VOLTA RIVER AUTHORITY

NORTHERN ELECTRICITY DEPARTMENT

NED LONG-TERM LOAD FORECAST

2011 To 2021

28/4/2011
PLANNING OFFICE, TAMALE
VRA/NED

Table of Contents

1.0 INTRODUCTION

Load forecasting is essential in electric power system operation and planning needed for various utility activities such as generation scheduling, fuel purchase scheduling, maintenance scheduling, and security analysis. Depending on time period of interest, NED load forecasting can be classified as Long-term (1 to 10 years) forecast, medium term forecast (1 month to 2 years) or short-term (1 day to 1 month) forecast.

This forecast focuses on NED Energy Demand and Peak Load Demand for a period of ten (10) years starting from 2011 to 2021. The forecast plays an important role in planning, analysis and operation of the power system and for that matter the operation of NED. Long-term peak load forecasting is an important issue in effective and efficient planning toward maintaining a high supply quality. Overestimation of the future load may lead to unnecessary over expenditure and vice versa. Hence, an accurate method is that which takes into account factors that affect growth in energy consumption and peak demand is necessary.

The objective of this forecasting task is to provide energy and peak load predictions that meet planning requirements in a consistent and credible manner.

This document presents a linear regression (LR) model based on the least error squares (LES) algorithm. The algorithm uses the historic data of the influence factors such as customer population, GDP per capita, average tariff and system losses.

2.0 DETERMINANTS OF ENERGY GROWTH

In long-term forecasting, economic and demographic factors such as stock of electricity using equipment, level and type of economic activity, price of electricity (tariff) and price of substitute sources of energy play the most important role in determining the evolution of electricity demand. The effect of other none economic factors such as marketing and conservation campaigns may also be considered. Future changes in these demand–determining factors will cause the demand for electricity to change accordingly.

In the NED operating Areas, other factors such as Government policies on electrification has affected the demand for energy over the past 10 years. Projects such as NEP and SHEP have continued to play a significant role in the pattern of the energy growth. Recent studies have shown that 63.5% of the energy consumption in NED is residential, 21.8 is non-residential, and 10.4% SLT (Special Load Tariff) customers. This clearly shows that the evolution of energy demand in NED is largely determined by economic and demographic factors.

In this forecast, Customer Population, Average Tariff, GDP per Capita based on Purchasing Power Parity and system loss were considered as the main determinants of Energy Consumption and Peak Demand.

3.0 FORECAST THEORY

In view of the fact that residential population largely determines the growth in energy demand in NED, the model for the load demand took into account the following factors:

- Population (POP),
- GDP per Capita based on Purchasing Power Parity (GDPC) ,
- Tariff (TAR),
- System loss (LOSS)

For purposes of simplicity we assume that these factors have linear relationship with the load demand. The demand equation can therefore be stated as follows:

$$P_L = f(POP) + g(TAR) + h(GDPC) + k(LOSS) \qquad (1)$$

Where *f, g, h and k* are functions of the variable stated between brackets.
With our assumption that they relate to the energy demand in a linear way, the demand equation is rewritten as

$$P_L = a_0 + a_1 POP + a_2 TAR + a_3 GDPC + a_4 LOSS \qquad (2)$$

Here a_0 a_1, a_2, a_3, and a_4 are the regression parameters to be determined by the Least Error Squares (LES) algorithm. We are going to determine these parameters using the past data available.

Equation (2) can be generalized for each year *i* as:

$$P_{Li} = \begin{bmatrix} 1 & POP & TAR & GDPC & LOSS \end{bmatrix}_i \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix}; \ \mathrm{i} = 1, \ldots \mathrm{m}. \qquad (3)$$

For i= 1,…m; m is the number of year observations available from past data history;

In vector form, Equation (3) can be written as

$$\mathbf{Z} = H\mathbf{X} + \xi \qquad (4)$$

Where **Z** is *mx1* measurement vector of Energy or Peak Demand, H is a mxn observation matrix contains factors that affect the Energy or Peak Demand. **X** the 5x1-column vector of the load parameters to be estimated and **ξ** is the mx1 error vector to be minimized. At least the past five years data was enough to enable us determine the peak load parameters **X.**

The solution to Equation (4) based on the Least Error Squares (LES) algorithm is

$$\mathbf{X}^* = \left[H^T H\right]^{-1} H^T \mathbf{Z} \qquad (5)$$

Having identified the Energy and Peak load parameters, the load can be predicted for a specified year, using Equation (1), provided that the other variable in this equation are known in advance for this year.

