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Community behavior analysis of electricity consumption in rural areas (a case study of Batang Regency)

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Abstract. The need for electricity linearly increases despite the lack of accessibility to electric power, especially in rural or downtown area. Since electricity has several positive impacts such as supporting human activities, increasing competitiveness and improving the economy, lack of access to it could lead to an area being underdeveloped. The government expected that procuring a 35,000 Mega Watt generator would overcome this problem. However, from the consumer's perspective, it is important to avoid over or under design during the infrastructure development lead. This study aims to analyze the energy reserve needs from the villagers' own perspectives by determining peak loads, electricity consumption, and the reliability of the power distribution systems. The research took place in Batang Regency, Central Java, Indonesia. It used interviews to deeply explore consumer behavior in energy consumption presented in commonly demanded factors, diversity factors, SAIDI and SAIFI values, and the respondent's understanding of energy saving. The results of this study revealed some unique characteristic behaviors of Batang electricity consumers based on their locations.

1. Introduction

The demand for electricity continuously rises every year as a consequence of economic growth [1] with the largest consumer being the household sector, followed by the industrial, business and public sectors [2] A very close relationship between economic growth and expanding electricity demand shows the energy needs as one of the main components for the development of a nation [3]. The very crucial role of electricity, as shown by Susila and Pribadi (2014), directly influences the constraints in the pace of development and the changes in social patterns such as the emergence of urbanization flows and the lack of opportunities to improve livelihoods as indicated by the low human development index [4].

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The electric power indicators of availability are generally expressed in the form of electrification ratio, which is the ratio between the number of electrified consumers compared to the total number of energy consumers [4]. In Indonesia, statistics from the PT PLN (the National Electric Company shows that the outside electrification ratio of Java has reached about 90% of the total demand [5]. Since the provision of equal and sustainable electricity is the main foundation in advancing a nation's economy, the development of reliable electric infrastructure is therefore fundamentally necessary. On the other hand, a comprehensive analysis of electric needs is crucial to prevent under design or over design. Over design condition occurs when the developed infrastructure yields products exceeding its initial planning, while under design is the opposite [6]. Both these conditions should be avoided as they affect the effectiveness of project resource utilization [7].

Two alternative analysis can be conducted to estimate the electricity needs in order to avoid the aforementioned conditions. First, electricity requirement can be calculated based on centralized statistical data, generally provided by the Indonesian Central Statistic Agency and commonly used by policy makers. Another alternative is based on consumers' perception of their electricity needs and how effective such needs have been fulfilled. Since the consumers are directly involved in how electricity is efficiently consumed, their perception will accurately describe the community participation in actively utilizing electricity infrastructure. Both alternatives are ideally carried out simultaneously to produce an optimum model as a framework for the development of electricity infrastructure.

This paper describes the analysis of electricity needs around Batang Regency in Central Java. The main concern of the paper is to explore the behavior of the consumers in a rural area and to directly correlate the behavior to its regional development planning.

2. Research methodology

The survey area was divided into three main regions characterized by their altitude as follow: high altitude (350–700m above sea level/ASL), low altitude (100–350m ASL) and coastal area (below 100m ASL). The electricity infrastructure efficiency level was assessed from public perceptions through the following steps:

1. Initial data collection. Interviews were conducted to the corresponding samples with various socioeconomic backgrounds using a set of questions with statistically satisfying validity and reliability. The questions were designed to profile the respondents' electrical consumption, which is their use of electronic devices daily. The data collected were subsequently processed to determine the estimated electric load profile of the groups of interest (the highland area, the low altitude region and the coastal region). According to Skrotzki and Vopat (1960) [6], there are several factors as follow:
   a. Maximum demand: Maximum load of one group (Watt/Volt Ampere).
   b. Connected load: Load connected in one group (Watt/Volt Ampere).
   c. Demand factor: The ratio of maximum demand with the connected load.
   d. Group diversity factor: The ratio between the sums of individual maximum demands to the group's actual demand at a specific time interval.
2. Secondary data collection. This was obtained from public information provided by the Indonesian Central Statistic Agency to identify the socio historical and economic condition of the areas of interest. The socio historic backgrounds of three interest groups could be described and qualitatively correlated with the electrical consumption profiles.
3. Two other indicators widely accepted to describe the reliability of electricity supply are System Average Interruption Index (SAIDI), and System Average Interruption Frequency (SAIFI) [7]. SAIDI provides an average amount of time per year where energy supply to customers is disrupted, while SAIFI is the number of disrupted experiences per customer per year. SAIDI and SAIFI are calculated as follow:

$$SAIDI = \frac{\sum r_i N_i}{N_T}$$

$$SAIFI = \frac{\sum N_i}{N_T}$$

where

r_i : duration of electricity power off in hours

N_i : the number of consumers power interruption

N_T: total number of consumers

4. The village community's knowledge of electricity was investigated using descriptive statistics and chi square test for homogeneity. All the indicators are subsequently compared to identify the overall use of electricity through a community perspective, yielding a comprehensive and integral picture of the electrical condition of the area of interest and how much electricity needs must be fulfilled in this perspective.

