The Socio-economic and Geographic Related Factors Affecting Electricity Consumption in Urban Households: A Case Study of Kota Tengah, Gorontalo

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Abstract. The population density in cities and economic growth are indicators of increasing demand for energy. The household sector is one factor that gives a significant influence on the energy consumption pattern of a city including electricity usage. This study aimed to analyze urban electricity consumption patterns, with specific emphasis on the household sector. More important than that, the research intended to find the relationship between geographic condition, i.e. greenness level, with the energy consumption specifically for the household sector. The approach used was a survey by interview method using a questionnaire to know the pattern of household energy consumption and the factors that influence it. This research was conducted in Kota Tengah as one of the sub-districts in Gorontalo city which has the highest population compared to other sub-districts so it has great potential in energy use. The results show lifestyles, income levels, and awareness of energy-saving concepts affecting electricity consumption patterns. The number of family members did not have a significant effect on household energy use compared to income. The cost of electricity demand that is still affordable on average ranges from 7 to 15% of the average income of heads of households will trigger an increase in demand for electricity in the future. Other physical factors that affect energy consumption are geographical conditions including green area and land use. This research is expected to become the recommendation for energy optimization policy and renewable energy in Gorontalo city.

Keywords: Factors Affecting · Electricity Consumption

1 Introduction

Energy demand has been increasing as an impact of population growth, which would further affect global climate change. Half of the world's population lives in urban areas, contributing to the significant increases in energy demand and greenhouse gas (GHG) emissions [1]. Geographical condition is also an important aspect that may affect energy

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consumption. Factors such as climate, vegetation, and topography are some of those indicators to detect the temperature or heat of that particular area.

The Comfort level of a specific area can affect people's behavior in energy consumption. In geography, the environment has become a crucial issue to be observed to maintain the energy balance and is very useful as a reference for policymakers in city planning and establishing the energy policy. Regarding the comfort level outside the houses, geographical factors are presumed to significantly influence electricity consumption behavior in households, climate, the physical condition of the city, and population density [2–4]. It is different from most previous research conducted; this research intended to observe and find the relationship between greenness and energy consumption. Socio-economically, the community also has an impact on their mindset in acting and behaving [5], which is also related to their ability to survive in the various situations they live in.

Gorontalo City, the study area, is a region with the potential to grow physically. It is a center of economic activities in its province. It has three transportation hubs that support people's activities and movements; they are inter-province bus stations, a seaport, and connecting port. Gorontalo is also a destination for the education of outsiders as it has state universities and some private universities.

The population growth in Gorontalo City, which is constantly increasing, will push further the land use and energy consumption. Zhao et al. stated that urban land use pattern is significantly correlated with energy consumption [6]. This research was intended to study the physical circumstance of the city through vegetation analysis to identify the green region of the research area as one of the factors that affect the climate, which further will affect environmental comfort and energy consumption. The lesser the vegetation density, the more the open area will be, and the more sunlight will be reflected. Inadequate vegetation will affect the absorption of carbon dioxide.

Land cover, the reduction of green areas, and heat produced from human activities can affect the climate change of that particular region. Vegetation as land coverage can reduce the temperature during summer, and this way, it will reduce the energy demand for cooling and at the same time improve the comfort of the surrounding environment [7, 8].

2 Materials and Method

2.1 Data

Vegetation analysis was done with remote sensing images using Landsat 8. The record for the summer season of 12 August 2018 was obtained from www.earthexplorer.usgs.gov. Landsat 8 is a satellite image due to a joint project with USGS, NASA, and NASA Goddard Space Flight Center in 2013. The painting records the earth's surface every 16 days, and therefore it is suitable to monitor a region periodically. The spatial scope from each pixel of Landsat is 30 m, with a radiometric resolution of 12 bits. Landsat 8 consists of two instruments, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Data to determine household energy consumption patterns was obtained through questionnaires. Secondary data such as population, population growth, population density, and other required data were also used in the analysis.

