DMU

Journal of Interdisciplinary Studies 8(2024) 1085-1095

Journal homepage: www.jims.dmu.edu.et

Volume 8(1), Jan 2024

DMU-JIDS

Determinants of Households' Maximum WTP for Improved Electricity Supply Services in Debre Markos Town, Northwestern Ethiopia

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Abstract

The majority of developing countries population including Ethiopia are not fulfilling the demand of reliable uninterrupted and enough quantity of electric power supply services. Therefore, the major objective of the paper was to analyze the determinants of maximum WTP by electricity service beneficiaries in order to improve electricity supply in Debre Markos Town. The study used 404 randomly selected sampled respondents in order to collect the cross-sectional data from Debre Markos town. By using Tobit as empirical models, the contingent valuation surveyed responses were analyzed and the estimated results from this model test statistics showed that the average staying years of households in Debre Markos town (at 5% level of significance) , income of the respondents (1% significant level), satisfaction level of respondents (1% level of significance), the current electric power reliability(5% significance level), the per day average electric power interruption (outage) (1% level of significance) and electric power quantity being used (1% significance level) had a positive effect on the highest amount of money that beneficiaries are willing to pay. But electricity source being used by households (1% level of significance) and providing improved electricity responsible organ (1 % level of significance) had negative effect on the highest amount of money that beneficiaries are willing to pay. Therefore, according to these findings, the town's the study recommended that stakeholders, particularly the town's utility managers need to create awareness among electricity users that providing improved electricity is not the only responsibility of the government, but the beneficiaries must take their part to share the cost for the development of electric power improvement scheme in the town.

Key Words: *Contingent Valuation Method, Willingness to Pay, Improved Electricity Supply, Tobit Model, Debre Markos, Ethiopia*.

1. Introduction

In least developed countries, especially Sub-Saharan Africa, even though some get access to electricity, particularly from the view point of project finance and research, reliability problems which lead to frequent power interruptions have received less attention. In Sub-Saharan Africa, for example, power disruptions happened 8.5 in some particular month, with one outage lasting 4.1 hours on the average (Anderson and Dalgaard, 2013).

In Sub-Saharan Africa (SSA) and emerging Asia, more than 95 percent of the estimated 1.2 billion people that live without electricity are particularly residing in rural regions. In Sub-Saharan Africa, 66% of the population lacks access to electricity, and the region's electrification rate of 35 percent is the lowest in the world, posing a major development problem particularly to these third world countries (Meles, 2017).

Ethiopia, like other developing countries, is unable to completely address its people's need for reliable and modern energy services. Despite the fact that the percentage of households with access to energy services such as electricity and clean cooking continues recently starts to rise, approximately 34 percent of Ethiopia's over 100 million inhabitants live in poverty, and the country has one of the lowest rates (44.3 percent) of access to reliable electricity, with biomass accounting for 92.4 percent of Ethiopia's energy supply, oil accounting for 5.7 percent and only 1.6 percent of the residents energy supply is covered by hydroelectric power (IEA, 2016).

According to data gathered from the Debre Markos local electrical supply office, even if electricity has immense important for the towns' residents in terms of cooking, lighting, income earning activities (tailoring, corn milling and haircutting), the existing electric supply is characterized by low generation potential which creates shortage of electricity supply in the town resulting high rate of outages (interruptions) with average estimated power outages of approximately 3 to 5 hours per day in the town which have been particularly chronic for the last 5 years. This electric outages exposing the town's domestic users to additional direct costs for alternative sources electricity and disrupts the residential users preferred order in performing certain activities in a day and all of this prompted them to improve service delivery by electric utility management sectors, claiming that residents incur financial losses as a result of electric power interruption, making them to pay higher prices in exchange for a better supply of electricity in order to avoid or to the minimum to decrease these power outage times per day, which usually happen without warning or prior notification. Furthermore, there is variation in the demand for reliable electric supply varies throughout the year and day, and it cannot be stored economically, making it difficult to set a market value for reliable electricity power, and these unreliable costs of electricity service to domestic users are more difficult to calculate than in the business sector due to the non-tangible attributes of the main losses (Electricity Supply Office of Debre Markos, 2021).

