Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Ambiental

Tesis

The impact of climate change on electricity demand in the city of Huancayo

Jennifer Condori Clemente
Guadalupe Angélica Lora Huanay
Steve Dann Camargo Hinostroza

Para optar el Título Profesional de
Ingeniero Ambiental

Huancayo, 2022

The Impact of climate change on electricity demand in the city of Huancayo

J Condori[1], G A Lora[1] and S D Camargo[1]

1 Environmental Engineering Academic School. Engineering Faculty. Continental University, Huancayo - Perú.
Email: 70301481@continental.edu.pe

Abstract. This paper analyses how climate change affects electricity demand in the city of Huancayo, Peru, in order to find the relationship between electricity demand and temperature in degree Celsius in the last 20 years, using Spearman correlation, based on heating degree days (HDD), cooling degree days (CDD) and electricity demand data in Mw, the conversion of average temperatures to degree days showed that only heating degree days (HDD) were found, our statistical results show that there is a moderate inverse relationship, which means that in the last 20 years the increase in electricity demand was partially due to lower temperatures, since these cause higher heating needs and thus increased electricity demand. It is suggested that the research can be carried out in different parts of Peru, since the results may vary due to the diversity of climates and it is also of utmost importance to work carefully with the temperature data, to have accurate results. This gives us a notion that energy reserves should be prepared, and the use of renewable energies must be implemented with greater emphasis.

1. Introduction

Climate change has become a global problem in recent years, as it causes negative impacts to the planet, among these impacts are deglaciation, global warming, and sea level rise as the most relevant. According to the "Report of the Intergovernmental Panel on Climate Change (IPCC), a global warming of 1.5°C can cause a greater number of heat waves and longer warm seasons, while a global warming of 2°C would have the capacity to produce more frequent episodes of extreme heat, putting at risk the quality of life of human beings and the planet's ecosystems [1]. Climate change can generate adverse effects on various resources such as coastal, agricultural, water, ecosystems and energy generation and consumption [2].

The demand for electricity works in conjunction with supply and regulation to allow economic progress and technological advancement of each nation; climatic seasonality has an influence on demand due to its characteristics and patterns [3]. As for the relationship between electricity demand and temperature change, it could be said that they have a dual effect, since the energy sector contributes to climate change and this has an impact on its demand, causing an increase or decrease according to the area and the population affected [4].

Europe is one of the continents that has been carrying out several research based on the interaction between climate and the energy sector, because several climatic phenomena have been presented. The “European Environment Agency” has published a series of maps that include various phenomena such as droughts, floods, forest fires and sea level rise that would affect various regions of this continent such as Central Europe, the Iberian Peninsula, Scandinavia, Brittany, and Venice [5]. Peru is not immune to climate change. So far, trends have been observed that confirm a massive increase in temperatures in watersheds and a decrease in rainfall, as well as an increase in the number of extreme events in various locations in Peru [6]. For this reason, several studies have been carried out on these effects; however,

there is still no study that demonstrates the effect of this climatic phenomenon and its influence on electricity demand in the short and long term. Therefore, the need arises to estimate the interactions between climate change and electricity demand in the city of Huancayo under models that allow the establishment of the relationship between climate and electricity demand, to contribute to the preparation of the energy sector in this area for future changes in the variables mentioned in the short and long term, as well as contributing as a basis for future research in other areas of Peru.

Latin American countries such as Paraguay have conducted research on this relationship, obtaining that there is a slight degree of impact of climate change on electricity demand, but that over time it could become significant, this study used an analysis based on drivers of electricity demand and the creation of a model based on heating degree days (HDD) and cooling degree days (CDD) [7]. While, for the Pacific Northwest and Washington State, substantial changes in energy quantity, supply, and demand are very likely to occur, this was determined under a study based on gridded estimates of heating degree days (HDD) and cooling degree days (CDD) [8]. A study in the Bangkok metropolitan region, Thailand analyses how weather factors affect electricity consumption in different time slots using Pearson's statistical regression test obtaining that dew point is the most important factor for weekly periodic electricity consumption [9].

The main objective of this research is to determine the relationship between temperature and electricity demand in the city of Huancayo in the last 20 years, under historical data of temperature and electricity demand which was obtained from web portals of SENAMHI (National Service of Meteorology and Hydrology of Peru) and ELECTROCENTRO, We chose to work with the spearman correlation analysis, this choice was due to the fact that our quantitative variables do not comply with the normality assumption, also with this analysis it was easy to understand the behaviour of the electricity demand and climate change for the years 2001-2021 and the analysis of the projection to the year 2040.

