Factors affecting electricity demand in Cambodia

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Abstract. Recently, there are many factors affecting electricity demand in different ways. The relation between electricity demand and economic, demographic, increasing new consumer connection, technological, climate, and government policies on electricity price, etc. This study aimed to identify the main factors that affect electricity demand and observed which factors had more relation affecting on electricity demand in Cambodia. The first method of defining relation to predicting annual power demand in the future on economic factors based on annual data from 2004 to 2018. The method was paring GDP with power demand delivered using regression analysis, then with GDP and Total consumer connection by multi-regression analysis. Secondly, for environmental factors affecting on predicting daily maximum power demand ($P_{max}$) by temperature and humidity from 1st Jan 2020 to 20th July 2020, using regression and multi-regression respectively. As a result of linear regression, we observed annual new consumer connection and GDP of Cambodia were the best factors affecting electricity demand. However, for environmental factors, temperature and humidity are not really affect the curve of ($P_{max}$) from our data. Daily temperature in Cambodia could be explained only 4.2% of daily maximum electricity demand while humidity was not significant.

1. Introduction

Cambodia is a developing country, located in South East Asia and became the 10th of ASEAN community member in 1999 [1]. Leaving from genocide and civil war in the last 20 years; Cambodia has been fighting challenges to reach a lower-middle-income economic status in 2015 and updating to become an upper-middle-income economic status by 2030 [2], by this reason it became one of the fast-growing economies in ASEAN and the world. Along with increasing economics, electricity demands also had been growing rapidly from 814 GWh in 2004 to 9,307 GWh in 2018, and it was 11.4 times greater and around 19% growth.
rate annually from 2004 to 2018 in the whole country [3]. As the result, the increasing of economic growth shows the need of using electricity, and the ability to afford more convenient and new electronic tools. Moreover, the more technology needed of production side and improvement of raw material production, the increasing machinery is once among the main factors influence electricity demand [4]. The increasing of new consumer connection entire country also lead to enlarge total energy demand. Secondly, environmental factors, the peak demand for electricity positively changes during the hot season, especially from March to May. Thus, the total electrical energy is expected to rise. Lastly, government policy on reducing the price of residents also acts as a crucial role in increasing electricity demand. Among the main factors, there are also many different macro actors affecting electricity demand. However, this study extracted only the important factors such as economic, environmental, and total new consumer connection. This study aimed to discuss in details for these main factors affecting annual electricity delivered demand and daily maximum power demand in Cambodia. Overall, it also applied the concepts from the model to future forecasting.

2. Objective and scope

2.1 Objectives
There were two objectives of this study consisted of:
1. To identify the factors that affect electricity demand.
2. To create the model forecasting on electricity demand in Cambodia in the future.

2.2 Scope
This study was limited with the following conditions.
- This project study about electricity demand in Cambodia.
- The forecast was based on the major factors such as: GDP of Cambodia, total new consumer connection, daily temperature, and humidity.

3. Literature reviews

3.1 Economic factor
Electricity was the main source of each nation and plays a necessary part in economic growing process [5]. So another author [6] established a model to predict the electricity demanded in national, regional and by sectors within the Grey model 1,1 model, and multivariate analysis were combined and adopted to disaggregate electricity consumption per unit of GDP. Moreover, as the study showed the decrease of China’s economy under the new normal lead to decrease of total electricity demand. So, it was the reason to reflect that whenever economic started to growth, people should had earned more money in variety contexts. Then the electricity consumption was resulted to increase as well. Not only the entire economic has been used to predict the electricity demand, but also the household electricity consumption was once influenced from economic growth too. The another analysis from household was studied about energy saving program by categorizing the tools with helped to save energy usage and following the labeling standard of Thailand [7]. From the result of main factors affecting electricity demand from five districts in Vientiane, Lao PDR was the characteristics of household using appliances. Thus, it shown that the economic pushed electricity demand by people has more ability to shop for new electronic tools.

