Factors affecting electricity consumption of residential consumers in Cambodia

V Noeurn*
Department of Industrial Engineering, Faculty of Engineering, Kasetsart University, 50 Ngamwongwan Rd, Chatuchak Bangkok 10900 Thailand

*Email: vibol.n@ku.th

Abstract. The main purpose of this paper attempted to examine major factors that affect the electricity consumption of residential consumer type in Cambodia by observing through two approaches, socio-economic and direct-use perspectives. The end-use model and stepwise linear regression analysis were applied. The residential consumers were categorized into three levels of household income, such as; high, medium and low. The results of the actual data from survey questionnaire illustrated that determinant factors of electricity usage depended on the income level. High income households consumed 52% in residential sector, more than medium and low income households which had 34% and 14%, respectively. The regression analysis expressed, from socio-economic factors, the electricity consumption of residents had significantly been influenced by total monthly income, level of education and number of people per household. In direct-use perspective, comfort appliances consumed the most energy for 40.53% of total monthly consumption. It followed by cooking appliances with 33.53%, and recreation used 10.9% in the household. Lighting system required 7.85%; hence, the least consumed energy materials were cleaning-use, only 7.19% of total monthly usage. The residential consumers could wisely consume their monthly electricity consumption by saving on the affected factors.

1. Introduction
Electricity normally acts as the most important role behind the development of every country and improvement of all key sectors. Distribution and consumption of electricity have a long-run relationship with economic growth which help in industry, business, and policy matter [1]. Many crucial investments and activities, nowadays, are required complementary energy inputs. It needs electricity to support manufacturing, facility, business, agriculture, construction and every household usage. Cambodia is one of the recent growing economic countries in the region for this new decade while the country is actively working on developing energy power distribution with accountability and sustainability to consumers.

The Royal Government of Cambodia curiously keeps an eye on further developing electrification throughout the country, and the electrical power sectors are providing by independent power producer, import and public sections to serve different areas [2]. Cambodia also has a clear structure of electricity organizations to share responsibilities on regulation, policy and size of authority [3]. Electricity consumption has been categorized by different types of consumers in Cambodia [4] which included purchase directly at medium voltage from grid substation, industrial, commercial, governmental organization, and especially residential customer. It sales in different prices based on types of purchase while tariff reduction policy is also applied in respective years by the authority tobe a part of helping the users.
Table 1. Types of purchasing electricity consumers in Cambodia from EAC (2018).

| Type of Purchase                                      | Unit       | Tariff to be applied for year |
|-------------------------------------------------------|------------|-------------------------------|
|                                                       |            | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
|Medium Voltage from Grid Substation                    | $/kWh      | 0.160 | 0.155 | 0.150 | 0.148 | 0.135 | 0.133 |
|Industrial connected to MV on 22kv                     | $/kWh      | 0.177 | 0.172 | 0.167 | 0.165 | 0.147 | 0.146 |
|Commercial & administration to MV on 22kv             | $/kWh      | 0.177 | 0.172 | 0.167 | 0.165 | 0.159 | 0.158 |
|Residents, governmental org. & embassy (>200kWh/month) | Riels/kWh  | 820   | 780   | 770   | 750   | 740   | 730   |
|Residents consume from 51 to 200kWh/month              | Riels/kWh  | 720   | 720   | 720   | 610   | 610   | 610   |
|Residents consume from 11 to 50kWh/month               | Riels/kWh  | 610   | 610   | 610   | 480   | 480   | 480   |
|Residents consume less than 10kWh/month                | Riels/kWh  | 610   | 610   | 610   | 380   | 380   | 380   |

According to annual report [5], the total electric power sale in 2019 was 10,287.54 GWh, and there were 3451.66 GWh or 33.52% sold to residential sector which was higher than other types of consumers. It noticeably increased from the previous years; therefore, factors affecting the usage of residents become the target purpose of this study paper.

1.1 Statement of Problem
In residential consumer’s case, it has variety of tariffs depends on the amount of monthly electric energy consumption. Finding out factors that affect electric consumption of residential consumers in Cambodia can help to address the major determinants of household electricity use and provide benefits to residents in term of consuming in a suitable electricity prices from monthly categories of electricity authority. The selected important factors to consider for affecting residential consumption were investigated on socio-economic and direct-use perspective. It should be a possible way to express possible solutions to the above problems.