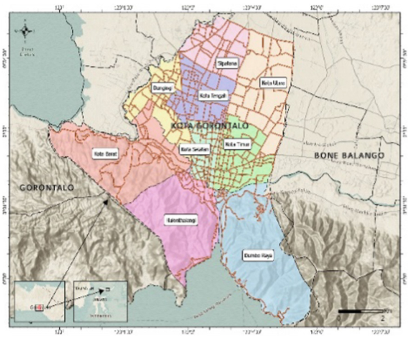

Fig. 1. Map of the study area

The green area distribution of the study area was done by using a remote sensing image. Vegetation analysis was performed by using a normalized difference vegetation index (NDVI). NDVI is one of the image transformation forms to see the vegetation conditions. Some previous researchers have used NDVI as the recommended method for urban green area mapping [9]. This research also investigated electricity consumption patterns but was limited to the households sector only. It aimed to determine the relationship between environmental comfort and energy consumption pattern through vegetation analysis. Ding et al. stated that household energy consumption contributed 35% of world energy consumption [10]. The household sector components that affect the energy consumption pattern include lifestyle, house occupancy, education level, monthly income, and the use of electrical appliances. This study is essential in an environmental setting, especially in connection with the city's characteristics, the city comfort level, and human behavior, which are essential inputs for the policymakers in establishing city planning and optimizing energy consumption.

2.2 Study Area

Gorontalo is a City in Gorontalo province covering a land area of 79,03 Km^2. Geographically, It is located between 0°28′17" North Latitude and 122°5′59" East Longitude (Fig. 1). The population of Gorontalo City was 198,539 in 2016 as per the population census conducted by the Central Bureau of Statistics Indonesia, with a population density of 2,473 persons/km^2.

2.3 Calculation of NDVI

Theoretically, the index of NDVI should be between –1 and 1. The low value of the image pixel of a location indicates the low vegetation intensity of that area and vice versa. Classification of the greenness level vegetation based on the NDVI index is shown in Table 1. NDVI value is calculated using the following formula:

Table 1. Classification of greenness level

Greenness level	NDVI Value
Very low	0.06–0.15
Low	0.15–0.25
Medium	0.25–0.35
Slightly high	0.35–0.45
High	0.45–0.55
Very high	0.55–1.00

Table 2. NDVI Value

	Value
Average	0.06–0.15
Maximum	0.15–0.25
Minimum	0.25–0.35
Standard deviation	0.35–0.45

$$NDVI = \frac{bNIR - bRed}{bNIR + bRed} \tag{1}$$

bNIR = reflection value in near-infrared region
bRed = reflection value in red region.

3 Results and Discussion

Based on the image analysis, the minimum NDVI value in the research area is –0.15, the maximum value is 0.62 and the average is 0.31 (Table 2). The NDVI index value close to 0 is identified as non-vegetated land while the vegetation area is an index range of more than 0. A low NDVI value indicates vegetation that is under moisture stress and a higher value indicates a higher density of green vegetation [11].

Figure 2 shows Kota Barat, Dumbo Raya, and Hulanthalangi as an area with high greenness levels. The lowest greenest level is seen for Kota Tengah, Kota Timur, Kota Selatan, Kota Utara, Sapitana and Dungini. The lowest brightness has been an indicator of dominant land cover, which is built area. Greenness level can affect the increase of the earth surface temperature. The greener the land cover of an area, the lower the earth's surface temperature and vice versa. Consequently, the urban area with less greenery will require more energy for cooling. Kota Tengah is one of the regions with a low level of brightness. This region has been chosen as a study area to analyze the household energy

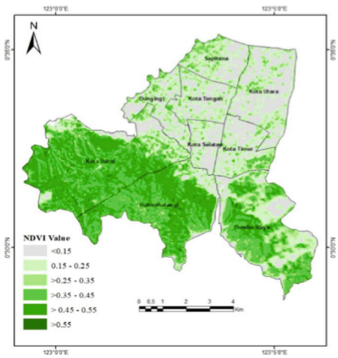

Fig. 2. NDVI Map of Gorontalo City

Table 3. Essential characteristics of the villages investigated in Kota Tengah town

Location (village)	Number of households surveyed	Average occupants of each household surveyed	Average electric bill (Rp)	The income per household (Rp)	Percentage of electricity expenses (%)
DulalowoTimur	18	6.7	242.056	3.050.000	7.94
Dulalowo	12	5	350.583	2.504.167	14
Pulubala	33	5	190.333	2.165.625	8.79
Paguyaman	18	4.6	340.722	2.288.889	1.89
Liluwo	43	4.6	341.679	2.815.581	12.14
Wumialo	27	5.8	231.111	3.187.037	7.25

