Economic Evaluation of a Time of Use Tariff for the Residential, Commercial, and Industrial Sector in Cortés, Honduras

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Abstract. The implementation of a time of use (TOU) tariff is a new stage, resulting from the modernization of the electric subsector in Honduras. The economic repercussions of a TOU tariff for the residential, commercial, and industrial sector are currently unknown. In this investigation, a TOU tariff will be compared to a fixed tariff through the calculation and comparison of electric bills, establishing in this way, which tariff is more convenient for the consumer. The electricity consumption data was obtained from two different circuits for each consumption sector. These were processed to know the monthly consumption. The prices for the TOU tariff were obtained by extrapolating the prices established in a 2016 tariff schedule for each of the tariff categories. The results have shown that the implementation of a TOU tariff would represent an average saving for the residential sector of 28.635% and for the industrial sector of 5.405% compared to a fixed tariff. On the other hand, in the commercial sector an average increase of 0.38% has been identified. This investigation aims to be used as a reference to get the consumers of each consumption sector to know the impact they would have on their bills with a TOU tariff.

1. Introduction
With the purpose of modernizing the electric subsector and helping the National Electric Energy Company (ENEE, by its Spanish acronym) to retrieve the costs of supplying electricity to the consumers, the time of use (TOU) tariff has been established through the Regulation of Tariffs. This new tariff modality consists of establishing different prices for electric energy depending on different periods of the day to reflect more efficiently the costs of electricity for each period [1]. However, this tariff modality has not been implemented yet. This type of tariff is part of demand response programs which can be an opportunity for the consumers to save on their bills and for the electric utility to shift energy consumption from peak demand hours to off-peak demand hours [2]. For example, in Guatemala, the Electric Company of Guatemala, S. A. (EEGSA, by its Spanish acronym) started applying a TOU tariff in 2019 and they assure a 10-12% of savings could take place for consumers under this tariff [3]. On the other hand, in Honduras, this economic impact (referring to the savings or increase in the consumers’ bills) is still unknown. Firstly, because this tariff has not been applied yet, and secondly because there have not been any studies regarding this matter in the country, at least not disclosed to the public.
Therefore, this investigation has the objective of determining the economic repercussions of the implementation of a TOU tariff and comparing them to a fixed tariff in order to know which one is more convenient (economically speaking) from the consumers’ perspective. First, a processing of the electric load profiles form the towns of Choloma, Puerto Cortés, and San Pedro Sula will be made. Second, the prices of the electric energy for the different time blocks will be determined. Next, the final amounts to pay on the bills for each sector with a TOU tariff and a fixed tariff will be calculated. Finally, a comparison and evaluation of the results to determine which tariff is more convenient for the consumers in each sector will be made. This investigation aims to help consumers in each sector know if they will have an increment or saving when the TOU tariff starts being applied. This, without them changing their energy consumption habits or shifting loads.

As mentioned before, Honduras lacks studies and investigations regarding this subject. However, some similar works from other countries can be listed. For example, García [4] made an analysis of the electricity prices for nine countries (one of them was Honduras) using a TOU tariff and the typical Costa Rican consumption curve. Figueiró et al [5] demonstrated the most likely consumptions to take place in the Brazilian residential sector with the application of a TOU tariff using the Monte Carlo Method. Cousins [6] explains the correct way to take advantage of the TOU tariff in the residential, commercial, and industrial sector.

Like these previous works, this investigation makes use of consumption data to apply a TOU tariff and measure its economic repercussions in the residential, commercial, and industrial sector. This article consists of four main parts. The first one is the background which explains the current situation in Honduras regarding the electric subsector. This first part will help understand why a TOU tariff is waiting to be applied. The second part consists of the breakdown of this new tariff modality and a brief description of the methodology used. How the prices were calculated for each period and which charges will be included on the simulated bill. On the other hand, the third part presents the results and relates the consumption of the electric load profiles with these results, whether these are positive or negative for the consumer. Lastly, the fourth part discusses the results and gives a short explanation on how these can be taken advantage of. It also states some of the limitations encountered while developing this investigation and a few recommendations.

