ENERGY DEMAND MODEL FOR VOLTA RIVER AUTHORITY

by

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I hereby declare that this submission is my own work towards the Master of Business Administration (MBA) degree, and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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ABSTRACT

The development of energy sources to accomplish useful work is essential if a country is to make industrial progress and continually improve the standard of living of its people. Shortfalls in national electricity supply were experienced in Ghana in 1983, 1998, 2006 and 2007. Evidently, an accurate forecast of electrical energy demand is one of the first steps in ensuring adequate and reliable energy supply. Under-forecasting results in energy shortages with far reaching costs for a nation whereas over-forecasting may also result in large amounts of capital being uselessly tied up for long periods. In this paper, candidate multiple regression and exogenous autoregressive demand models are developed in respect of the national electric power generation concerns of the Volta River Authority (VRA) of Ghana. Real GDP, real electricity price and the ratio of urban population to total population were used as explanatory variables for the multiple regression models. The electricity demand elasticities for the regression model were found to be 2.19 and -0.09 relative to real GDP and electricity price respectively. These demand elasticities were found to be comparable to results reported by a number of other authors. The exogenous autoregressive model gave demand elasticities of 0.74, 0.26 and -0.05 relative to electricity demand for two preceding years and price respectively. Demand forecasts for 2002 to 2007 were made using the models and the results were compared with actual energy demand for the six-year period as well as with exponential smoothing, and an Acres International/VRA model. The autoregressive model which used the natural logarithm of electricity demand for two preceding years and current real electricity price as exogenous variables performed much better than the other models.

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CHAPTER 1

INTRODUCTION

1.0 OVERVIEW

The development of energy sources to accomplish useful work is essential if a country is to make industrial progress and continually improve the standards of living of its people. The electric power industry is one of the major players in the production and transportation of energy to meet the needs of residential, commercial and industrial sectors of an economy. Moreover, highly trained professionals are needed to develop and implement technological and managerial advances in the electricity industry and to ensure energy availability with the utmost regard for the protection of the environment (Stevenson, 1982).

Electricity is a major form of energy used for the production of goods and services in small, medium and large scale industries. Electricity is also used in homes for lighting, cooking and entertainment. Street lights provide illumination for road users and are essential in ensuring security in industrial and residential neighbourhoods. Shortfalls in electricity supply were experienced in Ghana in 1983, 1998, 2006 and 2007. A Databank research cited by Oppong (2007) estimated that Ghana could have lost up to $1.4 billion by the end of 2007 if the 2006/2007 energy crises had not abated before the end of 2007. Some workers were also laid-off during the 2006/2007 nationwide load shedding exercise and this put heavy burdens on families.

The aspirations of developing countries for higher living standards can only be satisfied through sustained conscious development of nations' basic infrastructure used for electric power production, transmission and distribution as part of their development strategy. Electricity demand in Ghana will grow much faster than overall economic growth or population growth because continuing urbanization will allow newly urbanised segments of the population to expand their electricity consumption manifold (RCEER, 2005).

To forestall the devastating effects of energy shortage on an economy and the general population, accurate forecasts of electrical power and energy demands is crucial. Accurate demand forecast is required to ensure a smooth industrial growth and sustainable improvement in the standards of living of the people. This is especially important in developing economies where rapid economic growth results in swift improvements in standards of living leading to corresponding increases in the demand for electricity. Rural-urban migration is also very high in developing economies and the access to better quality and reliable electrical power in the urban areas lead to higher electricity consumption by new urban dwellers.

It takes between 1 and 10 years to construct a sizeable electrical power generating plant. Power plants are very capital intensive, sometimes accounting for up to 30% of the gross investments in countries. Under-forecasting would result in energy shortages whose costs are usually in multiples of the volume of energy not supplied. If forecasts are too high, large amounts of capital with high opportunity costs might be uselessly tied up for long periods of time (Amoako-Baah, 2001). An accurate integrated electrical energy forecast is therefore necessary in order to accurately plan how much supply capacity to build and at what time.

In this paper, estimated demand models were developed for Volta River Authority (VRA) using data from 1985 to 2001. Real gross domestic product (GDP), real electricity price and urbanisation (ratio of urban population to the total population) were used as explanatory variables. A dummy variable was introduced for years with nationwide load shedding exercises. Autoregressive models were also developed using natural logarithm of electricity demand for two preceding years, and real electricity price as exogenous variables. The models were validated using statistical techniques and used to forecast energy demand for 2002 - 2007. Exponential smoothing was also used to forecast demand for the same period. Actual consumption for 2002 - 2007 was compared with forecasts from the developed models, exponential smoothing and a VRA model. The results were briefly discussed and conclusions and recommendations made.

1.1 BACKGROUND OF STUDY

Power and energy demand forecasts estimate the amount of electricity needed in a geographic area served by a power system. Forecasts project the amount of energy in kilowatt hours (kWhs) and power in watts (W) that will be needed over a period. Forecasts typically look at energy and power requirements from five (5) to thirty (30) years into the future. A demand forecast is a prerequisite when planning how much new generation capacity may be needed, which generation resources are applicable, how transmission and distribution systems should be expanded, and in which customer groups or geographic areas these requirements will be concentrated.

The Volta River Authority (VRA) produces and transmits most of the electricity used in Ghana. It was established in 1961 under the Volta River Development Act, Act 46, of the Republic of Ghana. Its primary function is to generate and supply electrical energy for industrial, commercial and domestic use in the country. The Authority is also responsible for safe-guarding the health and socio-economic well being of the inhabitants of the communities alongside the Volta Lake, and the management of any incidental issues including sustainability of the environment.

In this study, candidate demand models were developed for VRA using historical data. Real GDP, Real price and Urbanisation were used as exogenous variables for the developed models. Autoregressive models were also developed using natural logarithm of electricity demand for two preceding years and real electricity price as exogenous variables. Forecasts from the models, adjusted exponential smoothing and a VRA forecast for 2002 to 2007 were compared with actual consumption. Conclusion and recommendations were made after the results were briefly discussed.

1.2 STATEMENT OF PROBLEM

Shortfalls in electrical energy supply were experienced in Ghana in 1983, 1998, 2006 and 2007. A research by Databank suggested that Ghana could have lost up to $1.4 billion if the recent nationwide load shedding exercise had not ended before the end of 2007. The nationwide load shedding exercise started from August 2006 and lasted until the end of September 2007. Ghana National Labour Department statistics show that about 33 companies filed for insolvency between September 2006 and March 2007 and over 2,300 workers lost their jobs (Oppong, 2007). An accurate forecast of electrical energy is one of the first steps in ensuring adequate and reliable energy supply.

1.3 OBJECTIVES OF STUDY

The objectives of the study are:

- To study different energy demand models in literature
- To develop a demand model for Volta River Authority
- To validate the model using statistical methods
- To compare forecasts made using the model, exponential smoothing and a VRA forecast
- To recommend a good demand model for VRA

1.4 JUSTIFICATION OF STUDY

Infrastructure investments have long been recognized in the development literature as an influential factor in economic growth and overall welfare. Infrastructure provision has been inadequate relative to needs in many African countries. Infrastructure deficits, in turn, have led to lower growth and private investment, a deteriorating investment climate, and worse social indicators. A World Bank report shows that infrastructure provision is important not only for growth, but also for equity and poverty reduction (Bogetic′ and Fedderke, 2006).

In the Sub-Saharan African context, infrastructure directly and strongly affects human welfare and equity across community and income groups. Sub-Saharan African entrepreneurs cite inadequate power supply as a major constraint to their growth, well ahead of some other constraints such as corruption. Investment in infrastructure does appear to lead to economic growth both directly and indirectly by raising the marginal productivity of capital.

The 1983, 1998, 2006 and 2007 energy shortages in Ghana are ample evidence that there has been inadequate investment in power generation. This has resulted in an area of potential policy concern and the Ghana government has recognised the need to scale up infrastructure investments and major investment plans have been prepared including the following:

1. A committee was set up to investigate the potential for the adoption of nuclear power production in Ghana.
2. Demonstrated government interest in the on-going West African Gas Pipeline Project (WAGP).
3. Balkan Energy has been contracted to produce power from the Osagyefo-Barge.
4. Some emergency diesel generator stations were commissioned in 2007.
5. A transmission company, Ghana Grid Company Limited has been formed to encourage Independent Power Producer (IPP) participation in electricity production.

In summary, the justifications for the study are:

- Recurrent shortfalls in the energy supply in Ghana from 1983 to 2007
- Increasing standard of living of Ghanaians since 1984 leading to increasing demand for electrical energy
- Power supply deficiency has major effects on different sectors of the economy
- The construction of a power plants involves large financial investment
- Between 1 and 10 years may be required to construct a power plant
- Demand forecasting is the first step in ensuring adequate power supply
- Highly trained professionals are required to construct and manage power generating stations

1.5 METHODOLOGY

Estimated multi-regression demand models were developed for VRA and validated using statistical methods. The models were developed using historical electricity demand data for the period 1985 to 2001. Secondary data on electricity demand and electricity prices were collected from the Volta River Authority. Data on percentage urban population were collected from the Ghana Statistical Service and data on real GDP growth and Consumer Price Index (CPI) were obtained from the 1996 to 2001 editions of *The State of the Ghanaian Economy* complied by The Institute of Statistical, Social and Economic Research (ISSER), University of Ghana.

A number of energy demand models were developed as functions of natural logarithms of real GDP, real electricity price and urbanisation. A dummy variable was added for years of nationwide load shedding exercises. Autoregressive models were also developed using natural logarithm of electricity demand for two preceding years and real electricity price as exogenous variables. Statistical and economic software packages including SPSS and EXCEL were used to analyse the data. The estimated models were validated and used to forecast demand for 2002 to 2007. The adjusted exponential smoothing technique was also used to forecast demand for the same period. The forecasts from the models, exponential smoothing, and a VRA forecast were compared with actual energy consumption for 2002 to 2007.

1.6 SCOPE OF THE STUDY

Electricity demand models were developed for Volta River Authority using secondary annual electricity demand data covering 1985 to 2001. The 17-year data was used to avoid problems associated with the validity of fixed coefficients in the electricity demand equations (Chang and Martinez-Chombo, 2003). Again, due to the Economic Recovery Programme embarked on by the Government after the drought in 1983, the late 1980s saw the beginning of significant increases in the demand for electrical energy in Ghana. The exogenous factors used in the development of the models were real GDP, real price of electricity, urbanisation, and a dummy variable for the particular years of nationwide load shedding exercise. Electricity demand for two preceding years and real electricity price were used to develop autoregressive models.

1.7 LIMITATIONS OF THE STUDY

- The demand models were developed using annual domestic energy consumption from 1985 to 2001. More accurate models may have been obtained using monthly demand data, but such data was not available.
- Data on disposable income was not available and so real GDP was used as a proxy for income.
- Due to time constraints, a more comprehensive search for a demand model most appropriate for VRA could not be carried out.
- Models using time variable coefficients (TVCs) may be better predictors than our models but we could not obtain such models due to time constraints.
- Time and financial constraints prevented the hiring of assistants to help with data acquisition and analysis.

6. The demand variables could not be auto regressed for higher lags to check whether better models could be developed.

1.8 ORGANISATION OF THE STUDY

The study is divided into five chapters to keep together relevant information and for easy reading. The first chapter introduces the study and present the background, objectives, justification, methodology and limitations of the study.

Chapter two contains literature review about forecasting techniques and some techniques used to forecast electricity demand in industrialized and developing countries. Demand models that may be appropriate for the VRA are also presented in the chapter.

The third chapter details the research methodology, the methods of data collection, the sampling size, and data analysis. The background of the Volta River Authority and the current methods used by the organization to forecast electricity demand are also presented in chapter three.

Regressive demand models were developed using real GDP, real electricity price and urbanisation as exogenous variables in chapter four. Autoregressive models were obtained using natural logarithm of electricity demand for two preceding years, and real electricity price as exogenous variables. Actual energy demand for 2002 to 2007 was compared with forecasts from the models, exponential smoothing, and a VRA model in this chapter.

A discussion of findings, conclusions and recommendations are presented in Chapter five. Bibliography and Appendices are also presented in the chapter.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

In this chapter, various forecasting techniques are briefly discussed together with some statistical methods that are used to validate a model. Some relevant electricity demand models in literature are also presented.

Forecasting is the making of projections about future performance based on historical and current data. It is the process of analyzing current and historical data to determine future trends. Demand forecasting is one of the main inputs when developing long-term strategic plans. There are three main forecasting techniques namely time series, regression and qualitative techniques (Mentzer and Moon, 2005 and Rusell and Taylor, 2003).

2.1 TIME SERIES

Time series methods are statistical techniques that make use of historical data accumulated over a period of time. They assume that what has happened in the past will continually re-occur in the future. Time series techniques are based on the interrelationship of the four data patterns: trend, cycle, seasonal and random patterns (Rusell and Taylor, 2003). Two of the most popular time series methods are moving averages and exponential smoothing.

2.1.1 MOVING AVERAGES

The **simple moving average** method uses data values from the recent past to smooth out random changes and develop a forecast. The method is effective and efficient provided the time series is stationary in both mean and variance. In the **weighted**

moving average method, higher weights are assigned to the most recent data. The forecast is therefore more responsive to recent data than in the case of the simple moving average (Rusell and Taylor, 2003).

2.1.2 EXPONENTIAL SMOOTHING

The exponential smoothing technique is also a method that weights the recent data more strongly than old data. It is one of the most successful forecasting methods and may be modified efficiently for use with data that have trend and seasonal patterns (Russell and Taylor, 2003). The larger the weight given to the recent data, the more sensitive the forecast will be to recent demand but provides a smaller amount of smoothing. Double exponential smoothing technique (Holt's model) adds a trend factor to the smoothing equation in the linear exponential smoothing. The equations used in the adjusted (double) exponential smoothing technique may be written as:

$L_t = \alpha D_t + (1 - \alpha)(L_{t-1} - T_{t-1})$ smoothed demand level value for period t

$T_t = \beta(L_t - L_{t-1}) + (1 - \beta) T_{t-1}$ smoothed demand trend value for period t

D_t = actual demand value for period t

The forecast value for period $(t + m)$ is given by,

$$F_{t+m} = L_t + T_t \times m$$

The Holt-Winter technique is an extension of the Holt's model and uses an additional equation to estimate the seasonal component of the time series.

