# Statistical Analysis of Electricity Generation and Consumption in Ghana

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Abstract: Ghana is now experiencing power shortages and regular interruptions in supply as a result of increase in electricity consumption and rapid growth of cities and population, much of which is driven by rural-urban migration. Regular power interruptions are of great concern and have serious effects on economic growth and productivity. The limited amount of electrical power in Ghana suggests that prevention strategies based on power control should be a central feature of the country's electricity control programs. The power shortages has led many people, organizations, companies and factories in the Ghana to rely on very costly generating plants as immediate remedy to the prevailing crisis. This situation requires among other things proper and urgent attention. Surprisingly, the frequency of occurrence of the problem of power shortages and regular interruptions of supply has not been well attended to by the Governments and other stake holders in Ghana. This paper discusses the association between the electricity consumed, the electricity generated and the population of Ghana and suggests a new concept on the nature and direction of reforms in the electricity generation using statistical analyses. The technique is very important as it will assists Governments and other stake holders in Ghana to be more aware of the consumer's energy usage patterns in real time, and provides directions that will help to achieve some increment in the average energy generation. The GDP Data from 2001 to 2012 obtained from World Bank National Account website was subjected to statistical analyses. The statistical techniques employed include regression, hypothesis test, ANOVA test, k density test, normality test, linktest, ovtest and acprt plot test. The electricity generated, the electricity consumed and the population were statistically tested for significance using ANOVA test. The results revealed that the electricity generated is better associated with the electricity consumed than the population of the country.

Keywords: ANOVA Tests, Kdensity tests, linktest, ovtests, Electricity Consumption, Electricity generation, population.

## **1. Introduction**

The concept of energy which was introduced by Leibniz emerged from the idea of vis viva. Surprisingly, Thomas Young was the first to use the term "energy" in its modern sense, instead of vis viva in his lectures to the Royal Society in 1802. (www.wikipedia.com, 2014). The idea of electricity was developed some years ago by a group of scientists who worked on an idea that would have impact on how people would use energy in their homes, offices, organizations, and factories. This invention finally led to the use of electricity from power plants and transmission lines to the needed places. (www.energy.Gov). The electricity industry in Ghana is dominated by three companies. Volta River Authority (VRA), Electricity Company of Ghana (ECG) and GRIDCO. VRA is the main generation and transmission company. The ECG and the GRIDCO are two subsidiaries of VRA which are responsible for power distribution (RCEER, 2005 and Gnansounou et al., 2007).

Ghana has suffered from endemic power outages as a result of limited power generation for many years. The electricity generation as well as consumption in Ghana has worsened during recent years despite Government's serious efforts to construct new electric power stations and transmission facilities. Unlike most consumer goods, electric energy has no shelf life and cannot be packaged and stored by a retailer until the time that the consumer is ready to purchase it. Indeed, it is impossible to store it in tanks or pipelines to improve the supply when demand is high. Electricity is produced in real time as customers demand it. Therefore, it is imperative for electricity producers to ensure that enough electricity is always available to meet the needs of consumers. Ghana has enough energy resources but it has become very challenging for the country to generate the required energy to meet the need of its people. The contributing factors to these challenges are numerous but one major challenge is the inability of the technocrats as well as the Government officials to look into the future by considering the fact that Ghana's population is growing and therefore needs expansions in the existing electricity infrastructures. Ghana's population has experienced a steadily growth since 1950. From 1950 to 20014, the population has increased from 5,243 to 26,562. A United Nations report has projected that Ghana would have a population of 33 million people by 2030. ( http://www.worldbank.org/afr/wps/wp110.pdf). This is an indication that serious efforts must be put into the expansion of electricity generation infrastructure in the country.

Electricity consumption patterns have changed over the years as the country kept on developing from stage to stage. Furthermore, industrialization and increased urbanization in Ghana has changed consumer's uses of electricity. However, very little is done in the field of electricity generation. There is still a large gap between the present trend of electricity generated and the electricity consumed.

