Estimating Electricity Consumption in the Commercial Sector of Nigeria's Economy

O Y Usman, M K Abdullah, A N Mohammed

Abstract: ***The level of electricity consumption in the commercial sector of Nigeria's economy has been increasing due to expanding economic opportunities in both urban and rural areas. The purpose of this study was to identify the notable variables dictating the volume of electricity consumption in Nigeria's commercial sector and use multiple linear regression analysis technique to model and forecast future energy demands in the sector. Seven explanatory variables were initially selected, out of which stepwise regression technique was used to select the best subset of model variables consisting of temperature, rainfall, total electricity delivered, total primary energy and relative humidity. Annual time series data covering a period of 1990 to 2014 was used for the study. The developed model has a coefficient of determination, R2, of 98.6% and a probability value of 2.2 x 10-16 and it shows appreciable capacity for predicting the observed values with a root mean square error of 176.12. The study suggests that the huge influence of rainfall, total electricity generated, total primary energy and population on electricity consumption in the sector should be given considerable attention in formulating concrete energy policy and power plant design for the purpose of guaranteeing sustainable energy supply.***

Index Terms: ***Commercial sector, Electricity consumption, Forecasting, Linear Regression, Variables.***

I. INTRODUCTION

The increasing socio-economic developments Nigeria is witnessing is greatly redefining the boundary conditions of her electricity consumption. Principal economic sectors delineated based on intensity of electricity consumption in Nigeria are the industrial, residential and commercial sectors, respectively. The commercial sector of any nation's economy is one of the key sectors responsible for such nation's overall wellbeing [1],[2] ,[3]. In Nigeria, electricity is the biggest infrastructure problem to the commercial sector owing to the erratic and unreliable nature of supply from the national grid [4]. However, the commercial sector is rapidly growing due to expanding economic opportunities in both urban as well as rural areas; and that requires a commensurate supply of electricity to support and sustain the sector in order to achieve the much-needed socio-economic development. Hence, understanding the key variables driving demand for electricity in the sector is crucial from the viewpoint of sustainability, demand management, forecasting and analysis of energy policy. Specifically, ascertaining the extent to which the demand for electricity in the commercial sector is particularly influenced by each identified key variable is a significant operation concern for electricity generation architecture operators, electricity market operators as well as energy policy makers.

Furthermore, combating the high level of unemployment among the teeming youths and able-bodied individuals in the country by promoting small scale commercial enterprises in addition to the government's determination to revive agro-allied commercial businesses will certainly increase the demand for electricity in the sector. This is against the backdrop of the fact that small and medium scale enterprises are globally recognized as catalysts for sustained, rapid and massive economic growth of any nation. Consequently, deter-mining the future electricity demand trajectory in the sector is strategic for capacity planning bearing in mind environmental concerns.

Generally, electricity generation and supply to all sectors in the country have been erratic and unreliable. As a result, several key players in the commercial sector have been forced to reduce their dependence on public power supply by employing privately generated electricity for sustaining their operations. Presently, it is difficult to access data on self-electricity generation in the country, and as such this study focuses on the trend of total annual electricity demand as a whole and not electricity consumption by various sub-sectors in the sector. In view of the recent reforms embarked upon by Nigerian government in the power sector christened "Electric Power Sector Reform" aimed at guaranteeing access to adequate and reliable electricity supply by the citizens, it becomes imperative to obtain accurate estimates of variables that dominantly drive electricity consumption for the purposes of demand and supply projections. The aim of this study is to ascertain the salient motivating factors responsible for commercial sector electricity demand as well as their potent empirical influences on present and future energy use in the commercial sector.

The aim of this study is to determine the salient factors motivating commercial sector electricity consumption as well as their potent empirical influences on present and future energy use in the commercial sector. The remainder of our study is arranged in this wise: Section 2 reviews previous study on commercial sector electricity consumption forecasting. In section 3, we discuss the method and data used in the study. In section 4 we present the formulation and evaluation of the proposed model. In section5 the future values of electricity consumption in the sector areforecasted based on the proposed model. In section 6, the conclusions of the forecasting exercise are summarized and the implications for energy policy

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formulation and implementation are discussed.

