DEVELOPMENT OF OPTIMUM ENERGY USE MODEL FOR A PETROL STATION

A case study of selected Libya Oil Kenya Limited petrol stations in Nairobi

by

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DECLARATION

STUDENT DECLARATION

This project is my original work and has not been presented for a degree in any other university. No part of this project may be reproduced without the prior permission of the author/ University of Nairobi.

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Date 30·04·2012

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SUPERVISORS' DECLARATION

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DEDICATION

This study is dedicated to my son, Adams Kimeu, may you grow to make the world better than you found it.

ABSTRACT

The objective of this study was to determine energy consumption trends for petrol stations and hence develop an optimum energy use model and identify energy saving opportunities. Three Libya Oil Limited petrol stations located in Buruburu, Pangani and Ngong road were used as case study.

Energy consumption data in the petrol stations was collected and analyzed using pie charts, regression graphs and cumulative sum of difference criteria.

An optimum energy use model was developed and its evident from the model that energy consumption is directly related to sales volume. The model has fixed element contributed by non-fuel related energy consumers namely lighting and compressed air system.

Further analysis of energy consumption at the petrol station using cumulative sum of difference criteria has revealed that effective energy saving measures are not used.

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ABBREVATIONS AND ACRONYMS

UPP – Universal Petrol Pipes

GI – Galvanized Iron

KAM – Kenya Association of Manufacturers

SPSS - Statistical Package for Social Sciences

KOSF - Kipevu Oil Storage Facilities

IPPs - Independent Power Producers

PES - Public Electricity Suppliers

IPCC - International Panel on Climate Change,

CUSUM – Cumulative Sum of differences

CHAPTER ONE
INTRODUCTION

1.1 Background

Petrol stations equipment's in Kenya are powered using electrical energy from the mains supply. In petrol station electricity is supplied by both 240 V single phase and 415 V three phase. The tariff structure consist of Maximum demand charges (MVA), Energy Charges (kWh), Power Factor penalty, Fuels Cost Adjustment charges and other standard commercial charges and levies. Monthly power bill ranges between KES 60,000.00 and KES 100,000.00 which is very high compared to the profit margins of the business which ranges from 3 to 2 shillings per liter.

In Kenya the electricity fuel cost charge rose from KES 1.22 per unit to KES 1.77 within one year from January 2009. Price of crude oil also rose from an average of USD 54.85 to USD 77.50 per barrel from January 2007 to January 2010 (Petroleum insight, July – September 2010). This situation is getting worse with average cost of a unit of electricity rising from around KES 12.00 in January 2009 to about KES 19.00 in September 2010. This has made the profit margins very thin for petrol station operators.

According to the African Press International (2008), the price rise on electricity threatens industry. The initial analysis shows that the overall effective cost per unit of electricity for the industrial sector has gone up from KES 8 to KES 15 on average, an increase of over 85% for one year.

The Kenyan oil market has previously been dominated by multinationals. Oil marketers enjoy a very thin margin in the sale of petroleum products; this makes management of operational cost a very key element for any company to be competitive. Between 1998 and 1999 several multinationals formed mergers to reduce operational cost. Some of the mergers formed were: Exxon/Mobil Oil, BP/Amoco, Chevron/Texaco, Total/ERF/Fina. In the local market, oil marketers were forced to form joint ventures to cut operational costs; Kenya shell went into joint venture with ExxonMobil for their Nairobi terminal operations which was terminated in 2006 following the acquisition of ExxonMobil by Libya oil Kenya Ltd. Kenol kobil, Total Kenya and Caltex went into a joint venture for their Nairobi and Mombasa fuels operations. All this efforts seemed not to work because from 2004 several multinationals have exited the Kenyan market citing low margins and high operation cost as the major reason: Agip petroleum in 2002, British petroleum (BP) in 2004, ExxonMobil in 2006, Caltex in 2008 and Kenya Shell in 2010 (Petroleum insight, July – September 2010). To remain competitive, management of energy cost as one of the operating cost is important.

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them. There are various motivations to improve energy efficiency. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a key solution to the problem of reducing greenhouse gas emissions (Turner & Steve, 2007).

According to the International Energy Agency, 2009, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases. Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Sant R., (1979), states that economic growth is directly proportional to per capita energy consumption. Economic growth and change in lifestyle increases pressure to already strained energy situation in the country hence the energy deficiency being experienced in the country is likely to get worse in the near future. Even though the country is expected to work towards energy stability in the long run, it is clear the cost of energy will not come down. This calls for more attention to energy especially energy use.

Energy is mainly consumed in four sectors in the country, namely the manufacturing, commercial, transport and the residential. The transport sector is the largest consumer of petroleum products followed by the manufacturing sector and others (agriculture, tourism, power generation, and government), respectively. Over the years, the transport sector generally consumed 70 percent of the total net domestic sales of petroleum products as compared to the manufacturing sector, which consumed only 25 percent of the total net domestic sales of petroleum products. However from the year 1997 to 2001, the other sector's petroleum consumption exceeded the manufacturing sector's consumption, which could be attributed to the increase in consumption of oil by electricity sector for thermal electricity generation. Fuel consumption by the agricultural sector has been on decline since 2005, a trend reversed in 2007 when its consumption increased by 62.4 percent. Aviation excluding government recorded an increase of 8.1 percent in fuel consumption in 2007 attributed to a booming tourism sector and increased domestic flights (Republic of Kenya, 2008).

All the petroleum products consumed in the transport sector, which is the leading sector of petroleum products consumption in Kenya, are dispensed through petrol stations therefore energy efficiency in operation of petrol station is of significance importance.

1.1.1 Petrol Station

A petrol station is referred to by different names depending on the region. It can be defined as a facility which sells fuel and lubricants (petroleum products) for motor vehicles. Some of other commonly used names include: filling station, gas station, fueling station, service station, garage, gasbar, petrol pump or petrol bunk. The term "gas station" is mostly used in the Canada and the United States, where the fuel is known as "gasoline" or "gas". Elsewhere in the English-speaking world, where the fuel is usually known as "petrol", the form "petrol station" or "petrol pump" is used including Kenya. In the United Kingdom and South Africa "garage" is still commonly used, even though the petrol station may have no service/maintenance facilities which would justify this description.

The most common fuels sold are petrol (Premium Motor Spirit), diesel (Automotive Gas Oil), Kerosene (Illuminating Kerosene) fuel. The lubricants vary from one oil marketer to the other and each marketer has a specific blending and confidential formulae for their lubricants. There are two major categories of lubricants, which are mineral based lubricants and synthetic lubricants.

The world's first filling station was established in Wiesloch , German and traded as City Pharmacy where Bertha Benz refilled the tank of the first automobile on its maiden trip from Mannheim to Pforzheim and back in 1888. As the name indicates, the first places that sold petroleum products were pharmacies as a side business. (www.en.wikipedia.org/wiki/Filling_station -Acessed on 18th August)

Petrol station operations are divided into two major categories, fore court and back court. Most of the petrol stations installation includes; underground storage tanks, fuel dispensing pumps, lube bay equipment's, compressed air system, forecourt canopy, and various security installations. Modem petrol stations also have small convenience stores shops and some have added fast foods to their primary business. This has considerably increased the amount of energy used in petrol station. (www.energyusernews.com – 17 August 2010).

1.1.2 Libya Oil Kenya Limited Nairobi Petrol Station

Libya Oil Kenya Limited petrol stations selected for this study are Buruburu, Pangani and Ngong road. These stations are located within Nairobi city, the capital city of Kenya. Table 1.1, 1.2 and 1.3 shows different types of facilities found in the petrol stations considered in this study.

Running all these facilities requires energy which is a challenge to petrol station operators because of the high cost of energy in the country. When the facilities are not efficiently operated the energy consumption may be too high leading to high operating cost hence reducing already thin profits margins of the business.

a) Buruburu Petrol Station:

It is located in Nairobi city, at Buruburu shopping center along Mumias road, opposite Mesora complex and next to Buruburu police station. Area topography is gentle slope towards East. Water is supplied from Nairobi Water Company and the station is connected to sewerage drainage. The station operates in two shifts; day and night shift Facilities found at the site are as listed in the table 1.1:

Table 1.1 : Buruburu petrol station facilities

FACILITY		NUMBER
Office:		1
Strong room:		1
Store:		1
Generator and room:		1
Canopy:		1
Forecourt:		1
Stairways:		None.
Remote filling point:		1
Underground storage tanks (UST):		5
Above ground storage tanks (AST):		None.
Product pumps:		7
Product lines:		16
Vents:		5
Dispensers		
Diesel		3
Unleaded Super		12
Kerosene		1
Isolation switch room:		1
Fire alarm:		1
Atlas Copco Compressor:		1
Service bay:		1
Sump:		1
Oil interceptor:		1
Tyre repair centre:		1
Pressure point (air and water):		2
Shop:		1
Management Toilets	Gents	1
	Ladies	1
Staff Toilets	Gents/	1
	Ladies	-
Changing room:		1
Security alarm:		1

Services available at the station include: vehicle refueling, spare shop, tire repair, and vehicle identification.

b) Pangani petrol station

It is located in the outskirts of Nairobi city, along Thika road next to Gurunanak hospital, behind Pangani police station. Area topography is gentle slope towards West. Water is supplied from Nairobi Water Company and the station is connected to sewerage drainage. The station operates in two shifts; day and night shift

Facilities found at the site are as listed in the table 1.2:

Table 1.2: Pangani petrol station facilities

FACILITY		NUMBER
Office:		1
Strong room:		1
Store:		1
Generator and room:		1
Canopy:		1
Forecourt:		1
Remote filling point:		1
Underground storage tanks (UST):		3
Above ground storage tanks (AST):		None
Product pumps:		5
Product lines:		5
Vents:		3
Dispensers: Diesel		4
Unleaded Super		6
Unleaded Regular		4
Isolation switch room:		1
Fire alarm:		1
Atlas Copco Compressor:		1
Mechanic garage:		1
Oil interceptor:		1
Pressure point (air and water):		2
Toilets	Gents	1
	Ladies	2
Changing room:		1
Security alarm:		1
Cash point:		2

Services available at the station include: vehicle refueling and tire inflation services.

c) Ngong road petrol station

It is located in Nairobi city, along Ngong road next to: East - Uchumi hyper supermarket, South – residential and West – Pentecostal church. Area topography is gentle slope towards East. The station operates in two shifts; day and night shift

Facilities found at the site are as listed in the table 1.3:

Table 1.3: Ngong road petrol station facilities

FACILITY		NUMBER
Office:		1
Strong room:		2
Store:		2
Generator and room:		1
Canopy:		1
Forecourt:		1
Remote filling point:		1
Underground storage tanks (UST):		3
Above ground storage tanks (AST):		1
Product pumps:		3
Product lines:		3
Vents:		3
Dispensers: Diesel		8
Unleaded Super		16
Isolation switch room:		1
Compressor:		1
Oil interceptor:		1
Pressure point (air and water):		2
Toilets	Gents	3
	Ladies	3
Security alarm:		Various.
Chemist		1

Services available at the station include: vehicle refueling, chemist and air gauge

Power supply for petrol stations in Kenya is from Kenya Power and lighting company but most of the stations have emergency generators which automatically come on when the mains power supply is not available. They are supplied with 240V single phase and 415 three phase electrical power.

Power consumptions in a petrol station depend on services offered at the petrol station, level of occupancy and type of equipment at the station. The major energy consuming equipment in a petrol station includes:

i. Dispensers
ii. Air Compressor
iii. Wheel balancing machine
iv. Under canopy and security lights
v. Office equipment

1.2 Statement of the problem

The major operating costs in a petrol station are labour, maintenance and energy. Petrol station operators pass these costs to consumers contributing to high petroleum products prices and in case the operators have to absorb the cost it reduces their profit margins. It is therefore important for petrol stations operators and oil marketers to monitor how and where energy is used in their petrol station to remain competitive while pricing their fuel products.

The type and amount of energy used has a direct impact on the environment. Environmental conservation has become a global concern which has led to signing of a number of agreements like; Rio de Janeiro Protocol/Agenda 21(1992), Bamako Convention (1991), Basel Convention (1992), Rotterdam Convention (1998), Kyoto Protocol (1997). In Kenya, the ministry of energy in conjunction with Energy efficiency Centre (an arm of Kenya Association of Manufacturers) are in the process of developing regulatory requirements were all facilities will be obligated to implement energy conservation measures in their facilities. This has been motivated by the fact that most of our energy sources in the country are limited and there is a need to conserve them and the need to conserve the environment. Some of the effects associated with environmental degradation are; change in local weather patterns, drought, increased tropical storm activity, sea level increase.

Further, both the government and the private sector have not been able to match energy demand and supply. The energy supply reserve has continued to narrow with time. It is estimated that there are 1,052 petrol stations in Kenya. The branded company owned stations are 634 while independent service stations are 418; if each of this station is able to save 20 percent of its current energy consumption then a significant amount of national peak demand can be saved monthly.

With this high energy cost, shortfall in energy supply versus demand in the country and continued pressure to reduce greenhouse gas emissions a study to establish the major energy consumers in a petrol station with an objective identifying opportunities for energy saving is justified.

The country has been facing an increasing number of motor vehicles, motor bikes and other machinery which require to be fuelled in a petrol station. Consequently, more petrol stations will require to be constructed in the country, hence this warrants a study to design an optimum energy use model for use in petrol stations which can be used in estimating energy cost.

1.3 Objectives of the Study

The specific objectives of the study will be to:

i. Collect historical energy data from identified petrol stations and develop optimum energy use model.
ii. Identify major energy consuming equipment and their energy consumption levels.
iii. Identify energy saving opportunities for the petrol stations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

In this chapter a brief review of energy use in a petrol station and relevant literature reviewed is presented. The current status of energy supply and demand in the country is also described. Further, studies on the relationship between economic development and energy management quoting both foreign and Kenyan based studies are reviewed.

2.1 Historical data

Onuonga, (2008) analyzed energy utilization in the Kenyan manufacturing sector over the 1970 – 2005 periods. Translog cost function was used to analyse total factor demands and inter-fuel substitutions. Estimation was done in two stages using maximum likelihood method. First, the sub-energy model was estimated and an aggregate energy index computed. In the second stage, total factor cost shares were analysed using the estimated energy price index as an instrumental variable. The study found that, price of energy, cross price, output, technology, price of capital and unexpected events influenced the sectors use of energy. The result of inter-fuel model indicated that demand for electricity and oil was price inelastic and that oil and electricity are substitutes. The fuel price and the cross price elasticities were found to be small but statistically significant. The results implied that manipulation of the fuel prices alone cannot achieve much in controlling the use of energy in the Kenyan manufacturing sector. The results for the total factor cost shares showed that demand for energy and labour were price inelastic while that one for capital had a unitary elasticity. The results further showed that energy labour and capital were substitutes, but the degrees of substitution among the factors were very low suggesting that costs of production within the sector might rise significantly as a result of the price increase of the inputs, especially of energy.

It is noted that, though some studies has been done on assessment of energy use in other industries, none of the studies have addressed themselves to energy use in petrol stations. Moreover, most of these studies focus on Asia (for example, Brenton (1997), Pesaran et al. (1998), Pourgerami and von Hirschhaussen (1991)) and Latin America (Balabanoff (1994), Hunt et al. (2000), Ibrahim and Hurst (1990), Edmonds and Reilly (1985)) leaving a glaring gap for sub-Saharan Africa, and Kenya in particular.

In Kenya, energy resources comprise commercial and non- commercial. Commercial energy mainly comprises of petroleum products and electricity, while non-commercial comprises of biomass, and to a lesser extent solar energy, wind power and biogas. Petroleum fuel accounts for about 21 percent of the total primary energy consumption (UNEP, 2006; Mwakubo et al., 2007) and it is also the major source of modern energy. Petroleum products are majorly transported from Mombasa to other parts of the country by Kenya Petroleum Company (KPC). The KPC also manages Government owned open access Kipevu Oil Storage Facilities (KOSF) in Mombasa and also runs common storage depots in Nakuru, Eldoret and Kisumu. Due to rise in domestic and regional demand for petroleum products on account of good economic performance, the ability of the current pipeline infrastructure is heavily constrained. Consequently, the Government is considering developing a parallel pipeline from Nairobi to Western Kenya in order to serve growing contiguous markets in the great lakes region. In addition, the Kenya Pipeline Company is undertaking major rehabilitation works aimed at doubling the pipeline through put from current 440 m3 per hour to 880 m3 per hour on the Mombasa-Nairobi line and from 220 to 440 m3/hour on the Nairobi-Western portion of the line. Following deregulation in 1994, fuel transportation modes and tariffs were liberalized. The KPC tariffs for all products except jet fuel in Nairobi and Mombasa International Airports are KESs. 1.53 per m3 to Nairobi, KES. 2.105 per cubic meter to Nakuru, KES. 2.706 per cubic meter to Eldoret and KESs. 2.703 per m3 to Kisumu. This contributes to the final price of petroleum products in a petrol station.

2.2 Electricity Billing

According to Energy Act , 2006, the Electricity Regulatory Board (ERB) was established under Section 119 of the Electric Power Act, 1997 to regulate the generation, transmission and distribution of electric power in Kenya. The Act empowers ERB to set, review and adjust tariffs, for all persons who transmit or distribute electrical energy for sale.