2. Background

It is important to know the context of why this new tariff is waiting to be applied, why it was established in the first place, and how it is backed up by the legal framework in Honduras. Currently, the energy sector is undergoing a reform process in which new entities have been created and roles for government institutions have been redefined. Technological advances have made it necessary to open up the electricity market in order to deregulate this sector and implement competitive rates that are established by an independent regulatory body, which is why the Electric Energy Regulatory Commission (CREE, by its Spanish acronym) was created. The CREE is now in charge of establishing regulations and supervise and manage the electric subsector.

On the other hand, ENEE is the company that manages transmission and distribution in Honduras. It continues to find itself in a precarious financial situation that has existed ever since the 1990s and has only aggravated over time despite the multiple attempts of the State to recover its finances. In 2017, the Energy Architecture Performance Index (EAPI) placed Honduras in position 82 out of 127, the lowest position among Central American countries [7]. This means that Honduras is the least efficient country with respect to the energy system in the region. According to the World Bank, Honduras has Gross Domestic Product (GDP) growth rates above the Central American average. In 2017 it was 4.8%, in 2018 it was 3.7% and in 2019 it was 2.7% [8]. It can be said then, that to maintain a GDP growth of this magnitude, Honduras needs much more energy than the other countries in the region due to the inefficiency of the entire energy sector. This is a result of the whole electric subsector being in a risky situation due to ENEE’s bad finances and the high percentage of losses in the transmission and distribution networks. The International Monetary Fund (IMF) identifies a series of factors that have contributed to the deterioration of the company’s finances. Among them are technical and non-technical losses that have not diminished, energy purchases, approval of tariffs below real costs and the constant payment exemptions to various consumption sectors [9]. As for the legal framework, in
2014 it established the application of tariffs that will help reflect the costs of generation, transmission, and distribution. But it was not until 2019 that a regulation was created for the application of these type of tariffs. It says that for consumptions greater than 500 kWh the TOU tariff will be applied and for less than this, the incremental blocks tariff will be used [10]. However, these are not being applied yet. At the same time, no studies have been published on the economic impact that these new types of tariffs would have on the consumption sectors. Leaving consumers waiting to know these impacts. As part of the legal framework, a provisional regulation was prepared by the CREE in 2016 for the implementation of TOU tariffs [11]. This and the Regulation of Tariffs published in 2019, also done by the CREE, can be compared since they serve the same purpose, which is to establish this tariff. However, many differences can be observed between these two. Based on the provisional regulation, a tariff schedule was prepared for 2016 [12] but it was never implemented. This was the schedule used to extrapolate prices to the year 2020.

3. Composition of the TOU tariff and methodology used

The before mentioned Regulation of Tariffs has established that the TOU tariff should include an electric energy rate and a power rate that all tariff categories should be charged with. To determine the electric energy prices in the different periods for each sector on weekdays, Saturdays, and Sundays; the prices of the 2016 tariff schedule were extrapolated to 2020. It was decided that using this method was the best option since these prices have not been updated since then. The 2016 tariff schedule was used to extrapolate prices, since only the CREE handles the specific data and methodology used to establish a price for electricity. The calculations were originally done in the Honduran currency, which is Lempiras, but the final results were exchanged to dollars. To calculate the price of the electric energy for the peak period, equation 1 was used. Next, equation 2 was used to obtain the price for an intermediate period. Last, to calculate the price of the valley period, equation 3 was used. Since the electric load profiles had data loss in some months, the ones with the least data loss were chosen for this analysis and these vary according to each circuit. Therefore, this calculation of the prices was done for the months of April, June, and July of 2020.

\[
\begin{align*}
\text{Peak rate for 2020} &= \frac{(\text{Fixed rate for 2020}) \cdot (\text{Peak rate for 2016})}{\text{Fixed rate for 2016}} \quad (1) \\
\text{Intermediate rate for 2020} &= \frac{(\text{Peak rate for 2020}) \cdot (\text{Intermediate rate for 2016})}{\text{Peak rate for 2016}} \quad (2) \\
\text{Valley rate for 2020} &= \frac{(\text{Intermediate rate for 2020}) \cdot (\text{Valley rate for 2016})}{\text{Intermediate rate for 2016}} \quad (3)
\end{align*}
\]