II. LITERATURE REVIEW

A number of previous studies have analyzed electricity demand in Nigeria. Whereas some of them have focused on the residential sector's electricity demand[5], [6], [7], [8], [9] and [10].others dwelt on the nexus between electricity connection and economic growth [11], [12], [13] and [14]. A few other studies examined specifically the power sector[15][16], [4], [17][18], [19]and [20].Oseni [6] studied household's access to electricity and energy consumption pattern in Nigeria. The study reported that a greater proportion of Nigerian household lack credible access to electricity. Despite the fact that several households are used for various commercial activities in the country, the author did not beam the rays of the study on the commercial sector. Similarly, Ibitoye [8] examined the millennium development goals and household energy requirements in Nigeria. Akinlo [11] investigated electricity consumption and economic growth in Nigeria using evidence from cointegration and co-feature analysis. The study recommended that investing more as well as reducing currently observed inefficiencies in electricity supply and consumption has the potential to further arouse economic growth. These studies, as well, did not define the parameters to be checked in order to keep electricity consumption at a sustainable level while boosting economic growth.

However, for commercial electricity demand, Oluseyi, et al. [1] assessed energy consumption trend and carbon footprint from the hotel industry within Lagos, Nigeria. The study modeled energy use so as to evaluate its impact on the level of diesel generators' emission of harmful gases into the environment, in the context of the fact that diesel generators constitute a significant source of electricity in Nigeria. The paper recommended urgent need to mitigate the carbon footprint in Nigeria's hotel industry as well as other commercial buildings. The study, also, while examining the trend of electricity consumption did not capture the key drivers of electricity consumption in the sector.

Several electricity forecasting models using variables ranging from economic, demographic, climate, technical to social variables have been formed and analyzed in both developed and developing countries.[21], [22, 23], [24], [25], [26], [27], [28]. These models are as varied as the time horizon of the forecast, the purpose of the forecast and the nature of available data. There are available both single and multiple equation techniques for forecasting time series variables, in which case one or more inputs are adjusted to forecast the future value of a variable [3]. Bianco, et al. [29], Bianco, et al. [30] used multiple linear regression technique to forecast electricity consumption in Italy.

Sandels, et al. [31] developed a model to predict day-ahead electricity consumption in a Swedish office building using weather, occupancy, and temporal data. They produced linear models between the predictors and the regressands in a step wise function, and employed the models developed to predict the consumption levels with day-ahead forecast data on the predictors.Günay [32] modeled the annual gross electricity demand of Turkey using multiple linear regression and artificial neural networks employing a data for the period between 1975 and 2013. The model was thereafter used to forecast the annual gross electricity demand for the future years, up to 2028.

Recent study on commercial sector electricity consumption using multiple linear regression analysis has proved useful in understanding the correlation between electricity consumption and identified main factors inspiring electricity use. Such factors constitute the core pillars in developing a forecasting model. However, the common difficulty in generating credible forecasts is the determination and access to adequate and required data for reliable prediction [29]. This difficulty is responsible for the use of simpler models such as multiple linear regression models in this study since they are proficient in handling smaller volume of data, they are less difficult to manage and their outputs could beused as inputs for the more complex models which are known to have capacity to handle larger datasets and can analyze non-linear equations[33], [34], [21].

III. DATA

A. Data Sources

This study used secondary data of electricity consumption for the period of 1990–2014 gotten from the International Energy Agency (IEA) and Nigeria's National Bureau of Statistics (NBS) to estimate the electricity demand forecast. Data obtained from the IEA include the country's population, total primary energy and total electricity generated and gross domestic product. The data on the annual rainfall and relative humidity were sourced from the Annual Abstracts of Statistics published by NBS. These variables were chosen from various literature reviewed and they were found to be compatible with and relevant to the country's energy experience.

B. Data Inspection and Cleaning

A data table was prepared for all the time series data collected. That was necessitated by the need to inspect all the data in order to ensure that all the values were properly represented and that there are no cases of invalid or missing values; or the presence of outliers which could lead to misleading inference at the end. Cases of missing values were treated using multiple imputation by chained equation (MICE). 'R' statistical software, employed in the entire data analysis, was used to show the pattern of missing values for all the variables having missing values.

IV. METHODOLOGY

The modeling and forecasting approach followed in the study are detailed in the succeeding sub-sections.:

A. Assessment of the Relationships Between the Variables

The complete table of variable produced after missing values were imputed was used to generate scatterplots of the variables with the aim of looking out for the presence and nature of linear relationships between the variables. Also, the Pearson's correlation matrix of the variables was produced to show the correlation coefficients for the variables. Correlation coefficients are very helpful in defining the numerical strength of any existing relationship between pairs of the variables, which gives indications on the presence (if any) and acuteness of multi-collinearity.

