A STUDY OF HOUSEHOLD ELECTRICITY DEMAND AND CONSUMPTION PATTERNS IN NAIROBI

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DECLARATION

A. Student's Declaration

I confirm that this project report is my work and has never been submitted before for examination purposes or any other purpose.

MAGAMBO, Cyprian Kiremu

Signature .....

Date ..7th..September..2010

B. Supervisors' Declaration

I confirm that the above student carried out the research under my supervision for the entire period of the research project.

Dr. Alex A. Aganda

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Date Sept 08, 2010

Prof. Felix M. Luti

Signature .....

Date September 08, 2010

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NOTATION

Units

%	Percent
A	Ampere
GWh	Gigawatt-hour
h	hour
kV	Kilovolt
kVA	Kilovolt-ampere
kW	Kilowatt
kWh	kilowatt-hour
m	metre
m/s	metre per second
MVA	Megavolt-Ampere
MW	Megawatt
°C	Degrees Celsius
V	Volt
W	Watt

Abbreviations

CFL	Compact Fluorescent Lamp
DSM	Demand Side Management
DVD	Digital Video Disk
ERC	Energy Regulatory Commission
Fig	Figure
GDP	Gross Domestic Product
GoK	Government of Kenya
HH	Household
ICT	Information Communication Technology
IEC	International Electro-Technical Commission

KEDSPHS	Kenya Energy Demand, Supply and Policy Strategy for Households, Small Scale Industries and Service Establishments Survey
KenGen	Kenya Electricity Generating Company Ltd
KIHBS	Kenya Integrated Household Budget Survey
KPLC	Kenya Power and Lighting Company Ltd
KS	Kenya Standard
KSh	Kenya Shilling
LCPDP	Least Cost Power Development Plan
MoE	Ministry of Energy
No. , no.	number
R&D	Research and Development
RH	Relative Humidity
Video	Video Cassette Player/Recorder

ABSTRACT

The study set out to generate baseline data and information through the analysis of secondary data available from Kenya Power and Lighting Company Ltd (KPLC) for domestic consumers of electricity in a Nairobi residential estate and contrasting the same with the corresponding weather and economic data gathered from Kenya's Meteorological Department and the Ministry of Planning respectively. Through interviews, household ownership of electrical appliances and end-use patterns were also evaluated. The current model for forecasting domestic energy demand for power planning purposes was interrogated.

It was established that weather (temperature, wind speed and relative humidity) and Gross Domestic Product (GDP) per Capita had insignificant influence on domestic energy consumption and trends. The energy consumption in the short to medium terms is fairly constant save for the month of July, the coolest month in Kenya, when the demand increases by about 13%. The average annual electricity consumption per household in the urban middle income class estate was 2501 kWh. The average monthly energy consumption per household was 208 kWh. The average annual household power demand is 285W and the maximum demand is 3.6kW. The load factor is 7.9%, much lower than the interconnected system load factor of 69.9%.

There is a very high (over 80%) ownership and usage of refrigerators, TV, HiFi music systems, videos and cloth Irons. There is also a very high ownership of electric cookers (79%) and water heaters (geysers and instant showers) (68%).
The other appliances with good penetration are computers (58%) and electric Kettles (42%). The other finding is that the penetration of energy efficient Compact Fluorescent Lamps (CFL) is 47% while that of incandescent lamps is 54%. Households that use incandescent lamps have a lighting load of 651 W

while those using CFL have an installed lighting load of 192W, which is 3.3 times lower.

GDP, temperature, relative humidity and the interconnected system load factor are among the variables used in forecasting the household power and energy demand. These variables have been shown to have insignificant influence on short to medium term electricity demand. Therefore, the econometric model currently in use for forecasting short to medium term energy demand for the domestic consumer category needs to be reviewed. The end-use method is recommended for further investigation.

CHAPTER ONE

INTRODUCTION

1.1 Background and Purpose of the Study

Power consumption and demand patterns contribute greatly to the planning of power supply systems by governments and electricity utilities. Governments utilize this information to develop models for forecasting future power demand and electrical energy consumption. The demand forecasts are then used to plan and schedule the development of power generation projects. Electricity utilities use the same information to plan their systems and network expansions and more importantly for plant dispatch planning for optimum and efficient system operation.

The importance of accurate forecasts of future power demand and electrical energy consumption patterns need not be over emphasized. A low forecast will lead to an inadequate power system expansion resulting in an in-adequate capacity to meet the demand. This would result in load shedding or the use of the costly peaking power plants for long periods because it takes a long time and huge capital resources to develop power plants. On the other hand, a high forecast will lead to development of a huge power system that would be under-utilized leading to high electricity tariffs. Both low and high demand forecasts have adverse effects on the economy. It is therefore important that the demand forecast be as accurate as is reasonably possible.

Kenya has current plans to connect 1 million new consumers by year 2012 and to increase electricity access to 40% of the population from the current 15% by year 2020 [1]. Most of these connections will be domestic and will be in urban and peri-urban areas. Currently, local power planning engineers use their own knowledge and engineering experience to estimate domestic power demand, load factor, expected annual energy consumption and expected

revenue from new connections. In assessing power demand, and based on the author's experience, the planning engineers use the number and nameplate ratings of the appliances provided by the applicant in the application form and apply a diversity factor based on their own experience. The accuracy of these predictions is not clear.

No detailed and elaborate research has been found that determines electricity consumption and demand patterns for urban households in Kenya. The KEDSPHS [5] electricity consumption study used electricity consumption data based on a single month's electricity bill. Using a single month's bill to estimate annual consumption introduces errors because it fails to take into account billing period (number of days consumption billed), meter reading errors, estimated bills, the weather, availability and reliability. A one month bill is not therefore representative. The energy data and information captured in KIHBS [6] provides very basic information on electricity usage for lighting and cooking in urban areas. However, the data and information gathered is rudimentary and grossly inadequate for power planning purposes.

The practice adopted by the utility for estimating demand and projecting revenue is not based on any empirical evidence applicable to Kenya. The correctness of the assumptions made and the accuracy of their predictions are not clear.

Whereas the model developed for estimating demand over 20 years ago [10] may generally be valid, it is highly unlikely that the load factor for domestic loads would be the same as that of commercial and industrial loads. A more accurate domestic demand forecast would use the annual load factor of domestic consumers.

The two studies [5, 6] carried out in Kenya that touched on household electricity consumption left significant baseline data and information gaps that need to be filled. The assumptions and practices in household demand

assessments at the local utility are not backed up with any empirical evidence applicable to Kenya. A fundamental assumption in the use of the national system annual load factor in the forecasting of domestic load is questionable.

It is therefore difficult to determine accurately the power demand, load factor, monthly consumption and consumption patterns. This significant knowledge gap needs to be filled to improve on power generation, transmission and distribution and dispatch planning that depend heavily on accurate forecast of future power demand and electrical energy consumption patterns.

It is against this background that this study on electrical energy demand and consumption patterns was undertaken to gain a better understanding of urban domestic electricity consumers and generate baseline data and information to guide in policy formulation and in the planning of power generation, transmission and distribution systems and also to provide a basis for development of new policies to encourage energy transition from traditional fuels to electricity.

Accurate power development planning (generation, transmission and distribution) in the country is critical for the country's development. Power demand, consumption and consumption patterns are critical inputs into the demand forecasting models that are used to predict future requirements. The future requirements are then used to prepare the power development and systems expansion plans. The accuracy of the forecasting model depends on the accuracy of the underlying data and assumptions. It is therefore paramount that these be as accurate as is reasonably possible. The results of the study are therefore of immediate application:-

- The GoK, ERC and KPLC would use the results to validate or improve on the accuracy of power planning models.
- The KenGen and KPLC would use the results to more accurately forecast energy consumption and resultant revenue from new domestic

connections in urban areas. This would greatly help them in planning their systems expansion, reinforcements and operational needs.

- The ERC would utilize the findings to understand the load profile and end-uses of electricity at household level. This can contribute greatly towards the development of improved domestic tariff policies and structures.
- The ERC can utilize the findings to develop demand model for domestic electricity consumption in urban areas.
- The GoK, KPLC and ERC can use the results to estimate the magnitude of energy substitution opportunities for households as an energy conservation and demand side management measure for the domestic consumer category.
- Both KPLC and KenGen can use the results to estimate demand patterns for households and improve on dispatch scheduling of machines.

1.2 Objectives

Main objective

The main objective of the study was to establish the electrical energy consumption and trends for a typical urban estate in Nairobi.

Specific Objectives

The specific objectives were:

i) To determine the household electrical energy consumption and approximate the demand and load factor.

ii) To establish the time series trends and patterns for electrical energy consumption

iii) To determine the effect of wind, temperature, humidity and GDP on electrical energy consumption

iv) To obtain the types, penetration levels and usage patterns of household electrical appliances.

1.3 Hypotheses

This study was a first small step towards filling the baseline data and information gaps identified, putting to test some of the assumptions used in power system planning and stimulating further academic and applied research in the energy sector.

The following hypotheses were developed for the study:

i) The annual electricity consumption by the households in middle income class in urban areas is much more than 931 kWh/year reported in KEDSPHS.

ii) The monthly electricity consumption in urban areas is fairly constant with no significant variations.

iii) The load factor of domestic electricity customers is much less than the load factor of the interconnected system.

iv) The demand for electricity in urban areas is almost price inelastic.

v) Weather has no significant influence on household electricity demand in Urban Kenya

vi) GDP growth has no influence on household electricity consumption in urban households.

CHAPTER TWO

LITERATURE REVIEW

2.1 Electricity Demand and Consumption Patterns

Household electricity demand and consumption patterns depend on economic, demographic, geographic and social factors. The variables that have major influence are household income, electricity price, weather, ownership and usage of electrical appliances, end-use technologies, household size, available alternatives and related costs, availability, adequacy and government policies.

Many studies have been carried out in different parts of the world to establish causal relationships between electricity demand, consumption patterns and the independent variables. In a study of household energy consumption patterns and demand in urban Ethiopia, Gamtessa [2] established that electricity is a substitute for other forms of energy and that its adoption and usage increases with increase in household income and decreases with increase in prices of electricity and substitute fuels. Furthermore, the consumption increases with household size. Houri and Ibrahim-Korfali [3] in a study of residential energy consumption patterns in urban Lebanon showed that seasons and months have a significant impact on energy consumption. Correlations were also indicated for energy consumption with apartment area, income, and number of residents. McNeil and Letschert [4] in a study of six countries demonstrated that increase in electrical appliance ownership is a major driver for increased electricity consumption in developing countries.

In a report on Kenya's energy demand, supply and policy strategy for households, small scale industries and service establishments (KEDSPHS), the Government of Kenya [5] established that at household level, electricity is

used for lighting by 99% of the households, entertainment (e.g. television, radios) by 90% , ironing of cloths by 69%, refrigeration by 35%, heating water by 26%, domestic cooking by 24%), home businesses by 16% and house heating by 9%. It further established that the national average household per capita consumption is 694 kWh/year with rural areas using 544 kWh/year and urban 844 kWh/year. Higher income urban households consumed the greatest amount of electricity (1,352 kWh/year) and the low income least (606 kWh). The middle income class in urban areas consumed 931 kWh/year.

The 2005/6 Kenya Integrated Household Budget Survey (KIHBS) [6] established that 51% of urban households use electricity for lighting but only 1.8% use it for cooking. Instead 85% of the urban households use paraffin, charcoal and gas for cooking. In rural areas, 3.9% use electricity for lighting but only 0.2% use it for cooking. One would expect that those households using electricity for lighting should also use it for cooking but this is not the case. Whereas the study did not establish the factors contributing to these usage patterns, urban areas have high electricity access, the household incomes are higher and they can afford alternative fuels.

Even though basic energy information was gathered under KIHBS, the overarching goal of KIHBS was to collect a wide spectrum of socio-economic indicators required to measure, monitor, and analyze the progress made in improving living standards in a single, integrated household survey. These surveys are therefore used to measure and monitor monetary and non-monetary welfare of households including income, expenditure, health, nutrition, employment, education, transport, water, sanitation, and energy services. These surveys are therefore multi-topic and multi-level and the survey data is used to model economic behavior in order to design better policies or choose between alternative public investments. The energy data and information captured in KIHBS relates to energy sources and costs for various end-uses. Whereas all major energy sources were included only two end-uses, cooking and lighting were covered. Where as such data and

information can provide some information on energy sources, use patterns and costs, it is grossly inadequate to inform energy policies and investments.

The KEDSPHS electricity consumption study was aimed at establishing connectivity, end-use patterns, quantities and costs. However the data gathered on consumption was based on a single month's electricity bill, based on the electricity part of the questionnaire. Secondly, the study was carried out in year 2001 when the country was experiencing serious power shortages due to a prolonged drought resulting in extensive power rationing and load shedding. Several other factors that have great influence on electricity consumption such as number of occupants, ownership and usage of electrical appliances, weather conditions, availability, adequacy and reliability were not considered.

2.2 Policy formulation and Power Planning

Power consumption and demand patterns contribute greatly to the formulation and planning of power supply and consumption policies by governments, sector regulators and electricity utilities. Governments utilize this information to develop models for forecasting future power demand and electrical energy needs and also to develop policies that encourage energy transition from traditional fuels to electricity. The demand forecasts are then used to plan and schedule the development of power generation projects. Electricity utilities use the same information to plan their systems and network expansions and more importantly for plant dispatch planning for optimum and efficient system operation including demand side management. Electricity sector regulators use the data and information to guide them in the formulation of fair electricity tariffs, settlement of disputes and in the development of regulatory policies to encourage development and investment in the sector.

Power planning and policy formulation requires a thorough understanding of economic, demographic, geographic and social dimensions as they relate to its utilization since these factors have great influence on demand,

consumption, consumption patterns. Electricity demand forecasting is the cornerstone of power planning and requires comprehensive knowledge of past and present demand and consumption patterns. Baseline data and information based on the past and present usage of electricity is a fundamental requirement for forecasting demand and consumption patterns.

Electrical demand forecasting is classified into three main categories: short-term, medium-term and long-term and various forecasting methods have been developed over time [7, 8 and 9].

Short term forecasts are aimed at predicting system load over a short time interval of hours, days, weeks or months and cover a time horizon of not more than one year. Short term forecasts are important in operational planning especially plant commitment and economical dispatch. Capacity adequacy and plant availability to meet demand as load varies is the key consideration. Short term forecasts are mostly influenced by geographical locations and weather patterns.

Medium term forecasts cover a time horizon of between 1 to 5 years. Medium term forecasts are required for fuel procurement, plant maintenance scheduling and diversity interchanges for interconnected utilities. Besides weather, medium term forecasts are influenced by economic and demographic variables.

Long term forecasts covering time horizons of between 5 and 25 years are carried out for system expansion and financial analysis. Economic variables have most influence on long term forecasts.

Several methods are used for demand forecasting of electricity. These are broadly classified as time series regression, econometric, end-use and neural networks [8, 9, 14]. Each of these methods has its advantages and disadvantages in terms of accuracy, complexity and suitability.

Time series regression

In time series method, the variable to be predicted is expressed purely as a function of time [14]. If E is taken to represent demand and F is the function, t is the time and C a constant. Then

$$E(t) = F(t) + C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

The time series regression's main advantage is its simplicity. Its main drawback is that it ignores social, economic, demographic, weather, policy and other causal factors that could greatly influence the demand. The cause and effect relationships are not therefore taken into account. Time series regression is suitable for generating short and medium term forecasts.

Econometric Methods

The econometric method combines economic theory with statistical methods to produce a system of equations for forecasting electricity demand [9, 14]. Demand for electricity is expressed as a function of various economic factors. If GDP represents income and Pr, Po, Te, Su and Ov represent price, population, technology, electricity substitute and other variables respectively, then the demand E is given by

$$E = F(GDP, Pr, Po, Te, Su, Ov) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

The main disadvantage of econometric methods is that they require a consistent set of data and information over a reasonably long period of time (over 20 years) and above. This is critically important to establish long-term

relationships between the variables involved. The other disadvantages include the need for use of prescribed values (e.g. growth rates, inflation etc.) that are not accurate and disregard of policy measures and economic shocks that certainly result in change of behavior of the variables being explained.

Econometric methods are suitable for generating long term forecasts.

End-use Methods

This method captures the impact of ownership and energy usage patterns of various electrical appliances and systems [14]. For domestic sector, end-use method focuses on electricity usage for lighting, heating, cooking, ICT, refrigeration etc. The basis of the end-use method is that electricity is required for the service it delivers. For a household the energy demand per household per appliance is given by:

$$e = p \times h \quad \text{..... (2.3)}$$

Where

e = energy demand of an appliance in kWh
h = hours of appliance use
p = power consumption or rating of an appliance in kW.

For the domestic sector the energy demand would be

$$E = N \times S \times P \times H \quad \text{..... (2.4)}$$

Where

E = energy demand of an appliance in kWh
S = penetration level in terms of number of such appliances per household

H = hours of appliance use

P = power consumption or rating of an appliance in kW.

N = Number of households in the sector.

The main advantages of this method is that it takes into account improvements in efficiency of energy use, utilization rates, inter-fuel substitution etc. in the sector as these are captured in the power requirement by an appliance, P. This approach implicitly captures the economic and policy effects. For example growing income would be reflected in the increased number of households getting connected, the increase in penetration level of appliances and eventual increase in demand. A policy effect of a DSM programme such as replacement of incandescent lighting with compact fluorescent lighting would easily be reflected in the reduction in the energy used.

The main disadvantage of this method is that it requires a high level of detail on each of the end-uses. It also does not give regard to the variations in the consumption pattern by consumers as a result of changes occasioned by demographic, socio-economic and cultural factors.

Hybrid Methods

To achieve greater precision in forecasting, it is common to use a combination of econometric and time series methods [14]. This hybrid method has the advantage of establishing causal relationships as in econometric methods along with the dependency relationship from time series approach. Various functional forms such as linear, quadratic, log-linear etc. are used to capture the possible trends that are evident from the data. A trial and error process is used to arrive at the functional form of a model. The model is then tested by making predictions for the last few time periods for which actual data is available.

A hybrid of econometric and end-use method though not common would allow integration of physical and behavioral factors in the forecasts. The econometric relationships would capture the influence of economic and policy factors while the end-use would accommodate new end-uses, alternative fuel mixes and penetration of appliances and technologies.

2.3 Power Planning for the Domestic Sector in Kenya

2.3.1 Household Power Demand and Consumption Assessment

Assessment of household power demand in Kenya is guided by the guidelines published in publications such as Institution of Electrical Engineer's wiring regulations for residential buildings and also in national and international publications and standards such as Kenya Standards (KS) and International Electro-technical Commission (IEC) standards. It is clearly indicated in these publications that the guidelines are general and a professionally qualified and experienced Engineer should be consulted for more accurate demand assessments.

Based on the author's experience, Engineers in Kenya use their engineering knowledge and field experience to estimate domestic power demand, expected annual energy consumption and expected revenue from new connections. In assessing power demand, Engineers use the number and nameplate ratings of the appliances provided by the applicant in the application form and apply an allowance for diversity based on their own experience. A load factor is assumed to calculate the expected annual energy consumption and expected revenue from new connections. Relationships between nameplate rating and actual consumption are not considered.

2.3.2 Forecasting National Domestic Power and Energy Demand

An econometric model [6] developed over 25 years ago is still used by KPLC and the Government in generating domestic forecast in Kenya. Based on this

model, the domestic power demand forecast is based on domestic energy sales forecast provided by the following equation:

$$Sales_t\ (MWh) = 17{,}780.49 \times 1.0414865^{t} \times GDP_{na}^{\ 0.62880} \times Tar^{-0.2} \quad \text{.....(2.5)}$$

Where

$Sales_t$ (MWh) = Projected energy demand for year t

t = Forecast year

DP_{na} = Non-Agricultural Gross Domestic Product

Tar = Moving Average Domestic Tariff

0.62880 = Non-agricultural GDP growth elasticity

0.20 = Domestic sector moving average tariff coefficient of elasticity.

Regression analysis on the historical data is first carried out to determine overall growth trend for the domestic category. In this case an analysis of historical data up to the year 2006/07 was first carried out to determine the constants and coefficients that are used in the above equation.

The power demand (MW) is then worked out by dividing the projected energy sales (MWh) by the annual load factor (LF) of the interconnected system [13], i.e.

$$MW = \frac{MWh}{LF} \quad \text{..... (2.6)}$$

This model is used for the short, medium and long term forecasts.

CHAPTER THREE

METHODOLOGY

In this chapter, the methods and procedures for obtaining participants' co-operation, sampling and data gathering and analysis are described.

3.1 Participants Co-operation

The research involved gathering of existing data on energy consumption in a representative sample of selected urban households. This data is only available from KPLC. To validate KPLC's readings, it was necessary to take measurements of energy consumption over a 6 months period in addition to gathering information on ownership and usage of electrical appliances in the sample households through interviews. This required co-operation from the heads of the sample households.

KPLC's buy-in and support were critical to access existing data on energy consumption and also obtain permission to read KPLC's electricity meters installed at the customer premises for data validation purposes. The Managing Director and the Chief Manager, Corporate Planning, Research and Development were approached and briefed on the study and its objectives. The company had some concerns but it was assured that all project activities would be carried out by the author and that the company will not be exposed to any risk significance. With this assurance, KPLC agreed to participate.

Having obtained the buy-in from KPLC, it was time to seek co-operation from the heads of the sample households. A list of prospective sample households was compiled with the households being identified by their house numbers. Letters to the occupants [Appendix 8] of the sample households introducing the author and explaining the rationale and purpose of the study were

provided by KPLC and the Chairman of the Department of Mechanical and Manufacturing Engineering. Armed with the two letters, each household in the sample was visited. During the visit, the Author introduced himself and explained the purpose of the study to the heads of the households and sought their cooperation. In the event that the head of the household was not present at the time of the visit the letters of introduction were left behind and follow up visits made thereafter. In some cases, it took several visits to persuade the household to participate in the study. Some households flatly refused to participate seeing it as a bother and others wondering how they would benefit from the study. Twenty households were eventually persuaded to participate is the study.

The other important participant was the Department of Meteorological Department, which would provide weather data. Weather data is available for sale provided that a written request explaining the use to be made of the data is made. No much persuasion was therefore necessary.

3.2 Sampling

3.2.1 Selection of a Housing Estate

A typical middle class urban residential household in Nairobi has between 2 and 4 bedrooms, sitting room/dining area, kitchen, toilet, bathroom and store. A servant quarter for at least 1 person is becoming common for properly planned developments these days but was not a standard feature in the past. However, provisions were usually made for such extensions during the planning stage and these extensions eventually get built. The plinth area varies between 140 and 200 square metres. The type of housing is usually of permanent construction (stone/bricks/blocks) and could be a flat/apartment, bungalow or maissonnete. The households have piped water, flush toilets and have electricity connection. The number of occupants varies between 1 and 7 with an average of 4 [6].

Typical electrical appliances owned by most of these households include lamps, entertainment electronics, refrigerators, cookers and water heaters. Households in many planned residential estates in Nairobi would fit the above description of a middle class urban residential household. Households in South C, Golden gate, Woodley, Buruburu, Greenfields, Embakasi and many others fall under this category.

Buruburu Estate is one of the residential estates developed for middle class occupation in the 70's and early 80's. All services and social amenities were planned for and the household structures have remained fairly the same. A few commercial developments have been developed but these are limited to areas reserved for them. The households in Buruburu estate are numbered so it was easy to identify the specific household making sampling and data gathering easier and more accurate. Buruburu estate was developed in 5 phases and Households have varying number of bedrooms, ranging from two to four. The estate has reached its development maturity. The households in the estate are therefore typical of middle class housing estate hence Buruburu Estate was selected as a representative housing estate.