3.2 Environmental factor
The connection between electricity demand and environmental factors was explained from many authors by using multiple techniques and methods. The temperature from entire day were not quite the same especially during daytime or night time. The study tests shown that a decrease of 1°C below 15°C in winter could increases the morning electricity demand by 2 MW per °C in year 2000 and 16.7 MW per °C in year 2007. For the evening peak decreases was −2.6 MW per °C in 2000 and increases by 22.9 MW per °C in 2007 [8]. After running the regression temperature factor has been shown to play the foremost essential
factor affecting electricity load demand [9]. As an example, the optimum time for low levels of electricity demand was found to be from time 24:00 midnight to 5:00 (see figure 1) in the early morning in Cambodia. While the height demand was during the daytime around 10:00 am within the morning and 2:00 pm in the afternoon respectively.

![Power demand curve in November 2018](source: National load control center)

**Figure 1.** Power demand curve in November 2018 (source: National load control center)

### 3.3 Correlation between factors

Another study about the importance relation of socio-demographic variables and psychological variables in relation to household energy use and changes in energy use [10]. Results base on correlation and regression analysis the variables affecting the electricity consumption can be divided into four different major variables, such as demographic, dwelling, socio-economic, and electric appliances as independent variables, [5]. The annual residential electricity consumption significantly impacted by independent variables on dependent variable, using multi regression analysis variables having t-stat values =>1.96 or p-values <=0.05 are considered significant. For instance, effective in long-term energy planning in Thailand because of the demand of energy has been rapidly increasing. Another study was about the model was developed to forecast the future of electricity usage of households in all provinces in Thailand. Some independent variables in this model were the factor has a strong correlation while other was not efficient or has no relationship [11].

### 4. METHODOLOGY

#### 4.1 Data collection:

**4.1.1 Sources.** In this research study all of data were taken from primary sources, there were no specific collection methods. The data were retrieved from the sources both internal and external to the organizations and government institutions. The sources were from: Electricity of Cambodia (EDC) annual report from year 2007 to 2017, which expressed about electricity supply and demand, and internal data from different departments. Electricity Authority of Cambodia (AEC) annual report on power sector from year 2008 to 2018 about the trend of electricity consumption and the government regulations on electricity price, National control center of Transmission Department, Electricity of Cambodia (EDC), World Bank’s data on Cambodia GDP growth from 2004 to 2018, and Accuweather website.
4.2 Method

After collecting the data from both primary sources internal and external government declaration and some websites. Firstly, all data was classified into yearly, monthly, and daily. Then it would short by category factors. Finally, data analysis was made by some excel formulas and calculation algorithms in SPSS application such as:

4.3 Linear Regression analysis

Linear regression is used to predict the Electricity demand delivered in GWh (dependent variable) with Cambodia GDP in Billion USD (independent variable), and Maximum power demand ($P_{\text{max}}$) in GWh with Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020 [12]. Moreover, was to see the relationship of changing in every unit of independent variable has affected on dependent variable. It helps to validate whether predictor of the model($X$) is significant or not to help in forecasting dependent variable($Y$).

Formula: 

\[ Y = a + bX \]

Where, $b$ is the slope of the line and $a$ is the $y$-intercept. For variables (See table 1.)

| Table 1. Dependent and Independent variables |
|---------------------------------------------|
| **Economic factor** | **Electricity demand delivered in GWh** | **Cambodia GDP in Billion USD** |

| **Environmental factor** | **Maximum power demand ($P_{\text{max}}$) in GWh** | **Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020.** |

4.4 Multi regression analysis

Multiple regression is another way to extend calculate of normal linear regression when there more than an independent variable. It was used when to forecast the relation of Electricity demand delivered in GWh and Daily Maximum power demand ($P_{\text{max}}$) in GWh as dependent variable ($Y$) with its independent variables ($X_1, X_2$) [13].