Historic data from 2000 - 2010 were used to determine the coefficients for the model.

4.0 ANALYSIS AND FORECAST OF DETERMINANT FACTORS

This section investigates the effect of the determinant factors on the dependent variable and forecast trends in them for the period under study.

4.1 Customer Population

Customer population growth naturally has the effect of increasing the demand for electrical energy. The customer population in NED area has grown from about 115,000 in year 2000 to over 340,000 in 2010. Within the same period, the annual electrical energy consumed has risen from 300 GWh over 600 GWh. Forecast of the population growth shows that in the year 2020, the population is expected to reach a value of 621,500 with an annual percentage increase of about 6.2%.

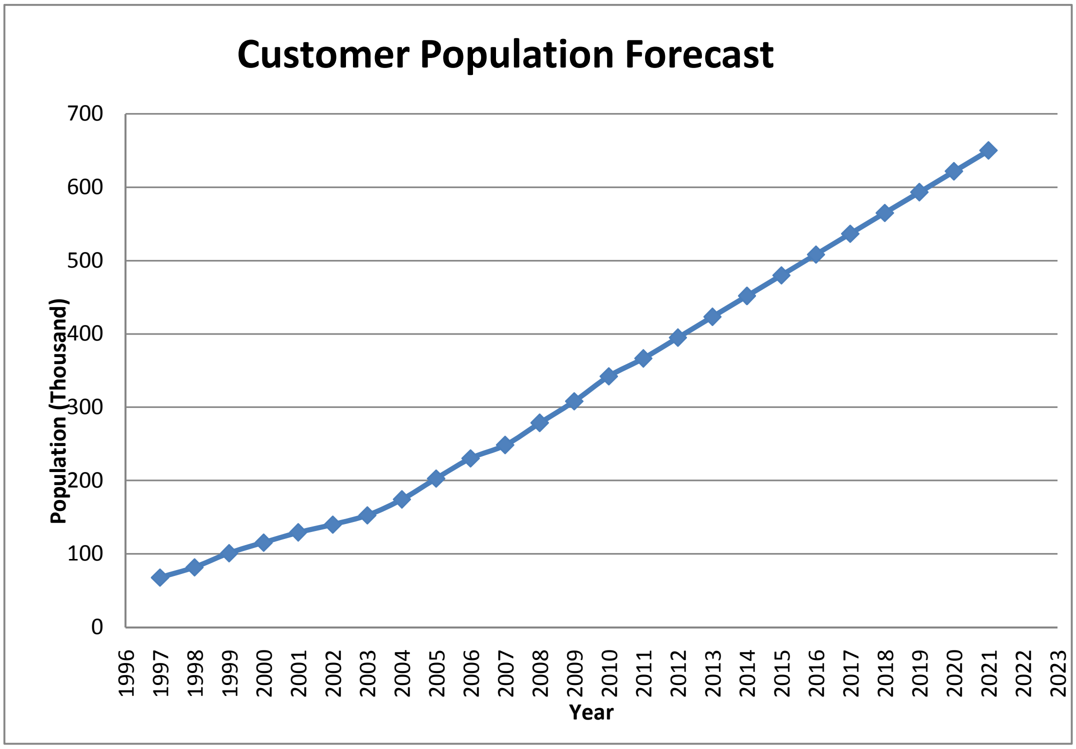

Figure 1: Customer Population Forecast

4.2 Average Tariff

Increase in Energy tariff tends to reduce the demand for electrical energy. It was observed that due to the recent sharp increment in electrical tariff, annual electrical consumption per customer has been gradually falling for both residential and non-residential customers. Among all the factors that were considered in this forecast, the tariff is the only one that has a slow down effect in the energy consumption as this is shown in our historical study.

In line with the Utility Company's fight for an economic tariff, the average tariff is expected to grow at an average rate of 9.3% per annum over the period under study.