3.2.2 Selection of Households

Buruburu housing estate has about 5000 households. Initially a sample of 100 households was planned. A sample of 25 households was settled upon after it was agreed that the differences between houses was not critical provided that the sample represents the population and more so because of limited resources. In this estate, the houses are similar and so are rents which imply that the household incomes and other demographic parameters would be similar. Since Buruburu estate was developed in 5 phases it was decided that all the five phases of the development would be represented in the sample and each phase would provide 5 households. In each phase, the starting household number was chosen randomly. Thereafter, the*10th*

household was selected until the desired number of 5 households for each phase of the estate was reached. To cater for households that were not willing to participate in the study additional 10 replacement households were selected to substitute them.

During the initial visits, it was discovered that the numbering of households in Phase one was not continuous. It became fairly difficult to identify the houses by their numbers. House designs in this phase were not also uniform. As a result it was decided to exclude phase one households from the study sample. The final sample was selected from households in phase two to five.

Even though some households refused to participate in the study, the majority agreed. Once the household agreed to participate and co-operate, basic household information on location, owner/occupiers name, electrical energy meter details and any other information deemed useful was sought. The sampling exercise ended once the basic information was provided. The households that participated in the study shown in Table 3.1

Table 3.1 Households in the Study Sample

Buruburu Estate	**Household No**					
Phase 2	277	287	297	317		
Phase 3	183	213	223	233	243	
Phase 4	375	385	395	405	415	425
Phase 5	521	531	541	551	571	581

3.3 Data Gathering and Processing.

To obtain energy consumption data for a period of 5 years, i.e. 2004 to 2008, a request was made to KPLC to provide the meter readings of the energy meters installed in the sample households. A meter number is unique in KPLC

database system and all that was required was to provide to KPLC with the meter numbers of the meters installed in respective households. For every household, the following information was sought and provided by KPLC.

- Electricity consumption (kWh)
- An indication of whether consumption was actual or estimated
- Dates of the meter reading.
- Maximum assessed and authorized load in kVA.

The raw data gathered from KPLC was processed to determine its completeness and correct any errors where possible. It was noted that the billing period did not correspond to the number of days in a particular month. This anomaly was corrected by use of linear extrapolation.

The data was also scrutinized for frequency of Zero consumption and estimated consumption for all the households over the study period. Estimated consumption is not necessarily wrong but when over 4 monthly consumptions for a single year is estimated for a household, the data is bound to be grossly misleading. This can be said of Zero consumption. Data for House No. 425 had too many estimated and Zero readings, consequently it was not included in the results and final data analysis. House No. 541 and 405 had separately metered extensions. Even though data for them was captured, it was not representative of the target households and was also excluded from the results. For ease of data analysis, households were each assigned a code number as shown in Table 3.2.

Table 3.2. Households and their corresponding code numbers

Household No.	521	531	541	551	571	581	375	385	395	405	415	183	213	223	233	243	277	287	297	317
Code No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

The primary data gathering was carried out through measurements and face-to-face interviews with the heads of the household. Monthly visits were made to the households to take readings from the KPLC energy meters already installed. The author took the readings in person. One household did not wish to be disturbed and requested to be allowed to take the monthly readings and send the same by short message system using his mobile phone.

Once the meter reading exercise was completed, KPLC was requested to provide their meter readings for the same period. This was used to compute the energy consumption data that was compared with the Author's data over the same period to determine the suitability and validity of KPLC's consumption data. To validate KPLC's previous data, its consumption adjusted to the actual number of days in the month was compared with the actual consumption recorded by the Author over five billing periods i.e. 5 months period.

To facilitate comparison, the two data sets were tabulated, side by side. The difference in percentage between the consumption provided by KPLC and the actual consumption was worked out to determine the margin of error between the data sets.

To gather information on appliance ownership and usage, face-to-face interviews lasting about 30 minutes per household were conducted. To guide the Author, a schedule was prepared in which the information was recorded [Appendix 9]. It was planned to take appliance nameplate ratings but the Author noted reluctance from the interviewees due to the intrusive nature of such an exercise and abandoned it. Standard domestic appliances (TVs, Videos, Lamps, Irons, Cookers etc) do not have major differences in power rating and standard ratings based on experience and a check on a few similar appliances were used. It was difficult to get accurate answers on daily appliance usage duration. The responses to questions relating to appliance usage duration per day or week were too general such as morning before

going to work, weekend only for baking, until we go to sleep etc. As result, appliance usage duration was estimated by the author from discussions on usage during the interviews. The recorded data and information obtained is provided in Table 4.13 and in Appendix 8.

The weather data for the study period was purchased from the Meteorological Department. Data on temperature, relative humidity and wind speed was purchased for JKIA airport, which is close to Buruburu estate. This data in raw form is contained in Appendices 3 and 4.

Further processing of the weather data was necessary to make it suitable for analysis. Monthly temperature data provided by the Meteorological Department contains averaged daily maximum and minimum values for each month. The mean of the two was computed to get the mean temperature for the month. The relative humidity data provided by the Meteorological Department contains averaged values for 6 a.m. and 12 noon for each month. The mean of the two values was computed to obtain the mean relative humidity for the month. The wind speed data provided by the Meteorological Department contains averaged values for midnight, 6 a.m. and 12 noon for each month. The mean of the three values was computed to get the mean wind speed for the month. This summary data was then tabulated and is provided in Chapter 4.

3.4. Data Analysis

The purpose of the analysis was to establish facts and also determine relationships between variables. Energy data for all households was summed up and the averages related to various parameters computed to establish the mean monthly and annual consumption per household. Time series regression was used to establish patterns, trends and causal relationships

between energy consumption and the independent variables such as temperature, humidity, wind speed, GDP etc.

Data analysis was carried out using standard statistical functions found in spreadsheet programs. In this case, Microsoft Excel spreadsheet functions were used.

CHAPTER 4

RESULTS

4.1. Validation of KPLC's Household Energy Consumption Data.

The primary data collected by the Author in person between February and August 2009 was used for validating the secondary data provided by KPLC for the measurements duration. Table 4.1 shows, side by side the two consumption figures.

Table 4.1. Comparison between monthly actual energy consumption measurement in kWh and KPLC's data for 5 months in year 2009.

House No.	1		2		3		4		5		6		7		8		9		10	
	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC
March	202	190	144	163	130	119	177	162	224	217	218	188	50	48	270	266	140	143	217	220
April	197	195	218	161	123	109	156	126	315	238	203	167	63	54	259	216	139	122	156	173
May	181	176	206	220	152	148	173	189	0	194	253	261	53	62	310	332	142	152	224	184
June	127	137	166	179	127	144	145	114	293	254	204	221	37	34	263	236	117	106	217	195
July	143	135	183	171	139	127	172	208	268	249	264	252	43	45	219	194	129	114	242	212

House No.	11		12		13		14		15		16		17		18		19		20	
	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC	Actual	KPLC
March	58	54	279	297	152	151	184	195	146	161	124	138	229	250	62	68	297	316	273	309
April	70	64	303	309	139	176	180	187	192	165	164	156	195	188	54	50	245	212	277	248
May	48	58	199	238	78	68	214	215	204	233	209	224	192	240	10	28	266	347	271	291
June	46	39	171	162	82	74	171	165	173	164	193	197	172	142	0	0	248	205	248	263
July	39	37	183	120	112	124	152	180	175	164	186	163	162	158	47	31	271	266	273	268

With the exception of house Nos. 5 and 18 where there was no observed consumption for one month in each case, hence reading taken to be zero,

KPLC consumption measurements were actually lower in most cases. Since the households were occupied, a faulty
energy Meter could have been the cause of this anomaly.

Table 4.2 is a presentation of the results of error margin analysis between the two consumption figures. The error in percentage represents the deviation of KPLC's data from the measurements.

Table 4.2. Error margin analysis results of validation data. The error in percentage represents the deviation from actual consumption of the KPLC's measurements.

	Month					
Household No.	March	April	May	June	July	Mean monthly error per household
1	-6%	-1%	-2%	8%	-6%	-1%
2	13%	-26%	7%	8%	-7%	-1%
3	-8%	-12%	-2%	13%	-9%	-4%
4	-8%	-19%	9%	-22%	21%	-4%
5	-3%	-24%	-	-13%	-7%	-11%
6	-14%	-18%	3%	8%	-5%	-5%
7	-4%	-15%	17%	-10%	3%	-2%
8	-2%	-16%	7%	-10%	-11%	-6%
9	3%	-13%	7%	-9%	-12%	-5%
10	1%	11%	-18%	-10%	-12%	-6%
11	-6%	-9%	21%	-14%	-6%	-3%
12	7%	2%	20%	-5%	-35%	-2%
13	-1%	27%	-13%	-9%	10%	3%
14	6%	4%	1%	-3%	18%	5%
15	10%	-14%	14%	-5%	-6%	0%
16	11%	-5%	7%	2%	-12%	1%
17	9%	-4%	25%	-17%	-2%	2%
18	10%	-7%	180%	-	-34%	37%
19	7%	-14%	31%	-17%	-2%	1%
20	13%	-11%	8%	6%	-2%	3%
Mean Monthly Error for sample	2%	-8%	17%	-5%	-6%	0%

Figure 4.1 is a graphical presentation of the mean percentage error for each household.

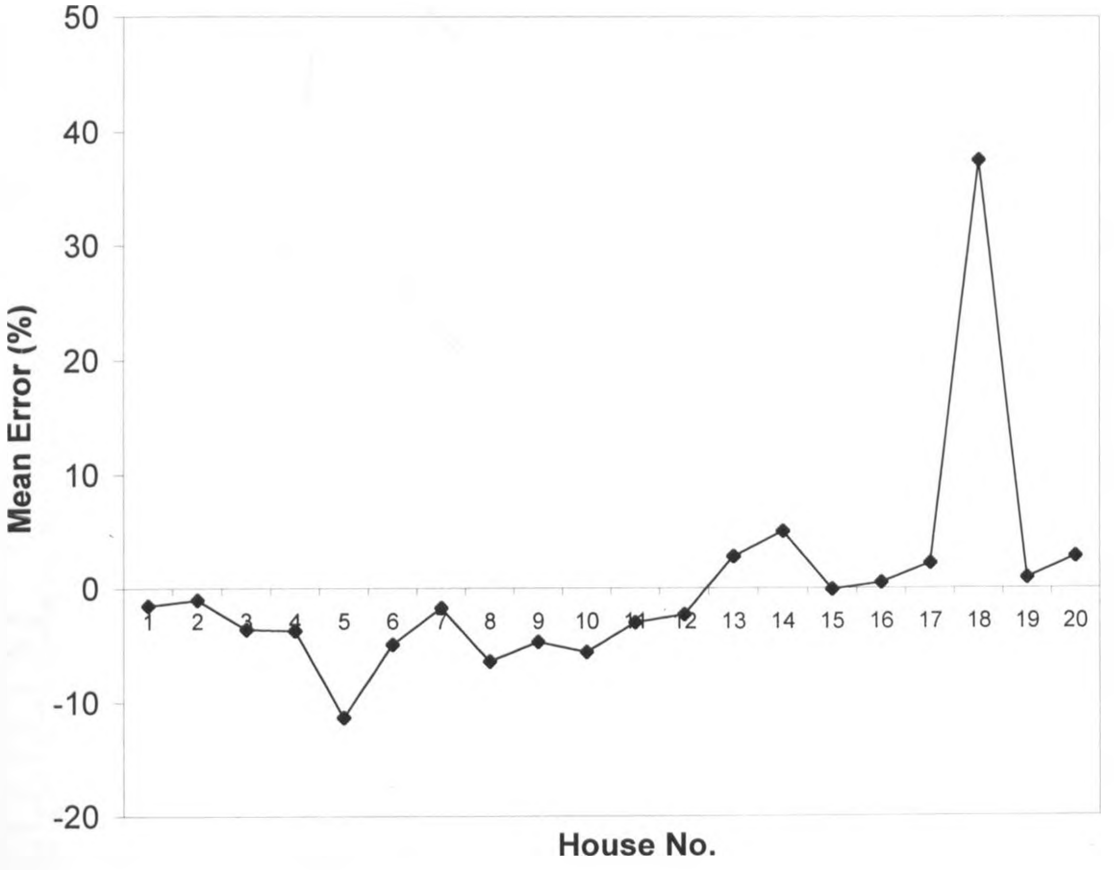


Figure 4.1. Mean percentage error for each Household over the 5 months period.

Even though absolute monthly errors recorded for individual households were sometimes substantial, the average error for the month for the whole sample over the study period is less than 10%. This is also true of the average error for each household over the 5 months period, except for household numbers 5 and 18 where data was distorted by lack of consumption for one month. The mean error for the sample over the duration of measurement is observed to be zero.

KPLC's data was therefore considered accurate enough for the study.

4.2 Energy Consumption Patterns

The authorized power demand and average energy consumption for each household in the sample is presented in Table 4.3. Table 4.4 and 4.5 respectively represent the average monthly and average annual energy consumption per household over the same period.

Table 4.3. Individual Household Mean Monthly Consumption and Authorized Demand

House No	Authorized Demand (kVA)	Avg. Monthly Consumption (kWh)
1	8	277
2	3	314
3	8	154
4	8	154
5	8	443
6	8	187
7	8	63
8	8	324
9	8	142
10	8	221
11	3	175
12	8	216
13	8	128
14	3	239
15	8	170
16	8	170
17	3	310
18	8	52
19	8	274
20	8	156

Based on the above results, the average household after diversity maximum power demand (ADMD) assessed by KPLC is either 3kVA or 8kVA. The average for the sample households is 7kVA but it should be noted that the mode is 8 kVA which is the ADMD for 80% of the households. The energy consumption varies between 63 and kWh/month and 443 kWh/month.

Figure 4.2 shows the households distribution by monthly consumption.

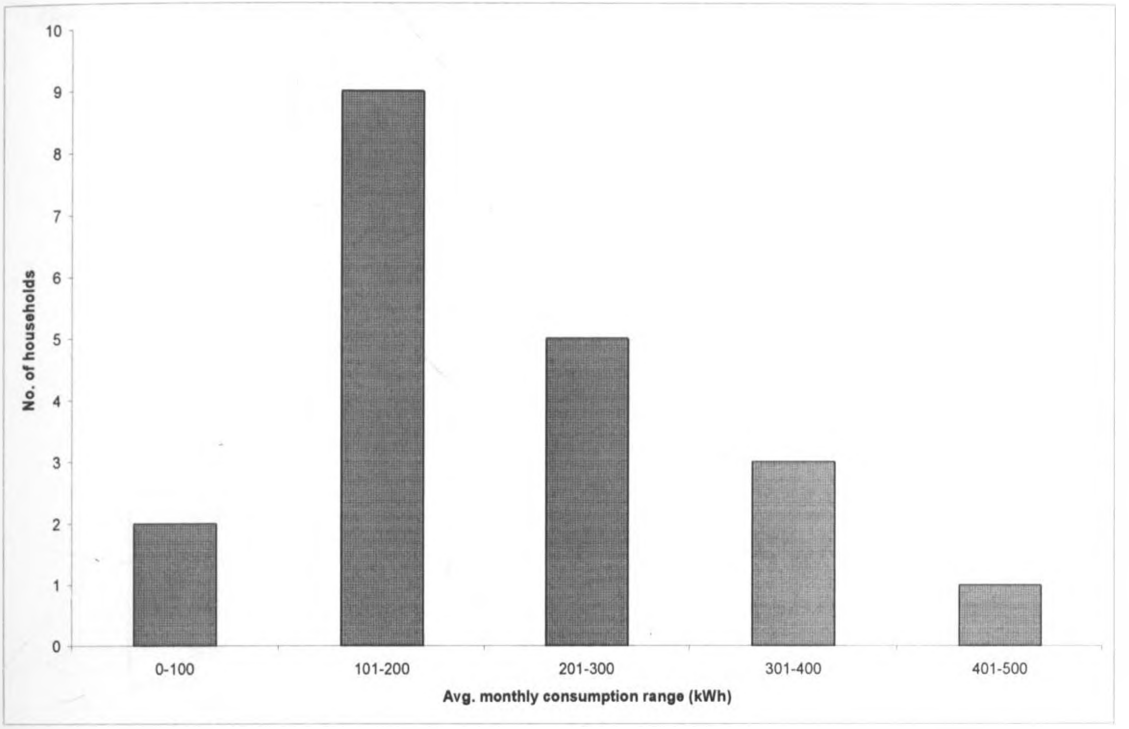


Figure 4.2. Average monthly consumption (kWh) distribution by number of households

The main observation in this case is that the majority of households consume between 100 kWh and 300 kWh per month.

The average monthly energy consumption for all households was calculated. The results are shown in Table 4.4.

Table 4.4. Average monthly household energy consumption in kWh for years 2004 to 2008

Month	Year				
	2004	**2005**	**2006**	**2007**	**2008**
Jan	273	220	178	197	222
Feb	236	210	165	197	219
Mar	201	214	199	202	223
Apr	183	188	175	182	228
May	217	188	192	204	218
Jun	215	184	190	202	223
Jul	242	198	223	241	225
Aug	224	203	235	220	226
Sep	220	211	181	233	218
Oct	186	198	195	237	180
Nov	231	158	178	241	190
Dec	228	214	197	255	175

To illustrate the monthly consumption patterns and to gain an understanding of the differences, if any between the same months in different years, a graphical presentation of the above data was prepared and is shown in Figure 4.3.

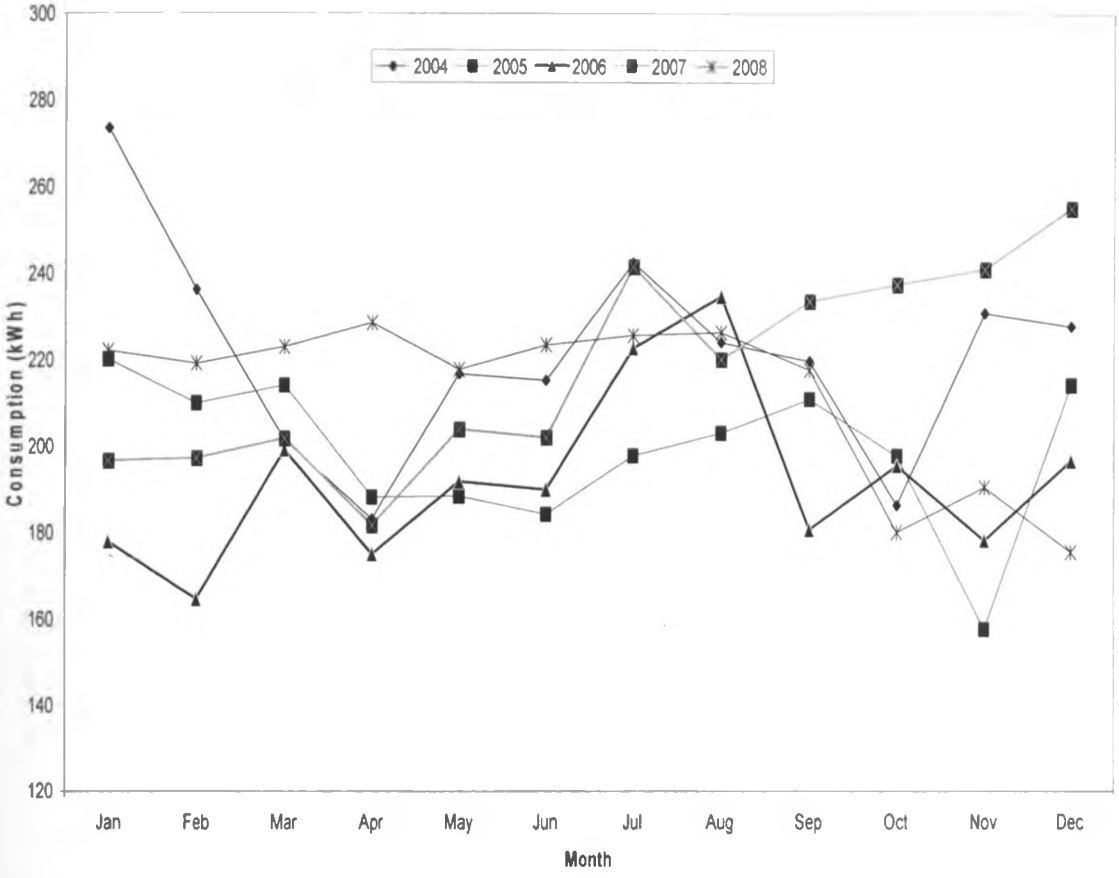


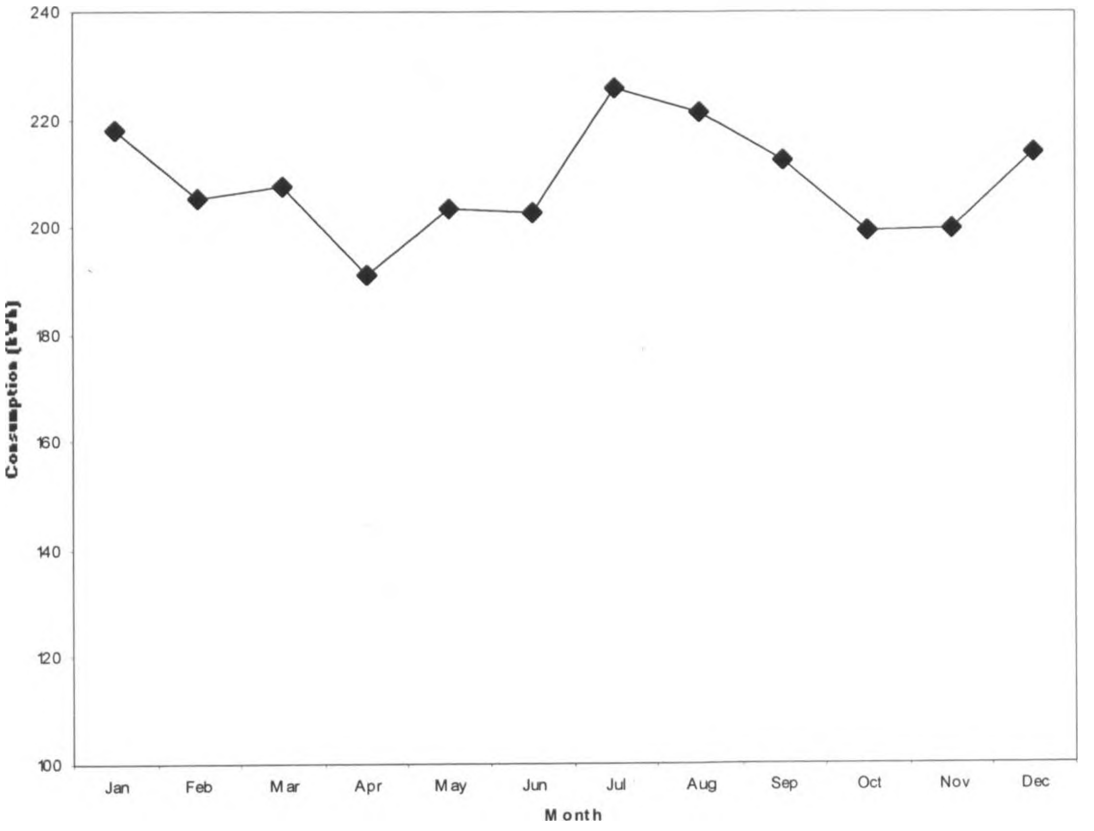
Figure 4.3. Monthly energy consumption patterns for years 2004 to 2008

The average monthly consumption for the 5 year period was calculated for the sample and the results are shown in Table 4.5.

Table 4.5. Average household monthly energy consumption

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumption (kWh)	218	205	208	191	204	203	226	221	212	199	200	214

The monthly patterns and annual trend of the monthly average household consumption is illustrated in Figure 4.4.



4.4. Average household monthly energy consumption pattern.

The mean and standard deviation of the monthly average consumption were calculated and the values obtained were 208 kWh and 10 kWh respectively. The 10 kW standard deviation is equivalent to 5%.

