Spatial distribution of Honduran electricity demand

Gabriela Munguía[1], *Héctor* Villatoro[1]

[1]Faculty of engineering, Universidad Tecnológica Centroamericana (UNITEC), San Pedro Sula, Honduras

Abstract. As energy demand rises and fossil fuel reserves become scarcer, energy planning grows to be necessary to every country including Honduras. The mapping of electricity consumption in Honduras through data visualization tools as Tableau, proposed in this paper, is a significant step toward the goal of creating instruments that increase energy planning. This instrument provides relevant information of the electricity demand behaviour: it was discovered that only 18 municipalities from the total of 259 municipalities studied consumed 80% of the electrical resource. It was also found the close-fitting relationship between Human Development Index (HDI) and Electricity Consumption per capita concluding that electrical consumption has great impact in the development of municipalities in Honduras and for this reason is necessary to change the actual context in which this resource is distributed unequally in the national territory.

1 Introduction

The decentralized energy systems are achieving acceptance in the electricity subsector of Honduras. If the government encourages the adoption of decentralized energy systems based on renewable sources and provides favourable circumstances for private investment in the nation [1] this type of energy generation with the many advantages, it represents (reduction of losses in the distribution network and reduction in reactive power loss [2]) should grow exponentially in a few years.

Decentralized and distributed energy systems which are energy systems that produce electricity close to the demand [3], such as some photovoltaic installations at residential and commercial level, consider an important factor: the location of the electrical demand.

Nowadays there is no tool in Honduras that locates the electrical demand. The mapping of electricity consumption in Honduras is a significant step toward the goal of creating instruments that increase energy planning. However, when studying the electricity consumption geographically in Honduras the disaggregation level reaches only a division of the country in three main regions: Atlantic Littoral Region, Central South Region, and North-western Region as shown in Figure 1.

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

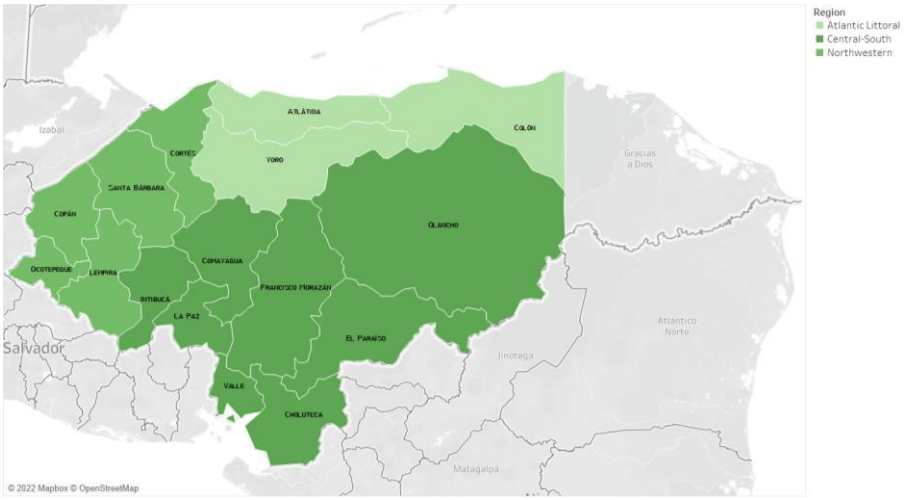

Fig. 1. Geographic location of electrical demand regions in Honduras
Source: Own elaboration based on information of Operador del Sistema (2022) [4]

At this level of disaggregation, the region with the most of electrical energy consumption in the last years (2007-2020) is the North-western Region, being accountable of 50% of the consumption in Honduras by 2020. The second region, the Central- South, does not vary that much in comparison with North-western, being responsible for 40% of consumption by 2020. In the Atlantic Littoral Region, the consumption varies between 9% and 10% through the lapse of time from 2017 to 2020. [4]

There are other articles that evaluate diverse options of data visualization for electrical demand in Honduras. Flores (2021) [5] exposed the electricity demand nationally per sector year by year, as well the generation of electricity in the country. Like the previously mentioned study, this article also evaluates the electricity demand but with a greater level of disaggregation. Electricity consumption at municipal level and the behaviour of the sectors within each municipality is studied in this article.

