# Power Infrastructure Sector Reforms, Power Generation and Private Investments: A Case Study from Ghana's Power Sector

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# Power Infrastructure Sector Reforms, Power Generation and Private Investments: A Case Study from Ghana's Power Sector

**Abstract:** This paper assesses the impact of power infrastructure investments in the developing economy of Ghana following sector restructure and reform and develops a forecasting model for predicting the future trend in electricity generation and electricity tariff. Secondary data sourced via the World Bank PPIAF/PPI Project Database for the period 1994 to 2013 and Energy Commission for the period 2000 to 2014 were used to analyze Ghana's power generation statistics using descriptive, exploratory data analysis and polynomial prediction models. Results reveal that reform has stimulated independent power producer (IPP) investment, particularly in thermal generation capacities to complement hydro alternatives. It is predicted that in the medium term the electricity tariff will continue to rise while electricity generation will decline if additional investments in power infrastructure are not made. This paper provides a case study that critically appraises Ghana's power sector reform; exposes the gap between policy implementation and policy objectives attainment; and proposes a simple yet novel polynomial prediction model that can facilitate short-to-medium term planning of generation and tariff management.

**Keywords:** Private investments; private sector participation; restructuring; power sector reform; independent power producers; models; forecasting.

## Introduction

Preserving energy security is crucial for promoting economic development and improving social equality in developing countries (Stern, 2002; EU, 2006; Finon and Locatelli, 2007). Within Ghana, population expansion and sustained economic growth at 6-7% annually has created an insatiable demand for electricity since 1990 with residential and commercial sectors accounting for 70% of total consumption (World Bank, 2013). Among the various electricity generation options, hydropower has traditionally dominated and constitutes 69% of the energy mix for industry and services sectors (Foster and Pushak, 2011; World Bank, 2013; Gand, 2009; IMF, 2012). However, global climatic change and specifically, drought threatens Ghana’s energy security and has engendered successive governments to diminish an over-reliance upon hydropower in preference for thermal power generation. Thermal electricity now contributes almost half of the reliable generation capacity but further diversification is inevitable (World Bank, 2013; Foster and Pushak, 2011). For example, gas-fired thermal generation is progressively replacing unreliable hydropower or costly oil-fired generation (World Bank, 2013; Ashong, 2010; Malgas, 2008). Compared to other African developing countries, Ghana has progressed its energy infrastructure development aspirations - as exhibited by improvements in generation capacity (Eberhard *et al.,* 2011; Banerjee *et al.,* 2009; Gwillliam *et al.,* 2008; World Bank, 2013). Moreover, independent power producers (IPPs) now form an integral part of Ghana’s sustainable power policy reform and collaborate with government to facilitate additional generation capacity (IFC, 2012). Yet, despite progress made, considerable challenges persistently confront Ghana, including: irregular maintenance and underperformance of generation plants; transmission failures; underinvestment; overridden debt; and operational inefficiencies (Gramlich, 1994; Badu *et al.,* 2012; UNECA, 2011; World Bank, 2013). Given these prevailing challenges, the Ghanaian government has orchestrated sweeping power generation restructure including: separating the technical functions of production, transmission and distribution; withdrawing from the market to encourage private investment; creating a competitive market structure thus ensuring competition; issuing shares ownership of utility companies via stock markets to raise necessary finance; and establishing independent legislative and regulatory framework to oversee the sector (e.g., the Public Utilities and Regulatory Commission, the Energy Commission Pursuant to the Public Utilities and Regulatory Commission Act, 1997 (Act 538) and the Energy Commission Act, 1997 (Act 541)) (Joskow and Schmalensee, 1983; Jamasb and Pollitt, 2005; Newbury, 2000; Pollitt, 2004; Eberhard and Gratwick, 2011; Andersen and Sitter, 2009; Badu *et al.,* 2012; UNECA, 2011). The government's ambition being to achieve universal access to electricity by 2020 and become West Africa's leading exporter of power (IMF, 2012; Badu *et al.,* 2012; UNECA, 2011; Andersen and Sitter, 2009; World Bank/IFC, 2010).

However, whilst the literature is replete with commentaries on power sector reforms at both national and international levels (Joskow, 2006; Erdogdu, 2013; Joskow, 2000; Newbury, 2000; Pollitt, 2004; Jamasb and Pollitt, 2005; Ishii and Yan 2004), studies that measure the impact of these reforms in developing countries are desperately needed. This research therefore: analyzes the trend of power infrastructure investments in Ghana's power sector post reform; assesses the ensuing impact upon promoting private investments; and develops a simple but novel polynomial prediction model that can forecast the future trend in electricity generation and electricity tariff. This critical literature review and complementary synthesis and analysis of data affords valuable information to Ghana's policymakers to reform and shape future policies for attracting greater private sector investment.

