Modelling and Forecasting Electricity Demand for Commercial and Industrial Consumers in Kenya to 2035

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Abstract

Commercial and industrial consumers are the largest users of electrical energy in Kenya. They play a central role in driving electricity demand by contributing to over 70% of the electricity demand in the country. Despite their consumption of electricity being the highest, there is a gap on the drivers of their demand. There are significant deviations between past official forecasts and actual putting into question the official forecast assumptions.This study adressed this gap by estimating the drivers of commercial and industrial electricity demand.The drivers included supply side constraints represented by hydro inflows hence contributing to literature. A demand forecast upto to the year 2035 was also undertaken and compared with the official forecast. Autoregressive distributed lag (ARDL) method and time series data from 1985 to 2016 was used in undertaking the analysis. The results indicated that commercial and industrial consumers' electricity demand is income elastic. Other drivers include efficiency, electricity price and hydro inflows. A projection of the demand indicated the official forecast could be overstated and may need to be reviewed.

Keywords: Commercial and industrial electricity consumers**,** Electricity demand, ARDL, Kenya

1. Introduction

The Kenya Vision 2030 identified six priority sectors that would drive the GDP growth to 10%. The sectors identified were tourism, agriculture, livestock, wholesale, retail, trade, manufacturing, finance and business process outsourcing. The sectors were selected due to their contribution to the economy making up to 57% of the GDP and employing about half of the population (Republic of Kenya, 2007). These sectors are classified as commercial and industrial consumers of electricity (Electricity Regulatory Board, 2005). They are also the highest consumers of electrical energy at 70% of total energy consumed in the country. Despite the number of customers accounting for less than 10% of the total connections (Lahmeyer, International GmbH, 2016). Therefore, for the Government to succeed in achieving the goals of the Vision 2030 there needs to have reliable and affordable supply of electricity to these sectors.

In a regulated market without a wholesale market such as Kenya, the purchase and supply of electricity is centralised. Kenya Power and Lighting Company (KPLC) undertakes the monopsonist role in the electricity sector. The reforms of 1998 unbundled KPLC from a vertically integrated utility, created an independent regulatory authority and allowed for private sector participation in power generation. All generators sign long term power purchase agreements with KPLC.The demand forecast defines the generation capacity to be added to the electricity interconnected system. It is undertaken prior to generation planning. This makes demand forecasting a critical step in the procurement of generation capacity and in retail tariffs designs (Electricity Regulatory Board, 2005).

An over projection of electricity demand could lead to overinvestment and high costs of electricity. This is because in determining electricity prices, the regulator relies on the total future costs of supply as well as demand to come up with cost-reflective tariffs. The cost of supply includes the expenses from generation, transmission, distribution, metering and billing (Electricity Regulatory Board, 2005). The projected demand affects electricity prices in two ways. First, the price per unit is based on the projected energy sales. The higher the sales compared to the total costs of supply the lower would be the price and conversely. Second, all investment requirements are dependent on future electricity demand (Electricity Regulatory Board, 2005). Therefore, the demand forecast for commericial and industrial consumers being the largest consumers of energy plays a critical role in determining the investment and costs of electricity.

Currently, electricity demand forecast for commercial and industrial consumers is undertaken using an end user model. The model multiplies the base electricity consumption with the GDP growth forecast and a correlation factor. The correlation factor is estimated using past GDP and electricity consumption data. The coefficient used in forecasting has ranged from 1- 1.5 (Republic of Kenya, 2013b; Lahmeyer International GmbH, 2016). The forecasting method therefore assumes the only driver of commercial and industrial electricity demand is GDP. The role of prices in the demand is not considered, a weakness of the end user models (Bhattacharyya, 2011). There is therefore need to explore the drivers of commercial and industrial energy demand using an econometric approach. The approach treats electricity demand like demand for a normal good or service, by exploring the price, quantity and other drivers' relationship.

The GDP growth rate in the last five years averaged 5.64% (Kenya National Bureau of Statistics (KNBS), 2019) while electricity consumption by commercial and industrial consumers averaged 3% (KPLC, 2019). This indicates the need to reassess the correlation factor used in forecasting demand. Table 1 presents the deviations between previous official forecasts and actual. The deviations put into question the official forecast assumptions.