This disaggregation is important because the access to electrical consumption information at municipal level empowers decision-makers such as municipal mayors to track the electrical demand as a step to start the process of energy planning. An energy planning that should focus on decentralized systems based on local energy sources which diversifies the resources and increases the self-sufficiency of a region.

In Honduras, distributed energy systems are already gaining track. In San Pedro Sula (municipality of the department of Cortés), more than 40 different shops have photovoltaic systems to meet a part of their electricity demand. In 2018, the installed power of photovoltaic systems in San Pedro Sula was 8.493 MW, representing an increase in installed capacity of 100% compared to 2017 [6]. San Pedro Sula is establishing a model for the rest of the municipalities.

The installation of photovoltaic systems is not just a great option for the commercial sector, they are an alternative to help alleviate the future demands of the residential sector that each year reflect a 20% growth [6]. The capacity of distributed generation needed near the demand for each municipality could be estimated with the assistance of the geographical tool developed through this research in Tableau because it allows to explore the electricity consumption for each municipality and the consumption for each sector within the municipality.

The rest of this article is divided into Methodology, Results and Conclusions. In section two, which is Methodology, the process of investigation is described, from the data collection to the visualization of it in Tableau. The results are shown in section three. And finally, the conclusion in section four contains the findings from analysing the results.

2 Methodology

2.1 Data collection

The first phase of this research was to obtain the data from legitimate sources such as statal organisms or companies associated to the electricity subsector of Honduras. Due to the goal of segmenting electrical demand, the data required for this study was the electricity consumption of each municipality in Honduras. Also, some demographic characteristics mentioned in Table 1 were required.

Table 1. National Sources to obtain sociodemographic characteristics.

Characteristics	Data Source	Date
Monthly Electricity Consumption [MWh]	National Electric Distribution utility "Empresa Energía Honduras" (EEH) [7]	March 2022
Monthly Electricity Consumption per sector [MWh]	National Electric Distribution utility "Empresa Energía Honduras" (EEH) [7]	March 2022
Total population [inhabitants]	Gubernamental Source: "Secretaría de Gobernación, Justicia y Descentralización" (SGJD) [8]	2021
Superficial area [square meters]	Governmental Source from: "Secretaría de Gobernación, Justicia y Descentralización" (SGJD) [8]	2022
Electrical coverage [%]	Statal Electrical Power Company "Empresa Nacional de Energía Eléctrica" (ENEE) [9]	2019
Human Development Index [-]	Governmental Source from: "Secretaría de Gobernación, Justicia y Descentralización" (SGJD) [8]	2020

2.2 Data filtering and organization

Once the six characteristics were identified in the national data sources for the achievable municipalities, the second phase started with the filtering and organization of the data. These processes took place in Excel.

Although in Honduras there are 298 municipalities in total, the sample for this study is composed of 259 municipalities. This fact is due the national electric distribution utility only provides the resource to these regions, the remaining municipalities obtain electrical services from other two distribution companies. With the data from electrical and social characteristics recollected, the organization takes place:

2.2.1 Monthly Electricity Consumption [MWh] and Monthly Electricity Consumption per sector [MWh]

In Excel, the monthly electricity consumption for 259 municipalities was tabulated. Within the municipalities the consumption per each sector (7) was obtained, this represents a total of 2,559 values tabulated for this project.

2.2.2 Total population [inhabitants]

This sociodemographic characteristic is necessary to obtain the ratio that will be called electricity consumption per capita (ECPC) which is defined by Equation 1.

$$\text{ECPC} = \frac{\text{Monthly Electricity Consumption [kWh]}}{\text{Total population [inhabitants]}} \quad (1)$$

This ratio will be used to create a choropleth map in Tableau in which ECPC will be the main variable.