Despite, several empirical studies using the Contingent Valuation Method (CVM) to value households' (individuals') Willingness to Pay (WTP) for various items were undertaken, including Aygul (2015), Carlsson *.et. al* (2011, 2009), Farhar (1999), Francis and Christian (2015), Gunatilake et al. (2012), Meles (2017), to collect information about families' actual WTP. But most of them utilized statistically less efficient methods, such as bidding game strategy and /or single bounded dichotomous choice (Champ, 2009). As a result, in addition to estimating domestic users' WTP for improved electricity supply, the study attempted to full fill this methodological crack by employing recently recognized as statistically efficient double bounded dichotomous choice format (in comparison to other formats) in eliciting stated WTP preferences for valuing certain goods and services such as electricity (Loomis, 2013). In addition, even though there are several studies on Willingness to Pay (WTP) for electricity supply accessibility characterized by its continuity and reliability and characteristics in Ethiopia, none has been done in Debre Markos town.

2. Methodology of the Study

2.1.Study Area Description

Debre Markos Town, which is located in Northwestern Ethiopia, was the study area. The town is 299 kilometers north of Ethiopia's capital, Addis Ababa, and 265 kilometers south of Bahir Dar, the capital of the Amhara region. The town has total area coverage of 6,000 hectare of land, with an average elevation between 2420-to-2455 meter above sea levels. The climate of Debre Markos is subtropical highland which is typical of the elevated portions of Ethiopia, irrespective of the proximity to the equator having an annual average temperature of 18.6°C (Debre Markos Town Information Communication Office, 2021).

The town has an estimated population of 132,361, of whom 61,647(46.8%) are males and 70,714 (53.2%) are females. When the population religion characteristics is considered, the major town inhabitants were Orthodox Christian representing 97.2 the town’s residents, while Muslim residents constitute 1.7 percent of the populations and, the remaining who constitutes 1.1% are Protestants, respectively.

Hydroelectric power is the primary source of electricity for Debre Markos domestic residents. Based on the information from the town's office of electricity supply, even though the electricity coverage in the town's is nearly 70 percent, there is still a power shortage with frequent interruptions that is unable to meet the current increasing town population power demand (2,000 additional private electric connections demanded by residents every year, particularly in the last 5 years), which is beyond the carrying capacity of two transformers and thus affects almost the entire town's population. In general, the electric power supply service is inadequate in comparison to the current electric power demand of the town's population. (Electricity Supply Office of Debre Markos, 2021).

2.2.Data Sources

This study used Contingent Valuation Method (CVM), which is one of the standard methods of measuring values of environmental public goods and some private goods like electricity. The 2021/22 primary data were used in this study. Secondary data collected from Ministry of Water and Energy (MoWE), Debre Markos Town Electric Supply Office, Website of National and Regional Electric Supply Office, Zonal Reports, Pamphlets, Office Manuals, Government Documents (published and/or unpublished), policy Papers, Circulars and different books were also used to provide additional information.

2.3.Sampling and Data Collection Techniques

Purposive sampling used to select the study area and probability sampling (multistage sampling) were used to select 404 sampled respondents through single population proportion formula. In the first stage, six (6) kebeles, kebele 01, 04, 05, 08, 09, and 11 were selected from the list of all eleven (11) kebeles, using Simple Random (lottery) Sampling (SRS) technique. In the second stage, individual households from a list of households in each sampled kebele administration involved were selected through Systematic Sampling (SS), using all listed households in these sampled kebeles as a sample frame, because the towns' residents have similar socioeconomic activities and topography. In this Systematic Sampling (SS), one sample household was randomly selected, and then sample households were taken at uniform intervals of K, where K=number of households in sample kebele i divided by sample units required from that kebele administration. In the situation when the k^{th} individual household was not live in that kebele, where $K+1$ or $K-1$ unit of household was selected for the study, which is one of the advantages of using systematic sampling over other techniques.

For collection of the primary data, this study used questionnaire as best instrument. To collect data from sampled households, face-to-face personal interview was used by distributing open ended questionnaires to collect cross-sectional data from those 404 randomly selected households from Debre Markos town. In this study, one of the censored regression models, Tobit model was used to analyze the determinants of the highest amount of money that urban users are WTP for improved electric power supply.