The maximum power of the respective month of each circuit was used for the bill. This charge was only applied for Medium Voltage even though the Regulation of Tariffs says that the residential tariff category (residential sector is charged in this category) should also pay a power charge. Currently there is no power rate for this category, therefore the price could not be established. The commercialization charge, also called fixed charge, is established by the CREE and is the same for the January-April, May-June, and July-September 2020 tariff schedules. As for the regulation charge that was obtained in each bill, this one represents 0.25% of the subtotal of the bill. [13]

After calculating the final amount for the electric bills with both tariffs, equation 4 was used to determine the percentage of difference of the TOU tariff with respect to the fixed tariff.

\[
\text{difference} = \frac{(T_f - T_T)}{T_f} \quad (4)
\]

Where: difference (%) = percentage of difference of the TOU tariff with respect to the fixed tariff.

\(T_f\) ($)= final amount of the electric bill with fixed tariff.

\(T_T\) ($)= final amount of the electric bill with TOU tariff.
4. Results

4.1. TOU tariff rates for each sector
For residential, different months were analyzed for each circuit. Therefore, the prices per time of use for two different months are presented in table 1.

**Table 1. Calculated TOU rates for 2020 for the residential sector.**

| Month | Price of the tariff schedule for 2020 ($/kWh) | Prices per time of use ($/kWh) |
|-------|---------------------------------------------|---------------------------------|
| April | Less than 50 kWh: 0.16 Greater than 50 kWh: 0.21 | Peak: 0.23 Intermediate: 0.12 Valley: 0.10 |
| June  | Less than 50 kWh: 0.14 Greater than 50 kWh: 0.18 | Peak: 0.19 Intermediate: 0.10 Valley: 0.09 |

The commercial and industrial sectors analyzed are in the medium voltage tariff category. The sample of the commercial sector that was analyzed is in this tariff category because it is mostly composed of offices. As with the load profiles for the residential sector, different months were analyzed for these sectors. Therefore, the prices per time of use for three different months are presented in table 2 for this tariff category.

**Table 2. Calculated TOU rates for 2020 for the commercial and industrial sector.**

| Month | Price of the tariff schedule for 2020 ($/kWh) | Prices per time of use ($/kWh) |
|-------|---------------------------------------------|---------------------------------|
| April | 0.14                                        | Peak: 0.20 Intermediate: 0.11 Valley: 0.09 |
| June  | 0.11                                        | Peak: 0.16 Intermediate: 0.08 Valley: 0.07 |
| July  | 0.10                                        | Peak: 0.15 Intermediate: 0.08 Valley: 0.07 |

4.2. Comparison and evaluation of consumption by applying both electricity tariffs
For the display of the next results, it is important to have in mind that the electric load profiles used represent whole circuits. For the residential sector, the application of the time of use tariff would be a good opportunity for savings as shown in table 3. In the first residential circuit there is a saving of 28.98%, which represents about $ 50,266.66 compared to a fixed tariff. For the second residential circuit the savings were 28.29% which represents approximately $ 91,916.12 less than with a fixed tariff. These are significant numbers considering that there was no change in consumption patterns but if there were a load management there would be greater savings.

As for the results obtained for the commercial sector circuits, it can be seen that in the difference column in table 3 the values are negative, this is due to the fact that there were no savings when
implementing the time of use tariff. In other words, 0.52% ($2,706.41) and 0.24% ($286.35) more is being paid with the TOU tariff than with the fixed rate. Meanwhile in the first industrial circuit, table 3 shows there are savings of 3.12%, which is about $3,699.52 less than with a fixed tariff. For the second circuit the savings were approximately $26,305.53 which represents 7.69% compared to a fixed tariff.

