CHAPTER 4
OPERATIONAL PERFORMANCE OF ELECTRICITY SUPPLY INDUSTRY IN KENYA

In the previous chapter, the electricity supply industry in Kenya was discussed, highlighting key features of electricity supply industry in Kenya. Various issues such as installed capacity, per capita consumption of electricity, demand and supply of power, number of customers in the urban and the rural areas were examined. We also analyzed the need for reforms in the power sector and the policy reforms undertaken in the Kenya electricity supply industry. Key issues such as formation of the Electricity Regulatory Commission, its functions, autonomy of the commission, extent of transparency in decision making process and Tariff orders passed by the commission have also been discussed.

The current chapter mainly examines the impact of reforms on the technical performance of electricity supply industry in Kenya. Technical performance, here, refers to how well or effective electricity supply industry accomplishes its work. This study attempted to investigate long-term (20 years) trend data. The long-term trends capture the changes better than short intervals of time because of the poor quality of the available statistical material, where specific annual totals and rates do not have much significance. The twenty years constitute a convenient stretch of time to identifying a pattern and progress of the power sector and also analyze the impact of various policy reforms on the Kenya power sector. To note the critical changes before and after reforms, the long term period was divided into pre-reform period, 1992-93 to 2002-03 and post-reform period, 2002-03 to 2012-13.

We adopted an innovative procedure termed as ‘change-point analysis’ to study the long-term trends, and indicators used to measure the operational performance of electricity supply industry in Kenya. The main distinguishing factor between ‘change-point analysis’ and simple trend line plots or charts is that simple trend line plots are generally better at identifying isolated uneven points and major changes, whereas a ‘change-point analysis’ can also detect modest changes that are
frequently unobserved by control charts. Moreover, the simple trend line plots or charts cannot quantify the change with its statistical significance including confidence levels. Estimation of confidence levels of change is essential to validate and determine the robustness of a change that appears in graphical plots and charts. While examining historical data, particularly when data sets are large ‘change-point analysis’ is favored, as it is scientifically robust than the control charts in terms of identifying the pattern of trend.

The other key advantage of a ‘change-point analysis’ is that it controls the change-wise error rate, therefore, each change identified is possibly the trust. Simple trend line plots or ‘control charts’ or descriptive tables of annual or decadal change do not control the point-wise error rate, and therefore, may provide an inaccurate assessment of change in a performance indicator. When analysis is performed in large numbers of data points, several points can go beyond the set limits even when no change may have occurred. The main advantage of ‘change-point analysis’ is that it is simple to apply and construe, especially for large data sets and when multiple changes may have occurred.

Through ‘change-point analysis’ of operational performance indicators of power sector, this study addresses four questions: (1) did change occur at all? (2) Did more than one change occur? (3) When did the change occur? (4) With what confidence level did the change occur? By assessing these four questions in the Kenyan context, this study attempts to identify the commencement of critical changes and multiple change points in various operational performance indicators over a long period of time. Implicitly, this study is an effort to integrate the changes with power sector reforms and policy shift and other government efforts to enhance progress in the power sector.

With the determination of critical change-points and their time points, this study is innovative to more accurately interpret the accounting factors of progress in progressive changes in the power sector in Kenya. To establish the causal relationship, this study compares past trends of Kenya Power sector with the current trends and the pattern of performance indicators such as installed capacity, electricity generated, plant load factor, per capital consumption, electricity transmission and distribution losses, and labor productivity.
The results of ‘change-point analysis’ demonstrate trends and patterns in key operational performance indicators of power sector in Kenya: (1) Installed Capacity, (2) Generating Capacity, (3) Plant Load Factor (PLF), (4) Electricity Per Capita Consumption (EPCC), (5) Transmission and distribution network, (6) Electricity Transmission and Distribution Losses (T&D Losses), (7) Employee Productivity. These seven operational performance indicators represent the components used to measure decline or increase of the operation of the power sector. The results are presented in accordance with the sequence of the seven indicators.

4.1: Installed Capacity

Installed capacity means the generating capacity that can be used to generate electricity. It is measured in watts. We analyzed installed capacity from hydro power plant, thermal oil power plant, geothermal power plant, and lastly from total installed capacity. The aim of this was to establish the critical change-points to individual power plants and try to relate it with the impact of policy reforms on the power sector.

Hydro Power Plants

There are 10 hydro power plants owned by KenGen with a total installed capacity of 4298 MW, as at 31 June, 2013, as shown in Table 3.1.
Figure 4.1 and Table 4.1 present a plot of installed capacity trend of hydro power plants and change-point estimates during 1993-2013. The graphical representation indicates that the installed capacity of hydro power plants was constant from 1993 to 1997. The reason for installed capacity from hydro power plants remaining constant during this period was because of lack of investment by the government in electricity infrastructure as the economy’s growth rate remained less than 3% from 1990 to 1997.

The sector depended heavily on funds from donors which were affected by the aid embargo imposed to the country by the World Bank and IMF in 1990. This resulted to the 1996-97 liberalization of the sector to allow IPPs to come in and assist in capacity addition. There was a slight decline in installed capacity from hydro power plants in the period 1998-1999. During this time, the government commissioned the third unit at the Gitaru power station which added a capacity of 80 Mw in 1999 which triggered the first critical change-point in 2000.

The critical change-point was much higher with confidence level of 100%. Installed capacity of hydro power plants had increased from 595 MW in 1999 to 675 MW in 2000, as shown in annexure Table 1. From 2000 to 2007 the trend for installed capacity of hydro power plants remained constant. This signifies that the 1997 reforms had not created much impact in capacity addition to hydro power plants.

There was not much attraction for the IPPs to invest in hydro power plants. This could be because of the low profits or the nature of contracts entered with the
regulator. There was a proposal to disband the ERB established in 1998 by the Electric Act, No.11, 1997 and replace it with Energy Regulatory Commission which was to combine both petroleum sub-sector and electricity sub-sector. The aim was to make the sector attractive to private investors and also create legislations which would facilitate tender contracts entered by the IPPs with the regulator.

The Energy Regulatory Commission was established in 2007, through the Energy Act No. 12, 2006. A number of projects which had been stalled for a long time because of clearance or the delay of funds from the funding agencies such as the Sondu Miriu Hydro Power Station, with an installation capacity of 393 MW, were completed in 2007 by the government and the through the Energy Recovery Projects funded by the donors and the company. This resulted to the second critical change-point in 2008 (KPLC Annual Report, 2009).

**Thermal Oil Power Plants**

There are 5 thermal oil power plants with total capacity of 560 MW as at 31 June, 2013. These are Kipevu I and Kipevu II diesel stations with installation capacity of 185 MW and 321 MW respectively, which were commissioned in 1999, Fiat-Nairobi South commissioned in 1997, Embakasi Gas Turbine with 27 MW and, and lastly, Garissa and Lamu with installed capacity 27 MW.

