ELECTRICITY CONSUMPTION IN LEARNING INSTITUTIONS: THE CASE OF KENYA MEDICAL TRAINING COLLEGE (KMTC)

Peter K. Tum
Master of Science in Energy Management, University of Nairobi, Kenya

Patrick Mutinda
Master of Science in Electronics and Instrumentation, Kenyatta University, Kenya

ABSTRACT

Learning institutions consume a significant portion of the total tertiary electricity and hence could contribute to energy saving in Kenya if the right energy saving measures are put in place. For evidence-based design of such policies, it is important to understand the reasons behind the dynamics of the electricity consumption and its structure. According to the researcher’s investigation, there has neither been a research-focused targeted project aimed at monitoring electrical energy consumption nor an economical level of per capita consumption in learning institutions in Kenya. The main purpose of this survey was to determine overall energy consumption in learning institutions, a case study of Kenya Medical Training College (KMTC) and to explore modalities of ensuring reduced energy consumption for such institutions. The research focused on five campus as a representative of all the 30 campuses. Results from this study show that the five sampled institutions consumed a total of 2,158,799 KWh which cost the college approximately KSh. 35,836,063. Specifically, this work presented the design and implementation of a microcontroller based power monitoring system to allow for reduction of electrical consumption at KMTC-Nairobi and consequently reduce the per capita consumption. The monitoring system was implemented using a single chip MC68HC908 microcontroller to control the switch ON/OFF of lights depending on the level of illumination in the room. Approximately 27.7% power savings in electricity consumption was achieved by the use of this system. The study also experimented on the use of high efficiency lights instead of the conventional ones. Results showed that 7.8% energy saving was achieved. The overall energy saved by instituting these two measures was 35.5%. Other energy saving opportunities were explored in the study and recommendations presented.

Key Words: electricity consumption, learning institutions, Kenya Medical Training College (KMTC)

INTRODUCTION

With the beginning of the industrial age human activities have influenced more and more the global environmental equilibrium and as a matter of fact the industrial development has also led to a deterioration of the quality of people’s lives. Many interventions have become necessary on world scale in order to reverse the trend. These interventions include strategic and political decisions which are supported by technical decisions connected to the specific field or sector in which they are applied.

The general purpose which has steered the interventions is the concept of sustainable development which is not only about the environment, but also economy and society as well (Brundtland Report, 1987). Sustainable Development encourages conservation and preservation of natural resources and of the environment and management of energy for the obvious reason of enhancing the well-being of humans through improvement of health and alleviation of poverty.
Energy management is a systematic on-going strategy for controlling a building’s energy consumption pattern. It is meant to reduce waste of energy and money to the minimum permitted by the climate where the building is located, its functions and other factors. The value of energy management in institutions in a wider sense can be described as a way of improving the energy efficiency in an existing building by continuously striving towards decreased energy consumption. This includes operating and maintaining the building in a way that sustains the energy efficiency gains achieved. The use of energy in buildings has increased in recent years due to the growing demand of energy used for heating and cooling in buildings. Energy efficiency is a prime consideration for all lighting professionals with the reasons being a threat from climate change, sustainability of energy supplies, burning of fossil fuels as well as rapidly increasingly costs (Loe D. 2009).

Lighting is a major contributor to the energy costs in both commercial and residential buildings. Energy is considered of great importance due to its role in reflecting the economy, the people’s welfare and the level of living. Also, energy data reflect infrastructure situation. Undoubtedly, availability of reliable statistical data on energy consumption is a major input in planning and development process.

Consumption of electrical energy in the tertiary sector is ever increasing. An increase of more than 2% per year is expected during the next 15 years. This sector includes companies and institutions of public and private services with heterogeneous economic and energy-related characteristics. Building managers and decision-makers may not be adequately aware of the potential benefits of putting in place structures that save on energy.

Within the Intelligent Energy projects carried out in institutions, an overview of existing studies showed that the availability of disaggregated data on electricity consumption and its use by purpose (lighting, office equipment, ventilation, air conditioning, etc.) is poor. The methods of determining the types of end use are weak; most studies are based on calculations and estimations, only a few on measurement. Moreover, saving on energy consumption is not a high priority item in most colleges, and other related institutions in Kenya, such that even the most low-hanging fruits for reducing energy consumption are often not picked up. Instead, priority is given to renovations and new constructions often leading to an increase in energy consumption because more new appliances are installed (Glennie W L et al, 1992). Although the more recently constructed facilities in colleges have more efficient electronic equipment, including liquid crystal display (LCD) monitors and florescent tubes and compact fluorescent lamps (CFLs), they are also characterized by the highest energy consumption due to the elevated number of computers and office equipment, as well as additional comfort elements, such as air conditioning and vending machines. Of importance to note also is the fact other than saving on cost, efficient use of electrical energy has a positive bearing on environment. Saved energy means less demand on generation and hence, less use of energy sources that harm the environment.
The last three decades has seen tremendous growth of urban population in Kenya. Nairobi which is the capital city has had its population increased by half in the past three years. This indicates that the current energy consumption in urban areas particularly in learning institutions has become considerably high and is expected to rise further in the near future. The present energy demand is almost five times larger than that of 1980’s (Karekezi, 1997). Hence, it is essential to attain the energy saving objectives in social institutions.

The emission cut from the use of air-conditioners in commercial and other residential areas could be effectively carried out through energy saving efforts by maximizing the use of natural ventilation. Therefore, the importance of natural ventilation has been increasingly revaluated partly due to the recent needs of energy saving. A number of studies related to natural ventilation in buildings have been carried out over the last few decades, for example the field survey of thermal comfort in natural ventilated buildings (Raja et al 2001).

Consumption is the total amount of electricity used during any given billing period. The amount of electricity required to keep an electric light bulb illuminated for an hour is an example of consumption (Karekezi, 1997) and the KWh (kilo-Watt-hours) is the unit in which electricity is typically measured. When the light is turned off, electricity is no longer being consumed. The amount of consumption is determined by a utility meter that records this item. Electrical demand portion of an electric bill is another specific part of the billing and is measured on a separate utility company demand meter. The monthly demand charge is based on the maximum amount of power used within any given 15 or 30 minute interval during the usual 30 day billing period. The intent of the utility company is to be adequately paid for the electrical generating equipment that must be in operation in order to meet these demand requirements of its users. Even when not in use, this electrical generating equipment must still be paid for, maintained, and ready for instant use by the utility company. More simply stated, any user not only pays for the amount of electricity it consumes, but also a demand charge for the highest amount of electricity used during a given period.

Kenya Medical Training College

Kenya Medical Training College which is under the Ministry of Medical Services is responsible for training middle level personnel for the health care system in Kenya. With a total of 30 campuses spread out in the republic, the college boasts of a student population of 25000. The headquarter of the college is within Nairobi campus and is situated about three kilometers North of Nairobi City Center, opposite Kenyatta National Hospital, along Old Mbagathi Road. The size of a campus is largely determined by the student population. Nairobi campus with 14 departments and a student population of 3000 is the largest, followed by Nakuru campus with a student population of 1200, , Kisumu 1000, Nyeri 980 and Mombasa 950. The researcher aimed at studying energy consumption in Nairobi campus to determine its actual energy consumption, device a practical solution besides recommending other faceable measures to save energy.
Electrical power in the college is mainly used in lighting, normal computer operations and running laboratory, workshop, air conditioning, office and other teaching equipment as well as running water pumps.

