

# LED lighting in Indonesian residential electricity sector: A user's behavior analysis for energy saving

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**LED lighting in Indonesian residential electricity sector: A user's behavior analysis for energy saving**Y S Akil<sup>1</sup>, S Mawar<sup>1</sup>, S Mangngene<sup>2</sup>, K Amar<sup>2</sup> and Hasniaty<sup>1</sup><sup>1</sup>Department of Electrical Engineering, Universitas Hasanuddin, Gowa, Indonesia<sup>2</sup>Department of Industrial Engineering, Universitas Hasanuddin, Gowa, Indonesia

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**Abstract.** Residential electricity demand can be influenced by the behavior of users. Therefore, it is essential to know users' behaviors to reduce electricity consumption or for energy saving. This research aims to analyze users' behaviors concerning the use of light-emitting diodes (LED) lamps in the residential sector in Makassar, Indonesia. Moreover, the drivers of users' behaviors in terms of usage and habitual behavior are also identified by two composed regression models. Some options for both models were compared by using statistical tests to get better models. A questionnaire was developed, and the survey was done on respondents that have 900 VA and greater of installed power capacity in their homes to get data for analysis. The main finding of this research shows that the user's perception of energy saving was quite good. Both proposed models, namely LED usage model and habit model, were well validated with  $R_{adj}^2$  a value above 39% for both models. Six considered variables can explain usage behavior better than the habit of users. Among the significance variables, the factor of the technology aspect has the highest effect on the usage of LED lamps and the general perception factor for the user's habit. Presented results may give useful information in designing programs for consumers in Makassar, such as energy conservation programs or home energy management systems.

**1. Introduction**

One of the sectors whose potential to enhance the efficiency of electricity usage is the residential sector associated with the use of household appliances. The increase in efficiency will reduce energy consumption and has positive impacts on many things, such as reduce the electricity bill of consumers. In general, the usage pattern of household appliances, which is proportional to the volume of electricity consumption, reflected the user's behavior [1]. Users with a positive perception of energy-saving are more willing to practicing energy-saving lifestyles in their daily life and otherwise. For instance, switch-off the light after used, temperature setting for used air conditioner (AC) in range of 24 to 27 degrees Celsius, drying the clothes without dryer if possible, to name a few of energy-saving behaviors. As a user's behavior is one of the critical parameters to the residential energy consumption [2-3] such as electricity [1], it contributes to forming characteristic of load demand. However, load characteristics for the residential area may vary at certain places due to several factors. Therefore, studies related to user's behavior and electricity load to manage energy consumption are generally location-based to ensure involved driver variables are suitable in developing load model. However,

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required data for analysis may unavailable, or they cannot be accessed by the public at a particular place. Furthermore, information about perception and user behavior cannot easily found in many places, including Indonesia. To dealing with this situation, electrical measurement at representative homes or surveys using questionnaires must be done to get the needed data. Next, usable data are analyzed using a specific approach, such as a statistical model.

Several previous works regarding electricity consumption for the residential area can be seen in [1] and [4-18]. Meanwhile, studies on electricity consumption, particularly related to users' behaviors, can found in [4-10,17]. For residential consumer behavior analysis for the Indonesian context, it is rarely founded in international journals. In this research, we focus on analyzing perceptions and behaviors of users in the residential sector, especially the use of energy-saving lighting (LED lamp) in Makassar, Indonesia. A questionnaire was developed to obtain data from respondents and analyzed statistically. The output of this study is useful for the policymaker as a reference to develop programs for energy saving or increasing efficiency of electrical energy usage. Moreover, as produced electricity is mainly from thermal power plants in Sulselrabar electric power system, the increasing efficiency of electrical energy usage can be viewed as an effective way of dealing with the environmental issue as well.

## 2. Residential Electricity Energy Users in Makassar

Residential electricity consumption level is influenced by various factors, such as the number of energy-efficient equipment used at home and the behavior of the user. Moreover, the types of activities at home in terms of lighting, cooking, entertainment, and amenity activities can also influence electricity consumption [5]. For load from lighting, it can give a significant contribution to residential load, and it can be analyzed separately [5,19]. Based on this, it is possible to reduce electricity consumption by managing activities at home. In other words, the residential sector is the potential to become a target for electricity energy saving. For this purpose, it is valuable to analyze and reveals some vital information related to users' behaviors and lighting at home. Previous studies regarding lighting utilization for a household in some places can be found in [4,7-8].

Figure 1 shows a typical residential load in Makassar based on the user classification for five consecutive years. The data were obtained from the power utility. The electricity load increased over the year. The difference in the amount of electricity consumed for each group can be influenced by the number of users. Besides that, it can also be affected by users' behaviors at the same time. To obtain more information, further analysis concerning electricity consumption from the perspective of the user's behavior is carried out, as described in the next section.