B. Initial Model Fitting

Commercial sector electricity consumption data, as dependent variable, was regressed on the selected predictor variables with the aim of determining their statistical significance as the basis for their inclusion in further analysis. Parameters of the variables and the model such as the probability value (p-value)and the coefficient of determination, (R^2), were used to evaluate the statistical significance of the variables and the fitted model.

C. Model Variable Selection

In order to select the best subset of variables for model development, all the variables used for initial model fitting, despite their various p-values, were exposed to further selection test. This further test was imperative to ensure that no candidate variable that contributes significantly to the variability of the commercial sector's electricity consumption was prematurely eliminated from the analysis. The model variable selection exercise was carried out using stepwise regression technique based on Akaike Information Criterion (AIC).

D. Final Model Fitting

The selected optimum subset of variables was used to fit the model that would become the anticipated model for predicting of the values of the observed residential electricity consumption. The product of the regression analysis was evaluated so that the statistical significance of the generated model and the contributions of each variables to characterizing the variability of the dependent variable will be ascertained.

E. Electricity Consumption Prediction

The suitability of the developed model for use in predicting the observed consumption values was further assessed by considering the root mean square error (RMSE) in addition to the other parameters such as the p-values and R^2 of the developed model. The more approximately the developed model predict the observed consumption values, the more suitable it will be for forecasting the future values of the dependent variable. So, the value of RMSE provided additional justification for the acceptance or rejection of developed model.

F. Forecasting

Preceding the use of the developed model to forecast the future values of electricity consumption in the residential sector, the multiple linear regression assumptions of linearity and homoscedasticity were tested. A model that fails to satisfy these assumptions would be deemed to be unsuitable as they are capable spurious results. When it was confirmed that these assumptions were satisfied by the model, it was later used to forecast the sector's future electricity consumption profile. Firstly, the point forecasts of all the variables were done and their values were used to forecast the sector's electricity consumption values. The implications of the forecast values for policy, practice and further studies were thereafter stressed.

V. V. RESULTS AND DISCUSSION

A total of eight independent variables were initially selected to be used in the modeling and forecasting exercise. When the variables' table was prepared, it was discovered that HHS, TEMP and TARIF were having some missing values. The pattern of missing values in the variables' table is shown in Table 1.

Table 1: Variables pattern of missing values

Variables	No. of missing data
CEC	0
RFALL	0
GDP	0
TEG	0
TPE	0
POP	0
TEMP	11
RH	12
ELEC PRICE	20
Sum of missing data	43

Table 1 shows that whereas TEMP and RH have 11 and 12 missing values respectively, ELEC PRICE alone missed about half the total number of the missing observations. And because the missing values of ELEC PRICE could not be imputed by means of the multiple imputation by chained equation (MICE), that variable was eliminated from further analysis. Consequently, a complete table of variables without any case of missing values or outlier was obtained.

The strengths and directions of the linear associations shown in the correlation coefficients are moderately significant in some cases. However, those values did not demand outright exclusion of any of the sets of the variables. This is because further eliminations will still be carried out while undertaking selection of the best subset of candidate variables for the model. Besides, their inclusion in the stage of model selection has no deleterious implications on the electricity consumption modeling process. In addition, the values of most of the correlation coefficients of the linear relationships between the variables are not outrageous.

The output of the primary model fitted using all the initially selected variables is shown in Table 2.

Table 2. Output of primary model fitting

Variables	Coefficients	Std. error	p-value
Intercept	-7.676e+03	3.960e+03	0.06936.
TEMP	1.398e+02	8.148e+01	0.10446
RH	2.747e+01	2.629e+01	0.31067
RFALL	2.422e-01	1.429e-01	0.10829
GDP	-2.889e-01	3.252e+00	0.93026
TEG	9.517e-02	2.528e-02	0.00155 **
TPE	6.400e+01	2.351e+01	0.01447 *
POP	-1.801e+01	2.075e+01	0.39767
Model Adequacy parameters			
Multiple R-squared	0.987		
Adjusted R-squared	0.982		

The result indicates that out of the seven variables considered, only TEG and

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TPE were considerably statistically significant going by their probability values. And as such they were chosen to be used for further analysis. The developed model's multiple coefficient of determination, (R^2), and probability values are highly statistically significant. Nonetheless, a further logical approach, known as model variable selection, was applied in selecting the best subset of variables considered suitable to produce the desired appropriate model. The choice of the candidate subsets was based on Akaike Information Criteria (AIC).

