Group, one of which is the group of low voltage consumers (Group B) of Residential Classes (Subgroup B1), Rural (B2), Other Classes (B3) and Public Lighting (B4), for In these classes, we have the Conventional Monomy: single tariff for electricity consumption, regardless of the hours of use; and White Tariff: differentiated tariff for electricity consumption, according to the hours of use of the day (tariff stations).

Within the B1 subgroup, it is important for residential consumers to verify their consumption and then assess the economic feasibility of migrating from the conventional tariff to the white tariff, a way of evaluating consumer behavior in the face of this change is to analyze the price elasticity factor -demand or tariff elasticity, there were some studies in Brazil about the elasticity estimate for the electric energy sector and according to Modiano (1984) estimated the demands for Brazil, for the three classes, in the period from 1963 to 1981, from annual data. He concluded that, for the residential, commercial and industrial classes, the short-run price elasticities were, respectively, 0.118, 0.062 and 0.451; the long-run price elasticities were 0.403, 0.183 and 0.222; short-run income elasticities were 0.332, 0.362 and 0.502 and long-run income elasticities were 1.13, 1.068 and 1.360. Andrade and Lobão (1997) estimated the demand for the residential case in Brazil, from 1963 to 1995, based on annual data.

They came to the conclusion that the short-run and long-run price elasticities

were 0.06 and 0.051; and the short-term and long-term income elasticities were 0.212 and 0.213. Comparing the two works mentioned above, for the residential case, the qualitative difference between the results is in the long-term income elasticity. Thus, the present work aims to evaluate the economic feasibility of migrating from the conventional electricity tariff to the white tariff, analyzing fluctuations in consumer behavior in relation to the price of tariffs.

MATERIAL AND METHODS

The study was carried out in the municipality of Campo Grande, located in the state of Mato Grosso do Sul in the year 2020. The data sources are residential consumers of different social classes, 3 (three) consumer units were analyzed in each location and they are: Rita Vieira, Moreninha, Vila Albuquerque and Alpha Vile. The way the data was analyzed was through an Embrasul RE-6000 energy analyzer.

Figure 1

The measurements lasted for 2 weeks in each residence, after the end of the measurements the results were tabulated and, from there, a load curve was set up in Excel according to the energy consumption of each consumer in their respective social class and a simple average. To understand the parameter used for division, it must be assumed that a class A consumer must live in a property with a commercial value equal to or greater than 600 thousand reais, a class B consumer must live in a property with a commercial value between 250 thousand and 600 thousand reais and a class C consumer a property worth up to 250 thousand reais. These division parameters for analysis are efficient, as there is a difference in the amount of energy consumed between the classes, as will be shown in the load curves, therefore, if a class C consumer chooses to change, it will have different financial impacts

on the energy bill in class A consumer. Therefore, when analyzing this difference, it becomes tangible to stipulate a percentage of viability for the entire municipality of the city according to the standards observed by each of the classes.

The elasticity formulas used are:

$$\text{Price elasticity - demand} = \frac{\% \text{ Variation in demand}}{\% \text{ Price variation}} \quad (1)$$

$$E(pd) = \frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}} \quad (2)$$

On what:

ΔQ = demand variation;

Q = initial demand;

ΔP = price variation; P = starting price.

$$\text{Cross elasticity: } \frac{\text{Variation \% of demand of } x1}{\text{Variation \% of price } x2} \quad (3)$$

$$E(c): \frac{\frac{\Delta Qx1}{Qx1}}{\frac{\Delta Px2}{Px2}} \quad (4)$$

On what:

ΔQx_1 = Variation of consumers of the conventional tariff;

Qx_1 = Conventional tariff consumers;

ΔPx_2 = White tariff price variation;

Px_2 = White tariff price;

The load curve of consumers was measured in the interval of 15 (fifteen) in 15 (fifteen) minutes and had very similar profiles as to the peak time of energy consumption, varying only the amount of which was consumed.

Table 1 - Table 2 - Table 3

The load curves show the average energy consumption of the analyzed households in each social class.