## Infrastructure Investments in Ghana’s Power Sector: An Overview

Public funds, donor assistance and concessionary loans have traditionally afforded the key sources of finance for power generation projects in West Africa (*c.f.* PSIRU, 2012; Shingore, 2009; Eberhard *et al.*, 2009; Banerjee *et al.*, 2009; Gwillliam *et al.*, 2008). Investment attracted is often insufficient for developing major power projects that are inherently capital intensive (Badu *et al.*, 2012; OECD, 2012; Shingore, 2009; IMF, 2012). Notwithstanding prevailing investment constraints, successive governments have progressed energy infrastructure developments when compared to other developing countries in Africa. During in the mid-2000s, 44.3% of Ghana’s population had access to electricity, when compared to 15.4% for low-income countries such as Togo and Benin and 59.9% for middle-income countries such as Nigeria and South Africa (Eberhard *et al.*, 2009; Banerjee *et al.*, 2009; Gwillliam *et al.*, 2008). Despite this progress, enormous challenges confront the sector (Gramlich, 1994; Badu *et al.*, 2012; UNECA, 2011). For example, the Volta River Authority (VRA) and Electricity Company of Ghana (ECG) face weakened financial stability (e.g. net losses, rising receivables and inter-utility debts) and are unable to undertake new investments or rehabilitate aging power generation and distribution infrastructure projects. VRA remains reliant upon government loans and other external credit sources to buy crude oil for operating its grossly underperforming thermal plants at Takoradi and Tema. Similarly, the Akosombo and Kpong hydro plants are inadequately maintained. The ECG is currently investing US$100 million annually vis-a-vis an estimated US$200 million needed to meet minimum investment requirements (World Bank, 2013). Long-term investment forecasts anticipate that US$1 billion is required to upgrade the transmission infrastructure during the period 2010–2020, with most investments taking place during 2015 (*ibid*). Due to its financial strength, Ghana Grid Company (GRIDCo) plans to raise private finance without government guarantee to execute its ambitious investment plans to upgrade its transmission systems (*ibid*). However, power transmission debts owed by ECG and the Volta Aluminum Company (VALCO) have exerted a toll upon GRIDCo's profitability (*ibid*)

To end the recurrent cycle of load shedding, additional investments are needed to increase existing generation capacity and upgrade existing transmission and distribution plants (IMF, 2012; World Bank, 2013). Load shedding is a method of reducing demand on energy generation system by temporarily switching off energy distribution to different regions of Ghana – this helps to reduce excessive load on generating plant. Investment in gas-fired thermal generation represents a favorable alternative to unreliable hydropower and costly oil-fired generation (World Bank, 2013; Ashong, 2010; Malgas, *2*008). The World Bank has already invested US$700 million into the development of the Sankofa Gas Project to increase Ghana's power generation and improve the volume of clean and inexpensive natural gas supply. It is anticipated that the guarantees will attract US$7.9 billion worth of new private investment and add 1,000 megawatts (MW) of power to the national grid when completed in 2018. The development of the combined cycle gas turbine plant (located in deep water 60km offshore of Western Ghana) will facilitate gas supply through the West African Gas Pipeline (WAGP) from Nigeria and electricity costs may reduce given such investments (World Bank, 2013). Nonetheless, gas-fired projects have also encountered several challenges, most notably, delays in completing the Jubilee gas project. Furthermore, supply disruption on the West Africa Gas Pipeline (WAGP) has created a gas shortage that undermines Ghana's gas-fired power generation potential (Foster and Pushak, 2011; World Bank, 2013).

## Power Sector Restructuring

Globally, recent decades have seen many countries invested hugely in liberalizing electricity markets (Erdogdu, 2013). Chile was the first country globally to implement a comprehensive electricity sector reform in 1982. Despite initial challenges regarding market structure and regulatory arrangements, the reform was successful (Pollit, 2004; Erdogdu, 2013). Joskow (2000) suggested that the persistent high price and price differentials of electricity were the driving force behind the electricity markets restructuring in several states in America. The northeast region and California were the first to restructure their power sectors in 1996 and 1997 because of their much higher prices than the nation's average (Joskow, 2006; Erdogdu, 2013). White (1996) examined the causes of this price gap and estimated its magnitude across the different states. This study (*ibid*) revealed dramatic differences in the price gap across states and suggested a more competitive structure for the power market in high-cost states. In New Zealand's electricity market, Nillesen and Pollitt (2011) studied the impact of the forced ownership policy (used for unbundling electricity distribution) upon electricity prices, quality of service and costs. Their study argued that ownership unbundling did not achieve the desired results of expediting competition in the electricity supply industry; nonetheless, the reform brought about lower costs and higher quality of service.

In the European Union (EU), major electricity market reforms did not occur until the EU's first Directive to its 15 member countries in 1996; this sought to partially open their retail markets by 2000 in a gradual effort to liberalize their electricity market (Trillas, 2010). By 2000, apart from Greece, all EU member countries, had opened their retail markets (Jamasb and Pollitt, 2005; Pollitt, 2009). In Asia, IPPs were first allowed into the Japanese electricity industry in 1995 as part of electricity reforms that sought to encourage cost cutting competition (Nakano and Managi, 2008). Although partially inclined, the liberalization effort has stimulated market competitions and contributed to about 30% share of total electricity demand (Asano, 2006). In Africa, most reforms implemented have been poorly designed and have mainly aimed at encouraging foreign private direct investment in power markets. South Africa is one of the few countries to have introduced a substantial reform program in their electricity industries. Initially the policy was designed to favour the minority white population group until the policy saw a fundamental shift in focus by the new democratic government in 1994 (Erdogdu, 2013). In African countries, state-run power utilities such as Energie Electrique de Côte d'Ivoire (EECI), Société d'Electricité du Senegal (SENELEC) and Energie du Mali (EDM) are classic examples of public institutions that have embraced private sector involvement following liberalization (UNECA, 2011). In selected market studies, Erdogdu (2013) investigated the impact of the electricity industry reforms on electricity price-cost margins using panel data from 63 developed and developing countries covering the period 1982–2009. The research (*ibid*) concluded that the implementation of similar reforms have different impacts across the different countries - this supports the argument that the adoption of the same reform from one country to another may not achieve similar results.