In line with the liberalization in Kenya's energy sector in October 1996, the electric power sub-sector was restructured with the aim of creating arm's length commercial relationships between sector entities and a legal and regulatory framework to facilitate private sector participation. A key output of the restructuring process was the enactment of the Electric Power Act, 1997, which facilitated the unbundling of generation from transmission and distribution thereby creating a framework for Independent Power Producers (IPPs) to sell electric power in bulk to Public Electricity Suppliers (PES).

KENYA CUSTOMER CATEGORIES

Table 2.1: The current customer categories in Kenya

Tariff	Type of Customer	Supply Voltage(V)	Consumption Range (KWh/Month)	Fixed Charges (KES/month)	Energy Charges (KES/KWh)	Demand Charges (KES/kVA/Month)
DC	Domestic Consumers	240 or 415	0-50	120	2.00	-
			51-1,500		8.10	
			Over 1,500		18.57	
SC	Small Commercial	240 or 415	Up to 15,000	120	8.96	-
CI1	Commercial/Industrial	415-3phase	Over 15,000	800	5.75	600.00
CI2		11,000	No limit	2,500	4.73	400.00
CI3		33,000/40,000		2,900	4.49	200.00
CI4		66,000		4,200	4.25	170.00
CI5		132,000		11,000	4.10	170.00
IT	Interruptible off-pick supplies	240 or 415	Up to 15,000	120-when used alone 240-when used with DC or SC	4.85	-
SL	Street Lighting	240	-	120	7.5	-

The electricity billing by utilities for medium enterprises, in Small Commercial category, is often done on two-part tariff structure, which is one part for capacity (or demand) drawn and the second part for actual energy drawn during the billing cycle. Capacity or demand is in kVA (apparent power) or kW terms. The reactive energy kVAh drawn by the service is also recorded and billed for in some utilities, because this would affect the load on the utility. Accordingly, utility charges for maximum demand, active energy and reactive power drawn (as indicated by the power factor) in its billing structure. Other fixed and variable expenses are also charged (Bureau of Energy Efficiency, 2007).

2.3 Energy uses in a petrol station

Energy consuming equipment's in a petrol station include; Fuel pumps/dispensers, lighting, compressors, tire changing machine and lube dispensing machine.

Petroleum consumption in the country increased from 3,664 million liters in 2008 to 4,105 million liters in 2009 (Petroleum insight, January – March 2010). This may be attributed to the fact that vehicle population in Nairobi has tripled in a period of twenty (20) years, though the road infrastructure remains relatively the same. In 1990 it was estimated that there were 250,000 vehicles in Kenya, while today they are about 800,000 vehicles. It is further approximated that there is an increase of 50,000 vehicles (6%) every year; this means the demand for petroleum products will continue to rise hence more petrol stations (www.kara.or.ke–5th July 2010).

2.4 Electrical Energy Supply Systems

The Bureau of Energy Efficiency- India; 2009, states that electric power supply system in a country comprises of generating units that produce electricity, high voltage transmission lines that transport electricity over long distances, distribution lines that deliver the electricity to consumers, substations that connect the pieces to each other and energy control centres to coordinate the operation of the components.

2.5 Electrical Energy Power Factor

This is one of the elements which influence small scale commercial enterprises power bills. The significance of power factor lies in the fact that utility companies supply customers with volt-amperes, but bill them for watts. Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). This increases generation and transmission costs. In Kenya, utilities typically charge additional costs to customers who have a power factor below 0.9.

In Kenya, Energy Regulatory Commission was established as an Energy Sector Regulator under the Energy Act, 2006 in July 2007. Energy Regulation Commission is a single sector regulatory agency, with responsibility for economic and technical regulation of electric power, renewable energy, and downstream petroleum sub-sectors, including tariff setting and review, licensing, enforcement, dispute settlement and approval of power purchase and network service contracts. As per Energy Act 2006, some of the functions of the energy regulation are to regulate:

i. Importation, exportation, generation, transmission, distribution, supply and use of electrical energy;
ii. Importation, exportation, transportation, refining, storage and sale of petroleum and petroleum products;
iii. Production, distribution, supply and use of renewable and other forms of energy;

Therefore institutions are obligated to monitor and maintain records of their energy use. Energy is the ability to do work and work is the transfer of energy from one form to another. In practical terms, energy is what we use to manipulate the world around us, whether by exciting our muscles, by using electricity, or by using mechanical devices such as automobiles. Energy comes in different forms - heat (thermal), light (radiant), mechanical, electrical, chemical, and nuclear energy.

2.6 Energy consuming equipment in a Petrol station

2.6.1 Compressed air systems

One of the major energy consuming equipment in a service station is compressed air system. Compressors with a rating of 4.5 or 7.5 HP are commonly used and when high pressure is desired two or more compressors can be connected in parallel or series depending on the desired output. Compressed air has become an indispensable tool for most manufacturing facilities. Its uses in a petrol station span from tire inflation to operation of lubes bay equipment's.

Unfortunately, staggering amounts of compressed air are currently wasted in a large number of facilities. It is estimated that only 20%–25% of input electrical energy is delivered as useful compressed-air energy. Leaks are reported to account for 10%–50% of the waste and misapplication accounts for 5–40% of loss in compressed air. Leaks repair can reduce this number to less than 10%. Estimations of leaks vary with the size of the hole in the pipes or equipment. In addition to increased energy consumption, leaks can make air tools less efficient and adversely affect production, shorten the life of equipment, lead to additional maintenance requirements and increase unscheduled downtime (Howe and Scales, 1998).

Some of the energy conservation measures that are suitable for compressed-air systems are listed below according to (Kreith F. and Yogi D. , 2008):

i. Repair of air leaks in the distribution lines. Several methods do exist to detect these leaks ranging from the use of water and soap to the use of sophisticated equipment such as ultrasound leak detectors.

ii. Reduction of inlet air temperature and/or the increase of inlet air pressure.

iii. Reduction of the compressed-air usage and air pressure requirements by making some modifications to the processes.

iv. Installation of heat recovery systems to use the compression heat within the facility for either water heating or building space heating.

v. Installation of automatic controls to optimize the operation of several compressors by reducing part load operations.

vi. Use of booster compressors to provide higher discharge pressures. Booster compressors can be more economical if the air with the highest pressure represents a small fraction of the total compressed air used in the facility. Without booster compressors, the primary compressor will have to compress the entire amount of air to the maximum desired pressure.

The compressed air pressure requirements in a petrol station are as follows:

Table 2.2: Petrol station compressed air pressure requirements

Item	Use	Pressure requirement (PSI)
1	Small car tire inflation	30
2	Light commercial tire inflation	60
3	Heavy commercial tire inflation	110

Source: Author of the report.

This shows that pressure requirement in a petrol station can generally be categorized into two; high and low pressure requirement.

2.6.2 Fuel dispensers

A fuel dispenser is a machine at a filling station that is used to pump premium spirit, diesel or kerosene which can be mechanically or manually driven. The first gasoline pump was invented and sold by Sylvanus F. Bowser in Fort Wayne, Indiana on September 5, 1885. This pump was not used for automobiles, as they had not been invented yet. It was instead used for some kerosene lamps and stoves. He later improved upon the pump by adding safety measures, and also by adding a hose to directly dispense fuel into automobiles.

Many early gasoline pumps had a calibrated glass cylinder on top. The desired quantity of fuel was pumped up into the cylinder as indicated by the calibration. Then the pumping was stopped and the gasoline was let out into the customer's tank by gravity. When metering pumps came into use, a small glass globe with a turbine inside replaced the measuring cylinder that assured the customer that gasoline really was flowing into the tank.

A modern fuel dispenser is logically divided into two main parts:

i. Electronic head - containing an in build computer to control when the pump should start running or stop, drive the pump's displays, and communicate to an indoor sales system;

ii. Mechanical section - which in a self-contained unit has an electric motor, pumping unit, meters, pulsers and valves to physically pump and control the fuel flow.

In some cases the actual pump may be sealed and immersed inside the fuel tanks on a site, in which case it is known as a submersible pump. In general submersible pumps are installed in hotter countries, where suction pumps may have problems overcoming cavitation with warm fuels or when the distance from tank to pump is longer than a suction pump can manage (www. en.wikipedia.org/wiki/Fuel_pump – Accessed 20 September 2010)

One of the greatest energy conservation steps for dispenser was the invention of automatic cut-off. The shut-off valve was invented in Olean, New York in 1939 by Richard C. Corson at a loading dock at the Socony-Vacuum Oil Company.

Most modern pumps have an auto cut-off feature that stops the flow when the tank is full. This is done with a second tube, the sensing tube, that runs from just inside the mouth of the nozzle up to a Venturi pump in the pump handle. While the tank is being filled, air displaced from the tank is drawn up this tube. Once the fuel level reaches the mouth of the sensing tube, air is no longer drawn up the sensing line. A mechanical valve in the pump handle detects this change of pressure and closes, preventing the flow of fuel.

The number of dispensers in a petrol station depends on the sales volume of the site and the number of different grades but an average petrol station has five dispensers (www. en.wikipedia.org/wiki/Fuel_dispenser#Automatic_cut-off_in_fuel_dispenser – Accessed on 20 September 2010).

2.6.3 Lighting

In a petrol station, lighting is used to provide general lighting in offices or to provide under canopy, security and task lighting in the lube bay. Fluorescent tubes, Compact Fluorescent (CFL) and incandescent lights are typically used for task and office lighting. High-Intensity Discharge (HID) sources are used for under canopy and security lighting including metal halide, high-pressure sodium and mercury vapour lamps. An average petrol station has an average of fifteen 400 W HID lamps. Lighting improvements are excellent investments in most stations because lighting accounts for a large part of the energy bill in a petrol station (Wayne C. Turner & Steve Doty, 2007).

Barney et al., (2008) points out that the lighting system provides many opportunities for cost-effective energy savings with little or no inconvenience. He further, suggests that in many cases, lighting can be improved and operation costs can be reduced at the same time. Lighting energy use represents only 5-25% of the total energy in industrial facilities, but it is usually cost effective because lighting improvements are often easier to make than many process upgrades. He further says that, while there are significant energy uses and power-demand reductions available from lighting retrofits, the minimum lighting level standards of the Illuminating Engineers Society (IES) should be followed to ensure worker productivity and safety. Inadequate lighting levels can decrease productivity, and they can also lead to a perception of poor indoor air quality.

2.7 Energy Audit Process

Energy auditing also referred to as energy survey, energy analysis or energy evaluation is the first step in any energy management process. It examines the ways energy is currently used in a facility and identifies some alternatives for saving energy.

The main objectives of an audit are:

i. To clearly identify the types and costs of energy use
ii. To understand how that energy is being used and possibly wasted
iii. To identify and analyze alternatives such as improved operational techniques and / or new equipment that could substantially reduce energy costs
iv. To perform an economic analysis on those alternatives and determine which ones are cost-effective for the business or industry involved.

The energy audit process consists of three phases: preparing for the audit visit; performing the facility survey and implementing the audit recommendations.

2.8 Monitoring and Targeting Technique

Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures. It builds on the principle "you can't manage what you don't measure". It essentially combines the principles of energy use and statistics.

While, monitoring is essentially aimed at establishing the existing pattern of energy consumption, targeting is the identification of energy consumption level which is desirable as a management goal to work towards energy conservation. Monitoring and Targeting is a management technique in which all plant and building utilities such as fuel, steam, refrigeration, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed. It involves a systematic, disciplined division of the facility into Energy Cost Centres. The utilities used in each centre are closely monitored, and the energy used is compared with production volume or any other suitable measure of operation. Once this information is available on a regular basis, targets can be set, variances can be spotted and interpreted, and remedial actions can be taken and implemented (www . em-ea.org – Monitoring & Targetting – Accessed on 3rd April 2012).

The main elements of monitoring include

i. Measuring energy consumption over time
ii. Setting targets for reduced energy consumption
iii. Frequent comparison of consumption with set targets
iv. Reporting variances and taking action to correct the same.

The benefits accruing from a monitoring routine include

i. Improved product cost since proper costing must include the energy component in the final product cost
ii. Improved budgeting
iii. Enhanced preventative maintenance since problems can be detected from the energy consumption deviations from an established pattern
iv. Material waste control since this is also reflected in the energy consumption

CHAPTER THREE
METHODOLOGY

3.1 Data Collection Procedure

This research used primary and secondary data. Primary data was obtained from electric meter reading at the station and fuel storage tank dips. The Kenya Power meter reading and tank dips were taken after every twelve hours. Daily energy consumption and sales volume was worked from the obtained readings. A check meter was installed on the air compressor power line to measure the power consumption by the compressor. Secondary data was obtained from petrol station historical energy bills and sales volumes for the last three years.

Historical electrical energy bills, for every petrol station was obtained from Kenya Power. Historical sales volumes for each petrol station were obtained from Oilibya Sales and Marketing department data base.

The following information was gathered for each petrol station on monthly basis:

i. List of energy consuming equipment
ii. The energy bills for the last three years
iii. Sales volumes for the last three years
iv. Petrol station layout and construction
v. Operating hours

All energy consuming equipment were identified for each petrol station. Simple leak test was conducted for the compressed air systems by pouring soapy water on the joints and observations made.

Once all the basic data had been collected, two petrol stations covered by the study were toured to further examine energy consumption patterns and equipment usage. Detailed data was then collected on all energy using equipment. Three major energy consuming sections in a petrol station namely fuel dispensing, under canopy lighting, security lighting and compressed air system were monitored to establish amount of energy consumed in each section.

3.2 Data Analysis

The data collected was analysed using pie charts, regression graphs and cumulative sum of difference criteria. Monthly energy use for the whole period considered in this study was plotted against sales volume in each petrol station. The energy use per liter of fuel dispensed in a petrol station was also determined and plotted for the considered period. The results were graphically represented conclusions drawn.

CHAPTER FOUR
DATA ANALYSIS AND DISCUSSION

Table 4.1 and 4.2 shows the energy consuming equipment for stations considered in this study.

4.1 Site survey and Discussion

1. **Buruburu petrol station**

Table 4.1: Power consuming equipment at Buruburu petrol station

Item	Equipment	Number	Power rating
1	Atlas Copco Compressor	1	7.5 HP /5600 W
2	Sodium vapour security lighting	10	400 W
3	Sodium vapour under canopy lighting	8	400 W
4	Office fluorescent lighting	22	24 W
5	Lube bay fluorescent lighting	12	36 W
6	Wayne fuel dispensers - Red jacket	4	1.5 HP /1120 W
7	Wayne fuel pumps	2	1.5 HP /1120 W

Table 4.1 shows that security and under canopy lighting make a significant part of energy demand in a petrol station due to their large number and high power rating.

Buruburu petrol station distribution board is an old model with analogue fittings and if upgraded to modern digital distribution board can lead to energy saving. The distribution board doesn't have the capacity to display the station power factor therefore the station management may not realize immediately when power factor drops outside the recommended levels.

Lighting fittings found in Buruburu petrol station are the traditional incandescent and fluorescent tube. It was observed that energy saving fittings has not been installed in this station. Some of the installations appear neglected and therefore they can be removed without affecting the station operation. Alternatively they can be maintained to give the intended light output.

2. Pangani petrol station

Pangani and Buruburu petrol station facilities are similar in many aspects except they differ in numbers. The services found on the two sites are the same.