Through the scenarios found for the three classes, scenarios were simulated, from which the value of the energy bill is compared by the conventional tariff and the white tariff (simulating a percentage of allocation of consumption at peak hours to off-peak hours) and checking the difference between the



Figure 1: RE-6000 Energy Analyzer



Table 1: Load curve - class A consumer

The left column indicates the power consumption in Watts (W)

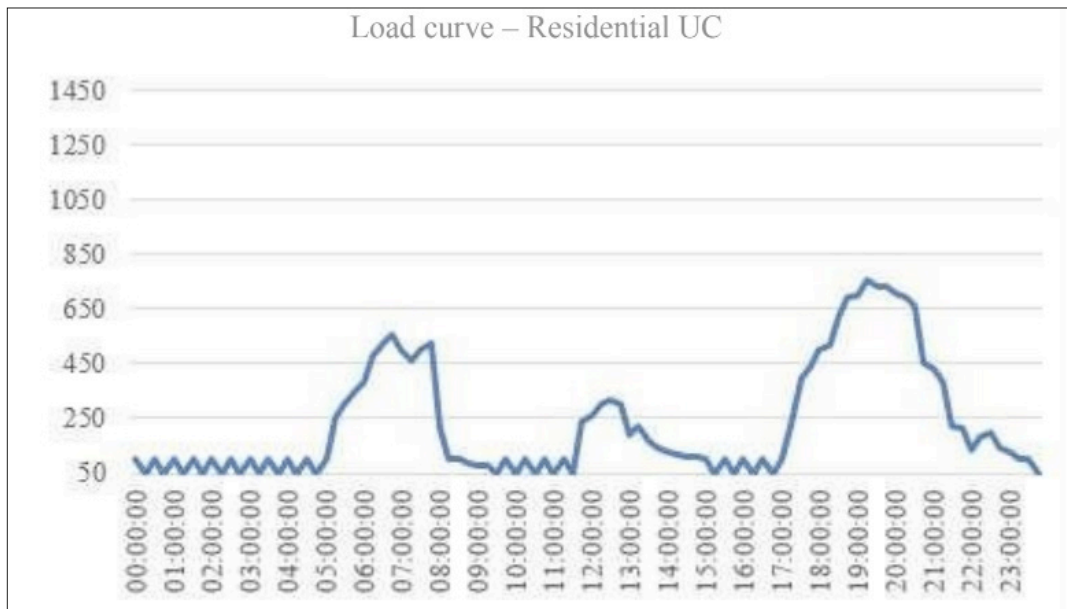


Table 2: Load curve - consumer class B

The left column indicates the power consumption in Watts (W)

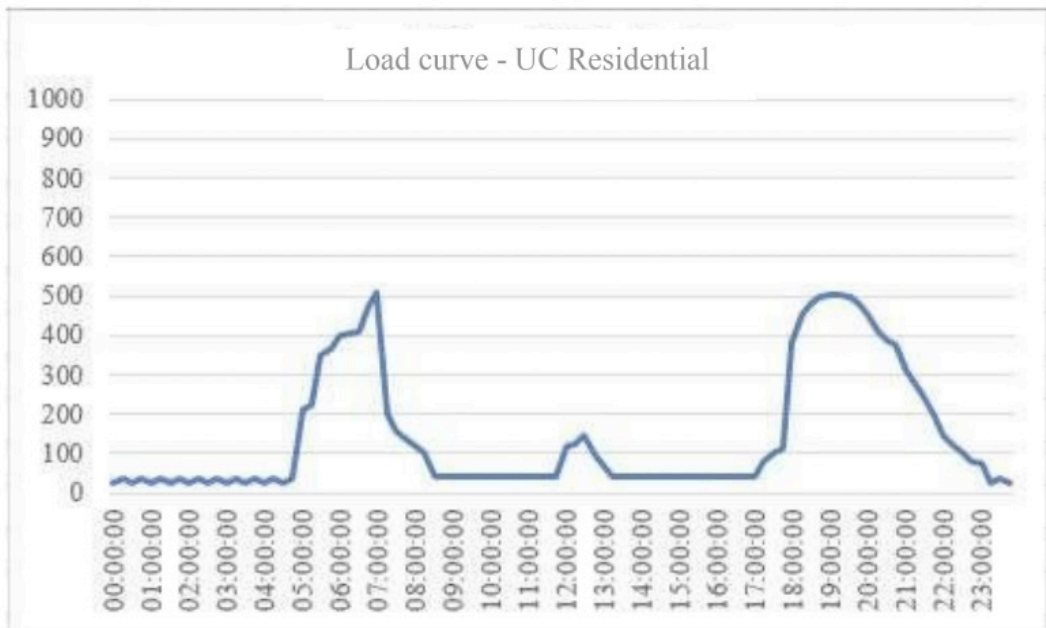


Table 3: Load curve - class C consumer

The left column indicates the power consumption in Watts (W)

values obtained.