This article attempted to fill this research gap by forecasting and estimating the drivers of commercial and industrial electricity demand using autoregressive distributed lag (ARDL) econometric methods. The article also contributed to literature by examining the effects of supply side constraints on the demand. Supply side constraints existing in a developing country such as Kenya include system outages and load shedding during drought period due to overdependence on hydro generated energy. The article sought to answer the following research questions: What drives commercial and industrial consumer's electricity demand? What are the price and income elasticities? How does the demand forecast based on econometric estimations compare with the official forecast?

Table 1: Comparison of previous official projections and actual demand

	Energy consumption in GWh			Deviation from Actual	
Year	Republic of Kenya (2013b) Forecast	Lahmeyer International GmbH (2016) Forecast	Actual Sales (KPLC, 2019)	Republic of Kenya (2013b) Forecast	Lahmeyer International GmbH (2016) Forecast
2016	7583	5783	5416	41.4%	7.9%
2017	8804	6136	5664	61.3%	12.4%
2018	10125	6501	5611	81.5%	16.5%

Source: Author's compilation from Lahmeyer International GmbH (2016), Republic of Kenya (2013b) and KPLC (2019)

2. Literature review

The theoritical foundation of energy demand is similar to that of other normal goods and should therefore be presented through a demand function. The theory of production is used to determine the demand for energy as a factor of production (Bhattacharyya, 2011). Commercial and industrial consumers use electricity as an input in production and are faced with a cost minimization objective. The factor demand functions are derived from the firms cost minimization objective, where output is produced at the point the technical rate of substitution equals the ratio of the inputs prices (Bhattacharyya and Timilsina, 2009).Thus, demand for electricity in firms is a derived demand.

Khayyat (2015) derives the demand function for energy from a production function using the Shephard's lemma approach. The resultant demand function specificies energy to be dependent on output, own price and price of alternative energy. The price of alternative energy captures substitution and complimentarity effects. The dependency of energy demand on output and price is supported by Bhattacharyya (2011) and Bhattacharyya and Timilsina (2009). A long-run relationship between GDP and energy demand has also been established by Magazzino (2014).

The empricial literature on commercial and industrial electricity demand is quite limited. The earliest work in this area is by Francisco (1988) in Philippines. The work identifies electricity price, income and price of alternatives to be the significant determinants of demand. Several recent studies consider price and income/output as the only drivers of commercial and industrial electricity consumption. These include Campbell (2018) in Jamaica, Bianco, Manca, Nardini and Minea (2010) in Romania, Bernstein and Madlener (2010) in Germany, Chaudhry (2010) in Pakistan, and Bjørner and Togeby (1999) in Denmark.

Studies have identified other determinants of demand. Cebula and Herder (2010) finds the consumption of electricity demand by commercial and industrial consumers in the United States increasing with cooling degree days, per capita disposable income and electricity generating capacity. Consumption decreases with price of electricity and energy efficiency. Otsuka (2015) study for Japan also finds commercial and industrial electricity demand to increase with temperature factors and output and, decrease with price.

Dilaver and Hunt (2010) show that industrial electricity demand in Turkey is driven by industrial value addition, electricity price and the underlying trend. Ghaderi, Azadeh and Mohammadzadeh (2006b) find the demand drivers of various industrial sectors in Iran to include electricity prices, number of industrial customers and industrial value addition. Their earlier study (2006a) has price of substitutes and electricity intensity as additional drivers of demand. A study for Pakistan by Sabir, Ahmad and Bashir (2013) also finds price of oil as a substitute to be a significant driver of industrial electricity demand. Other significant drivers include own price and industrial share of GDP.

Past estimates of elasticities of demand for commercial and industrial electricity are varied. Cebule and Herder (2010) find income elasticity of 1.57 and price elasticity of -0.887 in the United States. A recent study for industrial consumers in the United States finds price elasticity of -1.17 and income elasticity of 0.48 (Burke and Abayasekara, 2018). Bjornerand and Togeby (1999) have income and price elasticity for Denmark at 0.611 and -0.473, respectively. In Turkey, Dilaver and Hunt (2010) find income and price elasticity of 0.15 and -0.161, respectively. In Jamaica, Campbell (2018) finds income and price elasticities of 1.22 and –0.25 for industrial consumers respectively.

In Pakistan, Chaudhry (2010) finds the income and price elasticity of commercial and industrial demand is 0.194, and -0.574, respectively. Comparable estimates in Iran are 0.11 and -0.21, respectively (Ghaderi et al., 2006b). Separating high from low energy consuming industries in Iran, Ghaderi et al. (2006a) finds high energy consuming industries to be price elastic with an elasticity of -2.92. Low energy consuming industries have a price elasticity of -0.93. Sabir et al. (2013) study for Pakistan estimates the income elasticity to be 0.96 and price elasticity to be -0.28.