Table 4.2: Power consuming equipment at Pangani petrol station

Item	Equipment	Number	Power rating
1	Atlas Copco Compressor	1	7.5 HP / 5600 W
2	Sodium vapour security lighting	5	400 W
3	Sodium vapour under canopy lighting	8	400 W
4	Office fluorescent lighting	14	24 W
5	Lube bay fluorescent lighting	6	36 W
6	Wayne fuel dispensers - Red jackets	4	1.5 HP / 1120 W
7	Wayne fuel pumps	1	1.5 HP / 1120 W

3. Ngong road petrol station

Ngong road petrol station has a modern power distribution board in place. This is a more energy efficient distribution board compared to the one found in other stations and displays the station demand and power factor at any given time. The power factor displayed on the distribution board at time of survey 0.98

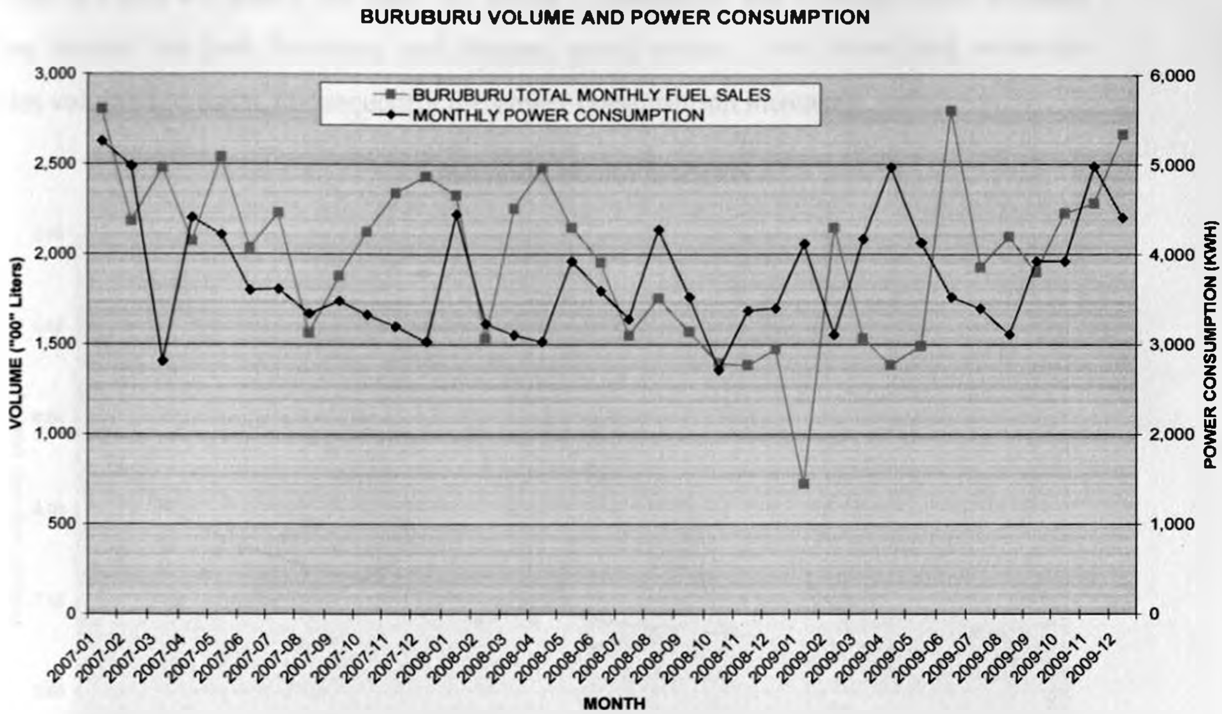
4.2 Historical Data Analysis and Discussion

Table 4.3: Buruburu historical data

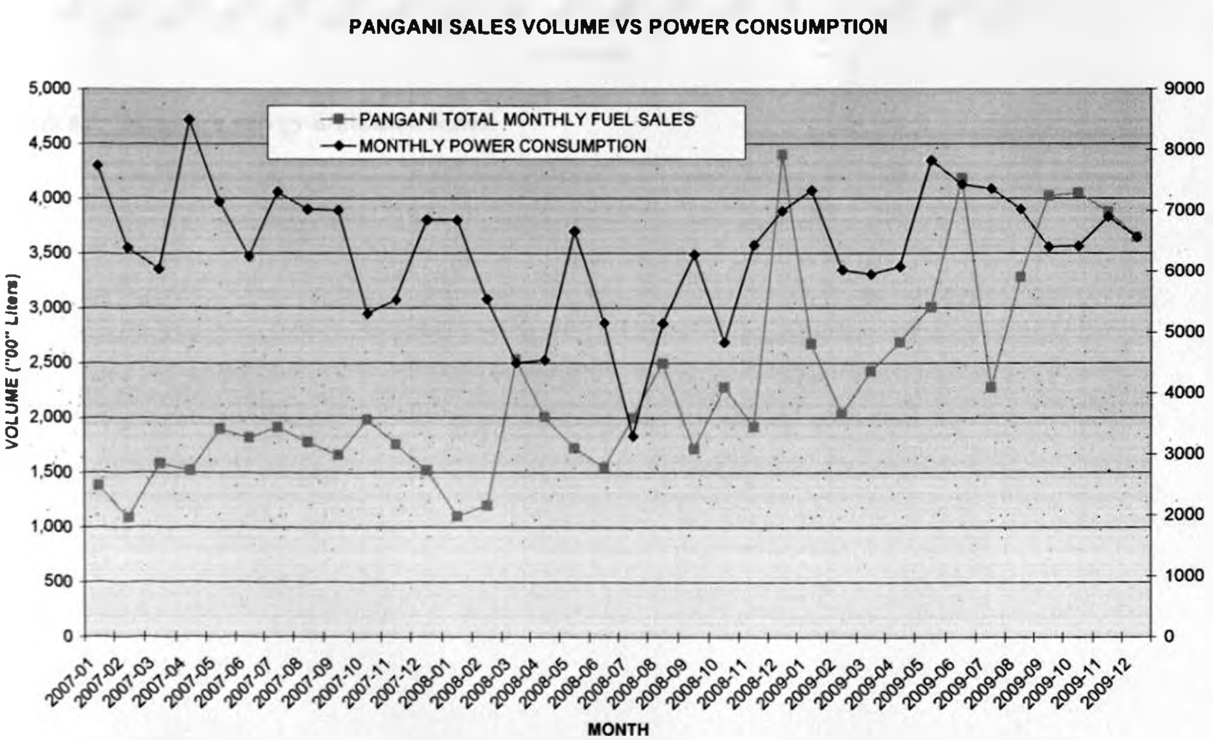
	BURUBURU				
MONTH	TOTAL MONTHLY FUEL SALES (Ltrs)	MONTHLY POWER CONSUMPTION (kWh)	MONTHLY ENERGY UTILIZATION INDEX (kWk/Ltr)	CUMULATIVE SALES VOLUME (Ltrs)	CUMULATIVE POWER CONSUMPTION (kWh)
2007-01	280,500	5,254	0.019	2,805	5,254
2007-02	218,500	4,980	0.023	4,990	10,234
2007-03	248,000	2,813	0.011	7,470	13,047
2007-04	207,500	4,410	0.021	9,545	17,457
2007-05	254,000	4,216	0.017	12,085	21,673
2007-06	203,500	3,604	0.018	14,120	25,277
2007-07	223,000	3,615	0.016	16,350	28,892
2007-08	156,500	3,341	0.021	17,915	32,233
2007-09	188,000	3,482	0.019	19,795	35,715
2007-10	212,500	3,330	0.016	21,920	39,045
2007-11	234,179	3,200	0.014	24,261	42,245
2007-12	243,500	3,031	0.012	26,696	45,276
2008-01	233,000	4,450	0.019	29,026	49,726
2008-02	153,500	3,231	0.021	30,561	52,957
2008-03	225,500	3,106	0.014	32,816	56,063
2008-04	248,000	3,032	0.012	35,296	59,095
2008-05	215,000	3,924	0.018	37,446	63,019
2008-06	195,500	3,595	0.018	39,401	66,614
2008-07	155,000	3,282	0.021	40,951	69,896
2008-08	175,500	4,274	0.024	42,706	74,170
2008-09	157,000	3,527	0.022	44,276	77,697
2008-10	139,500	2,719	0.019	45,671	80,416
2008-11	138,500	3,376	0.024	47,056	83,792
2008-12	147,500	3,403	0.023	48,531	87,195
2009-01	72,500	4,119	0.057	49,256	91,314
2009-02	215,000	3,112	0.014	51,406	94,426
2009-03	153,500	4,172	0.027	52,941	98,598
2009-04	138,500	4,969	0.036	54,326	103,567
2009-05	149,000	4,130	0.028	55,816	107,697
2009-06	280,000	3,527	0.013	58,616	111,224
2009-07	193,000	3,403	0.018	60,546	114,627
2009-08	209,923	3,112	0.015	62,645	117,739
2009-09	190,000	3,924	0.021	64,545	121,663
2009-10	223,000	3,924	0.018	66,775	125,587
2009-11	228,500	4,980	0.022	69,060	130,567
2009-12	267,000	4,410	0.017	71,730	134,977
TOTAL	7,173,102	134,977	0.728		
MONTHLY AVERAGE	199,252.83	3,749.36	0.020		

Table 4.4: Pangani historical data

	PANGANI				
MONTH	TOTAL MONTHLY FUEL SALES (Ltrs)	MONTHLY POWER CONSUMPTION (kWh)	MONTHLY ENERGY UTILIZATION INDEX (kWh/Ltr)	CUMULATIVE SALES VOLUME (Ltrs)	CUMULATIVE POWER CONSUMPTION (kWh)
2007-01	138,000	7,746	0.056	1,380	7,746
2007-02	109,000	6,395	0.059	2,470	14,141
2007-03	158,500	6,049	0.038	4,055	20,190
2007-04	152,000	8,495	0.056	5,575	28,685
2007-05	190,000	7,156	0.038	7,475	35,841
2007-06	182,000	6,249	0.034	9,295	42,090
2007-07	191,500	7,309	0.038	11,210	49,399
2007-08	178,000	7,031	0.040	12,990	56,430
2007-09	166,000	7,011	0.042	14,650	63,441
2007-10	198,500	5,309	0.027	16,635	68,750
2007-11	176,000	5,538	0.031	18,395	74,288
2007-12	152,000	6,850	0.045	19,915	81,138
2008-01	110,000	6,848	0.062	21,015	87,986
2008-02	120,000	5,552	0.046	22,215	93,538
2008-03	253,500	4,501	0.018	24,750	98,039
2008-04	201,000	4,551	0.023	26,760	102,590
2008-05	172,500	6,665	0.039	28,485	109,255
2008-06	154,500	5,161	0.033	30,030	114,416
2008-07	200,000	3,302	0.017	32,030	117,718
2008-08	250,000	5,153	0.021	34,530	122,871
2008-09	171,500	6,279	0.037	36,245	129,150
2008-10	228,000	4,838	0.021	38,525	133,988
2008-11	192,000	6,437	0.034	40,445	140,425
2008-12	440,000	7,000	0.016	44,845	147,425
2009-01	267,500	7,335	0.027	47,520	154,760
2009-02	204,000	6,029	0.030	49,560	160,789
2009-03	242,850	5,961	0.025	51,988	166,750
2009-04	269,000	6,083	0.023	54,678	172,833
2009-05	301,000	7,829	0.026	57,688	180,662
2009-06	418,896	7,433	0.018	61,876	188,095
2009-07	227,500	7,365	0.032	64,151	195,460
2009-08	328,485	7,028	0.021	67,435	202,488
2009-09	402,500	6,408	0.016	71,460	208,896
2009-10	405,000	6,418	0.016	75,510	215,314
2009-11	388,000	6,903	0.018	79,390	222,217
2009-12	365,000	6,562	0.018	83,040	228,779
TOTAL	8,304,231	228,779	1.139		
MONTHLY AVERAGE	230,673.08	6,354.97	0.032		

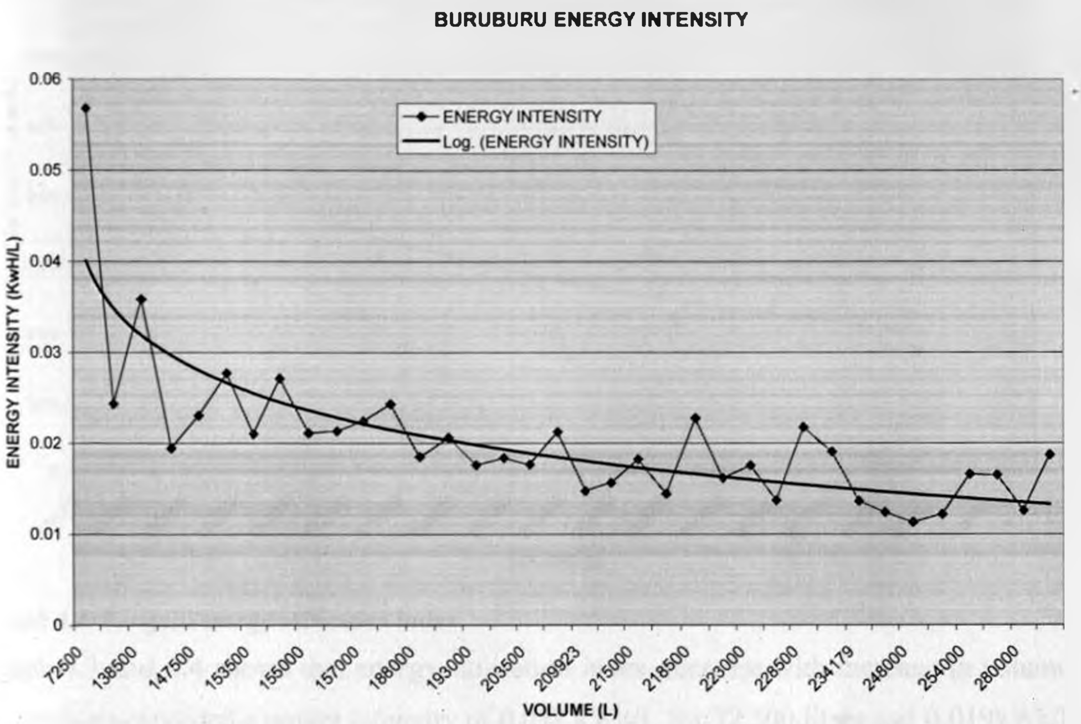


Graph 4.1: Buruburu sales volume vs power consumption.

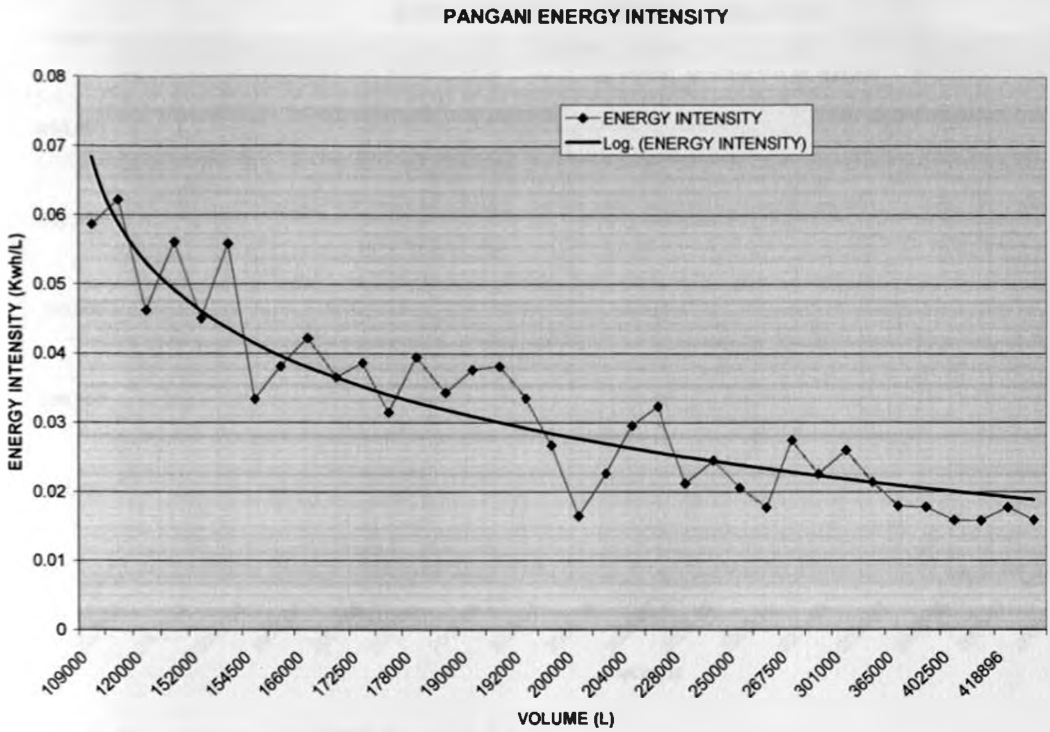


Graph 4.2: Pangani sales volume vs power consumption

Graph 4.1 and 4.2 shows the lines for power consumption and monthly sales volumes runs parallel for both Buruburu and Pangani petrol station. This shows that when the sales volume increases, consequently the power consumption increases.