RESULTS AND DISCUSSION

To obtain the results, the price-demand elasticity between the price and demand oscillation between tariffs and consumers was first calculated, reaching the conclusion that the analyzed consumer profiles are unitary, which means that as one oscillates the other oscillates inversely proportionally. Then, the tariff values of Energisa, which is the energy distributor in the municipality of Campo Grande, were collected for the calculation of the invoice (disregarding taxes) and according to Energisa (2018) the updated tariff data are shown in table 1.

It is worth mentioning that in the conventional fare there is a single value, while in the white fare there are price variations according to the time of day, with the lowest value at off-peak hours (R\$ 0.515) and the highest value at peak hours (R\$ 1.2316). Comparing the invoice values for the three classes without any change in consumption, we have the following results:

Table 4 - Table 5 - Table 6

What can be said about the values obtained in the comparison is that, due to the consumption habits of these consumers, the white tariff is much more expensive compared to the conventional tariff, therefore, migration between one and the other becomes unfeasible. However, assuming some changes in energy consumption for the three classes, it is possible to make this change feasible.

Scenarios were then simulated in which 10%, 20% and 30% respectively of the consumption at peak hours of each of the classes were allocated to the off-peak hours and it was concluded that in both classes it will be necessary to allocate more 30% of consumption during peak hours for off-peak hours for the tariff change to be feasible.

EVALUATION OF SIMULATIONS OF CHANGE IN ENERGY CONSUMPTION HABITS

Along with the elasticity calculation and the simulation, a final comparison was carried out to analyze for the three classes of consumers when it is feasible to migrate from the conventional tariff to the white tariff.

Figure 2

It can be said from these data that, by allocating up to 30% of consumption at peak hours to off-peak hours, the white tariff is still less advantageous than the conventional tariff for class A consumers, because, if we compare the values of the energy bills, we have that in the conventional tariff the value is R\$ 637,911 and in the white tariff R\$ 641,803.

Figure 3

It is also possible to say in relation to class B the same as class A, since the values obtained are even more discrepant, with 30% allocation of consumption at peak hours to off-peak hours, the energy bill turns around R\$ 440, while in the conventional tariff the bill would be R\$ 410.

Figure 4

For class C, it is noted that despite being the class that consumes less electricity, it is the one with the greatest discrepancy in the simulations, because, clearly, even allocating 30% of consumption at peak hours to off-peak hours, the energy bill for the white tariff (R\$ 287,994) is still considerably higher in relation to the value of the conventional tariff bill (R\$ 265,888).

It is worth noting that the numerical values presented in the tables refer to a closed monthly bill excluding taxes, that is, it is the energy bill corresponding to each simulated scenario.

CONVENTIONAL RATE	WHITE RATE
R\$ 0,645	R\$ 0,515
	R\$0,7861
	R\$ 1,2316

Table 1: Energisa tariff data (2018)