2.2 REGRESSION ANALYSIS

Regression analysis is a statistical technique that seeks to establish a relationship between a dependent variable (y) and exogenous or independent variables (x_i). Historical data on the independent and the dependent variables are analysed to determine the strength of the relationship. Where a strong relationship is found, the exogenous variables can be used to make future forecasts. Regression analysis is potentially the most accurate forecast technique available, but it requires a large amount of data. The technique is more useful as a longer range forecast tool. In practice, we build an estimated model of the true model, using the data available to us. Using past data on the values of y and x_i, regression analysis generate estimates of the model parameters. These estimates are designated b_i in the following equation:

$$\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + \ldots + b_k x_k$$

2.3 AUTO REGRESSION MODELS

An autoregressive model is similar to a regression model. It is a linear prediction formula that predicts an output of a system based on the previous outputs and inputs, such as:

$$Y(t) = \beta_1 + \beta_2 Y(t-1) + \beta_3 X(t-1) + \varepsilon_t,$$

$X(t-1)$ and $Y(t-1)$ are the actual value inputs and the forecast outputs respectively (Arsham, 2007). A model which depends only on the previous outputs of the system is called an autoregressive model (AR), while a model which depends only on the inputs to the system is called a moving average model (MA). A model based on both inputs and outputs is an autoregressive-moving-average model (ARMA). Deriving the autoregressive model (AR) involves estimating the coefficients of the model using the method of least squared error. Autoregressive processes regress on themselves. If an observation is made at time (t), then, a p-order autoregressive model satisfies the equation:

$$Y(t) = \Phi_0 + \Phi_1 Y(t-1) + \Phi_2 Y(t-2) + \Phi_2 Y(t-3) + \ldots + \Phi_p Y(t-p) + \varepsilon_t,$$

where ε_t is a white-noise series.

The current value of the series is a linear combination of the p most recent past values of itself plus an error term, which incorporates everything new in the series at time t that is not explained by the past values.

2.4 STAGES INVOLVED IN DEVELOPING A MODEL

A model is a representation of an actual system using either a physical or a mathematical rendering. Model building consists of the following three components: model specification, model fitting, and model diagnosis.

2.4.1 MODEL SPECIFICATION

Model specification is the process of determining the dependent variable and deciding the independent variables that should be included in the model. It involves the following steps:

- Deciding the problem we want to investigate.
- Listing the potential independent variables for our model.
- Gathering the sample data for all variables over a specified period

2.4.2 MODEL BUILDING

Model building is the process of actually constructing a mathematical equation in which some or all of the independent variables are used in an attempt to explain the variation in the dependent variable.

2.4.3 MODEL DIAGNOSIS

Model diagnosis is the process of analyzing the quality of the model constructed by determining how well the model fits the data. Examination of output values such as the coefficient of determination, R^2, and the estimate of the standard deviation of the model error helps in the diagnosis process. Assessment is also carried out on the extent to which the model's assumptions appear to be satisfied. If the model is unacceptable in any of these areas, another model will have to be re-specified. One does not need to build a sophisticated model if a simpler one will provide adequate results (Mentzer and Moon, 2005, Rusell and Taylor, 2003, and Groebner et al., 2005).

2.4.3.1 The Coefficient of Determination, R^2

The coefficient of determination, R^2, measures the proportion of variation in the dependent variable that is explained by its relationship to all the independent variables in the model. Some researchers prefer to use the ***adjusted R^2*** as a measure of goodness of fit since adding independent variables to the regression model will always increase R^2 even if the variables have no relationship with the dependent variable.

2.4.3.2 The *F-test*

The analysis of variance (***F-test***) is another method for testing whether the regression model explains a significant proportion of the variation in the dependent variable (Groebner et al., 2005).

2.4.3.3 Significance of Independent Variables

To determine which exogenous variables are significant, we test the significance of each independent variable using significance level of, for example, $\alpha = 0.05$.

2.4.3.4 Standard Deviation of the Model Error

The standard deviation of the regression model error measures the dispersion of observed dependent variable values around values predicted by the estimated regression model. Too large standard deviation of the model error, S_ε, does not provide adequate precision for confident prediction. Generally, if the range $\pm 2S_\varepsilon$ is acceptable for practical purposes, the estimate of the standard deviation of the model error might be considered acceptable (Groebner et al., 2005).

2.4.3.5 Multicollinearity

Multicollinearity is a high correlation between two independent variables such that the variables contribute redundant information to the model. Some of the indications of severe multicollinearity are the following:

- Incorrect signs on the coefficients
- The occurrence of sizeable changes in the values of slope coefficients when a new variable is added to the model
- A variable that was significant in the regression model becomes insignificant when a new independent variable is added
- The estimate of the standard deviation of the model error increases when a variable is added to the model

2.4.3.6 Variance Inflation Factor (*VIF*)

Variance inflation factor is a method of measuring multicollinearity. It is a measure of how much the variance of an estimated regression coefficient increases if the independent variables are correlated. The larger the ***VIF*** value, the greater the multicollinearity. Generally, if $VIF < 5$ for a particular independent variable, multicollinearity is not considered a problem for that variable (Groebner et al., 2005).

2.4.3.7 Analysis of Residuals

A great deal can be learnt about the aptness of the regression model by analyzing the residuals. Some of the problems that may be inferred through the graphical analysis of residuals are:

- Non-zero mean
- Non-constant variance
- Dependence of residuals
- Error terms not normally distributed

2.4.4 CORRECTIVE ACTIONS

If based on the residuals, we decide that the model constructed is not appropriate, some corrective action is warranted. There are three approaches that may be used to correct a regression model:

- Transform some of the existing independent variables
- Remove some variables from the model
- Re-develop the model

In general, the transformation of the variables such as raising them to a power, taking the square root of the independent variables or taking the log of variables are used to make the data better conform to a linear relationship (Groebner et al., 2005).

2.4.5 MEASURING ACCURACY

The most straightforward way of evaluating the accuracy of a model is to plot the observed values and the forecasts and identify the residuals. Some widely used statistical measures of error that can help select a good model or the optimum value of the parameters within a model are briefly discussed.

The **mean absolute deviation (MAD)** is the average of the absolute values of the difference between the forecast and observed values. The **mean absolute percentage deviation (MAPD)** measures the absolute error as a percentage of observed values. **Mean squared error (MSE)** is average of the squared error values. This is the most commonly used lack-of-fit indicator in statistical fitting procedures and it is very sensitive to any outlier.

The **Durbin-Watson Statistic (D-W)** quantifies the serial correlation of the errors in time series analysis and forecasting. For no serial correlation, a value close to 2 is expected. For a forecasting where the value of **D-W** is significantly different from 2, the estimates of the variances and co-variances of the model's parameters can be in error, being either too large or too small (Groebner et al., 2005).

2.5 QUALITATIVE TECHNIQUES

Subjective forecasting techniques are procedures that turn opinions of experienced personnel into formal forecasts. An advantage of subjective techniques is that they take into account the full wealth of knowledge of key personnel and require little formal data. The technique however takes a considerable amount of key personnel time. Qualitative techniques are used in forecasting when the future is not expected to look like the past. For new products, for example, historical data may not be available. Subjective techniques are typically used as part of long-range corporate level forecasting or for adjusting short-range product forecasting (Mentzer and Moon, 2005 and Russell and Taylor, 2003).

2.6 SOME ELECTRICITY DEMAND MODELS IN LITERATURE

Cointegration analysis and error correction models have become the standard techniques for developing electricity demand models. These methods were developed by Engle and Granger (1987) and applied to forecast electricity demand by Engle et al. (1989). An estimate of the cointegration relationship is obtained by an ordinary least squares regression of the contemporaneous values of the variables (Clemens and Madlener, 1999 and Chang and Martinez-Chombo, 2003).

Johansen (1988, 1991) and others have used a potentially more efficient systems approach which amounts to reduced-rank regression by maximum likelihood estimation. Other writers have still used new techniques to identify cointegrating relationships as well as include more specific energy-related variables in the models. Some recent examples of extensions to the cointegration analysis and error correction models include the work by Pesaran, Shin and Smith (1996) which is agnostic about orders of integration of the exogenous variables but requires that there is a long-run relationship between the variables. Estimation and testing for the relationship using ordinary least squares in a single equation analysis is possible when the long run-relationship assumption is satisfied.

Holtedahl and Joutz (2003) in another extension used a proxy variable, urbanization, to capture economic development characteristics and changes in electricity-using capital-stocks in Taiwan not explained by pure income effect. They intimated that the method holds promise for explaining residential energy consumption in other developing countries.

2.6.1 EXAMPLES OF DEMAND MODELS IN LITERATURE

Some relevant energy demand models in literature are presented below:

2.6.1.1 'Excess capacity and the demand for electricity in Scotland'

McGuire (1982) used regression analysis to estimate the future system maximum demand for The Scottish Electricity Supply industry. The model stated system maximum demand as a function of the average price of electricity, an index of industrial production, the mean January temperature and an average price of gas. The regression equation was stated as a linear double-log function of the dependent and independent variables. An Almon distributed lag of system maximum demand for the previous years was added. The lag necessitated the specification of the degree of the polynomial, as well as the period over which the lag was effective. The estimated elasticities derived from the analysis are as shown in the table below:

Table 2.1: Elasticity for system maximum demand in Scotland

Variable	Short-run	Long-run
Average price of electricity	-0.2469	-0.6508
Temperature	-0.0252	-0.0664
Income	0.5772	1.5217
Average price of gas	0.1216	0.3205

2.6.1.2 Estimating underlying energy demand trends using UK annual data

Dimitropoulos et al. (2005) wrote that it is unrealistic to expect trend to capture the sum of all the underlying trends including efficiency of appliances, capital stock, income, price, temperature and other important exogenous factors such as consumer preferences and economic structure using a simple deterministic time model. They used the Structural Time Series Model, allowing the Underlying Energy Demand Trend to be stochastic in order to capture these effects adequately.

Dimitropoulos et al. claimed that when these effects have been allowed for, the estimated long-run elasticities are robust to the different data frequencies used in the modelling. They used the approach suggested by Harvey (1997), and based on annual data for the UK from 1967–2002. Energy demand, they argued, is a derived demand, not demanded for its own sake but for the services it gives in conjunction with energy using appliances and capital stock. Their empirical results gave the long-run UK energy demand price and income elasticity estimates as 0.133 and 0.583 respectively – for the whole economy.

2.6.1.3 Seasonality, cointegration & forecasting UK residential energy Demand

Clements and Madlener (1999) forecast residential energy demand in the United Kingdom using the approach of Pesaran, Shin and Smith (1996). The approach is agnostic about the orders of integration of the explanatory variables but requires that there is a fundamental long-run relationship between the variables. They estimated and tested for the long-run relationship using Ordinary Least Squares in a single equation analysis.

Clements and Madlener claimed that in the case of demand modelling, there are few grounds for believing that the main explanatory variables adjust to disequilibrium in the long-run relationship governing the demand for energy. The results from their analysis gave income elasticity in the range of one third to one half and price elasticity close to zero.

2.6.1.4 Electricity vs. total energy demand: Analysis of the changing composition of demand

Hope and Stephenson (2005) in an NZIER report to the New Zealand Electricity Commission analysed possible energy demand functions. They estimated separate demand functions for industrial and commercial electricity demand based on theoretical demand drivers. Hope and Stephenson assumed producers respond to the need for energy in their production functions, demand for their production, and the relative price of energy alternatives.

The results indicated little response in electricity demand to price and the econometric estimates suggested that electricity demand is becoming increasing de-linked from demand for other types of energy/fuels. In addition, their estimates suggested that electricity demand in both commercial and industrial sectors are converging towards a stable equilibrium state relative to production/GDP. They concluded that there may be problems in their demand model mainly due to changes in equilibrium relationships in energy demand over time.

2.6.1.5 Household energy demand in Kuwait: an integrated two-level approach

To use an estimated model to forecast future energy demand in Kuwaiti households and villas under different policy options, Eltony and Hajeeh (1999), assumed energy consumption was a function of aggregate energy price index, real domestic product and ratio of villas to total dwellings. They added a dummy variable for the period of Iraqi occupation of Kuwait. Eltony and Hajeeh argued that energy consumption intensity differs by housing structure type and villas are expected to consume proportionately higher amounts of electricity.

They employed cointegration and error-correcting techniques to solve the problem of non-stationary time series with a mean and variance that increase over time resulting in long-run non-equilibrium. The long-run errors were fed into the short-run model, which also tended to be stationary, since there is no expected growth in difference variables. The major advantages of the approach were that it gave both the long-run and short-run elasticities, which are statistically reliable, and also provided an estimate of the speed of adjustment towards the long-run. The model suggested that energy consumption varies directly with economic growth and inflation.

2.6.1.6 Industrial energy policy: a case study of demand in Kuwait

Eltony (2006) constructed an energy model to evaluate past experience and assess the impact of different price policy assumptions on energy demand in the Kuwaiti industrial sector. His model had the total aggregate energy utilised in the industrial sector as a function of the output of the industrial sector, the real price of energy and a lagged dependent variable. The empirical results indicated that with nominal energy prices staying the same, energy consumption in the sector is projected to grow at an annual growth rate of about 3.5 per cent throughout the forecast period. However, when all energy subsidies are removed, the energy consumption is projected to grow by only 1.5 per cent annually throughout the same period.

2.6.1.7 Forecasting investment needs in South Africa's Electricity and Telecom Sectors

Bogetic and Fedderke (2006) adopted a general econometric approach to estimate the demand for electricity and telephony for South Africa through 2010. They used historical data from 1980 to 2002 to build their demand models. The estimator employed distinguishes between long-run equilibrium and short-run dynamics. In doing so, they claim, the danger of bias and inconsistency in estimation under the assumption of group homogeneity is avoided. This results in a set of more accurate parameter estimates underlying the remainder of the forecasting exercise.

Bogetic and Fedderke employed the Pooled Mean Group (PMG) estimator of Pesaran, Shin and Smith (1999). The general framework allows the formulation of the PMG estimator which allows the intercepts, short-run coefficients and error variances to differ freely across the groups, but the long run coefficients to be homogeneous. They argue that as long as sector-homogeneity is assured, the PMG estimator offers efficiency gains over the Mean Group (MG) estimator, while granting the possibility of dynamic heterogeneity across sectors. Their analysis gave the electricity demand elasticities with respect to real GDP and the outputs of the agricultural and manufacturing sectors as 1.428, -0.007 and 0.011 respectively.

2.6.1.8 Electricity Demand Analysis using Cointegration and Error-correction Models with time varying parameters: The Mexican Case

Chang and Martinez-Chombo (2003) used Cointegration and Error-Correction Models with Time Varying Parameters to conduct electricity demand analysis using monthly Mexican electricity data for residential, commercial and industrial sectors. They used income, prices and a nonparametric temperature measure as explanatory variables. The income elasticity was allowed to evolve slowly over time by employing the time varying coefficient cointegrating model. According to Chang and Martinez-Chombo, in most of these kinds of analyses the demand equation is specified as a linear double-log function, as a way to obtain elasticities directly from its coefficients.

The fixed coefficients (FC) feature, they said, is questionable in light of the long time span (185 months) of the data and changes that could have taken place in the economy over such a long period of time affecting the demand for electricity. The results of the analysis showed that the inclusion of the TVC in the model significantly reduces the levels of the estimated coefficients, which represent the elasticities, compared to those obtained from the usual fixed coefficient models. The income/production elasticity is substantially less than unity for all sectors, indicating that the demand is inelastic with respect to the changes in income/production in all sectors.

2.6.1.9 Residential electricity demand in Taiwan

Holtedahl and Joutz (2003) used a model with electricity demand as a function of household disposable income, population growth, the price of electricity and the degree of urbanization to estimate residential electricity demand in Taiwan. They separated short- and long-term effects through the use of an error correction model. Holtedahl and Joutz explained that energy demand models for a developing country may require a framework different from those used in the industrialized countries. One potential difference is that economic growth and structural changes associated with rapid development suggest that income and price elasticities will not be stable.