Figure 4.2: Change Point Analysis of Trend on Installed Capacity from Thermal Power Plants in Kenya, 1993-2013
Table 4.2: Results of Change-Point Analysis on Installed Capacity in Thermal Power Plants in Kenya

Table of Significant Changes for Thermal(Mw)

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>(2000, 2000)</td>
<td>97%</td>
<td>185.43</td>
<td>409.25</td>
<td>1</td>
</tr>
<tr>
<td>2008</td>
<td>(2008, 2008)</td>
<td>94%</td>
<td>375.75</td>
<td>532.83</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-1

The graphical presentation in Figure 4.2 indicates that the trend of thermal power plants was constant from 1993-1997. From 1997, there was a great increase in trend up to 2000 when the first major critical change-point was detected. The 2000 critical change-point indicates a high confidence level >97%. This is attributed to the 1997 reforms which paved way for the IPPs to invest in electricity capacity addition which showed industrial establishments installing 20 MW with generation capacity of over 100 KVA, the commissioning of Nairobi South Natural Gas power plant in 1997, with a capacity of 109 and 105 MW, out of emergency generators which were contracted by the government under World Bank funding in 2000 which represents an increase in the sector’s gross fixed capital formation.

There was a constant trend again from 2000-2003. All this period the capacity was maintained by the IPPs and the emergency thermal plants installed by the government in 2000 to deal with power shortages (KPLC Annual Report, 2003). In the year 2004-2005 there was a decline in installed capacity of thermal power plants, this resulted to the second critical change-point which was detected in 2004. This critical change-point was attributed to the government reduction in investment in emergency thermal generators.

Again, there was an increase in trend in 2006 up to 2008 when the third critical change-point is indicated. The increase in installed capacity from thermal power plants is due to the governments signing of Power Purchase Agreement (PPA) with IPPs for development of a total of an additional capacity of 167.1 MW,
Iberafrika Power (EA) Limited with installed capacity of 52.5 MW, Rabai Power Limited with installed capacity of 88.6 MW, and Mumias Sugar Company Limited with installed capacity of 26 MW in 2007. There was commissioning by the government to procure 140 MW of emergence diesel power generator in 2009 (KPLC Annual Report, 2009). The efforts made by the government and Energy Regulatory Commission together with KPLC and Ken Gen to implement projects to enhance supply by 2015, caused the increase in trend seen 2009 to 2013.

**Geothermal Power Plants**

There are four geothermal power plants owned by KenGen namely Olkaria I with installed capacity of 369 MW, Olkaria II with installed capacity of 696 MW, Eburu Hill with installed capacity of 9 MW, and Olkaria Wellhead 0w3+ with installed capacity of 23 MW. By 30 June, 2013 all these geothermal power plants were operational and they owned a combined installed capacity of 1096 MW (Table 3.1.)

**Figure 4.3: Change Point Analysis of Trend on Installed Capacity of Geothermal Power Plants in Kenya, 1993-2013**

![Change Point Analysis Chart](image)

**Table 4.3: Results of Change-Point Analysis on Installed Capacity of Geothermal Plants in Kenya.**
Figure 4.3 shows that, the trend in installed capacity of geothermal power plants was constant from 1993 to 1999. This time period the sector was performing financially poor and it could not fund its projects, also there was no private investors attracted to the sector because of its financial status. After Reforms were enacted in 1997, the trend started to increase upwards up to 2000 when the first critical change-point was detected; again it remained constant up to 2003 before an increase up to 2004, when the second critical change-point was detected. From 2005 to 2007, the trend was constant again till 2009 when the third critical change-point happened.

There are three critical change-points indicated by Table 4.3 (2000, 2004 and 2009). The first critical change-point in 2000 had a confidence level >96%. This critical change-point is attributed to the government response to meet the national demand. The government had taken steps to restructure the sector in 1997, as agreed by the World Bank and other development Partners which allowed the private sector to participate in development projects through competitive bidding. Hence, the increase came from the contribution done by the IPPs and the construction of Olkaria II geothermal power plant in 1999. The second critical change-point in 2004 had a confidence level >91% while the third critical change-point had a confidence level >95%.

The last two critical change-points are associated with the Energy Sector Recovery Projects (ESRP) formed in 2004 with the aim of improving efficiency, reliability and quality of supply as well as increase access of electricity to Kenyans. This programme shows many projects completed and others started in 2008 such as the commissioning of Orpower4 geothermal plant with installed capacity of 35 MW,
the creation of an important institution, Geothermal Development Company in 2009 and the efforts made by the government to increase power generation through geothermal and wind sources (KPLC Annual Report, 2009).

Figure 4.4: Change Point Analysis of Trend on Total Installed Capacity in Kenya, 1993-2013

Table 4.4: Results of Change-Point Analysis of Total Installed Capacity in Kenya.

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>(2000, 2000)</td>
<td>100%</td>
<td>830.71</td>
<td>1162.8</td>
<td>3</td>
</tr>
<tr>
<td>2008</td>
<td>(2007, 2008)</td>
<td>99%</td>
<td>1162.8</td>
<td>1475</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-1

The graphical presentation in Figure 4.4 indicates that the trend in total electricity installed capacity in Kenya was constant from 1993 till 1997. The stagnated growth in trend of installed capacity in Kenya during this period is attributed with the lack of investment resources by the government in electricity infrastructure. It is also due to the poor financial performance of the sector which
witnessed financial institutions such as the IMF, World Bank and other development partners withdrawing their support. The increase in trend from 1997 to 2000 when the first critical change-point is indicated is as a result of the reforms done in 1997, when the Kenya electricity supply industry was restructured to create atmosphere of attracting private investors.

Through the restructuring, Independent Power Producers started participating in development of capacity addition of power to the grid through competitive bidding. The Electricity Regulatory Board formed in 1998 by the Electric Act No. 11, 1997 started a number of projects which were meant to add capacity. The commissioning of the third unit of Gitaru power hydro power plant in 1999 which raised the station capacity to 225 MW, the commencement of Olkaria II with installed capacity of 57 MW in 1999, the installations of 20 MW capacity by various industrial establishments with the generation capacity of over 100 KVA and the 105 MW capacity out of the emergence thermal generator installed by the government funded by World Bank.

The trend remained constant from 2000 till 2003 when again there was a continuous increase in trend till 2008 when the second critical change point was is indicated. In 2003, a long-term Strategic Economic Development Plan was flagged off by the government where the National Energy Policy was adopted by the Government with the aim of attracting private projects and increasing the exploitation of indigenous resources as the government was keen to improve access to electricity in Kenya.

There were also a number of suggestions which were made in the Sessional Paper 4, 2004, which included the disbanding of the Electricity Regulatory Board formed in 1998 by the Electricity Act, 1997 and formation of Energy Regulatory Commission which came in place in 2007 by the Electricity Act, 2006. The second critical change-point can also be associated with policy initiatives, such as Kenya Vision 2030 in 2008, whose objective is to make Kenya a middle income country by 2030. In this policy, energy infrastructure has been given first priority as it is believed that it’s an engine to stimulate development.
4.2: Generation of Power in Kenya

Generation of Power in Kenya is mainly done by Kenya Electric Generating Company (KenGen), a government owned company which owns 70 percent of the generated power and the Independent Power Producers (IPPs) and Emergency Power Producers (EPPs) which owns the remaining 30 percent. Kenya depends on hydro, thermal oil, geothermal and other sources to generate electricity, with hydro being the highest contributor of electricity over the years (KIPPRA, 2010). The three major sources, hydro, thermal oil and geothermal generating plants are analyzed. The analysis is done to establish the major critical changes that have happened on electricity produced by different sources over the last 20 years.