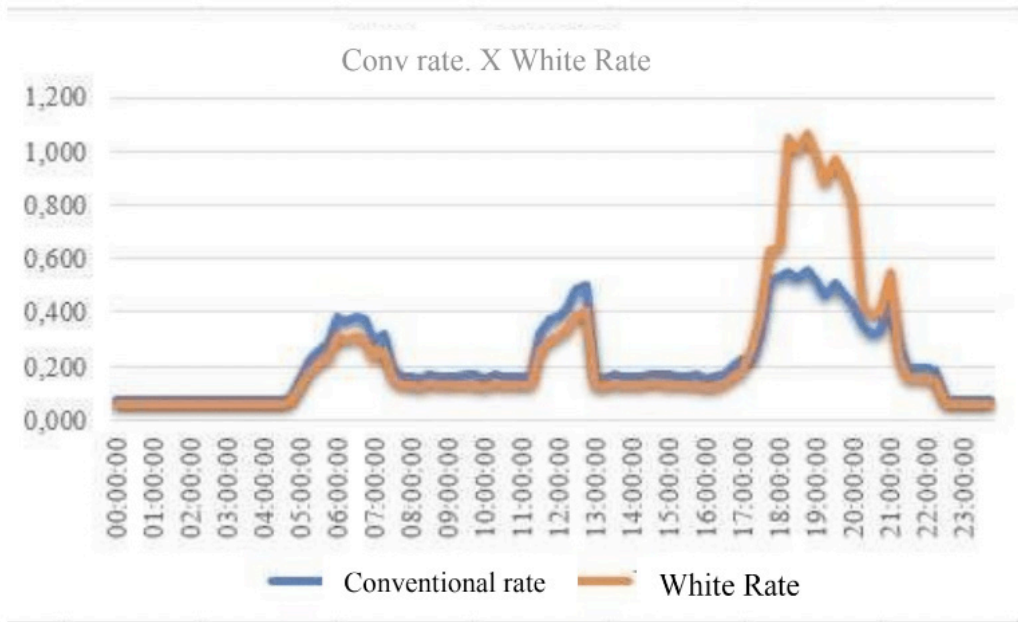


Table 4: Comparison between conventional tariff and white tariff - class A

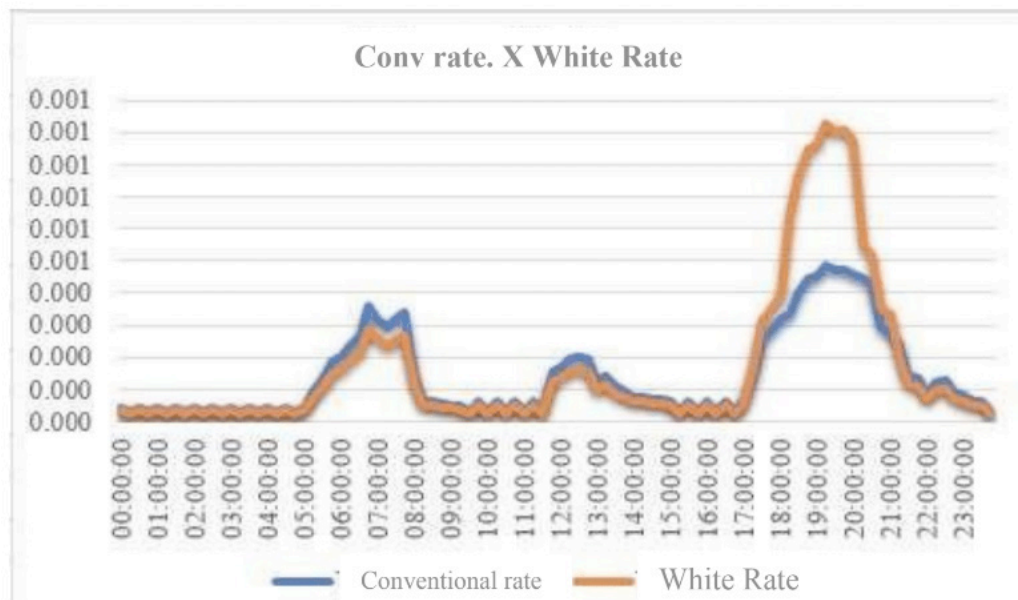


Table 5: Comparison between conventional fare and white fare - Class B

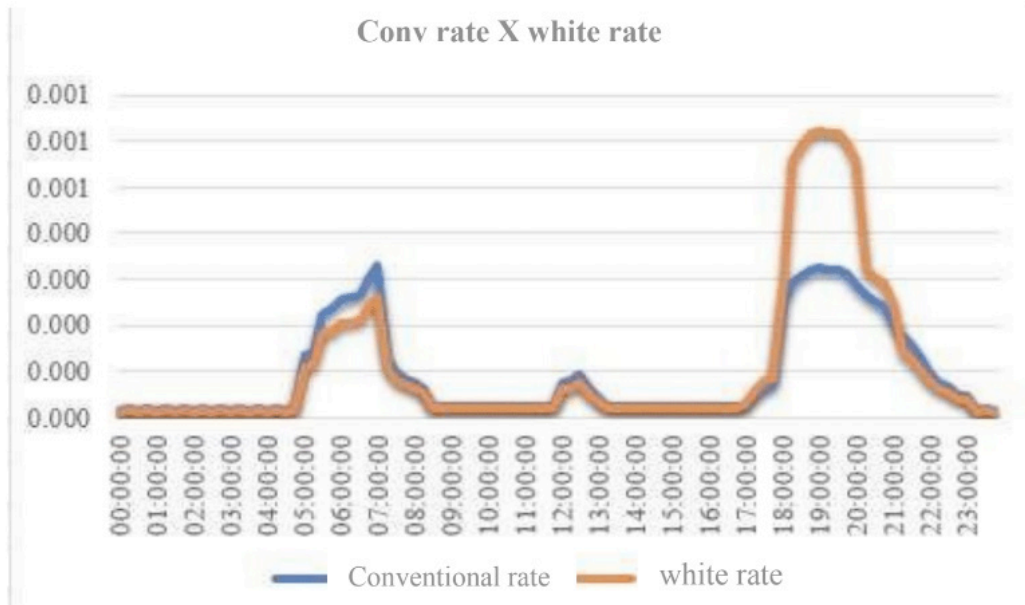


Table 6: Comparison between conventional tariff and white tariff - class C



Figure 2: Monthly invoice for conventional and white tariffs and simulation of reduction scenarios for white tariffs - class A

Class B