**STATEMENT OF THE PROBLEM**

Many organizations worldwide are faced with the challenge of cutting down on the cost of both electricity and water consumed. The high cost per unit of electricity has been largely attributed to inflation as well as climate change. Changes in weather patterns has adversely affected water levels in dams where hydroelectricity is generated forcing people to supplement with more expensive alternative sources of energy such as diesel engines, solar power and geothermal. While there has been considerable research in areas such as the energy consumption per capita for different countries and also in the field of energy management, energy per capita consumption for individual institutions is largely unexplored. It was therefore important to undertake an empirical study to establish per capita consumption of energy for individual institutions and also determine the extent to which energy-saving measures adopted would cut down on cost of energy consumed. Undoubtedly, availability of reliable statistical data on energy consumption is a major input in planning and development process. This study sought to establish the per capita consumption at KMTC and come up with an appropriate measure to cut down on the use of electricity.

**GENERAL OBJECTIVE**

To establish the energy consumption in learning institutions, precisely in Kenya Medical Training College (KMTC)

**SPECIFIC OBJECTIVES**

1. To determine energy consumption (per capita consumption) in KMTC
2. To determine the potential of energy saving measures in KMTC
3. Carry out a cost-benefit analysis of implementing energy saving measures and determine their payback period

**LITERATURE REVIEW**

**Electrical Energy**

Energy is a critical input to the social-economic development of any nation as well as to the protection of the nation’s environment. It fuels industry, commerce, transportation, agriculture and other economic activities. This substantial dependence on energy in practically all aspects
makes its efficiency of great importance to all of us. Energy efficiency is broadly defined as decreasing the amount of energy consumed per energy service without substantially affecting the level of these services or more simply the amount of energy used to accomplish the same task.

The idea and practice of energy efficiency is not new and has been with us for a long time. A number of factors have however brought to the fore the importance of and urgency for energy efficiency. These include the energy prices, the insecurity of energy supply, and concern about adverse environmental and health impacts and unease over the rate at which the major energy resources are being depleted. The energy crises, the oil shocks of the 1970’s occasioned by sudden sharp increase in the price of petroleum and its products had devastating impacts on the economies of many countries, both developed and developing, but in particular the latter. The continuing increase in the price of energy has significantly contributed to the increased interest in energy efficiency.

Energy shortage is one of today’s major problems. Undoubtedly, availability of reliable statistical data on energy consumption is a major input in planning and development process. Most countries pay special attention for providing statistics on energy due to the important role of energy in reflecting the situation of the infrastructure, economic situation and the level of living standards of a society. Energy statistics provide basic information on economic situation, environmental indicators and the level of living in the society.

The world experience

In the wake of growing awareness and appreciation of the importance of improved management of energy, many countries, both developed and developing, have in recent decades put in place measures to this end resulting in considerable energy savings. Many have developed and are implementing policies that specifically address energy efficiency, and also feature the establishment of appropriate institutions towards the enactment, as well as realization of suitable legislation. Within the developing countries, the actions taken by India and Thailand provide good examples of the extent of their commitment in this regard.

The Government of India, in recognition of the importance and benefits of energy management, enacted the Energy Conservation Act, 2001, which came into force in March 2002. Under the provision of the Act, India established the Bureau of Energy Efficiency whose mission is to institutionalize energy efficiency services, enable delivery mechanisms in the country and provide leadership to key players involved with energy efficiency. The broad objectives of the bureau are to provide a policy frame work and direction to national energy conservation activities, coordinate policies and programmes on efficient use of energy with stakeholders, establish systems and procedures to verify, measure and monitor energy efficiency improvements, leverage within multilateral, bilateral and private sectors the energy conservation Act 2001 and demonstrate energy efficiency delivery through public private partnership.
In Thailand, the energy Conservation Promotion Act, comprising of regulation, promotion and penalty measures, has been promulgated since 1992. On the basis of the Act, the government has restructured executing agencies to implement an energy conservation programme which includes compulsory energy conservation in designated facilities, establishment of an energy conservation fund, financial incentives for energy efficiency, development of energy efficiency standards and institutional development, public relations and a comprehensive training programme.

Energy consumption survey in Canadian universities

In 2004, Statistics Canada undertook, on behalf of the Office of Energy Efficiency (OEE) of Natural Resources Canada, the first Consumption of Energy Survey (CES) for universities, colleges and hospitals. The mandate of Office of Energy Efficiency is to strengthen and expand Canada’s commitment to energy efficiency in order to help address the challenges of climate change. The primary objective of this survey was to gather energy consumption data for universities, colleges and hospitals, as these are key sectors in the development of OEE programs.

According to this survey, in 2003, universities, colleges and hospitals consumed more than 100 million gigajoules (GJ), which equals the average annual energy use by 870 000 Canadian households, or over half of the private dwellings in Toronto. Hospitals accounted for 51 percent of the total energy consumption of all three sectors, compared with 36 percent for universities and 13 percent for colleges. The surveys narrowed down to energy consumption of the university sector. The survey population of university campuses was defined using North American Industry Classification System (NAICS) code 611310 and extracted from a list of university campuses provided by Statistics Canada’s Public Institutions Division, with the university campus as the statistical unit. The survey covered 123 university campuses. Viewed regionally, as follows:- 23 campuses in the Atlantic region, 22 in Quebec, 37 in Ontario, 30 in the Prairies, and 11 in British Columbia and the Territories. Table 1 presents a breakdown of the university energy consumption in gigajoules and by region. In 2003, the universities consumed nearly 37 million GJ, an amount equal to the annual average consumption of approximately 320 000 Canadian households, or of all the private 2003 household dwelling and learning institution.

Table 1: Energy consumption (GJ), 2003 in Canadian Universities

<table>
<thead>
<tr>
<th>Region</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>3,628 427</td>
</tr>
<tr>
<td>Quebec</td>
<td>6,621 471</td>
</tr>
<tr>
<td>Ontario</td>
<td>14,108 302</td>
</tr>
<tr>
<td>Prairies</td>
<td>9,604 469</td>
</tr>
<tr>
<td>British Columbia/Territories</td>
<td>2,960 091</td>
</tr>
<tr>
<td>Total</td>
<td>36,692 2760</td>
</tr>
</tbody>
</table>
Energy Intensity

Energy Intensity in addition to the numbers on energy consumption, the survey collected data on total campus floor area and the number of enrolled students. These data were used for establishing energy intensity ratios. Many factors have a direct bearing on energy intensity. One of the leading factors, the weather, affects energy consumption in different ways across Canada’s regions. Its impact is noticeable especially in regions where heating and cooling account for a significant portion of energy consumption. For example, the Prairies are relatively cooler than British Columbia, and the quantity of energy used for heating in the Prairies is accordingly greater. Energy intensity also depends on the age of the building, the energy source, the physical characteristics of the building, the air-conditioning settings, the floor area, the type of facilities, the degree to which energy conservation measures are implemented, and so forth. Each factor affects the level of energy intensity independently and in its own complex way. In this study, each individual factor is not dealt with. Moreover, none of these factors can alone explain the variations among the energy intensities of the Canadian regions. The average energy intensity of Canadian universities was 2.04 GJ/m². British Columbia and the Territories, and the Atlantic region, had the lowest ratios (1.64 GJ/m² and 1.69 GJ/m², respectively). The universities in Quebec had a ratio of 1.94 GJ/m², compared with 2.19 GJ/m² for Ontario and 2.26 GJ/m² for the Prairies.