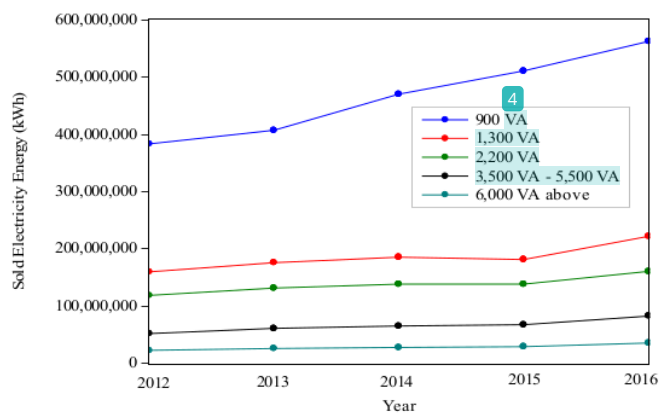


Figure 1. Yearly electricity consumption (kWh) for each user group

## 3. Research Methodology

At first, a questionnaire was designed to obtain data from respondents (residential consumers) who

stay in Makassar. The questionnaire was developed by using information from previous studies regarding lighting usage at home and other related studies [4,7,19], which is modified to suit the Indonesian environment and introducing mass media variables as another critical thing that may affect consumer's behavior. Next, the survey of households' consumers located in Makassar with installed power capacity 900 VA and above was used as a case study. Primary data was obtained from respondents using a judgment sampling technique in July 2017.

The questionnaire consists of some parts, namely general information of respondents, general perception and mass media factor, specific perception regarding the attribute of LED lamp, and usage level and habit of users. For example, questions for general information, including such as education, age, house size of the respondent, and power installed capacity in their homes. Meanwhile, statements for general perception concerning energy saving include items, e.g., "Utilization of low watt devices at home is important to support electricity conservation program." For items of mass media factor, namely, "The usage of low watt home appliances is influenced by information from mass media." For specific perceptions regarding the attribute of LED lamp (technology, shape, visual cosines, and cost aspect) [7], the sample items such as "LED lamp can be used for a long time," and "LED lamp supports good lighting condition in a room." To assess each item in the questionnaire, a 7 point Likert scale was used.

For depth understanding about the data, similar to [7], two regression models were proposed based on the collected information to evaluate the typical relationship between users' perceptions and mass media to their usage and habitual behaviors. The same variables were applied in both LED models to observe to what extent these variables affecting the usage and habit of users, as seen in Eqs. (1) and (2).

$$ULED_m = \hat{\alpha}_0 + \hat{\alpha}_1 GPR + \hat{\alpha}_2 SPT + \hat{\alpha}_3 SPS + \hat{\alpha}_4 SPV + \hat{\alpha}_5 SPC + \hat{\alpha}_6 MME + u_t \quad (1)$$

$$HLED_m = \hat{\beta}_0 + \hat{\beta}_1 GPR + \hat{\beta}_2 SPT + \hat{\beta}_3 SPS + \hat{\beta}_4 SPV + \hat{\beta}_5 SPC + \hat{\beta}_6 MME + u_t \quad (2)$$

where  $ULED_m$  is a LED usage model, and  $HLED_m$  is an LED habit model. GPR and MME are general perception and mass media variables in both models, respectively. Meanwhile, SPT, SPS, SPV, and SPC refer to specific perceptions for technology, shape, visual cosines, and cost aspect, respectively. Here to get the best model, some options for each behavior model are also composed by involving the autoregressive structure until orde-2 and assessed by the AIC test.

#### 4. Results and Analysis

To examine the reliability of the composed questionnaire, a survey sample for 36 respondents was used as a pilot study. Results shown internal consistency between items in the questionnaire (reliable) as proofed by Cronbach's alpha values are a minimum 0.6. Therefore, the questionnaire is used for the next survey and analysis. The results of the main survey are given below.

##### 4.1. Descriptive Statistics of respondents

From 136 respondents, 68.4% of them are female and 31.6% is male. From four categories, 27.9% of respondents has house with size  $< 60 \text{ m}^2$ , 49.3% has  $60 \text{ m}^2$  to  $120 \text{ m}^2$ , 18.4% has  $121 \text{ m}^2 - 180 \text{ m}^2$ , and only 4.4% of them has size  $> 180 \text{ m}^2$ . For household income (IDR/month), 62.5% has income below 2.5 million, 22.8% for 2.5 – 5 million, 10.3% for 5 – 7.5 million, and 4.4% has monthly income above 7.5 million. For power capacity (PC) at home, 51.5% has PC 900 VA, 36% for 1,300 VA, 8.8% for 2,200 VA, 3.7% for 3,500 – 5,500 VA, and 0% has PC 6,000 VA above. Meanwhile for LED lighting usage, 42.6% respondents has been using this energy saving lighting between 1 and 2 years, 39.7% below 1 year, and only 17.6% above 2 years.