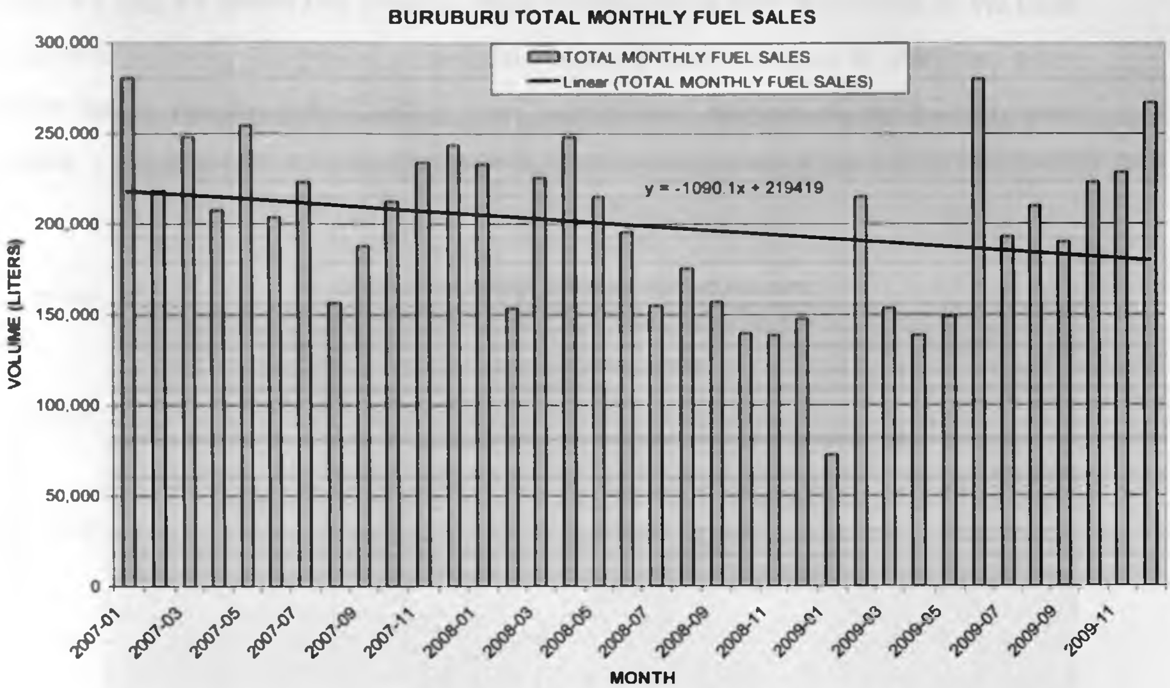


Graph 4.3: Buruburu energy utilization index

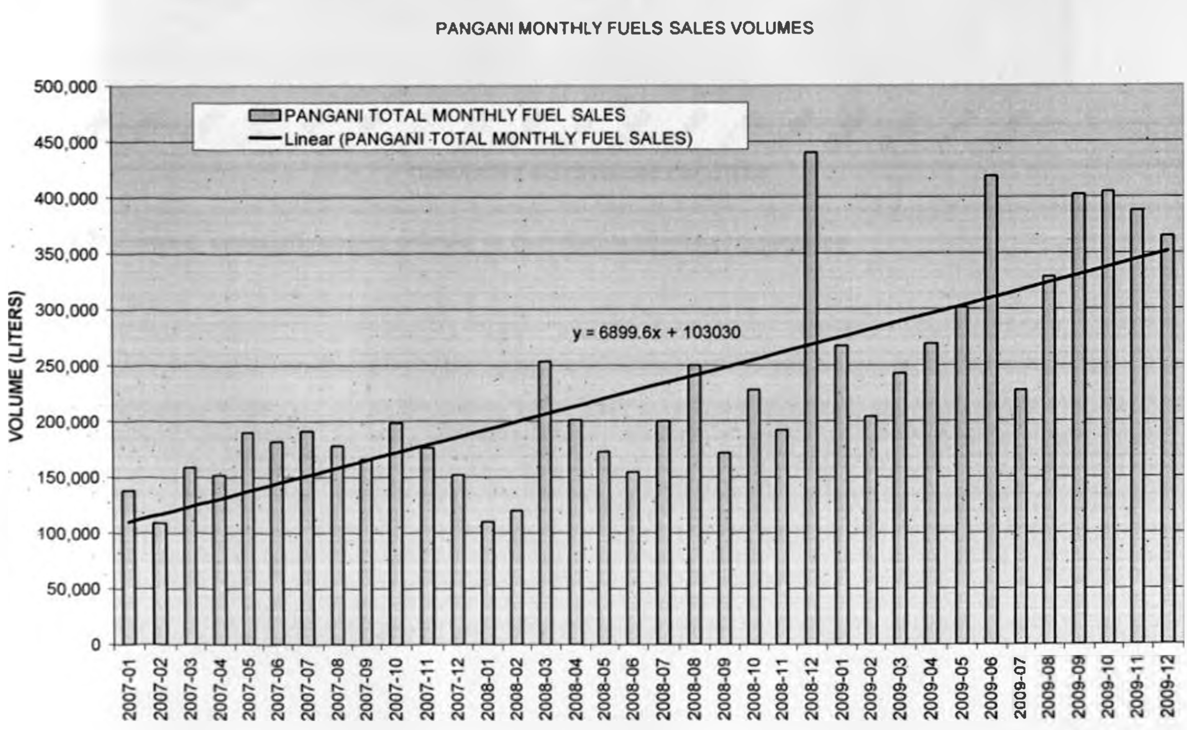


Graph 4.4: Pangani energy utilization index

Graph 4.3 and 4.4 shows that energy utilisation index decrease with increase in volume. Bururuburu recorded a power intensity of 0.057 kWh/L for 72,500 litres and 0.019kWh/L for 280.500 litres while Pangani recorded a power intensity of 0.057 kWh/L for 109.000 litres and 0.016 kWh/L for 440,000 litres. This is because as the volume increases the energy consumed is distributed on higher volume. Therefore, it is more economical in terms of power cost for the station to operate at high sales volume.

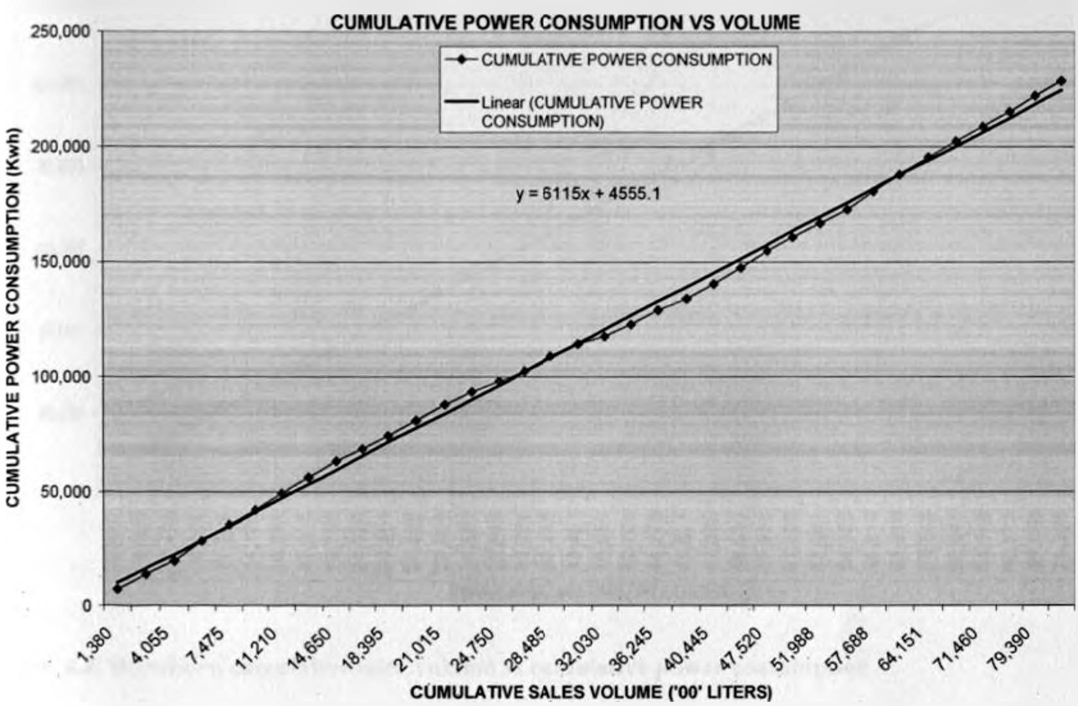


Graph 4.5: Buruburu total monthly fuels sales volume

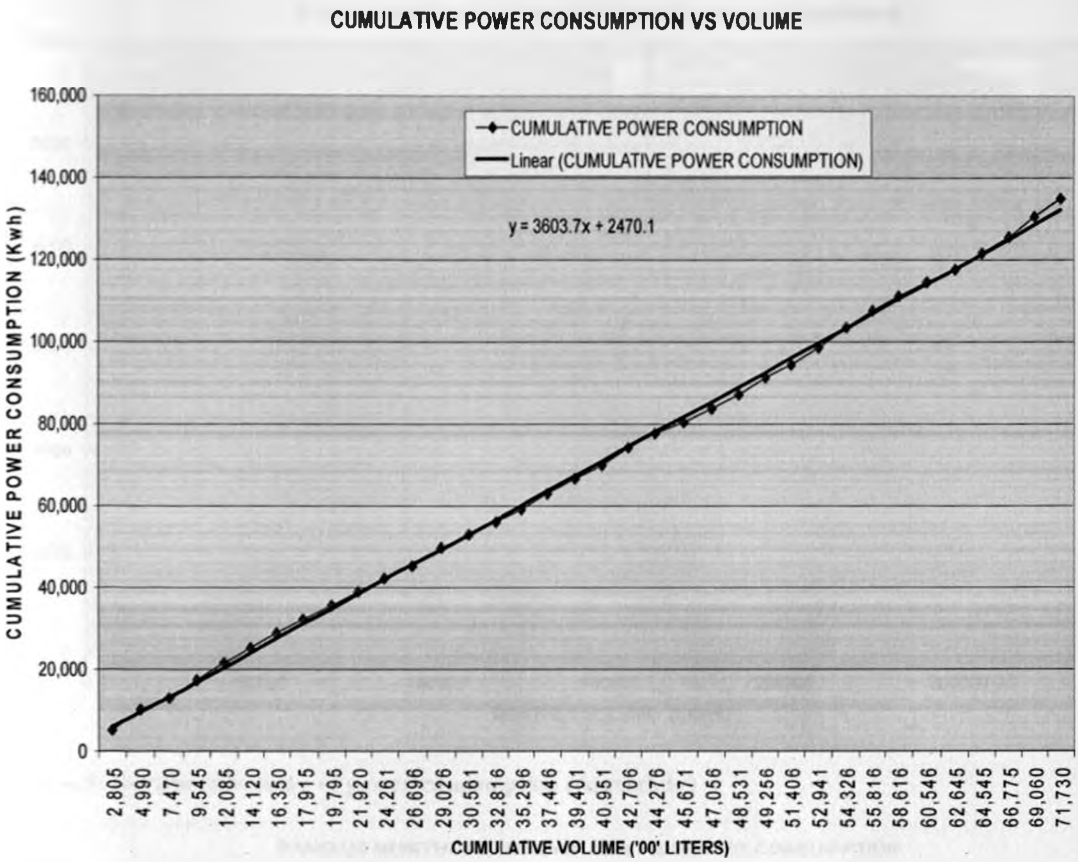


Graph 4.6: Pangani total monthly fuels sales volume

Graph 4.5 and 4.6 shows that monthly sales volume varies from one month to the other. Volume of sales for the period considered remained fairly constant in Buruburu petrol station but at Pangani petrol station there was gradual increase of the monthly sales volume.

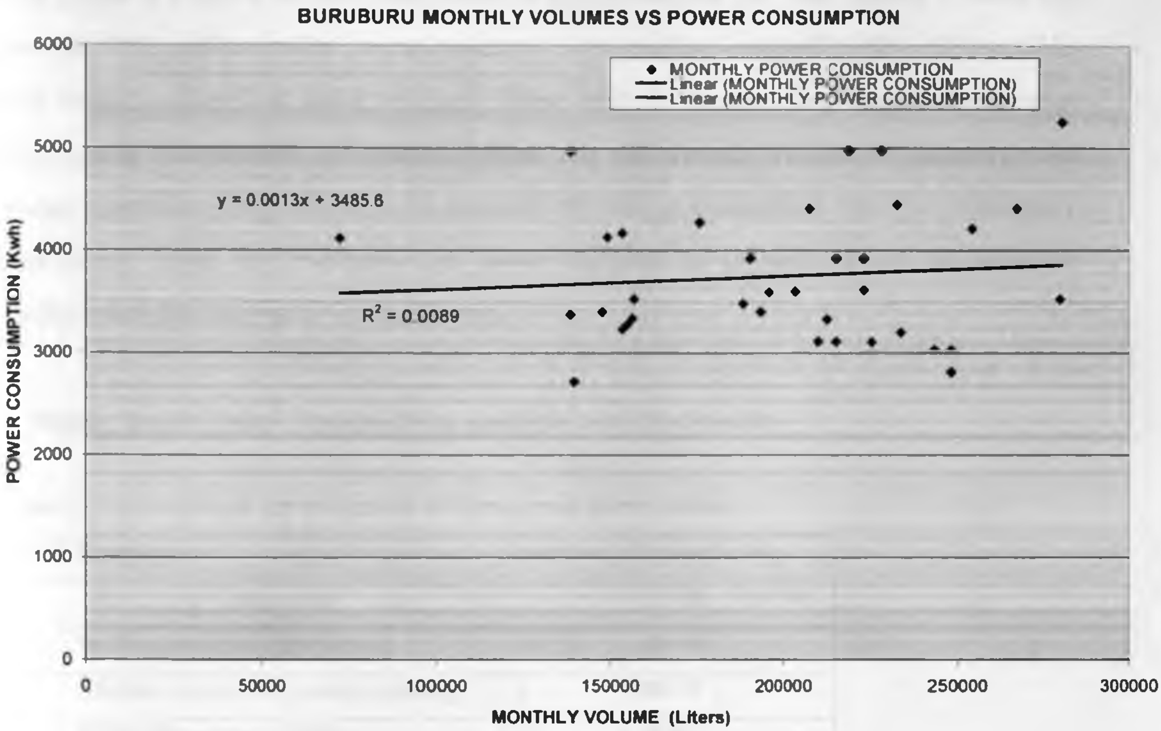


Graph 4.7: Pangani cumulative sales volume vs cumulative power consumption

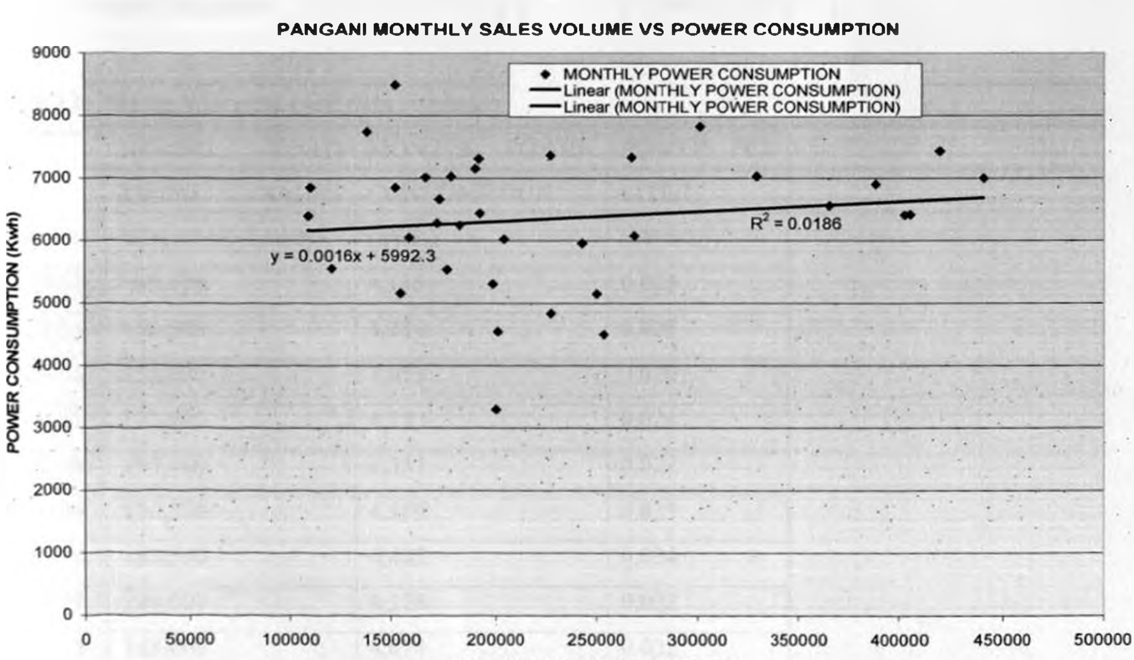


Graph 4.8: Buruburu cumulative sales volume vs cumulative power consumption

Graphs 4.7 and 4.8 shows that a plotting of cumulative sales volume verses cumulative power consumption follows a near straight line therefore for a given sales volume the energy required can easily be determined. If the cost of a unit of energy is known then the cost can easily be predicted which is very useful for budgeting and planning purposes.



Graph 4.9: Buruburu volume vs power consumption (Ascending)



Graph 4.10: Pangani volume vs power consumption (Ascending)

From graph 4.9 and 4.10, the coefficient of determination (R^{2}) test returns a value less than one. This indicates that monthly energy consumption is significantly influenced by other factors other than sales volume. These include security lighting, under canopy lighting and compressed air system, which are not directly related to monthly sales volume contributes significantly to amount of energy consumed. The Y- intercept is significantly large; this indicates that power required to support the site facilities not directly related to fuel sales is significant.