Formula: 

\[ Y = a + b_1X_1 + b_2X_2 + \ldots + b_nX_n + c \]

Where, $Y$ is the dependent variable, $X$ is the independent variable, $b_i$’s ($i=1, 2\ldots n$) is the slope of the line, $a$ is the $y$-intercept and $c$ is standard error estimated. For more variables (see table 2. And table 3.)

| Table 2. Economic factors Variables |
|-------------------------------------|
| **Variables** | **Description** |
| Y | Electricity demand delivered in GWh |
| X1 | Cambodia GDP in Billion USD |
| X2 | Total consumer’s connection in Million |

| Table 3. Environmental factor variables |
|-----------------------------------------|
| **Variables** | **Description** |
| Y | Daily Maximum power demand ($P_{\text{max}}$) in GWh |
| X1 | Daily temperature from 01 Jan, 2020 to 20 Jul, 2020. |
5. RESULTS AND DISCUSSION
Based on the objectives of the study for linear regression were to identify the factors that affect electricity demand and to create the model forecasting on electricity demand in the future in Cambodia and other regions than Cambodia.

5.1 Electricity demand versus GDP factor
First table of interested were analyzed from linear regression (Table 4) shown the R column value of .974 represent for the quality of electricity demand delivered in GWh R has a good level of prediction. From the value of \( R^2 = .949 \) mean that GDP of Cambodian could be explained 94.9% of electricity demand and only around 5% (100% - 94.9%) caused by other factors than predictor of this model.

Table 4. Model summary of Electricity Demand delivered in GWh with GDP in Billion USD

| Model | R   | \( R^2 \) | Adjusted \( R^2 \) | Std. Error |
|-------|-----|----------|---------------------|------------|
| 1     | .974a | .949     | .945               | 653.886    |

a. Predictors: (Constant), Cambodia GDP in Billion (USD)
b. Dependent Variable: Electricity demand delivered in GWh

Moreover, the test to see whether entire model is good for the data. See (table 5.) Sig. = P value = (.000) < (0.05) so, GDP growth of Cambodia is significant for predict electricity demand in Cambodia.

Table 5. ANOVA for Electricity Demand delivered in GWh with GDP in Billion USD

| Model     | Sum of \( S^2 \) | df | Mean \( S^2 \) | F          | Sig. |
|-----------|------------------|----|----------------|------------|------|
| 1 Regression | 103387163.194    | 1  | 103387163.194  | 241.803    | .000b|
| Residual  | 5558376.539      | 13 | 427567.426     |            |      |
| Total     | 108945539.733    | 14 |                 |            |      |

a. Dependent Variable: Electricity demand delivered in GWh
b. Predictors: (Constant), Cambodia GDP in Billion (USD)

Looking at (Table 6.) Coefficients for electricity demand delivered in GWh from GDP growth of Cambodia based on annual data from year 2004 to 2018 is Estimated model: Electricity Demand delivered in GWh = -3584.437 + 8.150 Cambodia GDP in Billion USD Based on 95.0% Confidence Interval for B the prediction of Electricity Demand delivered in GWh is 95% from -4673.416 + 7.018 Cambodia GDP in Billion USD to -2495.459 + 9.282 Cambodia GDP in Billion USD.

Table 6. Coefficients for electricity demand delivered in GWh with GDP in Billion USD

| Model | Unstandardized Coefficients | Standardized Coefficients | 95.0% Confidence Interval for B |
|-------|-----------------------------|---------------------------|--------------------------------|
|       | B                           | Std. Error                | Beta | t     | Sig.   | Lower Bound | Upper Bound |
| 1     | (Constant)                  | -3584.437                 | 504.071 | -7.111 | .000   | -4673.416   | -2495.459   |
|       | Cambodia GDP in Billion (USD) | 8.150                    | .524 | .974 | 15.550 | 7.018       | 9.282       |

a. Dependent Variable: Electricity demand delivered in GWh
5.2 Electricity demand versus GDP and total consumer connection factor

To be more accurate by using multi regression analysis we added one more factor; Total consumer’s connection in (Million) as more independent variable than GDP. Looking at (Table 7) shows that $R$, $R^2$, adjusted $R^2$ are greater than GDP factor alone. $R$ column represent for the quality of prediction for electricity demand delivered in GWh $R$ value of .998 has a better level of estimation. From the value of $R^2 = .995$ mean that GDP of Cambodian and increasing of new customers connection can pretty good explain 99.5% of electricity demand.