Some studies have seperate estimates for the short and long-run elasticities. Bianco et al. (2010) in Romania finds short-run income and price elasticity of 0.136 and -0.0752, respectively. The long-run elasticities are slightly higher at 0.496 and -0.274, respectively. Otsuka (2015) study for Japan also finds higher income elasticities in the long-run compared to the short-run. In the long-run, the income elasticity is 1.169 for the industrial sector and 1.106 for the commercial sector.The short-run income elasticity for industrial consumers is 0.274 while that of commercial consumers is 0.358.

From the studies reviewed, the main determinants of demand for electricity are output/income and electricity price. Other determinants are price of alternatives, energy efficiency, temperature (cooling degree days), number of customers and energy intensity. Temperature may, however, not be a relevant determinant in the Kenyan case. The climate is warm all year round with minimal variations in temperatures. The reviews of elasticity of demand for electricity showed varied results across consumer groups and countries. Long-run elasticities were found to be higher than the short-run elasticities. This could be attributable to the period required for consumers to adjust to price and income changes.

Demand forecasting is undertaken using the relationship established in the demand function. Forecasting is undertaken by changing the values in the independent variables for the forecast period and determining their effect on the dependent variable. Forecasting of the independent variables is based on judgement, trends and projected national growth rates (Bhattacharyya, 2011; Dilaver and Hunt, 2010; Ghaderi et al., 2006a). Studies consider various scenarios. In Iran Ghaderi et al. (2006a) considered three scenarios that is low, high and average. Dilaver and Hunt (2010) study for Turkey also considers the three scenario with average being the reference and most probable scenario.

3. Methodology

Following Cebule and Herder (2010) the commercial and industrial electricity demand function was specified as

$$\boldsymbol{CIE = f(Y, P_e, P_d, EF_{ic}, H, C_{ic}, D_1)} \quad (1)$$

where *CIE* was the electricity consumed by the commercial and industrial consumers, *Y* was income/output, P_e was electricity price, P_d was price of the alternative fuel (Diesel), EF_{ic} was efficiency levels in production, *H* was hydro inflows as a proxy for supply side constraints and C_{ic} was the number of commercial and industrial consumers. D_1 was a dummy variable to correct for structural breaks associated with reforms of 1998.

Equation 1 was rewritten as follows;

$$CIE_t = e^{\alpha} P_{et}^{a}\, P_{dt}^{b}\, EF_{ict}^{c}\, H_t^{d}\, C_{ict}^{e}, Y_t^{f}\, e^{gD_1}\, e^{\varepsilon_t} \quad (2)$$

where α, a, b, c, d, e, f and g were coefficients to be estimated, ε was the error term and t was time period.

The log linear form of equation (2) becomes

$$\boldsymbol{lnCIE_t = \alpha + alnP_{et} + blnP_{dt} + clnEF_{ict} + dlnH_t + elnC_{ict} + flnY_t + gD_1 + \varepsilon_t} \quad (3)$$

Equation (3) error correction model took the following form;

$$\Delta ln\, CIE_t = \alpha + \sum_{i=1}^{n} \beta_i \Delta ln\, CIE_{t-i} + \sum_{i=0}^{n} a_i \Delta ln\, P_{et-i} + \sum_{i=0}^{n} b_i \Delta ln\, P_{dt-i} + \sum_{i=o}^{n} c_i \Delta\, lnEF_{ict-i} + \sum_{i=0}^{n} d_i \Delta\, lnH_{t-i} + \sum_{i=0}^{n} e_i \Delta\, lnC_{ict-i} + \sum_{i=0}^{n} f_i\, \Delta lnY_{t-i} + \emptyset_1 ln\, CIE_{t-1} + \emptyset_2 ln\, P_{et-1} + \emptyset_3 ln\, P_{dt-1} + \emptyset_4 lnEF_{ict-1} + \emptyset_5 lnH_{t-1} + \emptyset_6 lnC_{ict-1} + \emptyset_7 lnY_{t-1} + gD_1 + \varepsilon_t \quad (4)$$

where $\beta_i, a_i, b_i, c_i, d_i$, e_i, f_i and g were short-run coefficients and $\emptyset_1 \dots . \emptyset_7$ were long-run coefficients. Equation 4 was estimated using the Autoregressive Distributed lag model (ARDL). Bounds testing cointegration approach was used to test for the existence of a long-run relationship. The test has the advantage of working with small samples (Belloumi, 2014) and stationary and nonstationary data (Pesaran, Shin and Smith, 2001).