2.4.Model Specification

Regarding the econometric methods the study used Tobit regression model for the open-ended response obtained from the respondents. Multi-co-linearity seriously affects the parameter estimates. Therefore, it is necessary to check associations among discrete variables and to test multi-co-linearity problem among continuous variables before fitting important variables into the econometric models. This problem was cross-checked by Correlation matrix of explanatory variables measure which is the most commonly used method to test the existence of multi-co-linearity for association among the explanatory variables. When it is less than 0.8, multi-co-linearity cannot be considered as problem (Gujarati, 2003). Another problem which affects the estimates of parameters is hetroschedasticity. It is defined as a situation where the variance of the residuals is unequal over a range of measured values. If heteroskedasticity exists, the population used in the regression contains unequal variance, standard errors, confidence intervals, P-values and other tests of significance are also no longer valid showing that the analysis results may be invalid, (Gujarat, 2003). To detect heteroscedasticity problem the study used Log likelihood Ratio Test (LRT) was used. If the explained variable will take positive values with few numbers of 'zeros', the responses' from the open-ended instruments were estimated by using Tobit which is one of censored model (Siglman and Zeng, 1999).

If the explained variable is not observable, that is censored or missed, instead of OLS, the Tobit model is more preferred. Tobin (1958) was the first person to develop the Tobit model which is the extension of Probit model. Since some electric users had zero highest willingness to pay amount from the open-ended questions for the proposed electricity improvement scheme, we faced a problem of censoring due to the dysfunctional electricity supply of the town, the appropriate model is using Tobit Model. As described before Tobit model is used to identify factors determining highest amount of money users are willing to pay for better electricity supply.

The general formula for Tobit model is given as follows: $\hat{Y}i = \alpha o + \alpha xi + ui ----- (1)$, where, $if\ \hat{Y}i \leq 0, Yi = 0, and\ Yi\ = \hat{Y}i\ if\ \hat{Y}i > 0, Yi\ = \hat{Y}i$, Where, the observed highest WTP of individual I is represented by $Yi\ and\ \hat{Y}i =$ is the unobservable variable, this variable is not observed when it is $\leq\ zero$ and observed if it $is\ > 0$, $Xi =$ the independent variable, $\alpha =$ slope parameters vectors, $ui\ =$ is the error term which is distributed normally with constant variance σ^2 and mean 0 (Gujarati, 2003).

According to Green (1997), the log likelihood function of censored regression model is:

$$\ln L = \sum_{yi>0} -\frac{1}{2}\ [\ \ln(2\prod) \ln\ \sigma 2 + (yi - \alpha' xi)/\sigma 2\ ]\ + \sum_{yi=0} \ln\ [1 - \varphi\ (\alpha' xi/\sigma)\ ----(2)$$

The two parts, i.e. $\sum_{yi=0} \ln [1 - \varphi\ (\alpha' xi/\sigma)$ and $\sum_{yi>0} -\frac{1}{2} [\ln(2\prod) \ln \sigma^2 + (y_i - \alpha' x_i)/\ \sigma^2]$ represents the relevant probabilities for the limit (zero) observations, and the classical regression for the non-limit (continuous) observations respectively. The censored, Tobit model which is represented as follows:

$$MWPi^{*}=\alpha_0+\alpha_1 GenderR+\alpha_2 EducationR+\alpha_3\ ElectricQ+\alpha_4\ HHeadR+\alpha_5\ AgeR+\alpha_6\ Resposible+\alpha_7\ SatisfactionLR+\alpha_8\ FamilysizeR+\alpha_9\ OccupationR+\alpha_{10} ElectricR+\alpha_{11} ElectricO+\alpha_{12} YearsLR+\alpha_{13}\ IB+\alpha_{14}\ IncomeHH\ +\alpha_{15}\ MaritalSR\ +\alpha_{16} HouseOR+\alpha\ 17 ElectricSO\ +\varepsilon i--(3)$$

Where $MWPi^{*}$ is representing the i^{th} respondents reported highest amount of Ethiopian Birr (ETB) that they are willingness to pay per one Kilowatt of better electric power services and if it is greater than zero, it is observed, but when it is less than or equal to zero, it is not observed. And $\sigma_0, \sigma_1 ----, \sigma_{17}$ are variable coefficients, εi -is the residual and the explanatory variables as shown in variable description. The average amount of money that electric users to calculate the mean WTP , i.e. $Mean\,WTP=\theta=\sum Mi/n$, where $n=$is the sample size and each Mi is the highest WTP amount from respondents is more suitable for measuring welfare in cost benefit analysis from open-ended CV survey results (FAO Corporate Document Repository, 2007).