In Ghana, the energy policy reforms began during the early 1990s when the Ghanaian Government sought assistance from World Bank to finance the 660 MW thermal plant located at Takoradi in the Western Region of Ghana (Wamukonya, 2003; UNCTAD, 2007). The project was financed on the basis that Ghana would reform the power sector to deliver an effective regulatory environment for promoting private investments and efficiency in internal operations and revenue management (World Bank, 1995). On the back of this contractual obligation, the *Ghana Power Sector Development Policy 1994* was developed. This policy contained a specific reform proposal, summarized by six fundamental requirements, namely to: i) introduce IPPs through Build Operate Transfer (BOT) arrangements to augment hydro and thermal generation capacities; ii) ensure transparent rules for coordinating generation and transmission operations; iii) introduce private investors into ECG's distribution operations; iv) separate Northern Electricity Department (NED) from VRA's transmission systems into a separate grid entity; v) introduce comprehensive regulated pricing regimes; and vi) create a regulatory body responsible for ensuring sector competition, granting licenses, regulating prices and monitoring performance agreements (PURC ACT, 1997; Malgas, 2008).

Following policy reforms, VRA (which was formerly responsible for all power generation and transmission in Ghana) was restructured; GRIDCo acquired its transmission assets and functions in 2008; and NED was unbundled from VRA into a separate, semi-independent, wholly owned subsidiary entity entitled NEDCo which assumed the distribution function of VRA in Northern Ghana (World Bank, 2013). This transition was encouraged by the World Bank, International Monetary Fund (IMF) and other international financial institutions (Erdogdu, 2014; Williams and Ghanadan, 2006a). The Bui Power Authority (BPA) took over hydropower generation at the Black Volta Basin and saw the completion of the US$790 million Bui hydroelectric plant (400 MW) financed from multiple sources – namely: US$263.5 million concessionary loans from the Government of China; US$298.5 million export buyer's credit from the Export-Import Bank of China; US$60 million from the Government of Ghana; and an additional US$168 million obtained from other project lenders (World Bank, 2013). Once state utilities were unbundled, transparent rules and regulations were essential to maintaining competitive markets (Joskow and Schmalensee, 1983; Jamasb and Pollitt, 2005; Newbury, 2000; Pollitt, 2004; Woodhouse, 2005; Alesina, *et al.*, 2003; Ishii and Yan 2004). However, Ghana's power sector reform embraced: i) the Public Utility Regulatory Commission (PURC) to act as a tariff regulator and licensor and ii) the Energy Commission (EC) to independently monitor the market, without a comprehensive legal framework backing their powers (Ashong, 2010; PURC, 2007; OFGEM, 2010). A complete reform of VRA has therefore proven ineffective because it dominates power generation plant ownership in Ghana despite the reform (Malgas, 2008). The sector's regulatory policies are predominantly politically orientated and promote a social agenda and/ or protect national industry. These myopic *'vote winning'* policies (which include the controversial fuel price and electricity tariffs subsidies) have affected ECG's financial sustainability. Consequently, ECG (as an off-taker) is unable to pay power producers and therefore IPP investors have been discouraged (Balouga, 2012; World Bank, 2013).

Hence, Ghana's power sector reform remains largely inconsistent and has progressed far slower than originally envisaged (Erdogdu, 2014). Consequently, the public sector continues to dominate ownership despite efforts to engender sector reform (Haney and Pollitt, 2013; Pollitt, 2008).

## Methods and Approach

This paper employed descriptive and exploratory data analysis techniques to analyze the trend of power infrastructure investments following sector restructure and reform. While descriptive analysis quantitatively summarizes features of dataset, exploratory data analysis involves the use of graphics and visualization techniques to identify significant features of the dataset (Saunders *et al*., 2009; Williams, 2007; Chatfield, 1995). The econometric approach of time series analysis was adopted for forecasting future trend in electricity generation and electricity tariff.

### ***Data***

Secondary data was compiled from databases sourced from the World Bank Public-Private Infrastructure Advisory Facility (PPIAF)/ Private Participation in Infrastructure (PPI) Project, Energy Commission, VRA, GRIDCo, and Bank of Ghana from 1994 to 2014. The PPIAF/ PPI database contains power project investment information (in millions of US$) and records of the private sector's intention to invest into large public infrastructure assets as opposed to actual disbursements. Data on projects is however, limited to these large projects. The data from the Energy Commission, VRA and GRIDCo covers energy statistics, power generation facts and figures, and IPP investments, spanning from 2000 to 2014 were used for the econometric modeling. Nonetheless, the small dataset available constitutes a limitation of the study. Once collected, data was checked for precision and then entered onto a Microsoft Excel spreadsheet and Statistical Package for the Social Sciences (SPSS). All charts, graphs and analysis were produced from Microsoft Excel spreadsheet and SPSS.

### ***Econometric Modeling***

In order to determine the appropriate model, time series datasets were first plotted to study patterns inherent within the data. Figures 1 and 2 are scatter plots for the two types of data series consisting of electricity generation and electricity tariff over the period 2000 to 2014.