The long-run ARDL model was used for forecasting the future demand. This was done by changing the independent variables and determining their effect on *CIE* (Bhattacharyya, 2011). The independent future variables were amended based on predictions in goverement documents and judgement.

3.1 Data and measurement

The annual data used in the analysis was for the period 1985-2016 (32 years) sourced from KPLC annual reports, Kenya National Bureau of Statistics Economic Surveys and Statistical Abstracts, World Bank, World Development Indicators and KenGen.

Table 2: Definition and measurement of variables used to estimate commercial and industrial demand for electricity in Kenya.

Variable	Definition and measurement	Source
CIE	Annual electricity sales to commercial and industrial consumers (GWh)	KPLC annual reports, various
P_e	Real price of electricity (Ksh/200kWh) based period February 2009.	KNBS statistical abstracts, various
P_d,	Annual diesel Price per litre (Ksh/) base period February 2009.	KNBS statistical abstracts, various
EF_{ic}	Computed by dividing the annual value added produced by industry with the annual electricity sales to commercial and industry consumers (Ksh/kWh).	The value added produced from Industry was collected from world bank statistics, World Development Indicators. Electrical energy consumed by industry was collected from KPLC annual reports
H	Total annual hydro inflows (Cumecs).	KENGEN
Y	Annual constant gross value added in Ksh	World Bank statistics, World Development Indicators
C_{ic}	Number of commercial and industrial customers as reported in KPLC annual reports	KPLC annual reports, various
D_1	Dummy variable. Captures the first Electricity sector reforms. 1985 - 1997 = 0 and 1998 – 2015=1	

4. Results and discussion

Eviews 10 software was used for the analysis. The number of customers and diesel were dropped from the estimation to reduce collinearity in the model.

Table 3: Summary statistics of variables used in the analysis.

Variable	Unit	Mean	Std. deviation	Min	Median	Max
Commercial and industrial electricity consumption	GWh	2941	1148	1476	2557	5362
Number of customers	No.	136122	83679	38695	109157	324801
Diesel price	Kshs/Liter	66	47	9	58	148
Energy Efficiency	Kshs/kWh	158	14	139	156	187
Output	Kshs Trillion	2.12	0.72	1.18	2.766	3.81
Hydro inflows	Cumecs	862	262	466	833	1559
Price of Electricity	Kshs/200kWh	56	44	7	45	138

Source: Author's computation from KPLC, KNBS, World Bank and KenGen data.

Table 3 provides the summary statistics of the data before the logarithmic transformation. Commercial and industrial consumption averaged 2,941GWh increasing from 1,476GWh in 1985 to 5,362GWh in 2016. The number of customers' averaged 136,122 while energy efficiency averaged Ksh 158/kWh. The highest efficiency level of kshs187/kWh was realised in 2001 a period that was marked with power rationing. The gross value added representing income/output averaged Ksh 2,117 billion having increased from Kshs 1,178 billion in 1985 to Kshs 3,809 billion in 2016. Hydro inflows averaged 862 cubic metre per second with the least inflows of 466 cubic metre being for the drought period of 2008. Electricity price averaged Kshs 56/200 kWh, the highest price of Kshs 138/200kWh was recorded in 2014 and could be associated with the electricity tariff review of December 2013. Diesel prices averaged Kshs 66 per liter.

4.1 Diagnostic tests

Unit root tests

Table 4: Unit root test

Variable	ADF	PP	DF-GLS	KPSS	Breakpoint	Conclusion
Y_t- Intercept	1.6861	1.4834	1.1003	0.7507	-0.9919	we reject the null hypothesis of a unit root, the series are stationary based on the KPSS test.
Intercept and Trend	0.2130	-0.0620	-0.3929	0.1708	-4.1202	
H_t - Intercept	-4.7899	-3.9734	-4.8675	0.3166	-6.2109	we reject the null hypothesis of a unit root, the series are stationary based on all the tests.
Intercept and Trend	-5.3143	-6.2777	-5.4709	0.2862	-6.0981	
P_t- Intercept	-1.2549	-1.2549	-0.2166	0.7149	-2.6779	we reject the null hypothesis