| Model | $R$  | $R^2$ | Adjusted $R^2$ | Std. Error |
|-------|------|-------|----------------|------------|
| 1     | .998a | .995  | .994           | 208.421    |

a. Predictors: (Constant), Total consumer’s connection in Million, Cambodia GDP in Billion (USD)

Once again, ANOVA test to see whether entire model is good for the data. See (table 8.) Sig. = P-value = (.000) < (0.05) so, GDP growth of Cambodia and total consumer connection is significant for annual electricity delivered demand.

| Model      | Sum of $^2$ | df  | Mean $^2$ | $F$     | P-value |
|------------|-------------|-----|-----------|---------|---------|
| Regression | 108424268.178 | 2   | 54212134.089 | 1247.998 | .000b   |
| Residual   | 521271.555   | 12  | 43439.296  |         |         |
| Total      | 108945539.733 | 14  |           |         |         |

a. Dependent Variable: Electricity demand delivered in GWh
b. Predictors: (Constant), Total consumer’s connection in Million, Cambodia GDP in Billion (USD)
General form of the equation to predict electricity demand delivered in GWh from GDP growth of Cambodia and total consumer connection (see table 9.), is: Estimated model: Electricity Demand delivered in GWh = -411.712 + 0.952 Cambodia GDP in Billion USD + 3077.358 Total consumer’s connection in (Million) + 208.421. Based on 95.0% Confidence Interval for the prediction of Electricity Demand delivered in GWh is 95% from Electricity Demand delivered in GWh = -1142.910 + (-0.549) Cambodia GDP in Billion USD + 2454.701 Total consumer’s connection in (Million) to Electricity Demand delivered in GWh = 319.485 + 2.453 Cambodia GDP in Billion USD + 3700.015 Total consumer’s connection in (Million).

Table 9. Coefficients for Electricity Demand delivered in GWh with GDP in Billion USD and total consumer in Million

| Model | Unstandardized Coefficients | Standardized Coefficients | 95.0% Confidence Interval for B |
|-------|-----------------------------|---------------------------|-------------------------------|
|       | B                           | Std. Error                | Beta                          | t       | Sig.     | Lower Bound | Upper Bound |
| 1 (Constant) | -411.712 | 335.595 | -1.227 | .243 | -1142.910 | 319.485 |
| Cambodia GDP in Billion (USD) | .952 | .689 | .114 | 1.382 | .192 | -.549 | 2.453 |
| Total consumer’s connection in Million | 3077.358 | 285.778 | .887 | 10.768 | .000 | 2454.701 | 3700.015 |

Table 10. The relation between independent variables: GDP of Cambodia and total consumer connection has Pearson’s .970 close to 1. So, every time the changes in one variable are strongly correlated with changes in the second variable. And correlation is significant at the 0.01 level.

Table 10. Correlation between Cambodia GDP in Billion (USD) and Total consumer’s connection in Million

| Cambodia GDP in Billion (USD) | Pearson Correlation | Sig. (2-tailed) | N | Total consumer’s connection in Million |
|-------------------------------|-------------------|----------------|---|--------------------------------------|
|                               |                   |                | 15 |                                      |
| Sig. (2-tailed)               | .000              |                |    |                                      |
| N                             | 15                |                |    |                                      |

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

5.3 Maximum Power demand (P\textsubscript{max}) versus Temperature

The model summary in (Table 11.) R column value of .205 represents for the quality of Maximum Power demand (P\textsubscript{max}) is not a good level of prediction. However, a Small R\textsuperscript{2} value is not always a problem [14]. The value of R\textsuperscript{2} = .042 means that Daily temperature in Cambodia can explain only 4.2% of maximum electricity demand. Thus, around each 95% may cause by other factors like GDP, demographic, technological, or other tariff policies of Cambodia, etc.

