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Estimation of electrical energy consumed during the construction of residential houses in San Pedro Sula, Cortés, Honduras

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Abstract: There are several technical and non-technical losses in the transmission and consumption of electrical energy in Honduras. Currently, the electrical energy consumed in the construction of residential houses is not charged. It is necessary to estimate the amount of electricity consumed at the time of construction of residential houses in order to be able to charge for it. In this research, permits to install meters and the collection of national data on construction areas were carried out. The installation of CL100 FM2 meters in each house. And from the data collected, a formula was generated using a scatter plot that related electrical energy consumption to square meters built. This formula was applied locally and nationally to calculate the electrical energy consumed and not billed. The research also revealed the millions that ENEE did not receive because the meters were not installed. This research will serve to estimate the calculation of the electric energy to be used for the construction of a residential house and thus be able to charge at the time of obtaining a construction permit.

1 Introduction

According to ENEE reports, it is known that 38% of the energy generated is not billed, either due to technical or non-technical losses [1]. In the year 2022, ENEE's annual losses amount to 20,788.7 million lempiras, which is estimated at 8,472.6 million dollars, of which technical and non-technical losses represent 38% in the year 2022. According to the Secretary of Energy, Erick Tejada, "We find this company with a historical debt of 75 billion lempiras, which represents 10.5% of the gross domestic product, is 50% of the government's fiscal deficit and represents the main hole of the State [2].

G. Gonzalez and L. Figueroa (2006), analyzed the non-technical losses of C.A. and showed the techniques and tools used by the company ELEVAL, among the tools that stand out are control devices and detection of alterations to the meters, among the most outstanding are those known as totalizing meters [6]. U. H. Bezerra, T. M. Soares, J. P. A. Vieira, M. E. L. Tostes, A. R. R. Manito J. C. H. Paye (2018) present what is an Equivalent

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Operating Impedance which is a new concept for the analysis of technical and non-technical distribution losses [12], this analysis serves to effectively calculate what are the technical and non-technical losses in medium and low voltage distributions. Adding the research of

N.H.V.T.N. Nanayakkara; C.D. Udawattha and R.U. Halwatura where they mention the costs of the construction of residential houses, where it is also mentioned that the electrical energy used for the construction of houses is not so high if we compare it to the other expenses that exist such as labor, materials and construction permits [9] [10] [11].

Similar to the past researches that sought to reduce non-technical and technical losses, or in the case of the research that looked at the costs of home construction, this research will focus on determining the electrical energy required for the construction of residential homes [15]. The methodology to be employed will involve obtaining permits and data, installing the CL100 FM2 single-phase meter, recording the electrical energy consumption of both houses on a weekly basis, to determine the electrical energy consumption according to their construction phases [7].

After registering all the required electric energy, a formula will be created to estimate the electric energy required at the moment of building a residential house, according to the amount of square meters of the house to be built, in the same way the formula will be used to determine the amount of electric energy that was not billed in the year 2022 in San Pedro Sula and in Honduras [8].

2 Context

Due to the lack of investment in electric energy distribution, the National Electric Energy Company (ENEE) allowed electric energy losses to increase to a percentage that in my opinion is high, since having losses of 38% means that ENEE continues to get into debt and from there they have a problem for their sustainability. According to ECLAC, in 2013 Honduras presented the highest level of losses in Central America, reaching 31.2%; Costa Rica, on the other hand, presented the lowest percentage of losses with 11.6%, and the average for the region was 17.1%. [4].

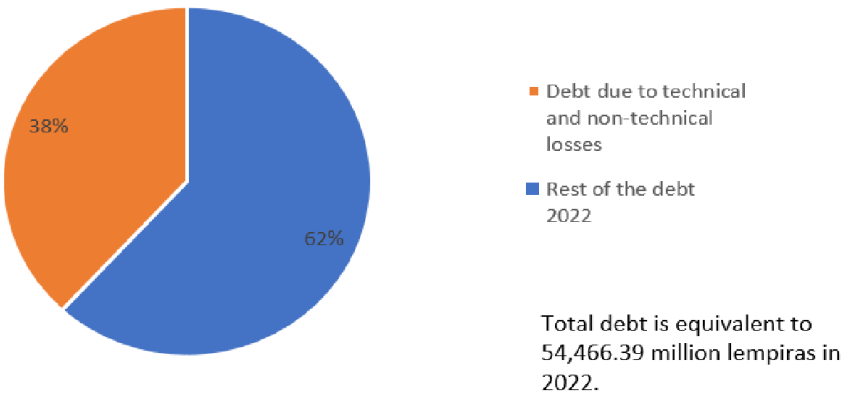

Fig. 1. ENEE total debt 2022

Source: Own elaboration based on [3].