The data gathered through this survey can also be used to calculate energy intensity ratios per full-time and part-time university students. These results are presented by region in Figure 2. The average energy intensity for all universities was 49 GJ per student. The region with the lowest ratio was Quebec, with 28 GJ per student, followed by British Columbia and the Territories, with 37 GJ per student, and Ontario with 56 GJ per student. Although the Atlantic region was among the least energy intensive in gigajoules per square meter, it was one of the most energy intensive by this measure, with a ratio of 66 GJ per student. The Prairies had the highest ratio, with 75 GJ per student, more than two and a half times that of Quebec, (Office of Energy Efficiency -OEE).

Greenhouse Gas Emissions

Energy consumption directly affects the rate of emission of Green House Gases (GHG). The survey in the said colleges in Canada did not directly gather data on greenhouse gas emissions. However, for each of the energy sources, an emissions factor can be used to calculate the GHG emissions stemming from the energy consumption of each of the sectors. The quantity of GHG emissions depends not only on total energy consumption, but also on the GHG intensity of each of the energy sources.
Energy Situation in Palestine

Most countries pay special attention to providing statistics on energy. Energy is considered of great importance due to its role in reflecting the economy, the people’s welfare and the level of living. Also, energy data reflect infrastructure situation. Undoubtedly, availability of reliable statistical data on energy consumption is a major input in planning and development process. There is substantial change in the economic structure and energy consumption pattern in Palestine in the last years. The total energy supply is mainly from imported fuel. The utilization of available renewable energy sources like solar, biomass and wind energy is of practical importance for future socio-economic development of the country. The following sections describe the energy situation in Palestine. In general, Palestine is considered one of the poorest countries in terms of energy resources. Energy resources are either dwindling or non-existent. Indigenous energy resources are almost limited to solar for photovoltaic and thermal applications (mainly for water heating), and biomass (wood and agricultural waste) for cooking and heating in rural areas. Potential of wind energy is relatively small but not yet utilized in Palestine. Biogas is also not yet utilized.

All fossil fuels consumed in Palestine are imported from Israel, for electricity generation, heating, transportation, cooking, operation of heavy machinery, etc. In 2002, the West Bank and Gaza Strip imported 7,128,611.1 MWh of energy, including 2,306,962 MWh of electricity, 104 million liters of gasoline, 207 million liters of diesel, 4 million liters of kerosene and 21 metric tons of oils and lubricants (A Abu, 2006). Statistics for energy consumption by sector show the role of the residential sector as the main energy consumer, with 38% of the total consumption in 2005. Energy consumption per capita for the Palestine in 2000 did not exceed 0.3 Toe, which is the lowest in the region. Israel’s per capita energy consumption (3.5 Toe) was more than 10 times greater than the Palestinian consumption level, while that of Jordan and Syria was 3 times superior.

Energy Situation in Kenya

While access to energy in Kenya is still very limited, significant opportunities nevertheless exist for improving energy in all sectors of the economy, including in particular, the industrial sector. In this sector, food, beverages and tobacco, paper and paper products, printing and publishing, chemicals as well as petroleum, rubber and plastic products are among the major consumers of energy. The major users of energy in any of the above mentioned categories are steam and motive power. Energy savings of up to 25 per cent are possible in steam systems, largely by improving the efficiency of steam boilers, better steam distribution and use and recovery of waste heat and condensate. Motor systems, the largest users of electricity in industry, are often oversized, resulting in lower efficiency of operation. Potential savings are of the order of 20-50 per cent through motor system efficiency improvement.
In the year 2004, the industrial sector in Kenya consumed an estimated total of 514 million tonnes of oil equivalent. This constitutes about 18.2 per cent of the total commercial energy consumed in the country in that year. It has been estimated that in the industrial sector, savings in excess of Kshs 2.5 billion are possible. The rate of economic growth in the country has, meanwhile, picked in the period between 2003 and 2006 and is expected to continue at that level or to grow at an even faster rate in the years ahead, with attendant increase in the demand for petroleum and petroleum products (Sessional paper on energy, 2004). All these should set the stage for higher savings in energy consumption in the industrial sector if the necessary measures are put in place. The expected increase in the price of energy too will further enhance the prospect for energy efficiency in the enterprises to look at their energy use critically, potential energy savings exist even in highly efficient, well-managed industrial plants.

Energy management is a key instrument in socio-economic development. At the national level it improves economic competitiveness, reduces the country’s import bill, improves the balance of trade, creates jobs, and thereby reduces poverty. It also improves security of energy supply, a matter of particular interest to Kenya which imports all her petroleum requirements.

The industrial and commercial sector in Kenya are genuinely concerned that the high cost of energy erodes the competitiveness of their products in the local, regional and international markets. Effective energy efficiency measures would result in lower production costs of goods and services and thus improved competitiveness of Kenyan products, higher productivity, increased profits, good prospects for new capacity investment and general strengthening of the manufacturing sector. This would also be reflected in increased job opportunities and generally improved economic activities within the country. Energy efficiency would, moreover, reduce overall demand for energy and thereby defer capital investments needed to provide additional energy supplies. Energy efficiency can play a vital role in the protection of the environment, including the reduction of adverse environmental impacts. These efforts have included arresting energy management systems.

Energy management depends on a holistic and well co-ordinated enterprise-wide effort, without proper attention to its coordination; an energy management programme will not succeed. To start with, every person within the organization needs to be involved. Consensus should be developed that the project is well worth the effort. The close participation of all staff in the design and implementation of the project is crucial to its success. Their involvement, however, must be structured, purposeful and well planned.

**Day lighting Control**

Lighting energy is essential in all buildings and more importantly in learning institutions. There is much evidence to suggest that people find daylight more appealing than artificial lighting and there has been a lot of research carried out to discover if daylight is linked to increases in
productivity performances. Past research supports the notion that daylight is important, with studies finding a direct relationship between higher satisfaction about daylight in an office and increased work. For example (Hedge, 1994) argues that windows provide more light than artificial lighting alone. He also suggests that “increased daylight relates to psychological well being”.

Efficient use of energy can reduce operating costs and have environmental benefits. Daylight is the preferred method for people to work in and studies undertaken show that working in daylight results in less stress and discomfort than working in artificial light. General and visual health becomes more apparent when working under daylight (Markus, 1965), (Heerwagen J et al, 1985).

Substantial energy and cost savings can be made if lighting is controlled correctly to make use of available daylight and to eliminate lighting use when the rooms are unoccupied (Hedge, 2004). Approximately 40-60% of the installed load can be saved when lighting controls are used effectively, (SEI Lighting Guide, 2008). However, even the most efficient lighting control system is wasteful if lighting is in use when it’s not required and this is where intelligent lighting systems play a major role in making cost savings. The environment in which we live and work has two basic elements: the external with which we have little or no control over and the internal, which can be controlled to our specified needs. There are many reasons for installing lighting controls to reduce energy consumption in buildings, providing a healthy environment for employees and reducing greenhouse gas emissions (GHG).

Extensive research has been carried out regarding lighting controls, especially Passive Infrared sensors (PIR’s) and photocells as these two are leading the way for lighting controls in modern office buildings (Hedge, 1994), (Heerwagen J et al, 1986). Lighting controls provide an array of functions such as dimming controls to adjust light output ‘up’ or ‘down’, and can integrate day lighting with artificial lighting to provide flexibility, energy and cost savings and also provide the functions of turning lights ‘on/off’. This may be achieved by either of the following ways.

**Day lighting Control mechanism**

There are a few different methods of occupancy detection such as Passive Infra-Red (PIR), ultrasonic and microwave. Ultrasonic sensors are more sensitive at greater distances than PIR. Both ultrasonic and microwave sensors detect in a sonic manner and they do not require a direct line of sight of a motion source. Presence detection sensor works by detecting the presence of people using PIR. These sensors are used to detect people in an area, sitting at a desk and working quietly, rather than requiring them to actually get up and move around the detection field in order to trigger lights. This makes them ideal for open flat office, corridors and reception areas etc.
**Constant Daylight**

This function causes photocell to sense daylight and to maintain a constant light level in that given space. It can be combined with presence detection to provide a constant lighting load which is switched off when occupancy has ceased. In some cases, on bright sunny days, constant light control can eliminate the need for artificial lighting completely. One major disadvantage with this is that it will not work at night.