2.2.3 Superficial area [m2]

This characteristic is necessary to obtain the ratio that will be called electricity consumption per area (ECPA) which is defined by Equation 2.

$$\text{ECPA} = \frac{\text{Monthly Electricity Consumption [kWh]}}{\text{Superficial area } [m^2]} \quad (2)$$

This ratio will be used to create a choropleth map in Tableau in which ECPA will be the main variable.

2.2.4 Electrical Coverage [%]

This characteristic is necessary to obtain the ratio that will be called electricity consumption per subscriber (ECPS) which is defined by Equation 3.

$$\text{ECPS} = \frac{\text{Monthly Electricity Consumption [kWh]}}{\text{Total population [inhabitants]} * \text{Electrical Coverage[\%]}} \quad (3)$$

This ratio will be used to create a choropleth map in Tableau in which ECPS will be the main variable.

2.2.5 Human Development Index [-]

The HDI is composed of life expectancy, education, and per capita income indicators. It helps in the labour of classifying countries. This data is necessary in the research to explore the relationship it may have with electricity consumption.

2.3 Data visualization

The third phase once the variables are arranged and organized in the excel database representing a total of 3,108 values, is to make this data interactive and interesting for the general population, decision-makers, and academia. This objective will be achieved in Tableau which is a data visualization tool that allows dashboards containing graphics and maps to be visualize for free just by a web link.

For this, a shapefile indicating the division of Honduras by municipalities is necessary. The shapefile where the municipal division of Honduras was obtained from a governmental source via web [10]. The content worked on Tableau by municipality is shown and discussed in section three.

3 Results

It was mentioned in section two, that in Tableau multiple graphic results would be obtained. These results will be shown in the current section as well as the web URL where they can be achieved by the general population via internet.

3.1 Choropleth map of Electricity Consumption [MWh]

The database constructed in the methodology section in Excel is linked with the shapefile obtained. The value that permits this merge of databases is the municipal code, that is unique for every municipality and exist in both sources.

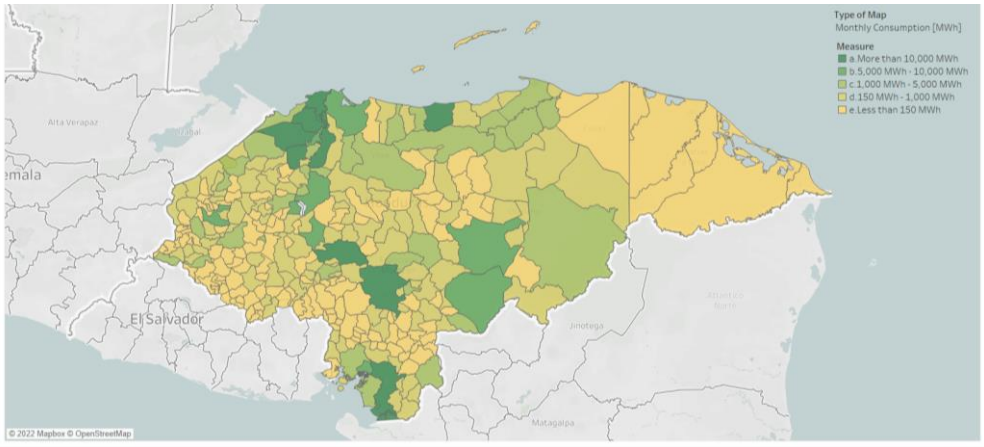

Fig. 2. Choropleth map of electricity consumption
Source: Own elaboration-based information from EEH, 2022 [8]

The Figure 2 shows the behaviour of electricity demand for the month of March 2022, where the municipalities that show dark shade exhibit greater consumption than the

municipalities that exhibit light shade. It is easily deducted that the consumption of electricity is unequal in the region.