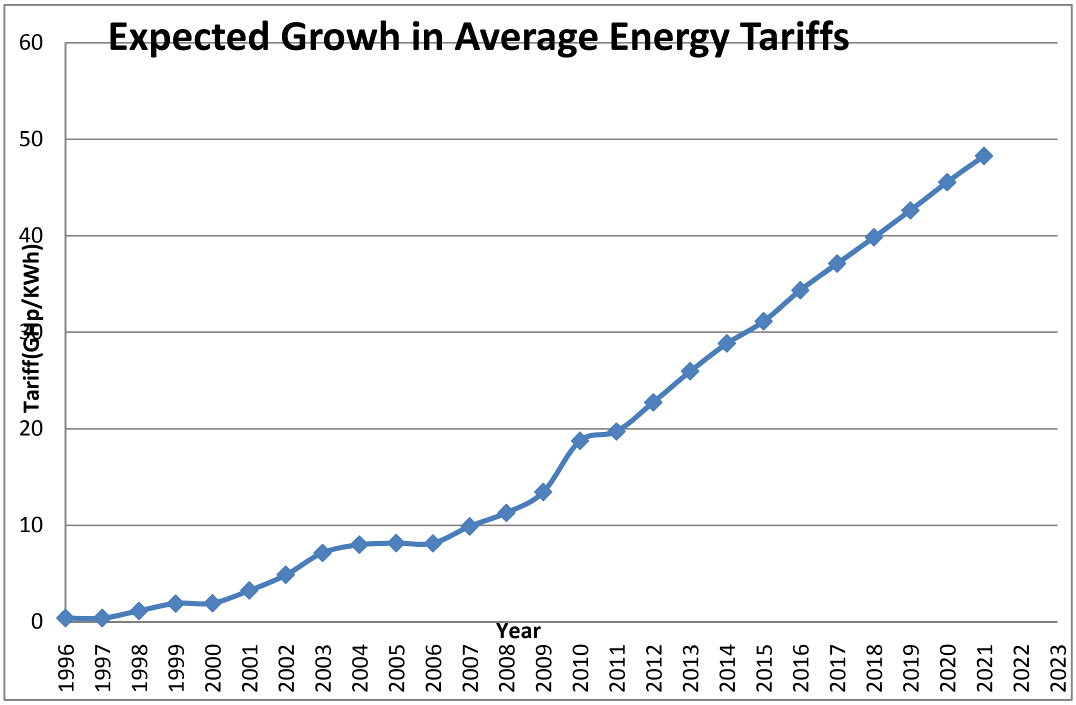

Figure 2: Expected Growth in Average Electricity Tariff

4.3 GDP per Capita

Higher levels of real incomes per capita will increase the stock of household electrical equipment and alter the intensity with which they are used. However, increase will not be proportional if increased income shifts the mix of final consumer goods, thus the effect on electricity demand will depend on the extent to which consumers purchase and use electricity-using equipment rather than other, goods and services.

The overall GDP per capita based on the Purchasing Power Parity of the country is showing a significant rise from 2003 to 2010 (source: IMF) and if this trend continues, the general well being of the citizens of the country will improve and the average disposable income will rise. This will also increase the stock of energy consuming gadgets and the stock of real estate, which will affect the energy growth. For the forecast period, GDP per capita is expected to grow at the current rate of 5.0% per annum (reference http://www.dfat.gov.au/geo/fs/ghan.pdf)