**Insert Figures 1 and 2**

Both plots show a nonlinear trend, indicating that the underlying pattern of the datasets follow upward trends which reflects growth in electricity generation and electricity tariff over time. This type of relationship is a curvilinear trend best represented by a polynomial regression function of suitable degree, which is linear in the coefficients (Vallence and Fabrice, 2016). Following the standard linear model for time series, where it is assumed that there is some relationship between a response variable $Y_t$ and a predictor variable $X_t = (X_{n-1}, X_{n-2}. . . X_{n-p})$, which can be written in the general form:

$$\hat{Y}_t = \beta_0 + \beta_1 X_t + \varepsilon_t, \qquad (1)$$

Polynomial regression extends the linear model by adding extra predictors, obtained by raising each of the original predictors to a power in order to provide a non- linear fit to data. The general polynomial regression model can be expressed as:

$$\hat{Y}_t = \beta_0 + \beta_1 X_t + \beta_2 X_t^{\,2} + \beta_3 X_t^{\,3} + \ldots + \beta_k X_t^{\,k} + \varepsilon_t, \qquad (2)$$

Where $\hat{Y}_t$ is the linear trend forecast in period t; $\beta_0$ is constant; $\beta_1$ is linear coefficient, $\beta_2$ is quadratic coefficient, and $\beta_3$ is cubic coefficient; $\beta_0 \ldots \beta_k$ are unknown fixed regression coefficients to be estimated; $X_t$ is time period; $K$ is the degree of the polynomial; and $\varepsilon_t$ is the random error.

### *Estimation Method*

The polynomial regression functions of any suitable degree exhibit a form of linearity in the coefficients (Vallence and Fabrice, 2016). As such, the least squares method was employed for simple linear regression to estimate coefficients $\beta_0 \ldots \beta_k$ in order to produce a non-linear fit. The overall significance of the estimation model was tested and based on the null hypothesis as against the alternative hypothesis that:

$H_0$: The proposed polynomial models of a suitable degree fit the data significantly better than linear trend model.

$H_a$: The proposed polynomial models of a suitable degree do not fits the data significantly better than linear trend model.

*Diagnostic checking*

Diagnostic checking confirms whether the estimated model is statistically adequate or inadequate. The statistical adequacy of time series modeling involves the assumption that the error terms are independent (Tobías and Saez, 2004; Vallence and Fabrice, 2016). A violation of this assumption, known as autocorrelation, renders the parameter estimates of the forecasting model inefficient and makes the model appear better than its predictive capability (Vallence and Fabrice, 2016). To diagnose autocorrelation in our datasets, Durbin-Watson statistic was computed viz:

$$d = \frac{\sum_{i=2}^{T}(e_t - e_{t-1})^2}{\sum_{i=1}^{T} {e^2}_t}$$

Where $T$ is the number of observations; $e_t$ is the error at time t. As a rough rule of thumb, if $d$ is less than 1, the errors are positively correlated; if $d$ is 2 or above, there is no autocorrelation; and if $d$ is more than 3, the errors are negatively correlated. The null hypothesis was then tested against the alternative hypothesis that:

$H_0$: The proposed models have no positive autocorrelation in the data

$H_a$: The proposed models have positive autocorrelation in the data

### *Forecasting Accuracy and Model Selection*

The accuracy of proposed models for forecasting the time series relative to the actual historical data was then assessed. Three alternative measures were adopted, namely: mean absolute deviation (MAD), mean square error (MSE) and mean absolute percentage error (MAPE). The formula for calculating each forecast error is given as follows:

$$MAD = \frac{\sum_{i=1}^{n} |Y_t - \hat{Y}_t|}{n}$$

$$MSE = \frac{\sum_{i=1}^{n} |Y_t - \hat{Y}_t|^2}{n}$$

$$MAPE = \frac{\sum_{i=1}^{n} |\frac{Y_t - \hat{Y}_t}{Y_t}|}{n} \text{ x } 100$$

Where $Y_t$ and $\hat{Y}_t$ are the actual observed values and the predicted values respectively while $n$ is the number of the predicted values. The accuracy of the forecast is evaluated based on the estimation of error; thus the smaller the value of MAD, MSE and MAPE, the better the forecast accuracy. Table 1 shows the criteria of MAPE for model evaluation based on Lewis (1982) (Shitan et al., 2010).

## Data Analysis and Empirical Results

### *Descriptive and Exploratory Data Analysis*

Table 2 presents descriptive summary statistics for generation capacity, electricity generation, and electricity end-user tariff.

**Insert Table 2**

Overall, Ghana’s total installed electricity generation capacity at the end of 2014 was 2,814 MW. The current mean generation capacity since the integration of thermal generation capacity into the national grid is 1,963 MW, with an average annual percentage growth of 5.26%. The lowest and highest capacities were recorded as 1,418 MW and 2,813 MW in 2000 and 2014 respectively. Hydro capacity contributes 55.8% of the total generation capacity. The remainder is shared between thermal (at 44.1%) and renewable (predominantly solar at 0.1%), making hydroelectric and thermal plants the two major types of generation facilities. The Akosombo hydroelectric plant contributes 64.6% of the total hydro generation capacity. As at the end of 2014, eight thermal generation plants are installed and operational. The Takoradi Power Company (TAPCO-T1), which came online in the last quarter of 2000, is the highest contributor at 26.4% of the total thermal generation; followed by Takoradi International Company (TICO-T2) installed in 2013 at 17.5% and Sunon Asogli Power Plant (SAPP) installed in 2010 at 16% of the total thermal generation respectively. The 2,813 MW generates 12,963 Gigawatt hours (GWh) of energy from the twelve installed generation facilities at the close of 2014. The total and mean generations at the same period stand at 132,976 GWh and 8,865.07 GWh respectively. These statistics indicate that power generation has witnessed a major boost since the introduction of non-hydro generation facilities; with a 5% average percentage growth annually in power generation. Since the integration of non-hydro generation into the national grid, the average end user tariff per GWh stands at GHC 0.1509, with an average percentage growth of 30.32% annually. In addition, capacity, generation and tariff variables are indicate low volatile, as their standard deviations are below their means.