Table 4.5: Results of Change Point Analysis on Generation from Hydro Sources in Kenya

No Significant Changes for Hydro Generation(Gwh)

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates, Analyze Ranks

Estimated Average = 3120.2857

Source: Annexure-1

The estimates in critical change-points for hydro generation of power in Kenya indicate that no significant changes have taken place over the 20 years. Though, the trend plot lines indicate an upward trend from 1993 to 1998 when there...
was a huge decline till 2000. The increase in 1993 to 1998 was due to good rains. From 1998 to 2000, there was drought in Kenya which aggravated the situation and to a large extent the power generation stations operated below capacity. The power outages, which were experienced in 1999 to 2000, shifted to rationing especially in major towns. This affected the economy which grew at the rate of 1.1 percent (Economic Survey, 2001). The situation started improving in 2001, as some rain was received which caused the upward trend from 2001 to 2005.

There was an upward trend in 2005 to 2007; the trend is associated with improved rains and the government’s efforts to enhance electricity supply in Kenya through the Energy Recovery Projects which started in 2004 supported by the government and the donors. The downward trend of electricity generated from hydro sources in 2008 to 2009 again is due to the dry spell of 2008 and 2009. From 2009 till 2013, there is an upward trend in electricity generated from hydro power sources in Kenya.

**Figure 4.6: Change Point Analysis of Trend on Generation of Electricity from Thermal Sources in Kenya 1993-2013**

![Graph showing the change point analysis of trend on generation of electricity from thermal sources in Kenya from 1993 to 2013.](image)
Table 4.6: Results of Change-Point Analysis on Generation form Thermal Plants in Kenya

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>(1999, 2000)</td>
<td>99%</td>
<td>378.33</td>
<td>1479.7</td>
<td>2</td>
</tr>
<tr>
<td>2008</td>
<td>(2006, 2008)</td>
<td>99%</td>
<td>1479.7</td>
<td>2387.7</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-1

There is an indication that, there were two major critical change-points in electricity generated from thermal sources in Kenya over the last 20 years. The first change-point happened in 1999 with a higher confidence level of >99% while the second change-point happened in 2008 with equally a higher confidence level >99% as shown in Table 4.6. The graphical presentation in Figure 4.6 shows that the trend in electricity generated from thermal sources in Kenya slightly increased from 1993 till 1997 when there was some decline.

The decline in 1997 coincides with the reforms period in electricity sector in Kenya. One of the reasons for the reforms was to increase electricity supply in Kenya and also open the sector to the private investors. Reforms were enacted and the sector was opened up where generation was left to Ken Gen a public utility and the IPPs while distribution was left to the government company Kenya Power and Lighting Company (KPLC Annual Report, 1998). The IPPs entered into contract with the Electricity Regulatory Board formed in 1998 through the Electric Act No. 11, 1997 to participate in electricity generation which triggered the increase in trend in electricity generated from thermal sources as from 1997 till 1999 when the first major critical change point happened. In 1999-2000, there was drought in the country and the government had to install emergency thermal generators to meet the demand.

The established industries and commercial enterprises had to install 20 MW capacity generators which caused the increase. There was a decline in trend from 2001 to 2003. This decline is associated to the increase in international oil prices. The government found it expensive to generate using thermal generators which heavily
depend on oil. There were also improved rains which added water to the hydro based plants. This showed the government switch to cheaper sources. Again there was an upward trend from 2003 to 2008 when the second major critical change point is indicated. This trend is associated to the combined efforts of the government and the ERC together with KPLC and Ken Gen which took steps to implement projects to enhance supply up to 2025 (KPLC Annual Report, 2007). The projects include procurement of 140 MW of emergency diesel power in 2007. The dry season in the country from 2008 to 2009 is also another factor for the increase in trend.

**Figure 4.7: Change Point Analysis of Trend on Generation from Geothermal Power**

![Graph](image)

**Table 4.7: Results of Change-Point Analysis on Generation from Geothermal Sources in Kenya.**

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>(2001, 2001)</td>
<td>100%</td>
<td>343.12</td>
<td>806.75</td>
<td>3</td>
</tr>
<tr>
<td>2009</td>
<td>(2007, 2009)</td>
<td>98%</td>
<td>806.75</td>
<td>1495.2</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Annexure-1

The assessment of generation from the geothermal power plant, during the 1993-2013, through the ‘change-Point Analysis Technique’ shows that in a period of 20 years, Kenya power sector has experienced major critical changes in its generation
from geothermal sources in 2001, 2009 as shown in Table 4.7. The change point estimates are statically significant with above 95 percent confidence levels.

The graphical presentation in Figure 4.7 indicates that the trend in electricity generation from geothermal sources was constant from 1993 till 2001 when the first major critical change point happened. The increase is associated with the IPPs participation and the contribution from the commissioned Olkaria II in 1999. From 2001 to 2003, the trend was constant; again there was an upward trend from 2003 to 2005. This upward trend was due to National Energy Policy 2003 which was aimed at attracting private investors. The government entered into Power Purchase Agreements with IPPs in 2003 (KPLC Annual Report, 2003). The Energy Sector Recovery Projects (ESRP) formed in 2004 with the aim of improving efficiency, reliability and quality of supply as well as increase access of electricity to Kenyans. This programme shows many projects completed and others started in 2008, such as the commissioning of Orpower4 geothermal plant with installed capacity of 35 MW.

All these were attributed to the increase in trend from 2004 to 2009 when the second major change point is indicated. The creation of an important institution, Geothermal Development Company in 2009, and the efforts made by the government to increase power generation through geothermal and wind sources also has kept the trend upwards 2009 till 2013 (KPLC Annual Report, 2009).

Figure 4.8: Change Point Analysis of Trend on Total Generated Power in Kenya, 1993-2013
Table 4.8: Results of Change-Point Analysis on Total Generated Power in Kenya.

Table of Significant Changes for Total Generation Capacity (Gwh)

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>(2000, 2002)</td>
<td>98%</td>
<td>4079.6</td>
<td>5385.3</td>
<td>1</td>
</tr>
<tr>
<td>2008</td>
<td>(2008, 2008)</td>
<td>99%</td>
<td>5385.3</td>
<td>7296.5</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-1

The trend line plot and estimate of change-points in Table 4.8 indicates that there are two critical change-points in total electricity generated in Kenya over the last 20 years. The first major critical change happened in 2000-2002 with a higher confidence level of (98%) and the second in 2008 with a confidence level of >99% as shown by Table 4.8.