The annual household energy consumption was calculated and the results are shown in Table 4.6.

Table 4.6. Household average annual energy consumption for years 2004 to 2008

Year	2004	2005	2006	2007	2008
Consumption (kWh)	2656	2385	2306	2610	2548

A time series graph was prepared to gain an understanding of annual consumption patterns and trend and the results are shown in figure 4.5.

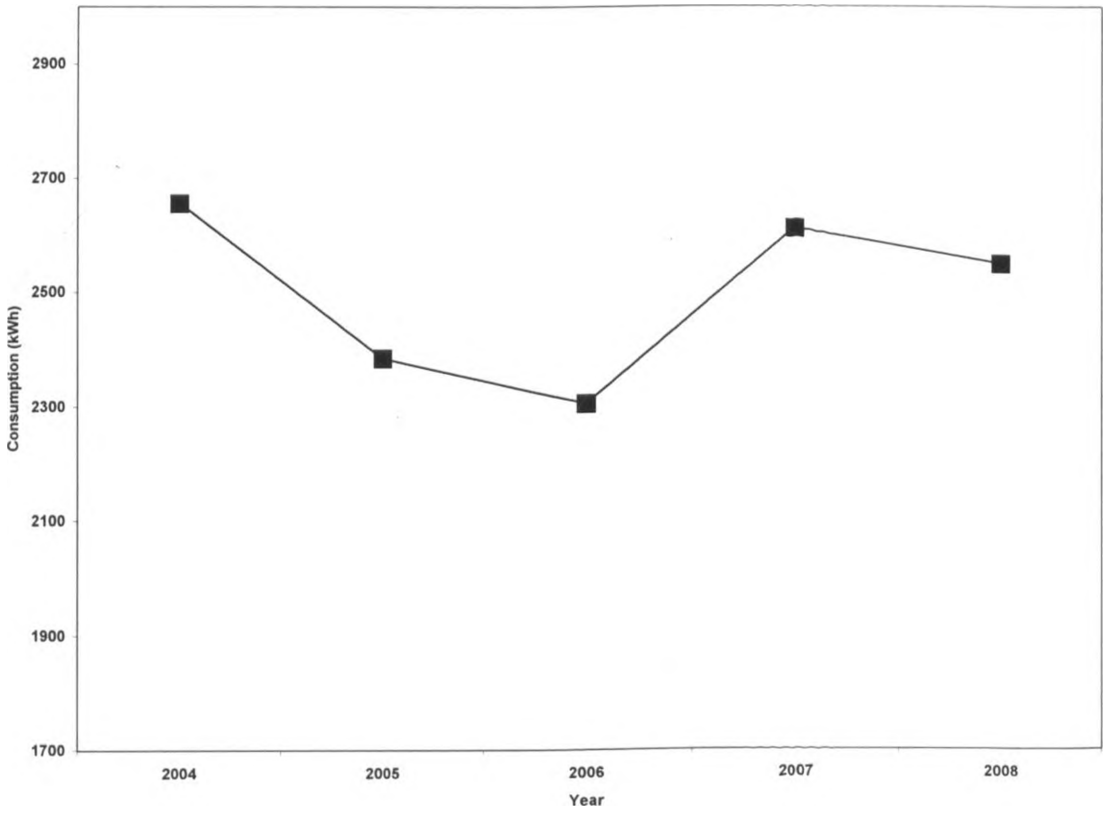


Figure 4.5. Average annual energy consumption pattern over the period 2004 to 2008

The average annual household consumption is 2501 kWh and the standard deviation is 150 kWh equivalent to 6%. The average annual growth between 2004 and 2008 is actually negative 0.6 %.

The major observation here is that the standard deviation is low hence annual consumption is fairly constant.

4.3 Weather Patterns and its Impact on Energy Consumption

The weather patterns in relation to temperature, wind speed and relative humidity were studied and the results are provided below.

Table 4.7 provides the mean monthly temperature for Jomo Kenyatta International Airport (JKIA) – the meteorological station close enough to Buruburu.

Table 4.7. Mean monthly temperature (°C) at JKIA for years 2004 to 2008

Month	Year				
	2004	2005	2006	2007	2008
Jan	21	21	21	20	20
Feb	21	22	22	21	20
Mar	21	22	22	22	21
Apr	21	21	20	21	20
May	20	20	19	7	19
Jun	18	18	18	6	12
Jul	18	17	17	6	11
Aug	18	18	19	7	12
Sep	20	-	19	20	13
Oct	21	-	21	20	13
Nov	20	-	20	20	21
Dec	-	-	20	20	21

A graphical presentation of the data to illustrate the monthly patterns and help to establish if there are any significant temperature differences between the same months in different years is shown in Figure 4.6.

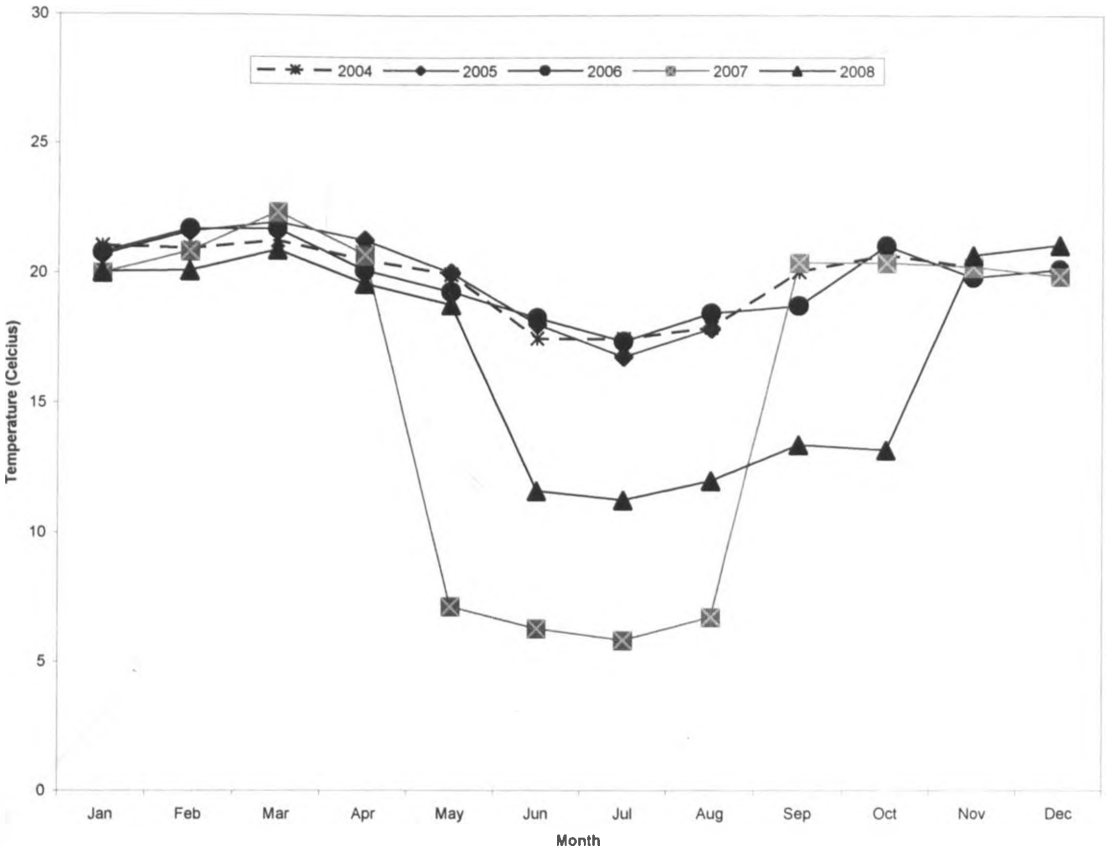


Figure 4.6. Mean monthly temperature patterns at JKIA for years 2004 to 2008

The main observation as regards monthly temperatures is that there is a temperature drop between June and September and this occurs in all the years. Save for the years that the data is missing, the annual temperature pattern is the same for all the years. Furthermore the differences between the temperatures of same the month in different years is small and insignificant. This means then that no significant temperature swings occur between the same months in different years. Consequently the mean for the same month for the 5 year period is a representative value for the monthly temperature. The means were calculated and the same are presented in table 4.8.

Table 4.8. Mean monthly Temperature for years 2004 to 2008

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. monthly Temperature (°C)	17	18	18	17	14	12	14	15	18	19	20	20

Between the months of January and December, the average temperature ranges between 12 °C and 20 °C. The mean temperature is 18 °C and the standard deviation is 3 °C.

If the unavailable data for year 2004 (one month) and 2005 (four months) is ignored the mean monthly temperature is 18 °C and the standard deviation is 3 °C. If the temperature for the missing months in year 2004 and 2005 is assumed to be the average between the monthly temperature for the year preceding the said month and that of the month in the succeeding year and that is applied for the suspect data in year 2007, the mean monthly temperature becomes 19 °C and the standard deviation becomes 2 °C. In this case, the average annual temperature ranges between 16 °C and 20 °C. The mean temperature is 18 °C and the standard deviation is 2 °C.

To find out if there are any relationships between the temperature and energy consumption, the temperature and consumption data were compared. The temperature and corresponding energy consumption data is provided in Table 4.9 and the same contrasted in figure 4.6.

Table 4.9. Monthly mean temperature and corresponding energy consumption

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. monthly Temperature (°C)	17	18	18	17	14	12	14	15	18	19	20	20
Consumption (kWh)	218	205	208	191	204	203	226	221	212	199	200	214

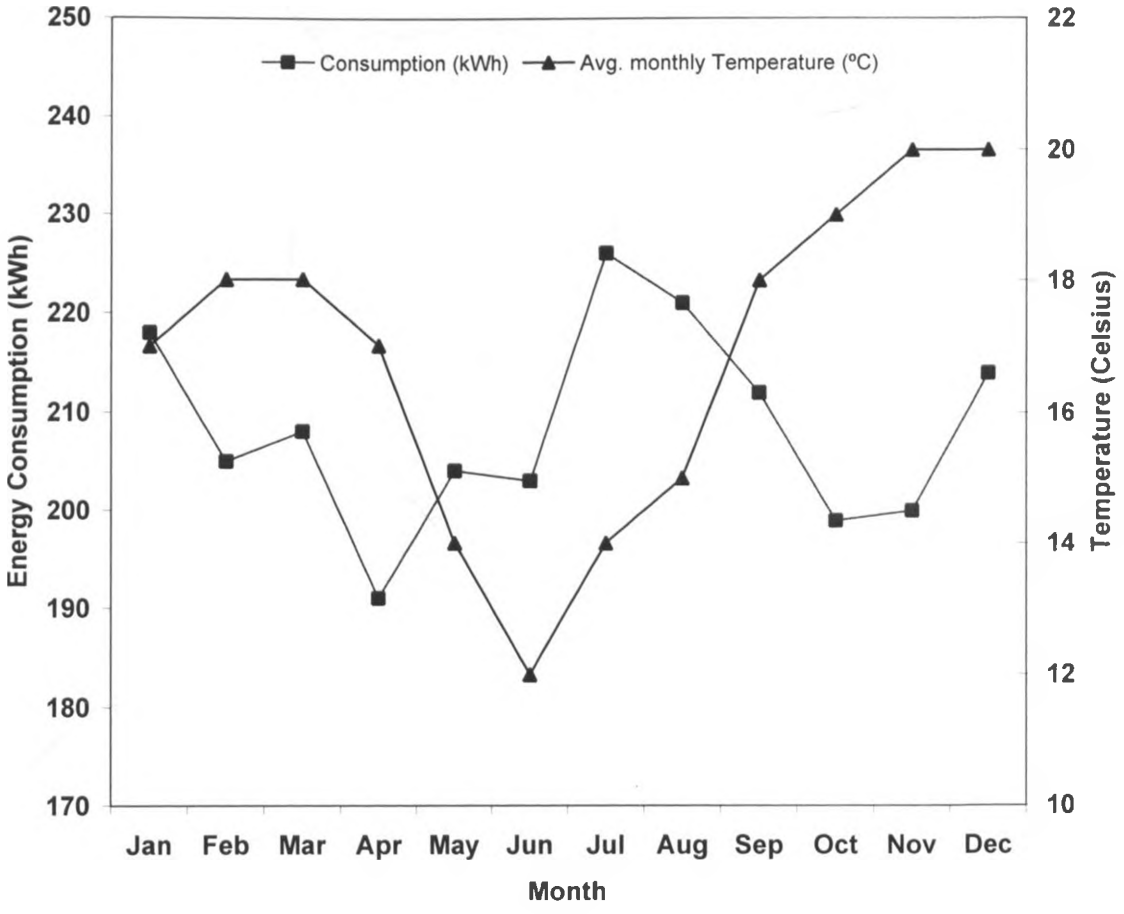


Figure 4.7. Contrast between average monthly temperature and energy consumption patterns.

If the temperature for the missing months in year 2004 and 2005 is assumed to be the average between the monthly temperature for the year preceding the said month and that of the month in the succeeding year and the same is assumed for the suspect data in year 2007, the resultant monthly mean temperature and corresponding energy consumption is as shown in Figure 4.8.

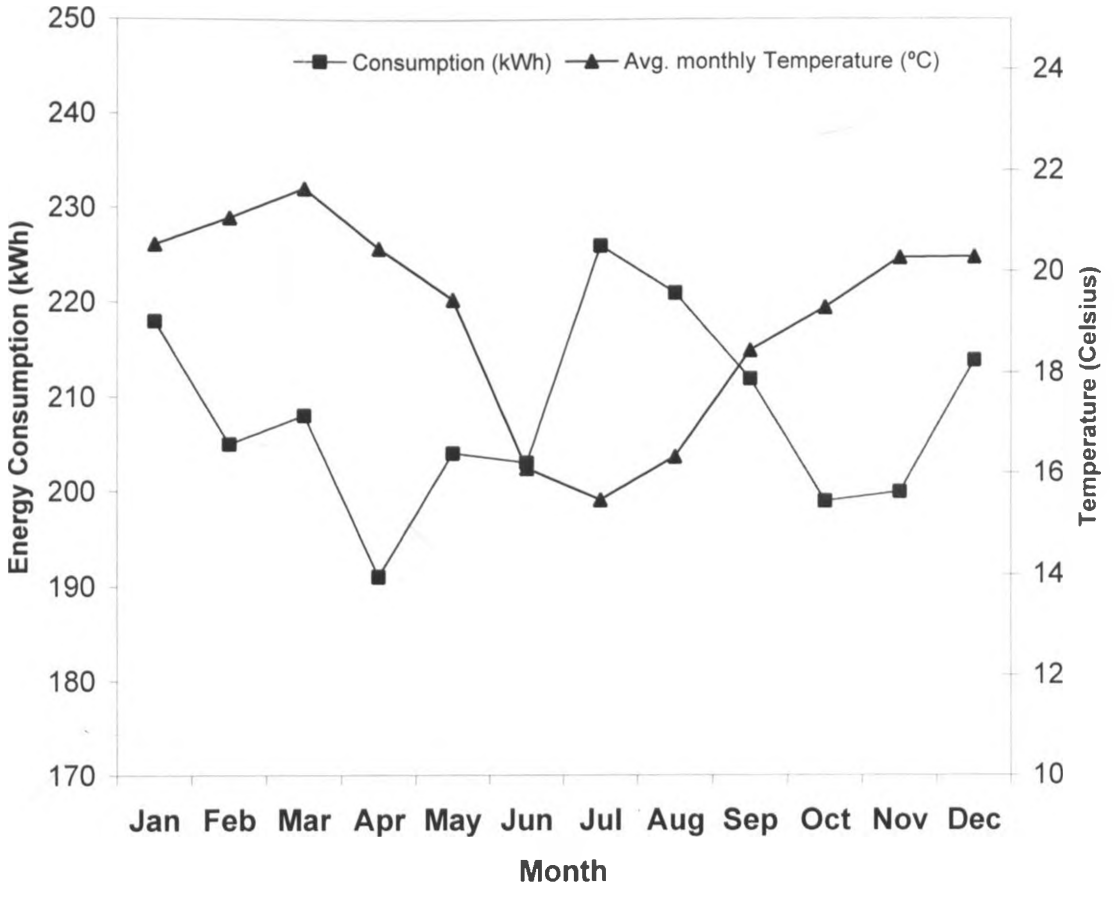


Figure 4.8. Contrast between monthly average temperature and corresponding energy consumption with missing and suspect data replaced with averages from same months in other years.

The major observation here is that there is an inverse relationship between consumption and temperature. Energy consumption increases when temperature falls to values below 18 °C. This is clearly evident between the months of June and September.

Relative Humidity is another weather variable that was investigated. The mean monthly relative humidity (RH) for JKIA for the 5 year period is shown in table 4.10.

Table 4.10. Mean monthly relative humidity for years 2004 to 2008.

Year	2004	2005	2006	2007	2008
Month	RH (%)	RH (%)	RH (%)	RH (%)	RH (%)
Jan	63	53	54	69	59
Feb	62	50	51	57	56
Mar	59	59	62	58	63
Apr	73	62	75	70	69
May	70	74	72	72	66
Jun	65	72	64	67	66
Jul	59	69	67	69	69
Aug	61	67	63	68	64
Sep	56	-	62	59	57
Oct	61	-	53	57	61
Nov	66	-	75	65	67
Dec	-	-	72	60	54

A graphical presentation of the data to illustrate the monthly patterns and help to establish whether there are any significant relative humidity differences between the same months in different years is shown in figure 4.9.

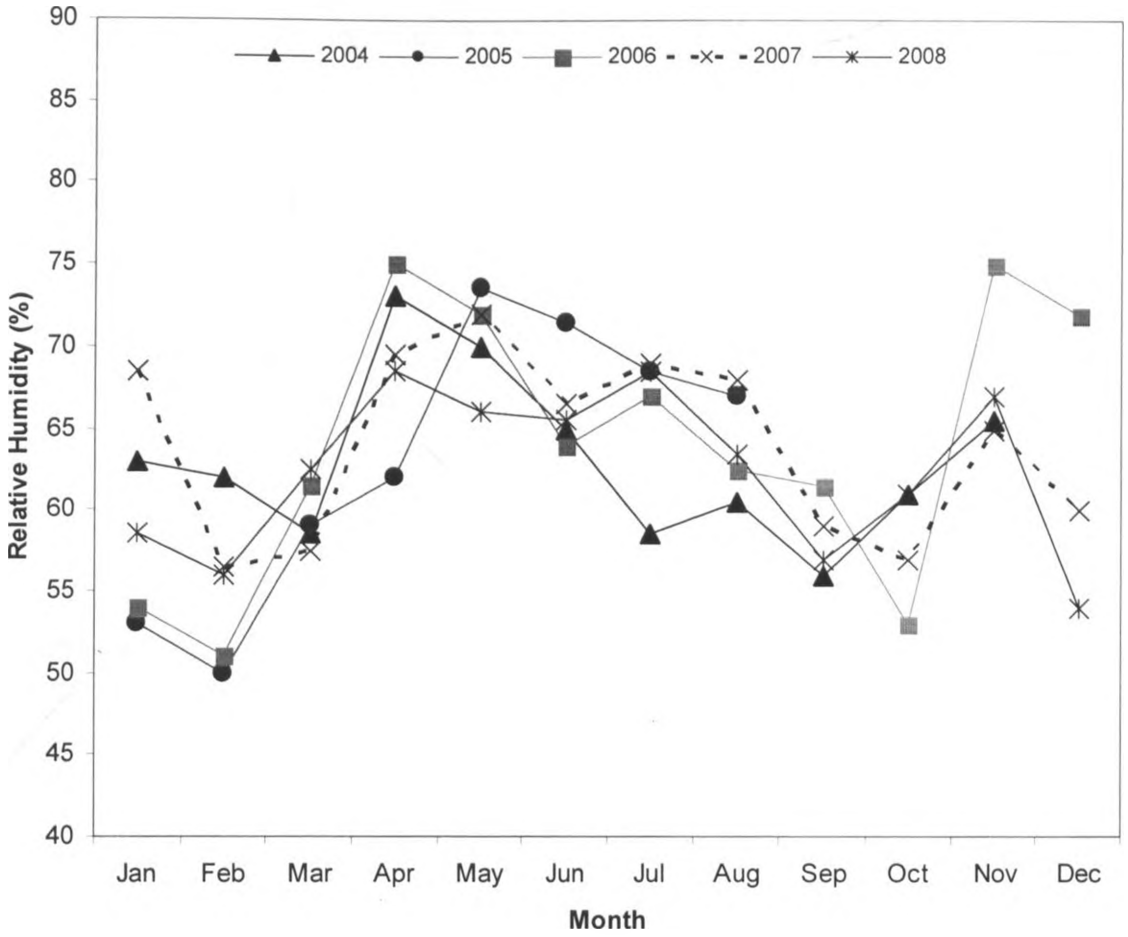


Figure 4.9. Average monthly relative humidity patterns at JKIA for years 2004 to 2008

The important observation is that the relative humidity is high between the months of April and August and also between October and December. This occurs in all the years and is therefore cyclic. Thus the annual pattern is the same for all the years and the differences between the temperatures of same month in different years is small and insignificant. This means then that no significant Relative Humidity swings occur between the same months in different years. Consequently the mean for the same month for the 5 year period is a representative value for the given month.

The average monthly relative humidity ranges between 46 % and 66%. The mean

relative humidity is 58% and the standard deviation is 7%. This is important for air conditioning which is not evident in domestic households in Nairobi.

To find out if there are any relationships between Relative Humidity and energy consumption, the relative humidity and energy consumption data were compared. The results are presented in Figure 4.10.

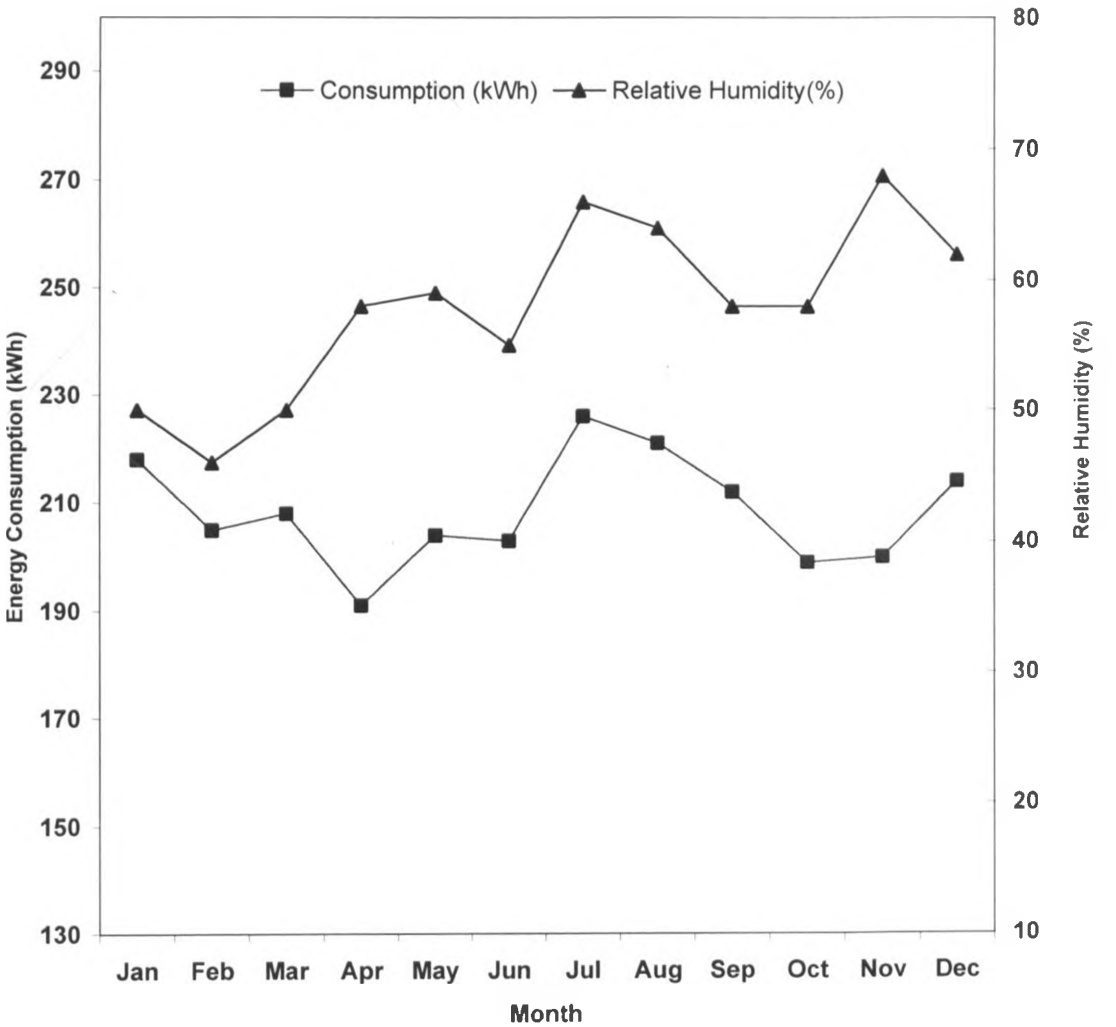


Figure 4.10. Contrast between monthly relative humidity and corresponding energy consumption.