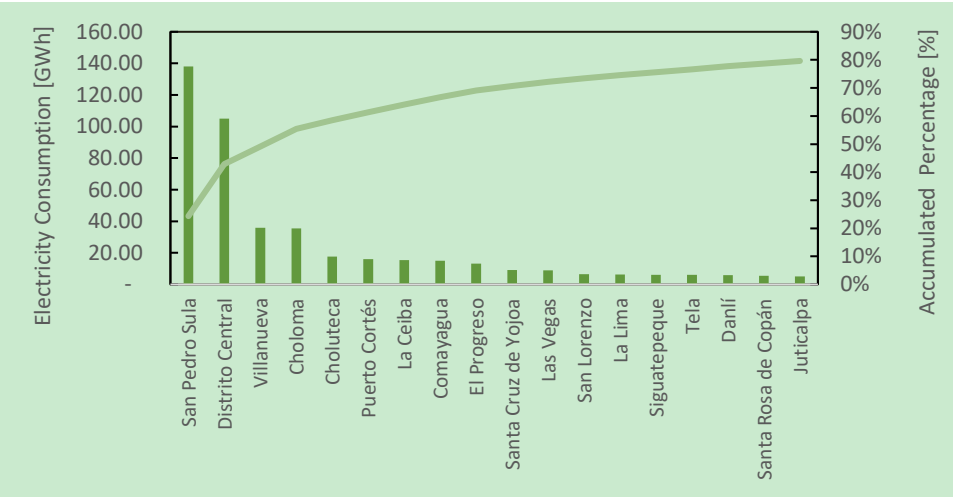

Fig. 3. Pareto diagram of electricity consumption
Source: Own elaboration-based information from EEH, 2022 [8]

In Figure 3, where the bar graph represents electricity consumption in Gigawatt-hour (in the left y-axis) and the line graph represents accumulated percentage (in the right y-axis), this inequality is better exposed. Only 18 municipalities, out of 259 that were studied in this research, consumed 80% of the electricity in the national territory by March 2022.

3.2 Choropleth map of Electricity Consumption per area [kWh· 〖m^2〗 ^ (-1)]

The electricity consumption per area was obtained through Equation 2 for each municipality. This parameter was stored in the Excel database and was linked with the shapefile through the municipal code in Tableau.

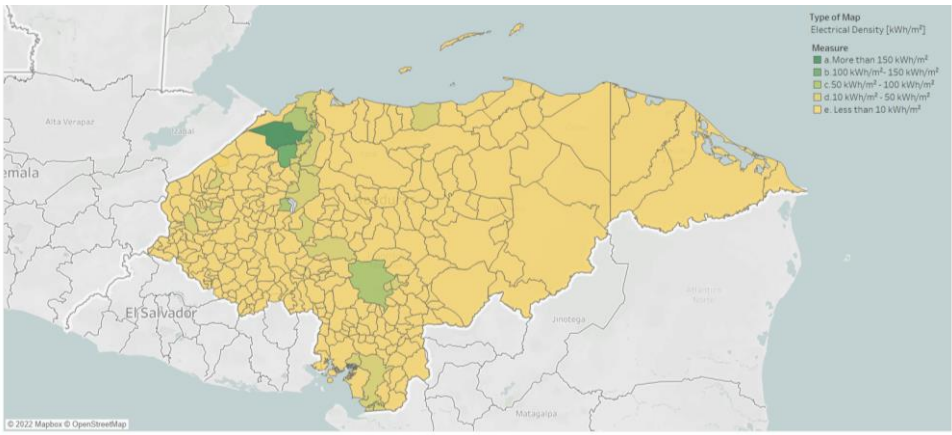

Fig. 4. Choropleth map of electricity consumption per area
Source: Own elaboration-based information from EEH, 2022 [8]

The choropleth map in Figure 4 indicates even more disparity when showing the electricity consumption per area than when electricity consumption was shown in Figure 2 in the national territory.