3. Results and discussion

Table 1 shows the average of electricity indicators in all geographic altitude zones in a 24-hour period. The maximum demand is the highest demand of electrical needs in one specific interval time while the connected load is all the electric devices connected to the distribution system. In Table 1, the maximum demand and the total connected load refer to the average of highest demands and whole devices connected to an electrical installation in one house in the area of interest. The highest maximum demand was found in the high altitude area, followed by the low altitude area in second place and the coastal area having the lowest electricity demand on average. On the contrary, the highest connected load was found in the low altitude area and followed by the high altitude area, while the coastal area showed the lowest connected load with a value of almost half of the highest value in all areas of interest. The ratio of maximum demand and the connected load is defined as the factor that describes how much system capacity is required to supply the connected load. The highest demand factor was found in the coastal area with 0.62, followed by the high altitude area with 0.49 and the low altitude area with 0.43 (lowest value). The all connected loads did not operate simultaneously, only partial equipment connected were under operation in a specific time window during the 24-hour period. The average sum of individual time windows of one house is shown in Table 1. The high altitude area had the highest value with the total average sum of 1,567.69 Watt, followed by the low altitude area with 1,395.46 Watt and 1,312.14 Watt in the coastal area. Since the residences all use 900 Watt of power, and assuming only 95 percent of the power could be used while the other 5 percent is dissipated, the actual demand of the system is about 850 Watt. The ratio of sum of individual demand with the actual demand of the system is called Diversity Factor. Table 1 shows that the group diversity factor in the high altitude area is 1.84, followed by the low altitude area with 1.64 and the coastal area with 1.54.

Table 1. The electricity indicators of the research area.

Geographical Altitude	Maximum Demand (Watt)	Connected Load (Watt)	Sum of Individual Demand (Watt)	Actual Demand of the System (Watt)	Demand Factor	Diversity Factor
High	495.44	1,019.69	1,567.69	850	0.49	1.84
Low	460.67	1,071.69	1,395.46	850	0.43	1.64
Coastal	389.47	623.38	1,312.14	850	0.62	1.54

The indicators in table 1 can be further assessed with the parameters indicated in table 2, which shows that the income per capita per area of interest in the highland is the highest, almost one and a half times that of the low altitude area. The lowest income per capita was found in the coastal area with around IDR 13,500,000,- per year, about five sixth of that in the lowland area. Interestingly, the household number in the high area is lower than the number in the low altitude zone, while the income per capita is about one and a half times higher. The data clearly indicated that with a small number of population, the income per capita in the highland area is significantly higher than the two other areas. The coastal area has the lowest population with only about 20,000 households as well as the lowest income per capita.

A direct comparison of the income per capita with maximum demand and connected load from Table 1 reveals some facts around the areas under consideration. With the total load connected about 1,071 Watts, the residents in the low altitude zone have more electric equipment in general than the other two areas. On the other hand, the maximum demand in the lowland area is relatively lower than that in the high altitude area, whereas the demand factor in the high altitude area is relatively higher than that in the lowland area, indicating a more effective use of electric power. Similarly, the same conclusion is seen from the higher diversity factor which indicates the less cost of energy generated for the system. Table 1 electric indicator data revealed the unique

facts in the comparison between people in the highland and low altitude areas: despite the relatively higher total connected load in the low land area, it is clear that the high altitude residents could use the equipment more efficiently. Based on per capita income as shown by table 2, the high income highland residents can afford more electric equipment but the data reveals the opposite: with an income of only two-thirds of the highland residents, the lowland residents own more equipment. The interview also explored the residents' knowledge of electricity efficiency and its results in Table 2 shows the same conclusion as that given by the electric parameters and income per capita: the highland residents have good knowledge of the importance of efficiently maintaining electricity, while the lowland residents showed lack of awareness.

The aforementioned approaches in describing people's characteristics in consuming electricity could not be implemented well in the coastal area. Instead of having the highest demand factor (about 0.62), the area's total connected load is almost about 40 percent less than the other two areas in general. This low connected loads signifies the area's economical condition: they only own very few electric equipment compared to other communities. This is in line with the finding that the income per capita of this area is also the lowest. The highest demand factor means that the lowland residents use their equipment effectively for fundamental needs only. Similarly, the knowledge of electricity efficiency is also poor in the coastal area as a direct result of the low income per capita and the low number of connected load. The number of households in the coastal region is about 20,000, and this is the lowest population in the area of interest. The region is less attractive since it has the lowest income per capita as well as the lowest connected load and the lowest diversity factor.