Between February and April there is a general decline in energy consumption as the relative humidity increases. Between April and July, the energy consumption appears to increase with increasing relative humidity. Between

July and October, energy consumption seems to decrease as relative humidity decreases. Hence there is no consistency in the relationship between the two variables. Temperature change is the cause of the changes in energy consumption as illustrated in Figure 4.8. There is therefore no causal relationship between energy consumption and relative humidity.

The other key weather variable that was investigated was wind speed. The wind speed has direct bearing on air velocity in the households hence it was used as a proxy for air velocity. The monthly wind speeds at JKIA taken at 10m height for five years are presented in Figure 4.11.

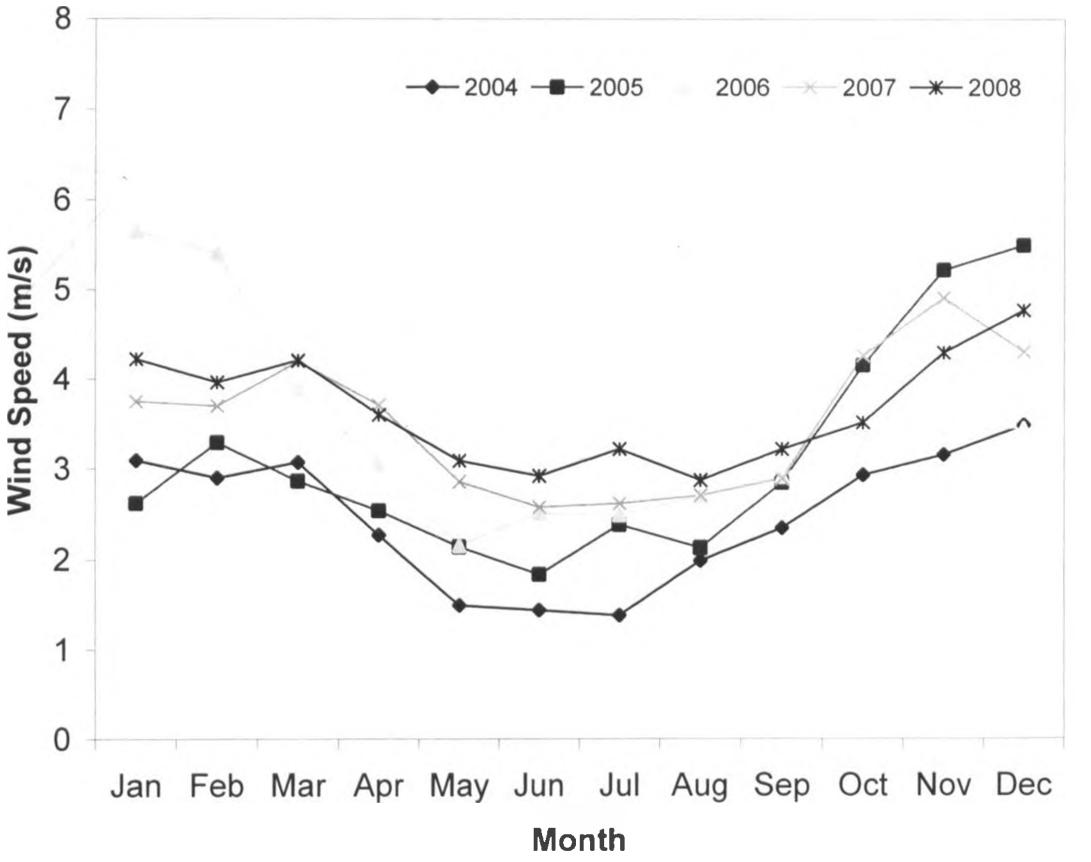


Figure 4.11. Monthly wind speed patterns over years 2004 to 2008.

The main observation is that the wind speed is low between the months of May and September and high between October and March. This occurs in all the years and is therefore cyclic. The annual pattern is the same for all the

years but there are major differences between the wind speeds of same month in different years. For example the wind speeds for January varies between 3m/s and 6 m/s i.e. one year may be double the other year. This means then that there are significant wind speed swings between the same months in different years. Therefore the mean for the same month for the 5 year period gives a general indication of what the speed might be but can not be taken to be a truly representative value for the given month. It was therefore felt that both the monthly and annual averages would be useful in determining whether wind speeds have any impact on energy consumption and were calculated. Table 4.11 shows the average monthly wind speed while table 4.12 shows the mean annual average wind speeds.

Table 4.11. Monthly average wind speeds at JKIA (at 10m height) for 5 years – 2004 to 2008.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed (m/s)	3.9	3.9	3.6	3.0	2.4	2.3	2.4	2.5	2.8	3.7	4.2	4.3

Table 4.12. Annual average wind speeds for JKIA (at 10m height) for years - 2004 to 2008.

Year	2004	2005	2006	2007	2008
Wind Speed (m/s)	2.5	3.1	3.4	3.5	3.7

The average monthly wind speed varies between 2.3 m/s and 4.3 m/s. The mean monthly wind speed is 3.2 m/s and the standard deviation is 0.8 m/s. The average annual wind speed ranges between 2.5 m/s and 3.7 m/s. The mean annual wind speed is 3.2 m/s and the standard deviation is 0.5 m/s.

Wind speed does have an impact on air conditioning and to find out if there are any relationships between wind speed and energy consumption, the wind speeds and energy consumption data were compared. The results of the

monthly average wind speeds and the corresponding energy consumption are presented in Figure 4.12.

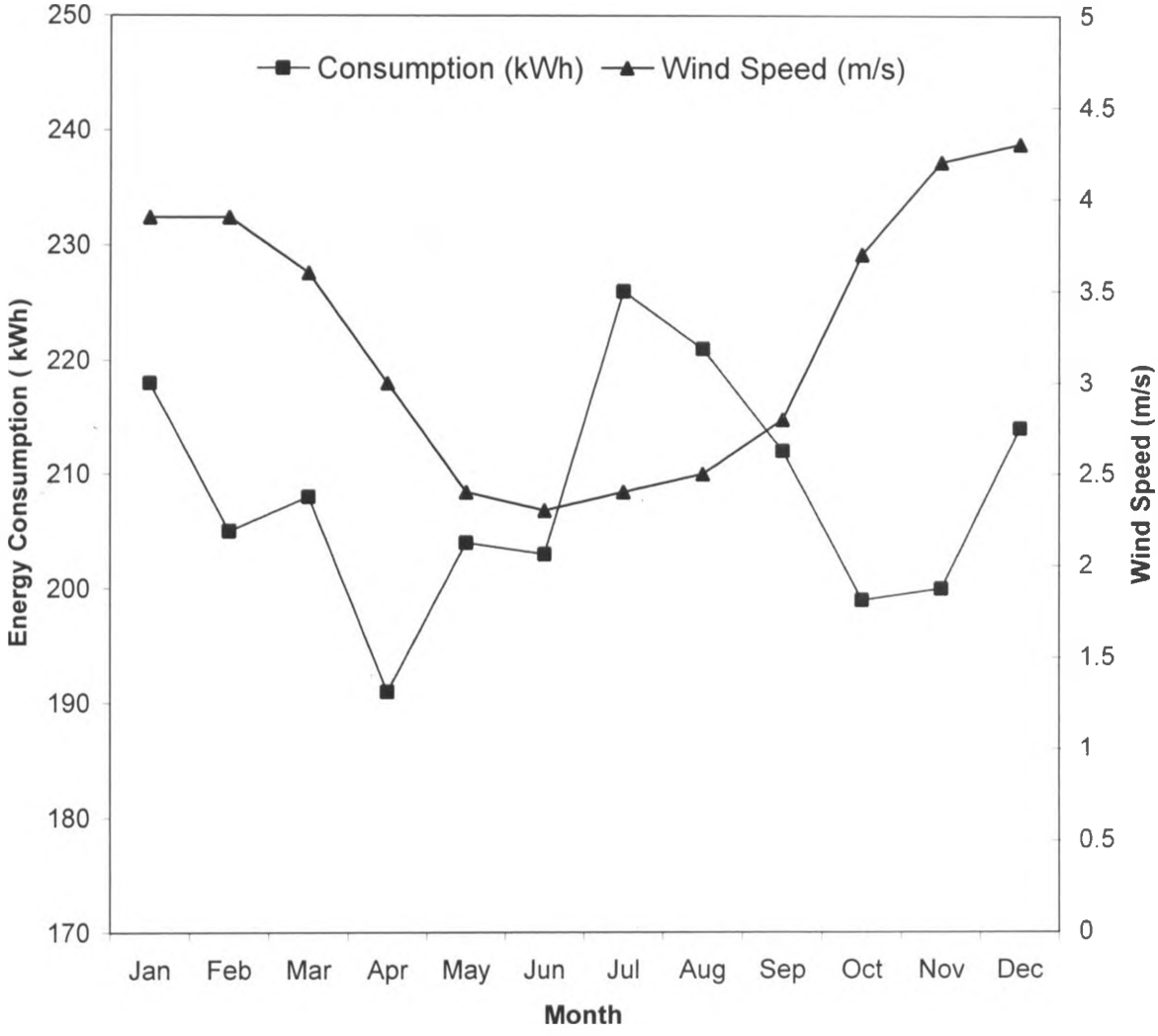


Figure 4.12. Contrast between monthly wind speed and energy consumption patterns

Considering that the average monthly wind speeds vary between years too, the annual average wind speeds and energy consumption data were also compared. The results are presented in Figure 4.13.

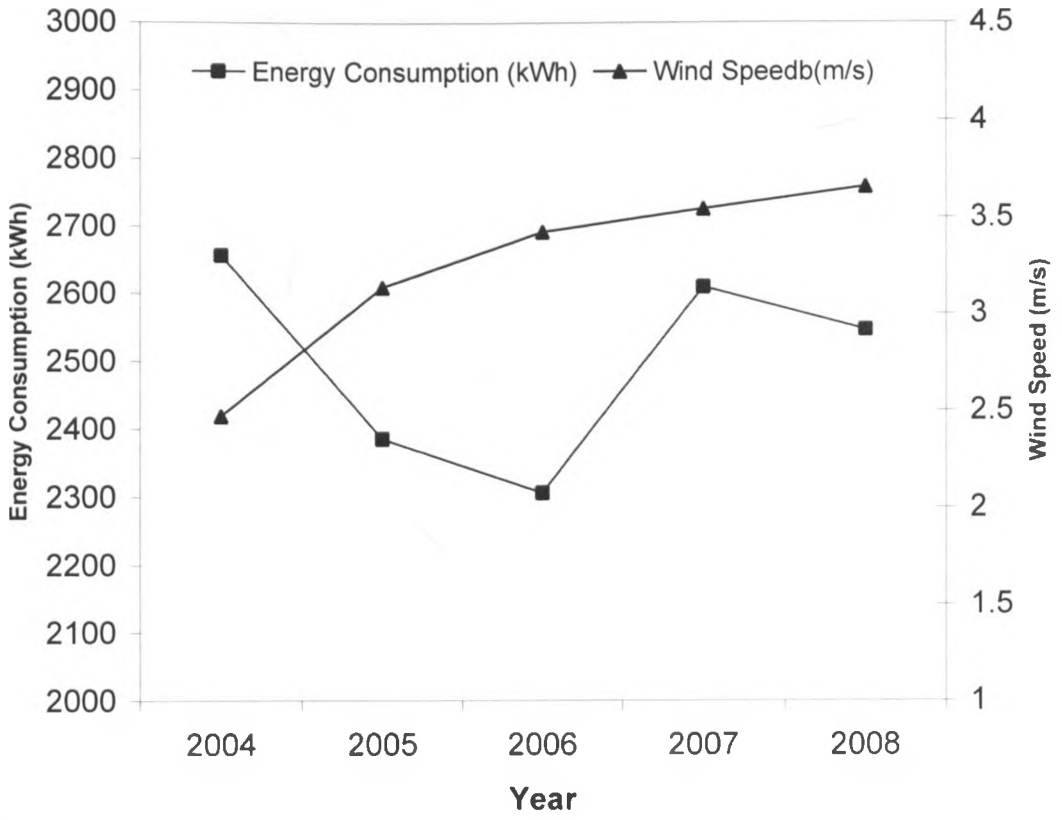


Figure 4.13. Contrast between annual wind speed and corresponding energy consumption

The above results show that there is no causal relationship between energy consumption and either monthly or annual average wind speeds.

4.4 Economic Growth and its Impact on Energy Consumption

GDP is a measure of a country's productivity hence income growth. GDP per Capita data extracted from the Economic Survey 2009 [GoK, 11] was analysed to determine time trend and the result is presented in Figure 4.14.

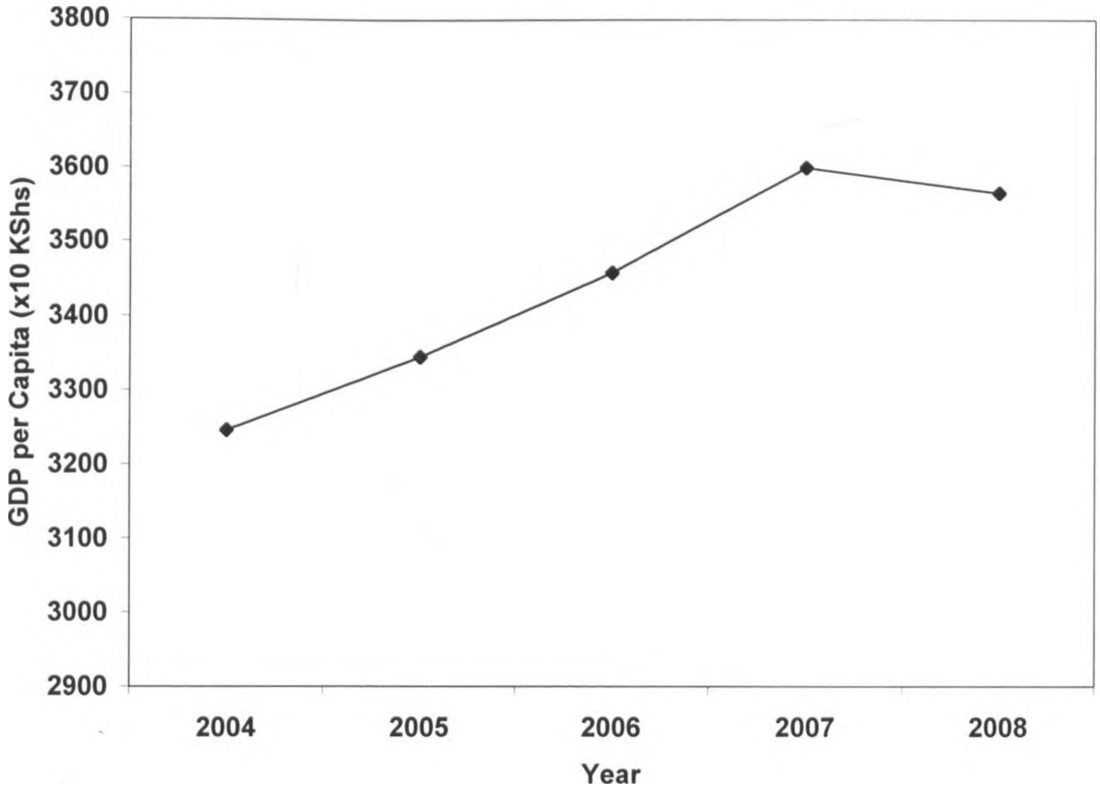


Figure 4.14. GDP per Capita growth trend between year 2004 and 2008.

The graph shows that there was a steady GDP per capita growth between 2004 and 2008 of KShs 896 per annum. This represents an average annual growth of 2.3%.

The annual GDP per Capita and the corresponding energy consumption were compared to determine whether there are causal relationships. The results are presented in Figure 4.15.

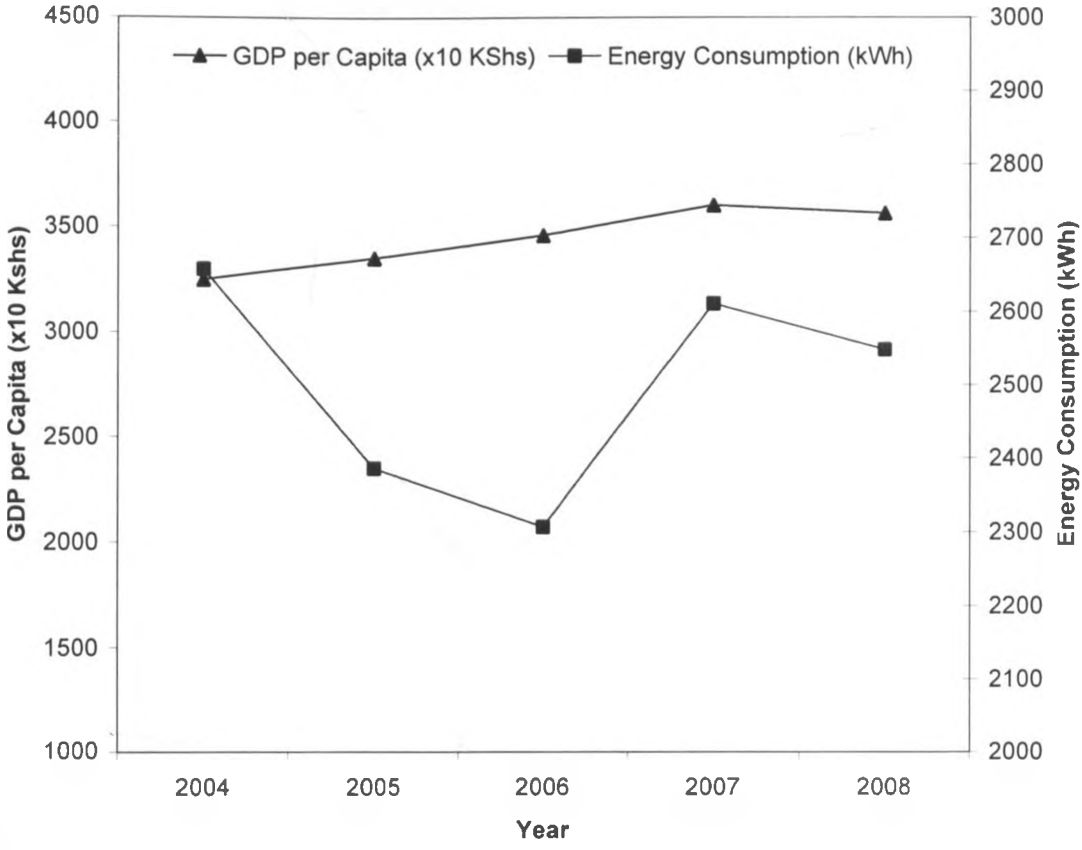


Figure 4.15. Contrast between GDP per Capita and annual energy consumption patterns.

The important observation is that GPD per Capita does not have any significant influence on household annual energy consumption.

4.5 Appliance Ownership and Usage Patterns

The survey was carried out to determine the penetration level and usage patterns of ordinary household electrical appliances and gadgets. This would help to estimate the household power demand and load factor and also provide insight in the understanding of energy consumption patterns.

The results of electrical appliances penetration (ownership) and usage levels by the households are summarized in Table 4.13. The ownership or usage represents the proportion (%) of households among the sample interviewed

that own or use the appliance. When a household owns an appliance which is not in use, then the ownership would be 100% but usage would be 0%. The ownership and usage are equal when an appliance is also being used.

Table 4.13. Household appliance ownership and usage, installed loads, active loads, power rating and daily usage duration.

Appliance Description	Ownership (%)	Usage (%)	Quantity / Household	Load Rating (W)	Daily Usage (hrs/day)
Lights - Incandescent Lamps	53	53	12	651	4
Lights - CFL Lamps	47	47	11	192	4
Refrigerator	95	95	1	200	8
TV	90	90	1	100	6
Video/DVD Player	84	79	1	15	6
HiFi Music System	79	68	1	10	6
Iron Box	95	95	1	1000	0.5
Cooker	79	11	1	3000	0.25
Water Heater (Geyser/Instant)	68	21	1	3000	1
Kettle	42	42	1	1000	0.5
PC desktop	58	53	1	200	1
PC Laptop	58	42	1	50	1
Hair Drier	26	21	1	1000	0.15
Booster Pump	16	16	1	400	0.25
Microwave	16	16	1	1000	0.25
Shaver	16	16	1	10	0.25
Fan – Cooling	11	5	1	100	0.75
Electric Room Heater (coil)	26	0	1	1000	0

The results show that ownership of an appliance does not necessary result in its usage. This is especially the case for electric cookers and water heaters where despite the high ownership the usage is very low. The room heater with an ownership rate of 26% has zero usage. Use of nameplate data therefore may not reflect the energy consumption. The other point of significance is the duration of usage of the appliances which is low for energy intensive appliances.

When asked what they used for cooking and water heating, the greater majority reported using Gas and Paraffin. Use of Charcoal was limited but the actual percentage was not determined.

The results were used to estimate the maximum power demand based on installed or owned appliances, the maximum power demand based on active load (appliances that are actually used in the household) and the estimated annual energy consumption based on the estimated average daily duration of use. Based on these, the household load factor was computed. The results are summarized in Table 4.14.

Table 4.14. Household power demand and annual energy consumption based on end-use method

Maximum Demand per Household (kW) based on appliance ownership	7.4
Maximum Demand (kW) per Household based on appliance usage active load	3.6
Estimated Annual Energy Consumption (kWh) per Household per annum based on active load and usage duration	2018
Load Factor	6.3%

To compare these results with the actual data obtained, the average annual power demand (P_{avg}) for a household was computed by dividing the average annual energy consumption obtained from this study by 8760, the number of hours in one year. -

$$Pavg = \frac{2501}{8760} \times 1000 = 286 \text{ W} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

This was then used to calculate the load factor. Using Maximum Demand (kW) per Household based on appliance ownership, the load factor (LF_{ao}):-

$$LFao = \frac{286}{7.4 \times 1000} \times 100 = 3.9\% \quad \text{..... (4.2)}$$

Using Maximum Demand (kW) per Household based on appliance usage, the load factor (LF_{au}) was calculated:-

$$LFau = \frac{286}{3.6 \times 1000} \times 100 = 7.9\% \quad \text{..... (4.3)}$$

A major observation from the above calculations is that a load factor based on end-use approach (6.3%) is much closer to the actual (7.9 %) compared with the installed load as per appliance ownership (3.9 %).