1.2 Objective of the Study
This research paper demonstrated on the three essential objectives which aimed to provide a good source for researchers, readers, stakeholders, and especially residential consumers in Cambodia related to main factors of affecting electricity consumption, regression and effective strategy of electricity usage. The research was conducted to accomplish the following objectives.

- To identify the major factors that affecting the amount of electricity consumption for each household income level of residential consumers in Cambodia.
- To build regression model of influencing factors for resident’s electric usage.
- To highlight the effective ways of monthly using electric energy in order to meet their suitable price categories for residential consumers.

1.3 Scope of the Study
To successfully achieve the objectives, this study only conducted on the electricity consumption which had supplied (a) by Electricity of Cambodia, EDC, areas in the country, (b) only residential consumer type, the other types will not be included, and (c) due to time constraint and limitation of available data, the study only focused on the most related factors likes; socio-economic and direct-use perspectives.

2. Literature Review
There have been many researchers who have previously worked on this related case. It was helpful to find out factors affecting resident’s electricity consumption in Cambodia with the following studies.

2.1 Household Income
Bill of electric consumption rose at higher rate when internal income of the family increased to be upper than affordable [6]. The energy price sensitivity of resident’s consumption was realized to be less for low income than high income households [7]. People would possess more efficient appliance to meet their needs, and it increased capacity use when they had better income to support family [8].

2.2 The Appliances for Lighting System
Lighting appliances in household normally provide adequate lighting, including fluorescent lamps, LED lamps and other materials. They used for a quite wide wattage range that could consume from 1 Watt up to 300 Watt [9]. For less income households, the cost of the modern technology for lighting system was the most costly items in the house [10]. It was a part of most energy consumption for government to plan for supply and demand. An estimation for 2018, about 91 billion kWh or about
6% of total residential sector electricity consumption was used by the U.S. residential sector for lighting [11].

2.3 The Appliances for Comfort
The appliance for comfort is to maintain temperature in the houses which included air conditioners and electric fans. Air conditioning accounted for a major part, up to 40%, of energy use in residential house[12]. In urban households, the average electric fan was one or more up to the size of family. The study result showed the using time was in different ranks, and the gears of the fan power had three types, power value included 27, 30, and 33W [13]. In order to strengthen the demand management for high electricity consuming households, policy of expand the supply of air conditioners with high efficiency should be considered [14]. It does involve in daily lifestyle of residents.

2.4 The Appliances for Cooking
Cooking included refrigerators, micro ovens, toasters, rice cookers, water dispensers and so forth. Operation mode of electric rice cooker had two kinds. During cooking time, power consumed about 520W, but for heat preservation condition time, the power needed approximately 45W [15]. Based on appliance efficiencies, consumers used 1517 kWh equal to 27.66% of individual household in Taiwan [16]. Regarding cooking appliances, the number of electric stoves, electric cooking and other cooking fuels had been linked to higher electricity consumption [17].

2.5 The Appliances for Cleaning-use
In direct use perspective, cleaning-use appliances had much consumed on resident electricity monthly spending. It has been used repeatedly such as: washing machines, dish dryers, electric iron, clothes dryers, water heaters, and so on. The study stated dishwasher increased electricity consumption in Irish homes by over 10.5% per week [18]. People use cleaning materials as a part of regular activities.

2.6 The Appliances for Recreation
Personal computers, Television, speaker, radio, and audio equipment could be counted as the recreation. A case study yielded recreation had a strong association with the average of electricity consumption for each house. It could explain 49% of variance in mean daily usage [19]. Furthermore, household lifestyle normally consumed energy much on recreation such as entertainment, news, or decoration. People liked their expenditure for daily activities at home [20].

3. Methodology
After the problem had been identified, this study applied some effective ways to dealing with the issue. Resident’s electricity consumption could be estimated from household appliances, usage hours, and capacity. The survey was conducted to collect the data by using related methods to express the following results and solutions.

3.1 Data Collection
This case study based on the actual data collecting, from primary data, by using survey questionnaire technique to get the responses from residential consumers at the field in Cambodia. It mainly got from both direct interview and Google form fulfilment. For the size of samples, it depended on available time constraint to address the results. The questionnaires were designed by included the following socio-economic and direct-use factors.
- Socio-economic perspective was contained the average monthly cost of electricity, level of income in each household, sex, age, level of education, and number of people per household.
- Direct-use perspective was basically covered on electrical appliances using in the house like: lighting, comfort, cooking, cleaning-use and recreation. So, the number, capacity and usage hour of individual appliance were curious in the questionnaires to yield the consumption.