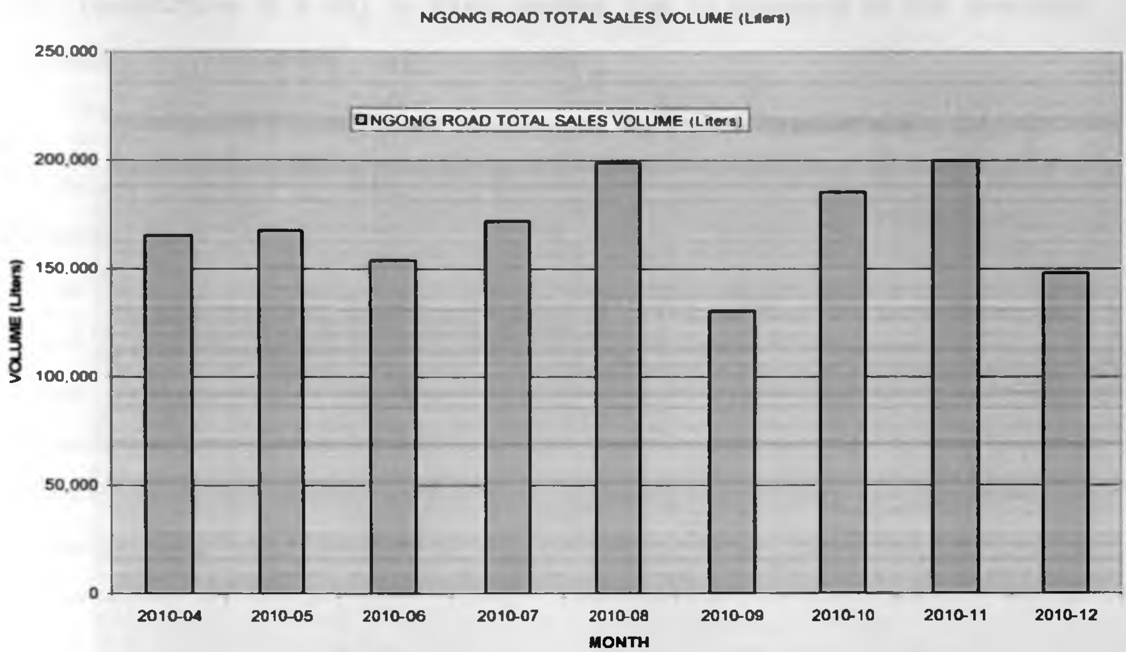
4.3 Ngong Road Petrol Station Data Analysis and Discussion

Table4.5 : Power consuming equipment at Ngong road petrol station

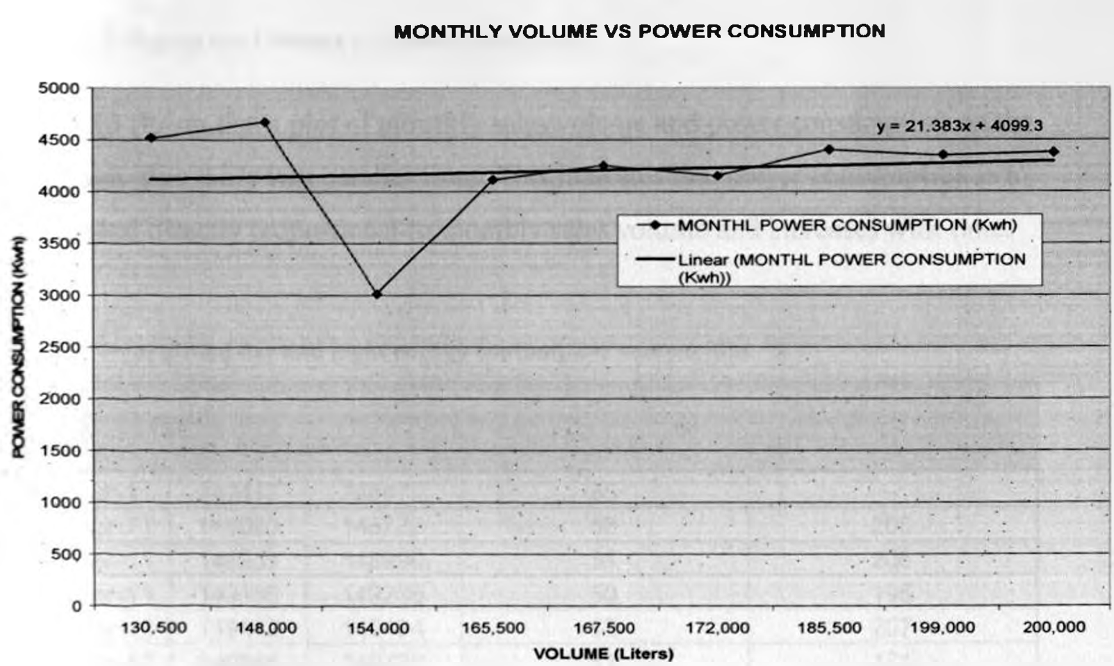
Item	Equipment	Number	Power rating
1	Atlas Copco Compressor	1	4.5 HP / 3360 W
2	Sodium vapor security lighting	20	400 W
3	Sodium vapor under canopy lighting	9	400 W
4	Office fluorescent lighting	12	36 W
5	Wayne fuel dispensers - Red jacket	4	1.5HP / 1120 W
6	Wayne fuel pumps	1	1.5HP / 1120 W

Table 4.6: Ngong historical road data summary

MONTH	NGONG ROAD TOTAL SALES VOLUME (Liters)	MONTHL POWER CONSUMPTION (kWh)	POWER PER LITER (kWh/L)
2010-04	165,500	4,115	0.025
2010-05	167,500	4,251	0.025
2010-06	154,000	3,013	0.020
2010-07	172,000	4,153	0.024
2010-08	199,000	4,351	0.022
2010-09	130,500	4,519	0.035
2010-10	185,500	4,402	0.024
2010-11	200,000	4,378	0.022
2010-12	148,000	4,674	0.032

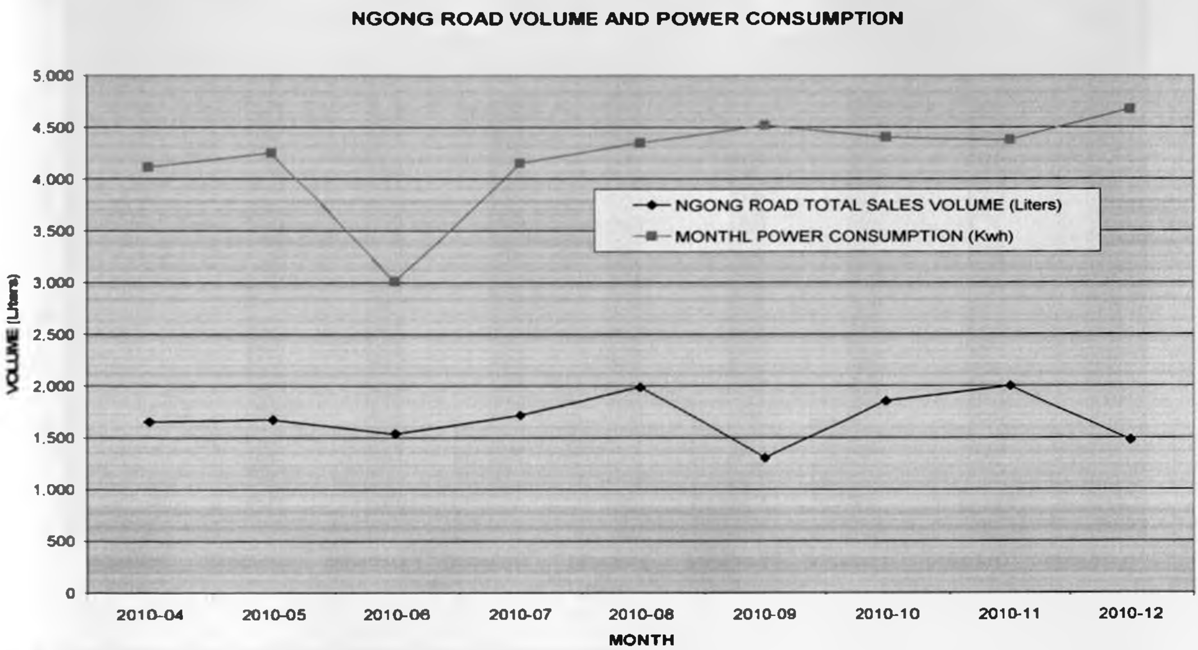


Graph 4.11: Ngong road total monthly sales volume



Graph 4.12: Ngong road monthly volume vs power consumption

Graph 4.12 shows that the petrol station has significant fixed power consumption. That is the amount of power which does not depend on the volume of fuel sold. Therefore, other energy consuming equipment like security lighting and under canopy lighting whose energy consumption in a day is fixed whether fuel is dispensed or not contribute significantly to the amount of energy consumed.

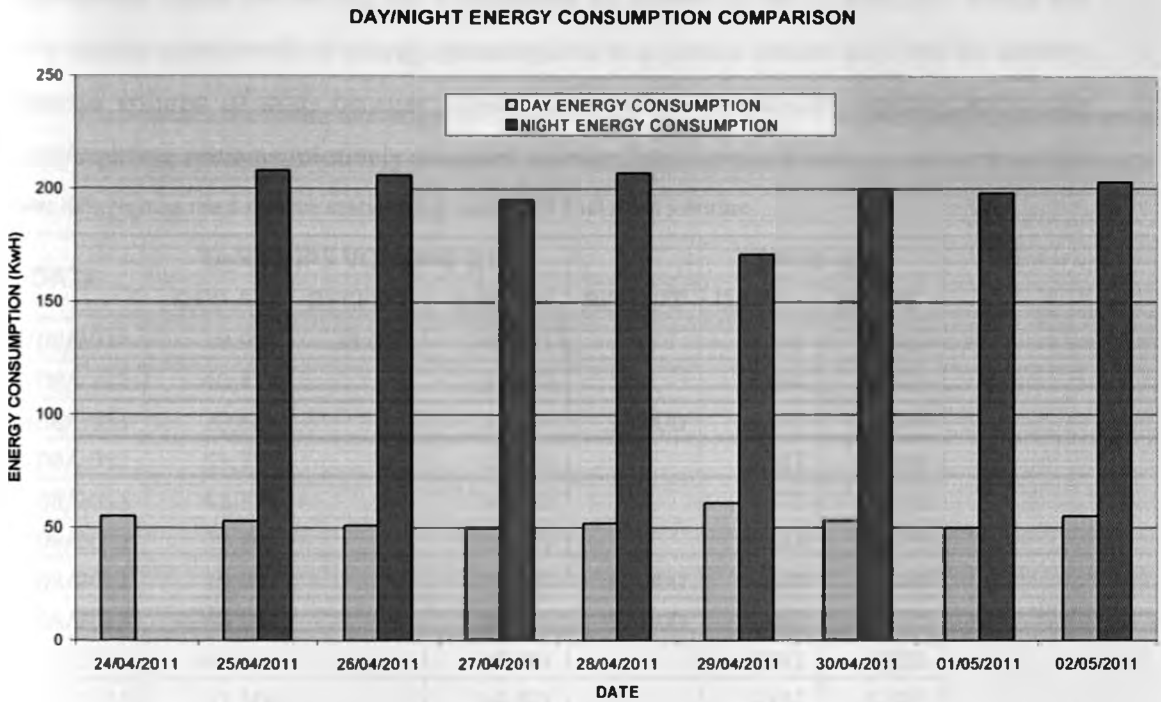


Graph 4.13: Ngong road volume vs power consumption

Graph 4.13 shows that a plot of monthly sales volume and power consumption on the same graph give fairly two parallel lines. This indicates that power consumption is to some extend directly proportional to monthly sales volume and increases with time.

Table 4.7: Ngong road day and night energy consumption comparison

DATE	METER READING		DAY ENERGY CONSUMPTION (kWh)	NIGHT ENERGY CONSUMPTION (kWh)
	6:00 AM	6:00 PM		
24-Apr-11	148417	148472	55	-
25-Apr-11	148680	148733	53	208
26-Apr-11	148939	148990	51	206
27-Apr-11	149185	149235	50	195
28-Apr-11	149442	149494	52	207
29-Apr-11	149665	149726	61	171
30-Apr-11	149926	149979	53	200
01-May-11	150177	150227	50	198
02-May-11	150430	150485	55	203
TOTAL			480	1,588
AVERAGE			53.33	176.44



Graph 4.14: Ngong road day and night energy consumption

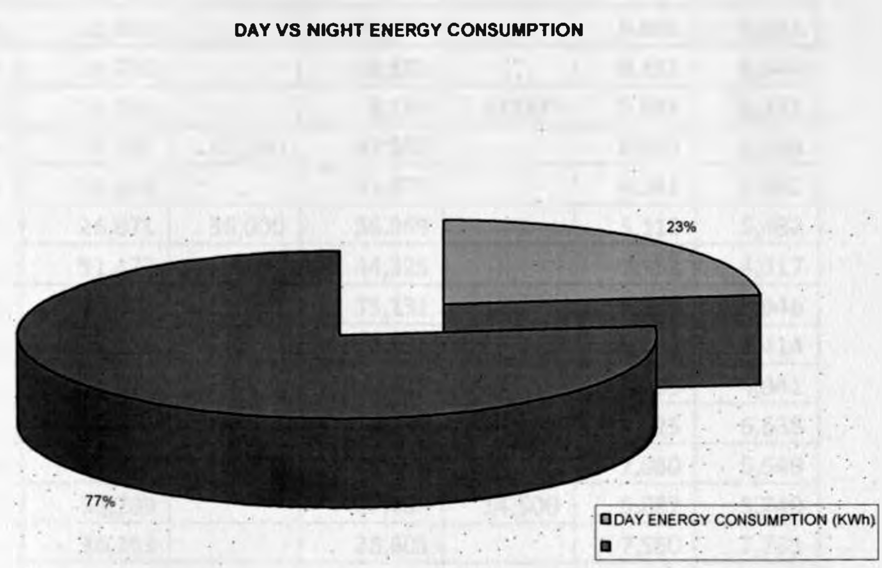


Figure 4.1: Ngong road day vs night energy consumption

From table 4.7, graph 4.14 and figure 4.1 the energy consumption during the night makes 77% of the total energy consumed in a whole day. During the night security lights and under canopy lights are on and the compressed air system is not in use. This points out that a certain component of energy consumption in a petrol station may not be directly related to volume of sales because power consumption by security lighting and under canopy lighting remains relatively constant whether fuel is sold or not.

Table: 4.8: Ngong road service station day and night fuel sales volume

DATE	TANK DIPS VOLUME (Lts)				SALES (Lts)	
	6:00 AM	RECEIPT	6:00 PM	RECEIPT	DAY	NIGHT
23/08/2011	18,954	33,000	45,841		6,113	5,427
24/08/2011	40,414		35,760		4,654	6,113
25/08/2011	29,647		23,076	36,000	6,571	5,324
26/08/2011	53,752		47,825		5,927	5,448
27/08/2011	42,377		34,902		7,475	5,101
28/08/2011	29,801		24,470		5,331	4,578
29/08/2011	19,892		13,654	32,000	6,238	4,660
30/08/2011	40,994		35,933	17,000	5,061	5,130
31/08/2011	47,803		42,061		5,742	4,553
01/09/2011	37,508		32,377		5,131	5,381
02/09/2011	26,996	36,000	56,808		6,188	7,575
03/09/2011	49,233		40,818		8,415	5,379
04/09/2011	35,439		29,774		5,665	4,981
05/09/2011	24,793		18,502		6,291	5,344
06/09/2011	13,158		8,114	17,000	5,044	6,331
07/09/2011	18,783	32,000	42,200		8,583	6,385
08/09/2011	35,815		31,473		4,342	5,402
09/09/2011	26,071	36,000	56,959		5,112	5,482
10/09/2011	51,477		44,325		7,152	4,317
11/09/2011	40,008		35,132		4,876	3,946
12/09/2011	31,186		21,931		9,255	7,414
13/09/2011	14,517		8,522		5,995	4,941
14/09/2011	3,581		2,056	14,500	1,525	6,638
15/09/2011	9,918	36,000	38,838		7,080	5,549
16/09/2011	33,289		27,402	14,500	5,887	5,749
17/09/2011	36,153		28,603		7,550	7,731
18/09/2011	20,872		16,581		4,291	4,953
19/09/2011	11,628		7,828	33,000	3,800	5,638
20/09/2011	35,190		30,753		4,437	5,472
21/09/2011	25,281	36,000	55,193		6,088	5,894
22/09/2011	49,299		44,595		4,704	5,586
23/09/2011	39,009	36,000	69,075		5,934	
		TOTAL			**186,457**	**172,422**
		AVERAGE			**5,827**	**5,562**

Table 4.8 shows an average sales volume 5,827 liters during the day and average sales volume of 5,562 liters during the night. Therefore, there is no much difference between sales volume during the day and during the night and it can be comfortably assumed that fuel related energy use during the day is equivalent to fuel related energy use during the night.

Day sales volume represents sales between 6:00Am and 6:00Pm while night sales represent sales between 6:00Pm and 6:00Am. The reason why sales volume between the two periods are comparable is mainly due to fueling which takes place in the evening when people leave work and matatu close business and also early in the morning as people drive to work. This makes up for the fueling time lost in the middle of the night.

Table 4.9: Ngong road service station day and night power supply

DATE	KENYA POWER METER READING (kWh)		POWER CONSUMPTION (kWh)	
	6:00 AM	6:00 PM	DAY	NIGHT
23/08/2011	176,819	176,880	61	208
24/08/2011	177,088	177,141	53	190
25/08/2011	177,331	177,393	62	210
26/08/2011	177,603	177,661	58	212
27/08/2011	177,873	177,938	65	205
28/08/2011	178,143	178,198	55	171
29/08/2011	178,369	178,432	63	207
30/08/2011	178,639	178,693	54	207
31/08/2011	178,900	178,956	56	190
01/09/2011	179,146	179,201	55	209
02/09/2011	179,410	179,472	62	210
03/09/2011	179,682	179,752	70	213
04/09/2011	179,965	180,022	57	217
05/09/2011	180,239	180,302	63	193
06/09/2011	180,495	180,549	54	209
07/09/2011	180,758	180,827	69	218
08/09/2011	181,045	181,097	52	215
09/09/2011	181,312	181,364	52	215
10/09/2011	181,579	181,646	67	211
11/09/2011	181,857	181,910	53	208
12/09/2011	182,118	182,189	71	179
13/09/2011	182,368	182,426	58	196
14/09/2011	182,622	182,671	49	205
15/09/2011	182,876	182,942	66	217
16/09/2011	183,159	183,219	60	191
17/09/2011	183,410	183,478	68	194
18/09/2011	183,672	183,725	53	211
19/09/2011	183,936	183,986	50	206
20/09/2011	184,192	184,243	51	218
21/09/2011	184,461	184,525	64	216
22/09/2011	184,741	184,793	52	196
23/09/2011	184,989	185,047	58	
	TOTAL		**1,881**	**6,347**
	AVERAGE		**58.8**	**204.7**

Table 4.9 shows that the average power consumption during the day for Ngong road service station is 58.8 kWh and during the night is 204.7 kWh. The high energy

consumption during the night can be attributed to lighting because the only energy consuming equipment's in use during the night are the dispensers and lighting.