A comparison was made between the average household after diversity maximum power demand (ADMD) assessed by KPLC based on applying a diversity factor on the total load based on installed appliance ratings and appliance ownership and usage levels. For households, the power demand by KPLC is either 3kVA or 8kVA. The average for the sample households was 7kVA but it should be noted that the mode is 8 kVA which is the ADMD for 80% of the households. These results show that the demand assessed by KPLC is almost the same as that assessed by the Author based on appliance ownership. They both however result in low and unrealistic load factors for domestic sector. The appliance usage approach seems to be a better method.

A KPLC annual report [12] shows that the annual average system load factor varied between 69.4% and 71.5% between 2004 and 2008. The average load factor was 69.9%. This is close to nine times more than the actual load factor for domestic loads.

CHAPTER FIVE

DISCUSSIONS

5.1 Electricity Demand and Consumption Patterns.

The aim of this study was to establish household electricity consumption patterns in a Nairobi urban estate and in the process help to fill significant baseline data and information gaps that were identified from known studies touching on this subject. To do this an investigation of weather variables that can influence the energy consumption patterns, namely temperature, wind speed and relative humidity were carried out. GDP per Capita growth which also could have an impact on consumption was also evaluated. The end-use patterns were investigated through face-to-face interviews with the sample households. A time series analysis of electricity consumption of a sample of 20 households taken from a middle income class was carried out. The results of these have been presented in Chapter 4. In this section, an attempt is made to interpret the observed household electricity demand and consumption patterns.

To start with, the exercise to validate the data provided by KPLC established (Table 4.2) that the margin of error is below 10%. The KPLC data was therefore considered accurate for the study.

Several studies [2, 3, 4, 7, 9] have established that economic, demographic, geographic and social factors have a major impact on energy demand, consumption patterns. In this study, some of these variables namely weather, GDP per capita, ownership and usage of electrical appliances and availability and usage of alternative fuels and their impact on energy consumption patterns were evaluated.

5.1.1 Temperature, Relative Humidity and Wind Speed

One of the hypotheses put forward for testing was that weather has no significant influence on household electricity demand in Nairobi. Three weather elements namely temperature, humidity and wind speeds were studied.

Where as there was missing data for year 2004 (one month) and 2005 (4 months) and suspect data for 2007 (4 months), based on the consistent data available for the rest of the period, the temperature can vary between 12 °C and 20 °C between January and December. Temperature data from May to August, 2007 was inaccurate and therefore was not used. No peculiar weather phenomena occurred in Nairobi during the said period and in any case it should have been reflected in relative humidity data which is not the case. There is however a general decline in temperature between the months of June and August for all the years (Table 4.7 and Figure 4.6). Table 4.9 and Figure 4.7 illustrate the relationship between temperature and energy consumption.

Clearly then, there is an inverse relationship between average monthly energy consumption and temperature but it only becomes pronounced when there is a significant temperature drop as happens between June and September. Energy consumption increases significantly when temperature falls below 18 °C. This is supported by the fact that 68% of the households own water heaters in the form of instant showers and geysers and that 21% of the households indicated that they use them.

The consumption is highest in July when the temperature is lowest and the consumption declines and stabilizes for the rest of the year. However, the increase in consumption between June and September is 4.4%, which is not substantial.

Considering that this increase is small and that the monthly consumption has a standard deviation of 10 kWh it would be correct to conclude that temperature has no significant impact on energy consumption.

The other weather variable that was investigated was relative humidity which is an important parameter for human comfort. Figure 4.9 shows that there are variations in average monthly relative humidity and it ranges between 46 % and 66%. As was observed from Figure 4.10, there is no apparent causal relationship between energy consumption and Relative humidity. Indeed a look at the months of February to June shows that a variation in relative humidity between 46% and 59% does not affect the energy consumption at all. The high consumption in July and August when Relative humidity is high may suggest a relationship but this is discounted by the October to December energy consumption figures. Indeed, November has the highest relative humidity but the energy consumption during the month is lower than most of the months of the year.

The most desirable relative humidity for human comfort lies between 30 and 70% [15] which is the case for Nairobi through out the year. The other factors that would influence comfort are temperature and air velocity but even with these, the relative humidity has to be kept within these limits. To do this requires household ventilation and air-conditioning equipment such as fans, air-conditioners and humidifiers and de-humidifiers. The survey on household appliance ownership and usage shows that there are no air conditioners installed in the sample households and that the penetration of ventilation fans is 11% while usage is at 5%. The mean relative humidity is 58% and the standard deviation is 7%. Clearly relative humidity has minimal influence on the energy consumption. Indeed the weather condition in Nairobi is good for human comfort.

The last evaluated weather variable was the average wind speed. Air velocity is important for maintaining uniform temperature in an environment to

maintain human comfort. Wind speed measured at JKIA was used as a proxy for average air velocity for the estate. In an air-conditioned zone, the air velocity should not exceed 0.2m/s. The average monthly wind speed ranges between 2.3 m/s and 4.3 m/s. It should however be noted that the wind speeds given here are for outdoor air rather than indoor air. The indoor air velocity would therefore be much lower.

The monthly and annual energy consumption and wind speed are compared in tables 4.11 and 4.12 and contrasted in Figures 4.12 and 4.13. Because of the considerable variations in average monthly wind speeds between the same months of different years, the annual average wind speeds and the corresponding energy consumption provide a clearer picture of the relationship between the two parameters. Between 2004 and 2006, the energy consumption was declining while the wind speed was increasing. As the wind speed continued to increase marginally thereafter, there was first a relatively steep rise in energy consumption in year 2007 and a decline in 2008. This clearly shows that there is no causal relationship between the wind speeds and energy consumption. This is also supported by the results of the survey on household appliance ownership and usage that shows that there are no air conditioners installed in the sample households and that the penetration of ventilation fans is 11% while usage is at 5%.

5.1.2 Gross Domestic Product

Economic variables that affect household energy consumption include household income, electricity price and Government policies. No review of electricity tariffs was carried out between 2003 and July 2008. The only variables that were contributing to price changes were the fuel cost and foreign exchange adjustments. These two are pass-through costs and would be reflected in household electricity bills. The fuel cost adjustment depends on the amount of electricity generated from petroleum fired thermal power plants and the price of petroleum fuels. In a wet year, the hydro power component of

the energy generated is high and the thermal component is low, hence the fuel cost adjustment is low and vice versa. When the international prices of crude oil are high, the fuel cost adjustment goes up and vice versa. The foreign exchange adjustment is meant to shield the Government against foreign exchange losses caused by fluctuations in Shilling exchange rate against the hard currencies while servicing foreign debts incurred in the development of the power system infrastructure. The foreign exchange cost is therefore influenced by the amount of foreign debt that is due for payment, exchange rate movements and Government's foreign exchange management policy. The foreign exchange and fuel cost adjustments vary from month to month and may be positive or negative. In the recent past however, fuel cost adjustment has been increasing due to a prolonged drought and increasing use of electricity generated from petroleum fired generators. The fuel and foreign exchange adjustments are so random and inconsistent that they can not be used to evaluate electricity price movements. To study the effect of electricity price on demand, a consistent and policy based electricity tariff review would be necessary. Since no such electricity tariff review was carried out for the duration of the study and the two variables that influence price movement are inconsistent and fluctuate rapidly, monthly to be exact, it was decided to leave the evaluation of the price elasticity on demand out of the study. As regards policy, economic growth has been the main focus that would affect energy consumption. As regards electricity, the policy drive has been more connectivity to increase electricity access to urban and peri-urban populations in addition to rural electrification. A demand side energy management policy can significantly affect energy consumption but none was developed or pronounced during the study period. Consequently, the only variable that could have had an effect on the energy consumption would have been economic growth.

Economic growth should have a significant influence on the medium term energy consumption patterns. The only authoritative and published economic data that is related to household income growth is GDP per Capita. This was

used as a proxy for household income growth. The GDP per Capita for the Years, 2004 to 2008 were obtained from the Economic Survey 2009 [11] and are shown in Figure 4.14. The annual GDP per Capita and the corresponding energy consumption were compared and the results are shown in Figure 4.15. Whereas there was steady GDP per capita growth between 2004 and 2006, the energy consumption was declining. As GDP per Capita continued to grow marginally thereafter, there was first a relatively steep rise in energy consumption in year 2007 and a decline in 2008. Over the study period, there was an average annual growth in GDP per Capita of 2.3% but the average growth rate in energy consumption was negative at -0.6% - well within the margin of error. On average therefore, the energy consumption remained fairly constant. It is possible that a family moves to a more affluent estate if its income increases. In this case, 68% had occupied the premises for 5 years and above and 89.5% had lived in the same premises for 3 years and above. Only 10.5% had occupied the premises for 2 years and below. This discounts the possibility that the families moved to more affluent estates. This clearly shows that there was no causal relationship between medium term GDP per capita growth and energy consumption among the study group.

It would be expected that growth in GDP per capita would result in increased household income that would in turn result in increased energy consumption as the households acquire more electrical appliances. In this case however the energy consumption remained fairly constant. One possible explanation is that the GDP per capita growth, being a reflection of the overall productivity indicator for the economy is not a true measure of the household income growth among the urban middle class. Perhaps there was no household income growth among the group. If this was the case, then there would be no extra funds to invest in additional appliances or more use of electricity that would be reflected in increased consumption. In this case, the consumption would not change. Another possible explanation is that the need for electrical appliances among the study group has reached saturation level since the households have been on electricity supply for a long time. As a result, there

is no need for more electrical appliances other than replacement of old ones. The survey on appliance ownership discounts this argument since ownership of various desirable household equipment such as computers, microwave heaters is still low. The third possible explanation of the lack of increase in energy demand despite the growth in the economy is that the equipment usage patterns have not changed perhaps because substitute fuels for specific household use that are probably cheaper exist. Consequently, electricity is used only where there is no suitable and cheaper alternative fuel. The results of the survey on appliance ownership and usage support this theory.

Despite the high ownership of cookers (79%) and water heaters (68%) among the households, the usage among the households is extremely low at 11% for cooking and 21% for water heating. The ownership of electric room heaters is 26% yet none of these households reported to be using them at all. The survey found out that most households use gas (LPG), kerosene and charcoal for cooking and heating. The survey results corroborates the KIHBS which established that 51% of urban households use electricity for lighting but only 1.8% use it for cooking. Instead 85% of the households use paraffin, charcoal and gas for cooking. The household equipment ownership and usage survey confirms that this is the case even for water and other forms of heating except ironing of clothes which has no suitable and readily available substitute. Since there is no suitable and convenient electricity substitute for lighting, refrigeration, and operating household electronics, then households have really no alternative. The usage patterns of these appliances will not change in the short to medium term as a result of marginally improved economic performance. The case may be different in the long term when incomes have substantially grown and propelled the group into the high income bracket. Then they can afford to acquire more electrical appliances and gadgets and also use electricity for energy intensive applications like cooking and heating. When this happens, the group will however not qualify to be described as middle income, hence the current electricity usage patterns will continue to

apply to the middle income class if all other factors remain unaltered. This theory would satisfactorily support the study findings that economic grown does not alter the annual energy consumption for households and the consumption will therefore remain fairly the same.

The results on monthly average household energy consumption presented in Table 4.4 and illustrated in Figure 4.3 show that the average monthly energy consumption per household is 208 kWh and the standard deviation of 10 kWh. A significant deviation from the monthly consumption pattern was observed in the last quarter of year 2007 during which the consumption peaked at 255 kWh in the month of December. As is seen from figure 4.4, the average monthly consumption tends to increase significantly in July by over 10%. Table 4.6 and Figure 4.5 illustrate the annual consumption and trends over the 5 year period. The annual average consumption per household is 2501 kWh and the standard deviation is 150 kWh. There was a 6.6 % per annum decrease in demand between 2004 and 2006. There was a 13.2 % increase in 2007 before the demand declined by 2.4 % in 2008. Taken together, the average annual change in consumption is -0.6%. This combined with the low 5% standard deviation for monthly energy consumption and 6% standard deviation for annual average energy consumption confirms that household electricity demand and consumption in the short to medium terms is fairly constant.

5.2 Domestic Demand Assessment and Forecasting Model

It was stated earlier that the assumptions and practices in household power demand assessments at the local utility are not backed up with any empirical evidence applicable to Kenya, mainly because no local studies have been carried out to verify them. A fundamental assumption in the use of the national interconnected system annual load factor in the forecasting of domestic load was questioned and an hypothesis advanced that the average annual load

factor of domestic power consumers is much less than that of the interconnected system.

In the forecasting model [13], the projected energy demand (MWh) is divided by the annual load factor (LF) of the interconnected system to obtain the domestic power demand (MW) i.e.

$$MW = \frac{MWh}{LF} \quad \text{..... (5.1)}$$

The results of the household survey to determine the penetration level and usage patterns of ordinary household electrical appliances and gadgets supports the hypothesis that the average annual load factor of domestic power consumers is much less than that of the interconnected system. The domestic consumer's annual average load factor at 7.9 % is over eight times lower than the interconnected system's of 69.9 %.

This study has also shown that GDP has no significant influence on short to medium term domestic electricity consumption.

In view of the above, the econometric model currently in use by MoE and KPLC for forecasting short to medium term energy demand for domestic consumer category does not reflect the consumption pattern.

This study has demonstrated that the end-use method of forecasting demand produces more accurate results. It is suggested that this approach be developed further and be adopted for future domestic consumer category electricity demand forecasts.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study set out to determine the short to medium term electricity demand, energy consumption, consumption patterns of a typical domestic customer in a well planned urban household. The influence of time, weather, GDP, appliance ownership and usage on consumption patterns was investigated. Based on the findings, the current model for forecasting domestic energy demand for power planning purposes was interrogated. The following are the conclusions:

- Two weather parameters, namely air speed and relative humidity have no influence on domestic energy consumption and trends.
- There is an inverse relationship between temperature and energy consumption. Energy consumption increases with reduction in temperature. This becomes significant when the temperature falls below 18° C as often happens in the month of July, the coolest month in Kenya, when the demand increases by about 13 %.
- GDP per Capita has no influence on short to medium term domestic energy consumption and trends.
- The energy consumption in the short to medium terms is fairly constant and the average annual electricity consumption per household 2501 kWh/year.
- The average energy consumption per household is 208 kWh/month.
- The average annual power demand is 286W.
- There is a very high penetration of refrigerators (95 %), TVs (90 %), HiFi music systems (79 %), videos/DVDs (84 %) and cloth Irons (95 %). There is also a high penetration of electric cookers and water heaters (geysers and instant showers) at 79 % and 68 % respectively.

The penetration of computers is 58 % and that of electric kettles is 42 %.

- Energy intensive appliances such as cookers and water heaters have low usage rate despite their high penetration rate.
- The penetration of energy efficient CFL lamps is good at 47 %. 53 % of the households still use incandescent lamps.
- The households that use incandescent lamps have an installed lighting load of 651 W while the ones that use CFL have an installed lighting load of 192W, which is 3.3 times lower. On average each household has 11.5 lamps
- The annual average load factor of domestic electricity consumers is low at 7.9 % compared with the interconnected system load factor of 69.9 %. The load factor for the interconnected system takes into account all the consumer categories including industrial, agricultural and commercial sectors whose power demand and usage patterns differ substantially from the domestic consumers.
- The maximum demand based on appliance penetration is 7.4kW which is almost the same as the KPLC assessed and authorized household demand of 8 kVA for most household. However, the actual demand when usage levels are factored in is only 3.6 kW per household.
- The econometric model for forecasting power and energy demand currently in use by MoE and KPLC does not reflect the energy consumption patterns of domestic household consumers. GDP growth rate, one of the key variables used in the model has no influence on short to medium term household energy consumption. The load factor of the interconnected system, another key variable used in the model, is over eight times higher than the average load factor of domestic consumers.
- The end-use method of forecasting household energy demand produces more accurate results for the household domestic consumer category.

6.2 Recommendations

Several observations were made during the study and the following is recommended:

- A sample comprising a homogeneous middle income class located in a single estate in Nairobi was studied. The results can only apply to a similar estate in Nairobi and they are many. It is unlikely that the penetration and usage levels of equipment like computers, toasters, juice blenders etc. would be the same as the study sample for the other income classes and domestic consumers in urban centres located in rural areas. There is a need for more studies covering estates housing other income groups and urban centres in rural areas.

- Even though the weather in the country has no extremes and there are no major differences in weather for most parts of the country, there are some differences that would affect appliance ownership and usage patterns and hence energy consumption. Studies focusing on urban centres located in areas with different weather conditions are recommended.

- The sample households have been using electricity for many years with 89% having occupied the said premises for three years and above. 68% have occupied the premises for five years and above. One can assume that the demand for domestic electrical appliances have reached saturation levels. Newly connected households take time to acquire electrical appliances and as such, their consumption would probably increase with time until it stabilizes at maturity. Studies focusing on newly connected consumers are recommended.

- The econometric model for forecasting power and energy demand currently in use by Moe and KPLC does not reflect the energy

consumption patterns of domestic household consumers. There is an urgent need for a study to review the model.

- Access to energy consumption data and consumer information at KPLC is not easy. It is recommended that the University and KPLC engage each other with a view to working out modalities for data sharing for energy research purposes.

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APPENDICES

Appendix 1. Monthly Energy Consumption in kWh of individual Households for 5 years.

House No	1	2	3	4	5	6	7	8	9	10
Demand (kVA)	8	3	8	8	8	8	8	8	8	8
Month/year										
Jan04	1203	351	103	103	472	183	32	248	159	161
Feb04	1090	329	92	92	443	189	37	209	119	139
Mar04	361	302	85	85	370	164	34	226	82	166
Apr04	214	289	110	110	464	189	41	218	61	163
May04	463	292	94	94	373	168	50	265	144	205
Jun04	594	320	119	119	397	212	56	259	113	149
Jul04	682	382	94	94	510	222	47	257	48	167
Aug04	714	310	105	105	491	200	62	68	165	0
Sep04	248	473	112	112	402	155	47	478	150	250
Oct04	226	412	118	118	500	164	28	240	101	179
Nov04	601	393	113	113	496	200	33	257	91	159
Dec04	461	311	94	94	720	162	41	237	200	151
Jan05	402	352	105	105	446	187	51	289	173	368
Feb05	422	129	248	248	448	230	43	245	145	153
Mar05	366	359	189	189	356	203	0	318	224	312
Apr05	403	308	131	131	448	193	43	184	116	147
May05	0	294	160	160	529	203	36	358	261	298
Jun05	202	233	101	101	282	135	43	145	213	123
Jul05	231	343	115	115	324	278	44	506	224	69
Aug05	91	321	102	102	337	141	102	192	207	198
Sep05	105	256	356	356	345	150	69	357	201	195
Oct05	145	265	195	195	351	99	63	335	220	192
Nov05	39	187	124	124	128	158	60	261	179	192
Dec05	323	200	254	254	579	50	73	263	134	217
Jan06	164	346	187	193	347	118	67	254	164	222
Feb06	153	216	150	150	440	136	36	180	65	214
Mar06	169	237	338	338	277	149	41	216	138	259
Apr06	160	244	21	21	586	156	56	281	115	204
May06	167	326	178	178	461	151	57	286	117	232
Jun06	188	283	169	169	479	151	56	267	124	327
Jul06	209	329	198	198	535	154	49	259	126	298
Aug06	295	440	238	238	647	223	94	275	127	317
Sep06	143	242	138	138	368	112	118	309	115	271
Oct06	200	283	180	180	262	128	66	258	128	280
Nov06	189	417	173	173	245	121	53	258	132	281
Dec06	212	440	183	183	290	126	80	308	127	320
Jan07	192	388	192	192	386	141	103	335	131	277
Feb07	156	296	174	174	390	156	151	351	116	238
Mar07	191	219	205	205	465	162	161	403	123	257
Apr07	185	405	181	181	508	157	112	5	122	229
May07	181	382	166	166	654	228	89	391	130	276
Jun07	169	404	177	177	605	197	73	394	119	259
Jul07	213	469	213	213	674	226	84	514	146	253
Aug07	138	435	171	171	537	228	62	518	168	259
Sep07	188	528	211	211	648	298	49	352	142	237
Oct07	213	453	172	172	505	334	100	421	151	257
Nov07	480	431	179	179	572	249	42	411	149	275
Dec07	92	400	163	163	586	305	83	476	155	268
Jan08	221	248	144	144	519	242	80	392	133	249
Feb08	183	255	109	109	507	243	82	373	127	229
Mar08	197	254	120	120	484	245	68	502	123	214
Apr08	207	226	142	142	531	287	80	459	140	202
May08	186	246	126	126	493	312	70	400	138	194
Jun08	246	194	126	126	437	300	78	483	164	215
Jul08	187	260	158	158	551	319	59	508	153	206
Aug08	207	241	156	156	522	330	41	481	136	237
Sep08	186	237	135	135	154	261	34	444	134	206
Oct08	176	299	133	133	258	23	25	446	139	210
Nov08	188	182	84	84	238	0	63	398	134	212
Dec08	215	172	109	109	202	0	67	397	141	207

Appendix 1 (Continued). Monthly Energy Consumption in kWh for individual Households for 5 years

House No	11	12	13	14	15	16	17	18	19	20
Demand (kVA)	3	8	8	3	8	8	3	8	8	8
Month/year										
Jan04	269	301	84	244	166	261	515	69	365	178
Feb04	218	210	75	101	127	265	482	34	290	180
Mar04	225	267	97	176	203	329	419	63	277	95
Apr04	231	212	65	182	140	264	387	10	212	99
May04	489	150	41	240	185	196	392	75	311	103
Jun04	425	130	51	182	137	453	343	22	222	0
Jul04	365	113	265	178	143	275	501	76	264	161
Aug04	181	121	185	270	162	251	628	53	231	174
Sep04	135	125	157	202	149	244	476	51	291	137
Oct04	127	133	92	147	134	209	375	36	262	124
Nov04	146	140	109	257	187	196	559	141	288	137
Dec04	244	174	101	277	182	190	458	55	271	131
Jan05	0	228	26	226	178	160	520	145	388	50
Feb05	250	152	79	185	145	228	408	54	240	144
Mar05	0	280	0	236	195	239	428	59	247	78
Apr05	246	189	73	171	126	86	471	0	239	56
May05	0	130	77	176	130	161	353	44	218	178
Jun05	0	164	76	363	233	117	745	0	330	75
Jul05	160	178	106	293	161	105	242	112	259	86
Aug05	359	139	62	316	167	104	701	36	281	99
Sep05	19	228	0	264	121	350	473	9	262	100
Oct05	256	253	34	247	200	74	388	94	247	100
Nov05	272	143	5	253	175	239	100	95	287	133
Dec05	312	397	57	211	228	107	163	39	277	144
Jan06	74	232	8	302	181	75	181	74	246	124
Feb06	251	252	8	232	126	108	179	31	248	117
Mar06	243	191	265	262	136	164	168	0	253	135
Apr06	153	170	87	223	287	146	175	46	258	110
May06	296	185	26	294	116	90	182	54	296	141
Jun06	291	180	68	257	55	70	181	59	281	141
Jul06	266	161	262	236	383	168	172	64	251	134
Aug06	90	224	110	250	234	249	163	9	300	167
Sep06	76	217	143	192	211	139	153	45	257	224
Oct06	64	264	104	194	125	162	240	85	584	116
Nov06	62	193	133	204	195	143	145	32	162	254
Dec06	111	219	116	244	245	167	151	0	233	175
Jan07	71	223	199	244	204	143	98	31	296	84
Feb07	119	271	154	216	185	118	246	44	280	105
Mar07	0	249	96	219	215	137	194	53	341	136
Apr07	61	153	115	274	187	125	166	50	273	143
May07	34	143	99	280	145	117	150	39	285	118
Jun07	67	155	125	276	142	117	148	38	258	139
Jul07	151	216	115	354	120	149	191	57	302	167
Aug07	285	173	100	306	184	66	185	41	260	114
Sep07	146	170	182	244	150	238	267	18	271	119
Oct07	134	294	199	210	158	153	390	77	207	146
Nov07	142	273	159	198	122	120	246	76	325	191
Dec07	175	293	228	252	188	166	355	78	407	267
Jan08	101	255	203	196	176	150	320	84	258	326
Feb08	282	325	190	260	156	147	293	37	234	238
Mar08	185	316	206	262	172	162	312	2	282	232
Apr08	192	268	225	252	163	160	323	92	246	232
May08	37	336	207	237	164	167	371	72	240	229
Jun08	275	236	231	238	149	96	334	32	256	248
Jul08	227	182	275	227	165	127	295	0	224	230
Aug08	127	243	270	207	176	141	307	24	263	259
Sep08	115	257	222	637	184	171	230	81	235	293
Oct08	109	244	202	181	129	168	229	52	201	243
Nov08	351	264	220	271	142	154	174	108	283	260
Dec08	223	377	197	8	179	118	179	71	291	247

Appendix 2. Raw data on electricity consumption provided by KPLC.