3.2 Data Analysis

Factors influenced electricity consumption could be determined by using end-use model to calculate the electricity consumption of the residential households, and it yielded which factors consume from the most to the least, respectively. The regression model would have total monthly cost of electricity consumption as a dependent variable while other socio-economic responses were independent (explanatory) variables to address their relationship.

**Actual data analysis for socio-economic perspective.** The regression model of affecting the electricity consumption can be explained and employed by Stepwise multiple linear regression model with the following dependent variable \( Y \) and independent variables \( X_i \):

\[
Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 \quad \text{(Equation 1)}
\]

Where:  
\( Y \): Total cost of electricity consumption per month in each household,  
\( X_1 \): Sex of each respondent,  
\( X_2 \): Age of each respondent,  
\( X_3 \): Level of education,  
\( X_4 \): Number of people per household, and  
\( X_5 \): Total monthly income per household.

Due to the gap of income between families who living in rural area and city centre, it resulted in different characteristics and behaviour of electrical using in their daily lives. Residential consumers were divided into three categories of household income level in Cambodia, such as; Low, Medium, and High [21].

**Table 2.** Categories of household income levels in Cambodia.

| Level     | Currency in Riel | Currency in USD |
|-----------|------------------|-----------------|
| Low income (L) | (L) < 820,000     | (L) < 200       |
| Medium income (M) | 820,000 ≤ (M) < 2,050,000 | 200 ≤ (M) < 500 |
| High income (H) | (H) ≥ 2,050,000   | (H) ≥ 500       |

*Note: Exchange rate of National Bank of Cambodia (2020): 1 USD = 4100 Riels.

From the actual data, there were 221 households as samples from the electrical users in Cambodia. Each household had a representative to give the data by responding to the survey. As a result, there were 134 male respondents which equal to 61%, and female were 87 or 39%. Most of representatives were in the age between twenty and thirty, with 83% or 183 people. Then it followed by the age of thirty to forty as 14% or 31 people; hence, the rest were younger than twenty and older than forty. Among the total respondents, it had more high residential household income with 74% or 163 representative households while the medium and low income had only 19% and 7% respectively. It provided an opportunity to study and explore the result in the different levels.

**Figure 1.** Percentage of number of residential household by income level.
At the same time, the responses got from representatives who had level of education in Bachelor were 76.9%, equally to 170 respondents. Master degree responding had 21.3% or 47 people, and 1.4% or 3 people were in secondary school. The residential consumer, who was in Ph.D., had 1 person or 0.5% of the total responses. The representatives had good educational background which was very useful to provide the crucial data.

![Figure 2. Level of education of respondents.](image)

**Actual data analysis for direct-use perspective.** Here are the collected data and parameter that can be used to estimate the monthly household electricity consumption.

- Average capacity per electric appliance: \( AC(i,j) = \frac{\sum_{i=1}^{n} CA(i,j) \cdot NA(i,j)}{TN(i,j)} \)
  - \( AC(i,j) \): The average capacity per electric appliance \( j \) in household income level \( i \), [W]
  - \( CA(i,j) \): Capacity of electric appliance \( j \) in household income level \( i \), [W]
  - \( NA(i,j) \): The number of electric appliance \( j \) in household income level \( i \), [unit]
  - \( TN(i,j) \): Total number of electric appliance \( j \) in household income level \( i \), [unit]

**Table 3.** The average capacity per electric appliance per household by income level, [W]

| Appliances                    | Income Level | Low       | Medium    | High      |
|-------------------------------|--------------|-----------|-----------|-----------|
| Fluorescent Lamp              |              | 25        | 25        | 25        |
| Incandescent Lamp             |              | 50        | 50        | 50        |
| LED bulb                      |              | 15        | 15        | 15        |
| Air conditioner               |              | 56.3      | 900       | 930       |
| Electric fan                  |              | 58.45     | 60.05     |           |
| Refrigerator                  |              | 90        | 110       | 120       |
| Electric pot                  |              | 600       | 600       | 600       |
| Electric rice cooker          |              | 650       | 650       | 650       |
| Electric stove                |              | 1000      | 1000      | 1000      |
| Microwave                     |              | 700       | 700       | 700       |
| Toaster                       |              | 500       | 500       | 500       |
| Water heater                  |              | 1000      | 1200      | 1200      |
| Electric iron                 |              | 984.61    | 1000      | 1000      |
| Washing machine               |              | 280       | 300       | 300       |
| Dish dryer                    |              | -         | 210       | 210       |
| Vacuum                        |              | -         | 650       | 650       |
| TVs                           |              | 55        | 70.3      | 75.48     |
| Speaker, radio and audio equipment |      | 25.45     | 34.62     | 46.25     |
| Computers                     |              | 220       | 220       | 220       |
• Average number of electric appliance per household: \( AN(i,j) = \frac{TN(i,j)}{TH(i)} \)
  