Stepwise regression analysis technique was used in undertaking the model's variable selection. The result of the variable selection (Table 3) indicates that of the seven independent variables originally selected for the study, only TEMP, RH, RFALL TEG and TPE are statistically significant for use in modeling the sector's electricity consumption.

Table 3. Result of model's variable selection

Variable subsets	AIC
TEMP, RH, RFALL, GDP, TEG, TPE, POP	274.56
TEMP, RH, RFALL, TEG, TPE, POP	272.57
TEMP, RH, RFALL, TEG, TPE	271.88

It is remarkable to observe that if the model variable selection did not go beyond the initial model fitting, TEMP, RH and RFALL would have been inadvertently excluded from the analysis. The consequence of such untimely elimination of relevant variables would have been an incomprehensive conclusion.

The results of the final model fitting using TEMP, RH, RFALL, TEG and TPE as independent variables is presented in Table 4.

Table 4. Result of the sector's final model fitting

Variables	Coefficients	Std error	p-value
Intercept	-9.476e+03	3.292e+03	0.009617
TEMP	1.633e+02	7.536e+01	0.043193
RH	4.030e+01	2.194e+01	0.081934.
RFALL	2.325e-01	8.526e-02	0.013387
TEG	9.616e-02	2.091e-02	0.000196
TPE	4.229e+01	5.903e+00	8.3e-07
	Model Adequacy parameters		
Multiple R-squared	0.9863		
Adjusted R-squared	0.9826		
p-value	< 2.2e-16		

The result of the regression analysis suggests that energy consumption is highly significantly affected by temperature such that, holding all other explanatory variables constant, one-degree Celsius increase in temperature would induce an increase of 163.3 GWh in annual demand for energy consumption in the sector. This tremendous influence can be attributed to the air conditioning needs of commercial/ services sector which fluctuates with the extant weather conditions. Consequently, air conditioning systems would experience higher cooling loads, for any unit change in temperature, in order to restore the temperature of the area being air-conditioned to satisfying levels. This result is consistent with the earlier findings reported in literature [35], [36].

Relative humidity, as a climatic variable, was shown to be statistically insignificant in influencing the volume and rate of energy consumption in the sector. Ordinarily, as temperature increases, relative humidity decreases, so long as there is no addition of moisture. In this study, the result of the regression shows that both temperature and relative humidity positively influences energy consumption in the commercial sector. However, the respective coefficients of the variables show that temperature has far higher influence on energy consumption than relative humidity. That means that electricity consumption in the country's commercial sector depends more on temperature than relative humidity. This result is in agreement with the findings of previous studies in other countries, for instance [37], [38].

The impact of rainfall on energy consumption in the country's commercial sector, though mild, has direct influence on other variables such as temperature and relative humidity. Rainfall lowers the ambient temperature and increases the relative humidity. The result of the regression analysis shows that, holding other explanatory variables constant, a unit increase in the amount of rainfall would lead to about 0.23 (GWh) increase in the amount of electricity demanded in the sector.

The total electricity generated (TEG), according to the regression output, has a weak positive influence on commercial sector's electricity consumption. One GWh increase in the total electricity generated leads to 0.096 increase in the sector's electricity demand. This apparent insignificant numerical impact of the total electricity generation is largely due to the widespread use of all sorts of diesel generators for self-power generation in order to make up for the inadequate and unreliable electricity supply by the grid operators. This inadequate total electricity generated has been due to the long sessions of both underinvestment and poor planning for electricity infrastructure.

Often times, electricity generation is undermined by gas constraints since most of the plants are thermal based. As at 2005, the installed electricity generating capacity stood at 6500 MW, but only 3959 MW could be supplied due to the ageing power plants, poor maintenance and lack of funds [4]. According to [39] the average power generation in Nigeria was 3200 MW as of November 2011.