Variable	ADF	PP	DF-GLS	KPSS	Breakpoint	Conclusion
Intercept and Trend	-2.3869	-2.3953	-2.4938	0.1406	-6.7625	of a unit root, the series are stationary based on the DF-GLS and PP tests.
CIE_t - Intercept	-0.2321	-0.3071	0.1839	0.7030	-3.7415	we reject the null hypothesis of a unit root, the series are stationary based on the breakpoint unit roor test.
Intercept and Trend	-2.2276	-1.5925	-2.3652	0.1228	-6.0064	
EF_{ict} - Intercept	-2.2927	-2.0722	-1.9950	0.3676	-4.1263	we reject the null hypothesis of a unit root, the series are stationary based on the breakpoint unit roor test.
Intercept and Trend	-2.7642	-2.0859	-2.8996	0.0594	-5.8505	

Source: Author estimates from KPLC, Economic surveys, World Bank statistics and KenGen data.

Critical levels at 1%, 5%, and 10% significance levels are as follows; Intercept ADF(-3.662,-2.960,-2.619), PP (-3.661661,-2.960411,-2.619160), KPSS (0.739000, 0.463000, 0.347000), DF-GLS (-2.644302,-1.952473,-1.610211) Break point (-4.949133, -4.443649, -4.193627) Intercept and Trend ADF(-4.309824, -3.574244, -3.221728) PP (-4.296729, -3.568379, -3.218382), KPSS (0.216000, 0.146000, 0.119000), DF-GLS (-3.77, -3.19,-2.89), break point; (-5.347598, -4.859812, -4.607324 – Intercept; -5.719131, -5.17571, -4.89395 - Trend and intercept; -5.067425, -4.524826, -4.261048)

The unit roots test details are in Table 4. Any variable found to be stationary at level by either the ADF, PP, DF-GLS, KPSS and break point unit root tests was considered I (0). All the variables were therefore I (0). This means the estimation using the ARDL bounds testing procedure which requires the variables to be either I (0) or I(1) (Pesaran et al, 2001), could proceed. Structural breaks with respect to the energy efficiency, hydro inflows and sales occurred in 1998. This was corrected by including the dummy variable called reform. Stationarity of the variables also makes it possible for the use of the series past behavior to forecast future movements (Magazzino, 2017).

Lag length, Residual and Stability tests

The Lag length 3 model failed the residual and stability diagnostic tests. Lag length 2 no intercept no trend model failed the Heteroskedasticity residual diagnostic test while the intercept with trend model failed the

CUSUM stability test. The model that passed all the test was ARDL(2, 2, 0, 1, 2) with a constant and no trend. Table 5 presents the lag length selection results. Table 6 provides the residual and stability diagnostic test results of the selected model. The CUSUM and CUSUM of squares results are presented in figure 1.This model was tested for cointegration and to analyse the commercial and industrial electricity demand.

Table 5: Lag length selection results

Model	Akaike information criterion	Bayesian information criterion	Hannan-Quinn criterion	Adjusted R-squared.
ARDL(2, 2, 0, 1, 2)	-6.827204	-6.220018	-6.632960	0.999612
ARDL(2, 2, 1, 1, 2)	-6.761869	-6.107976	-6.552683	0.999588
ARDL(2, 2, 0, 2, 2)	-6.760603	-6.106710	-6.551417	0.999588
ARDL(2, 2, 1, 2, 2)	-6.695288	-5.994689	-6.471160	0.999561

Source: Author estimates from KPLC, Economic surveys, World Bank statistics and KenGen data.

Table 6: Residual and stability diagnostic test results

Description	LM serial correlation	Normality	Heteroskedasticity	CUSUM and CUSUM of squares	Conclusion
Intercept and no trend model	0.4686	0.6192	0.3375	within the confines of the 5% significance	Diagnostic tests passed

Source: Author estimates from KPLC, Economic surveys, World Bank statistics and KenGen data.