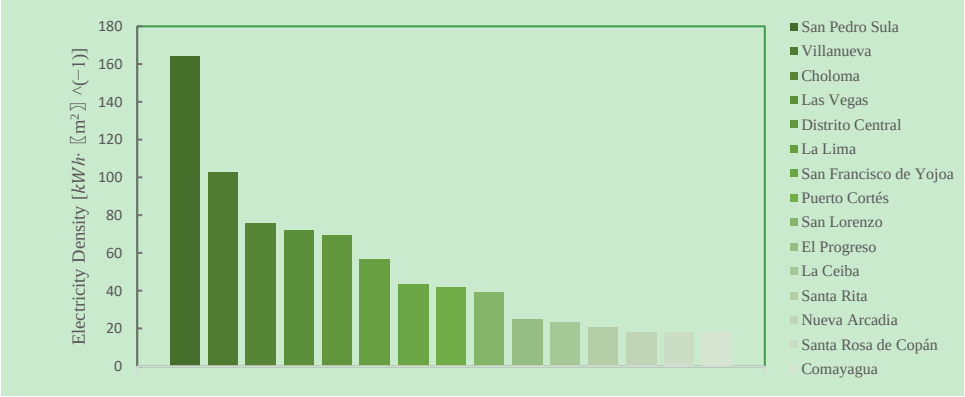

Fig. 5. Bar Graph of Top 15 highest consumers of electricity consumption per area
Source: Own elaboration-based information from EEH, 2022 [8]

In Figure 5, the electricity consumption per area in San Pedro Sula, that is known as the industrial municipality of Honduras, is eight times higher than electricity consumption in Comayagua, that is a municipality known for the tourism. Showing that even in the Top 15 consumers great distinctions of consumption behaviour are presented.

3.3 Choropleth map of Electricity Consumption per capita [kWh· 〖hab〗 ^ (-1)]

The electricity consumption per inhabitant was obtained through Equation 1 for each municipality. This parameter was stored in the Excel database and was linked with the shapefile through the municipal code in Tableau obtaining Figure 6.

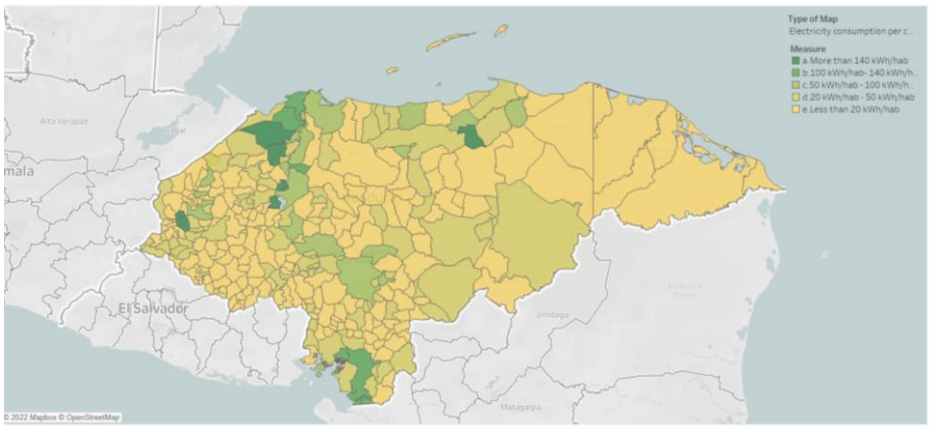

Fig. 6. Choropleth map of electricity consumption per capita
Source: Own elaboration-based information from EEH, 2022 [8]

Analyzing Figure 3 and 7; it can be concluded that the municipalities that lead in monthly consumption are not the same that lead in consumption per capita. Las Vegas, Saba, and La

Unión which lead the list of top consumers per capita but do not lead the top consumers in Figure 4 are seen as exceptional cases by the author and this behavior can be explained as the presence of large industries but low population values in these three municipalities which results in a great value when applying Equation 1.

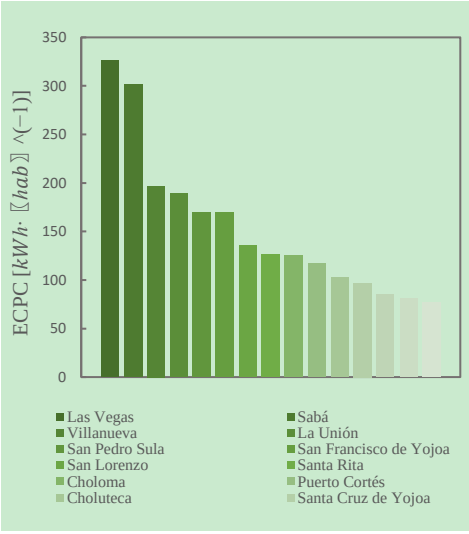

Fig. 7. Bar Graph of Top 15 highest consumers of electricity consumption per capita