Due to low electricity generation various communities in different regions in Ghana which are yet to be connected to the national grid. The use of electricity resumed growth steadily from the time Ghana gained her independence, but the expansions in the existing electrical infrastructures continued to remain stand still. Though some reforms in the electricity industry have gradually been undertaken under the initiatives of both Government of Ghana and other foreign allies, more needs to be done to improve consumers' demands. Indeed, in Ghana the overall pattern of electricity generation has remained fairly unstable for the last decade. The insufficient electricity consumption coupled with increased number of electricity supply interruptions are as a result of the mode of power production. Ghana relies mostly on hydro power and fuel for its electricity generation. The hydro power is subjected to strong multi-annual variability because of fluctuating hydrological conditions whilst oil price surge on the international market makes the procurement of fuel very difficult. These situations coupled with other factors have impacted strongly on Ghana's electricity generation.

The increase in population, electricity consumption and its generation are variables that may influence each other. However, at this time, it is not clear whether the electricity generation and the population of Ghana are really significant contributors to the electricity consumption in Ghana. In this paper population data, electricity generation and consumption were subjected to statistical analysis to determine the significant contributor. It finally tests the two independent variables individually and identifies among them, the one which is the significant predictor of the dependent variable.

## 2. Methods

The GDP data obtained from World Bank National Account website (was subjected to statistical analyses. SPSS and Stata 11 software packages with bivariate comparisons were used. The data entails electricity generated, electricity consumed and the population of Ghana from 2001 to 2012. Data interpretation was carried out using, regression, hypothesis test, ANOVA, k density test, normality test and acprt plot test.

# 3. Statistical Analyses

The information on the total electricity generated, total electricity consumed and the population with their respect to the years was extracted from the GDP data of World Bank National Account website. The SPSS and Stata 11 software packages were used to carry out statistical analyses on all the variables. The variables considered are tec(gwh), teg(gwh) and pp(million). These measure the total electricity consumed in Giga watt hour (tecgwh), total electricity generated in Giga watt hour (teggwh) and total population in millions pp(million).Table 1 shows the summary of the information from the GDP data of World Bank National Account.

Table 1: Summary of total electricity generated, total
electricity consumed and population of Ghana from 2001
to 2012

Year	Total Electricity	Total Electricity	Population
	Generated (GWh)	Consumed (GWh)	(million)
2001	7,859	7,149	19.4
2002	7,273	6,829	19.8
2003	5,882	5,241	20.3
2004	6,039	5,299	20.8
2005	6,788	5,964	21.3
2006	8,430	7,362	21.8
2007	6,978	6,441	22.3
2008	8,324	7,219	22.9
2009	8,958	7,452	23.4
2010	10,167	8,317	24.7
2011	11,200	9,187	25.3
2012	12,024	9,258	25.9

Source: GDP Data from World Bank National Account NB: Total Electricity consumed include Commercial losses

As one of the statistical analyses, this paper first seeks to build a linear regression model between the response variable total electricity consumed (tecgwh) and the independent variables total electricity generated (teggwh) and population (ppmillion) of a country. Table 2 displays the summary of ANOVA test by the software package.

 Table 2: Summary of ANOVA test of tec(gwh), teg(gwh) and pp(million)

Source	SS	df	MS
Model	18724642.7	2	9362321.37
Residual	458127.927	9	50903.103
Total	19182770.7	11	1743888.24

F (2, 9) = 183.92 Prob > F = 0.0000R-squared = 0.9761 Adj R-squared = 0.9708 Root MSE = 225.62

tecgwh	Coef.	Std. Err.	ţ	P> t	[95% Conf.	Interval]
teggwh	.7877	.0712481	11.06	0.000	.6265255	.9488744
ppmillion	-132.33	64.72002	-2.04	0.071	-278.7369	14.07682
cons	3538.555	972.4167	3.64	0.005	1338.796	5738.314

Enough information about the two independent variables, viz total electricity generated teg(gwh) and population Pp(million) of Ghana can be obtained by considering the scatter plots shown at Figs. 1a, 1b, 1c and 1d.