**Insert Figure 3**

Figure 3 compares the average end user electricity tariffs with installed capacity and power generation. The trends illustrates that the improvement in MW and GWh of power has a corresponding increase in the cost of power paid by the final consumer. Notwithstanding, power generation has suffered major setbacks during periods of low rainfall most notably during 2007 when drought plunged the country into darkness. Despite the generation short fall of hydro, generation from this source contributes 64.7% of the entire generation mix, with the Akosombo hydroelectric plant producing 77.6% of the total hydro generation. Thermal generation accounts for 35.3% of the total generation mix, with the SAPP, TAPCO-T1 and TICO-T2 accounting for 27.4%, 19.5% and 15.6% respectively. Despite the huge opportunity that solar power presents, Ghana has not harnessed this green energy effectively to boost power generation (see Figure 4).

**Insert Figure 4**

The types of fuel that feed the thermal plants for power generation include: natural gas; light crude oil (LCO); and dual (natural gas and LCO) fuel. Out of the eight installed thermal plants, five (representing 62.5% of installed thermal plants) run on either LCO or natural gas; one (12.5%) uses either diesel fuel oil (DFO) or natural gas, while the remaining two plants run on natural gas and LCO. It is planned that an estimated 2,206 MW capacity will be added to the national grid, expected to come online between 2015 and 2018 (EC, 2014) (see Table 3).

**Insert Table 3**

When these additional capacity investments are made, thermal will contribute 90.7% of the expected planned projects (*ibid*). A 1000-megawatt (MW) thermal power plant to be built by General Electric will drive this capacity investment by contributing 52.5% of thermal generation capacity and 47.6% of total generation capacity. Renewable energy driven by solar will contributes 9.3% of total energy capacity (*ibid*). It is anticipated that Mere Power Nzema (Blue Energy, UK) will lead this drive by contributing 75.6% of total renewable energy. By the end of 2018, total generation capacity is expected to be 5,038 MW, with planned capacity adding 43.8% to the total capacity) (see Table 2).

**Insert Figure 5**

Figure 5 reports upon investment (US$ million) over the period 1994 - 2013. The undulating trend reflects surges and dips in investment committed between the various projects implemented, and Ghana's economic prosperity over this period. A natural gas transmission project received the highest investment volume (US$ 590 Million) and was executed by the West African Gas Pipeline Company Ltd in 2005 whilst the project that received the lowest investment volume (US$ 100 Million) is the Osagyefo Power Barge (an electricity generation project) in 2007. By capacity, the public sector entity VRA controls 74.4% of the total generation capacity while IPPs currently manage 25.6% (split into: 14.1% hydro via the BUI hydropower project; and 11.5% thermal via the Sunon Asogli power plant). At present there is no private investment in renewable generation (see Table 4).

**Insert Table 4**

The statistics regarding the preferred contractual model of entry for private sector participation are as follows: greenfield model 70% (seven); concessions 20% (two), and management and leasing 10% (one). 50% of greenfield projects have been implemented through build, own, and operate (BOO) sub-type model, while build operate and transfer (BOT) and merchant sub-type models share the remaining 20%. Concession projects have taken the forms of build, rehabilitate, operate, and transfer (BROT) (10%) and rehabilitate, operate and transfer (ROT) (10%). The management and leasing method of entry has been implemented via management contract. Notably, none of these projects were executed by the privatization model (see Figures 6 and 7).

**Insert Figure 6 and 7**

In total, about 80% of private sector participated projects have been successful with the remaining 20% being a failure. Successful projects are defined as projects that have been well executed or are in operation whilst failed projects are projects that have been either cancelled or have experienced massive disruption and delays during construction and operation. Most of the successful projects are greenfield projects (60%) followed by concession (10%), and management and leasing contracts (10%). The 20% of failed projects are equally shared between one concession project and one greenfield projects (see Figure 8).

**Insert Figure 8**

The segment analysis reveals that 60% of all successful projects are electricity generation projects. This is probably because most PPP projects been electricity generation projects and so contractors and clients accumulate knowledge and experience iteratively from one project completed to another. The remaining 20% of successful projects are shared equally between electricity distribution and natural gas transmission projects. Curiously, all the projects that failed to reach full potential are electricity generation projects – there is no explanation for this and further research and investigation is required to determine causal factors (see Figure 9).

**Insert Figure 9**

### *The Results of Forecasting Models*

#### *Model Fitting*

The summary results of the linear model and proposed polynomial model to the 6th degree for electricity generation are presented in Table 5 along with the goodness-of-fit measures. This Table reveals among other things that the $R^2$ (coefficient of determination) values of the models ranges from 76% to 95%. The $R^2$ measures the overall degree of the strength of association between the predicted scores and the actual series data. The results show a significant improvement of the $R^2$ values of polynomial fits (ranging from 93% to 95%) from the linear model of 76%, indicating that the polynomials are better fit than the linear model. However, when comparing the polynomials, it is apparent that as the number of degrees of the function increases, there is a corresponding marginal improvement in the $R^2$ values. Moreover, fitting the polynomials of variant degrees, the F-tests display statistical significance at $p \leq 0.05$, satisfying the null hypothesis that the proposed polynomial model fits the data well when compared to the linear model for electricity generation. However, based on the statistical significance of $R^2$ and F-tests alone, it cannot be concluded with certainty that one degree of the polynomial model is better than the other.

**Insert Table 5**

Therefore to make a meaningful decision, the forecast errors of each polynomial as the basis of selecting the suitable degree are ascertained; the model with the lowest or minimized forecast errors is thus selected for forecasting. From Table 5, all the forecasting errors measures (i.e. MAD, MSE and MAPE) display a reduction in the forecast errors as the degree of the function increases from 2nd to the 4th degree but marginally deteriorated at the 5th degree and thereafter saw an improvement at the 6th degree. Therefore, since the polynomial model of 4th degree has the lowest forecasting errors it is selected for forecasting.