  - \( AN(i,j) \): The average number of electric appliance \( j \) in household income level \( i \), [unit/H]
  - \( TN(i,j) \): Total number of electric appliance \( j \) in household income level \( i \), [unit]
  - \( TH(i) \): Total number of households in household income level \( i \), [household]

**Table 4.** The average number of electric appliance per household by income levels, [unit]

| Appliances               | Income Level |
|--------------------------|--------------|
|                          | Low | Medium | High  |
| Fluorescent Lamp         | 3.4 | 4.14   | 5.77  |
| Incandescent Lamp        | 2.33| 2.97   | 4.06  |
| LED bulb                 | 0.86| 3.39   | 3.62  |
| Air conditioner          | -   | 0.83   | 2.02  |
| Electric fan             | 2.4 | 3.23   | 3.82  |
| Refrigerator             | 0.46| 0.88   | 1.06  |
| Electric pot             | 0.8 | 1.74   | 1.97  |
| Electric rice cooker     | 0.8 | 1.11   | 1.16  |
| Electric stove           | 0.46| 0.46   | 0.53  |
| Microwave                | 0.2 | 0.25   | 0.34  |
| Toaster                  | 0.13| 0.14   | 0.19  |
| Water heater             | 0.4 | 0.51   | 0.91  |
| Electric iron            | 0.86| 0.9    | 1.17  |
| Washing machine          | 0.26| 0.41   | 0.83  |
| Dish dryer               | -   | 0.23   | 0.09  |
| Vacuum                   | -   | 0.16   | 0.23  |
| TVs                      | 0.53| 1.04   | 1.5   |
| Speaker, radio and audio equipment | 0.4 | 0.86 | 1.17 |
| Computers                | 1.06| 1.6    | 1.81  |

The average number of each type of appliances in high income level, refer to Table 4, were used more than the medium and low income level; except dish dryer which had only 0.09 unit less than medium income family, with 0.23 unit. However, air conditioner, dish dryer and vacuum were not used in low income households.

• Average usage hours per day of each electric appliance: \( AU(i,j) = \frac{TU(i,j)}{TN(i,j)} \)
  
  - \( AU(i,j) \): Average usage hours/day of appliance \( j \) in household income level \( i \), [h/Unit]
  - \( TU(i,j) \): Total usage hours of electric appliance \( j \) in household income level \( i \), [h]
  - \( TN(i,j) \): Total number of electric appliance \( j \) in household income level \( i \), [Unit]

**Table 5.** Average usage hours per day of electric appliances by income level, [h/Unit]

| Appliances               | Income Level |
|--------------------------|--------------|
|                          | Low | Medium | High  |
| Fluorescent Lamp         | 1.82| 1.98   | 1.35  |
| Incandescent Lamp        | 2.65| 2.75   | 2.2   |
| LED bulb                 | 7.15| 2.41   | 2.47  |
| Air conditioner          | 3.83| 2.76   | 2.72  |
| Electric fan             | 12  | 12     | 12    |
| Refrigerator             | 12  | 12     | 12    |
| Electric pot             | 0.5 | 0.72   | 0.54  |
| Water heater             | 0.5 | 0.7   | 0.25  |
Overall, the average number of usage hours for those appliances were mostly consumed in the high income household more hours than the others. In contrast, for lighting system, it showed the usage hours of LED bulb, fluorescent, and incandescent lamp in high income family were less than the medium and low income households. Hence, the water heater in high income household resulted only 0.25 h/Unit which was less than the other levels.

### 4. Results and Discussion

From the survey of 221 households, 1106 people have been living in the houses. It expressed the average number of people per household were about 5 people/household. The characteristics of electricity consuming depend on the operation time period of each appliance in different income level family. In addition, all electric appliances are not used at the same time while they also have a wide-ranging of energy consumption.