Source: Own elaboration-based information from EEH, 2022 [8]

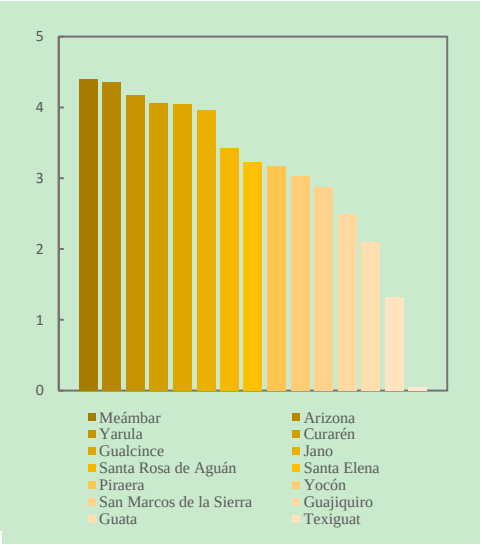

Fig. 8. Bar Graph of Bottom 15 lowest consumers of electricity consumption per capita
Source: Own elaboration-based information from EEH, 2022 [8]

This comparison between Figure 7 and 8; demonstrates that the ranges of electricity consumption per capita are 73 times higher in Figure 7 than in Figure 8. Considering that the access to electricity should be equal for every Honduran this should not be the case. Instead, a similar value of consumption per capita should be encountered when comparing municipalities.

3.4 Bar graph of seven sectors of electricity consumption [MWh]

For the sectorial analysis a bar graph where the seven sectors are represented will be shown in the Tableau Dashboard where the choropleth map by monthly electricity consumption will be the filter for the Bar Graph creating and interactive tool.

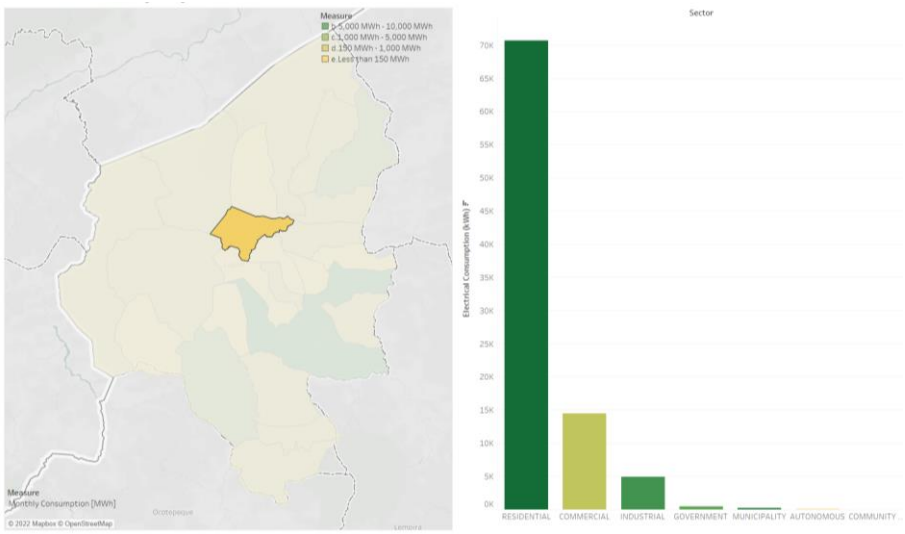

Fig. 9. Choropleth map of monthly electricity consumption filtering by municipality´s sectors

Source: Own elaboration-based information from EEH, 2022 [8]

If the user clicks on municipality "X" e.g., then the consumption per each sector of municipality "X" will be shown in the bar graph as shown in Figure 9.