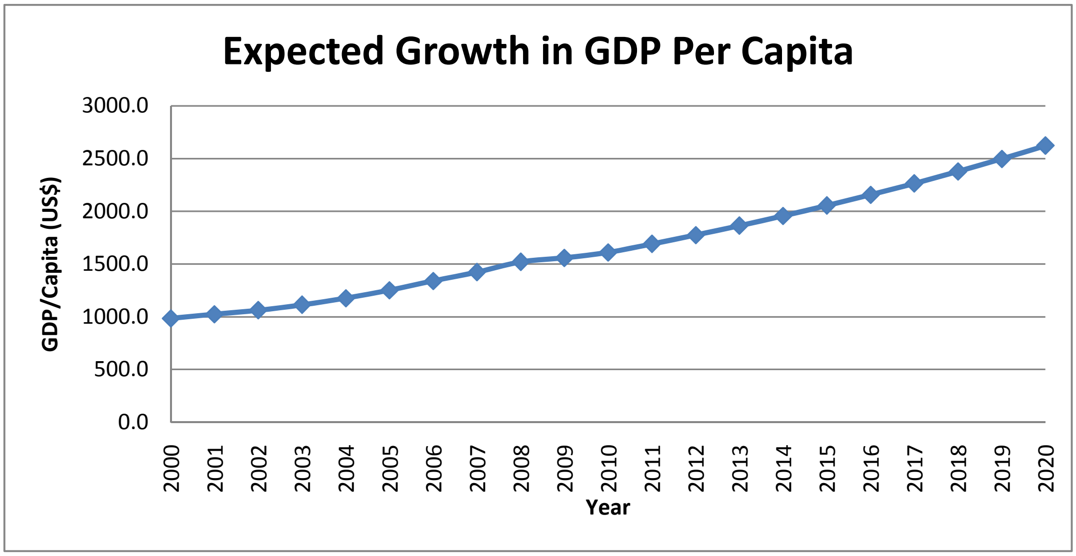

Figure 3: Expected Growth in GDP Per Capita - PPP

4.4 System losses

Higher system losses have the tendency of increasing the demand for electrical energy. The impact of system losses on the demand for NED necessitated energy's strike to reduce its system losses.

NED's system losses have been reducing consistently since 2004. For this purpose, systems losses are expected to reduce gradually to 12% in line with NED's strategic vision for the next 10 years.

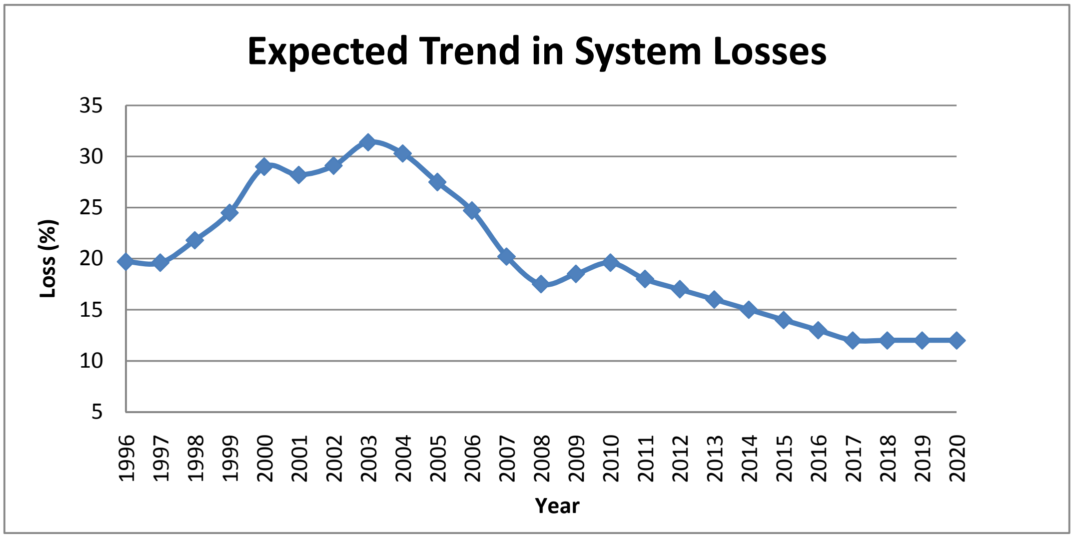

Figure 4: Expected trend in System Losses

5.0 ENERGY AND PEAK DEMAND MODELS

Table 1 (shown below) contains a historic data on the economic and system dependant factors that were considered in the Energy and Peak Demand Models.