Table 6 shows the summary results of the linear model and proposed polynomial model to the 6th degree for electricity tariff. The $R^2$ values of the models ranges from 83% of the linear model to 99% of the 6th degree polynomial model, signifying that the polynomials are better fit than the linear model. Comparison among the polynomials reveals that $R^2$ values slightly improves as the number of degrees of the function increases. The F-tests is statistically significant at $p \leq 0.05$ across all the degrees, satisfying the null hypothesis that the proposed polynomial model of a suitable degree fits the data well than linear model for electricity tariff. Similarly, it cannot be concluded with certainty that one degree of the polynomial model is better than the other.

**Insert Table 6**

However, a cursory examination of the accuracy measures shows that the polynomial model of 5th degree has the minimized forecasting errors of MAD and MSE, although its MAPE (0.16%) is slightly higher than polynomial model of the 4th and 6th degrees. Thus, a polynomial model of 5th degree is the selected forecasting model for electricity tariff.

*Diagnostic checking*

Diagnostic checking was conducted to examine the residuals of the selected estimated models to determine whether they are independent. When compared with other degrees, the selected 4th degree polynomial for electricity generation and 5th degree for electricity tariff have the highest Durbin-Watson statistic (*d)* of 2.28 and 2.27 respectively (see Table 5 and 6). It can be concluded that the residuals are independent - are not serially correlated - and that the null hypothesis can be accepted i.e. that the selected models have no positive autocorrelation in the data. This therefore renders the models efficient for forecasting.

*Forecasting*

To select suitable models for making a medium term (three years) prediction of electricity generation and electricity tariff respectively, the estimated 4th and 5th degree polynomial equations are specified as:

$$\hat{Y} = 7786 - 145.63x - 107.61x^2 + 22.136x^3 - 0.8506x^4$$

$$\hat{Y} = - 0.1206 + 0.1833x - 0.0657x^2 + 0.0104x^3 - 0.0007x^4 + 2E\text{-}05x^5$$

The actual and forecasted values are shown in Table 7 and Figures 10 and 11. It is observed that for the three successively years (2015 to 2017), electricity generation would decline while electricity tariff would rise. The implications for this forecast are that if additional investments are not made to supplement hydropower, a repeat of past power crises due to generation shortfall is unavoidable.

**Insert Figures 10 and 11**

## Discussion and Policy Recommendations

The reform of Ghana’s power sector has witnessed an investment boost from IPPs who now contribute 726 MW of power - representing 25.6% of the total generation capacity (as at 2014). IPPs participation has created an upward surge in power generation and has filled the generation shortfall created by the Akosombo hydroelectric plant during periods of low rainfall. Despite this effort, existing generation capacity remains insufficient to address the country’s energy needs. Additional investments are urgently needed to augment the existing capacity as well as upgrading the existing transmission and distribution infrastructure to avoid the recurring power crisis. Various planned generation capacity projects must be executed over the next 5-10 years to maintaining a healthy reserve margin and ensuring the reliable operation of Ghana’s electric system. These additional investments are urgently required to ensure economic growth and cater for urbanization and population growth, and a favorable investment environment (legal, fiscal and regulatory) is fundamental to fulfilling this need (World Bank, 2013).

Unlike the generation segment, both the transmission and the distribution segments have not seen any major private investments. One change in the transmission sector is the incorporation of GRIDCo in 2006 as a private limited liability company to take over the transmission assets and functions of VRA from 2008 onwards. This change has guaranteed a major investment boost in developing, modernizing and strengthening the National Interconnected Transmission System (NITS) to improve efficiency and reliability. Similarly, the only private sector participation in the distribution sector was a management and leasing contract sponsored by Electricite de France 1994 to bring efficiency in electricity distribution in ECG's operation. Since then, ECG has not received any major private investment. It is hoped that the Ghanaian Government in collaboration with Millennium Development Authority (MiDA) would carry out their plan to privatize ECG through concession in order to access the US$498 million Compact II Program funds to improve the efficiency of ECG. The current and future investments in thermal plants, coupled with unreliable hydro generation, means that thermal will dominate Ghanaian power generation. This paradigm shift will affect production costs and consequently, increase electricity tariffs. This is because the fuel sources for thermal (e.g. natural gas, light crude oil and diesel) are more expensive making the cost of thermal generation more than twice the cost of hydro-power generation. It is imperative that Ghana's Government and IPPs direct new investments into non-hydro generation plants, particularly into renewable energy sources which are abundant, freely available and have minimal environmental impact. A concerted effort must be made to complete existing power network infrastructure developments such as the joint Ghana/ Nigerian West African Gas Pipeline (WAGP); the Jubilee gas project; and the Sankofa gas project which has the potential of producing about 1,100 MW of electricity. Apart from providing feed for thermal plants, exploiting Ghana's plentiful natural gas resources will cater for the emergence of power barges and increasing demand for gas by the non-power sector between now and 2018. A power barge (or power ship) is a special purpose ship, on which a power plant is installed to serve as a power generation resource. This projection may not be met if prudent and timely investments are not made.