T. Conven	T.white	T.white 10%	T.white 20%	T.white 30%
410,181	475,529	464,613	442,660	440,333

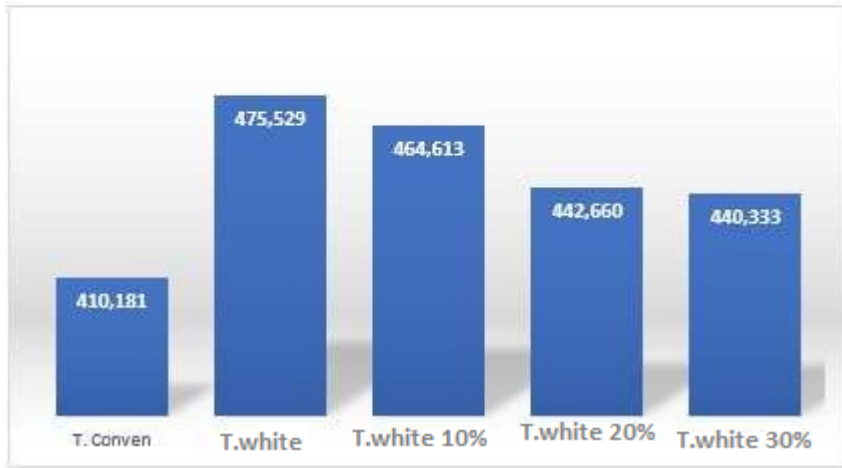


Figure 3: Monthly invoice for conventional and white tariffs and simulation of scenarios of reduction to white tariff - class B

Class C

T. conven	T.white	T.white 10%	T.white 20%	T.white 30%
265,888	313,259	301,949	296,307	287,994

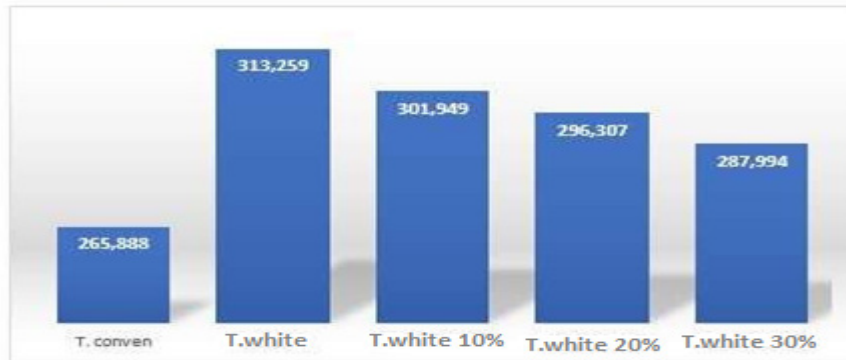


Figure 4: Monthly invoice for conventional and white tariffs and simulation of scenarios of reduction to white tariff - class B