**Central off**

Central off is a timing function that switches off forgotten lights. Some advantages of a centralized lighting system are:

1. Remote dimming of lighting within each zone
2. Automatic sequencing control of individual groups of lights
3. Remote status monitoring within the building

It is possible to find many commercial buildings where one measure or another has been undertaken by management to decrease electricity consumption. This thesis will focus on the energy saving potential by integrating the three lighting controls in a building, which may also offer significant benefits for both large and small office type buildings.

A number of reasons why daylighting sometimes does not provide for illumination as required have been mentioned:

1. Under-dimming, which results in less than expected energy savings.
2. Over-dimming, which results in user irritation.
3. Frequent cycling of dimming or switching, resulting in user irritation.
4. Lights left on at night, which results in less than expected energy savings (Di Louie, 2006)

The reasons mentioned above, such as over and under dimming and frequent cycling are very important and arguments as to why the use of daylight to reduce artificial lighting energy sometimes fails more like kinks in the system rather than major problems of the system and can be overcome with the right programming and training. If the proper training and commissioning of a well designed and installed system is achieved, then there is no reason why energy savings cannot be achieved. Indeed that is the central premise of this research.
RESEARCH METHODOLOGY

Research Design

The research design used in this study is descriptive survey method. Descriptive survey is the investigation in which quantitative data is collected and analysed in order to describe the specific phenomenon in its current trends, current events and linkages between different factors with respect to time. The survey method integrates both observational and experimental method of research with the aim of examining a specific sample in order to make statements about the population from which the sample was drawn. A survey was conducted to determine the number of units consumed at KMTC and analysis done to determine its energy per capita consumption.

Area of Study

The study was conducted at Kenya Medical Training College campuses namely Nairobi, Nyeri, Mombasa, Kisumu and Nakuru. These were sampled from 30 KMTC campuses, the sampling criteria being that only campuses with more than 900 students were considered. The study gathered information on electrical consumption, in addition to establishing the different ways electricity was consumed. Electricity in KMTC is mainly used in lighting, powering water pumps, office equipment, and laboratory equipment for student operations.

Implementation

The research was conducted in two phases with the first seeking to establish the energy consumption at KMTC and the second phase seeking to establish the various energy saving measures that if adopted, would cut down power consumed at KMTC. The researcher collected data from energy utility bills for the year 2010 for the sampled KMTC campuses. This data was then used to determine per capita consumption of electrical energy at KMTC. The researcher went ahead to collect utility data in the form of student numbers, lighting points, power rating of equipment and number of equipment in each campus. The researcher recorded monthly consumption of electrical energy from the Kenya power and lighting meters consumed in the same year. The energy monitoring activity was only concerned with the consumption of energy delivered to the college by the energy supplier. The electrical consumption recorded was compared to the per capita consumption level indicated in other research findings and then energy saving measures recommended in order to save on electrical energy consumption. The greatest opportunity identified by the researcher in regard to energy saving was on power used for lighting. The researcher hypothesized that with the over 3000 lighting point at the four sampled campuses, application of selected energy saving measures such as use of power monitoring devices and use of energy saving bulbs would result in a reduction of power used on lighting by approximately 50%. This is because most of the lights would remain off during day
hours where adequate illumination would be experienced as well as at night once the students left the lecture rooms or switched off the lights in the residential areas as they retired to sleep. On concluding the first phase of the survey, the researcher proceeded to determine the electrical energy saving measures within the campuses. The researcher carried out the two main experiments to cut down on electrical consumption:

1. Using a power monitoring system. This involved construction of a microcontroller based power monitoring which is a programmable device that would ensure a constant amount of illumination in a working area.
2. Replacing fluorescent fittings in selected areas of Nairobi campus with the energy saving bulbs.

**Power monitoring system**

The power monitoring system had to have the following features that made it the ultimate product to save on lighting energy consumed at KMTC.

1. It detects the presence of people using Passive-Infra Red (PIR) sensor located at strategic point within the lecture room. PIR was used to detect people in an area, sitting at a desk and working quietly, rather than requiring them to actually get up and move around the detection field in order to trigger lights. This makes them ideal for open flat office, corridors and reception areas etc
2. It has an inbuilt photocell to sense daylight and to maintain a constant light level in a given space.
3. It has timing function that switches off forgotten lights (Central-off system)
4. The device has centralized lighting system that enables remote dimming of lighting within each zone in addition to automatic sequencing control of individual groups of lights.
5. The device is programmable making it easy to adjust to meet user requirements
6. Delay function incorporated within the program ensures switching ON/OFF is gradual to enhance comfort for the occupants in the room and also that life span of lights is not compromised

**Installation**

The researcher identified two adjacent lecture halls and it was assumed their use in terms of occupation, illumination and orientation to sunlight was the same. The rooms also had the same number of lighting points and were supplied from the same meter. A power monitoring system was installed in one of the lecture halls and it was configured such that each of the lighting points was controlled from a specific relay from power controller.
Methods for Collecting Data

The researcher used various methods of collecting data during various site visits to the sampled colleges. The data was logged on excel spreadsheets and analyzed statistically. This facilitated calculation of per capita consumption and payback period. The electricity consumption was logged in KWh on weekly basis.

The system hardware design

The hardware components available for use were selected on the basis of logic family compatibility in addition to current and voltage ratings. Figure 1 shows the block diagram of a microcontroller based power monitoring system.

![Block diagram of the Microcontroller based power monitoring system](image)

Figure 1: Block diagram of the Microcontroller based power monitoring system

The control Section

The control section consists of

1. An analogue to digital converter
2. A microcontroller
3. Digital to analogue converter.
Microcontroller

The microcontroller is the brain of the power monitoring system implemented. The microcontroller selected for this project is the MC68HC908 microcontroller which has high performance architecture. The microcontroller is characterised by an inbuilt analogue to digital (ADC) converter as well as a digital to analogue to digital converter (DAC). The ADC has an 8-bit successive approximation A/D converter with serial and configurable input multiplexers with 8 channels. The 8-bit channel multiplexers are software configured for single ended or differential input as well as channel assignments. The microcontroller is a low cost, high performance, CMOS, and fully static 8-bit. The two-stage insulator pipeline allows all instructors to execute in a single cycle, except for program branches (which require two cycles). It has 128 bytes of RAM, 4,096 bytes of data EEPROM memory and 23 I/O pins. The SLEEP (power-down) mode offers power savings. The user can wake the clip from sleep through several external and internal interrupts and reset. The Input/output (I/O) flexibility makes the MC68HC908 very versatile even in areas where no microcontroller use has been considered before. A full-featured macro-emulator, a software simulator, an in-circuit emulator, a low cost development programmer and a full-featured programmer support this microcontroller. The 23 out port of the microcontroller enables it to independently activate 23 different outputs. More output can be realized by use of Series Input parallel Output chip. In this project it makes it possible to activate or deactivate 23 relays that are normally closed such that it can switch either ON or OFF the 6 lights within the lecture room depending on the level of illumination. The Passive Infrared sensor signals are fed directly to the microcontroller enhancing presence detection. The signal of the PIR can assume state 0 or 1 which will be interpreted as a student(s) is present or absent in the lecture room.