In the year 2022, ENEE's annual losses amount to 20,788.7 million lempiras, which is estimated at 8,472.6 million dollars, of which technical and non-technical losses represent 38% in the year 2022. According to the Secretary of Energy, Erick Tejada, "We found this company with a historical debt of 75 billion lempiras, which represents 10.5% of the gross domestic product, 50% of the government's fiscal deficit and represents the main hole of the State [5]. Within this percentage of non-technical and technical losses are the electricity not billed for the construction of houses.

3 Methodology

The research approach is quantitative, aimed at determining the amount of electrical energy consumed during the construction of houses in San Pedro Sula, Honduras. The variables of study are the square meters of construction and the consumption of electrical energy in the construction of houses. To carry out the research, two main instruments were used: a single-phase electric energy meter called CL100 FM2 and an Excel spreadsheet.

The meter was installed prior to the start of house construction and was used to measure electricity consumption throughout the process. The methodology involved obtaining permits and data, which was challenging due to the reluctance of some builders to cooperate. Finally, the necessary permits were obtained to measure two houses, house number one has a construction area of 142.8234 square meters and house number two has a construction area of 110 square meters. In addition, information on square meters of construction was requested nationwide through the Institute for Access to Public Information (Instituto de Acceso a la Información Pública) [13].

Electrical energy measurements began in March-April and were taken weekly in one of the houses, allowing detailed monitoring of consumption at each stage of construction. Information on house plans was limited for privacy reasons. Data obtained from the meters were continuously recorded, and a civil engineer with construction experience was involved to better understand the construction process.

The data analysis was executed using Excel, generating a scatter plot and a formula to estimate the electrical energy consumption per square meter built in San Pedro Sula and Honduras. This methodology would allow for an automatic update in the graph as more house data is obtained in future research.

Similarly, the formula can be used to estimate the amount of money that was not billed in the year 2022 by estimating the amount of electricity used and then multiplying it by the low voltage tariff.

4 Results and Analysis

In this section we will analyze the results of the amount of kWh needed for the construction of the houses. We will create a formula and estimate the amount of electricity that was used in the year 2022 in Honduras and thus calculate the amount of money that was not billed in that year.

First, we will look at the amount of electrical energy used in house number one, in which we were able to calculate the electrical energy consumed for each phase of construction [14].