House No	297 P2		House No	287 P2		House No	405 P4		House No	521 P5	
Meter No:	47617		Meter No:	192772		Meter No:	20204936		Meter No:	257834	
Max Auth. Load(KVA)		8	Max Auth. Load(KVA)		8	Max Auth. Load(KVA)		8	Max Auth. Load(KVA)		8
Period	Consumption	Actual/Estimate	Period	Consumption	Actual/Estimate	Period	Consumption	Actual/Estimate	Period	Consumpti	Actual/Estimate
26/01/2004	257	actual	26/01/2004	59	actual	26/01/2004	135	actual	29/01/2004	112	actual
24/02/2004	290	actual	24/02/2004	34	actual	23/02/2004	134	actual	28/02/2004	112	actual
24/03/2004	242	actual	24/03/2004	59	actual	24/03/2004	161	actual	29/03/2004	34	actual
28/04/2004	289	actual	28/04/2004	12	actual	26/04/2004	179	actual	01/05/2004	23	actual
25/05/2004	236	actual	25/05/2004	66	actual	25/05/2004	192	actual	31/05/2004	44	actual
24/06/2004	222	actual	24/06/2004	22	actual	23/06/2004	144	actual	29/06/2004	57	actual
23/07/2004	231	actual	23/07/2004	71	actual	23/07/2004	162	actual	28/07/2004	63	actual
27/08/2004	295	actual	27/08/2004	60	actual	25/08/2004	0	actual	27/08/2004	69	actual
23/09/2004	236	actual	23/09/2004	46	actual	24/09/2004	250	actual	29/09/2004	27	actual
27/10/2004	315	actual	27/10/2004	39	actual	26/10/2004	186	actual	30/10/2004	22	actual
24/11/2004	251	actual	24/11/2004	132	actual	23/11/2004	148	actual	26/11/2004	541	estim
24/12/2004	254	estim	24/12/2004	53	estim	24/12/2004	151	estim	30/12/2004	50	actual
26/01/2005	325	actual	26/01/2005	122	actual	26/01/2005	309	actual	29/01/2005	39	actual
23/02/2005	240	estim	23/02/2005	54	estim	23/02/2005	153	estim	25/02/2005	407	estim
24/03/2005	231	actual	24/03/2005	55	estim	22/03/2005	272	actual	30/03/2005	390	estim
26/04/2005	263	actual	26/04/2005	0	actual	22/04/2005	152	estim	28/04/2005	390	estim
26/05/2005	211	estim	26/05/2005	43	estim	26/05/2005	327	actual	30/05/2005	0	actual
28/06/2005	363	actual	28/06/2005	0	actual	01/07/2005	147	estim	30/06/2005	209	estim
27/07/2005	242	actual	27/07/2005	105	actual	27/07/2005	58	actual	28/07/2005	209	estim
26/08/2005	272	actual	26/08/2005	36	actual	24/08/2005	179	actual	29/08/2005	94	actual
22/09/2005	236	actual	22/09/2005	8	actual	23/09/2005	195	actual	28/09/2005	105	actual
26/10/2005	271	actual	26/10/2005	103	actual	26/10/2005	204	actual	31/10/2005	154	actual
25/11/2005	287	actual	25/11/2005	96	actual	25/11/2005	192	actual	30/11/2005	39	actual
22/12/2005	241	actual	22/12/2005	34	estim	22/12/2005	189	actual	29/12/2005	302	actual
27/01/2006	332	actual	27/01/2006	86	estim	25/01/2006	243	actual	30/01/2006	169	actual
23/02/2006	231	actual	23/02/2006	30	estim	23/02/2006	214	actual	28/02/2006	153	actual
27/03/2006	270	actual	27/03/2006	0	actual	27/03/2006	267	actual	29/03/2006	158	actual
25/04/2006	241	actual	25/04/2006	44	actual	25/04/2006	197	actual	28/04/2006	160	actual
25/05/2006	277	actual	25/05/2006	52	actual	26/05/2006	232	actual	30/05/2006	172	actual
23/06/2006	263	actual	23/06/2006	57	actual	27/06/2006	349	actual	30/06/2006	194	actual
24/07/2006	251	actual	24/07/2006	64	actual	25/07/2006	269	actual	28/07/2006	189	actual
23/08/2006	281	actual	23/08/2006	9	actual	24/08/2006	307	actual	21/08/2006	228	actual
25/09/2006	311	actual	25/09/2006	50	actual	25/09/2006	289	actual	29/09/2006	186	actual
15/10/2006	243	actual	15/10/2006	56	actual	25/10/2006	271	actual	27/10/2006	181	actual
23/11/2006	274	actual	23/11/2006	41	actual	23/11/2006	272	actual	29/11/2006	208	actual
27/12/2006	280	actual	27/12/2006	0	actual	23/12/2006	310	actual	30/12/2006	212	actual
25/01/2007	259	actual	25/01/2007	29	actual	25/01/2007	295	actual	31/01/2007	198	actual
23/02/2007	300	actual	23/02/2007	46	actual	23/02/2007	246	actual	28/02/2007	156	actual
23/03/2007	278	actual	23/03/2007	48	actual	23/03/2007	232	actual	29/03/2007	179	actual
26/04/2007	351	actual	26/04/2007	57	actual	26/04/2007	259	actual	29/04/2007	191	actual
26/05/2007	267	actual	26/05/2007	38	actual	24/05/2007	249	actual	29/05/2007	175	actual
25/06/2007	258	actual	25/06/2007	38	actual	26/06/2007	286	actual	30/06/2007	180	actual
24/07/2007	264	actual	24/07/2007	53	actual	25/07/2007	237	actual	30/07/2007	206	actual
25/08/2007	277	actual	25/08/2007	42	actual	23/08/2007	242	actual	31/08/2007	142	actual
25/09/2007	289	actual	25/09/2007	19	actual	26/09/2007	269	actual	29/09/2007	182	actual
29/10/2007	249	actual	29/10/2007	84	actual	27/10/2007	257	actual	31/10/2007	220	actual
27/11/2007	304	actual	27/11/2007	73	actual	26/11/2007	275	actual	30/11/2007	480	actual
21/12/2007	244	actual	21/12/2007	60	actual	21/12/2007	216	actual	24/12/2007	71	actual
28/01/2008	367	actual	28/01/2008	103	actual	28/01/2008	305	actual	31/01/2008	271	actual
26/02/2008	234	actual	26/02/2008	37	actual	26/02/2008	229	actual	29/02/2008	183	actual
24/03/2008	214	actual	24/03/2008	2	actual	24/03/2008	186	actual	28/03/2008	178	actual
24/04/2008	263	actual	24/04/2008	96	actual	23/04/2008	202	actual	29/04/2008	221	actual
27/05/2008	272	actual	27/05/2008	77	actual	26/05/2008	207	actual	30/05/2008	186	actual
24/06/2008	223	actual	24/06/2008	30	actual	24/06/2008	208	actual	28/06/2008	236	actual
22/07/2008	183	actual	22/07/2008	0	actual	22/07/2008	186	actual	29/07/2008	187	actual
23/08/2008	280	actual	23/08/2008	25	actual	22/08/2008	237	actual	28/08/2008	200	actual
24/09/2008	267	actual	24/09/2008	86	actual	23/09/2008	220	actual	27/09/2008	186	actual
27/10/2008	228	actual	27/10/2008	56	estim	24/10/2008	210	actual	31/10/2008	193	actual
25/11/2008	264	actual	25/11/2008	104	actual	21/11/2008	198	actual	29/11/2008	182	actual
23/12/2008	237	actual	23/12/2008	64	actual	23/12/2008	214	actual	31/12/2008	222	actual
27/01/2009	326	actual	27/01/2009	53	actual	25/01/2009	211	actual	30/01/2009	193	actual
21/02/2009	220	actual	21/02/2009	52	actual	21/02/2009	178	actual	26/02/2009	200	actual

Appendix 2 (cont'd). Raw data on electricity consumption provided by KPLC

House No	541 P5		House No	541ext P5		House No	571 P5		House No	581 P5	
Meter No;	250163		Meter No;	9340162		Meter No;	250372		Meter No;	9925855	
Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	8	
Period	Consumpti	Actual/Esti	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estima
29/01/2004	96	Actual	29/01/2004	36	Actual	29/01/2004	442	Actual	29/01/2004	171	Actual
28/02/2004	95	Actual	28/02/2004	31	Actual	28/02/2004	458	Actual	28/02/2004	195	Actual
29/03/2004	82	Actual	29/03/2004	40	Actual	29/03/2004	358	Actual	29/03/2004	159	Actual
01/05/2004	121	Actual	01/05/2004	49	Actual	01/05/2004	510	Actual	01/05/2004	208	Actual
31/05/2004	91	Actual	31/05/2004	33	Actual	31/05/2004	361	Actual	31/05/2004	163	Actual
29/06/2004	115	Actual	29/06/2004	69	Actual	29/06/2004	384	Actual	29/06/2004	205	Actual
28/07/2004	88	Actual	28/07/2004	49	Actual	28/07/2004	477	Actual	28/07/2004	208	Actual
27/08/2004	102	Actual	27/08/2004	56	Actual	27/08/2004	475	Actual	27/08/2004	194	Actual
29/09/2004	123	Actual	29/09/2004	47	Actual	29/09/2004	442	Actual	29/09/2004	170	Actual
30/10/2004	118	Actual	30/10/2004	35	Actual	30/10/2004	500	Actual	30/10/2004	164	Actual
26/11/2004	102	estim	26/11/2004	43	estim	26/11/2004	446	estim	26/11/2004	180	estim
30/12/2004	103	estim	30/12/2004	42	estim	30/12/2004	790	Actual	30/12/2004	178	estim
29/01/2005	102	estim	29/01/2005	44	estim	29/01/2005	432	estim	29/01/2005	181	estim
25/02/2005	239	Actual	25/02/2005	160	Actual	25/02/2005	432	estim	25/02/2005	222	Actual
30/03/2005	201	Actual	30/03/2005	25	Actual	30/03/2005	379	Actual	30/03/2005	216	Actual
27/04/2005	122	Actual	27/04/2005	0	Actual	27/04/2005	418	Actual	27/04/2005	180	Actual
30/05/2005	170	Actual	30/05/2005	0	Actual	30/05/2005	563	Actual	30/05/2005	216	Actual
30/06/2005	104	estim	30/06/2005	33	estim	30/06/2005	291	estim	30/06/2005	140	estim
28/07/2005	104	estim	28/07/2005	33	estim	28/07/2005	293	Actual	28/07/2005	251	Actual
29/08/2005	105	estim	29/08/2005	29	estim	29/08/2005	348	Actual	29/08/2005	146	Actual
28/09/2005	356	Actual	28/09/2005	0	Actual	28/09/2005	345	Actual	28/09/2005	150	Actual
31/10/2005	208	Actual	31/10/2005	0	Actual	31/10/2005	374	Actual	31/10/2005	105	Actual
30/11/2005	124	Actual	30/11/2005	120	Actual	30/11/2005	128	Actual	30/11/2005	158	Actual
29/12/2005	238	Actual	29/12/2005	200	Actual	29/12/2005	542	Actual	29/12/2005	47	Actual
30/01/2006	199	Actual	30/01/2006	1	Actual	30/01/2006	369	Actual	30/01/2006	126	Actual
28/02/2006	150	Actual	28/02/2006	55	Actual	28/02/2006	440	Actual	28/02/2006	136	Actual
29/03/2006	316	Actual	29/03/2006	68	Actual	29/03/2006	259	estim	29/03/2006	139	Actual
28/04/2006	21	Actual	28/04/2006	64	Actual	28/04/2006	586	Actual	28/04/2006	156	Actual
30/05/2006	184	Actual	30/05/2006	45	Actual	30/05/2006	476	Actual	30/05/2006	156	Actual
30/06/2006	175	Actual	30/06/2006	38	Actual	30/06/2006	495	Actual	30/06/2006	156	Actual
28/07/2006	179	Actual	28/07/2006	38	Actual	28/07/2006	483	Actual	28/07/2006	139	Actual
21/08/2006	184	Actual	21/08/2006	47	Actual	21/08/2006	501	Actual	21/08/2006	173	Actual
29/09/2006	180	Actual	29/09/2006	47	Actual	29/09/2006	478	Actual	29/09/2006	145	Actual
27/10/2006	163	Actual	27/10/2006	40	Actual	27/10/2006	237	Actual	27/10/2006	116	Actual
29/11/2006	190	Actual	29/11/2006	34	Actual	29/11/2006	269	Actual	29/11/2006	133	Actual
30/12/2006	183	Actual	30/12/2006	47	Actual	30/12/2006	290	Actual	30/12/2006	126	Actual
31/01/2007	198	Actual	31/01/2007	50	Actual	31/01/2007	398	Actual	31/01/2007	146	Actual
28/02/2007	174	Actual	28/02/2007	41	Actual	28/02/2007	390	Actual	28/02/2007	156	Actual
29/03/2007	192	Actual	29/03/2007	40	Actual	29/03/2007	435	Actual	29/03/2007	152	Actual
29/04/2007	187	Actual	29/04/2007	43	Actual	29/04/2007	525	Actual	29/04/2007	162	Actual
29/05/2007	161	Actual	29/05/2007	38	Actual	29/05/2007	633	Actual	29/05/2007	221	Actual
30/06/2007	189	Actual	30/06/2007	56	Actual	30/06/2007	645	Actual	30/06/2007	210	Actual
30/07/2007	206	Actual	30/07/2007	51	Actual	30/07/2007	652	Actual	30/07/2007	219	Actual
31/08/2007	176	Actual	31/08/2007	37	Actual	31/08/2007	554	Actual	31/08/2007	235	Actual
29/09/2007	204	Actual	29/09/2007	51	Actual	29/09/2007	626	Actual	29/09/2007	288	Actual
31/10/2007	178	Actual	31/10/2007	49	Actual	31/10/2007	521	Actual	31/10/2007	345	Actual
30/11/2007	179	Actual	30/11/2007	52	Actual	30/11/2007	572	Actual	30/11/2007	249	Actual
24/12/2007	126	Actual	24/12/2007	33	Actual	24/12/2007	454	Actual	24/12/2007	236	Actual
31/01/2008	177	Actual	31/01/2008	56	Actual	31/01/2008	636	Actual	31/01/2008	297	Actual
29/02/2008	109	Actual	29/02/2008	43	Actual	29/02/2008	507	Actual	29/02/2008	243	Actual
28/03/2008	108	Actual	28/03/2008	34	Actual	28/03/2008	437	Actual	28/03/2008	221	Actual
29/04/2008	151	Actual	29/04/2008	47	Actual	29/04/2008	566	Actual	29/04/2008	306	Actual
30/05/2008	126	Actual	30/05/2008	45	Actual	30/05/2008	493	Actual	30/05/2008	312	Actual
28/06/2008	122	Actual	28/06/2008	183	Actual	28/06/2008	422	Actual	28/06/2008	290	Actual
29/07/2008	158	Actual	29/07/2008	209	Actual	29/07/2008	551	Actual	29/07/2008	319	Actual
28/08/2008	151	Actual	28/08/2008	60	Actual	28/08/2008	505	Actual	28/08/2008	319	Actual
27/09/2008	135	Actual	27/09/2008	45	Actual	27/09/2008	154	Actual	27/09/2008	261	Actual
31/10/2008	146	Actual	31/10/2008	69	Actual	31/10/2008	283	Actual	31/10/2008	25	Actual
29/11/2008	81	Actual	29/11/2008	53	Actual	27/11/2008	214	Actual	29/11/2008	0	Actual
31/12/2008	113	Actual	31/12/2008	63	Actual	31/12/2008	221	Actual	31/12/2008	0	Actual
30/01/2009	115	Actual	30/01/2009	58	Actual	30/01/2009	196	Actual	30/01/2009	0	Actual
26/02/2009	105	Actual	26/02/2009	49	Actual	26/02/2009	187	Actual	26/02/2009	4	Actual

Appendix 2 (Cont'd). Raw Electricity Consumption Data Provided by KPLC

House No	405 ext	P4	House No	375	P4	House No	213	P3	House No	183	P3
Meter No;	378868		Meter No;	20115745		Meter No;	106805		Meter No;	9845842	
Max Auth. Load(KVA)		3	Max Auth. Load(KVA)		8	Max Auth. Load(KVA)		8	Max Auth. Load(KVA)		8
Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate
26/01/2004	158	Actual	26/01/2004	27	Actual	28/01/2004	76	Actual	28/01/2004	272	Actual
23/02/2004	134	Actual	23/02/2004	36	Actual	26/02/2004	75	Actual	26/02/2004	210	Actual
24/03/2004	136	Actual	24/03/2004	33	Actual	25/03/2004	88	Actual	25/03/2004	241	Actual
26/04/2004	161	Actual	26/04/2004	45	Actual	27/04/2004	71	Actual	27/04/2004	233	Actual
25/05/2004	182	Actual	25/05/2004	47	Actual	28/05/2004	41	Actual	28/05/2004	150	Actual
23/06/2004	153	Actual	23/06/2004	54	Actual	25/06/2004	48	Actual	25/06/2004	121	Actual
23/07/2004	171	Actual	23/07/2004	45	Actual	28/07/2004	282	Actual	28/07/2004	120	Actual
25/08/2004	0	Actual	25/08/2004	66	Actual	25/08/2004	167	Actual	25/08/2004	109	Actual
24/09/2004	357	Actual	24/09/2004	47	Actual	25/09/2004	162	Actual	25/09/2004	129	Actual
26/10/2004	124	Actual	26/10/2004	29	Actual	28/10/2004	98	estim	28/10/2004	142	estim
23/11/2004	0	Actual	23/11/2004	31	Actual	24/11/2004	98	estim	24/11/2004	126	Actual
24/12/2004	141	estim	24/12/2004	41	estim	24/12/2004	98	estim	24/12/2004	168	Actual
26/01/2005	34	Actual	26/01/2005	43	estim	26/01/2005	28	Actual	26/01/2005	243	Actual
23/02/2005	116	estim	23/02/2005	43	estim	23/02/2005	79	estim	23/02/2005	152	estim
22/03/2005	175	Actual	22/03/2005	0	estim	24/03/2005	0	estim	24/03/2005	262	Actual
22/04/2005	112	estim	22/04/2005	44	estim	25/04/2005	78	estim	25/04/2005	202	Actual
26/05/2005	209	Actual	26/05/2005	39	Actual	27/05/2005	79	estim	27/05/2005	134	estim
01/07/2005	95	estim	27/06/2005	46	Actual	01/07/2005	89	estim	28/06/2005	191	Actual
27/07/2005	274	Actual	27/07/2005	44	Actual	27/07/2005	89	estim	27/07/2005	149	Actual
24/08/2005	182	Actual	24/08/2005	92	Actual	25/08/2005	58	estim	25/08/2005	130	estim
23/09/2005	123	Actual	23/09/2005	69	Actual	23/09/2005	0	Actual	23/09/2005	220	Actual
26/10/2005	157	Actual	26/10/2005	67	Actual	29/10/2005	39	Actual	29/10/2005	294	Actual
25/11/2005	159	Actual	25/11/2005	60	Actual	30/11/2005	5	estim	30/11/2005	153	estim
22/12/2005	125	Actual	22/12/2005	64	Actual	29/12/2005	53	Actual	29/12/2005	371	Actual
25/01/2006	156	Actual	25/01/2006	74	Actual	30/01/2006	8	estim	30/01/2006	239	Actual
23/02/2006	143	Actual	23/02/2006	36	Actual	28/02/2006	8	estim	28/02/2006	252	Actual
27/03/2006	175	Actual	17/03/2006	29	Actual	30/03/2006	256	Actual	30/03/2006	185	Actual
25/04/2006	163	Actual	25/04/2006	73	Actual	27/04/2006	81	Actual	27/04/2006	159	Actual
26/05/2006	199	Actual	19/05/2006	44	Actual	30/05/2006	28	estim	30/05/2006	197	Actual
27/06/2006	197	Actual	27/06/2006	73	Actual	29/06/2006	68	Actual	29/06/2006	180	Actual
25/07/2006	186	Actual	20/07/2006	36	Actual	28/07/2006	245	Actual	28/07/2006	151	Actual
24/08/2006	185	Actual	24/08/2006	106	Actual	29/08/2006	114	Actual	29/08/2006	231	Actual
25/09/2006	178	Actual	20/09/2006	106	Actual	28/09/2006	143	Actual	28/09/2006	217	Actual
25/10/2006	162	Actual	25/10/2006	75	Actual	28/10/2006	101	Actual	28/10/2006	255	Actual
23/11/2006	160	Actual	23/11/2006	51	Actual	28/11/2006	137	Actual	28/11/2006	199	Actual
23/12/2006	151	Actual	19/12/2006	67	Actual	30/12/2006	120	Actual	30/12/2006	226	Actual
25/01/2007	160	Actual	22/01/2007	113	Actual	30/01/2007	199	Actual	30/01/2007	223	Actual
23/02/2007	174	Actual	19/02/2007	151	Actual	28/02/2007	160	Actual	28/02/2007	281	Actual
23/03/2007	144	Actual	23/03/2007	166	Actual	29/03/2007	90	Actual	29/03/2007	233	Actual
26/04/2007	171	Actual	26/04/2007	127	Actual	29/04/2007	119	Actual	29/04/2007	158	Actual
24/05/2007	195	Actual	24/05/2007	80	Actual	28/05/2007	93	Actual	28/05/2007	134	Actual
26/06/2007	192	Actual	26/06/2007	80	Actual	29/06/2007	133	Actual	29/06/2007	165	Actual
25/07/2007	201	Actual	25/07/2007	79	Actual	27/07/2007	104	Actual	27/07/2007	195	Actual
23/08/2007	184	Actual	23/08/2007	58	Actual	31/08/2007	113	Actual	31/08/2007	195	Actual
26/09/2007	186	Actual	26/09/2007	56	Actual	29/09/2007	176	Actual	29/09/2007	164	Actual
27/10/2007	164	Actual	18/10/2007	71	Actual	31/10/2007	205	Actual	31/10/2007	303	Actual
26/11/2007	202	Actual	26/11/2007	54	Actual	29/11/2007	154	Actual	29/11/2007	264	Actual
21/12/2007	103	Actual	21/12/2007	67	Actual	24/12/2007	184	Actual	24/12/2007	236	Actual
28/01/2008	79	Actual	28/01/2008	98	Actual	01/02/2008	255	Actual	01/02/2008	321	Actual
26/02/2008	116	Actual	26/02/2008	82	Actual	01/03/2008	190	Actual	01/03/2008	325	Actual
24/03/2008	106	Actual	24/03/2008	59	Actual	27/03/2008	173	Actual	27/03/2008	265	Actual
23/04/2008	208	Actual	23/04/2008	80	Actual	29/04/2008	247	Actual	29/04/2008	295	Actual
26/05/2008	157	Actual	26/05/2008	75	Actual	29/05/2008	200	Actual	29/05/2008	325	Actual
24/06/2008	184	Actual	24/06/2008	75	Actual	27/06/2008	223	Actual	27/06/2008	228	Actual
22/07/2008	159	Actual	22/07/2008	53	Actual	25/07/2008	248	Actual	25/07/2008	164	Actual
22/08/2008	176	Actual	22/08/2008	41	Actual	28/08/2008	296	Actual	28/08/2008	266	Actual
23/09/2008	183	Actual	23/09/2008	36	Actual	24/09/2008	200	Actual	24/09/2008	231	Actual
24/10/2008	192	Actual	24/10/2008	25	Actual	28/10/2008	222	Actual	28/10/2008	268	Actual
21/11/2008	173	Actual	21/11/2008	59	Actual	26/11/2008	213	Actual	26/11/2008	255	Actual
23/12/2008	186	Actual	23/12/2008	69	Actual	31/12/2008	222	Actual	31/12/2008	426	Actual
25/01/2009	193	Actual	25/01/2009	95	Actual	29/01/2009	187	Actual	29/01/2009	278	Actual
21/02/2009	156	Actual	21/02/2009	41	Actual	24/02/2009	160	Actual	24/02/2009	255	Actual