Relay Circuit

The output signal from the microcontroller acts as the input to the relay circuit. To power the solenoid of the relays, we have the mutilated Darlington pair transistors. A Darlington pair consists of two transistors connected together so that the current amplified by the first is amplified further by the second transistor. The overall current gain is equal to the two individual gains multiplied together. All the lights in the room where the power monitoring system is installed are controlled externally from the normal wall switch. Unless this switch is ON, then none of the lights can come on. This has the advantage that even if the PIR detects presence of a student the power monitoring system will not turn on the lights. The other advantage of the power monitoring system is that should the system fail due to unforeseen reason, this would allow for manual switching on and off of the lights. This is because the relays used are normally closed (N/C). The Central Off timing function turns off forgotten lights after a pre-set time when everyone has left the building.
Sensors

Two kinds of sensors were incorporated in this project; these were the Passive Infrared sensor (PIR) and the Light dependent Resistor (LDR). These were implemented by use of current sensing circuit that acted as a transducer that converts current readings to voltage signal. The differential mode was used to sense for current changes in the current sense resistor. It has the advantage of common mode noise rejection and is able to measure low voltage accurately.

Software design

The efficiency of the microcontroller based Power monitoring system heavily depends on the capability of the control algorithm. The program was written in assembly language which has the advantage of being rich in content compared to other programming languages. Simple loop with polling was utilized in developing the program. The controlling device employed in this project is the MC68HC908 microcontroller. It makes use of 35 simple but powerful instruction set. Its two-stage instruction pipeline allows all instructions to be executed in a single cycle except for program branches, which require two cycles. The system control and monitoring program of the power monitoring system consists of the main program and four subroutines for execution. The main programme starts with subroutine to determine whether the wall switch is ON or OFF. If

Figure 2: Schematic diagram of the relay circuit
‘OFF’, the program jumps to the main loop, if ‘ON’, the program then checks for occupancy of the room.

Figure 3: Pictorial representation of the power monitoring system motherboard
Figure 4: Programme flow chart
If presence of student(s) is not detected the program jumps to the main loop but if student is detected the program proceeds to establish the level of illumination via the light dependent resistor (LDR). If the level is to the desired level (preset value) the program jumps to the main loop. If the illumination of the room is not at the desired level the program will opt to either switch ‘ON’ or ‘OFF’ the light(s). The switching ON and OFF of the lights is sequential and incorporates delays to ensure that change in illumination in the room is gradual and comfortable to the occupants as well. This is made possible by use of delay subroutine which ensures there is a time lag between the time two successive lights turn ON or OFF. A counter subroutine used monitors the presence of students in the room. Should the PIR detect that there is no person (no movement). It will count for a set time; say 10 minutes after which all the lights would be turned off (cut-off). The counter subroutine ensures lights that are forgotten remain off thus energy is conserved and also that the life span of bulbs is not compromised. The program flow chart is given in figure 4.

**Energy saving bulbs**

The researcher conducted experiments to establish how replacement of the traditional lights with the compact florescent lights (CFLs) would affect the power consumption at Nairobi Campus.

**Installation of the Compact Fluorescent Lighting**

The more modern Compact Fluorescent Lighting (CFL) technology generates high illumination levels and generates minimal heat. A total of 912 traditional fluorescent fittings were removed and replaced with the CFLs and readings taken for a period of 12 months. The readings were tabulated and compared with those of the previous year. The variance was computed for purposes of determining the energy saved.

**RESULTS AND DISCUSSIONS**

**Electrical Consumptions at KMTC**

The electrical consumption patterns at the KMTC campuses were determined in this section. The researcher started by determining the number of lighting points, number of power points, wattage of electrical equipment used within each campus including water pumps. This information was useful in establishing suitable energy saving measures.
Table 2: information on usage of electricity in KMTC campuses

<table>
<thead>
<tr>
<th>No.</th>
<th>Campus</th>
<th>Number of students</th>
<th>Number of lighting points</th>
<th>Number of power points</th>
<th>Total rating of equipment (W)</th>
<th>Total rating of water pumps (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nairobi</td>
<td>3000</td>
<td>912</td>
<td>147</td>
<td>18752</td>
<td>4675</td>
</tr>
<tr>
<td>2</td>
<td>Mombasa</td>
<td>950</td>
<td>344</td>
<td>54</td>
<td>5709</td>
<td>475</td>
</tr>
<tr>
<td>3</td>
<td>Nyeri</td>
<td>980</td>
<td>415</td>
<td>48</td>
<td>4560</td>
<td>475</td>
</tr>
<tr>
<td>4</td>
<td>Kisumu</td>
<td>1000</td>
<td>376</td>
<td>71</td>
<td>5564</td>
<td>475</td>
</tr>
<tr>
<td>5</td>
<td>Nakuru</td>
<td>1200</td>
<td>501</td>
<td>85</td>
<td>6239</td>
<td>950</td>
</tr>
</tbody>
</table>

From table 2, it was evident that the number of electrical outlets was greatest in Nairobi campus as compared to other campuses. Equipment in Nyeri campus were of the lowest rating as compared to other campuses. Mombasa campus had the lowest population of students while Kisumu campus had the least number of socket outlets. In addition, the energy per capita consumption was calculated in terms of the number of students within the respective Campuses. Table 3 summarizes monthly electrical consumptions for the respective campuses of KMTC.

Table 3: Electrical consumption for the sampled campuses in the year 2010

<table>
<thead>
<tr>
<th>Month</th>
<th>Nairobi Campus (KWh)</th>
<th>Nyeri Campus (KWh)</th>
<th>Nakuru Campus (KWh)</th>
<th>Kisumu Campus (KWh)</th>
<th>Mombasa Campus (KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>80654</td>
<td>17690</td>
<td>33476</td>
<td>15856</td>
<td>14489</td>
</tr>
<tr>
<td>Feb</td>
<td>94997</td>
<td>19809</td>
<td>35601</td>
<td>16773</td>
<td>14900</td>
</tr>
<tr>
<td>Mar</td>
<td>91988</td>
<td>18996</td>
<td>35133</td>
<td>16902</td>
<td>14812</td>
</tr>
<tr>
<td>April</td>
<td>98010</td>
<td>17891</td>
<td>34321</td>
<td>19998</td>
<td>14709</td>
</tr>
<tr>
<td>May</td>
<td>78734</td>
<td>18790</td>
<td>35983</td>
<td>21631</td>
<td>13486</td>
</tr>
<tr>
<td>June</td>
<td>124045</td>
<td>21977</td>
<td>36467</td>
<td>24647</td>
<td>14440</td>
</tr>
<tr>
<td>July</td>
<td>94987</td>
<td>20123</td>
<td>36417</td>
<td>25001</td>
<td>15408</td>
</tr>
<tr>
<td>Aug</td>
<td>64883</td>
<td>19976</td>
<td>35680</td>
<td>26604</td>
<td>14500</td>
</tr>
<tr>
<td>Sep</td>
<td>71372</td>
<td>17655</td>
<td>35960</td>
<td>22872</td>
<td>14123</td>
</tr>
<tr>
<td>Oct</td>
<td>95022</td>
<td>18002</td>
<td>35675</td>
<td>22654</td>
<td>14789</td>
</tr>
<tr>
<td>Nov</td>
<td>104999</td>
<td>18765</td>
<td>36480</td>
<td>20555</td>
<td>16342</td>
</tr>
<tr>
<td>Dec</td>
<td>82605</td>
<td>17410</td>
<td>34039</td>
<td>14709</td>
<td>13987</td>
</tr>
<tr>
<td>Total</td>
<td>1,082,296</td>
<td>227,084</td>
<td>425,232</td>
<td>248,202</td>
<td>175,985</td>
</tr>
</tbody>
</table>

Approximately 1,082,296 KWh of electrical energy was consumed at the Nairobi campus while only 175,985 KWh was consumed in Mombasa campus. The total consumption in the four campuses was 2,158,799 KWh which cost the college approximately KSh 35,836,063. For all the campuses, the least amount of electrical energy was consumed in the month of December and January. This could be attributed to reduced activity in the campus following closure for the December holidays which goes up to mid January. Having determined the annual consumption
for each campus the researcher went further to compute the per capita consumption of each campus. The results were recorded in table 4.