Check meter was purchased and send to Kenya Bureau of Standards for calibration. It was then installed at the compressor power line and eleven readings obtained. This was used to approximate compressor power consumption at the petrol station.

Table 4.10: Ngong Road Service Station Air Compressor Power Consumption

ITEM	DATE	METER READING AT 6:00AM	POWER (KWh)
1	31/10/2011	98.04	6.56
2	01/11/2011	104.60	7.16
3	02/11/2011	111.76	6.41
4	03/11/2011	118.17	5.93
5	04/11/2011	124.10	5.12
6	05/11/2011	129.22	6.15
7	06/11/2011	135.37	5.32
8	07/11/2011	140.69	7.31
9	08/11/2011	148.00	6.72
10	09/11/2011	154.72	6.93
11	10/11/2011	161.65	7.67
12	11/11/2011	169.32	
	TOTAL		71.28
	AVERAGE		6.48

Table 4.10 shows the compressor power consumption during the day. During the night the compressor is not in use and it's switched off therefore no power consumption. The average compressor power consumption in a day is 6.48kWh for Ngong road service station.

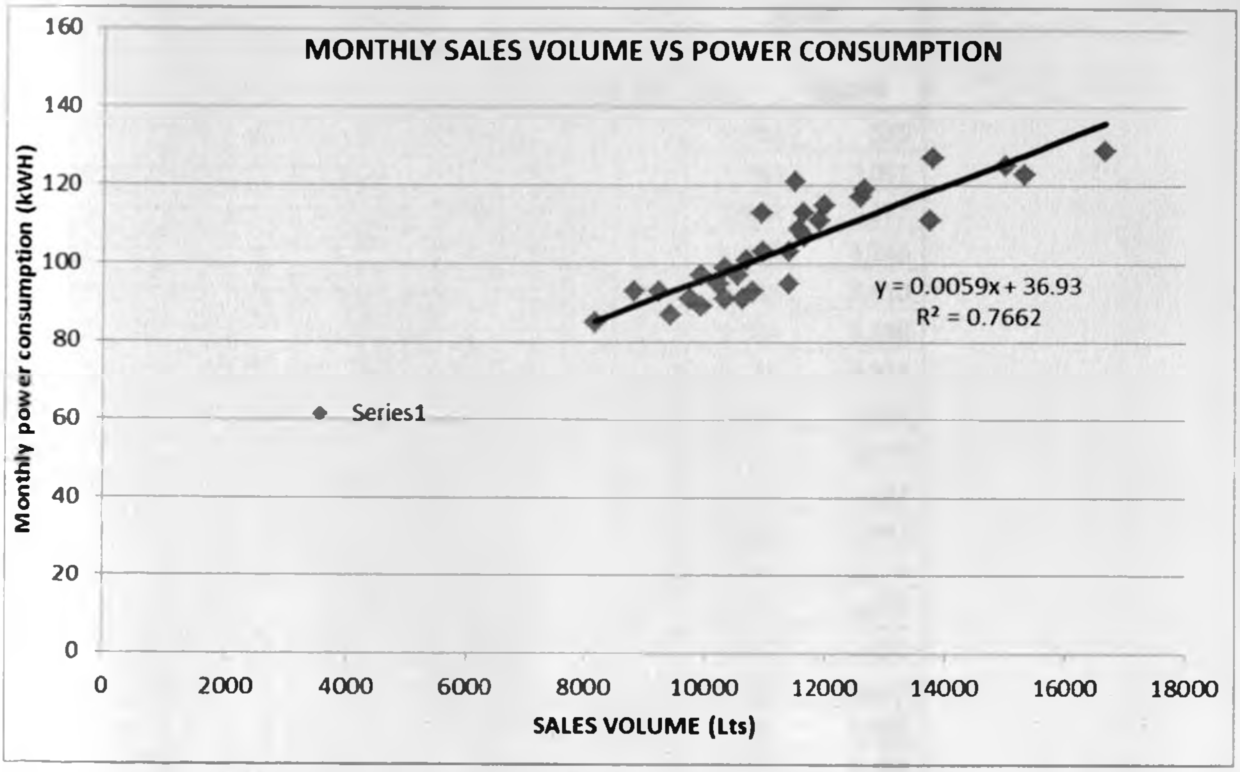
Therefore an average value of 6.48kWh can be reduced from the day time energy consumption to obtain the energy consumed by dispensers only as shown in the table 4.11.

4.11: Comparison of fuel related energy use and non-fuel related energy use for Ngong road service station

DATE	SALES VOLUME (Lts)			DAY POWER CONSUMPTION (KWH)		NIGHT POWER CONSUMPTION (KWH)		TOTAL POWER CONSUPTION - FUEL RELATED
	DAY	NIGHT	TOTAL	COMBINED	FUEL RELATED	COMBINED	LIGHTING	
23-Aug-11	6,113	5,427	11,540	61	55	208	153	109
24-Aug-11	4,654	6,113	10,767	53	47	190	143	93
25-Aug-11	6,571	5,324	11,895	62	56	210	154	111
26-Aug-11	5,927	5,448	11,375	58	52	212	160	103
27-Aug-11	7,475	5,101	12,576	65	59	205	146	117
28-Aug-11	5,331	4,578	9,909	55	49	171	122	97
29-Aug-11	6,238	4,660	10,898	63	57	207	150	113
30-Aug-11	5,061	5,130	10,191	54	48	207	159	95
31-Aug-11	5,742	4,553	10,295	56	50	190	140	99
1-Sep-11	5,131	5,381	10,512	55	49	209	160	97
2-Sep-11	6,188	7,575	13,763	62	56	210	154	111
3-Sep-11	8,415	5,379	13,794	70	64	213	149	127
4-Sep-11	5,665	4,981	10,646	57	51	217	166	101
5-Sep-11	6,291	5,344	11,635	63	57	193	136	113
6-Sep-11	5,044	6,331	11,375	54	48	209	161	95
7-Sep-11	8,583	6,385	14,968	69	63	218	155	125
8-Sep-11	4,342	5,402	9,744	52	46	215	169	91
9-Sep-11	5,112	5,482	10,594	52	46	215	169	91
10-Sep-11	7,152	4,317	11,469	67	61	211	150	121
11-Sep-11	4,876	3,946	8,822	53	47	208	161	93
12-Sep-11	9,255	7,414	16,669	71	65	179	114	129
13-Sep-11	5,995	4,941	10,936	58	52	196	144	103
14-Sep-11	1,525	6,638	8,163	49	43	205	162	85
15-Sep-11	7,080	5,549	12,629	66	60	217	157	119
16-Sep-11	5,887	5,749	11,636	60	54	191	137	107
17-Sep-11	7,550	7,731	15,281	68	62	194	132	123
18-Sep-11	4,291	4,953	9,244	53	47	211	164	93
19-Sep-11	3,800	5,638	9,438	50	44	206	162	87
20-Sep-11	4,437	5,472	9,909	51	45	218	173	89
21-Sep-11	6,088	5,894	11,982	64	58	216	158	115
22-Sep-11	4,704	5,586	10,290	52	46	196	150	91
23-Sep-11	5,934			58	52			
TOTAL	**186,457**	**172,422**	**352,945**	**1,881**	**1,674**	**6,347**	**4,725**	**3,244**
AVERAGE	**5,827**	**5,562**	**11,385**	**59**	**52**	**205**	**152**	**105**

Table 4.11 shows that Ngong road service station has an average daily sales volume of 11,385 liters of fuel. The average daily energy use related to fuel is 105 kWh while non-

fuel related one is 158.48 kWh (compressor and lighting). The non-fuel related energy consumption is not a function of volume of fuel sold.



Graph 4.15: Ngong road monthly sales volume against fuel related power consumption

Graph 4.15 shows that fuel related power consumption in a petrol station can be represented as a linear equation.

Y = 36.93 + 0.0059X ....(Eqn 4.1)

Where: Y – Daily power consumption in kWh

X – Daily sales volume in liters

4.4 Pangani Petrol Station Day and Night Data Analysis and Discussion

Table: 4.12: Pangani service station day and night fuel sales volume

DATE	TANK DIPS				SALES	
	6:00 AM	RECEIPT	6:00 PM	RECEIPT	DAY	NIGHT
12/10/2011	26,233		24,501		1,732	575
13/10/2011	23,926		19,966		3,960	3,051
14/10/2011	16,915	16,000	30,039		2,876	3,277
15/10/2011	26,762		23,809		2,953	3,246
16/10/2011	20,563		17,727		2,836	3,910
17/10/2011	13,817	21,500	32,393		2,924	3,398
18/10/2011	28,995		26,214		2,781	3,873
19/10/2011	22,341		19,517		2,824	2,831
20/10/2011	16,686		13,361		3,325	3,470
21/10/2011	9,891	14,500	21,087		3,304	3,752
22/10/2011	17,335		14,266		3,069	2,897
23/10/2011	11,369	32,000	40,326		3,043	3,276
24/10/2011	37,050		32,973		4,077	3,642
25/10/2011	29,331		26,099		3,232	4,262
26/10/2011	21,837		17,717		4,120	3,617
27/10/2011	14,100		11,115	10,000	2,985	3,000
28/10/2011	18,115		14,918		3,197	3,330
29/10/2011	11,588	14,500	22,426		3,662	2,660
30/10/2011	19,766	13,000	29,684		3,082	2,812
31/10/2011	26,872		23,746		3,126	3,245
01/11/2011	20,501		17,867		2,634	2,556
02/11/2011	15,311		11,921		3,390	3,573
03/11/2011	8,348	19,500	24,641		3,207	3,243
04/11/2011	21,398		18,551		2,847	3,824
05/11/2011	14,727	18,000	30,282		2,445	3,627
06/11/2011	26,655		23,238		3,417	3,969
07/11/2011	19,269	10,000	26,398		2,871	3,573
08/11/2011	22,825		20,377		2,448	3,452
09/11/2011	16,925		13,809		3,116	3,402
10/11/2011	10,407		7,188		3,219	3,342
11/11/2011	3,846	14,500	15,218		3,128	3,419
12/11/2011	11,799		8,863		2,936	
		TOTAL			**98,766**	**102,104**
		AVERAGE			**3,086**	**3,294**

Table 4.12 shows an average sales volume of 3,086 liters during the day and average sales volume of 3,294 liters during the night for Pangani petrol station. Therefore, day and night sales volumes are comparable and consequently it can be assumed that fuel related energy use during the day is equivalent to fuel related energy use during the night.

Table 4.13: Pangani service station day and night power supply

DATE	KENYA POWER METER READING (kWh)		POWER CONSUMPTION (kWh)	
	6:00 AM	6:00 PM	DAY	NIGHT
12/10/2011	94,826	94,852	26	82
13/10/2011	94,934	94,981	47	85
14/10/2011	95,066	95,104	38	86
15/10/2011	95,190	95,229	39	85
16/10/2011	95,314	95,352	38	88
17/10/2011	95,440	95,479	39	87
18/10/2011	95,566	95,603	37	89
19/10/2011	95,692	95,725	33	80
20/10/2011	95,805	95,843	38	86
21/10/2011	95,929	95,973	44	87
22/10/2011	96,060	96,094	34	84
23/10/2011	96,178	96,213	35	82
24/10/2011	96,295	96,335	40	90
25/10/2011	96,425	96,468	43	89
26/10/2011	96,557	96,601	44	86
27/10/2011	96,687	96,721	34	81
28/10/2011	96,802	96,838	36	85
29/10/2011	96,923	96,961	38	80
30/10/2011	97,041	97,072	31	81
31/10/2011	97,153	97,190	37	87
01/11/2011	97,277	97,308	31	83
02/11/2011	97,391	97,429	38	88
03/11/2011	97,517	97,554	37	87
04/11/2011	97,641	97,678	37	88
05/11/2011	97,766	97,802	36	87
06/11/2011	97,889	97,929	40	89
07/11/2011	98,018	98,056	38	86
08/11/2011	98,142	98,175	33	85
09/11/2011	98,260	98,297	37	84
10/11/2011	98,381	98,419	38	84
11/11/2011	98,503	98,540	37	86
12/11/2011	98,626	98,664	38	
	TOTAL		1,191	2,647
	AVERAGE		37.2	85.4

Table 4.13 shows that the average power consumption during the day for Pangani service station is 37.2 kWh and during the night is 85.4 kWh. Similarly, the high energy consumption during the night can be attributed to lighting because the only energy consuming equipment in use during the night are the dispensers and lighting and since the dispenser power consumption can be estimated, the rest of the consumption is related to lighting.

Table 4.14: Pangani Service Station Air Compressor Power Consumption

ITEM	DATE	METER READING AT 6:00AM	POWER (KWh)
1	14/10/2011	37.83	4.72
2	15/10/2011	42.55	3.87
3	16/10/2011	46.42	4.62
4	17/10/2011	51.04	4.12
5	18/10/2011	55.16	4.86
6	19/10/2011	60.02	4.87
7	20/10/2011	64.89	4.46
8	21/10/2011	69.35	3.91
9	22/10/2011	73.26	3.81
10	23/10/2011	77.07	4.61
11	24/10/2011	81.68	3.51
12	25/10/2011	85.19	
	TOTAL		47.36
	AVERAGE		4.31

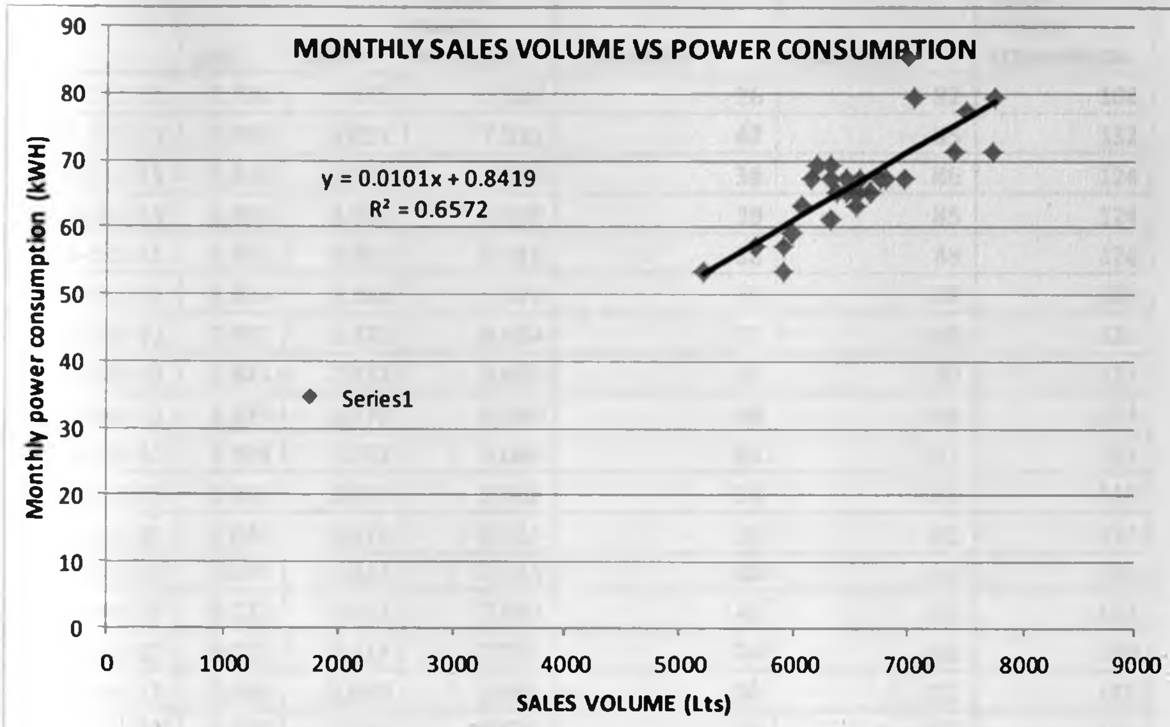
Table 4.14 shows the compressor power consumption for Pangani service station. During the night the compressor is not in use and it is switched off therefore no power consumption. The average compressor power consumption in a day is 4.31kWh for Pangani service station.

Therefore an average value of 4.31kWh can be reduced from the day time energy consumption to obtain the energy consumed by dispensers only as shown in the table 4.15 below.