In anticipation of a gas supply shortage, most thermal plants have been retrofitted to use light crude oil. This has significant cost implications for the end user who may be required to pay higher tariffs that could be socially exclusive particularly for the poor and infirm. Such a strategy could represent political suicide for a prevailing Ghanaian government whose predecessors have failed to adequately implement a full-cost pricing policy. To date, many sector policies have rather aimed at short-term social agendas and protecting national industry (such as the subsidy of electricity tariffs). The subsidy of electricity tariffs to VALCO has had a catastrophic impact upon VRA and ECG who are unable to sell power below their true cost and have incurred losses. The implementation of the comprehensive regulated pricing regime is therefore largely redundant, as one of the policy reforms objectives. Hence, finding a suitable and politically palatable (perhaps cross-party) approach and demonstrating transparency for regulating electricity tariffs is urgently needed to attract private investment.

## Conclusion

Ghana’s power sector reform sought to ensure an effective regulatory environment for promoting private investments and efficiency in internal operations and revenue management. Despite this effort, the power sector continues to be confronted with enormous challenges. It is imperative for the Ghanaian government to continue to reform the power sector to stimulate private sector investments in power generation plants and in upgrading of the existing transmission and distribution plants. New investments in power generation should be directed to renewable energy (such as wind and solar) and natural gas sources. These innovative generation sources have the benefits of ensuring accessible, reliable and affordable electricity for the consumer. If the government wants to achieve its generation capacity target, be power sufficient and end the cycle of load shedding, investments in such innovative generation sources should be made. To ensure the financial sustainability of ECG, the government has pay its debt owed to ECG. This will empower ECG to improve its human and technical capacities to improve efficiency in revenue mobilization and management, and reduce the high incidence of technical losses. Future research is required to: identify mechanisms to remove or reduce direct government financing in power utility companies in Ghana; develop and administer innovative and sustainable financial models; and further investigate the business case for using a greater proportion green energy generation. Given the sensitive political nature of major reform juxtaposed against the urgent need to deliver sustainable energy generation and transmission, Ghana's government may have to accept that cross-party collaboration is needed if a severe energy crisis is to be avoided.

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**Table 1:** MAPE Values for Model Evaluation

| **MAPE (%)** | **Evaluation** |
|---|---|
| MAPE ≤ 10% | High Accuracy Forecasting |
| 10% ≤ MAPE ≤ 20% | Good Forecasting |
| 20% ≤ MAPE ≤ 50% | Reasonable Forecasting |
| MAPE ≥ 50% | Inaccurate Forecasting |

**Source:** Lewis (1982) cited in Shitan et al., 2010**.**

**Table 2**: Descriptive summary statistics

| | **Obs.** | **Mean** | **SD** | **Min.** | **Max.** | **Total** |
|---|---|---|---|---|---|---|
| Total generation mix (GWh) | 15 | 8865.07 | 2412.38 | 5881.00 | 12963.00 | 132976.00 |
| Growth rate (%) | 14 | 0.05 | 0.12 | -0.19 | 0.24 | 0.70 |
| Average end-user tariff (GHC) | 15 | 0.15 | 0.12 | 0.02 | 0.46 | 2.26 |
| Growth rate (%) | 14 | 0.30 | 0.09 | -0.05 | 1.00 | 4.24 |
| Total generation capacity (MW) | 15 | 1963.20 | 433.35 | 1418.00 | 2831.00 | 29448.00 |
| Growth rate (%) | 14 | 0.05 | 0.07 | 0.00 | 0.23 | 0.74 |
| Hydro generation (GWh) | 15 | 6314.27 | 1459.93 | 3727.00 | 8387.00 | 94714.00 |
| Growth rate (%) | | 0.04 | 0.07 | -0.34 | 0.7 | 0.60 |
| Thermal generation (GWh) | 15 | 2550.33 | 1307.23 | 613.00 | 4634.00 | 38255.00 |
| Growth rate (%) | 14 | 0.27 | 0.15 | -0.62 | 1.43 | 3.76 |
| Renewable generation (GWh) | 15 | 0.47 | 0.32 | 0.00 | 4.00 | 7.00 |
| Growth rate (%) | 14 | 0.02 | 0.09 | 0.00 | 0.33 | 0.33 |

**Table 3:** Fuel Type by Plant and Planned Projects

| | **Water** | **LCO/ Natural Gas** | **DFO/ Natural Gas** | **Natural Gas** | **LCO** | **Solar** | **Total** | **Planned Projects** |
|---|---|---|---|---|---|---|---|---|
| Hydro | 3 | - | - | - | - | - | **3** | |
| Thermal | - | 5 | 1 | 1 | 1 | - | **8** | 2001 |
| Renewable | - | - | - | - | - | 1 | **1** | 205 |
| **Total** | **3** | **5** | **1** | **1** | **1** | **1** | **12** | **2206** |

Source: Constructed from Energy Commission's National Energy Statistics, 2000 -2014

**Table 4**: Ownership Structure in Generation Capacity

| | VRA | IPP |
|---|---|---|
| Hydro | 1,180 | 400 |
| Thermal | 922 | 326 |
| Renewable | 3 | - |
| **Total** | **2,105** | **726** |