4.2. The general perception of the user towards energy saving

The perception of users about energy saving is quite good. It is indicated by compared obtained mean value with the original value of the used Likert scale (1 to 7). The average mean value of the perception is 5.84. Usually, the decision to buy energy-saving appliances such as LED lamp is based on the excellent perception of users. In general, users with good perception have enough information with regards to the features of related appliances. For example, an LED lamp has low energy consumption and has better performance than other technologies [19]. This knowledge will derive them from using the LED lamp and even recommending it to others.

4.3. Influencing factors

Simulation for usage model: Regression results (coefficients and regression statistics) for the best ULED<sub>m</sub> model is shown in Table 1. From Table 1, the value for R<sup>2</sup><sub>adj</sub> of model is 0.4985. It means around 49.85% variation of usage behavior of users can be explained considered variables. The probability of F-statistics value is 0 confirms that at least one of the observed variables influences the usage behavior of users. The model has no autocorrelation problem (Durbin-Watson value is near 2). By applying a 10% significance level, GPR, SPT, SPS, and MME variables have significance in the model. It is shown by p-values for the four variables that are below 0.1. This confirmed GPR, SPT, SPS, and MME are factors which affect significantly usage behavior of users regarding utilization LED lamp at homes in Makassar. The more positive users' perceptions, and the more significant influence of mass media, the higher desire of users to buy and use energy-saving lighting, mainly LED lamps at their homes. Besides that, for specific perception, technology and shape aspect affect the usage of energy-saving lighting at homes. However, the technology aspect factor has the most significant influence on the usage behavior and followed by shape aspect, general perception, and mass media factor. The regression coefficient value indicated the highest for the technology aspect variable (0.2134) and the lowest for mass media (0.1011).

Simulation for habit model: Similar procedure and test for the ULE<sub>m</sub> model was applied for the HLED<sub>m</sub> model. The regression output for the best habit model is shown in Table 2. The model is well validated, with the value of R<sup>2</sup><sub>adj</sub> is 39.27%. Variables GPR, SPS, and MME have significance in the model at a 10% significance level. This means general perception, shape aspect, and mass media factor are main variables that influenced the habit of users in the sense of practicing energy saving in their daily activities at homes. Comparison between significance variables, general perception has the highest influence. It is indicated by its coefficient value (0.2421), which obtained higher than coefficient values for the other two variables.

Table 1. Result for the best behavior regression model 1

Variables	LED Usage Model		
	Coef.	p-value	t-statistic
$\hat{\alpha}_0$	1.7318	0.0040	2.9305
GPR	0.1634	0.0732	1.8060
SPT	0.2134	0.0833	1.7455
SPS	0.1833	0.0005	3.5542
SPV	0.0326	0.6689*	0.4285
SPC	-0.0156	0.6042*	-0.5195
MME	0.1011	0.0048	2.8709
R <sup>2</sup>	0.5208		
R <sup>2</sup> <sub>adj</sub>	0.4985		
Prob. (F-stat.)	0.0000		
AIC	1.7436		
DW Statistic	1.8653		

\*Non-significance variable; AIC is Akaike Information Criterion

**Table 2.** Result for the best behavior regression model 2

Variables	LED Habit Model		
	Coef.	p-value	t-statistic
$\hat{\beta}_0$	2.0119	0.0004	3.6324
GPR	0.2421	0.0082	2.6859
SPT	0.0927	0.3913*	0.8601
SPS	0.1288	0.0134	2.5067
SPV	0.0193	0.7704*	0.2924
SPC	0.0351	0.2878*	1.0673
MME	0.1507	0.0001	4.0261
$R^2$	0.4197		
$R^2_{adj}$	0.3927		
Prob. (F-stat.)	0.0000		
AIC	1.9186		
DW Statistic	2.1291		

The difference obtained values  $R^2_{adj}$  for both models indicated that variables have different influence on the usage level and habit of residential electrical energy users. Variables in models can explain usage behavior better than the habit of the observed users. Related to significant variables, increasing efforts such as campaigns regarding energy saving or promoting the use of energy-saving lighting at home through mass media are essential to achieve more energy saving at the consumers' side. More and full information will encourage residential consumers in Makassar to use fully energy-saving lighting (LED lamp) and will improve the awareness and habit of existing users.

## 5. Conclusions

In this study, behaviors of users regarding environmental lighting, particularly the use of LED lamps for the residential sector in Makassar, were analyzed statistically. A questionnaire was developed to get data from respondents. Research findings showed that the user's perception of energy saving was quite good. Other findings derived from composed models show among significance variables, the factor of technology aspect has the highest effect on the usage of LED lamp, and general perception factor for user's habit. Therefore, more information about attribute appliances and promoting the use of energy-saving lighting through mass media are important aspects to encourage residential consumers to use an entirely LED lamp. Presented results may give useful information in designing an energy conservation program through the use of LED lighting at home. It will support programs of the Indonesian government for society to save electrical energy, which is in line with the global energy management paradigm.

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