4.15: Comparison of fuel related energy use and non-fuel related energy use for Pangani service station

DATE	SALES VOLUME (Lts)			DAY POWER CONSUMPTION (kWh)		NIGHT POWER CONSUMPTION (kWh)		TOTAL POWER CONSUPTION - FUEL RELATED
	DAY	NIGHT	TOTAL	COMBINED	FUEL RELATED	COMBINED	LIGHTING	
12-Oct-11	1,732	575	2,307	26	22	82	60	43
13-Oct-11	3,960	3,051	7,011	47	43	85	42	85
14-Oct-11	2,876	3,277	6,153	38	34	86	52	67
15-Oct-11	2,953	3,246	6,199	39	35	85	50	69
16-Oct-11	2,836	3,910	6,746	38	34	88	54	67
17-Oct-11	2,924	3,398	6,322	39	35	87	52	69
18-Oct-11	2,781	3,873	6,654	37	33	89	56	65
19-Oct-11	2,824	2,831	5,655	33	29	70	41	57
20-Oct-11	3,325	3,470	6,795	38	34	76	42	67
21-Oct-11	3,304	3,752	7,056	44	40	87	47	79
22-Oct-11	3,069	2,897	5,966	34	30	70	40	59
23-Oct-11	3,043	3,276	6,319	35	31	72	41	61
24-Oct-11	4,077	3,642	7,719	40	36	70	34	71
25-Oct-11	3,232	4,262	7,494	43	39	109	70	77
26-Oct-11	4,120	3,617	7,737	44	40	76	36	79
27-Oct-11	2,985	3,000	5,985	34	30	71	41	59
28-Oct-11	3,197	3,330	6,527	36	32	75	43	63
29-Oct-11	3,662	2,660	6,322	38	34	70	36	67
30-Oct-11	3,082	2,812	5,894	31	27	81	54	53
31-Oct-11	3,126	3,245	6,371	37	33	97	64	65
1-Nov-11	2,634	2,556	5,190	31	27	73	46	53
2-Nov-11	3,390	3,573	6,963	38	34	78	44	67
3-Nov-11	3,207	3,243	6,450	37	33	77	44	65
4-Nov-11	2,847	3,824	6,671	37	33	88	55	65
5-Nov-11	2,445	3,627	6,072	36	32	67	35	63
6-Nov-11	3,417	3,969	7,386	40	36	79	43	71
7-Nov-11	2,871	3,573	6,444	38	34	86	52	67
8-Nov-11	2,448	3,452	5,900	33	29	85	56	57
9-Nov-11	3,116	3,402	6,518	37	33	74	41	65
10-Nov-11	3,219	3,342	6,561	38	34	74	40	67
11-Nov-11	3,128	3,419	6,547	37	33	84	51	65
12-Nov-11	2,936			38	34			
TOTAL	98,766	102,104	197,934	1,191	1,053	2,491	1,472	2,039
AVERAGE	3,086	3,294	6,385	37	33	80	47	66

Table 4.15 shows that Pangani service station has an average daily sales volume of 6,385 liters of fuel. The average daily energy use related to fuel is 66kWh while non-fuel related one is 51.31kWh (compressor and lighting).



Graph 4.16: Pangani monthly sales volume against fuel related power consumption

Graph 4.16 shows similar results as graph 4.18, that fuel related power consumption in a petrol station can be represented as a linear equation.

$Y = 0.8419 + 0.0101X$ ....(Eqn 4.2)

Where: Y – Daily power consumption in kWh

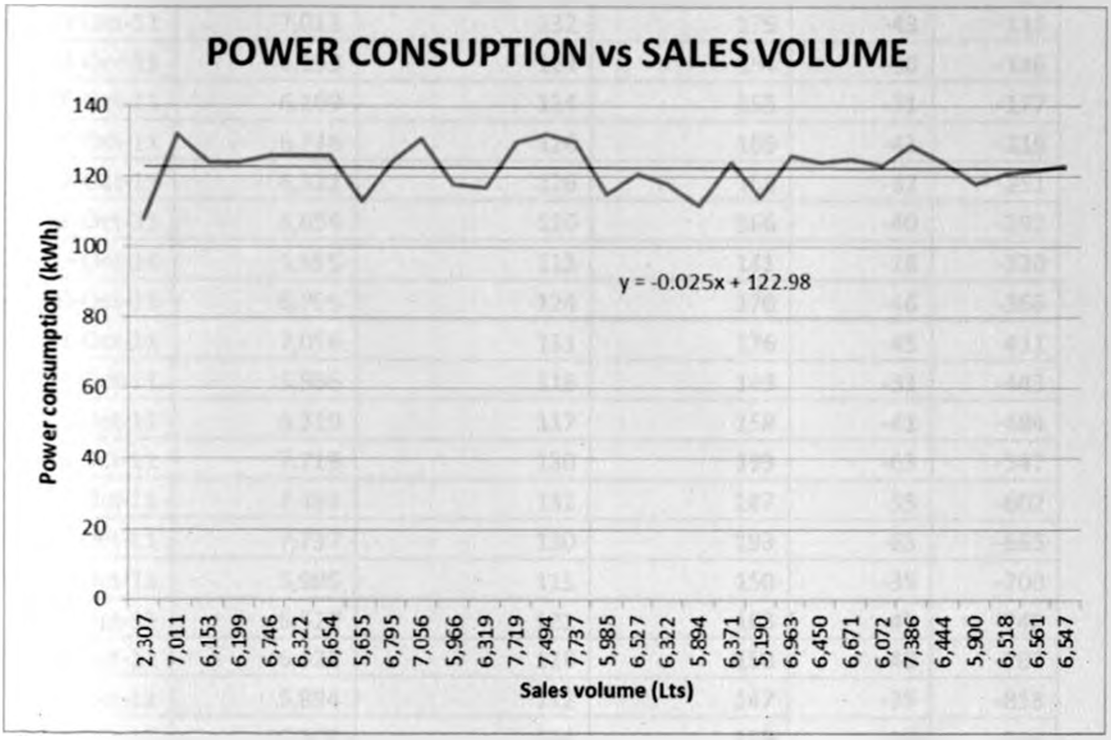
X – Daily sales volume in liters

4.5 Cumulative Sum (CUSUM) of differences for Pangani petrol station

Table 4.16: Pangani petrol station daily sales volume and power consumption

DATE	SALES VOLUME (Lts)			DAY POWER CONSUMPTION (kWh)	NIGHT POWER CONSUMPTION (kWh)	TOTAL POWER CONSUPTION
	DAY	NIGHT	TOTAL SALES VOLUME	COMBINED	COMBINED	TOTAL POWER CONSUPTION
12-Oct-11	1,732	575	2,307	26	82	108
13-Oct-11	3,960	3,051	7,011	47	85	132
14-Oct-11	2,876	3,277	6,153	38	86	124
15-Oct-11	2,953	3,246	6,199	39	85	124
16-Oct-11	2,836	3,910	6,746	38	88	126
17-Oct-11	2,924	3,398	6,322	39	87	126
18-Oct-11	2,781	3,873	6,654	37	89	126
19-Oct-11	2,824	2,831	5,655	33	80	113
20-Oct-11	3,325	3,470	6,795	38	86	124
21-Oct-11	3,304	3,752	7,056	44	87	131
22-Oct-11	3,069	2,897	5,966	34	84	118
23-Oct-11	3,043	3,276	6,319	35	82	117
24-Oct-11	4,077	3,642	7,719	40	90	130
25-Oct-11	3,232	4,262	7,494	43	89	132
26-Oct-11	4,120	3,617	7,737	44	86	130
27-Oct-11	2,985	3,000	5,985	34	81	115
28-Oct-11	3,197	3,330	6,527	36	85	121
29-Oct-11	3,662	2,660	6,322	38	80	118
30-Oct-11	3,082	2,812	5,894	31	81	112
31-Oct-11	3,126	3,245	6,371	37	87	124
1-Nov-11	2,634	2,556	5,190	31	83	114
2-Nov-11	3,390	3,573	6,963	38	88	126
3-Nov-11	3,207	3,243	6,450	37	87	124
4-Nov-11	2,847	3,824	6,671	37	88	125
5-Nov-11	2,445	3,627	6,072	36	87	123
6-Nov-11	3,417	3,969	7,386	40	89	129
7-Nov-11	2,871	3,573	6,444	38	86	124
8-Nov-11	2,448	3,452	5,900	33	85	118
9-Nov-11	3,116	3,402	6,518	37	84	121
10-Nov-11	3,219	3,342	6,561	38	84	122
11-Nov-11	3,128	3,419	6,547	37	86	123
TOTAL	95,830	102,104	197,934	1,153	2,647	3,800
AVERAGE	2,995	3,294	6,385	36	85	123

From the data in table 4.16, a sales volume graph is done and best fit straight line developed to obtain the base line equation.



Graph 4.17: Pangani petrol station trend line

Graph 4.17 gives us the power consumption trend line for Pangani petrol station. The equation of the trend line obtained is:

Y = 122.98 + 0.025x -- (Eqn 4.3)

Where

Y – Energy consumed (kWh)

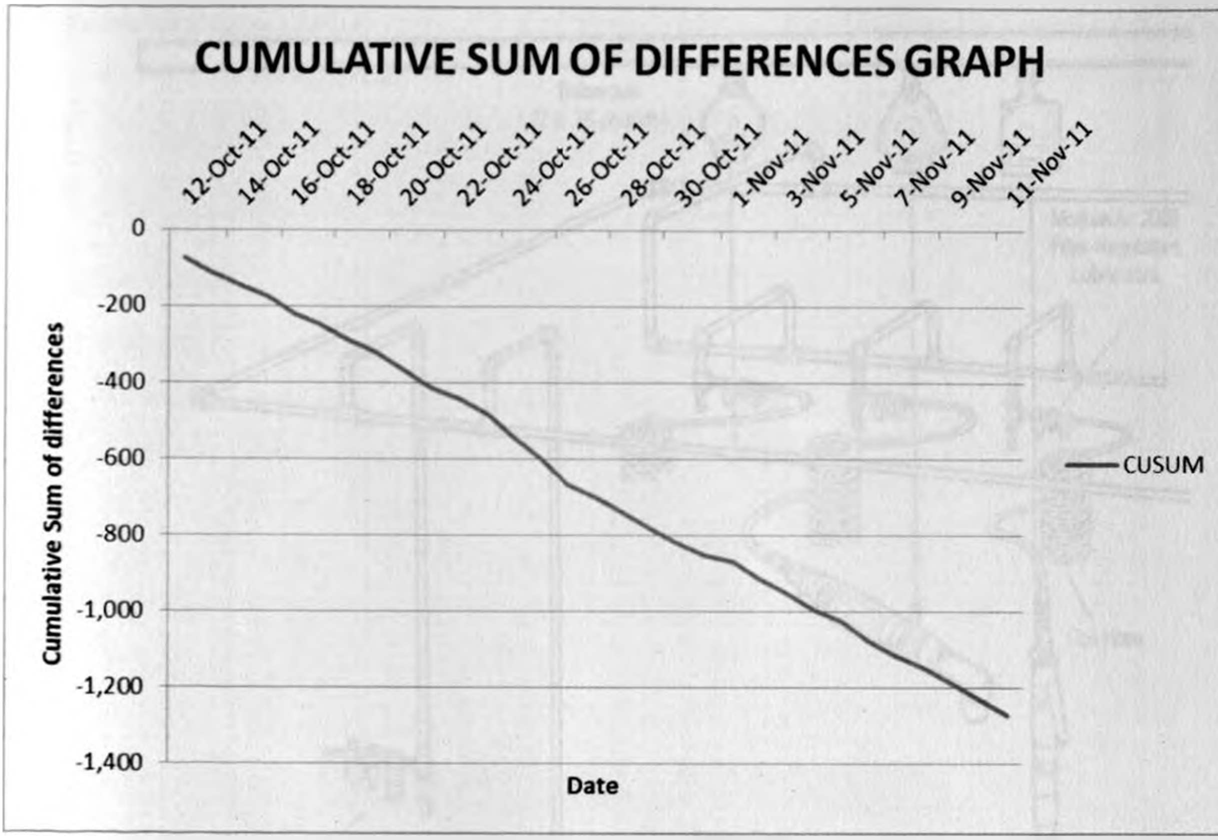
X – Sales volume for the period (Lts)

This equation is used to calculate the expected power consumption as shown in table 4.17. The values calculated acts as the power consumption bench marks at different levels of production.

Table 4.17: Pangani petrol station Cumulative Sum (CUSUM)

DATE	TOTAL SALES VOLUME (S_{act})	TOTAL POWER CONSUPTION (P_{act})	CALCULATED POWER (P_{calc})	P_{act} - P_{calc}	CUSUM
12-Oct-11	2,307	108	181	-73	-73
13-Oct-11	7,011	132	175	-43	-116
14-Oct-11	6,153	124	154	-30	-146
15-Oct-11	6,199	124	155	-31	-177
16-Oct-11	6,746	126	169	-43	-219
17-Oct-11	6,322	126	158	-32	-251
18-Oct-11	6,654	126	166	-40	-292
19-Oct-11	5,655	113	141	-28	-320
20-Oct-11	6,795	124	170	-46	-366
21-Oct-11	7,056	131	176	-45	-411
22-Oct-11	5,966	118	149	-31	-443
23-Oct-11	6,319	117	158	-41	-484
24-Oct-11	7,719	130	193	-63	-547
25-Oct-11	7,494	132	187	-55	-602
26-Oct-11	7,737	130	193	-63	-665
27-Oct-11	5,985	115	150	-35	-700
28-Oct-11	6,527	121	163	-42	-742
29-Oct-11	6,322	118	158	-40	-782
30-Oct-11	5,894	112	147	-35	-818
31-Oct-11	6,371	124	159	-35	-853
1-Nov-11	5,190	114	130	-16	-869
2-Nov-11	6,963	126	174	-48	-917
3-Nov-11	6,450	124	161	-37	-954
4-Nov-11	6,671	125	167	-42	-996
5-Nov-11	6,072	123	152	-29	-1,024
6-Nov-11	7,386	129	185	-56	-1,080
7-Nov-11	6,444	124	161	-37	-1,117
8-Nov-11	5,900	118	148	-30	-1,147
9-Nov-11	6,518	121	163	-42	-1,189
10-Nov-11	6,561	122	164	-42	-1,231
11-Nov-11	6,547	123	164	-41	-1,271

The difference between the actual power consumption and expected power consumption is calculated as shown in table 4.17 and plotted for the period of time considered.



Graph 4.18: Pangani petrol station Cumulative Sum of Differences

From graph 4.18, it is observed that performance declines continuously from the expected energy consumption. As per table 4.17, the difference between P_{act} and P_{calc} gives a negative, hence no energy saving measure has been implemented at the station.

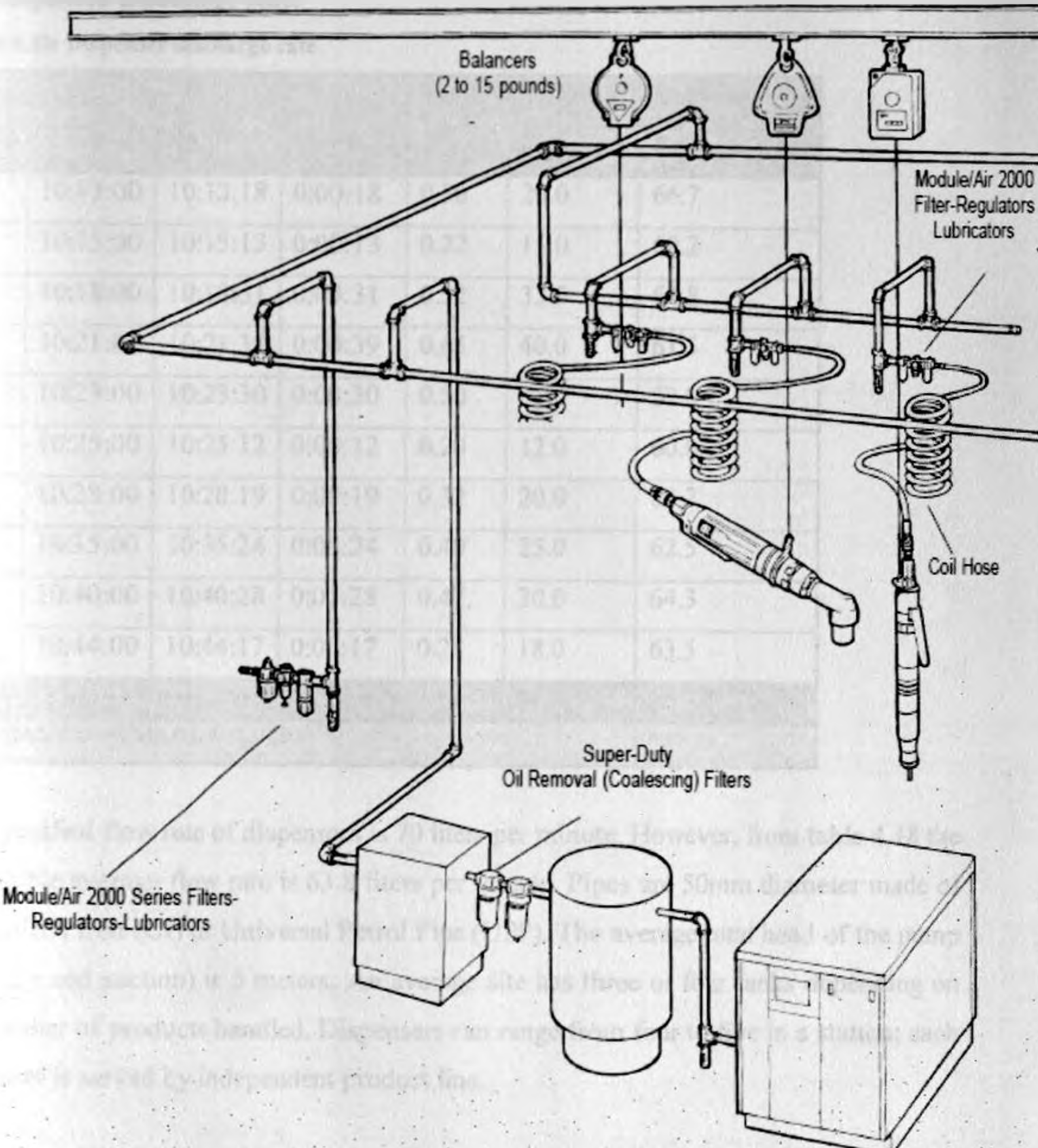


Figure 4.2: Typical compressed air/oil dispensing system in petrol station

4.6 Dispenser Discharge Rate

Table 4.18: Dispenser discharge rate

Item	Start	Stop	Time (Sec)	Time (Min)	Volume (liters)	Delivery Rate (L/M)
1	10:13:00	10:13:18	0:00:18	0.30	20.0	66.7
2	10:15:00	10:15:13	0:00:13	0.22	15.0	69.2
3	10:18:00	10:18:31	0:00:31	0.52	33.5	64.8
4	10:21:00	10:21:39	0:00:39	0.65	40.0	61.5
5	10:23:00	10:23:30	0:00:30	0.50	31.0	62.0
6	10:25:00	10:25:12	0:00:12	0.20	12.0	60.0
7	10:28:00	10:28:19	0:00:19	0.32	20.0	63.2
8	10:35:00	10:35:24	0:00:24	0.40	25.0	62.5
9	10:40:00	10:40:28	0:00:28	0.47	30.0	64.3
10	10:44:00	10:44:17	0:00:17	0.28	18.0	63.5
TOTAL				**3.85**	**244.5**	**637.7**
AVERAGE DISCHARGE RATE						**63.8**

The specified flow rate of dispensers is 70 liters per minute. However, from table 4.18 the achievable average flow rate is 63.8 liters per minute. Pipes are 50mm diameter made of Galvanized Iron (GI) or Universal Petrol Pipe (UPP). The average total head of the pump (delivery and suction) is 5 meters. An average site has three or four tanks depending on the number of products handled. Dispensers can range from four to five in a station; each dispenser is served by independent product line.