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Figure 1a: Scatter plot of teg(gwh)



Figure 1b: Linearity plot of teg(gwh)



Figure 1c: Scatter plot of Pp(million)



Figure 1d: Nonlinearity plot of Pp (million)

Whereas the residual versus predictor variable plots in Fig.1c and fig.1d show strong departure from linearity, Fig.1a and Fig.1b did not indicate any strong clear departure from linearity. The acprplot clearly displays both the nonlinearity and linearity of the predictor variables. Since Pp(million) is nonlinear there is the possibility that it is shift or skewed to a certain direction. We observed from the scatter plots the outliers of pp(million). These outliers are the very influential and worrisome in regression analysis and require proper attention. Fig. 2a and 2b continue to show linearity and nonlinearity using graph matrix.



Figure 2a Half graph matrix



Figure 2b: Full graph matrix

Volume 3 Issue 7, July 2014 <u>www.ijsr.net</u> Licensed Under Creative Commons Attribution CC BY The k density plot at Fig. 3a revealed that Pp(million) variable is skewed to the right. The normality of the residuals is clearly shown by the normal density plot which overlaid the initial plot as shown in Fig.3a. This situation suggests that Pp(million) variable must be transformed. One of such techniques is the log transformation of Pp(million) variable. Fig. 3b shows the graph of log Pp (million) which is the transformed Pp(million) variable.



Figure 3a: Normality plot of Pp(million) 1



Figure 3b: Normality plot of logPp(million) 2

Fig.3b shows how the transformation has reduced skewness. The normalized graph has smaller standard deviation as compared to the initial graph of pp(million).Therefore tec(gwh) was regressed on teg(gwh) and lgPp(million) to check the significance of the model using ANOVA test as shown in Table 3

 Table 3: Summary of ANOVA test of tec(gwh), teg(gwh)

 lgpp(million)

Source	SS	df	MS
Model	18708801 5	2	9354400.74
Residual	473969.18	9	52663.2422
Total	19182770.7	11	1743888.24

 $\begin{array}{ll} F(\ 2, \ 9) = \ 183.92 \\ Prob > F \ = \ 0.0000 \\ R-squared \ = \ 0.9761 \\ Adj \ R-squared \ = \ 0.9708 \\ Root \ MSE \ = \ 225.62 \end{array}$ 

tecgwh	Coef.	Std. Err.	ţ	P> t	[95% Conf	Interval]
teggwh	.7744124	.0686805	11.28	0.000	.6190463	.9297784
lgppmillion	2715.887	1404.337	-1.93	0.085	-5892.718	460.9434
cons	9118.132	3876.212	2.35	0.043	349.5299	17886.73

After the test, the problem of nonlinearity still persists as shown by the new acprplot in Fig. 4



Figure 4: Nonlinearity plot of logPp (million)

The directions of the pp (million) and teg(gwh) variables with respect to tec(gwh) is further checked using regression line. Fig.4a shows the downward trend of the regression line and its corresponding outliers. The value of the slope of the plotted line is the same as the coefficient of Pp (million). The populations for the years 2002, 2004, 2007 and 2012 are the potential outliers. The plot shows how the outliers influence the coefficient.

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Figure 4a: graph of tec(gwh) versus Pp (million)

Fig.4b shows how the regression line moved upwards trying to fit through all the data points. No year appeared as an outlier. From avplots of tecgwh against pp(million) in Fig.4a 2002, 2007 2012 and 2004 are the potential outliers and are very influential points in the analysis. Therefore, tec(gwh) can be regressed on teg(gwh) and pp(million) taking away these outliers from population observations. First of all let us regress all the variables together with the outliers.



Figure 4b: graph tec(gwh) versus teg(gwh)

Fig.4b clearly shows that as electricity generation increases the electricity consumption also increases. The validity of the association between tec(gwh) and teg(gwh) is further checked by using the model specifications. The stata command was used to test the model and the stata output is shown in Table 4

Table 4: Summary of ANOVA test of tecgwh teggwh

Source	SS	df	MS
Model	18511836.8	1	18511836.8
Residual	670933.916	10	67093.3916
Total	19182770.7	11	1743888.24

Number of obs = 12F(1, 10) = 275.91 Prob > F = 0.0000 R-squared = 0.9650 Adj R-squared = 0.9615 Root MSE = 259.02

tecgwh	Coef.	Std. Err.	t P> t	[95% Conf. Interval]
teggwh	.6603869	.039757	16.61 0.000	.5718028 .748971
cons	1644.402	339.3894	4.85 0.001	888.195 2400.608