3.5 Scatterplot of Human Development Index and Electricity Consumption

The electricity demand of a municipality is not just a technical term. It can be related with social and economic variables such as the Human Development Index (HDI). The hypothesis for this thesis was that as well as there is a relationship between HDI and Electricity consumption per capita at a country level, there will be a relationship between the HDI and Electricity Consumption per capita at a municipal level.

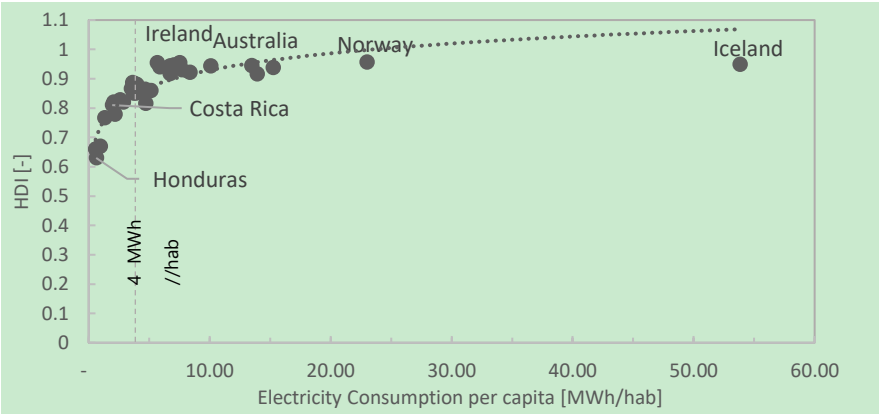

Fig. 10. Relationship between Human Development Index and Electricity Use (2014) for thirty Countries including *Honduras.*

Source: Own Elaboration based on information from World Bank Open Data (2020) [11]

Pasternak (2000) describes the relationship between these two parameters: "In this correlation, HDI reaches a maximum value when electricity consumption is about 4,000 kWh per person per year, well below consumption levels for most developed countries but also well above the level for developing countries" [12].

Which is true for the scatterplot shown above (Figure 10), given that Honduras and Costa Rica are below the 4,000 kWh per person per year asymptote as well as countries like Norway and Iceland are well above this value.

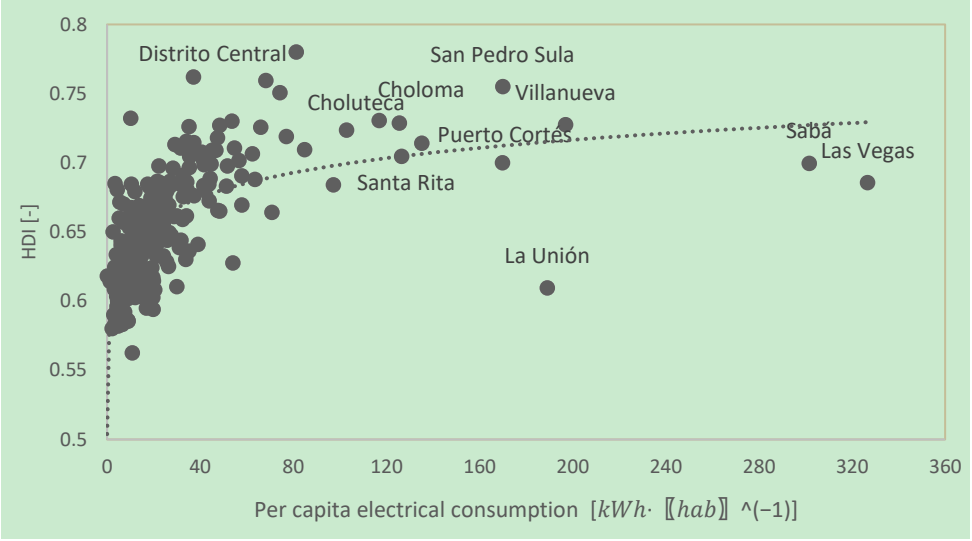

Fig. 11. Scatterplot of electricity consumption per capita and Human Development Index at municipal level

Source: Own elaboration-based information from EEH, 2022 [8]

In Figure 11, for greater values than 100 kWh· 〖hab〗 ^(-1) the HDI axis does not represent values less than 0.7 except for the municipalities of Sabá, Las Vegas and La Unión. These three municipalities present low values of Human Development Index values when electricity consumption per capita is high. These three municipalities were already described as outliers in Figure 7. In Figure 11 the behaviour of the scatterplot is like in Figure 10, both relationships are logarithmic.