2. Methods and Materials

The heating degree days (HDD) and cooling degree days (CDD) variables are widely used to estimate the relationship between temperature and electricity consumption, defined as the number of degrees the temperature falls below or exceeds certain base temperatures [10].

For the present investigation, first, climatic data were obtained from the conventional meteorological station of Huayao located in the district of Chupaca, Huancayo; these data are registered in the SENAMHI portal (National Service of Meteorology and Hydrology of Peru). To obtain a correct characterization, we worked with temperature data in degrees Celsius from 2001 to 2021, then we ordered these data in Microsoft Excel to calculate the average temperature and thus be able to convert them to HDD and CDD. The following formulas were used for this purpose:

$$Ti = \frac{Ti\ (max) + Ti\ (min)}{2} \quad [1]$$

Where:

Ti= Average daytime temperature

Ti (max)= Maximum daytime temperature

Ti (min)= Minimum day temperature

$$CDD = \sum t(Ti - 18°C) \quad \forall Ti > 18°C \ [11]$$

$$HDD = \sum_t (18°C - Ti) \quad \forall Ti < 18°C \ [11]$$

In this way, differentials are calculated for the days within the previously agreed period, as differences between an a priori defined temperature, or base temperature (generally 18ºC or 65ºF, which is considered a comfortable temperature, there is no heat or cold), and the average daily temperature (Ti). If the average temperature is above the base temperature, the difference will be called CDD, otherwise it will be called HDD [11].

2.1 Compilation of electricity demand data

This data was obtained from the various annual reports issued by ELECTROCENTO, which is the entity responsible for providing information on the consumption and demand for electricity in various cities, including Huancayo [12]. Data was also collected from 2001 to 2021 for subsequent analysis, as shown in Table 1.

Table 1: Average temperature, HDD and electricity demand

Year	Heating Degree Days (HDD)	Average Temperature (°C)	Electricity Demand (MW)
2001	69.50	12.17	15.98
2002	68.13	12.32	16.62
2003	68.23	12.31	19.50
2004	74.87	11.76	20.84
2005	69.66	12.20	31.14
2006	74.35	11.81	31.21
2007	74.63	11.78	28.81
2008	73.08	11.91	32.13
2009	66.53	12.46	44.78
2010	64.75	12.61	47.34
2011	69.70	12.19	42.39
2012	60.32	9.99	33.54
2013	67.99	12.37	26.85
2017	67.31	11.64	41.79
2018	64.46	12.43	43.46
2019	65.90	12.57	46.06
2020	66.15	11.71	44.39
2021	58.65	12.53	46.16

2.2 Correlation analysis

This analysis was carried out through the construction of a correlation model between climate and energy data, these data were worked in the SPSS program since it allows the linkage of both variables. The correlation model used was Spearman's, since only one of the variables complied with the normality test, which is why this model was chosen. The values of Pearson's correlation range from -1 to 1, with extreme values indicating greater correlation between variables, and 0 indicating no correlation, also the positive or negative sign of the coefficient indicates whether the relationship is direct (positive) or inverse (negative) [13].

2.3 Projection Model

This model was developed from the base data of electricity demand and the corresponding degree days for the years 2001 to 2021. The projection was elaborated in Microsoft Excel and the final year considered was 2040, after which it was analysed.

3. Results

3.1 Correlation Analysis: Spearman's Test

This test resulted in a significance level of 0.004, which means that there is a correlation between the variables under study. The Spearman's Rho coefficient was -0.647, which indicates a high inverse correlation, meaning that the higher demand for electricity is due to lower temperatures.

It was found that average temperatures for the years under study (2001-2021) are lower than 18°C; therefore, the heating degree days (HDD) are the only one to be worked on. The following graph shows that the heating degree days (HDD) vary in the range of 58.65 to 74.87 are found in Figure 1.