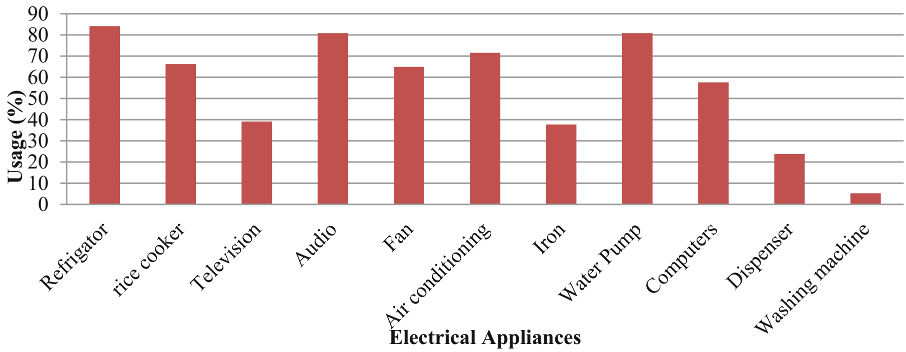

Fig. 3. The distribution of various electrical appliances used in the household sector

Table 4. Regression statistics of electricity bills vs household size

Multiple R	0.134993
R Square	0.018223
Adjusted R Square	0.011634
Standard Error	3.6151

consumption pattern. Six villages were observed. The information obtained from the interview is summarised in Table 3.

In addition to the above analysis, the regression was done to determine the relationship between energy expenses and various household variables. Table 4 shows a weak correlation as the r-value is 0.134. It implies no significant relationship between household size and electricity expenses [12]. However, many researchers have proven that household size affects energy expenses. The higher the household size, the higher is the electricity expenses, which mainly used for lighting and electrical appliances. It is presumed that the dissimilarity happened due to the different behavior and lifestyles, such as reducing appliances.

Liluwo village was the area with the highest number of respondents in the survey and the largest one in terms of location and population [13]. The average household size of all respondents is between 4 to 7 persons, while electricity expenses ranged from 7 to 15% of the total income. As a capital city of a province, the average income of the people is relatively low. However, the low electricity costs and easy access to it may trigger the electricity demand in the future. The regression analysis was also done to determine the correlation between electricity bills and average monthly income (Table 4). The outcome showed that there is a medium relationship between the two variables.

The previous study also showed that electrical appliances used in the household sector affect electricity consumption [14]. The dominant type of household appliance is used as an indicator of demand. The geographical and social conditions of society have an impact on household energy usage, especially electricity. Because it concerns lifestyle, accessibility gets the equipment as well as the comfort level of a city. In areas with warmer climatic temperatures, air conditioning is higher than in places with cooler temperatures. Conversely, areas that require more cold temperatures. Some of the electrical equipment encountered by the respondents in the study area is shown in Fig. 3.

Figure 3 shows the geographical and social conditions affecting the use of the appliances. A hot air temperature coupled with a low level of greenness triggers refrigerators, air conditioners, and fans. The need for dispensers, washing machines, irons, and water pumps is found in respondents with higher income levels, while high audio usage is part of society's lifestyle. The lifestyle and income level of urban citizens also contribute to the increase in energy consumption. Therefore, many studies have been carried out to sustain the stability of global energy demand [15,16].

4 Conclusion

This study has a limitation of assessing geographical factors based only on the greenness level of vegetation which indicates regional comfort. Future studies may involve other geographic factors such as topography, climate, and land surface temperature for urban energy analysis. Geographical and social factors influence urban energy consumption, especially in households.

The results showed that the number of family members did not significantly affect household energy use compared to income. Electricity consumption was dependent on the number of appliances used. Revenue affects lifestyles and increases energy consumption. The cost of electricity demand that is still affordable on average ranges from 7 to 15% of the average income of heads of households will trigger an increase in demand for electricity in the future. In the future, it is expected that the community, especially households, becomes an essential part of efforts to realize renewable energy, choose efficient technology, and reduce the number of appliances used.

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