The graphical presentation in Figure 4.8 indicates an upward trend of electricity generated in Kenya from 1993 till 1999 when there was a decline which continued till 2002 when the first major critical change point is indicated. The decline is due to the 1999 to 2000 drought which showed the hydro based plants reduce generation. From 2000 to 2002, the supply was supplemented by emergency generators contribution from IPPs who generated 450 Gwh and the imports (KPLC Annual Reports, 2003). Again, the situation started improving in 2002 till 2003 when the government took steps to improve the supply by the National Energy Policy and the Electricity Recovery Projects supported by the government together with donors.

Though, there is a general view that since the vertical unbundling of the Kenya Power Sector in 1998 through the Electric Act No.11 of 1997, the separation of Generation from Transmission and Distribution and allowing of the Independent Power Producers (IPPs) to contribute in the generation of power there are some improvement in power generation in Kenya. The Sessional Paper No. 4 of 2004 expressed a number of policy objectives including ensuring adequate, quality, cost-effective and affordable supply of energy to meet development, the enacting of Energy Act, 2006, the Rural Electricity Authority (REA) and the initiating of Policy
reforms such as The Kenya Electricity Access Investment Programme Prospectus 2009-2014, the Least-Cost Power Development Programme (LCPDP) 2009-2029, Strategy for the Development of the Bio-Diesel industry in Kenya (2008-2012 and The Grid Code are all the contributed to the upward trend in power generation as indicated by the Change-point analysis trend line plot and estimates of critical change points of total generation Capacity of Power in Kenya during 1993-2013.

4.3: Plant Load Factor

In order to measure operational efficiency of thermal power plants, we may use plant load factor as an indicator. It represents the rate of capacity utilization achieved by a thermal plant. It can be technically defined as the ratio of the actual energy generated to the energy that could be generated if the plant was operated at its full rated capacity. We can mathematically represent plant load factor as:

\[
PLF = \frac{\text{Actual Generation (Kwh)}}{\text{Rated Capacity (KW) } \times 8760 \text{ (No of hours in a year)}}
\]

Generally, a thermal plant is considered performing satisfactorily when the average plant load factor of a thermal power station is above 60 percent while a thermal station with a load factor less than 60 percent is considered as unsatisfactory. It technically means more than one third of the total capacity was unutilized. This may be due to planned maintenance of technical problems such as forced breakdown, etc.

The norms are that, for new turbine, PLF may be more than 80 percent, and as the plant ages, the PLF declines. The average for lower station consisting of a number of generating units (Turbines) may not be less than 60%. In order to analyze the trend changes in the Kenya Plant Load Factor, we used Change-Point Analysis’ to locate the critical changes over the 20 year period of study.
Figure 4.9 and Table 4.9 show change-point analysis for PLF trends during 1993-2013. The results indicate that over the period of 20 years, there is one major critical change-point in 2001. The trend in the graphical presentation indicates that the plant load factor in Kenya declined slightly in 1997, and again increased in 1998 till 2001 when the first major critical change-point is indicated. The critical change-point had high confidence level (>98%). This is the single period when the plant load factor in Kenya declined below 65% from 1993 to 2013. The huge decline was due to forced breakdown of many hydro power plants as there was insufficient water to continue generating electricity.

There was an upward trend from 2002 to 2006, and then there was a downward trend. The downward trend may be as a result of aging of some of the plants which are as old as 24 years. This result concurs with the study conducted by Bonuke, 2008 which indicated that many power plants were performing poor because
of aging. The plant load factor in Kenya has always remained almost constant for a long period. It has been above 65 percent and not increased beyond 70 percent (KPLC Annual Report 2012). It reflects that the plants in Kenya have always been available at 70 percent throughout the year. Though it falls under the minimum required standards for the plant load factor to be satisfactory, still there is need to improve the plant load factor to ensure continues generation of power throughout the year.

4.4: Per Capita Electricity Consumption

The per capita electricity consumption is often considered as a reflection of the level of economic maturity of the country. Kenya’s per capita electricity consumption is below 200Kwh. It is very low (11/10) as compared to the world per capita consumption of 2000 Kwh. One of the main reasons for the low per capita electricity consumption in Kenya is high cost of electricity and the high cost of connection fee. With low level of economic activities, limited resources and technical skills, a country has to attract IPPs and for that an investment friendly atmosphere needs to be created. There has been some improvement for the last one decade as the government has introduced some policy reforms to encourage economic growth in the country. The main focus has been to the rural population to get more connected to the national grid, getting the country industrialized, encouraging farmers to use irrigation not to depend on rain and investing in electricity infrastructure.

Figure 4.10: Change Point Analysis of Trend on Per Capita Electricity Consumption in Kenya, 1993-2013
Table 4.10: Results of Change-Point Analysis on Per Capita Electricity Consumption in Kenya.

Table of Significant Changes for PCEC (Kwh)

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>(1997, 2002)</td>
<td>93%</td>
<td>127.29</td>
<td>120</td>
<td>2</td>
</tr>
<tr>
<td>2005</td>
<td>(2005, 2005)</td>
<td>99%</td>
<td>120</td>
<td>146.56</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Annexure-2

As indicated in Figure 4.10, the trend in per capita consumption in Kenya increased at a constant rate till 1999 when there was a decline in trend till 2001. The increase in consumption at this period is attributed to the increase in number of customers connected with electricity. The first critical change-point was in the year 2000 which was a difficult year for the Kenya economy as we have discussed earlier. The critical change happened with a confidence level <93%. In this period many sectors of the economy were hit by the national rationing imposed by Kenya power and Lighting Company and a high cost of electricity which reduced consumption.

There was an upward trend in electricity per capita consumption from 2001 to 2005 when the major critical change point in per capita electricity consumption in Kenya was detected with a higher confidence level >99%. From this period, the trend for electricity per capita consumption has been upward. This upward trend is attributed to among other factors the increase in economic activities in Kenya during this period. The Customer Base Policy came in 2003 which was meant get a number of customers to the national grid. The Kenyan economy experienced better GDP growth rate of 5.8 percent. The increase in trend may also be attributed to the Rural Electrification Authority 2007, through their Master Plan 2008 with the strategy of targeting 200,000 annual connections in the rural areas in three phases of five years each where the first phase started in 2008 and ended in 2012.
4. 5: Electricity Consumption Pattern in Kenya

The electricity distribution company of Kenya sells electricity to various customers at a price/tariff determined by the Kenya Energy Regulatory Commission’s for various categories such as domestic, commercial and industrial (small), commercial and industrial (medium & large), off-peak, street-lighting and rural electrification programme. These categories of consumers have been labeled in this study as small consumers, large consumers, off-peak, street lighting and rural electrification programme as indicated in the KPLC Annual Report 2014.