#### linktest

Source	SS	df	MS
Model	18813058.3	2	9406529.15
Residual	369712.371	9	41079.1523
Total	19182770.7	11	1743888.24

Number of obs = 12F(2, 9) = 228.99 Prob > F = 0.0000 R-squared = 0.9807 Adj R-squared = 0.9764 Root MSE = 202.68

tecgwh	Coef.	Std. Err.	t	<b>P&gt; t </b>	[95% Conf.	Interval]
_hat	2.607123	.5953617	4.38	0.002	1.260321	3.953925
_hatsq	000107	.0000395	-2.71	0.024	0001965	0000176
_cons	-5853.222	2188.357	-2.67	0.025	-10803.63	-902.8145

. ovtest

Ramsey RESET test using powers of the fitted values of tecgwh

#### Ho: model has no omitted variables

F(3, 7) = 4.77Prob > F = 0.0408

**Table 5:** Summary of ANOVA test of tec(gwh) and pp(million) regress tecgwh ppmillion

11 .	, 0	0	11
Source	SS	df	MS
Model	12502799.7	1	12502799.7
Residual	6679970.93	10	667997.093

Number of obs = 12F(1, 10) = 18.72Prob > F = 0.0015  $\begin{array}{ll} \text{R-squared} &= 0.6518\\ \text{Adj R-squared} &= 0.6169\\ \text{Root MSE} &= 817.31 \end{array}$ 

tecgwh	Coef.	Std. Err.	t	P> t	[95% Conf.	Interval]
ppmillion	492.9951	113.9531	4.33	0.001	239.0917	746.8984
cons	-3862.781	2554.921	-1.51	0.161	-9555.499	1829.937

linktest

Source	SS	df	MS
Model	15034893.4	2	7517446.71
Residual	4147877.24	9	460875.249

Number of obs = 12F(2, 9) = 16.31 Prob > F = 0.0010 R-squared = 0.7838 Adj R-squared = 0.7357 Root MSE = 678.88

tecgwh	Coef.	Std. Err.	ţ	P> t	[95% Conf.	Interval]
_hat	-6.311085	3.125034	-2.02	0.074	-13.3804	.7582339
hatsq	.0005008	.0002136	2.34	0.044	.0000175	.0009841
_cons	26150.73	11242.39	2.33	0.045	718.6884	51582.77

. ovtest

Ramsey RESET test using powers of the fitted values of tecgwh

# 4. Results and Discussions

Statistical Analysis of the data gathered was used to determine whether the electricity generation and population of Ghana are really significant contributors to the electricity consumption in Ghana.

Table 2 indicated that electricity generation makes the best contribution to the electricity consumption in the study area. Though the model showed association between all the variables under consideration, thus, both the dependent and independent variables as justified by the Ftest at p = 0.000, it was not clear about the actual independent variable that serves as the significant predictor of the dependent variable. The R-squared value of 0.9761 indicates that 97.61% of the variation of electricity consumed is catered for by the model. An indication that 97.61% of the variation of electricity consumed is provided for by the amount of electricity generated and the population at that year. But the p-value of 0.077 (p=0.077) for the coefficient of population pp(million) shows that population was not significant. This was further confirmed by the coefficient of pp(million), thus -132.2. Statistically, it shows that for each increase in population, the electricity consumption in Ghana decreases by 132.2units. Thus, high population is related to lower electrical consumption. The result is misleading and consequently, seems to suggest that the population of the country cannot be a major factor for predicting electricity consumption. Statistically, it has been shown that the population of the country cannot always have positive relation with the electricity consumption. It may however, depend on the level of industrialization of the country. The coefficient for teg(gwh) is 0.7877 and the p-value is significant (p=0.00). This figure demonstrates that for every unit rise in electricity generated electricity consumption in Ghana increases by approximately 0.79 units (79%). This result makes some sense and this is what the study wants to look at. That is the more electricity is generated, the more the electricity is consumed.