#### 4.1 Socio-economic result

The analysis of Stepwise multiple linear regression model for the Equation (1) illustrated the coefficients of the three explanatory variables were significant, except the other two variables such as; the sex of respondent (X1) and age of respondent (X2) which were not related as shown in the Table 6 and 7.

**Table 6. Regression model summary and variance inflation factors testing (VIF).**

| Model | Variables Entered | R   | R²   | Adjusted R² | Std. Error of the Estimate | VIF  |
|-------|-------------------|-----|------|-------------|-----------------------------|------|
| 1     | Total monthly income per household | 0.40 | 0.16 | 0.16 | 73.69638 | 1.04 |
| 2     | Number of people per household. | 0.49 | 0.24 | 0.24 | 70.07864 | 1.03 |
| 3     | Level of education. | 0.51 | 0.26 | 0.25 | 69.44274 | 1.01 |

Source: computed from actual data (2020) by SPSS.

After the correlation testing, there were only X3, X4 and X5 remained in the model with Stepwise method that the probability of F to enter was less than or equal to 0.050 and the probability of F to remove was more than or equal to 0.100 accurately. The expressed results of variance inflation factors (VIF) were useable with no duplication of variables.

Refer to Table 7, the result of total monthly income per household, number of people per household and level of education were significant and had much influenced on the total cost of electricity consumption per month per household in a positive way.
Table 7. Coefficients of socio-economic factors.

| Model | Coefficients                  | Standardized Coefficients | t  | p-value |
|-------|-------------------------------|---------------------------|----|---------|
|       | Unstandardized                | Beta                      |    |         |
|       | B    | Std. Error |       |       |       |
| (Constant) | 47.26 | 6.59      | 7.17 | 0.0000 |
| Total monthly income/household. | 0.02 | 0.00      | 0.40 | 6.45   | 0.0000 |
| Total monthly income/household. | 4.62 | 10.70     | 0.43 | 0.6662 |
| (Constant) | -70.61 | 35.24     | -2.00 | 0.0463 |
| Total monthly income/household. | 0.02 | 0.00      | 0.35 | 5.80   | 0.0000 |
| Number of people per household. | 9.25 | 1.88      | 0.29 | 4.92   | 0.0000 |
| Total monthly income/household. | 0.02 | 0.00      | 0.30 | 5.06   | 0.0000 |
| Number of people/household. | 23.41 | 10.46     | 0.13 | 2.24   | 0.0262 |
| Level of education. | 0.076 | 0.178     | 1    |          |

Dependent Variable: Total cost of electricity consumption per month in each household (USD).

Therefore, the final regression model of Equation (1) should be written as the following:

\[ Y = 0.02X_5 + 9.43X_4 + 23.41X_3 - 70.61 \]

It explained that an increase in each US dollar of total monthly income per household can cause additional 0.02 dollar to total monthly cost of electricity consumption in the household. The level of education had coefficients 23.41 which means the higher degree of the electric users, the more used of electric energy and increase more cost to monthly expense on electricity. Lastly, the variable of number of people in the house also impacts to increase total cost of electricity with 9.43 dollars per month by adding one more person to the house.

Table 8. Correlation testing among the three factors of socio-economic perspective.

| Correlations | Factor | X_3 | X_4 | X_5 |
|--------------|--------|-----|-----|-----|
| Factor       | Pearson | Sig. (2-tailed) | N   | Pearson | Sig. (2-tailed) | N   |
| X_3          | 1      | -0.029 | 0.673 | 0.263 |
|              |        |        | 221  | 221   | 221   |
|              |        |        | -0.029 | 1     | 0.178* |
| X_4          |        | 0.673  | 0.008 |
|              |        | 221    | 221   | 221   |
|              |        | 0.076  | .178**| 1     |
| X_5          |        | 0.263  | 0.008 |
|              |        | 221    | 221   | 221   |

** Correlation is significant at the 0.01 level (2-tailed).

The correlation from Table 8 expressed that the relationship between number of people per household and total monthly income per household were statistically significant. It evidenced the significant influence each other with the positive correlation coefficient of 0.178, and it had the p-value at 0.008 which was less than the 0.01 level. For the other relationships showed the insignificant due to either the p-value greater than 0.05 or negative correlation coefficient.
4.2 Electricity consumption by types of appliance in each household income level

\[ E(i,j) = \sum_{n=1}^{N} \sum_{j=1}^{J} AN(i,j) \times AU(i,j) \times AC(i,j) \]

Table 9. Electricity consumption by types of appliances in low income level (L).