This web link is destined to access the data visualization dashboard in Tableau: https://bit.ly/3hwgEJ8. It is suggested to filter by department in the choropleth map to achieve a better experience with the platform of Tableau Public.

4 Conclusion

The consumption of electricity in Honduras is unequal in the national territory. Only 7% of the municipalities represent 80% of the electricity consumption. San Pedro Sula is the municipality that consumes the most electricity in the whole country, and it could be derived from its reputation as the industrial capital city. Las Vegas, Sabá and La Unión represent exceptional values in the electricity consumption of the region in which the per capita consumption of electricity is not representative of the actual scenario. In the data visualization tool in Tableau the consumption of 259 municipalities in March 2022 is shown as well as the consumption per sector within the municipality.

Acknowledgments

Without the support of the P.Eng. Fernando Vásquez from Empresa Energía Honduras (EEH) who shared the consumption electricity information and P.Eng. Gracia Pineda who provided through videocall sessions her expertise in the data visualization tool utilized (Tableau) this article could have not been possible. Special thanks to P.Eng. Alicia Reyes for her support revising this paper.

References

1. Flores, H. F. V., Furubayashi, T., & Nakata, T. (2015). "Decentralised electricity generation system based on local renewable energy sources in the Honduran rural residential sector." Clean Technologies and Environmental Policy, 18(3), 883–900. doi:10.1007/s10098-015-1067-x
2. Balamurugan, K., Srinivasan, D., & Reindl, T. (2012). Impact of Distributed Generation on Power Distribution Systems. Energy Procedia, 25, 93–100. doi:10.1016/j.egypro.2012.07.013
3. J. Paul Valencia Quintero (2008) "Distributed generation:democratization of electrical energy"(in spanish). Published
4. Operador del Sistema. (2022). Plan Indicativo de Expansión de la Generación 2022-2031. Tegucigalpa.
5. W. C. Flores et al. (2021). Energy System Observatory of Honduras. IEEE Electrical Power and Energy Conference. doi:10.1109/EPEC52095.2021.9621596
6. H Andino García , A Reyes Duke & H Villatoro Flores (2021). "Techno-economic comparison between photovoltaic systems with solar trackers and fixed structure in "El Valle de Sula", Honduras"
7. Empresa Energía Honduras (EEH) (2022) Information of electricity consumption obtaiend via email. Unpublished
8. Secretaría de Gobernación, Justicia y Descentralización (2020) "Perfiles Municipales en Base al índice de Desarrollo Municipal". [Online]Available:https://www.sgjd.gob.hn/bibliotecavirtual/sgd/perfiles-municipales
9. Empresa Nacional de Energía Eléctrica (2019) "Índice de cobertura y acceso a la electricidad en Honduras" [Online] Available: https://portalunico.iaip.gob.hn/portal/ver_documento.php?uid=ODQ1NzQ3ODkzNDc2MzQ4NzEyNDYxOTg3MjM0Mg==#:~:text=De%20acuerdo%20con%20la%20informaci%C3%B3n,a%20la%20Electricidad%20de%2086.97%25
10. "Shapefile de límites municipales de Honduras" (2019) [Online] Available: https://datos.gob.hn/en/dataset/limites-municipales/resource/0a086bb7-1e3e-4cb0-b7d8-e21a8417dc5f
11. World Bank Open Data. (2020). Honduras - Place Explorer - Data Commons. Retrieved from https://datacommons.org/place/country/HND?utm_medium=explore&mprop=amount&popt=Consumption&cpv=consumedThing%2CEnergy&hl=es
12. Pasternak, A. D. (2000). Global Energy Futures and Human Development: A Framework for Analysis. Retrieved from http://www.geni.org/globalenergy/issues/global/qualityoflife/HDI-and-electricity-consumption.pdf