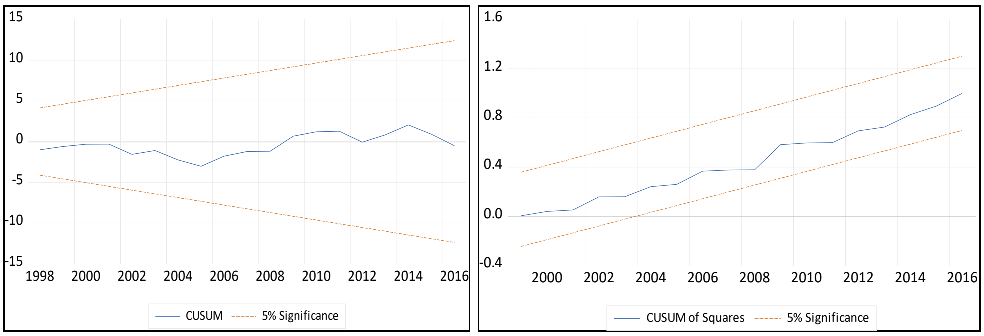

Figure 1: CUSUM and CUSUM of squares

4.2 Cointegration test

Table 7: Bounds Test Cointegration results for commercial and industrial electricity demand ARDL model (2, 2, 0, 1, 2)

Description	Critical Values		F statistics	Conclusion
Restricted intercept no trend	I(0)	I(1)	12.78	Long-run relationship exists
	2.2 (10%)	3.09(10%)		
	2.56(5%)	3.49(5%)		
	3.29(1%)	4.37(1%)		
	3.03 (10%)	4.06(10%)		
	3.47(5%)	4.57(5%)		
	4.4(1%)	5.72(1%)		

Source: Author estimates from KPLC, Economic surveys, World Bank statistics and KenGen data.

The bounds test cointegration test results are provided in Table 7. The test found an existing long-run relationship between commercial and industrial electricity demand on one part and income, electricity price, industry efficiency, hydro inflows, connections and reforms on the other.

4.3 Determinants of commercial and industrial demand for electricity in Kenya

Table 8: ARDL estimates of elasticities of demand for commercial and industrial electricity in Kenya

Variable	**Coefficient**
Short-run estimates	
C	-14.301 (2.096)
Commercial and industrial Electricity consumption(t-1)	-0.750*** (0.114)
Energy Efficiency (t-1)	-0.734*** (0.134)
Output (t-1)	0.847*** (0.128)
Hydro inflows	0.011* (0.006)
Price of Electricity(t-1)	-0.022** (0.008)
Change in Commercial and industrial Electricity consumption(t-1)	0.614*** (0.135)
D(Energy Efficiency)	-0.972*** (0.039)
Change in Energy Efficiency(t-1)	0.572*** (0.147)
Change in Output	1.054*** (0.071)
Change in Output(t-1)	-0.669*** (0.152)

Change in Price of Electricity	-0.003 (0.007)
Reform	-0.054*** 0.008
ECT	-0.750*** (0.075)
Long-run estimates	
Energy Efficiency	-0.979*** (0.045)
Output	1.129*** (0.022)
Hydro inflows	0.015* (0.008)
Price of Electricity	-0.030*** (0.008)
Constant	-19.061 (0.744)

Source: Author's estimates from KPLC, KNBS, World Bank and KenGen data.
Notes: *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10% level. The standard errors are in paranthesis.

The estimated short and long-run elasticities of demand are presented in Table 8. The estimated coefficients had the expected signs and were consistent with economic theory that stipulates demand to be a factor of price and income. The short-run elasticities were smaller than the long-run due to the time taken to make any adjustment to electricity consumption in the short-run. The error correction term was significant and negative indicating convergence to the equilibrium.

In the short-run, an increase in income by 1% increased electricity consumption in the next period by 0.84%. A 1% change in income increased electricity demand with 1.05%. This can be attributed to the need for more energy to produce the extra units of outputs, of which in the short-run period, alternative inputs into the production process may be difficult for the firms to adopt. However, a 1% change in income in the previous period was likely to decrease electricity demand in the current period by 0.67%. This could be as a result of consumers having a one-year period to make changes into their production processes.

In the long-run, commercial and industrial electricity demand was income elastic. This finding was consistent with Cebule and Herder (2010), Otsuka (2015) and Campbell (2018). A 1% increase in income increased electricity consumed by commercial and industrial consumers by 1.13%. Other studies that found electricity demand for commercial and industrial electricity consumers to be positively affected by the level of economic activity include Dilaver and Hunt (2010) in a study for Turkey, Ghaderi et al. (2006b) in a study for Iran and Sabir et al. (2013) in a study for Pakistan.

Electricity demand was found to be price inelastic in the short and long-run. In the short-run a 1% increase in the price of electricity decreased electricity demand by 0.02% in the subsequent period. In the long-run, a 1% increase in the price of electricity decreased electricity demand by 0.03%. The negative relationship between price and demand is consistent with demand theory for a normal good. Inelastic electricity demand with respect to price was also found by Campbell (2018) study for Jamaica, Otsuka (2015) study for Japan, Cebule and Herder (2010) study for the United States, Bjorner and Togeby (1999) study for Denmark, Dilaver and Hunt (2010) study for Turkey, Bianco et al. (2010) study for Romania and Sabir et al. (2013) in a study for Pakistan.