As reported by the "Advisory Power Team" under the office of His Excellency, the Vice-President of the Federal Republic of Nigeria, on 'Daily briefing on the Nigerian Power Sector', the average hourly energy sent out daily by the grid power suppliers stood at 3,803 MWh/h on 15th October, 2018. This, by all standard, is grossly inadequate for only the industrial sector energy needs of the country, not to talk of other sectors. Knowing that the total energy generated by a plant is directly linked to the variable cost of the plant's power units and to the inherent vicissitudes of fuel prices on the international markets; increasing electricity generation to meet both local needs and for export, demands that huge amount of the country's money be invested in the power sector in order to boost the economy.

Total primary energy resources utilized within the period under review was shown to be statistically significant. A GWh increase in the total primary energy consumption would lead to 42.29 GWh increase in electricity consumption in the sector. Nigeria, as a country, is enormously endowed with great primary energy resources such as coal, natural gas, oil, hydro and other renewable energy sources. The country, like several others, produces electricity from primary energy

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sources particularly, hydro and gas. Proportionately, electricity from hydro accounts for only 25% of the total electricity generation, while thermal plants which dots the country's landscape produces the balance of 75%. Over dependence on primary energy resources for meeting energy needs portends grave and irreparable consequences on the environment and human society.

A considerate reduction in primary energy consumption in the sector, characterized by reduction in the consumption of oil, natural gas and biomass, would lead to a substantial decrease of carbon emissions, which would, no doubt, have huge positive impacts on the environment, thereby benefitting the entire nation in addition to sustaining the sector [40]. Alongside the commercial sector, the building sector offers significant opportunity to reduce primary energy consumption (natural gas or fuel oil) through implementation of various energy efficiency measures [41]. Therefore, the country's energy policy makers need to put in place relevant policy options that enforces the security of energy supply by decreasing primary energy consumption thereby enhancing environmentally friendly energy consumption habit.

Having satisfied that the developed model is substantially statistically significant, it was used for predicting the future electricity needs of the sector. Prior to the prediction, the assumption of normality was assessed using a Q-Q scatterplot (see Figure 1). The assumption of normality was met as most of the points did not deviate strongly from the normality line.

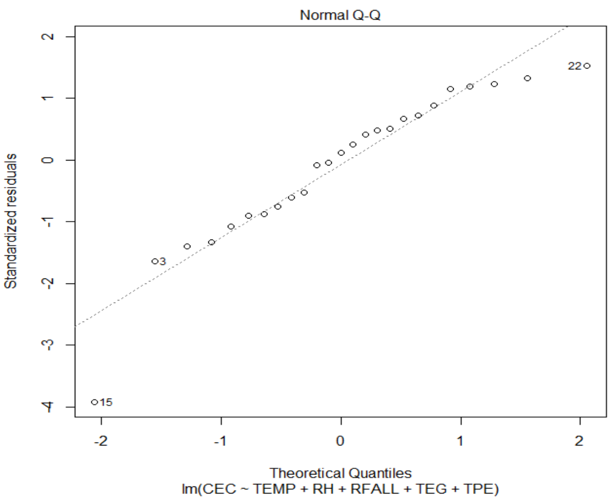

Fig. 1. Q-Q plot

Similarly, the assumption of homoscedasticity was also assessed with a residuals plot (see Figure 2). The rectangular array of the points' distribution shows that the assumption is satisfied by the model since the points did not fan out.

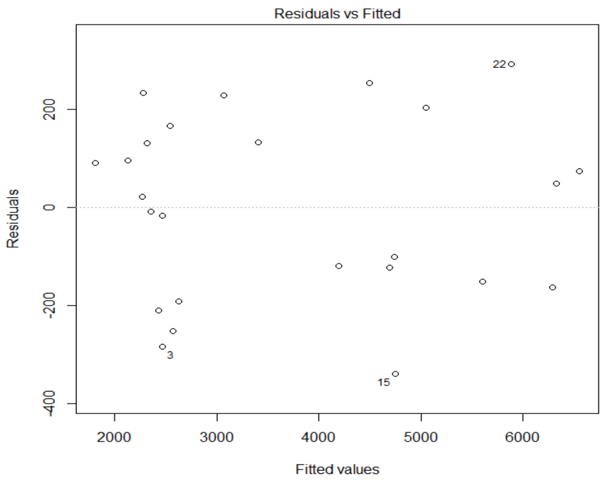

Fig. 2. Residuals plot

The plots of the observed and predicted values of the commercial sector electricity consumption is shown in Figure 3. The figure shows that the two plots are very close implying that the developed model has satisfactorily modeled the observed electricity consumption in the sector. The root mean square error of these plots was computed to be 176.12