Table 3. Final amounts of bills with TOU tariff and fixed rate.

| Evaluated sector                  | Monthly consumption [kWh] | Fixed rate bill [$]  | Time of use bill [$]  | Difference [%] |
|-----------------------------------|---------------------------|----------------------|-----------------------|----------------|
| Residential (ALAMOS BER-L248)     | 773,760                   | 173,414.08           | 123,147.43            | 28.98%         |
| Residential (MONTERREY CHM-L216)  | 1,450,122                 | 324,847.89           | 232,931.77            | 28.29%         |
| Commercial (EXTRACTORES_FUENTES BER-L248) | 3,017,720                | 510,976.94           | 513,683.35            | -0.52%         |
| Commercial (LA ISLA TSZ-L224)     | 625,440                   | 116,965.42           | 117,251.76            | -0.24%         |
| Industrial (INVEMAY)              | 668,830.97                | 118,439.32           | 114,739.80            | 3.12%          |
| Industrial (LVI-22L28)            | 2,682,428                 | 342,071.46           | 315,765.93            | 7.69%          |

4.2.1. Residential sector. For the ALAMOS BER-L248 circuit from 10:00 pm to 2:00 am there is a large amount of consumption as can be seen in figure 1. As for the MONTERREY CHM-L216 circuit, this one had more loads connected to it than the previous circuit, so its consumption is almost the double. The consumption of this second circuit presents abrupt variations of peaks and valleys between working days. On the other hand, the consumption for Saturdays and Sundays is quite similar.

Figure 1. Hourly electric load profiles for the residential sector circuits.

Unlike the other sectors, in the residential sector 67.5% of consumption occurs between intermediate and valley hours without even shifting loads. For this reason, they are the sector that received the most savings from the TOU tariff. The circuits of this sector had an average saving with the TOU tariff of 28.635% ($71,091.39).
4.2.2. Commercial sector. In the month analyzed for EXTRACTORES_FUENTES BER-L248, most of the consumption was made by office buildings since the other places were closed to the public due to the COVID-19 pandemic. As for LA ISLA TSZ L-224, during the processing of the monthly electric load profile, time intervals in which the energy was zero were observed for several days. This situation may be due to power outages, either from maintenance or from a failure. In figure 2 the EXTRACTORES_FUENTES BER-L248 curve is quite uniform since office buildings work throughout the week and all day long. However, due to this, 37% of their monthly consumption occurs during peak hours. In the circuit LA ISLA TSZ L-224 90% of the consumption was made between intermediate and peak hours.

In this sector, the average increase compared to the fixed tariff was 0.38% ($1,496.38). This is due to the fact that, as explained above, a good percentage of both of the consumptions of the circuits take place during peak hours, which is when the TOU tariff is more expensive.

4.2.3. Industrial sector. It can be inferred that INVEMA has a photovoltaic system since in the load profiles in figure 3 a valley is visualized in the hours where there is usually a greater production for a photovoltaic system. It can also be inferred that they work 24 hours a day. However, on Saturdays and Sundays the consumption lowers. As for LVI-22L28, for working days it can be observed that the consumption is within a certain range, but there are several peaks that show the diversity of loads.

In INVEMA, a saving is perceived in the bill with TOU tariff because 69% of the consumption is made during intermediate and valley hours. As in the case of INVEMA the consumption of LVI-22L28 is reduced for Saturdays and Sundays. However, LVI-22L28 presents a greater saving with the TOU tariff than INVEMA. This is because 51% of its consumption is during in valley hours. For this sector, the average saving with the TOU tariff was 5.405% ($15,002.52).
Figure 3. Hourly electric load profiles for the industrial sector circuits.

5. Discussion

In the residential sector, for the MONTERREY CHM-L216 circuit, the month of April 2020 was used and for the ALAMOS BER L-248 circuit the month of June 2020 was used. Therefore, there is a difference in prices. This difference is approximately of 15.36%. This means that it is 15.36% more expensive in April than in June. This is due to the fact that the April 2020 rates were more expensive.

In the commercial sector the same thing happened. For the EXTRACTORES_FUENTES BER-L1248 circuit the month of June 2020 was used and for LA ISLA TSZ L-224 the month of April 2020 was used instead. In this last month, the prices with TOU tariff are 20.20% higher than in the month of June 2020. The percentages differ since the residential sector is in the residential tariff category and the commercial sector in the medium voltage category. As for the industrial sector, since both circuits were analyzed in the same month, there is no difference between the prices.