4.1 Electrical Energy consumed by construction phases in house number one

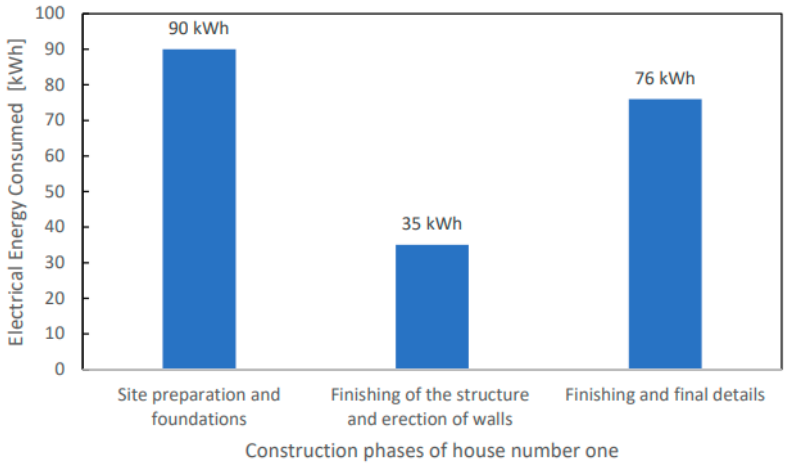

Fig. 2. Electrical Energy consumed by construction phases

Source: Own elaboration

Phase one was the phase that consumed the most electrical energy, as can be seen in Figure 2. In this stage, more energy was consumed because the land where this house was built was uneven, so it was necessary to raise the foundation with steel beams, which is why the welding machine was used more. This tool consumes a high amount of electrical energy compared to the other tools used in the construction of houses; this stage lasted six weeks. In stage two, only 35 kWh were consumed, since this stage only involved the erection of walls and the construction of the second-floor slab; this stage lasted seven weeks. And to finish the construction of the house in phase three, 76 kWh were consumed, in this phase the details and finishes of both floor and walls of division inside the house were finalized, this phase lasted eight weeks. This phase was the most time consuming since they are smaller details that require more time. In total, the construction of house number one used 201 kWh in a period of 5 to 6 months.

In Figure 3, as can be seen, house number one consumed more electrical energy for its construction because it has more square meters of construction. In the same way we can analyze that more electrical energy was consumed in this house due to its structure and foundation condition, since in house number one the welder was used more for the lifting of the structure due to the slope of the land. We can also calculate with the data obtained the amount of kWh needed for each square meter of construction.

4.2 Electricity consumption per household

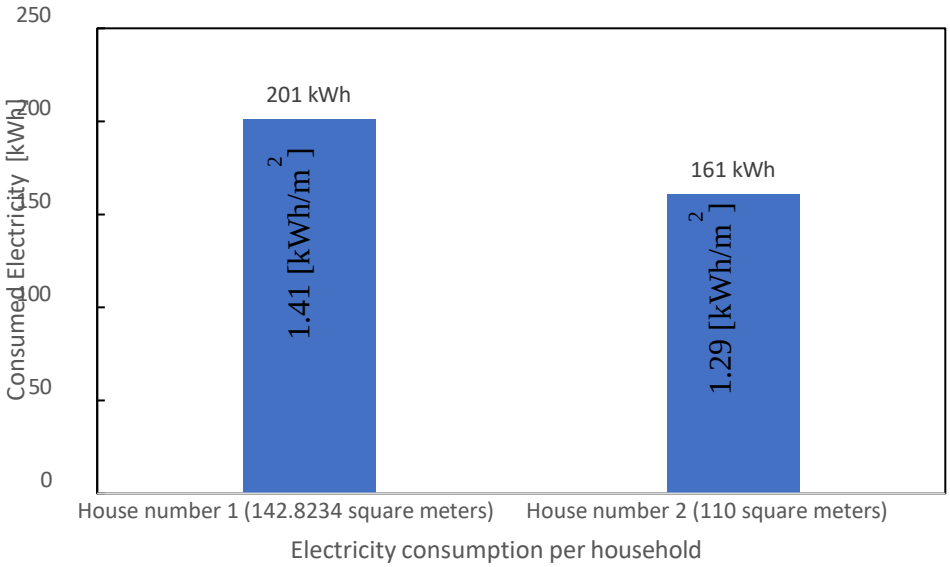

Fig. 3. Electricity consumption per household

Source: Own elaboration

4.3 Scatter plot and formula obtained

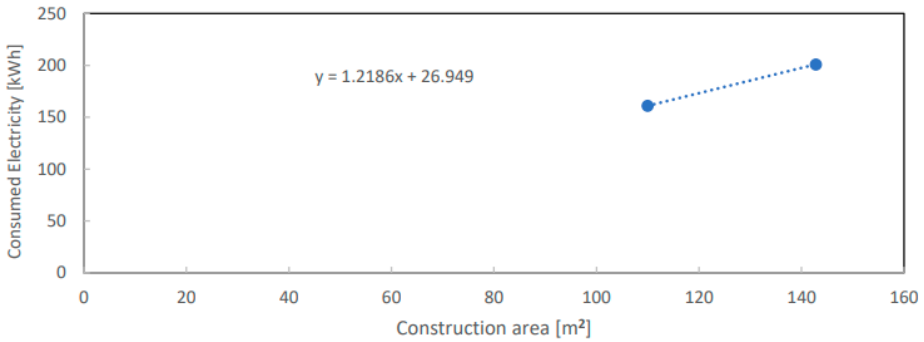

Fig. 4. Scatter plot

Source: Own elaboration

In the previous graph you can see what a formula is, which has as a result y = 1.2186 (x) + 26.949. This base formula will help us to calculate how much electrical energy was consumed in San Pedro Sula and Honduras. The next step will be to estimate the electrical energy consumed in San Pedro Sula and Honduras based on the square meters of construction in San Pedro Sula and Honduras. We know that in San Pedro Sula there are