Their study modifies the electricity demand model traditionally used in the literature for industrialized countries for the case of Taiwan. The degree of urbanization was used as a proxy variable for the extent of economic development that has occurred. The results revealed that the electricity price and oil price coefficients are roughly equal and of opposite signs. The income elasticity is slightly greater than unity and an increase of 1% in urbanization leads to nearly a 4% increase in residential electricity consumption.

2.6.1.9 An empirical investigation into the relationship between real GDP, Energy demand and real energy price

Amoako-Baah carried out a study to discover the most appropriate way to forecast Ghana's electricity demand using GDP and electricity price as exogenous variables. He sought to establish how the variables are related, such that any future changes in GDP and electricity price will help to determine the electricity demand. Amoako-Baah used data on electricity demand and electricity prices for a period of 30 years obtained from VRA. Secondary yearly data on GDP was collected from the Ghana Statistical Service and ISSER (University of Ghana). The demand elasticities obtained from empirical data analysis were 2.5 and -0.075 respectively for real GDP and real price of electricity. Similar elasticties were obtained for a model using nominal GDP and real price of electricity as independent variables.

2.7 DEMAND MODEL FOR VRA

The electricity demand model for VRA was developed as follows:

2.7.1 INDEPENDENT VARIABLES

Demand for a good or service such as electricity depends on the income of consumers, the size of the population, the price of electricity, the availability and price of close substitutes, etc. The law of demand states that; when the price of a commodity is raised, all other things being equal, buyers tend to buy less of the commodity. The demand law may be extended to electricity in the following manner: income is positively related to electricity demand, while price of electricity is negatively related to electricity demand. These assertions are supported by the elasticities values from literature.

In Ghana, demand for electricity increased tremendously as a result of strong growth in the national economy from 1983 (Amoako-Baah, 2001). Since 1983, the annual electricity demand growth rate has exceeded 9 percent. This could largely be attributed to the impact of the Economic Recovery Programme launched by the Government in 1983. The Energy Commission (EC) estimates that residential demand may reach anywhere between 7,000 and 13,000 GWh by 2020 depending on the rate of economic growth and urbanization (RCEER, 2005). The increase in demand may also be attributable to the growth of electricity demand by industry and the new affluent settlements springing up in the large cities of Ghana.

The demand for energy is also affected by prices and the effect of prices on energy demand is more pronounced in the long run, as habits of consumers may change. However, if the standards of living and economic growth are to be maintained, it is not possible to accept any major reduction in energy consumption. Increasing energy costs, therefore, may be largely tolerated by consumers in the short term. A significant feature of many developing countries is an uneven energy market, which in the economically more advanced areas, has a measurable marginal demand responding to price signals; by contrast, the poorer areas suffer from substantial suppressed demand and have no room for price resilience (Amoako-Baah, 2001).

The degree of urbanization (the percentage of the total population who live in urban areas) is also expected to be directly related to the quantity of electricity consumed in Ghana. The middle and high-income urban consumer classes typically use a number of high energy consuming household appliances such as air conditioners, fridges, water heaters, electric cookers in addition to a substantial amount of lighting equipment and bulbs for the houses. Urbanization implies greater access to electricity, since households can be more easily connected to the grid. Again, consumers who already had access to electricity before moving into urban areas are likely to increase their consumption once they arrive in an urban setting. The increase in demand will take place through increased use of existing appliances and the purchase of new ones (Holtedahl and Joutz, 2003).

2.7.2 PROPOSED DEMAND MODELS FOR VRA

The electricity demand model proposed for VRA modifies the electricity model traditionally used in literature for industrialized countries. The model is given by:

$$Ln\,(E_D) = b_0 + b_1\,Ln\,(GDP) + b_2\,Ln\,(P_E) + b_3\,Ln\,(U) + b_4\,L_S$$

where:

GDP = real gross domestic product for the year

E_D = aggregate electricity consumed for a year

P_E = average real electricity price for the year

U = urbanisation

L_S = dummy variable representing years of nationwide load shedding exercise

Since electricity is a normal good (service), increasing GDP is expected to lead to increase consumption through greater economic activity and purchases of electricity-using appliances. A rise in electricity prices, ceteris paribus, will lead to a fall in quantity demanded. It is believed that urbanization is a reasonable proxy for economic development factors not captured by pure income effect (Holtedahl and Joutz, 2003). The dummy variable L_S was added for years of nationwide load shedding exercise.

Autoregresssive models were developed for VRA using the following equation:

$$E_D = f\,(P_E, GDP, GDP_{-1}, GDP_{-2}, E_{D\text{-}1}, E_{D\text{-}2}, LS),$$

where, GDP_{-1}, $E_{D\text{-}1}$, GDP_{-2} and $E_{D\text{-}2}$ are the GDP and electricity demand for the two preceding years.

CHAPTER 3

METHODOLOGY AND ORGANISATIONAL PROFILE

3.0 INTRODUCTION

In this chapter, the methodology adopted in the study is presented with emphasis on the key independent variables. The history of electric power generation in the country is also presented and an organisational profile of VRA is given. Some approaches to electricity demand forecasting as used currently by VRA are also presented.

3.1 METHODOLOGY

Secondary data on electricity demand, electricity prices, annual real GDP growth, and percentage urban population were collected from various institutions. The aggregate annual energy demand was modelled as a function of real GDP, real price of electricity and degree of urbanisation. Statistical techniques were used to validate the model after it had been developed using historical data from 1985 to 2001. The 17-year period was used to avoid problems associated with long time span data - including concerns about the validity of fixed coefficients in the electricity demand equation. A dummy variable was included for years of nationwide load shedding exercise.

Statistical and economic software packages including SPSS and EXCEL were employed to develop the model. The estimated model and the adjusted exponential smoothing technique were used to forecast demand for 2002 - 2006. The two forecasts and a VRA forecast were compared with actual energy consumption for 2002 to 2006. The sources of the data and how the data were transformed for use in the regression model are presented below.

3.1.1 DOMESTIC ELECTRICITY DEMAND

The nation's domestic electricity demand data was obtained from VRA and it is presented in Table 3.1 below. It included the annual electricity consumption by ECG, NED and other direct VRA customers. Exports to Commutate Electricité de Benin (CEB) and Volta Aluminium Company Limited (VALCO) were not included is because they are determined by long term contracts. Data from 1985 to 2001 was used in the regression model since the late 1980s saw the beginning of significant increases in the demand for power in Ghana - due to the economic recovery programme launched by the government in 1983.

Table 3.1: Domestic electricity demand

Year	Electricity Demand (GWh)
1985	1309.08
1986	1453.16
1987	1576.25
1988	1654.82
1989	1811.54
1990	1987.14
1991	2308.61
1992	2633.90
1993	2980.19
1994	3280.31
1995	3594.23
1996	4097.01
1997	4452.55
1998	4050.66
1999	4550.34
2000	4937.72
2001	5162.86
2002	5353.77
2003	5607.61
2004	6004.37
2005	6411.64
2006	6734.06
2007	5810.27

3.1.2 REAL GDP GROWTH

Data on Ghana's percentage real GDP growth from 1985 to 2007 were collected from the 1991 – 2006 editions of **The State of the Ghanaian Economy** (published by ISSER) and the 2008 Budget Statement. The data is presented in Table 3.2.

Table 3.2: Percentage real GDP growth

Year	% Real GDP Growth
1985	8.6
1986	5.2
1987	4.8
1988	5.6
1989	5.1
1990	3.3
1991	5.0
1992	3.9
1993	5.0
1994	3.7
1995	4.5
1996	5.2
1997	5.1
1998	4.6
1999	4.4
2000	3.7
2001	4.2
2002	4.7
2003	5.2
2004	5.8
2005	5.8
2006	6.4
2007	6.3

Due to the Economic Recovery Programme launched by the Government in 1983, the late 1980s saw the beginning of significant increases in the demand for power in Ghana. The year 1985 was therefore taken as a base and used to transform the real GDP data into indices as shown in Table 3.3.

Table 3.3: Percentage real GDP growth and indices

Year	% Real GDP Growth	GDP / GDP_{1985}	$GDP / GDP_{1985} \times 100$ (%)
1985	8.6	1.000	100.00
1986	5.2	1.052	105.20
1987	4.8	1.102	110.25
1988	5.6	1.164	116.42
1989	5.1	1.224	122.36
1990	3.3	1.264	126.40
1991	5.0	1.327	132.72
1992	3.9	1.379	137.90
1993	5.0	1.448	144.79
1994	3.7	1.501	150.15
1995	4.5	1.569	156.90
1996	5.2	1.651	165.06
1997	5.1	1.735	173.48
1998	4.6	1.815	181.46
1999	4.4	1.894	189.45
2000	3.7	1.965	196.45
2001	4.2	2.047	204.71
2002	4.7	2.143	214.33
2003	5.2	2.255	225.47
2004	5.8	2.385	238.55
2005	5.8	2.524	252.39
2006	6.4	2.685	268.54
2007	6.3	2.855	285.46

3.1.3 PRICE OF ELECTRICITY

Data on average prices of electricity per kWh were obtained from the annual reports of VRA for the years 1985 to 2007 and are shown in Table 3.4.

Table 3.4: Average price of electricity

Year	Average Price of electricity (¢/kWh)
1985	0.84
1986	2.30
1987	2.66
1988	3.25
1989	3.39
1990	3.67
1991	4.33
1992	5.76
1993	8.29
1994	9.94
1995	27.70
1996	28.14
1997	29.05
1998	77.99
1999	105.78
2000	104.69
2001	176.17
2002	274.46
2003	415.07
2004	431.04
2005	425.74
2006	475.04
2007	548.57

The prices were deflated using Consumer Price Index (CPI) values obtained from ISSER's 1991 - 2006 editions of *The State of the Ghanaian Economy* and the 2008 *Budget Statement* to obtain real electricity prices (in constant 1985 cedis). The nominal and real electricity prices are given in Table 3.5 below.

Table 3.5: Average and real price of electricity

Year	Average Price of Electricity	CPI	CPI Deflator	Real Price of Electricity
1985	0.84	-	1.00	0.84
1986	2.30	24.60	1.25	1.84
1987	2.66	39.80	1.74	1.53
1988	3.25	31.40	2.29	1.42
1989	3.39	25.20	2.87	1.18
1990	3.67	37.20	3.93	0.93
1991	4.33	18.00	4.64	0.93
1992	5.76	10.10	5.11	1.13
1993	8.29	24.96	6.38	1.30
1994	9.94	24.87	7.97	1.25
1995	27.70	59.47	12.71	2.18
1996	28.14	46.56	18.63	1.51
1997	29.05	27.90	23.83	1.22
1998	77.99	19.30	28.42	2.74
1999	105.78	12.90	32.09	3.30
2000	104.69	25.20	40.18	2.61
2001	176.17	32.90	53.40	3.30
2002	274.46	14.80	61.30	4.48
2003	415.07	26.70	77.66	5.34
2004	431.04	12.60	87.45	4.93
2005	425.74	15.50	101.01	4.22
2006	475.04	10.50	111.61	4.26
2007	548.57	12.00	125.00	4.39

3.1.4 PERCENTAGE URBAN POPULATION

Percentage urban population for 1984 and 2000 were obtained from the Ghana Statistical Service. Data for 1985 to 2006 were derived from the given data by assuming a constant growth rate of 1.98 for percentage urban population. The percent urban population data is presented in Table 3.6 below.

Table 3.6: Percentage urban population

Year	% Urban Population
1984	**32.00**
1985	32.63
1986	33.28
1987	33.94
1988	34.61
1989	35.30
1990	36.00
1991	36.71
1992	37.44
1993	38.18
1994	38.94
1995	39.71
1996	40.49
1997	41.30
1998	42.11
1999	42.95
2000	**43.80**
2001	44.67
2002	45.55
2003	46.46
2004	47.38
2005	48.31
2006	49.27
2007	50.25

3.1.5 CROSS-SECTIONAL DATA

Data from Tables 3.1, 3.3, 3.5 and 3.6 were used to construct a cross sectional data over the period 1985 to 2007 as shown in Table 3.7.

Table 3.7: Cross-sectional data of electricity demand, GDP, price and urbanisation

Year	Electricity Demand (GWh)	Real GDP / real GDP for 1985	Real Price of Electricity	% Urban Population
1985	1309.08	100.00	0.84	32.63
1986	1453.16	105.20	1.84	33.28
1987	1576.25	110.25	1.53	33.94
1988	1654.82	116.42	1.42	34.61
1989	1811.54	122.36	1.18	35.30
1990	1987.14	126.40	0.93	36.00
1991	2308.61	132.72	0.93	36.71
1992	2633.90	137.90	1.13	37.44
1993	2980.19	144.79	1.30	38.18
1994	3280.31	150.15	1.25	38.94
1995	3594.23	156.90	2.18	39.71
1996	4097.01	165.06	1.51	40.49
1997	4452.55	173.48	1.22	41.30
1998	4050.66	181.46	2.74	42.11
1999	4550.34	189.45	3.30	42.95
2000	4937.72	196.45	2.61	43.80
2001	5162.86	204.71	3.30	44.67
2002	5353.77	214.33	4.48	45.55
2003	5607.61	225.47	5.34	46.46
2004	6004.37	238.55	4.93	47.38
2005	6411.64	252.39	4.22	48.31
2006	6734.06	268.54	4.26	49.27
2007	5810.27	285.46	4.39	50.25

3.2 THE GHANAIAN ELECTRIC POWER INDUSTRY

There are four electric power production and distribution utilities in the country, namely VRA, ECG, NED and TICO. The Electricity Company of Ghana (ECG) and the Northern Electricity Department (NED) are responsible for electric power distribution in the country. The Electricity Company of Ghana delivers power to customers in the southern half of the country while the Northern Electricity Department, a Department of the VRA, has responsibility for supplying power to customers in the northern half.

The Electricity Corporation of Ghana was incorporated under the Companies Code 1963 (Act 179). The corporation became a non-quoted public company – Electricity Company of Ghana - on the 21st February, 1997. All assets and liabilities of the former Electricity Corporation of Ghana and its predecessor the Electricity Division were vested in the company. The company owns and manages the distribution network infrastructure. It has an installed transformer capacity of over 3,000 MVA and 1,200 km of 33 kV sub-transmission lines, 450 km of 11 kV distribution circuits and approximately 4,049 km of other lower voltage distribution circuits for retailing electricity.

The Public Utilities Regulatory Commission (PURC) and the Energy Commission (EC) are two government agencies that regulate the utilities for the public good (MOE, 2008). The Energy Commission (EC) is a sector institution responsible for regulating, developing and managing the utilisation of energy resources. They are also responsible for preparing indicative plans for the development of the energy sector, licensing of public utilities and enforcing performance standards. The Public Utilities Regulatory Commission (PURC) is a statutorily independent body responsible for regulating and overseeing the provision of utility services whose functions include:

- Protection of the interests of utility providers and consumers,
- Approval of rates,
- Monitoring performance standards, and
- Promotion of competition among service providers.

3.2.1 HISTORY OF ELECTRIC POWER GENERATION IN GHANA

Before the construction of the Akosombo hydroelectric plant, electrical power generation and supply in Ghana was carried out with a number of isolated diesel generators dispersed across the country as well as standalone electricity supply systems. These were owned by industrial establishments such as mines and factories, municipalities and other institutions (RCEER, 2005).