Year	Cust. Population (Thousand)	Avg. Tariff (GHp/KWh)	GDP Per Capita (US$)	System Loss (%)	Energy (GWh)	Peak Demad (MVA)*
2000	115.276	1.9238	984.5	29.0	331.1	54.0
2001	128.967	3.2397	1024.1	28.2	354.9	59.2
2002	139.683	4.8609	1062.3	29.1	383.0	66.0
2003	152.471	7.1462	1113.3	31.4	423.9	88.0
2004	159.965	7.9812	1176.4	30.3	460.0	90.0
2005	202.758	8.1460	1251.4	27.5	501.7	92.0
2006	230.127	8.1333	1340.5	24.7	506.3	100.5
2007	248.287	9.8836	1424.1	20.2	517.5	121.6
2008	278.476	11.3000	1520.5	17.5	528.6	121.5
2009	307.871	13.4300	1547.3	18.5	564.9	110.0
2010	342.056	18.7368	1610	19.6	643.8	106.5

Table1: Historic data from 2000 to 2010

Energy data for 2006 and 2007 are forecasted figures from previous forecast. This was done to reduce the effect of the energy crises on the forecast. The actual figures are 437.2 GWh and 496.4 GWh for 2006 and 2007 respectively.

Peak Demand increased sharply in 2007 and dropped significantly in 2009. This is due to the fact that Newmont Ghana ltd. started its operations on the 34.5kV network of NED in 2007 until changing its source to the 161KV substation at Kenyasi in 2009. To minimize the effect of this, the peak demand for 2007 and 2008 were modified by taking into account the maximum demand for Newmont Ghana.

5.1 THE ENERGY DEMAND MODEL

Based on the historic data in table 1, equation (3) was solved for the co-efficient a_0, a_1, a_2, a_3 and a_4 using the LES algorithm (5)

The resulting co-efficient are as indicated in the table 2 below.

a0 Constant	***a1 Population***	***a2 Tariff***	***a3 GDP***	***a4 Loss***
-452.9825	0.6699	0.4960	0.3958	11.0160

Table 2: co-efficients of the Energy Model

The corresponding average and maximum errors are -0.04% and 3.3% respectively.

5.2 THE PEAK DEMAND MODEL

The same method when applied to the maximum demand yields the following co-efficients.

a0 Constant	***a1 Population***	***a2 Tariff***	***a3 GDP***	***a4 Loss***
-320.8140	-0.2753	-2.3914	0.3058	3.8714

Table 3: co-efficients of the Peak Demand Model

The corresponding average and maximum errors were 0.5% and 6.6% respectively.

6.0 ENERGY AND PEAK DEMAND FORECAST

Based on the Models above, the Energy and Peak Demand forecast for NED without spot loads from 2011 to 2021 is presented in the table 4 below.

Year	Cust. Pop (Thous)	Tariff (GHp/KWh)	GDP -PPP (US$)	Loss (%)	Energy (GWh)	Demand (MVA)*
2011	366.396	19.723	1690.50	18.0	669.56	117.9
2012	394.740	22.198	1775.03	17.0	712.21	126.1
2013	423.084	24.673	1863.78	16.0	756.53	135.7
2014	451.429	27.149	1956.97	15.0	802.61	146.6
2015	479.773	29.624	2054.81	14.0	850.54	158.9
2016	508.117	32.099	2157.55	13.0	900.40	172.8
2017	536.461	34.575	2265.43	12.0	952.29	188.2
2018	564.805	37.050	2378.70	12.0	1017.33	209.1
2019	593.150	39.525	2497.64	12.0	1084.62	231.8
2020	621.494	42.001	2622.52	12.0	1154.25	256.2
2021	649.838	44.476	2753.65	12.0	1226.36	282.6

Table 4: Energy and Peak Demand Forecast without spot loads

*Average power factor is 0.87

7.0 SPOT LOADS

Apart from the normal load growth based on mathematical model, we expect the following spot loads as shown the table 4 below within the ten-year period of this forecast. The total spot load is estimated to be 37.7 MVA consisting of 7.1MVA in 2011, 21.1 MVA in 2012, 3.8 MVA in 2013 and 5.7 MVA by the end of 2014. These loads are expected to increase energy and peak demand over the forecast period as indicated in the table below.