Table 4: per capita consumption for sampled campuses

<table>
<thead>
<tr>
<th>No.</th>
<th>Campus</th>
<th>Number of students</th>
<th>Amount of electrical consumed in 2010 (KWh)</th>
<th>Per capita consumption KWh/Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nairobi</td>
<td>3000</td>
<td>1,082,296</td>
<td>360.77</td>
</tr>
<tr>
<td>2</td>
<td>Mombasa</td>
<td>950</td>
<td>175,985</td>
<td>185.25</td>
</tr>
<tr>
<td>3</td>
<td>Nyeri</td>
<td>980</td>
<td>227,084</td>
<td>231.72</td>
</tr>
<tr>
<td>4</td>
<td>Kisumu</td>
<td>1000</td>
<td>248,202</td>
<td>248.20</td>
</tr>
<tr>
<td>5</td>
<td>Nakuru</td>
<td>1200</td>
<td>425,232</td>
<td>354.36</td>
</tr>
</tbody>
</table>

Nairobi campus recorded a per capita consumption of 360.77 KWh while Mombasa campus recorded a per capita consumption of 185.25 KWh. The wide range of the values of per capita consumption recorded signified variations in the ratio of the number of lighting/power points in a particular campus to number of student’s enrolment. This could also be attributed to the rating of appliances used in each campus. The water pump at KMTC Nairobi had a high power rating (4675W) compared to the pumps in the other colleges that had a rating of about 450W.

Potential areas of energy saving in KMTC

The key energy saving areas the researcher identified as discussed earlier are, one, use of the power monitoring system and two, the use of high efficiency light fittings.

Power monitoring system

Simulation of the power monitoring system

It was necessary to simulate the system to establish the appropriate threshold for the different parameters. The LDR was inclined to different angles until the correct orientation relative to the level of illumination was determined. The PIR’s worked effectively in the building but during the initial stages the LDR had to be calibrated such that lights were not switched off with students in the Lecture hall. The reason being, that the occupants often worked at their desk (typing, reading etc.) for long periods of time without moving around. The PIR would then turn lights off as they were designed to (after sensing no motion). This pre-set period was then increased (from 5-10 minutes to 15-20 minutes) because of complaints by users and this made the researcher re-adjust the pre-set period of the sensors. This had some side effects as, the energy savings would decrease if the pre-set period was increased but the occupants would be happier and have more control over their environment.
Contribution of the power monitoring system

The power monitoring system was installed at one of the classes at KMTC Nairobi campus at the school of nursing. Adjacent to it was a similar class with the same number of lighting points, number of students and same timings in terms of classes. The two classes were also assumed to have the same orientation to the sunlight. As earlier mentioned in chapter three, it was assumed that the energy consumption in those two classes was the same. Check meters were installed in series with the lights to monitor electrical consumption in the two rooms for a period of three months (May to July 2010). The readings from the class where the power monitoring meter was installed is summarised in table 5.

Table 5: Consumption with the power monitoring system

<table>
<thead>
<tr>
<th>Room with Power monitoring system installed</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>Weekly consumption (KWh)</td>
<td>Cumulative Consumption (KWh)</td>
</tr>
<tr>
<td>Week 1</td>
<td>16.4</td>
<td>16.4</td>
</tr>
<tr>
<td>Week 2</td>
<td>18.2</td>
<td>34.6</td>
</tr>
<tr>
<td>Week 3</td>
<td>18.5</td>
<td>53.1</td>
</tr>
<tr>
<td>Week 4</td>
<td>18.1</td>
<td>71.2</td>
</tr>
<tr>
<td>Week 5</td>
<td>17.4</td>
<td>88.6</td>
</tr>
<tr>
<td>Week 6</td>
<td>19.1</td>
<td>107.7</td>
</tr>
<tr>
<td>Week 7</td>
<td>18.3</td>
<td>126</td>
</tr>
<tr>
<td>Week 8</td>
<td>18.7</td>
<td>144.7</td>
</tr>
<tr>
<td>Week 9</td>
<td>18.1</td>
<td>162.8</td>
</tr>
<tr>
<td>Week 10</td>
<td>19.7</td>
<td>182.5</td>
</tr>
<tr>
<td>Week 11</td>
<td>16.9</td>
<td>199.4</td>
</tr>
<tr>
<td>Week 12</td>
<td>17.7</td>
<td>217.1</td>
</tr>
<tr>
<td>week 13</td>
<td>18.2</td>
<td>235.3</td>
</tr>
</tbody>
</table>

The readings from the check meter where lights were conventionally connected (no monitoring device was connected) is shown in the table 6.

The consumption in the room that had the power monitoring system installed recorded a total consumption of 235.3 kWh while the room that did not the power monitoring system connected recorded a consumption of 300.5 kWh this represented a power saving of 27.7%. This is a significant saving considering that if power monitoring systems were installed in the entire college and a similar margin of savings observed, then the Electrical consumption in the college would drop from 1,062,890 KWh to 662,180 KWh while the expenditure would fall from KSh 17,184,621 to Ksh. 10,706,018. The implication of this is that the college would make an annual financial saving of Ksh. 6,478,602.
Table 6: Consumption from the conventional setup

<table>
<thead>
<tr>
<th>Period</th>
<th>Weekly consumption (kWh)</th>
<th>Cumulative Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>22.9</td>
<td>22.9</td>
</tr>
<tr>
<td>Week 2</td>
<td>20.1</td>
<td>43</td>
</tr>
<tr>
<td>Week 3</td>
<td>22.1</td>
<td>65.1</td>
</tr>
<tr>
<td>Week 4</td>
<td>22.5</td>
<td>87.6</td>
</tr>
<tr>
<td>Week 5</td>
<td>22.6</td>
<td>110.2</td>
</tr>
<tr>
<td>Week 6</td>
<td>25.6</td>
<td>135.8</td>
</tr>
<tr>
<td>Week 7</td>
<td>24.9</td>
<td>160.7</td>
</tr>
<tr>
<td>Week 8</td>
<td>21.6</td>
<td>182.3</td>
</tr>
<tr>
<td>Week 9</td>
<td>22.1</td>
<td>204.4</td>
</tr>
<tr>
<td>Week 10</td>
<td>22.4</td>
<td>226.8</td>
</tr>
<tr>
<td>Week 11</td>
<td>24.1</td>
<td>250.9</td>
</tr>
<tr>
<td>Week 12</td>
<td>24.4</td>
<td>275.3</td>
</tr>
<tr>
<td>Week 13</td>
<td>25.2</td>
<td>300.5</td>
</tr>
</tbody>
</table>

The new Energy per student values would then be

\[ I = \frac{662180}{3000} = 220.72 \text{ KWh/Student} \]

Payback period for the power monitoring system

The Simple Payback (SPB) is the amount of time it will take to recover installation costs based on annual energy cost savings. The equation for simple payback is annual energy cost savings per year divided by the initial installation cost. The annual cost of energy savings proposal is the cost of electricity for operating the energy saving equipment and the annual cost of maintenance on the energy saving proposal.