Table 11. Model Summary of Maximum Power demand (P\textsubscript{max}) versus Temperature

| Model | R     | R\textsuperscript{2} | Adjusted R\textsuperscript{2} | Std. Error |
|-------|-------|----------------------|-------------------------------|------------|
| 1     | .205a | .042                 | .037                          | 128.960    |

a. Predictors: (Constant), Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020.
b. Dependent Variable: Daily Maximum power demand (P\textsubscript{max}) in GWh
Sig. = P-value = (.003) < (0.05) so, temperature is significant relation for Maximum Power demand ($P_{\text{max}}$) see (table 12.).

Table 12. ANOVA for Maximum Power demand ($P_{\text{max}}$) versus Temperature

| Model  | Sum of $^2$ | df | Mean $^2$ | F    | P-value |
|--------|-------------|----|-----------|------|---------|
| 1      | Regression  | 1  | 146423.798| 8.804| .003b   |
|        | Residual    | 200| 16630.931 |      |         |
|        | Total       | 201|           |      |         |

a. Dependent Variable: Daily Maximum power demand ($P_{\text{max}}$) in GWh

b. Predictors: (Constant), Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020.

(Table 13.) Coefficients for prediction Maximum electricity demand ($P_{\text{max}}$) from temperature from 01, Jan 2020 to 20, Jul 2020. Estimated model: $P_{\text{max}} = 1199.097 + 11.851$ Temperature. Based on 95.0% Confidence Interval for B the prediction of $P_{\text{max}}$ is 95% from 924.738 + 3.975 Temperature to 1473.456 + 19.726 Temperature

Table 13. Coefficients Maximum electricity demand ($P_{\text{max}}$) with Temperature

| Model    | Unstandardized Coefficients | Standardized Coefficients | 95.0% Confidence Interval for B |
|----------|----------------------------|---------------------------|--------------------------------|
|          | Std. Error  | Beta  | t    | Sig.  | Lower Bound | Upper Bound |
| 1 (Constant) | 1199.0 | 139.135 | 8.618 | .000 | 924.738 | 1473.456 |
| Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020. | 11.85 | 3.994 | .205 | 2.96 | .003 | 3.975 | 19.726 |

a. Dependent Variable: Daily Maximum power demand ($P_{\text{max}}$) in GWh

Charts

Figure 8. Histogram standardized residual of $P_{\text{max}}$.  
Figure 9. Normal P-P plot standardized residual of $P_{\text{max}}$. 

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5.4 Maximum Power demand ($P_{\text{max}}$) versus Temperature and Humidity

R column value .209 represent for the quality of prediction of dependent variable for 20.9%; Maximum Power demand ($P_{\text{max}}$) is not a quite good level of prediction. From the value of $R^2 = .044$ mean that Daily temperature in Cambodia and humidity can explain only 4.4% of maximum electricity demand.

### Table 14. Model Summary of Maximum Power demand ($P_{\text{max}}$) Versus Temperature and humidity

| Model | R    | $R^2$ | Adjusted $R^2$ | Std. Error |
|-------|------|-------|----------------|------------|
| 1     | .209 | .044  | .034           | 129.191    |

a. Predictors: (Constant), Daily Humidity from 01 Jan, 2020 to 20 Jul, 2020, Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020.

b. Dependent Variable: Daily Maximum power demand ($P_{\text{max}}$) in GWh

ANOVA test to see whether entire model is good for the data. See (table 15.) Sig. = P-value = (0.012) < (0.05) so, temperature and humidity is significant relation for Maximum Power demand ($P_{\text{max}}$).

### Table 15. ANOVA for Maximum Power demand ($P_{\text{max}}$) Versus Temperature and humidity

| Model | Sum $^2$ | df | Mean $^2$ | F | P-value |
|-------|----------|----|-----------|---|---------|
| 1     | Regression | 151208.919 | 2 | 75604.459 | 4.530 | .012b |
|       | Residual  | 3321401.150 | 199 | 16690.458 |          |       |
|       | Total     | 3472610.069 | 201 |          |         |       |

a. Dependent Variable: Daily Maximum power demand ($P_{\text{max}}$) in GWh
b. Predictors: (Constant), Daily Humidity from 01 Jan, 2020 to 20 Jul, 2020. Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020.