The study also found efficiency to be a significant determinants of demand in the short and long-run. In the short-run, 1% increase in energy efficiency reduced electricity demand in the next period by 0.73%. A 1% change in energy efficiency decreased electricity demand by 0.97% in the current period but increased electricity demand by 0.57% in the subsequent period. In the long-run, a 1% increase in energy efficiency decreased electricity demand with 0.98%. This finding is consistent with that of Cebule and Herder (2010).

Another significant determinant of commercial and industrial electricity demand was hydro inflows, as a proxy for supply side constraints. In the short-run, a 1% increase in hydro inflows increased electricity demand by 0.01%. In the long-run a 1% increase in the hydro inflows increased demand for electricity by 0.015%. None of the studies reviewed had included a variable for supply side constraints in their analysis. This finding is therefore a contribution to literature.

The reforms of 1998 were found to negatively affect electricity demand. This could be attributed to the coinciding of the reforms with the worst drought and economic recession declining the demand for electricity (Republic of Kenya, 2004). Previous period demand also negatively affected demand in the short-run. A 1% increase in previous period demand decreased demand in the current period with 0.75%. This indicates that commercial and industrial consumers are likely to reduce their demand in the current period based on their previous period demand.

4.4 Comparison of article forecast with the official forecasts

Using the ARDL model forecasting was undertaken by amending the independent future variables.Table 9 shows the assumptions taken in forecasting in this article. Three scenarios were considered in line with the official government forecasts namely low, base and high scenarios. The base scenario is the most probable scenario and informs the investments implemented by government. A comparison of the economic growth rates assumptions with those used in the official forecasts indicates significant differences in Republic of Kenya (2013b) but minimal differences in Lahmeyer International GmbH (2016). Republic of Kenya (2013b) assumed growth rates of 6% for the low case, 10% for the base case and 12% for the high case. Lahmeyer International GmbH (2016) forecast assumed average GDP growth rate of 5.1% for the low case, 6.9% for the base case and 10% for the period beyond 2020 for the high case.

Table 9**:** Assumptions in forecasting commercial and industrial demand for electricity in Kenya to 2035

Variable	Optimistic scenario assumption(high)	Reference scenario assumption (base)	Pessimistic scenario assumption (low)
Price of electricity	The electricity tariff was assumed to reduce from 15.56KSh/kWh in 2016 to 10.45KSh/kWh in 2035 as proposed by the investment prospectus 2013-2016 (Republic of Kenya, 2013a)	The retail tariff was projected to increase from 15.56KSh/kWh in 2016 to 16.33KSh/kWh in 2035, the highest recorded average tariff in the study period 1985 to 2016 collected from KPLC annual reports.	The retail tariff was projected to increase from 15.56 KSh/kWh in 2016 to 24.64 KSh/KWh by the year 2024. This is as projected in Republic of Kenya (2018c). The retail tariff was assumed to remain the same for the remainder of the forecast period
Hydro inflows	Assumed hydro inflows to increase until they reached 2499 Cumecs, the highest inflows recorded in the el-nino period of 2012/13.	The inflows were assumed to decline from KenGen's estimates of 1053 Cumecs in 2018 to the 35-year average inflows of 857 Cumecs by the year 2035.	Assumed the hydro inflows will decrease until they reach 466 Cumecs, this is the least inflows realised in the drought period of 2008/09.
Gross Value added	The growth rate projections were; 7.66% in 2019 and 8.36% in 2020 and the remainder of the forecast period. Assumed the vision 2030 projections in the Kenya Economic Report (Kenya Institute for Public Policy Research and Analysis (KIPPRA), 2017). The projected GDP growths were adjusted to exclude the contribution of taxes, whose contribution was 12% in 2017 (KNBS, 2018).	The projected growths rates were; 5.72% in 2019 and 5.9% in 2020 and for the rest of the forecast period. Assumed the baseline projections in the Kenya Economic Report (KIPPRA, 2017). An adjustment similar to the high scenario was undertaken.	The assumed growth rates were; 5.37% for the forecasting period. Assumed the low projections in the Kenya economic report (KIPPRA, 2017). Similar adjustment to high and reference scenario was undertaken.