General petrol station layout

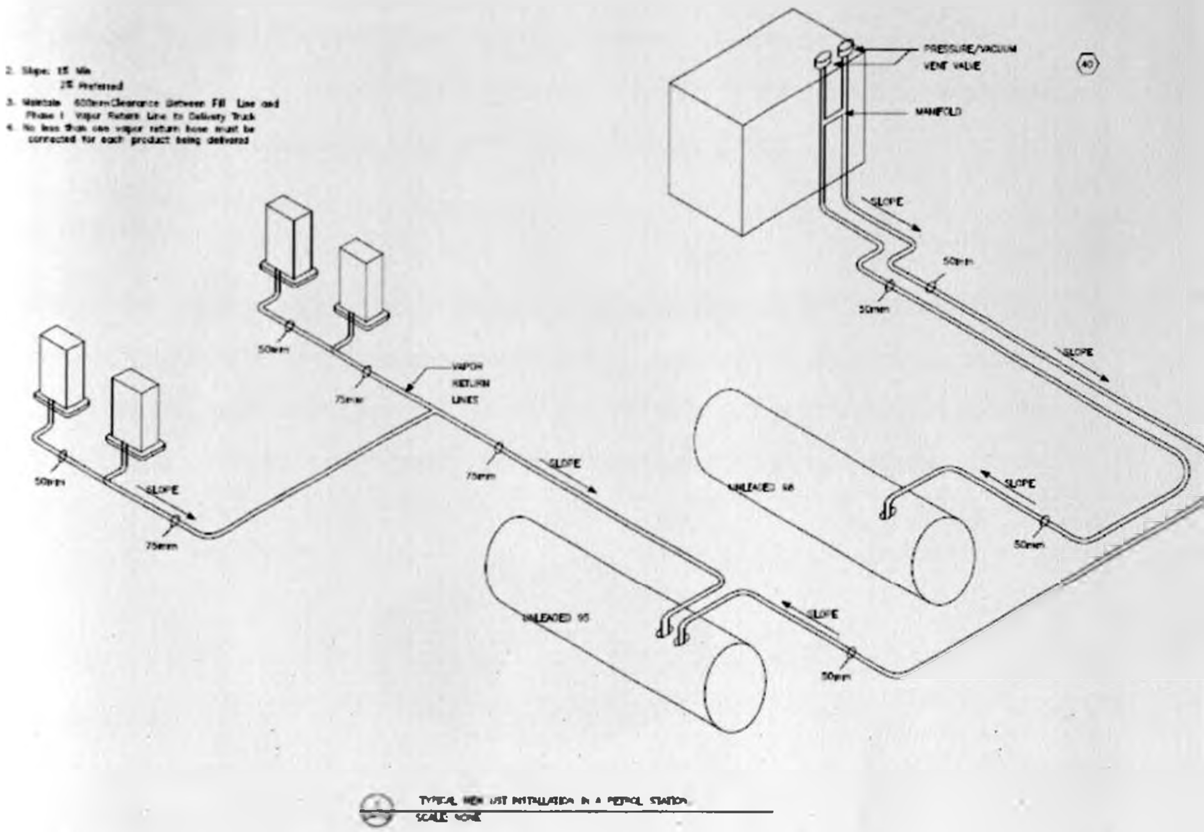


Figure 4.3: Typical petrol station layout

4.7 Operation of Pumps

From observations made by the author, pumps are left running even when they are not dispensing. The common practice is when a vehicle drives into a petrol station; the pump attendant starts the pump then engages the customer on the quantity of fuels to fill. Sometimes it takes more than a minute for the pump attendant to agree with the customer. After filling starts, the pump attendant starts wiping the wind screen because most of the nozzles are fitted with automatic fuel sensor. If the set batch of fuel is completed before the pump attendant completes wiping the screens or checking the engine, the pump is kept running until those tasks are completed.

Every time the pump is running without dispensing, energy is wasted because the power drawn by the pump is dissipated in to the product inform of heat.

CHAPTER FIVE

DEVELOPMENT OF ENERGY USE MODEL

5.0 Introduction

In this chapter, an optimum energy use model for the petrol stations considered in this study is designed. Various factors affecting energy use in a petrol station are discussed and an equation representing energy use in a petrol station proposed.

5.1 Model design

In summary, site surveys and power consumption data log showed that the major energy consumers in a petrol station are compressed air system, lighting and dispensers/pumps. Further, the factors influencing amount of energy used in a petrol can be grouped into four; lighting, sales volume, compressed air system and operation & maintenance.

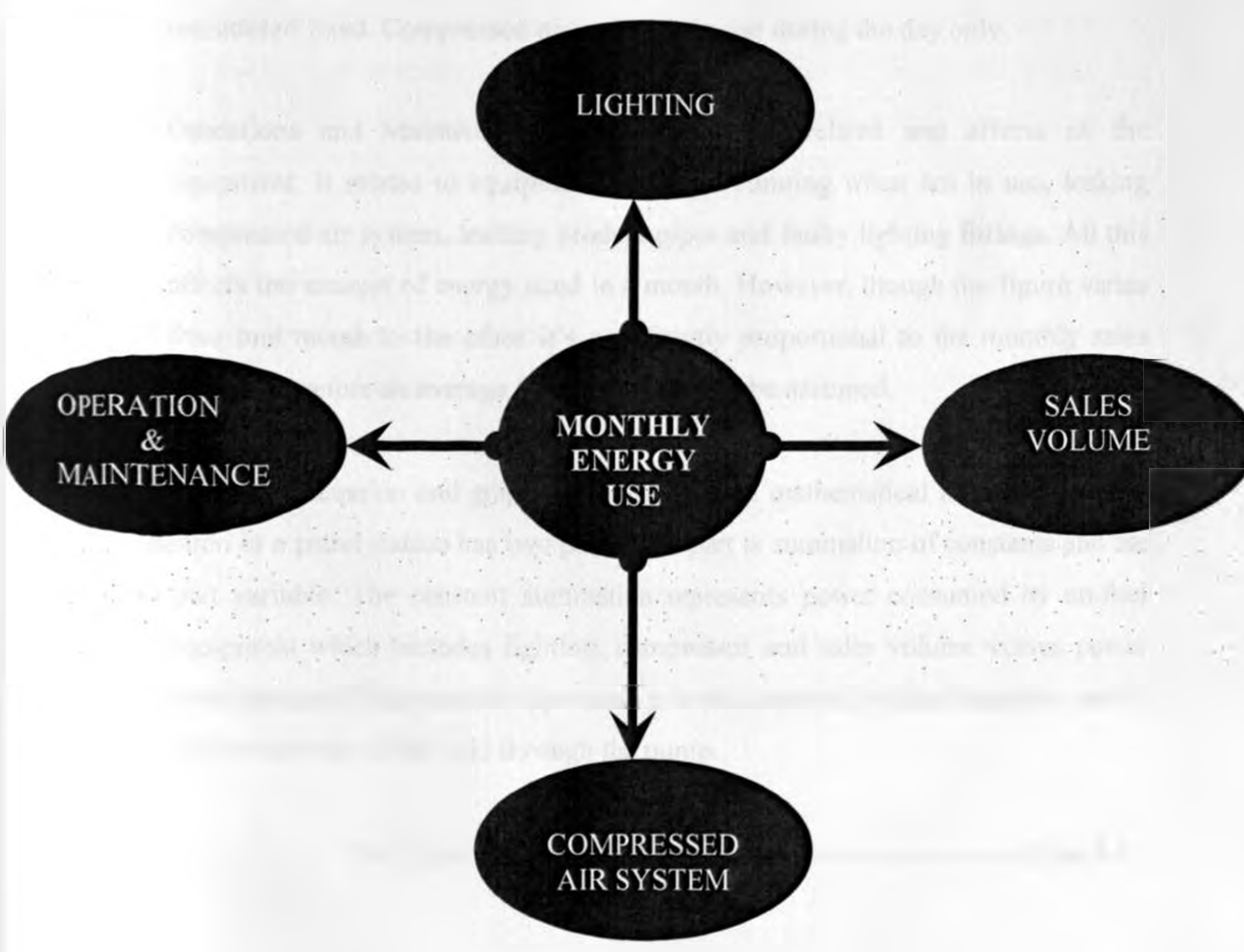


Figure 5.1: Energy use schematic diagram

The factors affecting amount of energy used in petrol station are interrelated and can be represented in a schematic diagram as shown in figure 5.1.

i. Lighting – This refers to security, under canopy and office lighting. The number of light fittings are generally fixed in month and the time in use is also fixed therefore their energy use in a month is fixed.

ii. Sales volume – This relates to dispensers and fuel pumps. The amount of volume sold in a month indicates the time the pumps or dispensers where running hence the energy use varies with the volume of fuel sold.

iii. Compressed air system – This relates to the compressor, air gauge and the piping system. The amount of energy use is relatively small and an average value can be considered fixed. Compressed air system is in use during the day only.

iv. Operations and Maintenance – This is human related and affects all the equipment. It relates to equipment being left running when not in use, leaking compressed air system, leaking product pipes and faulty lighting fittings. All this affects the amount of energy used in a month. However, though the figure varies from one month to the other it's not directly proportional to the monthly sales volume therefore an average fixed figure should be assumed.

From the above discussion and graphs 4.15 and 4.16, a mathematical model for energy consumption in a petrol station has two parts. One part is summation of constants and the second part variable. The constant summation represents power consumed by no-fuel related equipment which includes lighting, compressor and sales volume versus power consumption constant. The variable represents power consumed by the dispensers and it varies with the amount of fuel sold through the pump.

$$Y = \sum A_i + Bx \quad \text{--} \quad \textbf{(Eqn 5.1)}$$

Where

$A_i = A_1+A_2+A_3$

A_1 – Compresses air power consumption

A_2 – Lighting power consumption

A_3 – Fuel sales volume versus power consumption Y-intercept

B – Coefficient of the variable

x – The variable (Sales Volume in liters)

A_1 and **A_2** can be measure for each station while **A_3** and **B** can be obtained from plotting station fuel sales against the fuel related power consumption. Equation 4.1 and 4.2 shows that both stations have similar general energy use equation.

When **A_1** cannot be measured, the table below can be used to approximate its value. This is because the volume of sales gives an indication of the number of cars visiting the site and consequently the number of cars likely to use compressed air. Values within the provided range can be determined by interpolation while those outside can be extrapolated.

Table 5.1: A_1 Schedule

AVERAGE DAILY SALES (L)	A_1
11,385.00	6.48
6,385.00	4.31

The table below can be used to approximate the value of **A_2** by interpolation or extrapolation if the total lighting demand for the station is known. Total demand lighting is obtained by summing the entire lighting related load at the station. It is assumed that all the lights are in use for twelve hours in a day.

Table 5.2: A_2 Schedule

LIHGTING DEMAND (W)	A_2
5,752.00	47.00
12,032.00	152.00

Model 5.1: General petrol station energy use model

$Y = A_1+A_2+36.93+ 0.0059x$ ------------ Ngong road petrol station

$Y = A_1+A_2+0.8419+ 0.0101x$ ------------ Pangani petrol station

These models can be used to determine energy cost element for planning purposes when designing a new petrol station with a high level of accuracy. Planning and design of a new petrol station are a critical element of appraising the investment. In the process of planning and design there is a need to critically analyze the true costs, benefits and environmental consequences of projects. A lack of this analysis can often lead to a level of design quality which falls far short of optimal with respect to the requirements which can lead to a bad investment. Therefore accurate estimation of the energy use is important both for cost and environmental impact management.

This model can also be used for energy management in existing petrol stations. Any station whose energy consumption is above the output of the model should be investigated with an objective of optimizing the energy use.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

In this chapter, conclusions from the findings of the study are drawn. Energy saving opportunities for the three major energy consumption areas namely compressed air system, lighting and dispensers/pumps are then recommended.

6.1 Conclusions

The following conclusions have been drawn from this study:

i. A plot of monthly sales volume against monthly power consumption for Pangani petrol station obtained a trend line represented by $Y = 5992 + 0.0016x$ while the same plot for Buruburu petrol station gave a trend line represented by $Y = 3486 + 0.0013x$. The coefficient of determination (R^2) for both cases is small (0.0089 for Buruburu and 0.0016 for Pangani) because of large contribution of non-fuel related energy consuming equipment that includes lighting and compressed air system. Hence, the study shows that monthly energy consumption in petrol station is related by equation with two parts, one constant and the other varies with sales volume. The constant part is contributed by non-fuel related energy consumers namely security lighting, under canopy lighting and compressed air system.

ii. In Buruburu petrol station the energy intensity ranges from 0.057 kWh/L when the station was operating at a monthly sales volume of 72,500 liters to 0.012 kWh/L when the station was operating at monthly sales volume of 280,000 liters while in Pangani petrol station, the energy intensity ranges from 0.062 kWh/L when the a station was operating at a monthly sales volume of 110,000 liters to 0.016 kWh/L when the station was operating at monthly sales volume of 440,000 liters. Therefore, energy intensity decreases with increasing sales volume.

iii. The main energy consuming equipment's in a petrol station are security and under canopy lighting, fuel pumps and compressor. In Ngong road petrol station, the average daily energy consumption was as follows: security lights – 152 kWh, dispensers – 105kWh, and compressor – 6.48kWh, while at Pangani petrol station it was as follow: security lights – 47 kWh, dispensers – 66kWh and compressor 4.31 kWh. Hence non fuel related energy consuming equipment contribute significantly amount of energy used in a petrol station.

iv. Ngong road petrol station recorded average power consumption 176.44 kWh during the night and an average power consumption of 53.33 kWh during the day as shown in table 4.7. Hence, energy consumption during the night forms 77% of the total energy in the station and is mainly due to security lighting and under canopy lighting. Further to this, an average daily non-fuel related energy consumption of 148.52 kWh was recorded and an average daily fuel consumption directly related to fuel was recorded at 115 kWh for the petrol stations. Since the core business of petrol station is to sell fuel the high energy consumption on non-fuel related equipment should therefore form a basis of energy cost saving.

v. The resulting Cumulative Sum (CUSUM) of differences plot showed that energy consumption performance declines continuously from the calculated energy consumption expected. Further analysis showed that between P_{act} and P_{calc} gives a negative value hence no energy saving measure in use at the station.

6.2 Recommendations

i. In the course of the study, it was observed that pump attendants leave pumps running when not dispensing. Training should be conducted for pump attendants on operation of fuel pumps. They should not leave fuel pumps running while not dispensing and should ensure they complete fueling the vehicle before moving to check the bonnet of a motor vehicle. Security and under canopy lights should not be left on when not necessary. These measures will help in saving on energy consumption.

ii. Energy consumption should be computed on monthly basis and compared with monthly sales to monitor any significant deviations as predicted by the developed energy consumption model.

iii. A combination of solar and mains electrical energy can be used as an alternative source of energy in petrol station mainly for lighting.

iv. 400W Sodium vapour lamps are still being used in most of our retail sites for security/under canopy lighting and 36W fluorescent tubes for building and lubes bay lighting. According to table 4.1 and 4.2 Buruburu petrol station has a total of twenty four 400W sodium vapour lamps while Pangani has a total of twenty one lamps. These high energy consuming light fittings should be replaced with energy saving fittings.

v. The most common observed areas of leaks during this study are couplings, hoses, tubes, fittings, pressure regulators and shut-off valves, pipe joints, disconnection and thread sealants. An improvised simple way to detect leaks is to apply soapy water to suspect areas. The recommended way to detect leaks is to use an ultrasonic acoustic detector, which can recognize the high frequency hissing sound associated with air leaks. It is therefore recommended that leak detection should be done regularly, possibly on weekly basis and after detection; it is advisable to track and repair them to reduce energy wastage through the leaks.

vi. The station considered in this study occupied between half and one acre of land. Large plot of land requires large number of security lights which results to high energy demand. When designing a new petrol station, the compound occupied should be minimized to reduce the lighting demand.

vii. This study was done for stations in Nairobi city and a similar study is therefore recommended for stations in other regions of Kenya. This will give a comparative study on energy consumption in petrol stations to help improve on the development of the energy consumption model

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