Appendix 2 (Cont'd). Raw Electricity Consumption Data Provided by KPLC

House No	223 P3		House No	233 P3		House No	243 P3		House No	531 P5	
Meter No;	137428		Meter No;	214974		Meter No;	193481		Meter No;	20051965	
Max Auth. Load(KVA)	3		Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	3	
Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimat	Period	Consumpti	Actual/Estimate
28/01/2004	220	Actual	28/01/2004	150	Actual	28/01/2004	236	Actual	29/01/2004	328	actual
26/02/2004	101	Actual	26/02/2004	127	Actual	26/02/2004	265	Actual	28/02/2004	340	actual
25/03/2004	159	Actual	25/03/2004	183	Actual	25/03/2004	297	Actual	29/03/2004	292	actual
27/04/2004	200	Actual	27/04/2004	154	Actual	27/04/2004	290	Actual	01/05/2004	318	actual
28/05/2004	240	Actual	28/05/2004	185	Actual	28/05/2004	196	Actual	31/05/2004	283	actual
25/06/2004	170	Actual	25/06/2004	128	Actual	25/06/2004	423	Actual	29/06/2004	309	actual
28/07/2004	190	Actual	28/07/2004	152	Actual	28/07/2004	293	Actual	28/07/2004	357	actual
25/08/2004	244	Actual	25/08/2004	146	Actual	25/08/2004	227	Actual	27/08/2004	300	actual
25/09/2004	209	Actual	25/09/2004	154	Actual	25/09/2004	252	Actual	29/09/2004	520	actual
28/10/2004	156	estim	28/10/2004	143	estim	28/10/2004	223	estim	30/10/2004	412	actual
24/11/2004	231	Actual	24/11/2004	168	Actual	24/11/2004	176	Actual	26/11/2004	354	estimate
24/12/2004	268	Actual	24/12/2004	176	Actual	24/12/2004	184	Actual	30/12/2004	341	estimate
26/01/2005	241	Actual	26/01/2005	189	Actual	26/01/2005	170	Actual	29/01/2005	341	estimate
23/02/2005	185	estim	23/02/2005	145	estim	23/02/2005	228	estim	25/02/2005	124	actual
24/03/2005	221	Actual	24/03/2005	182	Actual	24/03/2005	224	estim	30/03/2005	382	actual
25/04/2005	182	estim	25/04/2005	134	estim	25/04/2005	92	Actual	27/04/2005	287	actual
27/05/2005	182	estim	27/05/2005	134	estim	27/05/2005	166	estim	30/05/2005	313	actual
28/06/2005	424	Actual	28/06/2005	249	Actual	01/07/2005	137	estim	30/06/2005	241	estimate
27/07/2005	246	Actual	27/07/2005	151	Actual	27/07/2005	88	Actual	28/07/2005	310	actual
25/08/2005	296	Actual	25/08/2005	156	Actual	25/08/2005	97	estim	29/08/2005	331	actual
23/09/2005	256	Actual	23/09/2005	117	estim	23/09/2005	338	Actual	28/09/2005	256	actual
29/10/2005	287	Actual	29/10/2005	232	Actual	29/10/2005	86	estim	31/10/2005	282	actual
30/11/2005	270	Actual	30/11/2005	187	Actual	30/11/2005	255	Actual	30/11/2005	187	estimate
29/12/2005	197	estim	29/12/2005	213	Actual	29/12/2005	100	Actual	29/12/2005	187	estimate
30/01/2006	312	Actual	30/01/2006	187	Actual	30/01/2006	77	estim	30/01/2006	357	actual
28/02/2006	232	Actual	28/02/2006	126	estim	28/02/2006	108	Actual	28/02/2006	216	actual
30/03/2006	254	Actual	30/03/2006	132	estim	30/03/2006	159	Actual	29/03/2006	222	estimate
27/04/2006	208	estim	27/04/2006	268	Actual	27/04/2006	136	Actual	28/04/2006	244	actual
30/05/2006	313	Actual	30/05/2006	123	estim	30/05/2006	96	estim	30/05/2006	336	actual
29/06/2006	257	Actual	29/06/2006	55	Actual	29/06/2006	70	Actual	30/06/2006	292	actual
28/07/2006	221	Actual	28/07/2006	358	Actual	28/07/2006	157	Actual	28/07/2006	297	actual
29/08/2006	258	Actual	29/08/2006	242	Actual	29/08/2006	257	Actual	21/08/2006	341	actual
28/09/2006	192	Actual	28/09/2006	211	Actual	28/09/2006	139	Actual	29/09/2006	315	actual
28/10/2006	188	Actual	28/10/2006	121	Actual	28/10/2006	157	Actual	27/10/2006	256	actual
28/11/2006	211	Actual	28/11/2006	202	Actual	28/11/2006	148	Actual	29/11/2006	459	actual
30/12/2006	252	Actual	30/12/2006	253	Actual	30/12/2006	172	Actual	30/12/2006	440	actual
30/01/2007	244	Actual	30/01/2007	204	Actual	30/01/2007	143	Actual	31/01/2007	401	actual
28/02/2007	224	Actual	28/02/2007	192	Actual	28/02/2007	122	Actual	28/02/2007	296	actual
29/03/2007	205	Actual	29/03/2007	201	Actual	29/03/2007	128	Actual	29/03/2007	205	actual
29/04/2007	283	Actual	29/04/2007	193	estim	29/04/2007	129	Actual	29/04/2007	419	actual
28/05/2007	262	Actual	28/05/2007	136	Actual	28/05/2007	109	Actual	29/05/2007	370	actual
29/06/2007	294	Actual	29/06/2007	151	Actual	29/06/2007	125	Actual	30/06/2007	431	actual
27/07/2007	320	Actual	27/07/2007	108	Actual	27/07/2007	135	Actual	30/07/2007	454	actual
31/08/2007	346	Actual	31/08/2007	208	Actual	31/08/2007	74	Actual	31/08/2007	449	actual
29/09/2007	236	Actual	29/09/2007	145	Actual	29/09/2007	230	Actual	29/09/2007	510	actual
31/10/2007	217	Actual	31/10/2007	163	Actual	31/10/2007	158	Actual	31/10/2007	468	actual
29/11/2007	191	Actual	29/11/2007	118	Actual	29/11/2007	116	Actual	30/11/2007	431	actual
24/12/2007	203	Actual	24/12/2007	152	Actual	24/12/2007	134	Actual	24/12/2007	310	actual
01/02/2008	246	Actual	01/02/2008	221	Actual	01/02/2008	189	Actual	31/01/2008	304	actual
01/03/2008	260	Actual	01/03/2008	156	Actual	01/03/2008	147	Actual	29/02/2008	255	actual
27/03/2008	220	Actual	27/03/2008	144	Actual	27/03/2008	136	Actual	28/03/2008	229	actual
29/04/2008	277	Actual	29/04/2008	179	Actual	29/04/2008	176	Actual	29/04/2008	241	actual
29/05/2008	229	Actual	29/05/2008	159	Actual	29/05/2008	162	Actual	30/05/2008	246	actual
27/06/2008	230	Actual	27/06/2008	144	Actual	27/06/2008	93	Actual	28/06/2008	188	actual
25/07/2008	205	Actual	25/07/2008	149	Actual	25/07/2008	115	Actual	29/07/2008	260	actual
28/08/2008	227	Actual	28/08/2008	193	Actual	28/08/2008	155	Actual	28/08/2008	233	actual
24/09/2008	573	Actual	24/09/2008	166	Actual	24/09/2008	154	Actual	27/09/2008	237	actual
28/10/2008	198	estim	28/10/2008	141	Actual	28/10/2008	184	Actual	31/10/2008	328	actual
26/11/2008	262	Actual	26/11/2008	137	Actual	26/11/2008	149	Actual	29/11/2008	176	actual
31/12/2008	9	Actual	31/12/2008	202	Actual	31/12/2008	133	Actual	31/12/2008	178	actual
29/01/2009	12	Actual	29/01/2009	179	Actual	29/01/2009	104	Actual	30/01/2009	184	actual
24/02/2009	507	Actual	24/02/2009	138	Actual	24/02/2009	141	estim	26/02/2009	171	actual

Appendix 2 (Cont'd). Raw Electricity Consumption Data Provided by KPLC

House No	551 P5		House No	385 P4		House No	395 P4		House No	415 P4	
Meter No.	9931371		Meter No.	20203773		Meter No.	20055390		Meter No.	228203	
Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	8		Max Auth. Load(KVA)	3	
Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate
29/01/2004	96	actual	26/01/2004	208	Actual	26/01/2004	133	Actual	26/01/2004	226	Actual
28/02/2004	95	actual	23/02/2004	202	Actual	23/02/2004	115	Actual	23/02/2004	210	Actual
29/03/2004	82	actual	24/03/2004	219	Actual	24/03/2004	79	Actual	24/03/2004	218	Actual
01/05/2004	121	actual	26/04/2004	240	Actual	26/04/2004	67	Actual	26/04/2004	254	Estimate
31/05/2004	91	actual	25/05/2004	248	Actual	25/05/2004	135	Actual	25/05/2004	457	Actual
29/06/2004	115	actual	23/06/2004	250	Actual	23/06/2004	109	Actual	23/06/2004	411	Actual
28/07/2004	88	actual	23/07/2004	249	Actual	23/07/2004	46	Actual	23/07/2004	353	Actual
27/08/2004	102	actual	25/08/2004	72	Actual	25/08/2004	176	Actual	25/08/2004	193	Actual
29/09/2004	123	actual	24/09/2004	478	Actual	24/09/2004	150	Actual	24/09/2004	135	Actual
30/10/2004	118	actual	26/10/2004	248	Actual	26/10/2004	104	Actual	26/10/2004	131	Actual
26/11/2004	102	estimate	23/11/2004	240	Actual	23/11/2004	85	Actual	23/11/2004	136	Actual
30/12/2004	103	estimate	24/12/2004	237	Estimate	24/12/2004	200	Estimate	24/12/2004	244	Estimate
29/01/2005	102	estimate	26/01/2005	242	Estimate	26/01/2005	145	Actual	26/01/2005	0	Estimate
25/02/2005	239	actual	23/02/2005	245	Estimate	23/02/2005	145	Estimate	23/02/2005	250	Estimate
30/03/2005	201	actual	22/03/2005	277	Actual	22/03/2005	195	Actual	22/03/2005	0	Estimate
27/04/2005	122	actual	22/04/2005	190	Estimate	22/04/2005	120	Estimate	22/04/2005	254	Estimate
30/05/2005	170	actual	26/05/2005	393	Actual	26/05/2005	286	Actual	26/05/2005	0	Estimate
30/06/2005	104	estimate	01/07/2005	174	Estimate	27/06/2005	227	Actual	27/06/2005	0	Estimate
28/07/2005	104	estimate	27/07/2005	424	Actual	27/07/2005	217	Actual	27/07/2005	155	Actual
29/08/2005	105	estimate	24/08/2005	173	Estimate	24/08/2005	187	Actual	24/08/2005	324	Actual
28/09/2005	356	actual	23/09/2005	357	Actual	23/09/2005	201	Actual	23/09/2005	19	Actual
31/10/2005	206	actual	26/10/2005	357	Actual	26/10/2005	234	Actual	26/10/2005	272	Actual
30/11/2005	124	actual	25/11/2005	261	Actual	25/11/2005	179	Actual	25/11/2005	272	Estimate
29/12/2005	238	actual	22/12/2005	229	Actual	22/12/2005	117	Actual	22/12/2005	272	Estimate
30/01/2006	199	actual	25/01/2006	279	Actual	25/01/2006	180	Estimate	25/01/2006	81	Actual
28/02/2006	150	actual	23/02/2006	180	Estimate	23/02/2006	65	Actual	23/02/2006	251	Actual
29/03/2006	316	actual	27/03/2006	223	Estimate	27/03/2006	142	Actual	27/03/2006	251	Actual
28/04/2006	21	actual	25/04/2006	272	Actual	25/04/2006	111	Actual	25/04/2006	148	Actual
30/05/2006	184	actual	26/05/2006	286	Actual	26/05/2006	117	Actual	26/05/2006	296	Actual
30/06/2006	175	actual	27/06/2006	285	Actual	27/06/2006	132	Actual	27/06/2006	310	Actual
28/07/2006	179	actual	25/07/2006	234	Actual	25/07/2006	114	Actual	25/07/2006	240	Actual
21/08/2006	184	actual	24/08/2006	266	Actual	24/08/2006	123	Actual	24/08/2006	87	Actual
29/09/2006	180	actual	25/09/2006	330	Actual	25/09/2006	123	Actual	25/09/2006	81	Actual
27/10/2006	163	actual	25/10/2006	250	Actual	25/10/2006	124	Actual	25/10/2006	62	Actual
29/11/2006	190	actual	23/11/2006	249	Actual	23/11/2006	128	Actual	23/11/2006	60	Actual
30/12/2006	183	actual	23/12/2006	298	Actual	23/12/2006	123	Actual	23/12/2006	107	Actual
31/01/2007	198	actual	25/01/2007	357	Actual	25/01/2007	139	Actual	25/01/2007	76	Actual
28/02/2007	174	actual	23/02/2007	364	Actual	23/02/2007	120	Actual	23/02/2007	123	Actual
29/03/2007	192	actual	23/03/2007	364	Estimate	23/03/2007	111	Actual	23/03/2007	0	Actual
29/04/2007	187	actual	26/04/2007	6	Actual	26/04/2007	138	Actual	26/04/2007	69	Actual
29/05/2007	161	actual	24/05/2007	353	Actual	24/05/2007	117	Actual	24/05/2007	31	Actual
30/06/2007	189	actual	26/06/2007	433	Actual	26/06/2007	131	Actual	26/06/2007	74	Actual
30/07/2007	206	actual	25/07/2007	481	Actual	25/07/2007	137	Actual	25/07/2007	141	Actual
31/08/2007	176	actual	23/08/2007	485	Actual	23/08/2007	157	Actual	23/08/2007	267	Actual
29/09/2007	204	actual	26/09/2007	399	Actual	26/09/2007	161	Actual	26/09/2007	165	Actual
31/10/2007	178	actual	27/10/2007	421	Actual	27/10/2007	151	Actual	27/10/2007	134	Actual
30/11/2007	179	actual	26/11/2007	411	Actual	26/11/2007	149	Actual	26/11/2007	142	Actual
24/12/2007	126	actual	21/12/2007	384	Actual	21/12/2007	125	Actual	21/12/2007	141	Actual
31/01/2008	177	actual	28/01/2008	480	Actual	28/01/2008	163	Actual	28/01/2008	124	Actual
29/02/2008	109	actual	26/02/2008	373	Actual	26/02/2008	127	Actual	26/02/2008	282	Actual
28/03/2008	108	actual	24/03/2008	437	Actual	24/03/2008	107	Actual	24/03/2008	161	Actual
29/04/2008	151	actual	23/04/2008	459	Actual	23/04/2008	140	Actual	23/04/2008	192	Actual
30/05/2008	126	actual	26/05/2008	426	Actual	26/05/2008	147	Actual	26/05/2008	39	Actual
28/06/2008	122	actual	24/06/2008	467	Actual	24/06/2008	159	Actual	24/06/2008	266	Actual
29/07/2008	158	actual	22/07/2008	459	Actual	22/07/2008	138	Actual	22/07/2008	205	Actual
28/08/2008	151	actual	22/08/2008	481	Actual	22/08/2008	136	Actual	22/08/2008	127	Actual
27/09/2008	135	actual	23/09/2008	474	Actual	23/09/2008	143	Actual	23/09/2008	123	Actual
31/10/2008	146	actual	24/10/2008	446	Actual	24/10/2008	139	Actual	24/10/2008	109	Actual
29/11/2008	81	actual	21/11/2008	371	Actual	21/11/2008	125	Actual	21/11/2008	328	Actual
31/12/2008	113	actual	23/12/2008	410	Actual	23/12/2008	146	Actual	23/12/2008	230	Actual
30/01/2009	115	actual	25/01/2009	261	Actual	25/01/2009	134	Actual	25/01/2009	64	Actual
26/02/2009	105	actual	21/02/2009	295	Actual	21/02/2009	125	Actual	21/02/2009	60	Actual

Appendix 2 (Cont'd). Raw Electricity Consumption Data Provided by KPLC

House No	425 P4		House No	277 P2		House No	317 P2	
Meter No;	20125234		Meter No.	176975		Meter No.	178690	
Max Auth. Load(KVA)	3		Max Auth. Load(KVA)	3		Max Auth. Load(KVA)	8	
Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate	Period	Consumpti	Actual/Estimate
26/01/2004	84	Actual	26/01/2004	432	Actual	26/01/2004	149	Actual
23/02/2004	0	Actual	24/02/2004	482	Actual	25/02/2004	180	Actual
24/03/2004	0	Actual	24/03/2004	392	Actual	24/03/2004	89	Actual
26/04/2004	0	Actual	28/04/2004	452	Actual	29/04/2004	115	Actual
25/05/2004	0	Actual	25/05/2004	341	Actual	26/05/2004	90	Actual
23/06/2004	0	Actual	24/06/2004	343	Actual	24/06/2004	0	Actual
23/07/2004	16	Estimate	23/07/2004	469	Actual	26/07/2004	151	Actual
25/08/2004	0	Actual	27/08/2004	709	Actual	27/08/2004	197	Actual
25/09/2004	11	Estimate	23/09/2004	428	Actual	23/09/2004	123	Actual
26/10/2004	11	Estimate	27/10/2004	411	Actual	27/10/2004	136	Actual
23/11/2004	11	Estimate	24/11/2004	522	Actual	24/11/2004	128	Estimate
24/12/2004	11	Estimate	24/12/2004	443	Estimate	24/12/2004	127	Actual
26/01/2005	500	Actual	26/01/2005	436	Actual	26/01/2005	42	Actual
23/02/2005	44	Estimate	23/02/2005	408	Estimate	23/02/2005	144	Actual
22/03/2005	44	Estimate	24/03/2005	400	Estimate	24/03/2005	73	Actual
22/04/2005	48	Estimate	26/04/2005	518	Actual	26/04/2005	62	Actual
26/05/2005	60	Estimate	26/05/2005	342	Estimate	26/05/2005	172	Actual
27/07/2005	69	Estimate	28/06/2005	820	Actual	28/06/2005	82	Actual
24/08/2005	37	Estimate	27/07/2005	226	Actual	27/07/2005	80	Actual
23/09/2005	22	Actual	26/08/2005	701	Actual	26/08/2005	99	Actual
26/10/2005	28	Actual	22/09/2005	426	Actual	23/09/2005	93	Actual
25/11/2005	38	Estimate	26/10/2005	426	Actual	26/10/2005	106	Actual
22/12/2005	38	Estimate	17/11/2005	48	Actual	25/11/2005	133	Actual
25/01/2006	38	Estimate	25/11/2005	52	Actual	22/12/2005	125	Actual
23/02/2006	5	Estimate	22/12/2005	142	Actual	27/01/2006	144	Actual
27/03/2006	5	Estimate	27/01/2006	210	Actual	23/02/2006	109	Actual
25/04/2006	5	Estimate	23/02/2006	167	Actual	27/03/2006	139	Actual
26/05/2006	5	Estimate	27/03/2006	179	Actual	26/04/2006	110	Actual
27/06/2006	5	Estimate	25/05/2006	345	Actual	25/05/2006	132	Actual
25/07/2006	5	Estimate	23/06/2006	175	Actual	23/06/2006	136	Actual
24/08/2006	16	Estimate	24/07/2006	172	Actual	02/07/2006	134	Actual
25/09/2006	428	Actual	23/08/2006	158	Actual	23/08/2006	162	Actual
25/10/2006	0	Actual	25/09/2006	163	Actual	25/09/2006	239	Actual
23/11/2006	0	Actual	15/10/2006	155	Actual	23/10/2006	105	Actual
23/12/2006	45	Estimate	23/11/2006	189	Actual	23/11/2006	262	Actual
25/01/2007	0	Estimate	27/12/2006	166	Actual	27/12/2006	192	Actual
23/02/2007	94	Actual	25/01/2007	92	Actual	25/01/2007	79	Actual
23/03/2007	49	Estimate	23/02/2007	255	Actual	23/02/2007	109	Actual
23/03/2007	49	Estimate	23/03/2007	175	Actual	23/03/2007	123	Actual
26/04/2007	58	Estimate	26/04/2007	188	Actual	25/04/2007	157	Actual
24/05/2007	57	Estimate	26/05/2007	145	Actual	26/05/2007	118	Actual
26/06/2007	62	Estimate	25/06/2007	148	Actual	25/06/2007	144	Actual
25/07/2007	67	Estimate	24/07/2007	179	Actual	24/07/2007	156	Actual
23/08/2007	72	Estimate	25/08/2007	191	Actual	28/08/2007	129	Actual
26/09/2007	0	Actual	25/09/2007	276	Actual	25/09/2007	111	Actual
27/10/2007	45	Estimate	29/10/2007	428	Actual	27/10/2007	151	Actual
26/11/2007	48	Estimate	27/11/2007	238	Actual	27/11/2007	197	Actual
21/12/2007	48	Actual	21/12/2007	275	Actual	21/12/2007	207	Actual
28/01/2008	0	Actual	28/01/2008	392	Actual	29/01/2008	410	Actual
26/02/2008	0	Actual	26/02/2008	293	Actual	26/02/2008	230	Actual
10/03/2008	201	Actual	24/03/2008	272	Actual	24/03/2008	202	Actual
23/04/2008	221	Actual	24/04/2008	334	Actual	23/04/2008	232	Actual
26/05/2008	196	Actual	27/05/2008	395	Actual	27/05/2008	251	Actual
24/06/2008	26	Actual	24/06/2008	312	Actual	25/06/2008	240	Actual
22/07/2008	105	Actual	22/07/2008	266	Actual	22/07/2008	200	Actual
22/08/2008	124	Actual	23/08/2008	317	Actual	23/08/2008	267	Actual
23/09/2008	98	Actual	24/09/2008	245	Actual	24/09/2008	313	Actual
24/10/2008	104	Actual	27/10/2008	244	Actual	27/10/2008	259	Actual
21/11/2008	110	Actual	25/11/2008	168	Actual	25/11/2008	251	Actual
23/12/2008	90	Actual	23/12/2008	162	Actual	23/12/2008	223	Actual
25/01/2009	95	Actual	27/01/2009	254	Actual	27/01/2009	166	Actual
21/02/2009	225	Actual	21/02/2009	202	Actual	21/02/2009	351	Actual

Appendix 3. Raw data on Temperature and Relative Humidity from the Meteorological Dept.