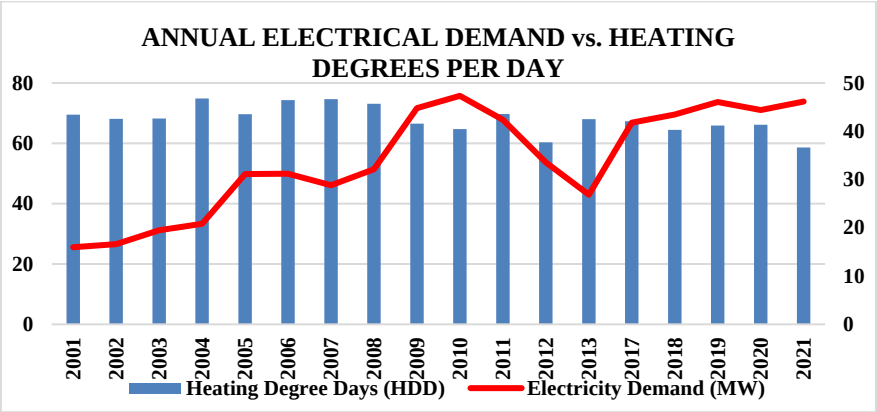

Figure 1. Annual electrical demand and HDD

3.2 Projected annual electricity demand and heating degree days to the year 2040

The data projection was made from 2022 to 2040 for further analysis, as shown in Table 2.

Table 2. Projected annual electricity demand and HDD

Year	Heating Degree Days (HDD)	Average Temperature (°C)
2022	62.98	50.08
2023	62.28	50.88
2024	61.40	51.45
2025	60.45	51.95
2026	60.09	52.25
2027	59.34	53.20
2028	59.06	54.05
2029	58.99	54.48
2030	59.00	54.95
2031	58.50	56.65
2032	57.76	59.01
2033	57.63	61.26
2034	56.23	62.53
2035	55.72	62.26
2036	55.40	63.23
2037	54.88	64.24
2038	54.60	65.42
2039	54.51	66.28
2040	53.64	67.17

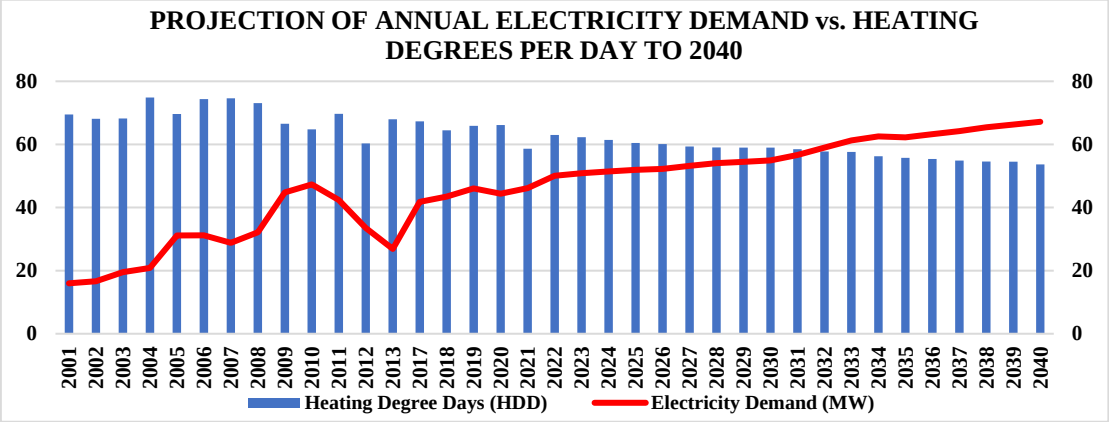

Figure 2. Projection of annual electricity demand and HDD

According to the graph, it could be seen that the demand for electricity would have an increasing trend towards the year 2040 reaching 67.17 MW, which is related to the decrease in temperature that would occur in the following years causing the heating degree days (HDD) to also suffer a decrease reaching 53.64 in the year 2040, which would explain the increase in heating needs and therefore the use of more electricity are found in Figure 2.