See (Table 16) Coefficients for prediction daily Maximum electricity demand ($P_{\text{max}}$) from temperature and Humidity from 01st, Jan 2020 to 20th, Jul 2020. Seeing separately in the test of temperature and humidity respectively tell us that temperature factor has P value (0.03) < (0.05) is significant. However, for variable humidity P value (0.593) > (0.05) is not significant. This mean that humidity factor is not necessary for this model anymore. There no affecting to daily Maximum power demand. Estimated model: $P_{\text{max}} = 1076.509 + 12.077 \text{ Temperature} + 1.541 \text{ Humidity} + 129.191$. Based on 95.0% Confidence Interval for B the prediction of $P_{\text{max}}$ is 95% from 547.951 + 4.143 $\text{Temperature} - 4.134 \text{Humidity}$ to 1605.068 + 20.011 $\text{Temperature} + 7.215 \text{Humidity}$.

### Table 16. Coefficients Maximum electricity demand ($P_{\text{max}}$) with Temperature and humidity

| Model | Unstandardized Coefficient | Standardized Coefficient | 95.0% Confidence Interval for B |
|-------|---------------------------|--------------------------|--------------------------------|
|       | B (Constant)              |                          |                                |
| 1     | 1076.509                  | 268.038                  | 547.951 1605.068              |
|       | 12.077                    | 4.023                    | 4.016 3.002                   |
|       | 1.541                     | 2.878                    | .535 .593                     |

a. Dependent Variable: Daily Maximum power demand ($P_{\text{max}}$) in GWh
See table 17. The relation between Daily Maximum temperatures Daily Humidity from 01 Jan, 2020 to 20 Jul, 2020 Pearson’ r is negative correlation -.105. Meaning that, whenever amount of temperature keep increase changes in variable humidity decreases. And correlation is not significant with Sig. = .137.
Table 17. Correlation between Daily Maximum temperature and Daily Humidity from 01 Jan, 2020 to 20 Jul, 2020

|                              | Daily Maximum temperature from 01 Jan, 2020 to 20 Jul, 2020. | Daily Humidity from 01 Jan, 2020 to 20 Jul, 2020. |
|------------------------------|---------------------------------------------------------------|----------------------------------------------------|
| Daily Maximum temperature    | Pearson Correlation: 1                                        | Sig. (2-tailed): -.105                             |
| from 01 Jan, 2020 to 20 Jul, | N: 202                                                         | Sig. (2-tailed): .137                              |
| 2020.                        |                                                               | N: 202                                            |
| Daily Humidity               | Pearson Correlation: -.105                                    |                                                   |
| from 01 Jan, 2020 to 20 Jul, | N: 202                                                         |                                                   |
| 2020.                        |                                                               |                                                   |

6. CONCLUSION

From putting all the results together, it could write to sum-up of regression and multi regression analysis. It was run to predict annual Electricity Demand delivered in GWh. According to both factors; the annual GDP of Cambodia and annual total new consumer connections were added statistically significant to the prediction. The highest contributing predictor is the total new consumer connection. The value of $R^2 = .995$ means that the GDP of Cambodian and increasing of total new customer connection can explain 99.5% of electricity demand. So, there was only a very small amount of percentage caused by other factors than the predictor of this model. Secondly, the model was to predict daily Maximum power demand ($P_{max}$) out of two independent variables, temperature and humidity, only temperature was significant with $P$-value < 0.005, the value of $R^2 = .042$ mean that temperature in Cambodia can explain only 4.2% of maximum electricity demand. Thus, around 95% probably caused by other factors like GDP, demographic, technological, or government of Cambodia policy to reduce electricity price than a predictor of the model. However, humidity $P$-value > 0.05, has, therefore, no substantial contribution in explaining the Maximum power demand ($P_{max}$). Finally, whether the estimated model has been created to predict electricity demand in Cambodia in the future, there will be more micro-factors; for instance, force major which cannot be advance predicted. So, the confident interval of 95% from the lowest to the highest future demand may help predictor to control risks.

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