2.5.Description of Explanatory Variables

The most relevant demographic and socio-economic variables assumed to determine domestic electric users' willingness to pay for better electricity supply were used in this study taken from economic theories and reviewed empirical studies (Francis and Christian 2015; Kateregga 2009; Quartey 2011; Carlsson, 2009).

GenderR: -Respondents' Gender- is a dummy variable represented with 1 for male respondents and 0 for female respondents. The sign which shows the direction, how it affects WTP cannot be identified a priori between this variable and the WTP, even though it influences choices by households for the provision of improved electricity service.

HouseOR: -House Ownership of the Respondent- is a dummy variable that takes 1 if the respondents own a home and 0 otherwise. It is hypothesized that there is a positive association between home ownership and respondents' WTP because households with private ownership are more aware of the significance of better supply of electric power in their household members.

AgeR: -Respondent's Age- the desire to pay for improved power supply is projected to diminish with age, i.e., it is a continuous in its nature. Since, older people wish to maintain tradition and hence are less inclined to support improved services, negative relationship is expected.

EducationR: -Respondent's Educational Level- is a dummy variable that takes 1 if the respondent's attended formal education and 0 not attending formal education. Because households with greater educational levels are more conscious of the significance of better and enhanced provision of electricity, a positive link between household WTP and education is expected.

MaritalSR: - Respondents' Marital Status: - It is dummy in its nature and takes 1 if the respondent is married and 0 non-married. Because married households place a larger importance on better electricity supply, a positive association is expected.

Satisfaction LR: Level of Satisfaction of Respondents- it is characterized as dummy and taking 1 if respondents is dissatisfied with the current electricity supply and 0, if they were satisfied. It has a priori positive sign because households who are dissatisfied with current electricity supply services are more likely to pay for getting better electric power services.

Responsible: Responsible Organ for Better Supply of Electricity services-it is a dummy variable with a coefficient of 1 if the respondent answered the government is accountable to provide better electricity and 0, otherwise.

OccupationR: -Respondent's Occupation-this is a non-continuous variable that takes 1 if the respondent is employed in government, private organizations, NGOs, Owen business, and other relevant fields; 0 if they are not employed. It has positive expected sign, since employed individuals had better chance to earn a higher salary and hence have more WTP for better electricity delivery.

HHeadR: -Respondent's Household Head- is a dummy variable that takes 1 if the respondent is the household's head and 0 if the respondent is not. This variable's coefficient is projected to have a positive sign, this is so because those households who are household heads are responsible for the whole family members to full fill all the requirements such as cooking and lighting, so that he/she gives more value for the supply of better electricity and thus has more WTP.

FamilySR: -Average Family Size- The size of a respondent's family is one of the most important predictors of electric users' willingness to pay in order to get better energy accessibility. There are differing perspectives on the influence of family size on their preference to pay for improved electric power. Some argues that as a family's size grows, so does the family's requirement for electricity, and leading to increase WTP for reliable and better electric power supply. On the other hand, households that cook traditionally using wood fuel have a lower preference for private connections when their family grows, owing to the additional labor involved to use other energy sources such as biomass fuel, having less WTP for better electricity supply. As a result, it is difficult to hypothesize prior.

ElectricR: -Reliability of the Current Electricity Supply- This is a dummy variable that returns 1 if the supply of current electric power is unreliable and 0 if it is reliable. Because households' WTP for better supply of electricity power service will be high if the current supply is unreliable, showing that positive sigh is expected.

ElectricO: -Average Daily Electricity Outage- this is a dummy variable that takes 1 if there is serious and continuous electricity outage and 0 otherwise. The variable's coefficient should have a positive value since a household with greater electrical interruption per day is more likely to demand in the supply of reliable and better electricity services.

YearsLR: -Total Years a respondent Lived in Town- It is projected that the coefficient will be positive. This is due to the fact that urban dwellers who have lived in the town for so many years clearly understanding seriousness of the town's electric problem and are thus eager to pay more for better services compared to their counterpart.

ElectricSO: Electricity Source Used by Respondents-this is a dummy variable that takes 1 if the family received electricity from a hydroelectric power source and 0 if the household did not. This variable coefficient's anticipated sign is negative, because respondents who are using hydroelectric power is likely to pay less for better electric power service than those using other inconvenient sources such as dry dung, fuel wood and others.