Figure 4.11: Change Point Analysis of Trend on power Consumption by Small Consumers in Kenya, 1993-2013

Table 4.11: Results of Change-Point Analysis on Consumption by Small Consumers in Kenya

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>(2001, 2002)</td>
<td>99%</td>
<td>1083.6</td>
<td>1464.1</td>
<td>1</td>
</tr>
<tr>
<td>2008</td>
<td>(2008, 2008)</td>
<td>99%</td>
<td>1464.1</td>
<td>2360.9</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-4

Note: A* Small consumers include domestic, commercial & industrial.
The graphical presentation in Figure 4.11 indicates a constant upward trend in electricity consumption by small consumers in Kenya from 1993 till 2000. There was a downward trend in electricity consumption by small consumers from 2000 till 2002 when the first major critical change-point is indicated as shown in Table 4.11. The critical change point happened immediately when the economy was picking-up from its worst performance since independence.

There was constant growth in consumption because of the various policies of the government. The second critical change happened when a number of policy reforms which were proposed in the Sessional Paper No4. 2004 had been implemented. The adoption of the Energy Act, No.12, 2006, which led to the formation of the Energy Regulatory Commission 2006, the Rural Electrification Authority in 2007 which came up with the Rural Electrification Master Plan in 2008 and the Energy Tribunal Act which allowed the government to venture to the indigenous sources of energy which are cheaper. All these provide many reasons for the increase in consumption of electricity from small consumers more especially the Rural Electrification Master Plan which has seen increase in customers’ connection to the grid from the rural areas.

Figure 4.12: Change Point Analysis of Trend on Power Consumption by Large Consumers in Kenya, 1993-2013
Table 4.12: Results of Change-Point Analysis on Power Consumption by Large Consumers in Kenya.

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>(2000, 2002)</td>
<td>100%</td>
<td>2094.9</td>
<td>2568.6</td>
<td>1</td>
</tr>
<tr>
<td>2007</td>
<td>(2007, 2008)</td>
<td>97%</td>
<td>2568.6</td>
<td>3265.5</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Annexure-4

Note: B* Large consumers include commercial industrial (medium), and commercial industrial (large).

There have been two critical change-points during the past two decades as indicated by the plot of large consumers’ trend and change-point estimates in Figure 4.12 and Table 4.12. The two critical Change-points were in the year 2002 and 2007. All the critical change-point are statistical significant with a confidence level >95%, and though, the first critical change-point happened with a confidence level >100%.

The graphical presentation in Figure 4.12 indicates that there was a decline in consumption of electricity by large consumers in 2000. The decline is due to the high cost of electricity as there was shortage of power caused by the drought. It may be also because of power rationing which was imposed by Kenya Power and Lighting Company. There was an increase in trend as from 2002 when the first major critical change point is indicated till 2007 when again there was a decline in trend. The increase is associated with higher economic activities and government policies which triggered the economy to grow at 6.2 percent in 2006 and also many alternatives which were provided to the commercial and industrial establishment through the National Energy Policy 2003 which welcomed private sector to participate in providing electricity. There were some motivations by the government to stimulate development which led to the commercial and industrial consumers being subsidized.

In 2007, there was decline in trend of electricity consumption by large consumers in Kenya again. The decline may be attributed to the election violence in
2007-2008 which shows many commercial activities shutdown as property was destroyed. There was again drought in 2008-2009, which caused electricity supply decline and the cost of electricity increased. The trend again increased after 2009 till 2013 as the situation improved.

Figure 4.13: Change Point Analysis of Trend on Power Consumption by Off-Peak Consumers in Kenya, 1993-2013

Table 4.13: Results of Change-Point Analysis on Power Consumption by Off-Peak Consumers in Kenya.

Table of Significant Changes for Off-Peak Consumers (Gwh)

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates, Analyze Ranks

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>(2000, 2001)</td>
<td>100%</td>
<td>103.09</td>
<td>57</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>(2007, 2009)</td>
<td>97%</td>
<td>57</td>
<td>36.32</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-4

Table 4.13 reveals that two major critical change-points have taken place for the last 20 years in consumption of electricity by the Off-Peak consumers in Kenya. The first critical change point happened in 2000 while the second happened in 2009. All the critical change-points are statistically significant with a confidence level >95%. The graphical presentation shows a decline in trend for consumption of
electricity by the Off-Peak consumers in Kenya from 1994 till 1999. The decline in trend is due the shift of this consumer from Off-Peak consumption to peak consumption as the interruptions in supply of electricity increased.

There was further decline in trend from 2000, the year when the first major critical change point is indicated till 2001 when again there was some slight increase in trend till 2003. From 2003 till 2005 there was decline in trend which again increased till 2007 and again decline till 2009 when the second major critical change point is indicated. The 2009 decline is associated with decline in electricity supply as there was drought. Again, the consumers shifted from Off-Peak consumption to peak consumption. All the declines and increase in trend of consumption of electricity of this type of consumers is based on the supply of electricity available. This is because these types of consumers have two types of meters and they are supplied interruptible electricity at cheaper cost.

**Figure 4.14: Change Point Analysis of Trend on Power Consumption by Street Light in Kenya, 1993-2013**
There is an indication from the plot of street lighting trend and change-point estimates during 1993-2013, two critical change-points have occurred mostly in the years 2000 and 2007 as shown from Figure 4.14 and Table 4.14. All these changes are statistically significant with a confidence level >99%. The first critical point is attributed to the shortages of power in this period and the rationing of power which was imposed nationwide by the Kenya Power and Lighting Company which is in charge of transmission and distribution of power in Kenya. This made most of the public and local authorities supplied with electrical energy for public lamps such as street lighting remaining off in most of the time. The second critical change took place in a time when the situation of electricity had improved. The economy of Kenya at this year was also doing well growing at 6.5 percent. This is also when the local authority had installed streets lights in almost all major cities for security and traffic purposes (Economic Survey, 2006).

Table of Significant Changes for Street Lighting (Gwh)

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
</table>

Source: Annexure-4
Figure 4.15: Change Point Analysis of Trend on Power Consumption by REP in Kenya, 1993-2013

Table 4.15: Results of Change-point Analysis on Consumption by Rural Consumers in Kenya

Table of Significant Changes for REP Consumers (Gwh)

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>(2000, 2003)</td>
<td>94%</td>
<td>134.81</td>
<td>180.78</td>
<td>3</td>
</tr>
<tr>
<td>2008</td>
<td>(2008, 2008)</td>
<td>98%</td>
<td>180.78</td>
<td>316.22</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-4

Figure 4.15 and Table 4.15 represents a plot of rural electrification Programme (REP) trend and change-point estimates during 1993-2013. For the past two decades, results indicate two major critical change-points. The graphical presentation in Figure 4.15 also indicates a constant increase of consumption of electricity by REP from 1993 to 2013. Though there was a decline in 2000 which is as a result in shortage in electricity supply during this period due to the drought of 1999-2000.

The first major critical change occurred in a very important year 2003 in the economy of Kenya. This coincides with the year when major economic reforms were introduced in Kenya through the long-term Strategic Economic Development Plan 2003 which adopted the National Energy Policy 2003. The Kenya power sector was exposed to competitive Markets, which gave Independent Power Producers (IPPs) an
opportunity to contribute to the national grid. There was also recovery of the economy as the rain provided better yields for farmers based in the rural areas.