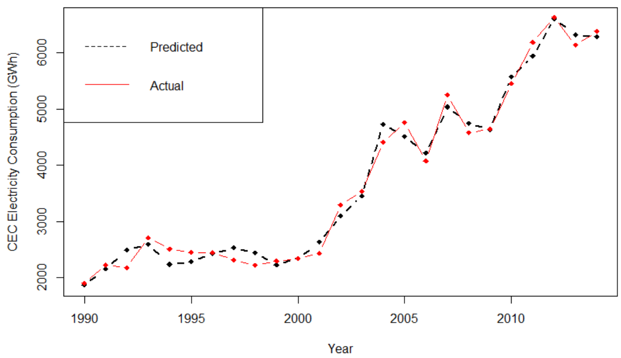

Fig. 3. The plot of the predicted and observed commercial sector electricity consumption values

The plot of the medium-term forecast of the commercial sector's electricity consumption is shown in Figure 4. Just like the point forecasts of most of the explanatory variables that were used to generate the sector's forecast, the future electricity consumption trajectory shows an upward trend, implying a growing pattern in the amount of electricity that will be required in the sector in the coming years. The forecast shows an annual electricity demand growth of 246.78 GWh. The electricity consumption is indicated to rise from 6773 GWh in 2015 to 8994 GWh in 2024 (Table 5).

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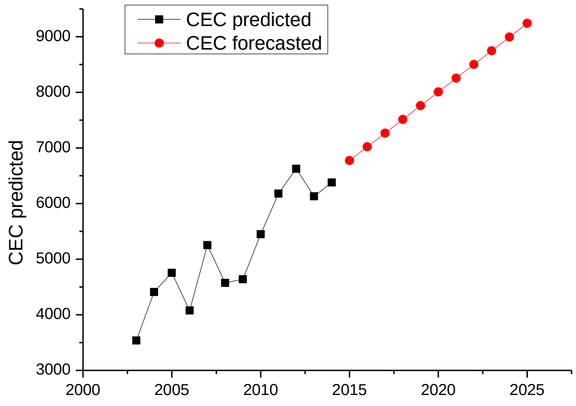

Fig. 4. Plot of sector's mid-term forecast

Table 5. Commercial sector's mid-term electricity consumption forecast values

Year	Electricity Forecasted (GWh)	Year	Electricity Forecasted(GWh)
2015	6773	2020	8007
2016	7020	2021	8254
2017	7266	2022	8501
2018	7513	2023	8747
2019	7760	2024	8994

VI. V. CONCLUSION

This paper set out determine the fundamental drivers of electricity consumption in the commercial sector and then used those consumption drivers to forecast electricity demand for commercial sector in Nigeria for the period from 2015 to 2035. The variables analysed are commercial electricity consumption, temperature, rainfall, total electricity given, total primary energy and relative humidity. Observed data frame from 1990 – 2014 was used. The regression equation formulated for these data was used to estimate the consumption as well as the regression coefficients of the predictors. A plot of the actual or observed and predicted consumption values are acceptably close and the root mean squared error (RMSE) value is 176.11. Each predictor was then forecasted and their point forecasts were later used to forecast the commercial sector's future consumption values. The forecasted values indicated a considerable increase in commercial electricity consumption in the years ahead. This finding prompts the following conclusions:

1. From the analysis of the model, it is imperative to consider rainfall, total electricity given, total primary energy and population as significant explanatory variables in forecasting models for Nigerian commercial sector electricity consumption.
2. Electricity price and relative humidity do not significantly induce electricity consumption in the commercial sector, in this given instance.
3. Consequently, there is need to intensify electricity generation in the country, taking advantage of all available renewable energy resources in order to accommodate the influence of rainfall on the demand for commercial electricity. This is very important given the link between rainfall, agriculture and commerce in the country.
4. In addition, a considerable increase in commercial electricity use driven by increase in population should be expected in the country.

It is believed that the model, electricity consumption forecasts and recommendations set forth in this paper would be important aids to operators of power utilities, energy policy makers as well as energy market operators in building outlines of future electricity demand in the nation's commercial sector.

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