No.	Area	Project/Industry	Location	Capacity (MVA)	Expected Year	Avg. Demand (MVA)	Annual Energy (GWh)	Est. Coin. Peak Dem. (MVA)
1	Techiman	Cashew Company	Techiman	0.80	2011	0.52	2.1	0.61
2	Techiman	Gold Cement Factory	Wenchi	0.80	2012	0.52	2.1	0.61
3	Northern	Shea butter Company	Buipe	1.00	2011	0.65	2.7	0.76
4	Northern	Savana Cement	Buipe	6.50	2011	4.23	17.3	4.94
5	Northern	Savana Cement	Buipe	2.50	2014	1.63	6.6	1.90
6	Northern	Hospital Upgrade	Tamale	5.00	2012	3.25	13.3	3.80
7	Northern	Mango Factory	Gushe	1.00	2011	0.65	2.7	0.76
8	Northern	Sugercane Company	Salaga	5.00	2012	3.25	13.3	3.80
9	Northern	Rice Project (MiDA)	Nasia	0.50	2012	0.33	1.3	0.38
10	Northern	STX Housing Project	Tamale	2.00	2013	1.30	5.3	1.52
11	Northern	Steel Factory	Zabzugu	2.00	2013	1.30	5.3	1.52
12	Upper East	Goldmine	Sheaga	5.00	2012	3.25	13.3	3.80
13	Upper East	Goldmine	Sheaga	5.00	2014	3.25	13.3	3.80
14	Upper West	Goldmine	Cherekpong	10.00	2012	6.50	26.5	7.60
12	Upper West	Surface Dam	Dorimon	1.50	2012	0.98	4.0	1.14
13	Upper West	Regional Hospital	Wa	1.00	2013	0.65	2.7	0.76
TOTAL				**49.6**			**131.7**	**37.7**

Table 5: Expected Spot Loads

Hence the overall energy and peak demand forecast for NED taking into consideration spot loads is presented in the table below.

Year	Energy (GWh)			Peak Demand			
	Normal	Spot Load	Total	Normal	Spot Load	Total (MVA)	Total (MVA)
2011	669.56	24.7	**694.3**	117.9	7.1	**125.0**	**122.49**
2012	712.21	98.5	**810.7**	126.1	28.2	**154.3**	**151.26**
2013	756.53	111.8	**868.3**	135.7	32	**167.7**	**164.35**
2014	802.61	131.7	**934.3**	146.6	37.7	**184.3**	**180.62**
2015	850.54	131.7	**982.2**	158.9	37.7	**196.6**	**192.71**
2016	900.40	131.7	**1032.1**	172.8	37.7	**210.5**	**206.27**
2017	952.29	131.7	**1084.0**	188.2	37.7	**225.9**	**221.36**
2018	1017.33	131.7	**1149.0**	209.1	37.7	**246.8**	**241.86**
2019	1084.62	131.7	**1216.3**	231.8	37.7	**269.5**	**264.06**
2020	1154.25	131.7	**1286.0**	256.2	37.7	**293.9**	**288.05**
2021	1226.26	131.7	**1358.0**	282.6	37.7	**320.3**	**313.89**

Table 6: Energy and Peak Demand Forecast with Spot Loads

The Energy is expected to grow from its present value of 643.8 GWh to 1286 GWh by the end of 2020 at an average growth rate of 7.2% annually whilst the peak demand is expected to rise from its present value of 106.5 MVA to 288.1 MVA over the same period at an average growth rate of 10.6% annually.

8.0 PENETRATION RATE

The penetration of NED based on the number of customers served increased from 32.2% as at the end of 2009 to **34.8%** as at the end of 2010. The details have been tabulated below.

REGION	Population (2000 Census)	Growth rate (%)	Population (2010)	Number of Customers	Average Household size	Penetration (%)
Brong Ahafo	2,282,128	2.5	2,921,317	175,020	5.3	31.75
Northern	2,468,557	2.8	3,253,676	89,430	7.4	20.34
Upper East	1,031,478	1.1	1,150,725	46,865	6.4	26.06
Upper West	677,763	1.7	802,209	30,741	7.2	27.59
TOTAL(NED)	**6,459,926**		**8,127,926**	**342,056**	**6.58**	**27.67**

Figure 7: Penetration Rate of NED

9.0 SUPPRESSED DEMAND

Suppressed demand in NED is mainly due to low voltages especially at the peak periods due to overstretched networks and linked transformer substations.