The first government-sponsored public electricity supply in Ghana commenced at Sekondi in 1914. The Gold Coast Railway Administration operated the system and it was used mainly to support the operations of the railway system and the ancillary facilities which went with its operations. Supply from the system was extended to the Takoradi Township in 1928. Meanwhile, the Public Works Department had commenced a limited direct current (dc) supply in Accra during the year 1922. This was immediately followed by a large alternating current (ac) project which also commenced on 1st November, 1924.

The first major electricity supply in Koforidua commenced in 1926 and consisted of three horizontal single cylinder oil-powered engines commissioned on 1st April, 1926. In addition, work commenced to provide electric lighting and power to Kumasi in 1926 resulting in a restricted evening supply starting in May 1927. A power station was brought into full operation on 1st October, 1927 in Kumasi. In the same year, dc supply was installed at Winneba but this was subsequently changed to ac by extending an existing supply from Swedru.

During the period 1929 - 1930, a limited electricity supply was extended to Tamale until a new ac plant was sited there in 1938. The next power station to be established was Cape Coast, which came into being in 1932. Subsequent to its takeover by the Electricity Department from the Public Works and Railways on 1st April, 1947, the power station at Swedru was commissioned in 1948.

The Tema power station was commissioned in 1956 with a 3 × 650 kW generating set. From 1961 - 1964 the Tema Station was upgraded to a maximum capacity of 35,298 kW, thus making it probably the biggest single diesel-powered generating station in Africa at the time. Again in 1963, the Electricity Division brought into operation the first 161,000 volt transmission system in Ghana, which was used to carry power from the Tema Power Station. At its peak in 1965, about 75 percent of the power generated the Tema Station was used in Accra.

3.2.2 HYDRO-ELECTRIC POWER GENERATION IN GHANA

In 1915, Mr. E. A. Kitson of the Gold Coast Geological Survey Department drew attention to the potential of the Volta River as a source of hydro-electric power and linked it with the bauxite deposit, discovered the previous year, in the development of an aluminium industry. Proposals for this dual development were first made by the Gold Coast Government in 1924. Between 1938 and 1945, Duncan Rose, a private entrepreneur carried out field surveys in connection with the project and proceeded to acquire certain concessions in the country. His activities were carried further by the West African Aluminium Company, WAFAL, of which he became its first Chairman in 1945. Aluminium Limited of Canada acquired an interest in the project in 1949.

The Ghana Government's interest in the project was revived in 1949 with the appointment of Sir William Halcrow and Partners to prepare a report on the potential uses of the Volta River Basin. The report, published in 1951, recommended that in view of the widespread effects it will have on the life and economy of the country, the project should be undertaken as a Government enterprise under the control of VRA. They however recommended that the production of aluminium should be entrusted to private companies who would contract with the VRA for power. In the meantime a joint mission sponsored by the British Aluminium Company and Aluminium Limited of Canada investigated and reported favourably on the prospects of an aluminium industry as a part of the project.

In September 1960, tenders were invited on a world-wide basis for the construction of the main civil engineering works which included the dam, saddle dam, powerhouse, intake structure and appurtenances. In May 1961 an award was made to the Italian consortium, Impresit-Girola-Lodigiani, S.p.A. and Impresa Costr. Ing. E. Recchi in the sum of approximately Ghana Pounds 16,000,000 and mobilization of equipment and work force started soon after.

In June 1961, the Government of Ghana invited manufactures and contractors by world-wide advertisement to submit tenders for the supply of major equipment and for installations under nine separate contracts. The tenders were received in Accra in October 1961 and after analysis and evaluation by the Engineer, Kaiser Engineers and Constructors, Inc., the Volta River Authority awarded contracts to the recommended low tenderers on 29th December, 1961 (VRA website, 2007).

3.3 ORGANISATIONAL PROFILE – VOLTA RIVER AUTHORITY

The Volta River Authority (VRA) was created by the Volta River Development Act (Act 46) of 1961. The VRA is responsible for generation of electric energy in Ghana by developing the hydro potential of the Volta River and the operation of the transmission system. Since 1987, the VRA has also been responsible for the distribution of electricity to customers in the regions north of Ashanti region.

The Volta River Development initially involved the construction of the Akosombo Hydroelectric Plant comprising the power generating station and the Akosombo dam. The Kpong Hydroelectric Plant was later constructed downstream the Akosombo dam. The construction of the Akosombo dam resulted in the creation of the Volta Lake. Lake Volta, the head pond of Akosombo dam, has a surface area of 8,500km^2 and a storage capacity of $148 \times 10^9 m^3$.

The Volta River Authority's primary function is to generate and supply electrical energy for industrial, commercial and domestic use in Ghana. The Authority is also responsible for safe-guarding the health and socio-economic well being of the inhabitants of the communities alongside the lake, and management of any incidental issues including maintenance of the environment. VRA started with the development of the hydroelectric potentials of the Volta River and the construction of a nation-wide grid transmission system. Today, it has assumed responsibility for the development of other energy potentials of the country.

Ghana's first hydro plant, the Akosombo Generating Station in the Eastern Region, started producing 588 MW of power in 1965 from four generating units. In 1972, two additional generating units of total capacity 324 MW were commissioned to bring Akosombo's total installed capacity to 912 MW. In 1982, a second hydro generating station, 31 km down stream of Akosombo, was commissioned on the Volta River at Kpong, also in the Eastern Region. This added 160 MW capacity to that of Akosombo, to bring the total installed generation capacity to 1,072 MW.

VRA commenced the Akosombo Generating Station Retrofit Project (AGSRP) in 1992 after the Station had operated for over 25 years. Guaranteed peak efficiency of 93.5% was met during efficiency test after the retrofit of the first unit. The retrofit involves systematic replacement of the turbine runners to increase efficiency and prolong the life span of the generating station for another 30 years. The Project was suspended in 1995 partly in order to sustain the supply capability during a period of anticipated shortage. Work was resumed in 1998 and completed in 2005 and this has increased the generating capacity at Akosombo from 912 MW to 1020 MW.

To address the increasing demand and also reduce the risk of hydro power shortage due to the variability of inflows into the Volta Lake, a 330 MW Combined Cycle Thermal Plant was commissioned at Aboadze near Takoradi in 1999. This was followed in 2000, by the addition of a further 220 MW simple cycle thermal plant at the same site, developed through a joint-venture partnership between the VRA and CMS Energy of Michigan, USA.

VRA has a transmission system made up of over 43 substations and approximately 4,000 circuit kilometres of transmission lines that cover the entire country. The Authority has service transmission lines to Togo and Benin through Communaute' Electrique du Benin (CEB), and has an inter-tie with the power system of Cote d'Ivoire through Compagnie Ivoirienne d' Electricité (CIE). VRA serves the border towns of Po and Leo in Burkina Faso via distribution extensions.

In 1987, VRA established the Northern Electricity Department (NED) to distribute electricity in Brong-Ahafo, Northern, Upper East and Upper West Regions and parts of Ashanti Region. NED was developed as an integral part of the larger Northern Electrification Project that extended the national electricity grid beyond Kumasi, almost 25 years after the Akosombo Dam was commissioned. In 1999 NED's operational area was extended to the northern parts of the Volta Region.

The annual firm energy supply from VRA's combined hydro and thermal generation systems is approximately 8,300 GWh. This is made up of 5,800 GWh hydro and 2,457 GWh thermal energies. However, depending on water inflows into the Volta Lake, the two hydro units can produce about 6,100 GWh of energy per annum. VRA sells power to seven major bulk customers. The major sale in (foreign currency) is to the Volta Aluminium Company (VALCO) in Tema. VRA's second major customer is the Electricity Company of Ghana (ECG). The ECG is responsible for the distribution of the bulk of local electricity consumption in Ghana. Bulk sales are also made to a number of smaller industrial and mining consumers (ACRES International, 2001).

3.3.1 ELECTRICITY DEMAND FORECASTING IN VRA

Generation and transmission planning in the Volta River Authority are carried out by the Engineering Services Department. Energy forecasting is based on consumers' historic consumption patterns, known future requirements and the country's future economic outlook. Annual peak demands are derived mainly from estimates of expected annual load factors and the step loads based on customers' requests to the utilities. The forecast addresses six specific areas of consumption:

- Sales to ECG
- Sales to Northern Electricity Department
- Direct sales to mines
- Other Direct sales within Ghana
- VALCO smelter load
- Export to CEB.

The assumptions used for electricity demand forecasts is that total domestic consumption is determined by factors such as the level of economic activity in Ghana, the rate of electrification and the price of electricity. Electricity demand by the mining sector responds to the availability of suitable ore deposit, the world price of minerals (chiefly gold) and the investment programs by the individual mines. VALCO smelter load and export demands are governed by the provisions of individual contracts (ACRES International, 2001).

Demand forecasting is essential in VRA due to the following reasons:

- The electrical power industry requires huge capital investments.
- Electrical power production equipment have long life spans.
- The construction of an electrical power plant takes a long time.
- Demand forecasts are inputs into long term integrated plans.
- Demand forecasts are inputs in financial forecasts.

VRA conducts demand forecasting every 2 years with short term forecasts covering 3 year periods. Time series techniques are used in short term forecasts. Econometric methods using real GDP and real price of electricity are used for long term energy and demand forecasts. The VRA 2001 forecast values assumed an annual real GDP growth rate of 5% from that year onwards and expected real electricity price increases included 29% in 2000, 10% in 2002 and 5% in 2003, and then no further real price growth beyond that point.

CHAPTER 4

MODEL DEVELOPMENT AND ANALYSIS

4.0 INTRODUCTION

In this chapter, energy demand models are developed using real GDP, real electricity price and urbanisation as exogenous variables. 2002 to 2007 forecasts from the regression models, exponential smoothing, and a VRA model are compared with actual energy demand. Electricity demand for two preceding years and real electricity price are used as exogenous variables to develop autoregressive models that are used to forecast demand and compare with actual demand.

4.1 DATA ANALYSIS AND REGRESSION MODEL DEVELOPMENT

An analysis of the data in Table 3.1 reveals that the average growth of domestic demand in Ghana was over 9 percent from 1985 to 2007. Major deviations from the trend occurred in 1998, 2006 and 2007 due to nationwide load shedding exercises. Graphs showing domestic electricity demand and percentage growth electricity demand for years 1985 to 2007 are presented in Figures 4.1 and 4.2.

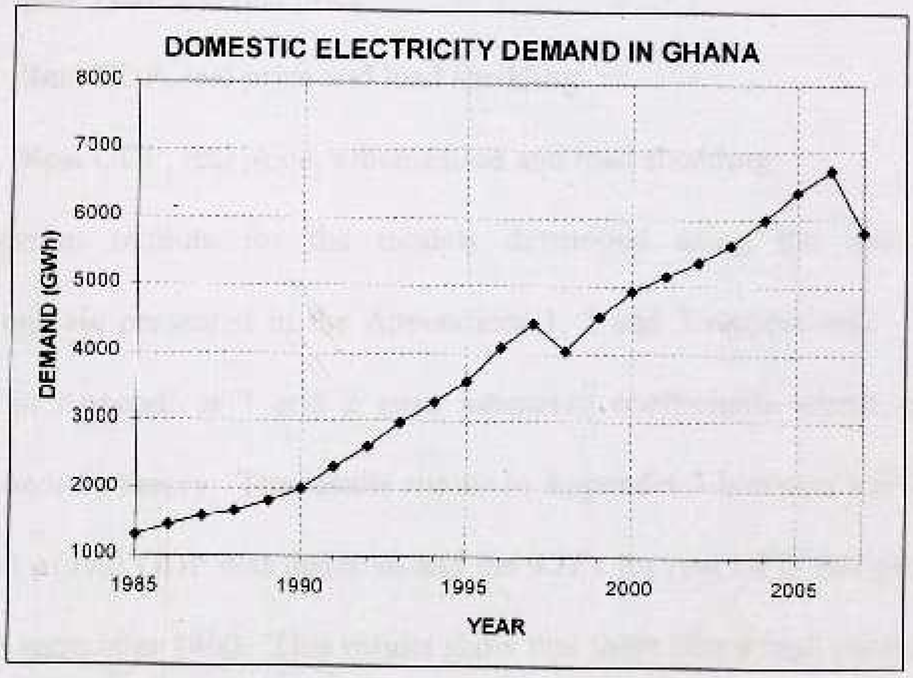

Figure 4.1: Domestic electricity demand for 1985 2007

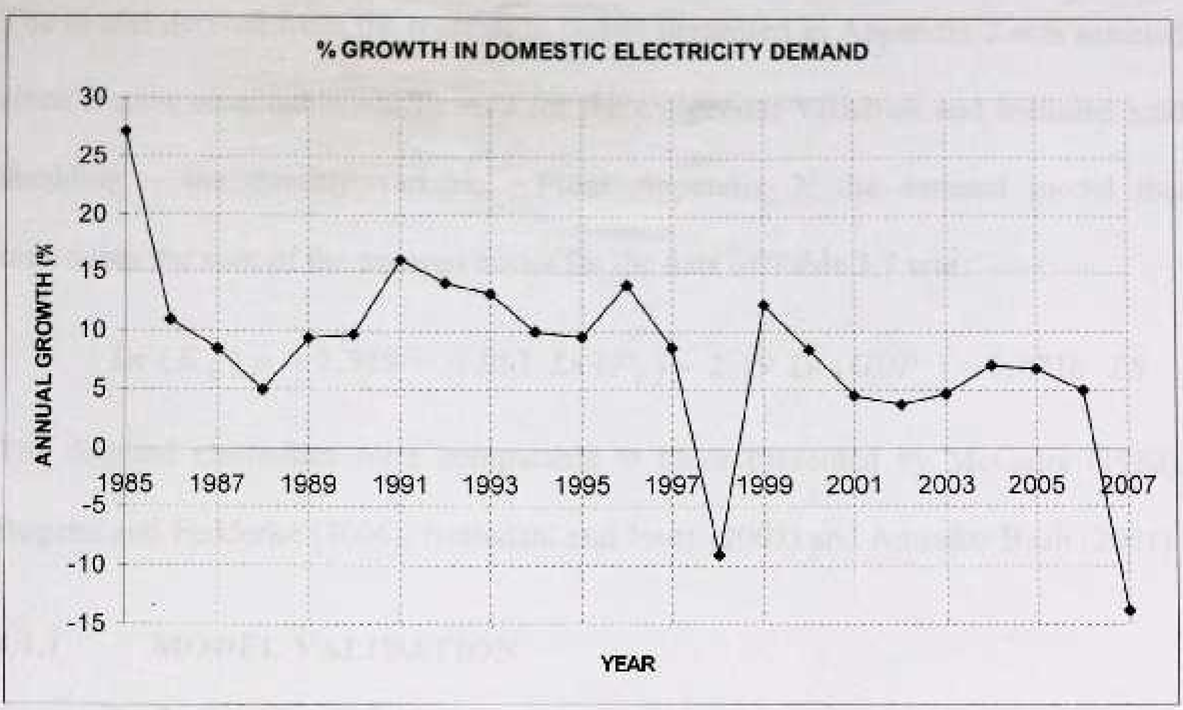

Figure 4.2: Percentage domestic electricity demand growth

A look at Table 3.3 indicates that the average real GDP growth in Ghana from 1985 to date is about 5 percent. Growth rates of around 6 percent were recorded from 2004 to 2007. Natural logarithms of the 1985 – 2001 cross-sectional data presented in Table 3.7 were analysed using SPSS 11.0 for windows. The analyses were carried out by using the following groupings of the exogenous variables:

a. Real GDP and real price

b. Real GDP, real price and load shedding

c. Real GDP, real price, urbanisation and load shedding

The regression outputs for the models developed using the above variable combinations are presented in the Appendices 1, 2 and 3 respectively. The results presented in Appendices 1 and 2 gave estimated coefficients which agreed with general economic theory. The results shown in Appendix 3 however showed that the co-efficient of real GDP was negative and the ***VIFs*** for real GPD and percent urban population were over 1400. This results show that there was a high multicollinearity between real GPD and percent urban population.