Variable	Optimistic scenario assumption(high)	Reference scenario assumption (base)	Pessimistic scenario assumption (low)
Energy Efficiency	Energy efficiency growth rates for the three scenarios were based on the energy saving rate projections for industry, commercial and institutional sectors in the generation and transmission masterplan. The rates were 8% for 2018 – 2021, 4% for 2022- 2024, 2% for 2025-2027, 2.4% for 2028-2033 and 1.4% 2034-2035 (Lahmeyer International GmbH., 2016).		

Source: Authors compilation from Republic of Kenya (2013a, 2018c), KNBS, KenGen, KPLC, Lahmeyer International GmbH (2016) and (KIPPRA, 2017)

The results of the forecast are presented in Table 10. The two official forecasts are higher than this article's forecast. The forecast in Republic of Kenya (2013b) is the highest. It is over nine times the forecast in this article at 82,388 GWh in 2033 in the reference scenario. The official forecast is, therefore, overstated. This can be attributed to the high economic growth assumptions as well non-considerations of other demand drivers.

Table 10: A comparison of the official forecast with the article forecast

Year	Low scenario			Reference scenario			High scenario		
	Study Forecast	Lahmeyer Inter	Republic of Kenya	Study Forecast	Lahmeyer Inter.	Republic of Kenya	Study Forecast	Lahmeyer Inter	Republic of Kenya
2019	5516	6520	8767	5603	6876	11644	5805	7104	13366
2020	5465	6838	9556	5607	7324	13390	5969	7632	15772
2021	5420	7160	10416	5612	7792	15399	6145	8088	18611
2022	5590	7490	11353	5836	8288	17709	6575	8575	21960
2023	5747	7833	12375	6051	8808	20365	7016	9093	25913
2024	5899	8193	13489	6266	9355	23420	7477	9644	30578
2025	6165	8571	14703	6612	9932	26933	8122	10234	36082
2026	6440	8969	16026	6966	10539	30973	8806	10863	42576
2027	6725	9387	17468	7332	11180	35619	9540	11534	50240
2028	6995	9827	19040	7685	11876	40962	10291	12251	59283
2029	7277	10290	20754	8056	12598	47106	11103	13017	69954
2030	7571	10775	22622	8445	13368	54172	11980	13835	82546
2031	7876	11287	24658	8853	14189	62297	12926	14710	97404
2032	8193	11825	26877	9281	15067	71642	13947	15643	114937
2033	8522	12391	29296	9730	16001	82388	15049	16641	135626
2034	8951	12988		10302	16999		16399	17708	
2035	9393	13604		10899	18041		17837	18849	
Average growth rate (%)	3.4%	4.7%	9.0%	4.3%	6.2%	15%	7.3%	6.3%	18%

Source: Author's compilation from own forecast, Lahmeyer International GmbH (2016) forecast and Republic of Kenya (2013b) forecast.

5. Conclusions and Policy recommendations

The study sought to estimate drivers and forecast demand for commercial and industrial electricity consumers. The results showed the key drivers were efficiency, income, hydro inflows(supply side constraints) and price of electricity. Commercial and industrial electricity demand was found to be income elastic but price inelastic. The demand is estimated to rise to 10,899 GWh by 2035 in the reference scenario, representing an average growth rate of 4.3%. The comparison of the forecast with the official goverment forecast indicates the goverment forecast may be overstated.

Price of electricity was found to be a significant consideration for commercial and industrial consumers. The government and the regulatory agency should be careful of this causal effect on the demand when setting electricity tariffs. Innovative policy measures such as special tariffs for industrial parks, time of use tariffs and tax rebates should be considered.

The government should also address supply side issues to ensure stable energy supply.The proposed measures include diversification of energy supply sources to avoid dependency on hydro generated energy that has resulted in load shedding programs in the past during drought. Electricity access and grid strengthening programs should also be implemented to reduce suppressed and unmet demand associated with lack of power supply and power blackouts respectively.

The Ministry of Energy initiated several generation capacity expansion projects that would see the installed capacity grow to 6,700 MW by 2016 (Republic of Kenya, 2013a). This was later revised to 5,221MW by 2022 (Republic of Kenya, 2018b). This expansion was largely informed by anticipated growth in demand from commercial and industrial consumers. From the projections in this article the anticipated growth in electricity demand was overstated. The Ministry of Energy should review the planned generation projects to avoid a situation of excess supply and stranded capacity that would in turn increase electricity costs.

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