| Appliances                        | Average Energy [Wh/H-Day] | The share of Consumption [%] |
|-----------------------------------|---------------------------|------------------------------|
| Lighting                          | 558                       | 14.81                        |
| Electric rice cooker              | 520                       | 13.80                        |
| Electric fan                      | 518                       | 13.75                        |
| Refrigerator                      | 504                       | 13.37                        |
| Computers                         | 462                       | 12.26                        |
| Electric iron                     | 337.58                    | 8.96                         |
| Electric pot                      | 240                       | 6.37                         |
| Electric stove                    | 233.33                    | 6.19                         |
| Water heater                      | 200                       | 5.31                         |
| TVs                               | 80.67                     | 2.14                         |
| Microwave                         | 35                        | 0.93                         |
| Washing machines                  | 34.67                     | 0.92                         |
| Toaster                           | 33.33                     | 0.88                         |
| Speaker, radio and audio equipment| 11.88                     | 0.32                         |
| Air conditioner                   | -                         | -                            |
| Dish dryer                        | -                         | -                            |
| Vacuum                            | -                         | -                            |
| **Total Average Energy Consumption (L)** | **3768.46**               | **100%**                      |

The output from Table 9 shared total electricity consumption in low income level was approximately 3768 Wh/H-day. The lighting acted the most consumed energy appliance with 14.81% of total consumption which used around 558 Wh/H-day higher than other appliances. It followed by electric rice cooker, electric fan and refrigerator for more than 13%. Then, computers were used 12.26% equal to 462 Wh/H-day, and other appliances were used less than 10%, respectively. However, high consumed energy items such as; air-conditioner, dish dryer and vacuum were not used in low income level.

Table 10. Electricity consumption by types of appliances in medium income level (M).

| Appliances                        | Average Energy [Wh/H-Day] | The share of Consumption [%] |
|-----------------------------------|---------------------------|------------------------------|
| Air conditioner                   | 2511.63                   | 27.97                        |
| Refrigerator                      | 1166.51                   | 12.99                        |
| Computers                         | 762.33                    | 8.49                         |
| Electric pot                      | 753.49                    | 8.39                         |
| Lighting                          | 738.84                    | 8.23                         |
| Electric rice cooker              | 725.58                    | 8.08                         |
| Electric fan                      | 521.97                    | 5.81                         |
| Electric iron                     | 505.81                    | 5.63                         |
| Water heater                      | 429.77                    | 4.79                         |
| Electric stove                    | 302.33                    | 3.37                         |
| TVs                               | 235.42                    | 2.62                         |
| Washing machines                  | 109.63                    | 1.22                         |
| Speaker, radio and audio equipment| 54.75                     | 0.61                         |
| Microwave                         | 53.72                     | 0.60                         |
| Toaster                           | 52.33                     | 0.58                         |
| Dish dryer                        | 39.07                     | 0.44                         |
| Vacuum                            | 15.76                     | 0.18                         |
| **Total Average Energy Consumption (M)** | **8978.94**              | **100%**                      |
In medium household income level, the average energy consumption was 8978.94 Wh/H-day which used the most for air-conditioner with 2511.63 Wh or 27.97% of their daily usage. Then refrigerator was about 13% equal to 1166.51 Wh. For computer, electric pot, lighting, and rice cooker consumed more than 8%. There was less than 1% of electricity usages for dish dryer, toaster, microwave, and speaker, radio and audio equipment, respectively. The least used item was vacuum with 0.18%.

Table 11. Electricity consumption by types of appliances in high income level (H).

| Appliances                  | Average Energy [Wh/H-Day] | The share of Consumption [%] |
|-----------------------------|---------------------------|------------------------------|
| Air conditioner             | 6675.75                   | 47.57%                       |
| Refrigerator                | 1537.18                   | 10.95%                       |
| Computers                   | 902                       | 6.43%                        |
| Lighting                    | 806.41                    | 5.75%                        |
| Electric rice cooker        | 757.67                    | 5.40%                        |
| Electric pot                | 640.49                    | 4.56%                        |
| Electric fan                | 625.74                    | 4.46%                        |
| Electric iron               | 513.85                    | 3.66%                        |
| Electric stove              | 373.62                    | 2.66%                        |
| Water heater                | 274.23                    | 1.95%                        |
| TVs                         | 271.59                    | 1.94%                        |
| Washing machines            | 227.96                    | 1.62%                        |
| Speaker, radio and audio equipment | 138.13               | 0.98%                        |
| Vacuum                      | 91.72                     | 0.65%                        |
| Toaster                     | 73.62                     | 0.52%                        |
| Microwave                   | 72.15                     | 0.51%                        |
| Dish dryer                  | 50.26                     | 0.36%                        |
| Total Average Energy Consumption (H) | 14032.35    | 100%                         |