Table 2. The socio economic profiles of the research area.

	High Altitude Area (350-700m ASL)	Low Altitude Area (100-350m ASL)	Coastal Area (0-100m ASL)
Income per Capita per Year	IDR 23,647,059	IDR 16,200,000	IDR 13,571,429
Household number	87,347	130,705	20,140
Knowledge of Electricity Efficiency	Good	Poor	Poor

Table 3 shows the reliability of the electricity distribution in the area of interest. Table 3 clearly shows the coastal area as the area with the most frequent blackouts. Its SAIDI rate is estimated at 114-1,152 hours per customer per year and SAIFI > 48 disruptions per customer per year. A reduced scale time period of power off duration is about 3 hours a day, and based on Poland's category, this region is reaching the "disaster" level. The low altitude land occupies the second place in terms of SAIDI with about 12-36 hours per customer per year and SAIFI 12 disturbances per customer per year while the highland area has the lowest disturbances with SAIDI less than 12 hours per customer per year and SAIFI 12 disruptions per customer per year. The reliability clearly shows that the highland area has a robust electric supply, while the area of low altitude has relatively low stabilization and the coastal area has a very unpredictable power supply. A very interesting fact is clearly displayed here: the low population density of high altitude region shows a good level of electricity consumption, higher income per capita, high distribution reliability and high level of energy saving awareness. It seems like this awareness drives them to maintain more effective behavior in consuming electricity, which consequently leads to high power supply reliability. The residents in the low altitude zone have the highest population and high connected load but with lower demand factor, lower income per capita, and relatively less robust power supply stabilization. The coastal area displays less efficient profile with a small population, less income and high disturbances in power supply.

Table 3. The SAIDI and SAIFI of interest area.

Geographical Altitude	SAIDI (hours/consumers/years)	SAIFI (disruptions/consumers/years)	Duration of disruption (hours a day)	Category according to Poland's Standard
High	114-1,152	>48	>3	Very long-disaster
Low	12-36	12	1-3	Long
Coastal	<12	12	<1	Short-long

The low altitude community living near Batang's activity centers such as the Pantura Highway, which is the most important highway for national logistics, ideally has convenient access to information for productive

activities including how to effectively maintain electric power. On the other hand, people in the high altitude area has more effective electrical consumption behavior which leads less power supply fewer disturbances. Lastly, the lack of electricity infrastructure in the coastal area (marked by the very high value of SAIFI and SAIDI) causes this region to be less attractive to live in (reflected by the low population) and results in an urgent need to build said electricity infrastructure.

4. Conclusions

This research has been successfully carried out up until the public perceptions data collection stage about electricity efficiency. The electricity usage pattern in Batang Regency shows unique characteristics where the highland residents showed a high level of electrical energy consumption accompanied by the highest level of distribution network reliability. These two factors affect one another: the high network distribution reliability (thus a relatively very few blackouts in a year) is directly related to electricity consumption in the area. The highland population is relatively lower in number than that in low altitude area but those living in low altitude zone frequently access information since the main highway of national transportation and logistics (the Pantura Highway) is located in this zone. This fact reinforces the assumption that existing power production has not been able to cover the electricity needs of the entire population of Batang. This assumption is also strengthened by the high value of SAIFI and SAIDI in the coastal and low altitude regions. As the low number of the highland population has a relatively higher income than those in other areas, the power supplied here can fulfill the electricity needs. On the contrary, the high number of lowland population and its high electricity demand cannot be adequately met by the current supply as shown by the relatively high SAIDI and SAIFI values. Lastly, the coastal area, with its less efficient profile compared to the others, should receive first priority with regards to building electricity infrastructures.

The high productivity of the highland population is accompanied by a relatively high level of awareness with regards to the importance of saving electricity. This fact is also supported by the high public access to information about energy saving efforts. At the same time, highland communities show good knowledge in utilizing electricity for agricultural productivity as their main livelihood. There is an imbalance in meeting the extraordinary electricity needs between coastal areas and areas with higher altitude. In the lowland area, the presence of Pantura Highway as the center of attraction causes many residents to choose to live there, leading to an increase in population and subsequently an increase in electricity consumption. Understandably, the existing power installation is unable to meet the demands of the area's entire population.

Meanwhile the coastal area is still lacking in electricity infrastructure, causing its lack of attractiveness as reflected by its very small population. This study managed to explore and show the current urgency of developing new electricity infrastructure in Batang district, especially to meet the needs of its densely populated areas at low altitudes and coastal areas. However, such infrastructure development must be accompanied by an increase of awareness regarding the importance of energy saving. The existence of Pantura Highway located lowland has indeed triggered a high level of public interest to living in the area, but this interest is not accompanied by a high level of awareness with regards to energy saving and the use of electricity towards productive activities.

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