To evaluate the benefits of controls, a cost benefit analysis was performed. This cost benefit analysis examined the payback period for the system installed at the campus. It took into account the capital cost of the system, annual maintenance, electricity bills and tariffs etc. The payback period does have certain limitations and qualifications for its use. It will not take into account the time value of money, the risk involved or opportunity cost.

The initial cost of installing a power monitoring system would be high as it would require fresh lighting installation. The installation cost excluding the cost of purchasing the monitoring systems was estimated to be Ksh. 7, 580,000. Since the system is a new product in the global market, initial production would be relatively high with a single product selling at Ksh. 17,000. Purchasing this product for the whole college would cost Ksh. 1,530,000 bringing the total
installation cost to Ksh. 9,110,000. The annual saving as a result of installing this product was found to be Ksh 4,388,392.11. Hence the payback period is 2.08 years.

**High efficiency lighting**

The traditional (incandescent) light bulb, which constitute a third of the lighting systems used in KMTC, produces light by heating its tungsten filament until it is almost white hot. In the process of generating the light, a great deal of heat is also generated and lost as waste energy. The result is that the incandescent light bulb has low energy efficiency. The more modern Compact Fluorescent Lighting (CFL) technology generates high light levels while producing minimal wasteful heat. The researcher conducted experiments to establish how replacement of the traditional lights with the compact florescent lights would affect the power consumption at the KMTC Nairobi Campus. The results were recorded in table 7.

<table>
<thead>
<tr>
<th>Table 7: Comparison of consumption of Traditional lights versus Compact Fluorescent Lights</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of lights</strong></td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Traditional</td>
</tr>
</tbody>
</table>

**Contribution by the CFLs**

From table 4.4, use of CFLs resulted in a drop of electrical consumption by 84,777KWh. This was a significant value as the cost on electrical energy in KMTC went down by about KSh 2,735,298. The low consumption was due to the efficiency of the CFLs and also the fact that they positively affected Power Factor correction as compared to the conventional florescent fittings with ballasts. It was assumed that the power rates and other factors such as student population, and climatic conditions for the two years of the study were constant.

Compared to the incandescent bulb, the CFL gave the same amount of light, but at about one quarter the cost, in terms of the electrical energy consumption. The CFL also lasts ten times as long as the incandescent light bulb. The ratings of CFL lights range from 9 to 36 watts, which can respectively replace traditional incandescent bulbs of 40 to 100 watts directly in the same lamp holders to produce the same amount of light. For example, although a 9 watt CFL light costs several times the traditional incandescent light to initially purchase, but will be cost effective in the long run.

In the same category of efficient lighting are fluorescent luminaries which use electronic instead of traditional magnetic ballasts to initiate the lighting. Electronic luminaries have an efficiency level of more than 40 per cent higher than the conventional magnetic ballast ones because
electronic ballasts consume only about one fifth the amount of energy lost through magnetic inductance. Very high efficiency lights now available in the market produce 80 to 100 lumens (of light) per watt of energy consumed, while fluorescent tubes produce about 60 lumens per watt. These are in stark contrast to the incandescent bulbs 12 lumens per watt.

**Payback period of the CFLs**

Initial capital for installing the CFLs was Ksh 1,441,440. This included the cost of purchasing 912 CFLs, the lamp holders, other accessories as well as the labour costs. The saving realised by installing the CFLs in terms of cost is KSh 2,735,298. Using the simple payback method, this would take 0.5 years or 6 months. Many Kenyan enterprises and institutions including KMTC should install high efficiency lighting systems because of the high energy savings.

**Other energy saving measures**

**High efficiency motors**

Due to the limitations posed by their design, ordinary motors have energy efficiencies in the region of 80 to 85 per cent, while the High efficiency (HE) type motors have efficiencies that exceed 90 per cent. Water pumps used within KMTC should be of high efficiency to cut down on energy consumption within the institution.

**Power factor correction**

The most important measurements of the electrical power supplied to a consumer are the total power demand in kilo-volt-amperes (Kva or apparent power), and the actual energy consumed in kilowatts (Kw or real power). For any piece of equipment, the fraction of real power to apparent power is referred to as the power factor (PF). The electrical power Supply Company bases its bills on the total power drawn in Kva, and penalizes unacceptably low power factors by a consumer’s equipment. Thus, the ideal power factor should be as close as possible to 1.0 and every effort should be made never to allow it fall below 0.95.

Poor PF arises in installations with equipment utilizing circuit windings such as transformers, motors and conventional fluorescent lighting which have high electrical inductance. In such equipment, the raising of PF is achieved by neutralizing the reactive power requirements, through the use of capacitor banks, obtainable from electrical equipment suppliers. Capacitor banks are not complicated to install. Thus, improving the PF is a fairly easy means of reducing the cost of electrical energy. KMTC has large capacity banks installed and the power factor correction monitored by the maintenance department to ensure that the power factor is within the desired value. In spite of the very attractive consequent electrical energy cost savings, the initial cost of installing PF improvement is substantial, and should be carefully planned for.
Some of the benefits of improving power factor are as follows:

1. The consumption in the organization sector will decrease. Low power factor requires an increase in the electric utility’s generation and transmission capacity to handle the reactive power component caused by inductive loads. Low power factor will charge a penalty fee to customers with power factors less than a given value. The learning institutions can avoid this additional fee by increasing the power factor.

2. The organization electrical systems branch capacity will increase by reducing the current drains from the network, so uncorrected power factor will cause power losses in distribution systems.

**Maximum demand regulation**

The maximum (or peak) power drawn by electrical equipment determines the capacity of the system of power transformers, switchgear, cables, and ultimately the electricity generating plant serving that load. This system capacity requirement is true even if the peak power required by a load is many times the average (or normal) operating power, and lasts for only a fraction of the total operating time. For example, an electric motor during switch-on can take as much as 4 to 5 times its normal operating power. Its electricity supply system must be designed to carry the 4 to 5 times load, even though it happens only briefly during motor switch on. Thus, equipment electricity supply must be designed to cope with both the peak power and the average running power demands.

**Automation**

Automation provides a means of using mechanical, electrical or electronic controls to change the behaviour of equipment in a way that would otherwise require human intervention to achieve. Such automatic control includes:

1. Load flow control, i.e. ensuring that machines are not unintentionally over-loaded beyond their technically advisable levels;
2. Plant optimization, i.e. ensuring that only the absolute minimum number and combination of machines are running at any one time at the appropriate load; and
3. Speed control, i.e. automatically adjusting the running speed of equipment to the most appropriate level based on all its technical and production output requirements.

All these measures improve the collective energy efficiency of equipment in a learning institution, hospital or other organizations.
Other Technologies

Apart from those explained above, there are many other technologies and techniques used to improve the efficiency with which a college, an industry, hotel, hospital or other institution utilizes energy. The most common of these are:

1. Reducing the number of lighting lamps: This can be arranged by measuring the illumination level at the specific area and comparing it with the international standards for illumination, this measure saves a good percentage of energy especially that when you remove a lamp, you remove also its ballast that consumes energy. This study discussed in detail how energy consumption in a learning institution can be reduced by use of a power monitoring device which determined the number of lights that would remain on at any given time depending on the level of illumination.

2. Installing Reflectors in Light Fixtures: Reflectors are highly polished "mirror-like" components that direct light downward, reducing light loss within a fixture. Reflectors can minimize wasted light and hence allow few lighting and more efficient units to be used.