Table 11 shown total average energy consumption for (H) was 14032.35 Wh/H-day for daily usage. The air-conditioner consumed 6675.75 Wh, equal to 47.57% as the highest energy consumption. It followed by refrigerator 10.95%, computer 6.43%, lighting 5.75%, and electric rice cooker 5.4%. Electric pot, fan, iron, stove and so forth were respectively used. For the least usage items, speaker, radio and audio equipment, vacuum, toaster, microwave and dish dryer were used less than 1%, respectively.

4.3 Total electricity consumption by types of appliance in direct-use factors

When it was further investigated to electricity demand for residential sector, among the total of electricity energy consumption, electricity energy has been supplied the most in high income household for 52%. While the medium income level required 34% of electric energy, the low income household consumed only 14% of total energy in residential sector, refer to Table 12. It proved that the higher income of households, the more electricity they consumed in their family.

Table 12. The share of household electricity consumption by household income level.

| Appliances    | Average consumption by income level [Wh/H-Day] | Total    |
|---------------|-----------------------------------------------|----------|
|               | Low    | Medium | High   |                     |
| Comfort       | 518    | 3033.6 | 7301.48| 10853.08            |
| Cooking       | 1765.67| 3483.72| 3728.96| 8978.35             |
| Recreation    | 554.54 | 1052.5 | 1311.72| 2918.76             |
| Lighting      | 558    | 738.84 | 806.41 | 2103.25             |
| Cleaning-use  | 372.25 | 670.28 | 883.78 | 1926.31             |
| Total electric consumption | 3768.46 | 8978.94 | 14032.35 | 26779.74 |
| Share of electric consumption | 14% | 34% | 52% | 100% |
Figure 3. Percentage of electricity consumption by types of appliance.

The pie chart of Figure 3 guided readers to clarify the factors of direct-use perspective which respectively affecting from much to less for electricity consumption of residential consumers. Electricity energy was used the most for appliances of comfort, with 40.53% of daily consumption. The cooking appliances consumed 33.53% while the recreation appliances needed 10.9%. Plus, lighting and cleaning-use appliances required only 7.85% and 7.19%, respectively, from the total electric energy consumption.

5. Conclusion

Based on the above analysis, the electricity consumptions of residential consumers in Cambodia has been influenced by both socio-economic factors and direct-use appliances. Total monthly income in the household, the number and level of education of people who are living in the family had positive impact on electricity usage. The higher electricity consumption was observed in the household with high income level, respectively followed by the medium and low income households. From the results, the low income household used electricity energy around 3768 Wh/day which approximately consumed 113 KWh per month. So, those residents could meet the price of 610 Reils/KWh. Households with medium and high income consumed more than 200 KWh/month; therefore, they need to purchase 730 Reils/KWh for their monthly electricity tariff.

The appliances of comfort was the most used materials of electricity for residential consumers, like air-conditioner and electric fan accounting for 40.53% of total monthly usage. Secondly, cooking appliances were 33.53% used for refrigerator, electric pot, rice cooker, stove, microwave, and water heater. Recreation appliances included computer, TVs, speaker, radio, and audio equipment were 10.9%, the third factor for electricity consuming. Lighting used regularly, but it consumed less electric energy for only 7.85%. The cleaning-use appliances were 7.19% which is the least affecting factors as they did not use them daily. As a result, residential consumers could be able to save monthly electricity consumption by reducing number of appliances and time (hours) of usage for individual material of most affected factor and the respective influenced factors. It could be a possible solution to wisely use and save monthly electricity consumption.

Due to data availability and time constraint, the scope of this study had limitation. The further study should be recommended to point out the other factors affecting the electricity consumption, such as: electricity price, population, GDP, size of the household, and so forth.

6. References

[1] Dogan E 2015 The relationship between economic growth and electricity consumption from renewable and non-renewable sources: A study of Turkey Elsevier Renew. and Sust. Ener. Rev. 52 534-546

[2] Poch, K. and S. Tuy 2012 Cambodia’s electricity sector in the context of regional electricity marketintegration, in Wu, Y., X. Shi, and F. Kimura (eds.), Energy Market Integration in East Asia: Theories, Electricity Sector and Subsidies ERIA Research Project Report 2011-17 pp.141-172.