We estimate that 20% of all NED customers have voltages lower than the lower limit thus contributing to suppressed demand. The average demand per customer in NED is 500W. The customers with voltages lower than the lower limit have maximum demand of 400W. The suppressed demand per customer with voltage lower than the lower limit is therefore 100W. NED has a customer population of about 342,000. The estimated suppressed demand is therefore 34.2 MW as at the end of 2010. There are plans to release the suppressed demand in the systems through major network rehabilitation and reinforcement.

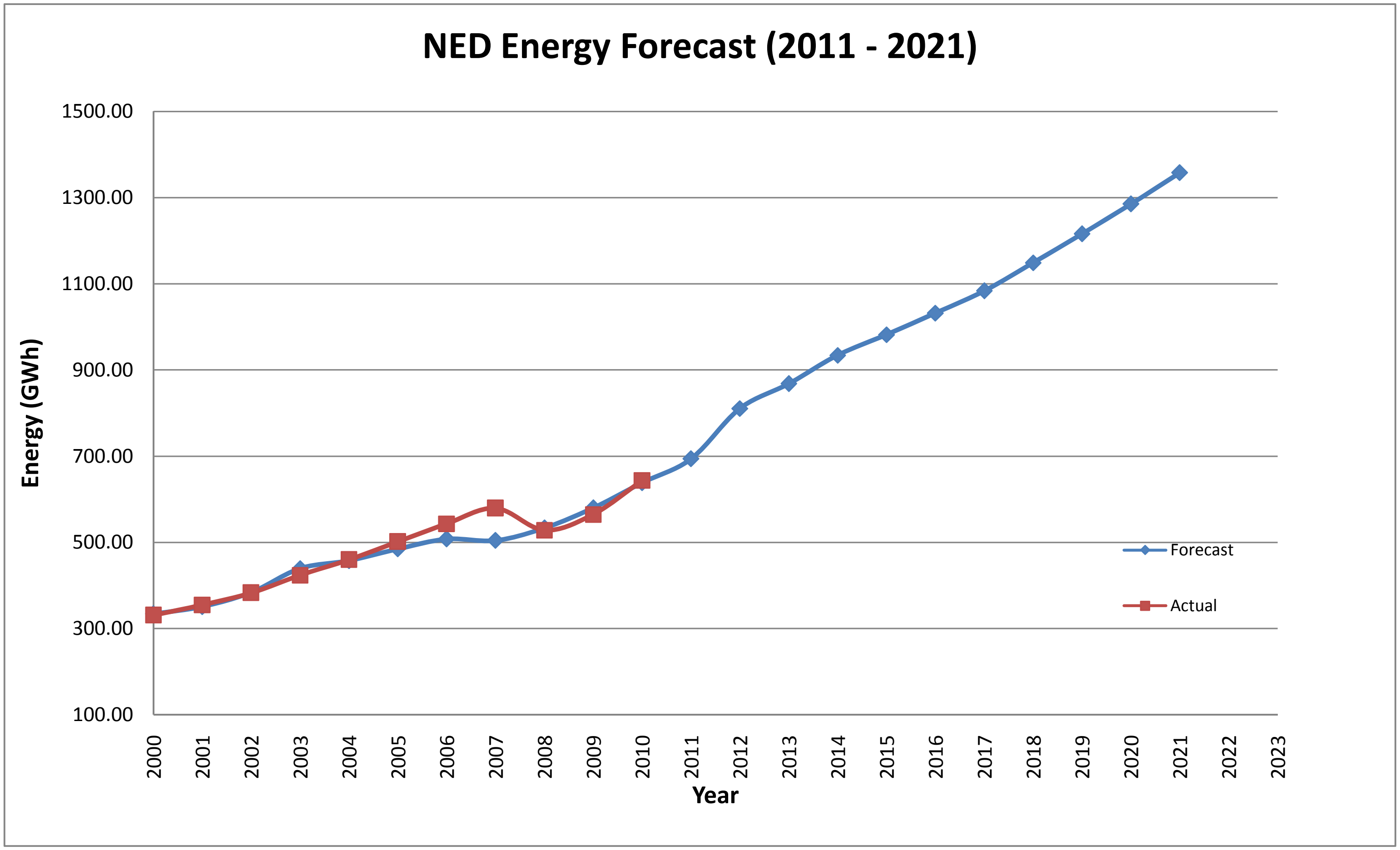

Figure 5: Energy Forecast with Spot Loads

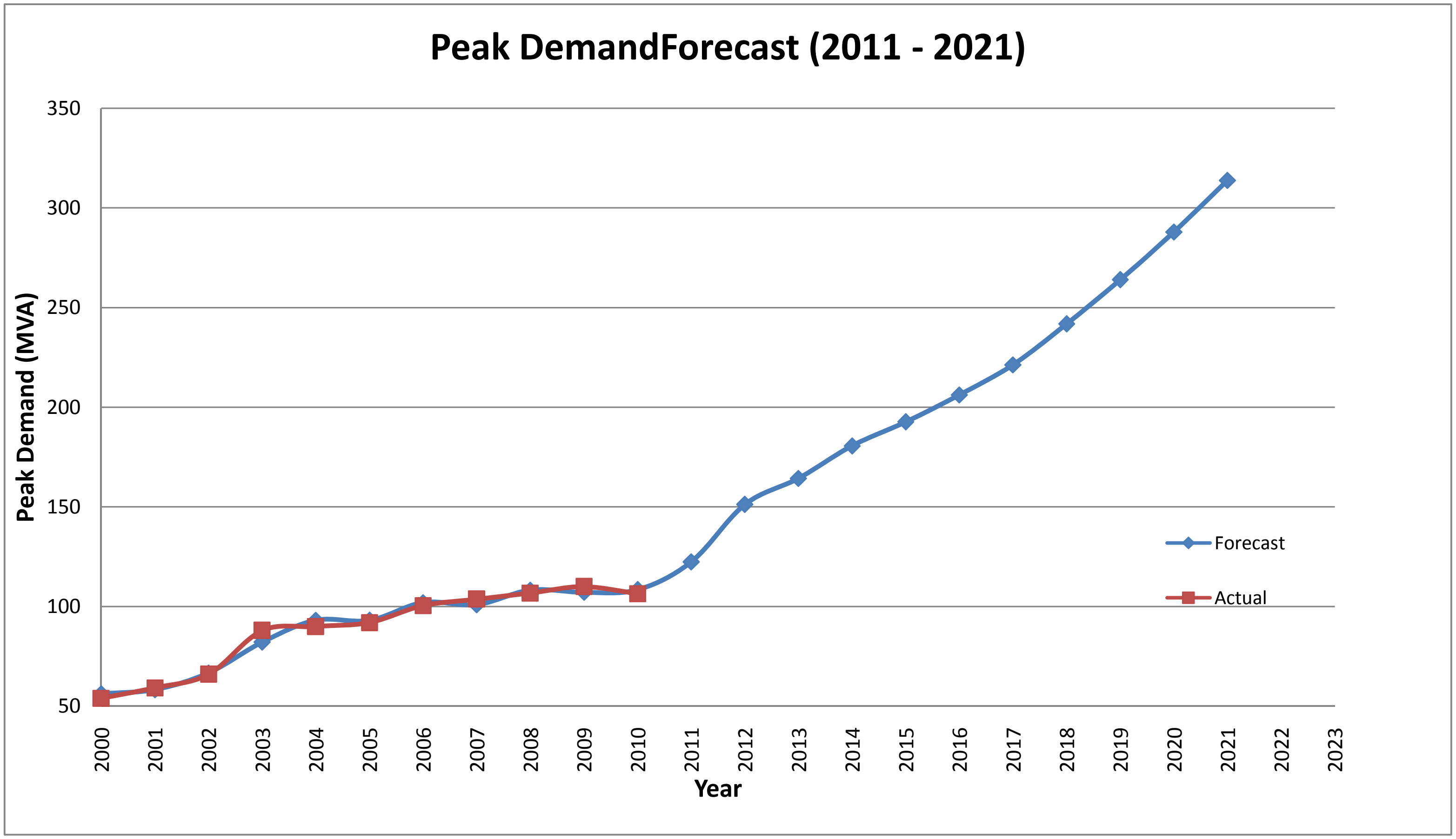

Figure 6: Peak Demand Forecast with Spot Loads