319,243.80 square meters of construction and nationwide there are 1,520,600 square meters. Knowing the square meters, we would only have to insert the data in the formula to know the electric energy consumed and not billed. Then, based on the results, we will calculate how much money was not billed because the meters were not installed before construction began. Based on that result we will calculate the percentage of electric energy that was consumed and not billed in the year 2022 and that turned out to be attributed to technical and non-technical losses.

4.4 Electricity consumed in the year 2022

By applying the obtained formula of y= 1.2186 (x) + 26.949, with the data from San Pedro Sula, the result of unbilled kWh consumed is 389,057.44 kWh in San Pedro Sula alone. This was achieved by replacing the x in the formula with the number of square meters of construction in San Pedro Sula. In terms of money, in the city alone, L. 2,267,232.25 or its equivalent in dollars of $92,502.34 was not billed. At the national level, approximately 1,853,030.11 kWh were not billed, which is equivalent to

L. 10,798,532.96 or its equivalent in dollars of $ 440,576.62.

The electricity consumption in Honduras for the whole year 2022 in the residential sector was 2,802,718.1 MWh, of which 38% was registered as technical and non-technical losses. To make a more exact comparison we will use the amount of money that was billed in the residential sector in the whole year 2022, since the exact amount in the San Pedro Sula sector is not mentioned. In the year 2022, 15,719.75 million lempiras were billed in the residential sector alone, according to information from ENEE's statistical bulletin for the year 2022. Based on this value and knowing that at the national level 10.80 million lempiras were not billed approximately or $ 440,576.62 which would represent 0.70% of what was billed at the national level. We may think that this is not so much but considering the current state of ENEE's debt, it is not possible that all this electric energy is not being billed.

The amount of unbilled electric energy that was used for the construction of residential houses, compared to the electric energy that was lost and accounted for as technical and non-technical losses at the national level. The result was that 0.2% of this unbilled electric energy is due to the fact that there are no devices to measure the electric energy at the time of starting the construction of the residential

houses. As a final point we can mention that, for each square meter built in the residential sector, based on the results of the two houses, 1.35 kWh of electrical energy is required for the construction of each square meter.

5 Conclusions

A formula that estimates the electrical energy required for the construction of a house. Measurements of two residential houses in Honduras allowed us to estimate and create a formula that, according to the square meters of construction of the houses, to estimate how much energy was or will be required at the time of construction. We also used this formula to determine how much electricity was not billed in San Pedro Sula and in Honduras in the year 2022. The most important results of this thesis are the following:

1. The amount of square meters of construction in San Pedro Sula in 2022 was 319,243.80 m2.
2. The formula generated with the scatter plot was y= 1.2186 (x) + 26.949.
3. Applying the formula we obtained as a result that the total electrical energy used in San Pedro Sula was of 389,057.44 kWh and in Honduras in the year 2022 was 1,853,030.11 kWh.

4. In San Pedro Sula alone, a total of L. 2,267,232.25 or its equivalent in dollars of $92,502.34 kWh was not billed. At the national level, approximately L. 10,798,532.96 or its equivalent in dollars of $ 440,576.62 was not billed.

The main limitation of this work was the number of houses that could be obtained to install the meters and record the amount of electricity required for the construction of the houses. Therefore, the results are the estimation of these two particular houses, so in order to obtain a better formula, a greater number of houses would be needed to create a more accurate formula.

Despite this limitation, the consumption of these houses was successfully recorded and in one of them it was possible to determine the amount of electricity required for each phase of construction. This research can be used to be able to charge the electric energy that will be consumed in the construction of the houses at the time of obtaining their respective construction permits.

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