[3] Lean, T. 2019 Operationalizing NEXSTEP at national level Cambodia Mr. Sareth Nong.pdf.
[4] EAC 2018 *Salient Features of Power Development in Kingdom of Cambodia Until 2018* Consolidated Report. p. 9. https://eac.gov.kh/uploads/salient_feature/english/salient_feature_2018_en.pdf

[5] EAC 2019 Salience Feature of Power Development in the Kingdom of Cambodia until 2019 Consolidated Report. p. 8. https://www.eac.gov.kh/uploads/salient_feature/english/salient_feature_2019_en.pdf

[6] Yalcintas, M. and A. Kaya 2017 Roles of income, price and household size on residential electricity consumption: Comparison of Hawaii with similar climate zone states. *Energy Reports* 3 109-118.

[7] Nesbakken, R. 1998 Price Sensitivity of Residential Energy Consumption in Norway *Discussion Papers, Statistics Norway, Research Department* 232. https://www.econstor.eu/bitstream/10419/192215/1/dp232.pdf

[8] Liu Y., Gao Y., Hao Y. and Liao H. 2016 The relationship between residential electricity consumption and income: A piecewise linear model with panel data. *Energies* 9(10) 831 https://doi.org/10.3390/en9100831

[9] Sarfatti R. 2001 Domestic Lighting and Energy Efficiency: The Assoluce (the Italian Association of Lighting Manufacturers of Federlengo-Arredo) Position. In: Bertoldi P., Ricci A., de Almeida A. (eds) *Energy Efficiency in Household Appliances and Lighting*. Springer 17-22. https://doi.org/10.1007/978-3-642-56531-1_4

[10] Kumar, N. and Devadas 2016 A Household-based analysis of domestic energy consumption for lighting in Jaipur City. *Int. J. of Built Env. and Sust.* 3(2) 130. https://doi.org/10.1111/ijbes.v3.n2.129

[11] EIA, U.S.E.I.A. 2019 *How much electricity is used for lighting in the United States?* https://www.eia.gov/tools/faqs/faq.php?id=99&t=3 Accessed: 2020 November 29

[12] Narayanan R. 2017 *Heat-Driven Cooling Technologies Clean Energy for Sustainable Development*. p. 191-212. https://doi.org/10.1016/B978-0-12-805423-9.00007-7

[13] Yang Q., Liu M., Huang C., Min Y. and Zhong Y. 2015 *A model for residential building energy consumption characteristics and energy demand: a case in Chongqing*. Procedia Engineering 121 1772-1779. https://doi.org/10.1016/j.proeng.2015.09.154

[14] Kim, M.-J.E.R. 2018 Characteristics and determinants by electricity consumption level of households in Korea *Energy Reports* 4 70-76.

[15] Yang, Q., et al. 2015. A model for residential building energy consumption characteristics and energy demand: a case in Chongqing. *Procedia Engineering*. 121: p. 1777. DOI: 10.1016/j.proeng.2015.09.15

[16] Chen, Y. 2017 The Factors Affecting Electricity Consumption and the Consumption Characteristics in the Residential Sector—A Case Example of Taiwan *Sustainability* 9(8): p. 1484. DOI: 10.3390/su9081484

[17] Huebner, G., et al. 2016 Understanding electricity consumption: A comparative contribution of building factors, socio-demographics, appliances, behaviours and attitudes. *Applied Energy* 177 692-702.

[18] Jones, R.V., A. Fuertes, and K.J. Lomas 2015 The socio-economic, dwelling and appliance related factors affecting electricity consumption in domestic building Renewable Sustainable energy Review 43 901-917.

[19] Satre-Meloy, A., M. Diakonova, and P.J.E.E. Grünewald 2019 Daily life and demand: an analysis of intra-day variations in residential electricity consumption with time-use data. *Energy Efficiency* 1-26.

[20] De Laurotis, S., F. Gherzi, and J.-M.J.A.e. Cayla 2017 Energy consumption and activity patterns: an analysis extended to total time and energy use for French households. *Applied Energy, Elsevier* 206 (C) 634-648.

[21] Sovannala M.J.C 2005 Household Electricity Use Analysis and Forecasting: the Case of Phnom Penh. Corpus ID: 166447535