IncomeHH: Total Monthly Household Income- It represents the total amount of income that the whole family earns per month. For ordinary goods, most microeconomic theories and empirical evidence from various disciplines suggest that income and quantity required are positively associated. Since, families with higher income have more preference for better electric energy, positive coefficient is expected.

IB: Starting Bid posed to Respondents- This variable will assist to assess whether the initial bid has a meaningful influence on household WTP responses. Because the link will be known throughout the investigation, determining the coefficient of this variable a priori is challenging.

ElecrticQ: Used Quantity of Electricity - is a dummy variable and thus 1 is representing when the responses of the households for the amount of electricity in Kilowatt (KW) is low currently and 0, if the amount is high. Positive coefficient is expected, because households have more WTP for better supply of electric services.

3. Results and Discussion

As shown in Table 1, source of electricity power where urban dwellers used has a significant negative effect on the highest amount of ETB that respondents are willing to pay (1% significant level). This finding indicates that household who got electric power from hydroelectric source has less interest to pay for the development of electricity project compared to their counterpart using from other inconvenient power sources. This finding is similar with Nomura and Akai finding (2004).

Table 1. Tobit Model maximum likelihood estimates

				Number of obs =404 LR $chi^2_{(17)}$ =429.99 Pseudo R^2 = 0.4858
Variables	Coefficients	Std.Err	T	$p > \|t\|$
Electric SO	−.2277	.0541	−4.21	0.001
Electric O	.4970	.0704	7.06	0.000
Electric Q	.2849	.0563	5.06	0.000
Electric R	.1968	.0678	2.90	0.026
Satisfaction LR	.2823	.0629	4.49	0.000
IB	.6678	.0622	10.73	0.000
Gender R	.0149	.0468	0.32	0.721
HHead R	−.0045	.0476	−0.10	0.593
Age R	−.0025	.0049	−0.50	0.649
Education R	.0625	.0719	0.87	0.827
Occupation R	.0679	.0455	1.49	0.174
Income HH	.0001	.00002	4.24	0.000
Family SR	−.0522	.0358	−1.46	0.169
House OR	−.0671	.0519	−1.29	0.108
Marital SR	.0545	.0641	0.85	0.816
Years LR	.0196	.0082	2.37	0.019
Responsible	−.2703	.0498	−5.43	0.000
_cons	.7259	.2617	2.77	0.000

$$Log\ likelihood = -227.57129$$
$$Restricted\ Log\ likelihood = -442.56382$$

The regression results also showed that quantity of electricity being used affects positively and significantly the maximum amount of money that respondents are willing to pay (1% significance level. This finding suggests that if the existing electricity quantity is low, households preferred to pay more for electricity improvement in the town. The result confirmed the study conducted in Ghana using CVM by Quartey (2011) on demand for energy and economic welfare.

Electric power outage time per day is the other significant (1% significant) variable which has a positive effect on beneficiaries' maximum willingness to pay for town's improved electricity supply services. This finding suggests that household who says more electricity interruption time per day have more demand for improved electricity supply services and thus have more willing to pay more for the development of electricity improvement scheme. This finding is in line with the previous finding of Kateregga (2009), who conducted a study in three Ugandan suburbs by using the CVM.

Unexpectedly the initial bid offered to households affects positively and significantly (at 1% level) respondents' highest amount of birr that they preferred to pay. In order to test whether it creates a starting point bias on the responses of service beneficiaries' highest amount of money that they are willing to pay, this initial bid is included in this estimation. This result is in similar to the finding of the study conducted in Ghana by Quartey (2011) on economic welfare and demand for energy using CVM indicating that users' preference to pay is upwardly biased.

As hypothesized priorly, the highest amount of money that households are willing to pay is affected by income positively and significantly (1% significant). This finding suggests that individuals who earn more income have the capacity to pay for their preference to have better electricity supply services. The result confirms that, regarding with normal goods quantity demanded and income have a positive relationship which is consistent to a study of Carlsson et al., (2009) who tried to studied a CV survey using two elicitation formats including open-ended and Dichotomous Choice format to assess the factors affecting outages of power.