It cannot be confirmed with 100% certainty that the results above are the true reflection of the situation on the ground. Therefore, other tests need to be carried out to be sure of these initial results. Fig.1a, 1b, 1c and 1d were used to standardize the predictor variables in the regression model and pp(million) variable was found to have a many outliers which has little effects on the model thus, confirmed by p-value in Table 2. This seems to suggest that population of a country is not a good predictor variable for electricity consumption. Fig. 2a and 2b also confirmed that the relation between tec(gwh) and Pp(million) is nonlinear. Since pp(million) is nonlinear there is the possibility that its effects on electricity consumption may be tilted to one side. An indication that the population may be dense but the electricity consumption may or may not be high depending on how industrialized the country is.

Fig.3a and 3b transformed the pp(million) variable into normal. Thus, the effect of skewness was reduced. The association between the population and electrical consumption was done to check whether the new result indeed correlates well with the response variable. Unfortunately, it was realized from Table 3 that the transformed pp(million) variable was not significant as shown by P- value of 0.085 (p=0.085). Table 3 confirmed that teg(gwh) was significant and it could be used to predict electricity consumed.

Fig.4a and 4b showed the downward and upward trend of the regression line and its corresponding outliers respectively. It was realized from Fig.4a that pp(million) variable was not a good predictor as a result of more potential outliers which virtually may influence the analyses.

Table 5 also goes to confirm that pp(million) was not a better predictor for electricity consumption. The variable of squared prediction represented by hatsq was not significant. Thus, the linktest failed to reject the assumption that the model was specified correctly. The ovtest showed that the p-valve was significant; therefore we reject the null hypothesis that the model has no omitted variables. This is an indication that the model has some omitted variable distribution.

# 5. Conclusions and Recommendations

The statistical analyses finally provided the following conclusions. All the tables and diagrams proved that Population of Ghana was not a reliable predictor for electricity consumption. Among the two predictors used for the analyses, there seems to be close association between total electricity generated and total electricity consumed. The linktest and ovtest rejected the null hypothesis that the model has no omitted variables. The analyses showed that about 97.61% of the variation of electricity consumed can be explained by the model. The kdensity plot was used to transform the population variable to normal but the results could not have any meaningful effect on the electricity consumption. The model was significant. Thus, from the statistical analyses electricity generation has close association with electricity consumption. Based on the study there is the need to increase electricity generation in Ghana since for every electricity generated 79% of it are consumed.

Based on the conclusions it is recommended that the Government of Ghana reinforce the electricity generation infrastructures by constructing new generation and transmission facilities. It is important that companies, factories, industries and most consumers install self electricity generating facilities to complement the electricity supply from the national grid. The obsolete electricity equipment must be frequently checked and replaced. Management and other stake holders should sensitize the consumers to switch off their deep freezers during the peak times to conserve electricity. Finally, as a short time measure, the Government should ensure that there is prompt availability of fuel for electricity generation even at the higher cost.

# 6. Future Scope

This research will help policy makers and other stake holders to properly address the issue of electricity outages in Ghana. It will enable the Governments to have a fair idea that the consumption of electricity depends strongly on industrialization of the country and not on the population of the country. The study also revealed the needs of sufficient electricity supply to make it possible for the consumers to enjoy optimum electricity which is crucial with respect to the improvement of the standard of living. The frequent power outages as a result of low electricity generation lead to job losses and finally increase the rate of unemployment. Its further creates high standard of living in the country, which of course increases social vices in the country. It is therefore imperative for the Government and other stake holders to effectively tackle the issue of electricity generation in the country to avoid any future problems. Believably, electricity creates a lot of employment. Its promotes proper ventures for the people in the country to enjoy good living, therefore, there is the need for the policy makers and other agencies to work together to provide effective, efficient and long-term plans that will sustain and promote proper electricity generation. The issue of obsolete electricity equipment must be frequently monitored and replaced to avoid continuous electricity

leakages. It is believed that the problems associated with electricity generation in Ghana can be improved, and to overcome these problems there is the need for proper coordination and collaboration, using holistic and integrated approach, across many sectors and disciplines. Thus the technocrats from other disciplines must be involved in effective monitoring and planning of electricity generation in the country. Indeed, if effective management is properly put in place, the issue of inadequate electricity generation, job losses and unemployment would gradually be reduced, and the people will enjoy quality life.

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