The second critical change is a beneficiary of the Rural Electrification Authority 2007 which came up with the Rural Electrification Master Plan 2008. The master plan was divided into three major strategic phases each phase covering five years. The first phase was starting from 2008-2012. In this phase, there was a target of having 200,000 connections annually in the rural areas. It also included having all the public offices, institutions of learning and church buildings in the rural connected with electricity throughout the country by 2012. The target has been achieved. It can also be due the Constituency Development Fund which was passed by parliament in 2003 which contributed in improving the economic status of the rural population (Economic Survey, 2004).

Figure 4.16: Change Point Analysis of Trend on Total Power Consumption in Kenya, 1993-2013

Table 4.16: Results of Change-Point Analysis on Total Power Consumption in Kenya.

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>(2003, 2003)</td>
<td>100%</td>
<td>3451.1</td>
<td>5327.3</td>
<td>2</td>
</tr>
</tbody>
</table>
The plot of total electricity consumption trend and change-point estimates in Figure 4.16 and Table 4.16 indicates only one critical change-point has happened in the total consumption of electricity in Kenya for the past two decades. The critical change happened in the year 2003 with higher confidence level of 100%. As we have seen earlier, 2003 was a very important year in the economy of Kenya as it’s the period when major economic reforms took place.

The graphical presentation in Figure 4.16 shows a constant growth in electricity consumption in Kenya. From 1993 to 2000 there was a downward trend which followed an upward trend from 2001 to 2003, the year in which the first major critical change point is indicated. The only critical change for the two decades also explains why still Kenya’s per capita electricity consumption has been below 200Kwh.

In general, we can say that electricity consumption pattern in Kenya has changed more especially after the 2003 which falls under post reform period in this study. The different categories of consumers have increased their consumption such as the small consumers, large, Rural Electrification Programme while others such as Off-Peak and Street Lighting has declined. The increase in consumption is due to the government’s efforts to increase access to electricity and some policy initiatives which have seen the number of consumer increase. The Policy initiatives include the Strategic Economic Development Plan 2003 which adopted the National Energy Policy 2003. The customer Base policy 2003, whose aim is to have many customers connected to the national grid, The Energy Act No.12, 2006, Rural Electrification Authority 2007 which came up with the Rural Electrification Master Plan 2008. The master plan was divided into three major strategic phases each phase covering five years (Economic Survey, 2004).

4.6: Transmission and Distribution Network System

Transmission network system refers to the interface between the distribution system and the generating plants; it is therefore the integral pillar to the provision of high quality and reliable supply. Kenya is implementing a number of new projects totaling 4,066 Kilometers of 132kv, 220kv and 400kv transmission lines, as well as
2,421 MVA of substations capacity at a cost of US $1.24 billion by 2016. These projects are meant to upgrade the existing system with the view to creating a strong and adequate transmission system to support the increased generation capacity and demand. Figure 4.18 and Table 4.18 show results of a change-point analysis for the transmission and distribution network in 220 km/Kv as from 1998-2012 in Kenya.

**Figure 4.17: Change Point Analysis of Trend on 220 Km/KV in Kenya, 1998-2012**

![Change Point Analysis of Trend on 220 Km/KV in Kenya, 1998-2012](image)

**Table 4.17: Results of Change-Point Analysis on 220 KV Network in Kenya.**

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>(2004, 2004)</td>
<td>98%</td>
<td>899.67</td>
<td>1323</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>(2009, 2009)</td>
<td>98%</td>
<td>1323</td>
<td>1331</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-3

Figure 4.17 presents a plot of 220 KV network in kilometers trend and change-point estimates during 1998-2012. During the study period, the results indicate two major critical change-points 2004 and 2009. Table 4.17 indicates that all the two change-points had higher confidence levels (>95%). The change in 2004 is attributed to the completion of Kiambere-Nairobi 220 Kv line and associated substations by KEC International of India and also the 117 km 220 Kv double circuit line by the
Olkaria II Geothermal Power Project which was implemented by KenGen in 2003. This was meant to improve the transmission of power from the hydro stations in Nairobi. The second change in 2009 is a beneficiary of the Energy Sector Recovery Projects (ESRP) which commenced in 2004. The programme financed a number of projects with the aim of improving efficiency, reliability and quality of supply, as well as, increasing access of electricity to Kenyans (KPLC Annual Report, 2003 and 2009).

Figure 4.18: Change Point Analysis of Trend on 132 Km/ KV in Kenya, 1998-2012

Table 4.18: Results of Change-Point Analysis on 132 KV Network in Kenya.

Table of Significant Changes for KV Network (Km)
Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates, Analyze Ranks

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>(2007, 2007)</td>
<td>100%</td>
<td>2021.6</td>
<td>2179.7</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Annexure-3

The assessment of the trend line plot and estimate of change-points in Figure 4.18 and Table 4-18 indicates that Kenya experienced one major critical change-point in 2007 on 132 KV network trend during the study period. The change was statistically significant with significance level above 99 percent as shown in Table 4.18. The critical change was as a result of the construction of 132 Kv line by Kinden
Corporation of Japan on the 60 Km Sondu-Miriu-Hydro Power Station in July 2007. It was also as a result of the increase in projects of expanding and upgrading the distribution system which had led to 22 percent network growth compared to an average of 10 percent annual growth achieved in 2006.

**Figure 4.19: Change Point Analysis of Trend on 66 Km/ KV on Kenya, 1998-2012**

![Change Point Analysis Trend on 66 KV Network](image)

**Table 4.19: Results of Change-Point Analysis on 66 KV Network in Kenya.**

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>(2006, 2006)</td>
<td>97%</td>
<td>577.75</td>
<td>635.75</td>
<td>1</td>
</tr>
<tr>
<td>2010</td>
<td>(2010, 2010)</td>
<td>90%</td>
<td>635.75</td>
<td>791.25</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-3

Figure 4.19 and Table 4.19 presents ‘Change-Point analysis’ trend line plot and estimates of critical change-points for 66Kv network in Kenya during 1998-2012. The trend line and estimates indicate major two critical change-points experienced in Kenya on 66 Kv network trend. The first critical change-point happened in 2006 with a higher confidence level >97% which is above the statistical significance of 95 percent. The second change happened in 2010 with a confidence level >90% slightly
lower than the first change. All the two critical change-points are beneficiaries of the completion of the Energy Sector Recovery Projects which were flagged off in 2004. This show many projects achieved under the largely donor-funded US dollars 153 million Distribution System Reinforcement and Upgrading Component of the Energy Sector Recovery Projects (ESRP) in 2006 (KPLC, 2006 and 2009).

**Figure 4.20: Change Point Analysis of Trend on 40 Km/ KV in Kenya, 1998-2012**

![Figure 4.20: Change Point Analysis of Trend on 40 Km/ KV in Kenya, 1998-2012](image)

**Table 4.20: Results of Change-Point Analysis on 40 KV Network in Kenya.**

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>(2007, 2007)</td>
<td>99%</td>
<td>58</td>
<td>12.429</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Annexure-3

Figure 4.20 and Table 4.20 present a plot of 40 Kv network trend and change-point estimates in Kenya for the period 1998-2012. For the past 16 years, results indicate two major critical change-points. The first critical change-point occurred in 2002 with a confidence level (>93%) while the second critical change happened in 2007 with a confidence level which is statistically significant at above 95 percent confidence level. At all these two critical change points indicate that there was a
decline observed on the 40 Kv network. In 2002, there was a decline from 126 km to 58km while in 2007 it further declined from 58 km to 12.4km.