4. Discussion and Conclusion

In this research an analysis was conducted on the degree of influence that climate change has on the demand for electricity in the city of Huancayo, the results show that if there is an influence of climate change on the demand for electricity in a slight way, to demonstrate this we worked only with the heating degree days (HDD), since the average temperatures obtained are below 12°C, we also worked Spearman's hypothesis test to establish the type of correlation that in this case was inverse with a high degree of -0. 647, and the projection made for the year 2040 indicates the same trend, so it is necessary to implement new energy sources to meet future demand. These results are similar to those obtained by Rodriguez Angel and Trotter Ian in 2019 in their research elaborated climate change scenarios for energy demand in the years 2017-2050 for Paraguay obtaining that the degrees day of HDD and CDD a variable of little impact on demand in the short term but if significantly affecting in the long term, this research is very useful for energy planning, in addition the creation of these scenarios serve as evidence to demonstrate the great power generation capacity that Paraguay has [7]. For the research carried out by Eskland GS and Mideksa Tk the climate has a statistically significant effect on the demand for electricity, in addition its simulation model over the next few years showed the decrease in heating demand in northern Europe in countries such as Greece and Italy, while the demand for cooling would increase in southern Europe [14]. Scapin, S., Apadula, F and Brunetti, obtained as a result that the impact on electricity demand is greatest in the summer months, where it exceeds 5% of Italy's average monthly electricity demand, while the decrease in winter demand is quite low due to a very limited use of electricity for heating, despite the fact that climate change has a small impact on electricity demand, it is important to conduct your study [15]. In this sense, we could say that this research reaffirms the existence of the relationship between climate change and electricity demand, which varies and may intensify depending on the study area. This research could be carried out more extensively in various Peruvian cities with different climatic conditions, which would allow greater preparation for climate change and, above all, promote the use of renewable energies as an alternative source to the increase in electricity demand. On the other hand, the importance of working with historical climate data that are freely available in this case in the SENAMHI Portal was demonstrated, in this case we worked with 18 years of study that in an initial situation were contemplated with an amount of 21 years, however, 3 years of study (2014-2016) were not found, therefore, it is a recommendation that this institution improves the availability of data to be able to replicate this study throughout Peru.

5. References

[1] IPCC - ONU 2021 El cambio climático es generalizado, rápido y se está intensificando
[2] Forero G, Saldarriaga J and Vargas M 2014 Cambio climático: impactos y perspectivas de investigación desde una visión multidisciplinar *Tendencias*. **18** pp 122
[3] Francon C, Olaya Y y Velásquez J 2008 Caracterización de la demanda mensual de electricidad en Colombia usando un modelo de componentes no observables *Cuad. Adm*. **21**(36) pp 221-35
[4] Barría F 2014 Impacto del cambio climático sobre la demanda eléctrica urbana en Santiago hacia fines del Siglo XXI
[5] Fundación Aquae 2020 Cambio climático en Europa: urge una solución
[6] Servicio Nacional de Metereologia e Hidrologia del Perú [online]. Available from: https://www.senamhi.gob.pe/?p=pronostico-meteorologico
[7] Rodriguez A and Trotter I 2019 Climate change scenarios for Paraguayan power demand 2017–2050 *Climatic Change*. **156** pp 425–445
[8] Hamlet A, Lee S, Mickelson K and Elsner M 2010 Effects of projected climate change on energy supply and demand in the Pacific Northwest and Washington State *Climatic Change*. **102**(1-2) pp 103–128
[9] Ratanawaraha Y, Kaewkitipong T, Nardviriyakul S and Tang J 2019 How weather factors affect electricity consumption in the different times ranges: A study in the Bangkok metropolitan region of Thailand *International Journal of Environmental Science and Development*. **10**(8) pp 252–256
[10] Shuguang Z, Guohe H, Xiong Z and Xiaohang Z 2020 Climate-change impacts on electricity demands at a metropolitan scale: a case study of Guangzhou, China. *Applied Energy*. **261**
[11] Henriquez P 2012 Derivados Climaticos: Valorización De Opciones Sobre Precipitaciones
[12] Electrocentro 2020 Memoria Anual
[13] Díaz I, Garcia C, León M, Ruiz F and Torres F 2014 *Guía de Asociación entre variables (Pearson y Spearman en SPSS)*
[14] Eskeland G and Mideksa T 2010 Electricity demand in a changing climate. *Mitigation and Adaptation Strategies for Global Change*. **15**(8) pp 877–897
[15] Scapin S, Apadula F, Brunetti M and Maugeri M 2015 The sensitivity of present-time electricity demand on past climate change: a case study for Italy *Earth Perspectives*. **2000**

Acknowledgments

In these lines we would like to express our gratitude to the people who have given us their support to complete our thesis work.
To God for giving us the strength to complete the research successfully and not to give up at any time.
To my parents for their support, especially to my father for his trust and for accompanying me throughout the process of my academic training.
To my professors, people with wisdom who have tried to help me reach the point where I am now.