The model derived from the regression output presented in Appendix 2 was selected since it gave reasonable coefficients for the exogenous variables and included load shedding – the dummy variable. From Appendix 2, the demand model that minimises the sum of the squared errors for the data of Table 3.7 was:

$$Ln(\hat{E}_D) = -2.919 - 0.092\ Ln(\hat{P}_E) + 2.19\ Ln(\hat{GDP}) - 0.0716\ \hat{LS}$$

The demand elasticities were comparable to those presented by McGuire (1982), Bogetic and Fedderke (2006), Holtedahl and Joutz (2003) and Amoako-Baah (2001).

4.1.1 MODEL VALIDATION

Appendix 2 provided information about the precision of the estimated demand model. From the table, **Model Summary**, R^2 was 0.982. This means that the estimated demand equation explains 98.2 percent of the total variation in electricity demand across the 17-data observations. The ***adjusted*** R^2 from the table was 0.977, close to the R^2 value, indicating that the high R^2 is not as a result of excessive number of estimated coefficients relative to the sample size. The sum of squares residual of the estimated model was 0.068. This low residual value supports the high R^2 value to indicate that we have a model that should be a good predictor of electricity demand.

The ***F-statistic*** reported in Appendix 2 is 232.40, much greater than the 5.74 read from the upper 1% probability *F-distribution* curve. The significance level of the regression is 0.000 indicating that there is a very low percent chance that the estimated regression model fits the data purely by accident. The constant and coefficient of real GDP were significant within 95 percent confidence interval. The coefficients of electricity price and load shedding were however not significant within 90 percent confidence interval. ***T-values*** confirmed the levels of significance.

VIFs reported in the regression output were less than or equal to 2, indicating little multicollinearity between the variables. From Appendix 2, the mean of the standard residuals was zero with standard deviation less than 1. This indicates that the residuals might satisfy the required assumptions of zero mean, constant variance, non-dependence of residuals and normal distributed residuals.

The estimated model confirmed the economic theory that energy demand is positively related to real GDP and negatively related to real electricity prices. These are shown by the signs of the coefficients of GDP and real electricity price which were positive and negative respectively. A one percent increase in real GDP will result in a 2.19 percent increase in electricity demand whilst a one percent increase in real electricity price will result in a 0.092 percent decrease in electricity demand.

4.2 FORECAST USING ADJUSTED EXPONENTIAL SMOOTHING

A time series forecast was conducted using the adjusted exponential smoothing technique with $\alpha = 0.35$ and $\gamma = 0.3$. These α and γ values gave good smoothing and a low mean absolute percentage error value. A table showing the adjusted exponential forecast values derived using the demand data for 1985 to 2001 is presented in Appendix 4. A graph comparing the actual demand and the adjusted exponential forecast values is shown in Figure 4.3 below.

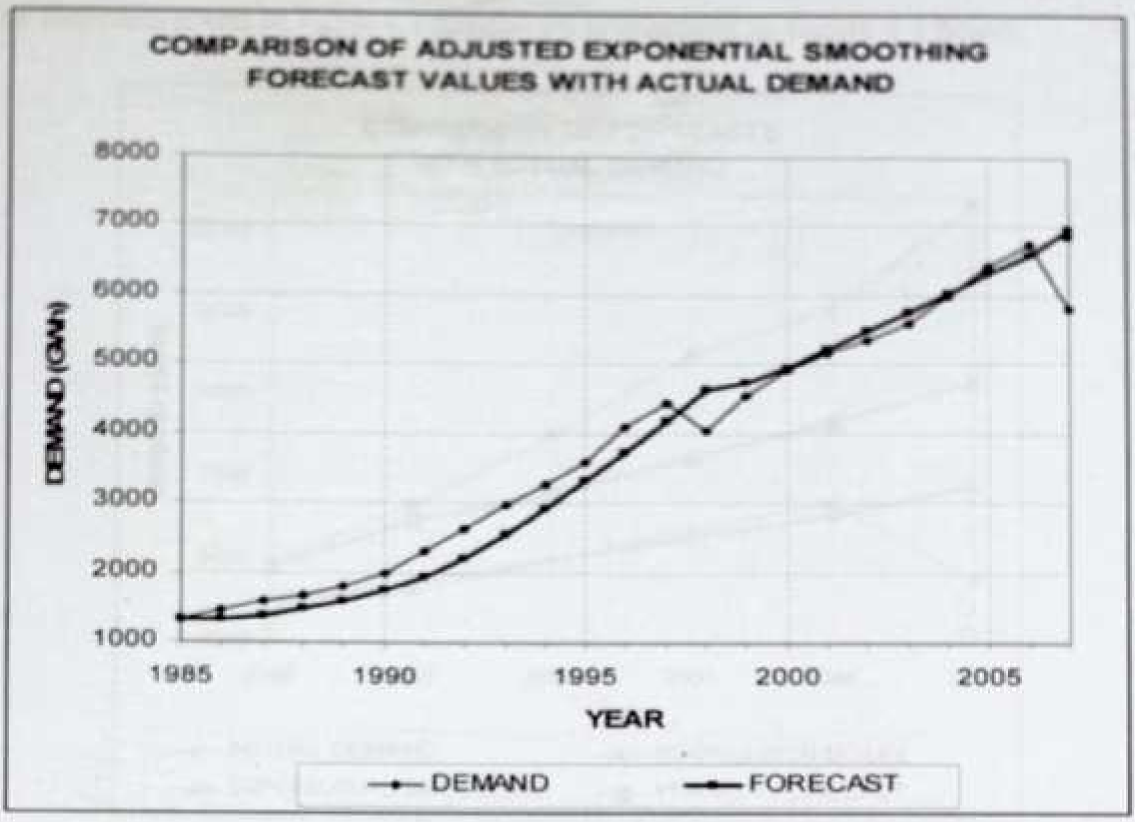

Figure 4.3: Comparison of actual demand with exponential smoothing forecasts

4.3 COMPARISON OF DIFFERENT FORECASTS WITH ACTUAL DEMAND

A table comparing actual electricity demand with forecasts by the regression model, the adjusted exponential smoothing technique and a VRA 2001 forecast are shown below. Forecasts from the regression model was based on an assumed real price of electricity of ¢4.60 per kWh, real GDP growth of 5 percent and no load shedding.

Table 4.1: A comparison of different forecasts with actual demand

Year	ACTUAL DEMAND	REGRESSION MODEL	EXPONENTIAL SMOOTHING	VRA-FORECAST
2002	5354	5975.6	5482	5907
2003	5608	6677.2	5756	6505
2004	6004	7554.7	6031	6823
2005	6412	8547.5	6305	7286
2006	6734	9114.8	6579	7728
2007	5810	10420.0	6953	8226

The forecasts given in Table 4.1 are shown graphically in Figure 4.4 below.

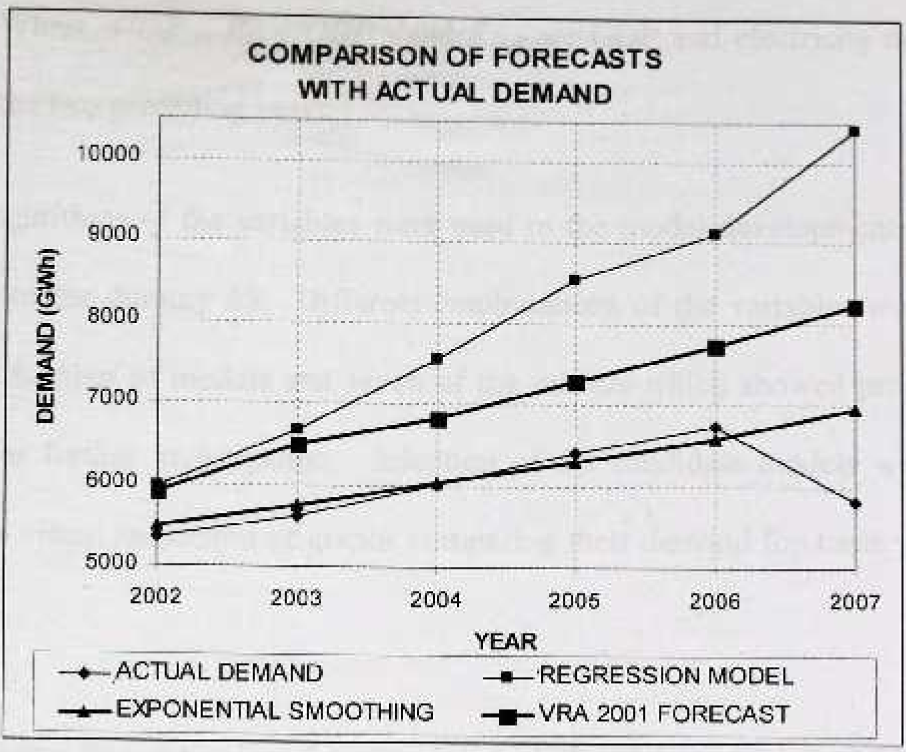

Figure 4.4: Comparison of actual demand with different forecasts values

The forecast values from the developed regression model were much higher than the actual demand values. Forecast values from the VRA-Masterplan (Acres International, 2001) were also higher than the actual demand albeit with a smaller margin. The forecast from the adjusted exponential smoothing were however very close to the actual electricity demand for 2002 - 2007. Autoregressive models were considered at this stage to investigate whether they would forecast demand values closer to actual demand.

4.4 DEVELOPMENT OF AUTOREGRESSIVE MODELS

The forecast values from the developed regression model were much higher than the actual electricity demand for 2002 – 2007. Autoregressive models were therefore developed to investigate whether they would give demand forecast values closer to actual demand for 2002 - 2007. The models were developed based on the following equation:

$E_D = f\,(P_E, GDP, GDP_{-1}, GDP_{-2}, E_{D-1}, E_{D-2}, LS)$,

Where, GDP_{-1}, E_{D-1}, GDP_{-2} and E_{D-2} are GDP and electricity demand for the two preceding years.

Natural logarithms of the variables were used in the model development - with the exception of the dummy *LS*. Different combinations of the variables were used to develop a number of models and seven of the models which showed promise were selected for further investigation. Selection of the candidate models were at first based on a visual inspection of graphs comparing their demand forecasts with actual demand.

In determining forecast values for a model, real electricity price of ¢4.60 per kWh, real GDP growth of 5 percent and zero nationwide load shedding were assumed. The candidate autoregressive models are presented in the Sections 4.4.1 to 4.4.7 below. The regression outputs for the candidate autoregressive models are presented in Appendices 5 to 11.

4.4.1 AUTOREGRESSIVE MODEL USING VARIABLES *PE, LS, ED₋₁* AND *GDP₋₁*

The following autoregressive model was developed using the above-mentioned variables:

$$Ln(\hat{E}_D) = -0.31 - 0.0544\,Ln(\hat{P}_E) - 0.15(LS) + 0.817\,Ln(\hat{E}_{D-1}) + 0.379\,Ln(\hat{GDP}_{-1})$$

The R^2, ***Adjusted*** R^2, and ***F-statistic*** of the model were 0.994, 0.992 and 507.58 respectively. These values indicated an apt model. The ***VIF*** for E_{D-1} and GDP_{-1} were 51 and 52, indicating some amount of multicollinearity between the two variables. The variables E_{D-1} and *LS* were significant within a 95% confidence interval whereas the other variables and the constant were not significant within a 90% confidence interval. The residual of the sum of squares for the model was 0.020 and the maximum standard residual for the model was 1.95. The mean of the model's standard residuals was zero and the standard deviation of the standard residuals was 0.866.

Forecast values using the model and actual demand for 2002 – 2007 are compared and presented in Figure 4.5. The Mean Absolute Percentage Deviation (MAPD) of the forecast values was 11.1%.

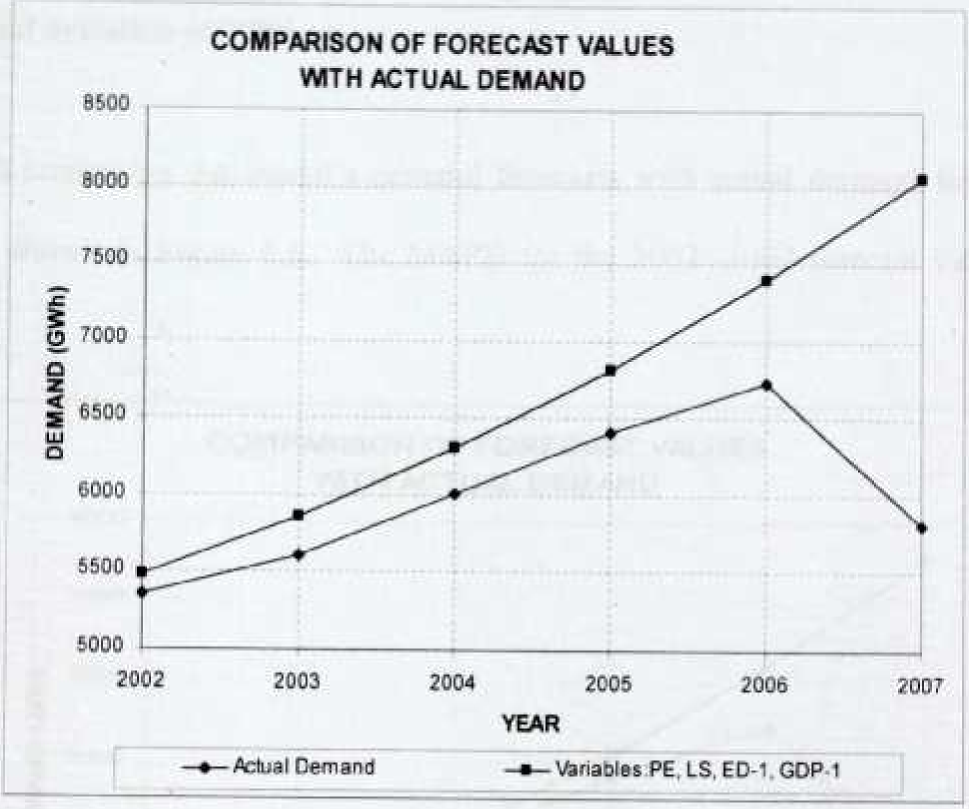

Figure 4.5: Comparison of forecast values with actual demand (variables: P_E, LS, E_{D-1}, and GDP_{-1})

4.4.2 AUTOREGRESSIVE MODEL USING VARIABLES P_E, E_{D-1} AND GDP_{-2}

The mathematical model developed using the variables mentioned above is:

$$Ln(\hat{E}_D) = -0.535 - 0.0814\, Ln(P_E) + 0.682\, Ln(\hat{E}_{D-1}) + 0.379\, Ln(GDP_{-2})$$

From the regression output presented in Appendix 6, $R^2 = 0.989$, ***Adjusted*** $R^2 = 0.986$ and ***F-statistic*** = 387.41 for this model. These goodness of fit values indicated that the model was good for the prediction of electricity demand. The ***VIF*** for E_{D-1} and GDP_{-2} were 48 and 50 indicating some amount of multicollinearity between the two variables. E_{D-1} was significant within a 95% confidence interval and P_E was significant within a 90% confidence interval. GDP_{-2} and the constant were however not significant within a 90% confidence interval. The residual of the sum of squares for the model was 0.038 and the absolute value for the maximum standard residual for the model was 1.996. The mean of the model's standard residuals was zero with a standard deviation of 0.901.