It seems that there was no importance given to this type of network as it kept declining towards zero towards 2012, as shown by the graphical presentation in Figure 4.20. Actually, the government has not been carrying out projects on this type of network for the last four years. The government shifted focus to the 33 Km/Kv and 11Km/Kv as the aim was to expand connection of electricity to the rural areas.

Figure 4.21: Change Point Analysis of Trend on 33 Km/ KV in Kenya, 1998-2012

![Figure 4.21: Change Point Analysis of Trend on 33 Km/ KV in Kenya, 1998-2012](image)

### Table 4.21: Results of Change-Point Analysis on 33 KV Network in Kenya.

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>(2003, 2004)</td>
<td>99%</td>
<td>4821.3</td>
<td>8833</td>
<td>2</td>
</tr>
<tr>
<td>2009</td>
<td>(2009, 2009)</td>
<td>95%</td>
<td>8833</td>
<td>14727</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Annexure-3

In the trend assessment of 33 Kv network, during the period 1998-2012 the ‘Change-Point Analysis technique’ shows that for the period of 16 years, Kenya experienced critical changes in its 33 Kv network at two point periods 2004 and 2009 as shown in Figure 4.21 and Table 4.21. All the two change-point estimates are
statistically significant with above 95 percent confidence levels. The first change in 2004 is attributed to the National Energy Policy 2003 whose aim was to provide a more investor friendly, fiscal, regulatory and legal regime of the sector so as to attract private projects to increase exploitation of indigenous resources and significantly improve access to electricity in Kenya.

The 2009 critical change is attributed to the completion of many projects under the Energy Sector Recovery Projects which started in 2004. Among the projects were the eight 132/33kv and 33/11 Kv substations in Nairobi, Naivasha, Lanet, Lessos and Kamburu in 2007. This called for 500 km of transmission lines target in 2007 and it was achieved in 2009 (KPLC, Annual Report, 2007 and 2008). The graphical representation in Figure 4.21 also indicates that the trend for the 33Kv network happened to increase progressively after 2003-2004. This is a very important year in the Kenya power sector since a number of the policy reforms were initiated during this period (Sessional Paper No.4, 2004)

**Figure 4.22: Change Point Analysis of Trend on 11 Km/ KV in Kenya, 1998-2012**
Table 4.22: Results of Change-Point Analysis on 11 KV Network in Kenya.

Table of Significant Changes for KV Network (Km)

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%,
Bootstraps = 1000, Without Replacement, MSE Estimates, Analyze Ranks

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>(2008, 2008)</td>
<td>99%</td>
<td>16696</td>
<td>25946</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Annexure-3

Figure 4.22 and Table 4.22 present a ‘Change-Point analysis, trend line plot and estimates of critical change-points for 11Kv network during the period 1998-2012. The assessment of the trend line plot and estimate of change-points indicate that Kenya experienced two critical change-points. The first critical change happened in 2002 with a significance level (>92%) and the second critical change-point happened in 2008 with a greater confidence level (>99%). The 2002 change is attributed to the completion of the building of the Rabai 11Kv network board (KPLC, Annual Report, 2003) while the 2008 change is the result of the completion of the Energy Sector Recovery Projects (ESRP) which started in 2004.

Figure 4.23: Change Point Analysis of Trend on Total Network Km/ KV in Kenya, 1998-2013
Table 4.23: Results of Change-Point Analysis on Total Network Km/ KV in Kenya

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>(2006, 2006)</td>
<td>100%</td>
<td>21177</td>
<td>42189</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Annexure-3

Figure 4.23 and Table 4.23 show change-point analysis for total length covered by network in Km/KV trends during the period 1998-2012. The results unravel only one critical change-point 2006 for total Kv network over the period of 16 years. The critical change is highly significant with a confidence level (>100%) This long-term critical change is also viewed to be closely tied with a number of policy reforms initiated in 2004 such as the National Energy policy 2003 which was meant to attract private investors to exploit the indigenous resources as the government aimed at improving access to electricity in Kenya, secondly the Customer Connection Policy 2004 was aimed at developing a market friendly and customer focused connection policy to reduce costs and accelerate power supply connections to new customers, Thirdly, the commencement of the Energy Sector Recovery Projects (ESRP) in 2004 saw a number of projects completed by 2009. The Energy Act No.12, 2006 also played a great role by putting into place the Rural Electricity Authority (REA) in 2007.

Through the Rural Electricity Authority Master Plan 2008, many projects were started with the aim of connecting the rural areas with electricity. We can say that the improvement seen on the transmission network after the reforms was due to the increased funding for the distribution and transmission projects by development agencies under the energy sector recovery project. These funds were aimed at enhancing the transmission and distribution system, losses and improving the quality of supply in 2006, the commissioning of a concessionary loan from the government of Kenya of about Us $ 20 million to finance construction of a 132 Kv, 115 km line between Kamburu and Meru, a 61 km 132 Kv transmission line between Chemosit
and Kisii in 2005 and the 70 km 33kv line from Malindi, the three other 33kv lines Musaga- Simbembe, Nakuru- Elburgon and Lanet- Nyaburu which were completed in 2008, tells it all.

4.7: Energy Losses

Energy losses consist of technical and non-technical losses. Technical losses mainly occur due to inherent characteristics of the generation, transmission and distribution systems in the process of transmission, transformation and distribution activities, some amount of energy is consumed by the conductors used as part of network system. Non-technical losses are also known as commercial losses. They may result from meter tampering and poor billing methods and also pilferage of power that is caused by unauthorized users. Due to unreliable data for non-technical losses we computed T&D Losses simply by getting the difference between the total power available for sale and the power reported to be sold in Kenya power sector and then used this data to analyze the critical changes for the last 20 years.

Figure 4.24: Change Point Analysis of Trend on Power T&D Losses in Kenya, 1993-2013

![Change Point Analysis of Trend on Power T&D Losses in Kenya, 1993-2013](image-url)
Table 4.24: Results of Change-Point Analysis on Power T&D Losses in Kenya

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
</table>

Source: Annexure-2

The trend assessment of T&D Losses during the period 1993-2013 through the ‘Change-Point Analysis’ shows that in the last 20 years, Kenya Power Sector has experienced three major critical change points in T&D Losses in 1999, 2005 and 2008 as shown in Table 4.24. However, only one critical change-point 1999 shows a change point estimate which is statistically significant above 95 percent. The other two critical change-points 2005 and 2008 show critical change-points with confidence level <95%, though the change in 2005 shows a higher confidence level of 93% as compared to 92% in 2008.