SCATTER ANALYSIS TO FIND WHAT PERCENTAGE WOULD BE ACHIEVED FOR MAKE THE TRANSITION POSSIBLE

After the simulations carried out and the verification that even with 30% of allocation the change is unfeasible, an estimate was made to determine the allocation percentage to make the change possible for the three classes.

Table 7

From the equation found in the table, it was possible to estimate how much the class A consumer will have to allocate from their consumption so that the transition between the conventional tariff and the white tariff is viable, this value is 33%. The calculation steps are:

$$y = -134,31x + 682,08$$

$$637,911 > -134,31x + 682,08$$

$$x = 0,32886 \text{ ou } 0,33$$

$$y = -134,31 * (0,33) + 682,08$$

$$y = 637,677$$

Therefore, reducing 33% of consumption at peak hours and reallocating it to off-peak hours, we have that the white tariff bill will be R\$ 637,677 while the conventional tariff will be R\$ 637,911

Table 8

Unlike the first case, here we observed a need for a 51% change in consumption, which is a considerable change that can affect many day-to-day tasks, which makes this change difficult and perhaps definitely unfeasible for these consumers. The calculations to obtain the numerical values are:

$$y = -127,91x + 475$$

$$410,181 > -127,91x + 475$$

$$y = -127,91 * (0,51) + 475$$

$$y = 409,765$$

Therefore, reducing 51%, we have an invoice for the white tariff of R\$ 409,765 which is cheaper than the invoice for the conventional tariff in the amount of R\$ 410,181

Table 9

Finally, class C would be the most difficult to adopt measures to enable the exchange between the conventional tariff and the white tariff, as it would have to allocate 57% of its consumption at peak hours to off-peak hours, which could mean in major impacts on the routine of these consumers. The calculations to obtain the numbers are:

$$265,888 > -81,443x + 312,09$$

$$x = 0,5698 \text{ ou } 0,57$$

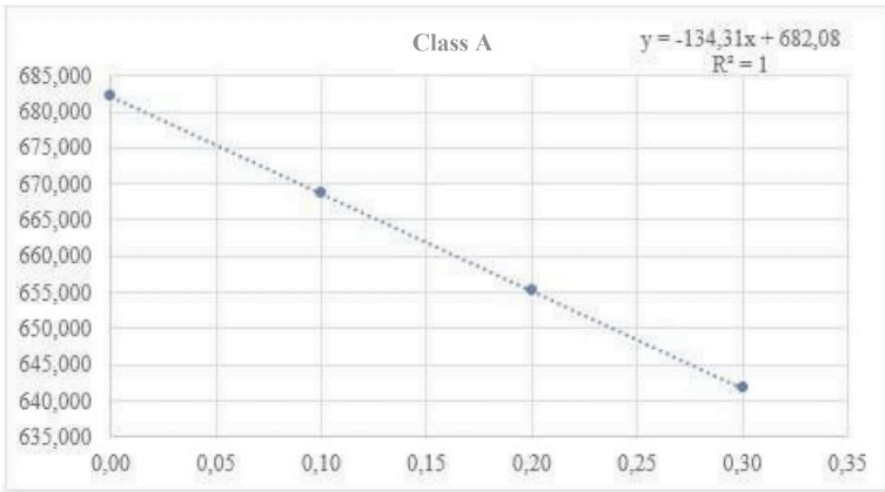
$$y = -81,443 * (0,57) + 312,09$$

$$y = 265,67$$

So, in conclusion, the bill through the white tariff when allocating 30% of consumption at peak hours to off-peak hours (R\$ 265.67) becomes cheaper than the conventional tariff bill (R\$ 265.888), however, it is noted that it is a tiny difference from one to the other, reaffirming that perhaps the effort required to make the permutation viable is not valid.