The variable beneficiaries' level of satisfaction regarding to the current power services affects positively and significantly the highest amount that they are willing to pay (1% significance). This finding shows that non-satisfied users with the current electricity supply have more preference to pay for better power services which is similar to Francis and Christian (2015) who conducted a CV survey study in Ghana to evaluate households' preference for paying to have efficient electrical services, besides identifying the detrimental factors.

The other variable which affects electric users' highest amount of ETB that they preferred to pay positively at 5% level of significance was the current electricity reliability status of electric power in the town. This result indicates, electric users who believe that the town electric supply is unreliable, have higher preference of paying to the proposed electricity improvement. This finding confirmed the study undergone (Gunatilake, 2012) in Madhya Pradesh (MP), India, using CVM to determine communities' preference to pay for reliable and high-quality power.

As expected, responsible organ for providing improved electricity supply affects the maximum amount that service beneficiaries preferred to pay for improved electricity supply negatively at 1%

significant level. The result indicates that electric users have less interest to pay if the government is responsible for supplying better electric power supply, so because they think that they are not responsible to contribute more for electric power development scheme. This finding is similar to the findings (Wiser, 2007) conducting a study in USA by taking a total sample of 1574 to investigate residents' preference to pay for renewable energy by using collective and voluntary payment scheme.

Numbers of years that respondents have been living in the town is also another variable which has a positive significant (5% significance level) effect on their interest of paying for better electricity supply services. This finding result confirmed that, comparing to their counterpart, those beneficiaries who lived for longer time in the town have more preference to pay maximum amount of birr amount, this is because of the reason that they know seriousness of the electricity power supply shortage in the town. This finding is consistent with the finding of Abdullah and Mariel (2010), who used an iterative bidding elicitation format to study utility users' WTP for better electricity in Kenya.

From the descriptive analysis it was found that the cumulative highest amount that respondents are preferred to pay was found to be 532.02 birr. And thus, it is possible to determine the mean amount of the respondents' maximum preference to pay (WTP), which represents the average WTP from open-ended contingent valuation (CV) results collected from electric beneficiary users in the town. Thus $Mean\,WTP = \theta = \sum Mi/n$, where '$Mi$' is the surveyed urban dwellers responses of highest WTP amount by surveyed households and the size of the sample is represented by 'n', and thus $\theta = 532.02/404 = 1.3168811881$

Thus, it is possible to confirm by saying the mean WTP calculated using open-ended format is 1.32 birr to the development of better electric power services/KW which is significantly more than 2021/22 town electric bill tariff rate of $birr\ 0.00442$ per Kilo Watt for the usage range of $0 - 50\,KWH$ which is consistent with the findings of Kateregga (2009), who surveyed 200 households in three Ugandan districts with the application of the CVM to extract interruption costs of electric energy consumers. Consequently, the town's utility management can implement the new electric power supply improvement scheme, and in addition to solving the town's electric power supply problem, it can dramatically increase the electric bill collected from these supply of better electric power services, thereby increasing total revenue from the sale of better electric power, improving household welfare, and reducing the average power outage time of electricity services in the study area, that is Debre Markos town.

4. Conclusion and Recommendations

4.1. Conclusion

The findings of this study showed that the beneficiaries' willingness to pay for improved electric supply in the town was much higher that the prevailing electric tariff for one kilowatt. This indicates that it is promising for planning strategy to develop the electric improvement scheme in Debre Markos town. Urban dwellers' satisfaction level, reliability of the existing electric power being used, average electric power interruption (outage) per day, quantity of electric power being used, household income and urban dwellers total years of living in the town had significant positive effect on respondents' maximum amount that they want to pay for developing better electric power supply. On the other hand, source of electric power being used, and responsible organ for power provision were factors found to have significant negative expected effect on the highest amount of money that the town's electric power users were preferred to pay for better supply of electric power in the town.

4.2.Recommendations

The overall findings of the study showed that the current electric power service is characterized by continuous interruption, low quantity of electric power being used and unreliability, Debre Markos town electric power supply office should take into consideration these fundamental poor electricity infrastructure attributes in order to design improved electric power development scheme in the town to provide uninterrupted (low electric power outage),enough quantity, and reliable electric power supply services.

Accordingly, it is possible to give recommendation concerning about stakeholders, particularly the town's utility managers need to create awareness among electricity users that providing improved electricity is not the only responsibility of the government, but the beneficiaries must take their part to share the cost for the development of electric power improvement scheme in the town.

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