A graph comparing the model's demand forecasts with actual demand for 2002 – 2007 is shown in Figure 4.6. The MAPD for the 2002 -2007 forecast values was 7.3%.

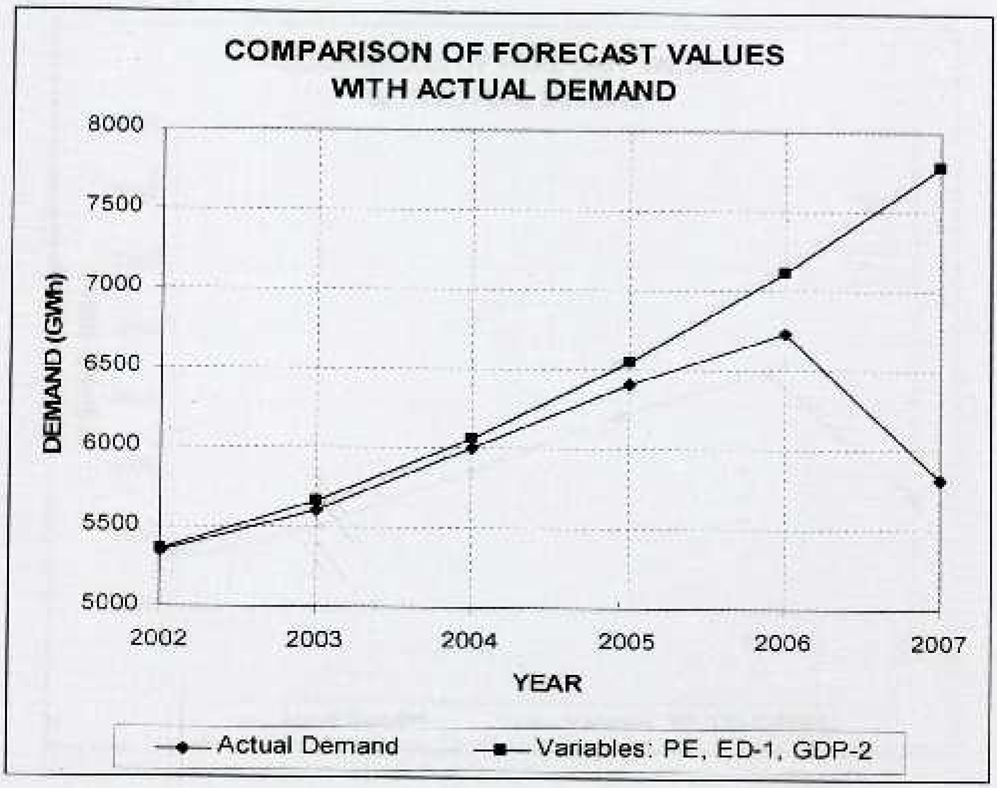

Figure 4.6: Comparison of forecast values with actual demand (variables: P_E, E_{D-1}, and GDP_{-2})

4.4.3 AUTOREGRESSIVE MODEL USING VARIABLES P_E, E_{D-1} AND GDP_{-1}

The model developed using variables P_E, E_{D-1} and GDP_{-1} was:

$$Ln(\hat{E_D}) = -0.686 - 0.0811\,Ln(\hat{P_E}) + 0.67\,Ln(\hat{E}_{D-1}) + 0.691\,Ln(\hat{GDP}_{-1})$$

The model had R^2 = 0.989, ***Adjusted*** R^2 = 0.987 and ***F-statistic*** = 398.33 indicating that it might be a good predictor of electricity demand. The ***VIF*** for E_{D-1} and GDP_{-1} were 48 and 46 indicating some amount of multicollinearity between the two variables. E_{D-1} was significant within a 95% confidence interval and P_E was significant within a 90% confidence interval. GDP_{-1} and the constant were not significant within a 90% confidence interval. The sum of squares residual for the model was 0.037 and the mean of the standard residuals was zero. The standard deviation of the standard residuals was 0.901. A graph comparing the model forecast values to actual demand for 2002 – 2007 is shown in Figure 4.7 below. The MAPD of the forecast values was 10.7%.

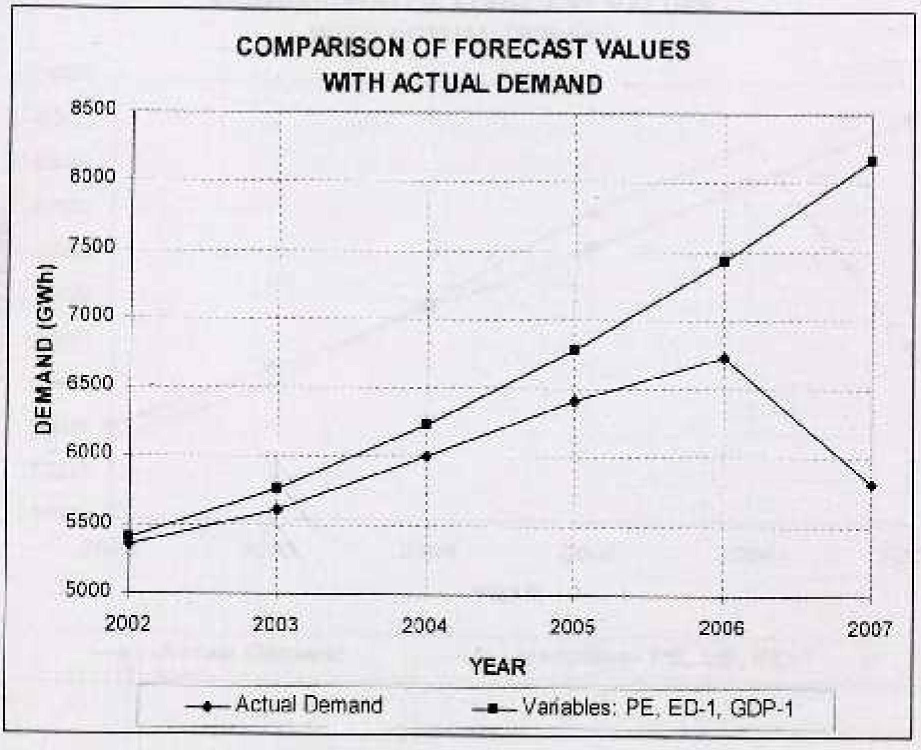

Figure 4.7: Comparison of actual demand and forecast values (variables: P_E, E_{D-1}, and GDP_{-1})

4.4.4 AUTOREGRESSIVE MODEL USING VARIABLES P_E, LS AND E_{D-1}

The model developed using P_E, LS and E_{D-1} as exogenous variables was:

$$Ln\,(E_D) = 0.235 - 0.0436\;Ln\,(P_E) + 0.167\;LS + 0.986\;\hat{L}n\,(E_{D-1})$$

The model had $R^2 = 0.993$, ***Adjusted*** $R^2 = 0.992$ and ***F-statistic*** $= 659.37$, indicating that it might be a very good model. The ***VIF*** for all the variables were less than 1.9 indicating very little multicollinearity between the variables. LS and E_{D-1} were significant within a 95% confidence interval. The variable P_E and the constant were however not significant within 90% confidence interval. The sum of squares residual for the model was 0.023 and the absolute value of the maximum standard residual for the model was less than 2.3. The mean of the standard residuals for the model was zero with standard deviation of the standard residuals was 0.901. In Figure 4.8 is a graph comparing forecast values using the model with actual demand for 2002 – 2007. The MAPD of the autoregressive forecast values was 4.4%.

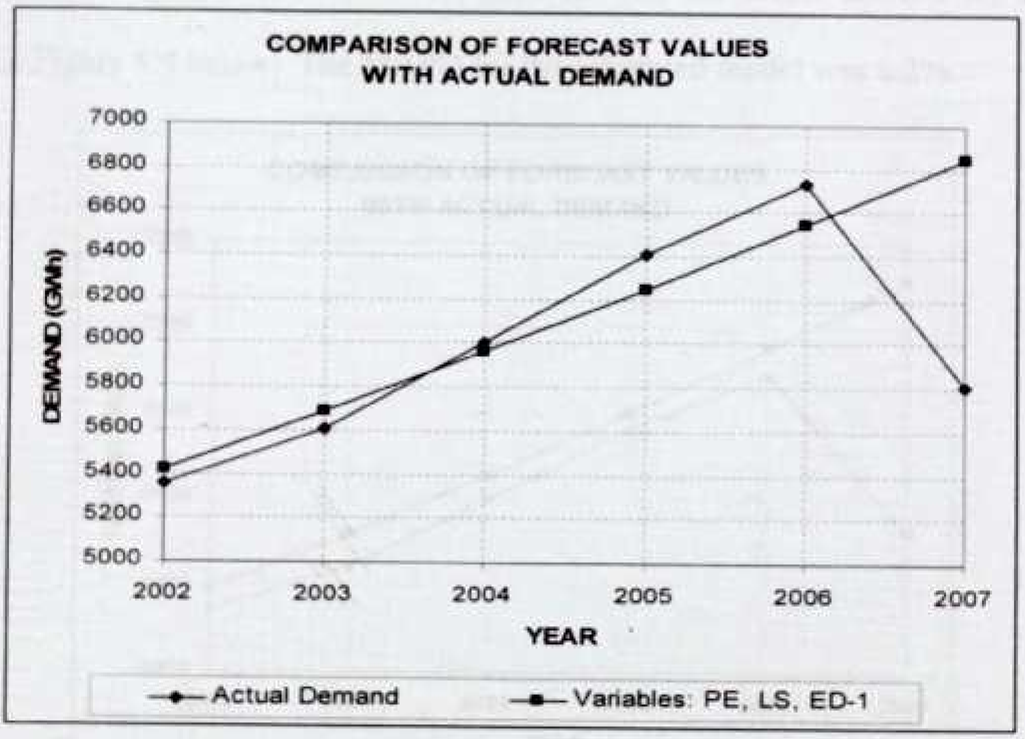

Figure 4.8: Comparison of forecast values and actual demand (variables: P_E, LS, and E_{D-1})

4.4.5 AUTOREGRESSIVE MODEL USING VARIABLES P_E, LS, E_{D-1} AND E_{D-2}

The model developed using the above-mentioned variables was:

$$\hat{Ln(E_D)} = 0.198 - 0.0488\, Ln(\hat{P_E}) - 0.168\, \hat{LS} + 0.738\, Ln(\hat{E}_{D-1}) + 0.256\, Ln(\hat{E}_{D-2})$$

It had $R^2 = 0.996$, ***Adjusted*** $R^2 = 0.994$ and ***F-statistic*** = 700.85. The estimated coefficient values indicated that we might have developed an excellent model. The ***VIF*** for E_{D-1} and E_{D-2} were 32 indicating that there was some amount of multicollinearity between the two variables. The variables LS, E_{D-1} and E_{D-2} were significant within a 95% confidence interval. The variable P_E and the constant were however not significant within a 90% confidence interval. The absolute value of the maximum standard residual for the model was less than 1.84 and the mean of the standard residuals was zero. The standard deviation of the standard residual for the model was 0.866 and the residual of the sum of squares for the model was 0.015. Forecast values from the model are compared with the actual demand for 2002 – 2007 in Figure 4.9 below. The MAPD for the estimated model was 6.2%.

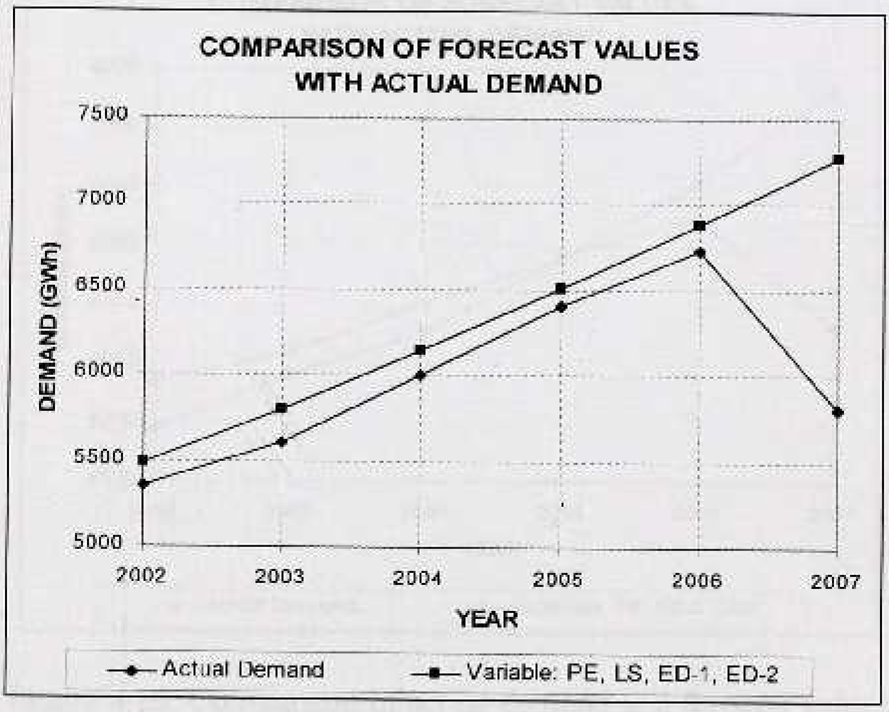

Figure 4.9: Comparison of forecast values with actual demand (variables P_E, LS, E_{D-1} and E_{D-2})

4.4.6 AUTOREGRESSSIVE MODEL USING VARIABLES P_E, E_{D-2} AND GDP

The developed model was:

$$Ln(\hat{E}_D) = -0.877 - 0.0847\ Ln(\hat{P}_E) + 0.637\ Ln(\hat{E}_{D-2}) + 0.775\ Ln(\hat{GDP})$$

With R^2 = 0.989, ***Adjusted*** R^2 = 0.987 and ***F-statistic*** = 408.33, the model showed good promise as a predictor. The ***VIF*** for E_{D-2} and GDP were 50 and 53 indicating some multicollinearity between the two variables. E_{D-2} was significant within a 95% confidence interval whereas the other variables were significant within 90% confidence interval. The constant was however not significant within a 90% confidence interval. The sum of squares residual for the model was 0.037 and the absolute value of the maximum standard residual for the model was less than 2.11. The mean of the standard residuals was zero with a standard deviation of 0.901.