Parameter Name	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature; daily maximum	2004	27.3	27	27.9	25.6	25.5	23.6	25.1	24.6	27.2	26.9	25.5	25.8
Temperature; daily maximum	2005	27.6	29	28.6	27.2	25	23.1	22.5	23.6	26.1	27.6	26.1	28.8
Temperature; daily maximum	2006	27.9	29.2	27.7	24.8	24.6	24.5	22.5	25	25.1	27.7	24.3	24.8
Temperature; daily maximum	2007	25.1	28.1	30	26.3	N/R	N/R	N/R	N/R	27.7	26.7	25.7	25.6
Temperature; daily maximum	2008	26.8	27.1	27.4	24.8	24.5	23.2	22.5	24	26.8	26.4	26.3	28.1
Temperature; daily maximum	2009	27.8	28.3	29.1	27.4	25.4	25						
Temperature; daily minimum	2004	14.8	14.9	14.6	15.4	14.4	11.4	9.9	11.3	13	14.6	15.1	14.7
Temperature; daily minimum	2005	13.8	14.2	15.3	15.3	15	13	11.1	12.2	12.8	13.6	14.7	13.9
Temperature; daily minimum	2006	13.7	14.2	15.7	15.4	14	12.1	12.3	12	12.5	14.5	15.5	15.6
Temperature; daily minimum	2007	14.9	13.6	14.7	15.1	14.3	12.6	11.7	13.5	13.2	14.2	14.9	14.3
Temperature; daily minimum	2008	13.3	13.1	14.4	14.4	13.1	N/R	N/R	N/R	N/R	N/R	15.2	14.2
Temperature; daily minimum	2009	13.9	14.1	14.4	15.4	15.2	13.7						
Relative humidity at 6am	2004	79	80	77	88	85	79	77	77	75	77	82	84
Relative humidity at 6am	2005	70	67	79	80	85	86	82	82	73	71	80	67
Relative humidity at 6am	2006	72	69	81	87	85	80	81	80	76	70	89	86
Relative humidity at 6am	2007	83	73	76	85	85	82	83	83	77	76	83	75
Relative humidity at 6am	2008	77	75	82	87	81	81	83	78	74	78	82	72
Relative humidity at 6am	2009	69	79	74	79	83	82						
Relative humidity at 12noon	2004	47	44	40	58	55	51	40	44	37	45	49	50
Relative humidity at 12 Noon	2005	36	33	39	44	62	57	55	52	40	34	47	35
Relative humidity at 12 Noon	2006	36	33	42	63	59	48	53	45	47	36	61	58
Relative humidity at 12 Noon	2007	54	40	39	54	59	51	55	53	41	38	47	45
Relative humidity at 12 Noon	2008	40	37	43	50	51	50	54	49	40	44	52	36
Relative humidity at 12 Noon	2009	39	37	31	43	54	46						

N/R - Represents No Record that means due to unknown circumstances observations were not carried out.

Appendix 4. Raw data on wind speeds at JKIA from Meteorological Department

Year	Month	0000 - Midnight	0600 AM	12 Noon
2004	1	2.26	5.45	10.35
2004	2	2.82	4.61	9.50
2004	3	3.71	5.13	9.10
2004	4	2.70	3.33	7.23
2004	5	1.32	2.23	5.19
2004	6	1.27	2.60	4.57
2004	7	1.74	2.19	4.16
2004	8	3.06	3.68	4.90
2004	9	4.07	3.20	6.47
2004	10	4.00	4.84	8.29
2004	11	4.53	5.60	8.30
2004	12	3.23	6.35	10.77
2005	1	3.00	3.93	8.37
2005	2	3.18	6.07	9.96
2005	3	3.52	4.53	8.68
2005	4	3.27	3.77	7.80
2005	5	2.97	3.77	5.77
2005	6	2.60	3.53	4.60
2005	7	3.03	4.42	6.48
2005	8	2.61	3.94	5.90
2005	9	3.23	3.80	9.60
2005	10	7.55	4.94	11.77
2005	11	6.10	10.23	14.17
2005	12	5.35	11.74	15.00
2006	1	5.03	10.42	17.55
2006	2	4.54	9.68	17.36
2006	3	4.19	5.42	13.03
2006	4	2.93	4.23	10.67
2006	5	2.77	3.39	6.45
2006	6	2.50	4.93	7.20
2006	7	2.61	3.97	8.00
2006	8	3.13	3.87	8.74
2006	9	3.93	4.67	8.43
2006	10	5.58	4.19	10.00
2006	11	4.50	5.47	10.13
2006	12	5.19	5.71	9.26
2007	1	4.24	7.19	10.45
2007	2	4.15	5.33	12.11
2007	3	4.65	7.17	12.65
2007	4	5.79	5.63	10.23
2007	5	3.97	4.79	7.94
2007	6	3.76	5.07	6.23
2007	7	4.37	4.77	6.16
2007	8	4.10	4.77	6.94
2007	9	4.34	4.90	7.66
2007	10	6.80	6.50	11.61
2007	11	6.43	8.83	13.40
2007	12	5.10	7.71	12.32
2008	1	4.67	7.62	12.37
2008	2	4.33	7.00	11.80
2008	3	5.31	6.92	12.33
2008	4	4.95	5.88	10.19
2008	5	4.53	4.91	8.61
2008	6	4.38	5.19	7.50
2008	7	5.61	5.97	7.22
2008	8	4.74	5.40	6.64
2008	9	5.10	4.79	8.90
2008	10	6.65	5.71	8.17
2008	11	5.83	8.70	10.57
2008	12	5.48	9.84	12.52
2009	1	5.16	9.06	12.81
2009	2	5.54	8.33	14.21
2009	3	5.34	7.07	13.00
2009	4	5.07	5.71	11.43
2009	5	5.47	6.67	8.74
2009	6	3.91	5.09	7.41

Appendix 5. Author's meter reading data for validation purposes

House No.	Meter No.	Start		February		March		April	
		Reading	Date	Reading	Date	Reading	Date	Reading	Date
521	257834			71574	28.2.09	71756	28.3.09	72012	6.5.09
531	20051955	29079	14.2.09	29154	27.2.09	29284	28.3.09	29546	3.5.09
541	250163	53606	14.2.09	53662	28.2.09	53779	29.3.08	53923	2.5.09
541ext	9340162	13159	14.2.09	13184	28.2.09	13242	29.3.09	13306	2.5.09
551	9931371	14778	14.2.09	14848	27.2.09	15008	28.3.09	15185	1.5.09
571	250372	90143	14.2.09	90374	28.2.09	90576	28.3.09	90944	2.5.09
581	9925855	17749	14.2.09	17758	28.2.09	17955	28.3.09	18192	2.5.09
375	20115745	4230	14.2.09	4246	28.2.09	4291	28.3.09	4365	2.5.09
385	20203773	25482	14.2.09	25599	28.2.09	25843	28 3.09	26145	2.5.09
395	20055390	12584	14.2.09	12644	28.2.09	12770	28.3.09	12928	1.5.09
405	20204936	17101	14.2.09	17186	28.2.09	17382	28.3.09	17559	1.5.09
405 ext	378868	30260	14.2.09	30345	28.2.09	30520	28.3.09	30706	1.5.09
415	228203	79929	14.2.09	79952	28.2.09	80004	28.3.09	80086	2.5.09
425	20125234	4304	14.2.09	4356	2.3.09	4465	29.3.09	4606	2.5.09
183	9845842	28770	14.2.09	28912	28.2.09	29164	28.3.09	29518	2.5.09
213	106805	445	14.2.09	513	28.2.09	650	28.3.09	812	2.5.09
223	137428	88124	15.2.09	88215	28.2.09	88381	28.3.09	88591	2.5.09
233	214974	78641	15.2.09	78713	28.2.09	78845	28.3.09	79056	1.5.09
243	193481	77938	15.2.09	78008	28.2.09	78120	28.3.09	78311	2.5.09
277	176975	73110	15.2.09	73210	28.2.09	73417	28.3.09	73644	2.5.09
287	192772	9041	14.2.09	9070	28.2.09	9126	28.3.09	9187	1.5.09
297	47617	1519	14.2.09	1651	28.2.09	1919	29.3.09	2189	1.5.09
317	178690	19973	14.2.09	20116	28.2.09	20363	28.3.09	20686	2.5.09

Appendix 5 (cont'd). Author's meter reading data for validation purposes

House No.	Meter No.	May		June		July	
		Reading	Date	Reading	Date	Reading	Date
521	257834	72146	29.5.09	72269	27.6.09	72431	1.8.09
531	20051955	29719	29.5.09	29879	27.6.09	30086	1.8.09
541	250163	54055	29.5.09	54178	27.6.09	54335	1.8.09
541ext	9340162	13362	29.5.09	13413	27.6.09	13478	1.8.09
551	9931371	15341	29.5.09	15481	27.6.09	15675	1.8.09
571	250372	90944	29.5.09	91227	27.6.09	91530	1.8.09
581	9925855	18412	29.5.09	18609	27.6.09	18907	1.8.09
375	20115745	4411	29.5.09	4447	27.6.09	4496	1.8.09
385	20203773	26415	29.5.09	26669	27.6.09	26196	1.8.09
395	20055390	13056	29.5.09	13169	27.6.09	13315	1.8.09
405	20204936	17761	29.5.09	17971	27.6.09	18244	1.8.09
405 ext	378868	30860	29.5.09	31006	27.6.09	31186	1.8.09
415	228203	80128	29.5.09	80172	27.6.09	80216	1.8.09
425	20125234	4699	1.6.09	4791	30.6.09		1.8.09
183	9845842	29691	29.5.09	29856	27.6.09	30063	1.8.09
213	106805	880	29.5.09	959	27.6.09	1086	1.8.09
223	137428	88777	1.6.09		27.6.09	89154	1.8.09
233	214974	79240	29.5.09	79407	27.6.09	79605	1.8.09
243	193481	78493	29.5.09	78680	27.6.09	78890	1.8.09
277	176975	73811	29.5.09	73977	27.6.09	74160	1.8.09
287	192772	9196	29.5.09	9196	27.6.09	9249	1.8.09
297	47617	2429	29.5.09	2669	27.6.09	2975	1.8.09
317	178690	20922	29.5.09	21162	27.6.09	21470	1.8.09

Appendix 6. KPLC's meter reading data for validation purposes

Reading Date	Meter No.	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09
27/01/2009	47617	1351	1571	1867	2086	2422	2634	2891	3116
27/01/2009	192772	9001	9053	9117	9169	9196	9196	9226	9302
25/01/2009	20203773	25232	25527	25793	26031	26374	26634	26834	26998
25/01/2009	20055390	12479	12604	12747	12881	13038	13155	13273	13406
25/01/2009	20204936	16953	17131	17351	17541	17731	17946	18165	18398
30/01/2009	257834	71352	71552	71736	71950	72132	72283	72422	72537
30/01/2009	20051995	28967	29138	29296	29473	29700	29897	30073	30226
30/01/2009	250163	53544	53649	53764	53884	54037	54195	54326	54432
30/01/2009	9340162	13130	13179	13234	13288	13355	13418	13474	13523
30/01/2009	9931371	14684	14834	14991	15130	15325	15450	15665	15765
30/01/2009	250372	90135	90322	90532	90794	90994	91273	91530	91867
30/01/2009	9925855	17749	17753	17935	18119	18388	18631	18891	19110
27/01/2009	176975	72943	73145	73379	73573	73805	73952	74105	74262
27/01/2009	178690	19682	20033	20322	20578	20860	21132	21391	21635
25/01/2009	378868	30132	30288	30490	30654	30841	30990	31133	31301
25/01/2009	20125234	4097	4322	4412	4558	4651	548	4796	4982
25/01/2009	228203	79879	79939	79993	80063	80123	80166	80204	80236
25/01/2009	20115745	4194	4235	4283	4342	4406	4443	4489	4520
29/01/2009	106805	329	489	630	812	880	959	1083	1145
29/01/2009	9845842	28601	28856	29134	29453	29691	29864	29984	30232
29/01/2009	137428	87669	88176	88358	88551	88766	88942	89122	89287
29/01/2009	214974	78547	78685	78836	79007	79240	79415	79579	79741
29/01/2009	193481	77856	0	78109	78270	78494	78704	78867	78999

Appendix 7. Data errors report on sample households

	House No.	Meter No.	Zero Consumption	No.	Estimated Consumption	No	Major Observation
Phas 5	521	257834	May-05	1	Nov 04, Feb 05, Mar 05, Apr 05, Jun 05, Jul 05	6	41.67% of Year 2005 Consumption estimated
	531	2005195	Nil	0	Nov 04, Dec 04, Jan 05, Jun 05, Nov 05, Dec 05, Mar 06	7	33.33% of Year 2005 and 16.67% of year 2004 consumption estimated
	541	250163	Nil	0	Nov 04, Dec 04, Jan 05, Jun 05, Jul 05, Aug 05	6	33.33% of Year 2005 and 16.67% of year 2004 consumption estimated
	541 ext	9340162	Apr 05, May 05, Sep 05, Oct 05	4	Nov 04, Dec 04, Jan 05, Jun 05, Jul 05, Aug 05	6	33.33% of Year 2005 and 16.67% of year 2004 consumption estimated
	551	9931371	Nil	0	Nov 04, Dec 04, Jan 05, Jun 05, Jul 05, Aug 05	6	33.33% of Year 2005 and 16.67% of year 2004 consumption estimated
	571	250372	Nil	0	Nov 04, Jan 05, Feb 05, Jun 05, Mar 06	5	25% of Year 2005 consumption estimated
	581	9925858	Nov 08, Dec 08, Jan 09	3	Nov 04, Dec 04, Jan 05, Jun 05,	4	16.67% of year 2004 and 2005 consumption estimated
Phase 4	375	20115745	Nil	1	Dec 04, Jan 05, Feb 05, Mar 05, Apr 05, Jun 05,	5	41.67% of year 2005 consumption estimated
	385	20203773	Nil	0	Dec 04, Jan 05, Feb 05, Apr 05, Jun 05, Aug 05, Feb 06, Mar 06, Mar 07	9	41.67% of year 2005 consumption estimated
	395	20055390	Nil	0	Dec 04, Feb 05, Apr 05, Jan 06	4	16.67% of year consumption estimated
	405	20204936	Aug-04	1	Dec 04, Feb 05, Apr 05, Jul 05	4	25% of Year 2005 consumption estimated
	405 ext	378868	Aug 04, Nov 04	2	Dec 04, Feb 05, Apr 05, Jul 05	4	25% of Year 2005 consumption estimated
	415	228203	Nil	5	Apr 04, Dec 04, Feb 05, Mar 05, Apr 05, May 05, Jun 05, Nov 05, Dec 05	10	58.33 % of Year 2005 and 16.67% of year 2004 consumption estimated
	425	20125234	Feb, Mar, May, Jun, Aug, 04; Oct 06, Nov 06; Sep 07, Jan 08, Feb 08	11	Jul, Sep, Oct, Nov, Dec 04; Feb, Mar, Apr, Jun, Jul, Aug, Nov, Dec 05; Jan-Aug, Dec 06; Mar-Aug 07, Jan 07, Oct 07	32	53.33 % of all the consumption data collected estimated and 18.33% of all the data is zero consumption
Phase 3	183	9845842	Nil	0	Nov 04, Feb 05, May 05, Aug 05, Nov 05	5	33.33% of Year 2005 and 16% of year 2004 consumption estimated
	213	106805	Sep-05	1	Oct, Nov, Dec 04; Feb, Mar, Apr, May, Jun, Jul, Aug, Nov, Dec 05; Jan, Feb, May 06	14	75% of Year 2005, 25% of year 2006 and 16% of year 2004 consumption estimated
	223	137428	Nil	0	Nov 04, Feb 05, Apr 05, May 05, Dec 05, Apr 06, Oct 08	7	33.33% of Year 2005 and 16% of year 2004 consumption estimated
	233	214974	Nil	0	Oct 04, Feb, Apr, May, Sep, 05, Feb, Mar, May 06; Apr 07	9	33.33% of Year 2005 and year 2006 consumption estimated
	243	193481	Nil	0	Oct 04; Feb, Mar, Apr, May, Jun, Aug, Oct 05; Jan, May 06; Feb 09	10	58.33% of Year 2005 consumption estimated
Phase 2	277	176975	Nil	0	Dec 04; Feb, Mar, May 05	4	25% of Year 2005 consumption estimated
	287	192772	Apr 05, Jun 05, Mar 06, Dec 06	4	Dec 04; Feb, Mar, May, Dec 05; Jan, Feb 06, Oct 08	7	50% of Year 2005 consumption estimated/zero, 25% of year 2006 estimated/zero
	297	47617	Nil	0	Dec 04; Feb 05	2	
	317	178690	Jun-04	1	Nov-04	1	

Appendix 8. Households' appliance ownership and usage survey results

Household No.		1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20
Appliance/End-use																				
Lamps/Lighting	Ownership	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
	Usage	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v
Refrigerator	Ownership	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	X	v	v
	Usage	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	X	v	v
TV/Video	Ownership	v	v	v	v	v	v	X	v		v	v	v	v	X	v	v	v	v	v
	Usage	v	v	v	v	v	v	X	v		v	v	v	v	X	v	v	v	v	v
Video/DVD (30W)	Ownership	v	v	v	v	v	v	X	v	v	v	v	v	v	X	X	v	v	v	v
	Usage	v	v	v	v	X	v	X	v	v	v	v	v	v	X	X	v	v	v	v
HIFI (10W)	Ownership	v	v	X	v	v	v	v	v	v	v	X	v	v	v	X	v	X	v	v
	Usage	v	v	X	X	v	v	v	v	v	v	X	v	X	v	X	v	X	v	v
PC Desk top (200W)	Ownership	X	X	X	X	v	v	v	v	v	X	X	v	v	v	v	v	X	X	v
	Usage	X	X	X	X	v	v	v	v	v	X	X	v	v	v	v	X	X	X	v
PC Laptop	Ownership	X	v	X	v	X	v	X	v	v	v	X	X	v	X	X	X	X	X	v
	Usage	X	v	X	v	X	v	X	v	v	v	X	X	v	X	X	X	X	X	v
Iron box (1000W)	Ownership	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	X
	Usage	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	X
Fan - Cooling (120W)	Ownership	X	X	X	X	X	X	X	X	X	v	X	X	v	X	X	X	X	X	X
	Usage	X	X	X	X	X	X	X	X	X	v	X	X	X	X	X	X	X	X	X
Room Heater (500W)	Ownership	v	X	X	X	X	X	X	v	v	X	X	X	v	X	X	v	X	X	X
	Usage	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Shaver	Ownership	X	X	X	v	X	X	X	v	X	X	X	X	X	X	X	X	X	X	v
	Usage	X	X	X	v	X	X	X	v	X	X	X	X	X	X	X	X	X	X	v
Hair Drier	Ownership	v	v	X	X	X	X	X	X	v	X	X	X	v	X	v	X	X	X	X
	Usage	X	v	X	X	X	X	X	X	v	X	X	X	v	X	v	X	X	X	X
Cooker	Ownership	v	v	v	v	v	v	v	v	v	v	v	v	X	v	v	X	X	X	v
	Usage	X	v	X	X	X	X	X	X	X	v	X	X	X	X	X	X	X	X	v
Water Heater - Geyser/Instant Shower	Ownership	v	v	X	X	v	v	v	v	v	X	v	v	v	v	v	v	X	X	X
	Usage	v	v	X	X	X	X	X	v	X	X	X	X	v	X	X	X	X	X	X
Water Heater - Kettle	Ownership	v	X	v	X	X	v	X	X	X	v	v	X	X	v	X	X	X	v	v
	Usage	v	X	v	X	X	v	X	X	X	v	v	X	X	v	X	X	X	v	v
Bosster Pump	Ownership	v	v	X	X	X	X	X	X	X	X	X	X	v	X	X	X	X	X	X
	Usage	v	v	X	X	X	X	X	X	X	X	X	X	v	X	X	X	X	X	X

Appendix 9. Household Appliance Ownership and Usage Survey Interview Schedule

UNIVERSITY OF NAIROBI

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

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STUDY ON DOMESTIC ELECTRICITY DEMAND AND CONSUMPTION PATTERNS

ELECTRICITY USE SURVEY SCHEDULE

1. House Hold Details

House Number	
Phase	
Resident Name/ Interviewee (where applicable)	
Interviewer (where applicable)	
Date	
No. of Bedrooms	
No. of people who normally reside in the house – ***when schools are open***	
No. of people who normally reside in the house – ***during school holidays***	
When did you start residing in this House? (provide year, and month if possible)	

2. Electric Lighting - Lamps and Usage Duration

Please indicate the number of lamps and estimated hours used per day. (*NB: If it is difficult to get the watts of each lamp/bulb, just provide the total number in the house and leave other rows blank)*

	Number	**Daily Usage (Hours/day)**
Normal (incandescent filament) Bulbs 25W		
Normal (incandescent filament) Bulbs 40W		
Normal Bulbs (incandescent filament) 60W		
Normal Bulbs (incandescent filament) 75W		
Normal (incandescent filament) Bulbs - other		
Total Number of Normal Bulbs		
Fluorescent tubes 36-40W		
Fluorescent tubes 56-75W		
Fluorescent tubes 18-20W		
Total Number of Fluorescent tubes		
Energy Saving Bulbs 11W and below		
Energy Saving Bulbs 12-15W		
Energy Saving Bulbs 16-20W		
Energy Saving Bulbs 21W and above		
Total Number of Energy Saving Bulbs		
.....		
.....		
.....		

.....		

NB: The blank rows are left for you to add any other type of bulbs/lamps you may be having in the house.

When did you start using **Energy Saving Bulbs** (indicate year and month)?
.....

3. Other Electrical Appliances and Usage Duration

Below is a list of other household electric appliances commonly used in households. Please indicate the number of such appliances used in your house and provide an estimate the number of hours each appliance is used per day under normal usage. (*If it is difficult to get the watts of an appliance leave the space blank. Also leave row blank if appliance is not used in your house)*

Appliance	**Number**	**Daily Usage (hours/day)**	**Power Rating (watts)**
Refrigerator			
TV (Colour)			
TV (Black&White)			
Video/DVD			
HiFi Music System			
Radio			
Computer (desk top)			
Printer (for computer)			
Computer (Laptop)			
Iron Box			
Fan (table/Floor/ceiling Fan)			
Fan Heater			
Water booster pump			
Shaver unit			
Hair Dryer			
.....			
.....			
.....			
.....			

NB: The blank rows are left for you to add any other appliances you may be using in the house.

4. Cooking and Heating

IF YOU USE electricity for cooking and Heating please indicate the type of appliance used and when (year) you started using it and estimated hours of use per day? *(Tick in the box where applicable and indicate year and estimated hours it is used per day)*

	Tick if applicable	**Year**	**Daily Usage (Hours/day**
Cooking (table top hot plate/coil)			
Cooking (Stand alone electric cooker)			
Heating Water (using Geyser/Hot water cylinder)			
Heating Water (instant Shower)			
Heating water (electric Kettle)			
Room fan Heater			
.....			
.....			
.....			

If you DO NOT USE electricity, what do you use for:-

a) Cooking (tick the one applicable)?

Paraffin.....; Charcoal; ....., Cooking Gas ....

Other(indicate) .....

b) Heating Bathing Water?

Paraffin.....; Charcoal .....; Cooking Gas .....;

Solar .....; Other (Indicate) .....

c) If you were INITIALLY USING ELECTRICITY for either cooking or water heating, when (indicate year) did you change to the new fuel for:

- Cooking? .....
- Water Heating .....

RESEARCHER: ..... **DATE:**

.....

Eng. Kiremu Magambo

0722 306 276

APPRECIATION

Completing this form entitles you to 3 Energy Saving Bulbs, free of charge. Please indicate (tick) below the type of lamp holder you use in you house so that you get a suitable bulb suitable.

Screw type? .....

Pin type? .....