The graphical presentation in Figure 4.24 shows that the T&D Losses in Kenya were in an increasing trend from 1995 to 1999 when the first major critical change point was detected. The increase is associated with lack of investments in electricity infrastructure as the sector was performing financially poor. There were no funds to facilitate repairs and replace the worn out transmission and distribution lines. This led to the restructuring of the sector in 1997. The first critical change-point happened almost immediately when the reforms had been introduced in the Kenya power sector 1997.

Before reforms and restructuring there was a target of reducing the T&D Losses to a level of 13.5 percent by the year 2002 (World Bank, (1997), but instead the losses had increased by 20.42 percent. One of the reasons for the reforms was to deal with this issue of T&D Losses. The sector was facing high technical and non-technical losses which made the company lose a significant amount of power. There
was also the issue of drought which caused the water level to decline in the hydro-based power plants.

From 2001, the trend of electricity T&D Losses in Kenya declined continuously till 2005 when the second major critical change point is indicated and there was a further decline till 2008 when the third major critical change point was detected. In 2005 and 2008, critical changes happened when Kenya Power and Lighting Company had set a reduction target of 14.5 percent. With efforts to bring down the losses, the company had taken many steps such as: the signing of management contract with Manitoba Hydro International (MHI) following a competitive bidding process for provision of management services for a period of two years. MHI was required to achieve defined stringent performance targets within the two years, including reduction of system losses by 4 percent over two years, reduction of electricity supply outages from 11,000 to 3000 per month and the improvement of operational efficiency (KPLC Annual Report, 2005).

The launching of prepaid metering project in 2009 has given customers convenience, flexibility and control of their electricity use while it has improved revenue management for the company. By the year 2012, a total of 164,117 customer premises had been installed with prepaid meters compared to 118,698 in the previous year. The company aimed at installing 500,000 meters by 2013 and has targets to complete the programme for the existing customers by 2015; this will help to improve the T&D Losses. Realizing that the target had not been achieved after putting all these efforts Kenya Power and Lighting Company again decided to revise the 2005 target of 14.5 percent in 2013.

The T&D Losses are not satisfactory as per the international standards of 10 percent. They are even higher than 15 percent which many developing economies have maintained. They seem to have even shown an upward trend after the reforms and restructuring process. Then, it seems that the cause of T&D Losses in Kenya is not only the issue of cent percent metering. In practical terms, it does not help to bring down the losses as expected to. This could be because of a numbers of challenges such as:

- Poor functioning of meters
- Meter tempering by consumers
• Improper meter reading
• Involvement of staff in power theft case

4.8: Employee Productivity in Kenya Power Sector

Employee Productivity may be defined as the output per worker in a given period of time. It is concerned with the amount of output that is obtained from each employee. Employee productivity is an important factor in determining the productive potential or efficiency of the company particularly the company where production is labor intensive. On examining employee productivity at the distribution end the number of customers served is commonly used as a measure of performance efficiency indicator. The internationally accepted standards is about 168 customers per employee we used the following formula

\[
\text{Employee Productivity} = \frac{\text{Total Number of Customers}}{\text{Total Number of Employees}} \times 100
\]

This was meant to enable us analyze the trend changes this important indicator has undergone for the last 20 years. It will also show how efficient Kenya Power and Lighting Company have been in serving its customers. Figure 4.25 represents the change point analysis of trend in labor productivity in Kenya power sector as from 1993-2013.

**Figure 4.25: Change Point Analysis of Trend on Employee Productivity in Kenya Power Sector, 1993-2013**
Table 4.25: Results of Change-Point Analysis on Employee Productivity in Kenya Power Sector

<table>
<thead>
<tr>
<th>Period</th>
<th>Confidence Interval</th>
<th>Conf. Level</th>
<th>From</th>
<th>To</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>(2003, 2004)</td>
<td>99%</td>
<td>66.73</td>
<td>122.5</td>
<td>1</td>
</tr>
<tr>
<td>2009</td>
<td>(2009, 2009)</td>
<td>96%</td>
<td>122.5</td>
<td>193.3</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Annexure-2

The assessment of the ‘change-point analysis’ trend line plot and estimates of critical change-points for employee productivity during 1993-2013, in Figure 4.25 and Table 4.25, indicates that Kenya power sector experienced three major critical change-points, (1998, 2003-2004, 2009) during the past two decades. All the three change-points are statistically significant at a confidence level >95%.

However, the long-term trend in Kenya power sector revealed a greater change in 2004 with greater confidence levels of 99%. The graphical presentation of trend line in Figure 4.25 shows that, the rate of increase in trend on employee productivity for the last 20 years has been high more especially after 2004. We can also say that the number of customers increased due to the rural electrification programme master plan where 200,000 households were to be connected annually.

The increase in trend for employee productivity in Kenya is because of a number of reasons such as the increase in the number of projects through the Electricity Recovery Projects which started in 2004, the enactment of the Energy Regulatory Commission in 2006 which required staff, and the establishment of Rural Electricity Authority 2007 which employed a large staff. The company took advantage to enhance economic activities at the counties to expand its business which required skills. We can conclude that, employee productivity in Kenya power sector has improved and is above the internationally recommended standard of 168 customers per employee.
The findings of this study foster that the long-term operational performance trend of electricity supply industry in Kenya in terms of the seven indicators brings out a few major changes. ‘Change-Point analysis’ for installed capacity, generation capacity, PLF, per capita electricity consumption, consumption pattern, transmission and distribution network, transmission and distribution losses and labor productivity reveal a few critical changes over the 20 years of study. All the critical changes were caused by change in socio-economic, climatic conditions and structural policy reforms. The policy changes that occurred in the period 2000-2003 mainly were caused by drought in the country which affected all the sectors of the economy. Electricity supply industry was hit more during these periods as there was declines in generation of electricity more especially from the hydro- based sources as indicated in Figure 4.5 for generation from hydro power sources.

The country was forced to import power and also use emergency generators which pushed the cost of power to increase as consumption of power from all categories of consumers had declined. This kind of challenges triggered phase two reforms as we may call them in 2003-2004 to try and tackle the problem of power shortage in Kenya. However, the critical change-points observed in post-reforms period 2003-2013 majorly are attributed to government efforts for economic development and power sector reforms more especially those that emerged from the suggestions made in Sessional Paper No.4, 2004, Energy Act No. 12, 2006 and the Rural Electrification Authority 2007.

All the changes that happened in post-reform period 2003-2013 indicate certain improvements in all the indicators analyzed. Overall, the operational performance of electricity supply industry in Kenya has seen some improvement. We can conclude that the reforms which started in 1997 were either half baked or they took time to reflect the impact on the sector. The intentions to restructure Kenya electricity sector in 1997 were to attract private investments to participate in capacity addition, to reduce T&D Losses as the company was performing financially poor prior reforms. But till 2003 hardly a number of Independent Power Producers (IPPs) had invested in the sector even after the Electricity Regulatory Board had called for the biddings. The T&D Losses did not come down either. The cost of power remained high. The main reasons were because the government was following weak macro-economic and structural policies which were forced by the World Bank.