3. Monitoring the heating and cooling system; Thermostat settings can make a big difference in how a college uses energy especially where fans or air conditioning systems are installed. This drastically reduces the heating and air conditioning use, which will help with overall energy usage. Teachers should also watch for airflow around the vents. Books and furniture blocking the vents will prevent the warm or cool air from entering the room.

4. Establishing a college’s “Energy Patrol” program; one of the best things about undertaking an energy saving program in colleges is that it can help educate young people about energy savings. They can take this knowledge and apply it at home. Lectures can let students know about the benefits of saving energy and ways they can help the college save energy (like turning lights off and keeping doors closed). With students keeping watch, energy saving changes will be made more easily.

5. Effective preventive maintenance; this allows for maintenance for quality lighting. If maintenance is affected appropriately in building, wastage of electrical energy is minimized.

6. Appointment of an energy manager: The College’s staff can appoint an energy manager who will help identify areas of energy waste and develop a plan for fixing those energy problems. Energy managers can familiarize themselves with recent policies on energy savings and help suggest energy management solutions. Appointing an energy manager can help a college to develop a cohesive plan for energy savings.

7. Energy Audits - As per the Energy Conservation Act, 2001, Energy Audit is defined as “the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption”. In any industry, the
three top operating expenses are energy (both electrical and thermal), Labor and Materials. Any industry requiring cutting down on cost will definitely look at energy. This means that the energy management function constitutes a strategic area for cost reduction. The Energy Audit therefore gives an orientation to the energy cost reduction and preventive maintenance which are vital for an optimal running of an institution. Energy audits also help to ensure availability and reliability of supply of energy, and as well decide on appropriate energy programs to identify energy conservation technologies. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a “bench-mark” (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

8. Air drying and purification for compressors;
9. Heat pumps in air conditioning;
10. Combined heat and power(CH+P);
11. Co-generation(Co-Gen);

Each of these provides an opportunity for reducing a facility’s energy consumption.

CONCLUSIONS AND RECOMMENDATIONS

Results from this study show that in the year 2010, KMTC, Nairobi campus, consumed 1,082,296 KWh which cost the college approximately KSh. 17,498,374. This translates to per capita consumption of 360.77 KWh/Student. This value is relatively small compared to findings from study done in Canada where the per capita consumption in the University of Quebec was 7777.78 KW/Student (28GJ/S) while that in the prairies was 20833.33Kw/Student (75GJ/student). The variation in the values could be attributed to the difference in climatic condition. It follows that due to the extreme temperatures ranges i.e. either cold or hot in Canadian Universities, significant amount of energy is used for the heating ventilation and air conditioning systems (HVAC) compared to KMTC which lies in the tropics. The nature in terms of type and rating of equipment within these institutions could also contribute to the variation in per capita consumption. The study explored energy saving measures that were applicable to learning institutions specifically the use of high efficiency lights (Compact Fluorescent Lights) instead of the conventional ones. Results showed that 7.8% energy saving was achieved. The aspect of power factor correction was also examined and use of capacitor banks to adjust it to the desired value considered. Other measures looked at include electric power regulation, installation of reflectors in light fixtures and use of energy audits. Automation of the electrical systems was discussed, mainly by presenting the design and implementation of a microcontroller based power
monitoring system to allow for reduction of electrical consumption at KMTC-Nairobi and consequently decreasing the per capita consumption. The maximum monitoring system was implemented using a single chip MC68HC908 microcontroller to control the switch ON/OFF of lights depending on the level of illumination in the room. The main goal was to ensure that students maximized on the daylight and artificial lighting was utilized on a need be basis. Some benefits of using the power monitoring system include the highest level of flexibility and user satisfaction. It also presents the greatest energy savings opportunity. The system power rating is 13.4W and at sleep mode it consumed 2.7W. Some disadvantages include the extra costs of rewiring the buildings in addition to the initial cost and commissioning. It was found out that with the three particular controls examined in this study that energy savings was to be made. The PIR’s worked effectively in buildings and data gathered from Nairobi campus building indicates that savings were made using the lighting controls as described in chapter four. The central off lighting control worked efficiently as well. It could turn off forgotten lights in the buildings within the campus. The researcher projected a 50% savings the lighting controls installed for the whole year. The main findings from this data were that a 27.7% savings in electricity consumption was made in three months of the year. The deviation from the expected value could have been due to the energy management policies in the campus as well as the climatic conditions. Lighting controls when designed properly can therefore add value to buildings. Not only are the controls important but the design is very important so as to accommodate alterations in future by requiring only re-programming of the system but not re-wiring the building or producing new products. This is the great benefit of using this product because it allows the building energy rating to be improved which is becoming an increasingly important factor in modern building design.

REFERENCES

Aunan et al, 2000: Reduced damage to health and environment from energy saving in Hungary Paper presented at the IPCC Workshop “
Hedge A 1994: *Reactions of computer users to three different lighting systems in windowed and windowless offices*, Work with Display Units'94, Milan, Italy, October 2-5.

Hungarian


**ANNEX 1: PROGRAM FLOW**

This is an interrupt based looping.

All the work gets done in the Interrupt Service Routines ISR

BEGIN

Initialise counters and flags;

MAIN_LOOP:

if(timer_interrupt)
    TIMER_ISR;

if(someone_detected_interrupt)
    PRESENCE_ISR;

if(ADC_interrupt)
    ADC_ISR;

jump_to_MAIN_LOOP;

```
/status_polling
```

// port_state == 1 when somebody is detected
// and obviously interrupt_state == 0 when nobody is around.
if(port_state == 1)
{
    set presence_flag;
}
else
{
    clr presence_flag;
}

if(switch_state == 1)
{
    set switch_flag;
}
else
{
    clr switch_flag;
}
RET

ADC_ISR
---------------------
ADC_sample = Funct_take_ADC_sample(); // take a sample ...
sample[sample_count] = ADC_sample; // ... and store value in an array
sample_count++; // increment array pointer for next access

if(sample_count >= MAX_SAMPLE_COUNT) // have we filled the array?
{
    Funct_find_ADC_sample_average(); // find the average of samples taken
// make a decision based on the average of samples taken
// the TURN ON/OFF THRESHOLD is a band with [lower limit] = threshold_1
// and [upper limit] = threshold_2

if((switch == ON) AND (presence_flag == set))
{
    if((average > threshold_1) AND (average < threshold_2))
    {
        // maintain the status quo;

        turn_on_light = clear
        turn_off_light = clear

    }

    if(average < threshold_1)
    {
        // enable turning ON next light in sequence;

        turn_on_light = set
        turn_off_light = clr
    }

    if(average > threshold_2)
    {
        // enable turning OFF next light in sequence;

        turn_on_light = clr
        turn_off_light = set
    }
}
else //((switch == OFF) OR (presence_flag == clear))
{
    // enable turning off next light in sequence;

    turn_on_light = clr
    turn_off_light = set
}

return_from_interrupt;

-----------------------------------------------------------------------------------------

TIMER_ISR

---------------------
// The timer counts out a DELAY before turning ON/OFF the lights.
//

delay_counter++; // increment delay_counter

if(delay_counter == MAX_DELAY_COUNT)
{
    delay_counter = 0; // reset delay count

    if((turn_on_light == set) AND (switch == ON) AND (presence_flag == set))
    {
        turn on next light in sequence;
    }

    if(((turn_off_light == set) AND (switch == ON)) OR (turn_on_light == set))
    {
        turn off next light in sequence;
    }
}

trigger ADC interrupt;
return_from_interrupt;

// NOTE: The condition (switch == ON) is not necessary but is meant to make
//      the system rugged.
-----------------------------------------------------------------------------------------