Although the residential sector has already seen positive results with the implementation of this tariff, there is still the possibility that consumers may move certain loads to valley or intermediate hours or change their consumption habits. This increases the possibility of savings since the hourly rate is designed to reduce consumers' bills if they regulate their loads during the day. The commercial sector has less flexibility when moving their loads. This happens because consumers in this sector follow a schedule, therefore, they maintain a fixed consumption. As mentioned in the results, these circuits carried out most of their consumption during peak and intermediate hours. Therefore, in order to reduce the percentage of increase in the bill, it would be necessary to implement energy efficiency programs since there is an inelasticity in their consumption. In the case of INVEMA, considering that on Saturdays and Sundays the range of consumption decreases. And that currently 28% of the consumption is done in valley hours, some processes that are carried out on weekdays could be postponed or displaced to Saturday and Sunday to increase this percentage (since these days have more intermediate and valley hours) and therefore the savings. On the other hand, LVI-22L28 already makes 51% of consumption in valley hours. So, if there were no longer the possibility of moving loads or processes to the intermediate and valley hours, its possibility to perceive a saving higher than 7.69% would be by means of energy efficiency.

This research was undertaken at a time when several limitations took place. These include the COVID-19 pandemic, as consumptions may have been affected by the lockdown. For the residential sector it increased, as most users remained in their homes full time. For the commercial and industrial sector, consumption may have decreased since there was only a partial opening in Honduras during the months analyzed. Another limitation is the loss of data in the electric load profiles: LA ISLA TSZ L-224 and LVI-22L28. This may have affected the results since it clearly affects the consumption and therefore, the amount to be paid in the bills. From the last two limitations, a new limitation arises due to the fact that in some of the places that make up the circuits there was no consumption since industry and commerce were only partially open. Also, in some months there was a large amount of data loss. Therefore, different months had to be selected for the analysis. Last, load profiles represent circuits
that are made up of several grid users, but this is only a limitation because there were users in the commercial sector who did not belong there.

On the other hand, based on the results obtained, it is advisable to implement the TOU tariff in the residential and industrial sector. The application of this has proved to be economically convenient even without the shifting of loads. At the same time, for this same reason it is very likely that consumers will be willing to accept this new tariff modality. At the same time, it is suggested to accompany the application of this tariff with consumer education programs based on energy efficiency. This would apply to all consumer sectors but should put a special emphasis on the commercial sector. This would be done so that savings can be increased by requiring less electricity from the grid. At the same time, it is suggested that the TOU tariff may be optional for consumers in the commercial sector if it turns out that even with energy efficiency programs it is not an attractive option for certain consumers in that sector.

6. Conclusions
The investigation presented has helped determine which tariff is more convenient from the consumers’ perspective, a TOU or fixed tariff. The results were the following:

- The TOU tariff has proven to be beneficial for two of the three sectors analyzed. For the residential sector, it has resulted in an average saving of 28.635% ($71,091.39). However, for the commercial sector this tariff has shown an average increase of 0.38% ($1,496.38) compared to the fixed tariff. As in the residential sector, in the industrial sector this tariff has resulted in an average saving of 5.405% ($15,002.52).
- Therefore, for the residential and industrial sector, the most affordable tariff has been the TOU tariff. Meanwhile in the commercial sector, the fixed tariff showed better results.

Understanding the results is important when implementing the TOU tariff.

The results can be analyzed from two perspectives, that of the consumer and that of the entity in charge of designing the tariff (regulatory or distribution entity). In the case of the consumer, they can be more flexible at the time of accepting the tariff since in the residential and industrial sector there is an opportunity for savings. If consumers are encouraged by these savings, they could reduce their demand, thus reducing the need to hire more power. As for the entity in charge of designing the tariff, knowing that only two of the three sectors perceive a saving in their electricity bill, they must adjust it. So that the tariff can be applied equally in all three sectors and with the satisfaction of the consumers.

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