A graph comparing model forecast values with actual demand for 2002 – 2007 is shown in Figure 4.10 below. The MAPD of the estimated forecast values was 9.0%.

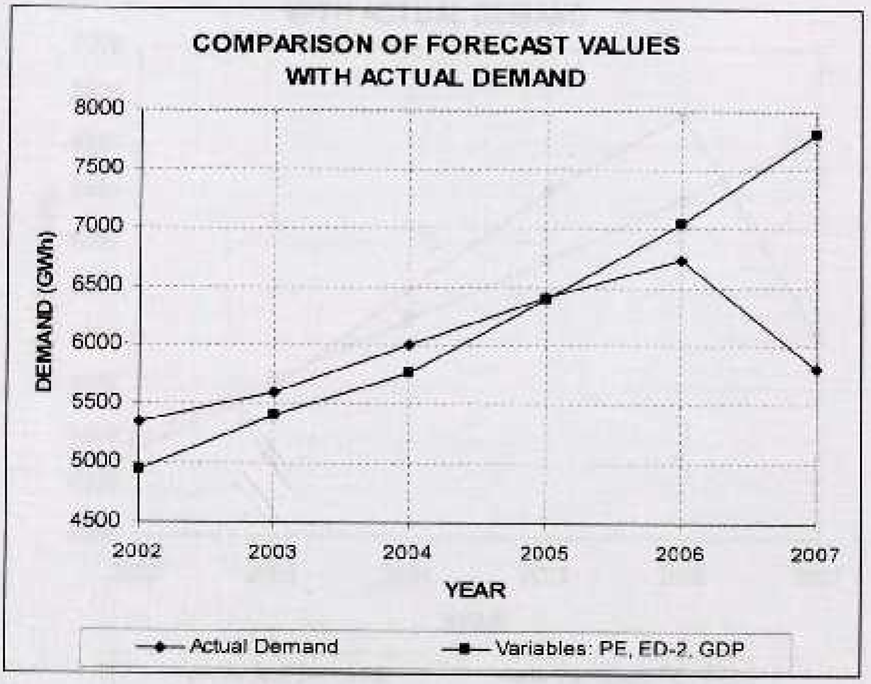

Figure 4.10: Comparison of actual demand and forecast values (variables: P_E, E_{D-2}, and GDP)

4.4.7 AUTOREGRESSIVE MODEL USING VARIABLES P_E AND E_{D-2}

The model developed using P_E and E_{D-2} as variables was:

$$Ln(\hat{E}_D) = 0.496 - 0.0547\ Ln(\hat{P}_E) + 0.962\ Ln(\hat{E}_{D-2})$$

R^2 = 0.97, ***Adjusted*** R^2 = 0.966 and ***F-statistic*** = 228.46 for the model indicating that this was a good model. The VIF for P_E and E_{D-2} were less than 1.82 indicating little multicollinearity between the variables. Variable E_{D-2} was significant within a 95% confidence interval whilst variable P_E and the constant were not significant within a 90% confidence interval. The sum of squares residual for the model was 0.103. The maximum standard residual for the model was 1.68 and the minimum standard residual was -1.664. The mean of the standard residuals was zero and the standard deviation was 0.935.

A graph comparing model forecast values with actual demand for 2002 – 2007 is shown in Figure 4.11 below. The MAPD for the model forecast values was 4.5%.

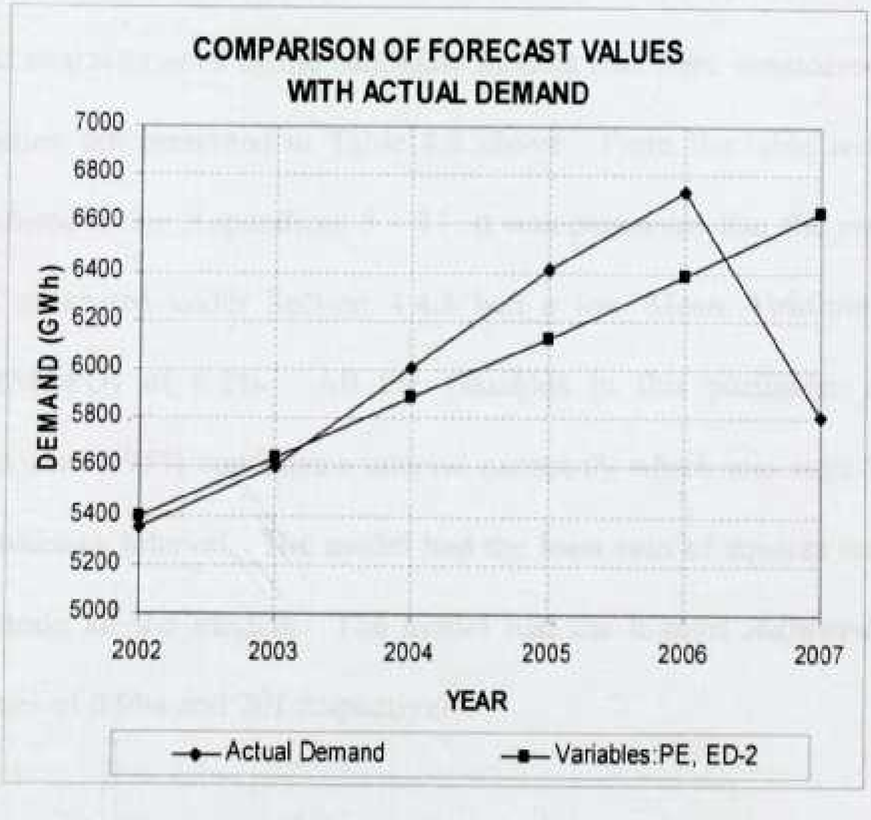

Figure 4.11: Comparison of actual demand and forecast values (variables: P_E, E_{D-1}, and GDP)

4.4.7 AUTOREGRESSIVE MODEL SELECTION

Table 4.2: Summary of characteristics used to select preferred autoregressive model

Auto regressive Model #	Variables	Adjusted R^2	F Statistic	Sum of Squares Residual	Significant variables (95% confidence interval)	MAPD (%)	Residual Standard Deviation	Standard Deviation - Predicted Value
1	P_E, LS, ED_{-1}, GDP_{-1}	0.992	508	0.020	LS, ED_{-1}	11.1	0.036	0.465
2	P_E, ED_{-1}, GDP_{-2}	0.986	387	0.038	ED_{-1}	7.3	0.049	0.464
3	P_E, ED_{-1}, GDP_{-1}	0.987	398	0.037	ED_{-1}	10.7	0.048	0.464
4	P_E, LS, ED_{-1}	0.992	659	0.023	ED_{-1}, LS	4.4	0.038	0.465
5	P_E, LS, ED_{-1}, ED_{-2}	0.994	701	0.015	LS, ED_{-1}, ED_{-2}	6.2	0.030	0.465
6	P_E, ED_{-1}, GDP	0.987	408	0.037	ED_{-1}	9.0	0.048	0.464
7	P_E, ED_{-2}	0.966	229	0.103	ED_{-2}	4.5	0.080	0.459

An analysis of the major characteristics of the candidate models presented in the foregoing sections was carried out in order to select one as the proposed VRA model. Some of the characteristics of the candidate models that were considered during the model selection are presented in Table 4.2 above. From the table and the output results presented in the Appendices 5 – 11, it was perceived that the autoregressive Model # 5 presented under Section 4.4.5 had a low Mean Absolute Percentage Deviation (MAPD) of 6.2%. All the variables in this particular model were significant within a 95% confidence interval except P_E which was significant within an 88% confidence interval. The model had the least sum of squares residual value of 0.015 among all the models. The model had the highest ***Adjusted R^2*** and ***F-statistic*** values of 0.994 and 701 respectively.

We selected this model over Model #s 4 and 7 with smaller MAPD because these models had some of their demand estimates lower than the actual electricity demand from 2002 to 2007 – as seen in Figures 4.8 and 4.11. An electricity demand estimate that is lower than the actual demand would imply load shedding and this is to be avoided for purposes of prudent planning. Therefore the proposed autoregressive model to be used by VRA to estimate domestic electricity demand in Ghana is:

$$Ln(\hat{E}_D) = 0.198 - 0.0488\ Ln(\hat{P}_E) - 0.168\ \hat{LS} + 0.738\ Ln(\hat{E}_{D-1}) + 0.256\ Ln(\hat{E}_{D-2})$$

In Figure 4.12 below is a graph comparing the forecast values using the adjusted exponential smoothing technique, the selected autoregressive model, and actual electricity demand for the period. The MAPD for the forecast values using the adjusted exponential smoothing method is 4.85. The autoregressive model is preferred since some forecast values using the adjusted exponential smoothing technique are lower than actual electricity demand for 2002 to 2007.

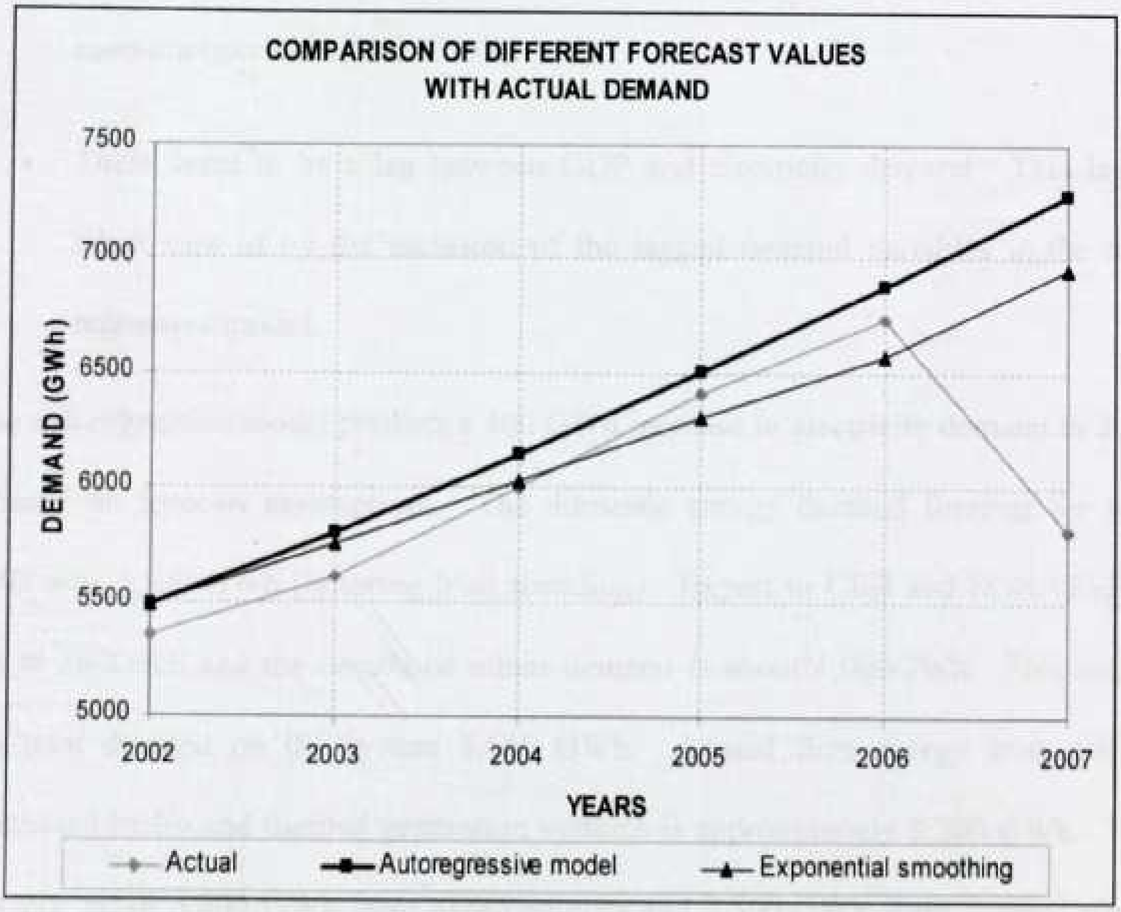

Figure 4.12: Comparison of actual demand with forecast values using exponential smoothing and auto regression model

4.5 DISCUSSION OF RESULTS

- Results of the analysis indicate that there is a high correlation between electricity demand and GDP.
- The distortion in the demand model caused by the nationwide load shedding exercise in 1998 is corrected by including the dummy *LS* in the equation.
- The price elasticity of electricity demand was low. This is probable because the price of electricity in Ghana is indirectly regulated by Government through the PURC.
- The autoregressive model with exogenous variables including electricity demand for two preceding years, real price of electricity and load shedding predicted electricity demand values that were very close to actual consumption from 2002 to 2007.
- There seem to be a lag between GDP and electricity demand. This lag is taken care of by the inclusion of the lagged demand variables in the auto regressive model.

The autoregressive model predicts a 400 GWh increase in electricity demand in 2008 - based on forecast assumptions. The domestic energy demand forecast for year 2007 was 7,300 GWh (ignoring load shedding). Export to CEB and SONABEL is put at 360GWh and the combined mines demand is about 1,000GWh. This makes the total demand on the system 8,660 GWh. Annual firm energy from VRA's combined hydro and thermal generation systems is approximately 8,300 GWh. This is made up of 5,800 GWh from hydro sources and 2,500 GWh from thermal plants (Acres International, 2001). Imports from CIE and generation from emergency diesel plants add up to 1,000 GWh each. The total available power generation is therefore 10,300 GWh. VALCO would however require an annual supply of 2,146 GWh (four pot lines). The above figures suggest that the hydro and thermal plants that are currently being constructed by VRA, the Ghana government and Independent Power Producers (IPPs) should continue since there is a growing market for electricity.

CHAPTER 5

FINDINGS, RECOMMENDATIONS AND CONCLUSION

5.0 INTRODUCTION

In this chapter, the findings of the study are summarised. Based on these findings and other considerations arising from the study, a number of pertinent recommendations are offered and conclusions drawn.

5.1 SUMMARY OF FINDINGS

- The analysis showed that average growth in domestic electricity demand for the years 1985 to 2007 was over 9 percent. Negative growths were however recorded in 1998, 2006 and 2007 due to the nationwide load shedding exercises.
- Estimated multi-regression demand models developed using SPSS showed that there is a very high correlation between real GDP growth and electricity demand.
- When both real GDP and percentage urbanisation were included as explanatory variables in any model, it showed a very high level of multicollinearity between the two variables.
- The estimated multi-regression model developed in this study gave 2002-2007 forecasts that were higher than actual demand within the period.
- Adjusted exponential smoothing forecasts using $\alpha = 0.35$ and $\gamma = 0.3$ gave estimates very close to actual electricity demand values for the years 2002 to 2007.
- An autoregressive model with exogenous variables including electricity demand for two preceding years, real price of electricity and load shedding

predicted electricity demand forecast values very close to actual consumption from 2002 to 2007.