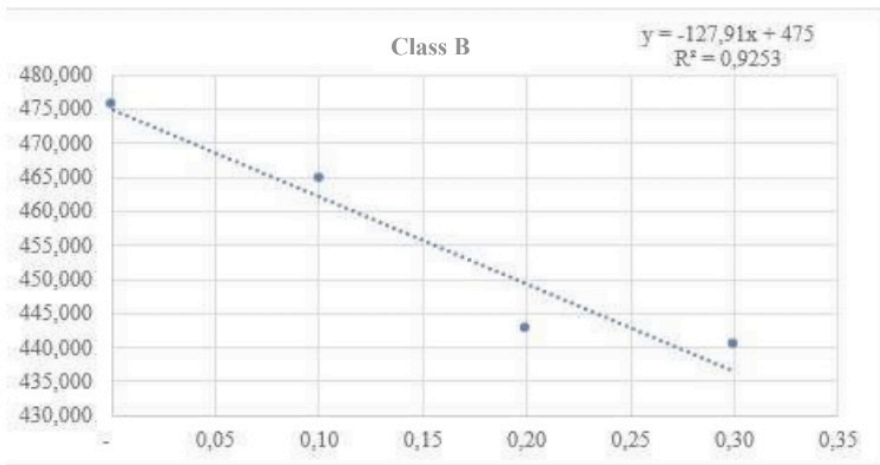
CONCLUSIONS

The present study obtained as a result that it would take a great effort to change the habits of consumption of electricity on weekdays by these consumers of the three classes, mainly of class C to change from the conventional tariff to the white tariff. A correlation was also seen in the general energy consumption with the value of the bill for the white tariff, since the greater the energy consumption by the consumer, the lower the percentage of consumption allocation to adopt a new tariff. So, finally, for the class A consumer, it becomes more advantageous to go for the white tariff than a class C consumer. However, it must be noted that the change in energy consumption habits can cause the change in fare type, as well as a change in fare can lead to a change in habits.



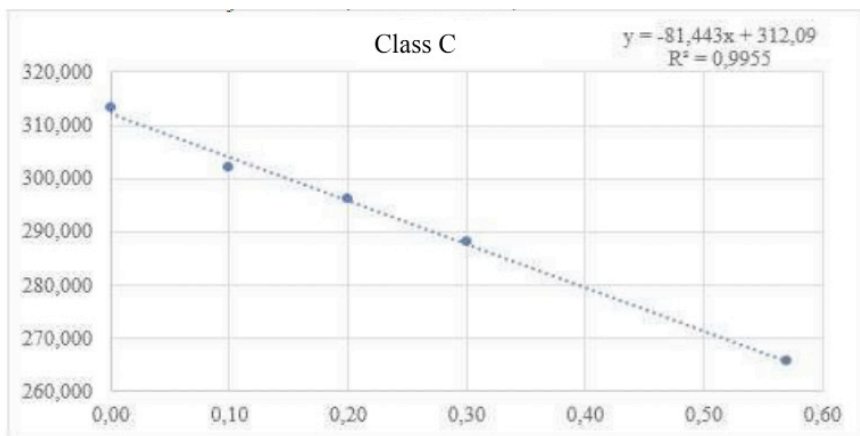
33%

Table 7: Linear correlation dispersion of the simulation for class A



51%

Table 8: Linear correlation dispersion of the simulation for class B



57%

Table 9: Linear correlation dispersion of the simulation for class C

REFERENCES

Andrade, T. & Lobão, W. (1997). Elasticidade-renda e preço da demanda residencial de energia elétrica no Brasil. Texto para discussão n. 489, RJ, IPEA.

ANEEL - A TARIFA DE ENERGIA ELÉTRICA; presente em <<https://www.aneel.gov.br/tarifas>>. Acesso em 30. Out. 2020.

Modiano, E. M. (1984). Elasticidade-renda e preço da demanda de energia elétrica no Brasil. Texto para discussão nº 68, Departamento de economia - PUC/RJ.

RESOLUÇÃO NORMATIVA Nº 414, DE 9 DE SETEMBRO DE 2010. Presente em: <<http://www2.aneel.gov.br/cedoc/ren2010414.pdf>>. Acesso 31. Out. 2020.