Source: Constructed from World Bank PPIAF and PPI Project Database

**Table 5**: summary forecasting statistics for electricity generation

| **Coefficients** | **Linear** | **Polynomials** | | | | |
|---|---|---|---|---|---|---|
| | | **2nd degree** | **3rd degree** | **4th degree** | **5th degree** | **6th degree** |
| $\beta_0$ | 5096.21 | 7672.25 | 8916.27 | 7785.96 | 7546.22 | 3865.38 |
| | (662.57)*** | (630.35)*** | (870.4)*** | (1287.23)*** | (2083.66)*** | (3146.18) |
| $\beta_1$ | 471.11 | -438.08 | 1244.06 | -145.63 | 164.67 | 6042.61 |
| | (72.87)*** | (181.29)*** | (455.93)*** | (1036.44) | (2321.09) | (4498.98) |
| $\beta_2$ | | 56.82 | 178.79 | -107.61 | -226.67 | -3241.91 |
| | | (11.02)*** | (65.12)*** | (251.93) | (829.63) | (2164.37) |
| $\beta_3$ | | | -5.08 | 22.14 | 40.95 | 728.50 |
| | | | (2.68) | (23.31) | (126.63) | (475.59) |
| $\beta_4$ | | | | -0.85 | -2.15 | -79.35 |
| | | | | (0.72) | (18.61) | (52.33) |
| $\beta_5$ | | | | | 0.03 | 4.21 |
| | | | | | (0.21) | (2.81) |
| $\beta_6$ | | | | | | -0.09 |
| | | | | | | (0.06) |
| N | 15 | 15 | 15 | 15 | 15 | 15 |
| $R^2$ | 0.76 | 0.93 | 0.94 | 0.95 | 0.95 | 0.96 |
| *F-test* | 41.79*** | 75.34*** | 62.28*** | 48.67*** | 35.14*** | 33.65*** |
| *MAD* | 1001.09 | 527.59 | 452.79 | 353.31 | 356.33 | 3.32 |
| *MSE* | 12.89E05 | 4.01E05 | 3.02E05 | 2.65E05 | 2.65E05 | 2.07 |
| *MAPE (%)* | 12.78 | 6.57 | 5.77 | 4.79 | 4.80 | 4.24 |
| *d* | 0.62 | 1.78 | 2.27 | 2.28 | 2.27 | 2.44 |

**Legend: * statistically significant at ** at 95% (p<0.05) level ; standard errors in parentheses**

**Table 6**: summary forecasting statistics for electricity tariff

| **Coefficients** | **Linear** | **Polynomials** | | | | |
|---|---|---|---|---|---|---|
| | | **2nd degree** | **3rd degree** | **4th degree** | **5th degree** | **6th degree** |
| $\beta_0$ | -0.0470 | 0.0600 | -0.0137 | 0.0180 | -0.1206 | 0.0617 |
| | (0.0284) | (0.0288) | (0.0351) | (0.054) | (0.0624) | (0.076) |
| $\beta_1$ | 0.0247 | -0.0130 | 0.0347 | 0.0039 | 0.1832 | -0.1078 |
| | (0.0031) | (0.0083) | (0.0184) | (0.0433) | (0.0695)*** | (0.0967) |
| $\beta_2$ | | 0.0024 | -0.0049 | 0.0032 | -0.0657 | 0.0837 |
| | | (0.0005)*** | (0.0026) | (0.0105) | (0.0248)*** | (0.0465) |
| $\beta_3$ | | | 0.0003 | -0.0005 | 0.0104 | -0.0236 |
| | | | (0.0001) | (0.0010) | (0.0038)*** | (0.0102)*** |
| $\beta_4$ | | | | 0.0000 | -0.0007 | 0.0031 |
| | | | | (0.0000) | (0.0003)*** | (0.0011)*** |
| $\beta_5$ | | | | | 0.0000 | -0.0002 |
| | | | | | (0.0000)*** | (0.0000)*** |
| $\beta_6$ | | | | | | 0.0000 |
| | | | | | | (0.0000)*** |
| N | 15 | 15 | 15 | 15 | 15 | 15 |
| $R^2$ | 0.83 | 0.94 | 0.96 | 0.97 | 0.98 | 0.99 |
| *F-test* | 62.70*** | 92.92*** | 99.36*** | 72.12*** | 103.00*** | 191.27*** |
| *MAD* | 0.0367 | 0.0222 | 0.0170 | 0.0179 | 0.0135 | 0.0064 |
| *MSE* | 0.0024 | 0.0008 | 0.0005 | 0.0005 | 0.0004 | 0.0000 |
| *MAPE (%)* | 45.51 | 27.95 | 11.16 | 0.15 | 0.16 | 0.04 |
| *d* | 0.77 | 1.49 | 1.79 | 1.71 | 2.27 | 3.15 |

**Legend: * statistically significant at ** at 95% (p<0.05) level ; standard errors in parentheses**

**Table 7**: Actual and Forecasts of the annual electricity generation electricity tariff

| Year | Electricity Generation | | Electricity Tariff | |
|---|---|---|---|---|
| | Actual Values (GWh) | Predicted values (GWh) | Actual Values (GHC) | Predicted values (GHC) |
| 2000 | 7222 | 7554 | 0.017 | 0.007 |
| 2001 | 7859 | 7228 | 0.034 | 0.056 |
| 2002 | 7273 | 6909 | 0.065 | 0.065 |
| 2003 | 5881 | 6681 | 0.071 | 0.062 |
| 2004 | 6038 | 6603 | 0.074 | 0.060 |
| 2005 | 6788 | 6717 | 0.073 | 0.069 |
| 2006 | 8430 | 7044 | 0.078 | 0.087 |
| 2007 | 6978 | 7584 | 0.097 | 0.113 |
| 2008 | 8324 | 8316 | 0.148 | 0.141 |
| 2009 | 8958 | 9199 | 0.148 | 0.168 |
| 2010 | 10167 | 10174 | 0.211 | 0.192 |
| 2011 | 11200 | 11157 | 0.245 | 0.216 |
| 2012 | 12025 | 12047 | 0.232 | 0.252 |
| 2013 | 12870 | 12722 | 0.307 | 0.321 |
| 2014 | 12963 | 13040 | 0.464 | 0.455 |
| 2015 | | 12836 | | 0.700 |
| 2016 | | 11927 | | 1.119 |
| 2017 | | 10109 | | 1.795 |