- The price elasticity of electricity demand from the autoregressive model was low, due probably to the regulation of electricity prices by government.
- The actual demand for 2006 and 2007 were low due to the nationwide load shedding exercises. The electricity demand for 2007 was very low because the load shedding exercise was carried out for 9 months in the year.

Recommendations and conclusions based on the findings are given in the next section.

5.2 RECOMMENDATIONS AND CONCLUSIONS

The following conclusions and recommendations are made based on the findings stated in the above section:

- There is a very high correlation between electricity demand and real GDP. Also, real GDP explains most of the demand increases caused by an increase in the percentage urban population.
- The auto regressive model obtained using a natural logarithm of electricity demand, demand for two preceding years, and real electricity price as exogenous variables performed very well when used to forecast demand for 2002 to 2006. The model is recommended to the VRA and other interested researchers and decision makers.
- VRA currently uses exponential smoothing for short term demand forecasts and regression model for longer term forecasts. The auto regressive model developed here may however be used for both short term and long term forecasts.

- The distortion in the demand model caused by a nationwide load shedding exercise is corrected by including the dummy *LS* in the equation.
- The forecast showed that demand for electricity in Ghana continues to increase rapidly. The construction of the Bui Hydroelectric Power Plant and other hydro and thermal plants should continue in order to produce enough power for both domestic consumption and export.
- It should be noted by the PURC and other authorities that the sustainability of power plants built by independent power providers (IPPs) depends on the charging of realistic electricity tariffs.

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APPENDICES

Appendix 1: Regression output
Variables: GDP, Price

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Ln (real price), Ln (real GDP)[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Ln (demand)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.990[a]	.980	.978	.069693396	.621

a. Predictors: (Constant), Ln (real price), Ln (real GDP)

b. Dependent Variable: Ln (demand)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.412	2	1.706	351.283	.000[a]
	Residual	.068	14	.005		
	Total	3.480	16			

a. Predictors: (Constant), Ln (real price), Ln (real GDP)

b. Dependent Variable: Ln (demand)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-2.893	.516		-5.611	.000		
	Ln (real GDP)	2.185	.107	1.055	20.423	.000	.523	1.912
	Ln (real price)	-.103	.055	-.097	-1.886	.080	.523	1.912

a. Dependent Variable: Ln (demand)

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.187214	8.610860	7.925594	.461822855	17
Residual	-.093429	.11444264	.00000000	.065192202	17
Std. Predicted Value	-1.599	1.484	.000	1.000	17
Std. Residual	-1.341	1.642	.000	.935	17

a. Dependent Variable: Ln (demand)

Appendix 2: Regression output
Variables: GDP, Price, Load shedding

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	load shedding, Ln (real GDP), Ln (real price) [a]		Enter

a. All requested variables entered.
b. Dependent Variable: Ln (demand)

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.991[a]	.982	.977	.070005670	.453

a. Predictors: (Constant), load shedding, Ln (real GDP), Ln (real price)
b. Dependent Variable: Ln (demand)

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.417	3	1.139	232.396	.000[a]
	Residual	.064	13	.005		
	Total	3.480	16			

a. Predictors: (Constant), load shedding, Ln (real GDP), Ln (real price)
b. Dependent Variable: Ln (demand)

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-2.919	.519		-5.627	.000		
	Ln (real GDP)	2.190	.108	1.057	20.353	.000	.522	1.917
	Ln (real price)	-9.20E-02	.056	-.087	-1.634	.126	.499	2.004
	load shedding	-7.16E-02	.077	-.037	-.936	.367	.889	1.125

a. Dependent Variable: Ln (demand)

Residuals Statistics [a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.182570	8.625234	7.925594	.462113057	17
Residual	-.091168	.10606536	.00000000	.063102258	17
Std. Predicted Value	-1.608	1.514	.000	1.000	17
Std. Residual	-1.302	1.515	.000	.901	17

a. Dependent Variable: Ln (demand)

Appendix 3: Regression output
Variables: Percent urban population, GDP, Price, Load shedding

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Ln (percent urban pop), load shedding, Ln (real price), Ln (real GDP)[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Ln (demand)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.992[a]	.984	.979	.068093623	.651

a. Predictors: (Constant), Ln (percent urban pop), load shedding, Ln (real price), Ln (real GDP)

b. Dependent Variable: Ln (demand)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.425	4	.856	184.658	.000[a]
	Residual	.056	12	.005		
	Total	3.480	16			

a. Predictors: (Constant), Ln (percent urban pop), load shedding, Ln (real price), Ln (real GDP)

b. Dependent Variable: Ln (demand)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-15.697	9.699		-1.618	.132		
	Ln (real GDP)	-1.633	2.900	-.788	-.563	.584	.001	1471.439
	Ln (real price)	-.110	.056	-.104	-1.946	.075	.471	2.125
	load shedding	-4.29E-02	.078	-.022	-.552	.591	.819	1.221
	Ln (percent urban pop)	8.729	6.617	1.854	1.319	.212	.001	1482.875

a. Dependent Variable: Ln (demand)

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.226630	8.646165	7.925594	.462658423	17
Residual	-.096919	.09079389	.00000000	.058970807	17
Std. Predicted Value	-1.511	1.557	.000	1.000	17
Std. Residual	-1.423	1.333	.000	.866	17

a. Dependent Variable: Ln (demand)

Appendix 4: Adjusted Exponential Smoothing Table (1985 - 2001)
Forecast: 2002 - 2007

YEAR	DEMAND D_t (GWh)	SMOOTHED DEMAND LEVEL L_t (α=0.35)	SMOOTHED TREND LEVEL T_t (γ=0.3)	DEMAND FORECAST F_t
1985	1309.08	1309.08	0	1309.08
1986	1453.16	1359.50	15.13	1309.08
1987	1576.25	1445.20	36.30	1374.63
1988	1654.82	1542.16	54.50	1481.50
1989	1811.54	1671.87	77.06	1596.66
1990	1987.14	1832.30	102.07	1748.93
1991	2308.61	2065.36	141.37	1934.37
1992	2633.90	2356.24	186.22	2206.72
1993	2980.19	2695.66	232.18	2542.46
1994	3280.31	3051.20	269.19	2927.84
1995	3594.23	3416.23	297.94	3320.40
1996	4097.01	3848.17	338.14	3714.18
1997	4452.55	4279.49	366.10	4186.311
1998	4050.66	4437.36	303.63	4645.59
1999	4550.34	4674.26	283.61	4740.991
2000	4937.72	4950.82	281.49	4957.871
2001	5162.86	5208.00	274.20	5232.311
2002	5353.77			5482.21
2003	5607.61			5756.41
2004	6004.37			6030.61
2005	6411.64			6304.81
2006	6734.06			6579.01
2007	6047.56			6853.21

Appendix 5: Auto Regression Output
Variables: Electricity Price, Load Shedding, Demand (year-1) GDP (year-1)

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	Real Price of Electricity, load shedding, Demand for year-1, GDP for year-1	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.997[a]	.994	.992	**********	1.005

a. Predictors: (Constant), Real Price of Electricity, load shedding, Demand for year-1, GDP for year-1

b. Dependent Variable: Electricity Demand (GWh)

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.460	4	.865	507.582	.000[a]
	Residual	.020	12	.002		
	Total	3.480	16			

a. Predictors: (Constant), Real Price of Electricity, load shedding, Demand for year-1, GDP for year-1

b. Dependent Variable: Electricity Demand (GWh)

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.310	.518		-.599	.560	-1.438	.818		
	load shedding	-.150	.048	-.078	-3.159	.008	-.254	-.047	.801	1.248
	GDP for year-1	.379	.328	.185	1.155	.271	-.336	1.094	.019	52.367
	Demand for year-1	.817	.148	.867	5.506	.000	.494	1.141	.020	50.659
	Real Price of Electricity	-5.44E-02	.034	-.051	-1.624	.130	-.127	.019	.490	2.042

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics [a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	.46502903092	17
Residual	********	********	********	.03575095982	17
Std. Predicted Value	-1.783	1.404	.000	1.000	17
Std. Residual	-1.465	1.951	.000	.866	17

a. Dependent Variable: Electricity Demand (GWh)

Appendix 6: Auto Regression Output
Variables: Electricity Price, Demand (year-1), GDP (year-2)

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	GDP for year-2, Real Price of Electricity, Demand for year-1 [a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.994[a]	.989	.986	**********	1.517

a. Predictors: (Constant), GDP for year-2, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.442	3	1.147	387.414	.000[a]
	Residual	.038	13	.003		
	Total	3.480	16			

a. Predictors: (Constant), GDP for year-2, Real Price of Electricity, Demand for y

b. Dependent Variable: Electricity Demand (GWh)

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.535	.615		-.869	.400	-1.884	.794		
	Demand for year-1	.682	.191	.723	3.576	.003	.270	1.094	.021	48.059
	Real Price of Electricity	-8.14E-02	.043	-.077	-1.894	.081	-.174	.011	.518	1.929
	GDP for year-2	.647	.413	.324	1.566	.141	-.246	1.540	.020	50.385

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics [a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	.46381451778	17
Residual	********	********	********	.04905327536	17
Std. Predicted Value	-1.773	1.367	.000	1.000	17
Std. Residual	-1.996	1.360	.000	.901	17

a. Dependent Variable: Electricity Demand (GWh)

Appendix 7: Auto Regression Output
Variables: Electricity Price, Demand (year-1), GDP (year-1)

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	GDP for year-1, Real Price of Electricity, Demand for year-1[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.995[a]	.989	.987	**********	1.573

a. Predictors: (Constant), GDP for year-1, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.443	3	1.148	398.329	.000[a]
	Residual	.037	13	.003		
	Total	3.480	16			

a. Predictors: (Constant), GDP for year-1, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95% Confidence Interval for B Lower Bound	95% Confidence Interval for B Upper Bound	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-.686	.655		-1.047	.314	-2.101	.730		
	Demand for year-1	.670	.183	.710	3.655	.003	.274	1.066	.022	45.631
	Real Price of Electricity	-8.11E-02	.042	-.077	-1.924	.077	-.172	.010	.523	1.912
	GDP for year-1	.691	.407	.337	1.698	.113	-.188	1.570	.021	47.632

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	.46388483010	17
Residual	********	********	********	.04838383131	17
Std. Predicted Value	-1.736	1.367	.000	1.000	17
Std. Residual	-2.110	1.166	.000	.901	17

a. Dependent Variable: Electricity Demand (GWh)

Appendix 8: Auto Regression Output
Variables: Electricity Price, Demand (year-1), Load Shedding

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	load shedding, Demand for year-1, Real Price of Electricity [a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary [b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.997[a]	.993	.992	***********	1.193

a. Predictors: (Constant), load shedding, Demand for year-1, Real Price of Electricity

b. Dependent Variable: Electricity Demand (GWh)

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.458	3	1.153	659.369	.000[a]
	Residual	.023	13	.002		
	Total	3.480	16			

a. Predictors: (Constant), load shedding, Demand for year-1, Real Price of Electricity

b. Dependent Variable: Electricity Demand (GWh)

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.235	.215		1.092	.295	-.230	.701		
	Demand for year-1	-.986	.029	1.046	34.390	.000	.924	1.048	.543	1.840
	Real Price of Electricity	-4.36E-02	.033	-.041	-1.338	.204	-.114	.027	.532	1.881
	load shedding	-.167	.046	-.087	-3.630	.003	-.266	-.067	.881	1.135

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics [a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	46487618704	17
Residual	********	********	********	03768635636	17
Std. Predicted Value	-1.816	1.380	.000	1.000	17
Std. Residual	-1.598	2.292	.000	.901	17

a. Dependent Variable: Electricity Demand (GWh)

Appendix 9: Auto Regression Output
Variables: Electricity Price, Demand (year-1), Demand (year-2), Load Shedding

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	Demand for year-2, load shedding, Real Price of Electricity, Demand for year-1[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.998[a]	.996	.994	**********	1.060

a. Predictors: (Constant), Demand for year-2, load shedding, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.466	4	.866	700.853	.000[a]
	Residual	.015	12	.001		
	Total	3.480	16			

a. Predictors: (Constant), Demand for year-2, load shedding, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.198	.182		1.089	.298	-.198	.594		
	Demand for year-1	.738	.101	.783	7.297	.000	.517	.958	.031	32.384
	Real Price of Electricity	-4.88E-02	.027	-.046	-1.777	.101	-.109	.011	.528	1.892
	load shedding	-.168	.039	-.088	-4.351	.001	-.253	-.084	.881	1.135
	Demand for year-2	.256	.101	.271	2.526	.027	.035	.477	.031	32.389

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	.46540623300	17
Residual	********	********	********	.03044945013	17
Std. Predicted Value	-1.696	1.383	.000	1.000	17
Std. Residual	-1.830	1.238	.000	.866	17

a. Dependent Variable: Electricity Demand (GWh)

Appendix 10: Auto Regression Output
Variables: Electricity Price, Demand (year-1), GDP

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	GDP over GDP for 1985, Real Price of Electricity, Demand for year-1 [a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.995[a]	.989	.987	***********	1.471

a. Predictors: (Constant), GDP over GDP for 1985, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.444	3	1.148	408.328	.000[a]
	Residual	.037	13	.003		
	Total	3.480	16			

a. Predictors: (Constant), GDP over GDP for 1985, Real Price of Electricity, Demand for year-1

b. Dependent Variable: Electricity Demand (GWh)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	5% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.877	.717		-1.223	.243	-2.426	.672		
	Demand for year-1	.637	.190	.676	3.355	.005	.227	1.047	.020	50.216
	Real Price of Electric	8.47E-02	.042	-.080	-2.016	.065	-.175	.006	.514	1.946
	GDP over GDP for 19	.775	.428	.374	1.810	.093	-.150	1.699	.019	52.856

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics [a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	.46394596549	17
Residual	********	********	********	.04779405647	17
Std. Predicted Value	-1.728	1.372	.000	1.000	17
Std. Residual	-2.108	1.112	.000	.901	17

a. Dependent Variable: Electricity Demand (GWh)

Appendix 11: Auto Regression Output
Variables: Electricity Price, Demand (year-2)

Variables Entered/Removed [b]

Model	Variables Entered	Variables Removed	Method
1	Demand for year-2, Real Price of Electricity [a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Electricity Demand (GWh)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.985[a]	.970	.966	***********	1.768

a. Predictors: (Constant), Demand for year-2, Real Price of Electricity

b. Dependent Variable: Electricity Demand (GWh)

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.377	2	1.689	228.459	.000[a]
	Residual	.103	14	.007		
	Total	3.480	16			

a. Predictors: (Constant), Demand for year-2, Real Price of Electricity

b. Dependent Variable: Electricity Demand (GWh)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	.496	.436		1.137	.275	-.439	1.431		
	Real Price of Electricity	-5.47E-02	.066	-.052	-.831	.420	-.196	.087	.550	1.818
	Demand for year-2	.962	.059	1.019	16.398	.000	.836	1.088	.550	1.818

a. Dependent Variable: Electricity Demand (GWh)

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	********	********	********	.45941610060	17
Residual	********	********	********	.08041751825	17
Std. Predicted Value	-1.716	1.326	.000	1.000	17
Std. Residual	-1.664	1.680	.000	.935	17

a. Dependent Variable: Electricity Demand (GWh)