UNIVERSITY OF NAIROBI

DEPARTMENT OF MECHANICAL ENGINEERING

ENERGY SAVING OPPORTUNITIES AT TWIGA CHEMICAL INDUSTRIES LIMITED

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F56/71327/2007

Master of Science

Energy Management

UNIVERSITY OF NAIROBI

OCTOBER 2012

DECLARATION

A. Students declaration

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

Esther Chelangat Ruto, F56/71327/2007

Signature: …………………………………..

Date: ………………………………………..

B. Supervisors' Declaration

I confirm that the above student carried out this project work under our supervision.

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Date: …………………………………………..

ACKNOWLEDGEMENT

I am grateful for the opportunity given to me to participate in the energy management course. This has enriched me as an engineer in my day to day activities.

I wish to stress my appreciation to the following without whose support I would have found it challenging to carry out this project to successful completion:

My gratitude goes to my supervisors; Dr. A. A. Aganda and Prof. J. A. Nyang'aya, for their continual challenge, guidance and encouragement throughout the exercise

My appreciation to:- the management of Twiga Chemical Industries Limited for allowing me to access the packaging industrial facility, company information on energy consumption and production to carry out this study.

My gratitude to:- the technical staff at Twiga Chemical Industries Limited, for their cooperation and assistance within the various sections of the industry.

My gratitude to:- Kenya Power personnel who assisted in the calibration and installation of the sub-meters for measurements, and downloading of data.

The greatest gratitude to our God, family (who gave me time and understanding) and friends whose support strengthen me and gave me determination to carry out this study to completion

CONTENTS

CHAPTER THREE: METHODOLOGY

CHAPTER FOUR: ANALYSIS

LIST OF FIGURES

LIST OF TABLES

LIST OF PICTURES

ABBREVIATION AND ACRONYMS

A - ampere
CI - commercial/industrial customers
DC - domestic customers
ERC - Energy Regulatory Commission
g - gram
GJ - gigajoule
GHG - green house gases
h - hour
HFO - Heavy fuel oil
HHV - higher heating value
hp - horse power
IDO - Industrial diesel oil
IPPA - Interim Power Purchase Agreement
IT - interruptible
J - Joule
KPLC - Kenya Power & Lighting Company
kg - kilogram
kJ - kilojoule
kV - kilo volt
kW - kilowatt
kWh - kilowatt hour
kVar - Kilovars
kVA - kilovolt ampere
LPG - liquid petroleum gas
LHV - lower heating value
MVA - Megavolt ampere
pf - power factor
RE - Renewable Energy
SC - small commercial customers
SL - Street lighting
TJ - Terajoule
TCIL - Twiga Chemical Industries Limited
V - Volt
VA - volt ampere
W - Watt

ABSTRACT

This study was to identify the energy usage at Twiga Chemical Industries Limited (TCIL) and analyze the pattern of consumption with respect to production. The other objective was to identify and recommend energy conservation opportunities that can be instituted by TCIL.

The sources of energy are electricity, heavy fuel oil (HFO) and diesel in the ratio in percentage of 76:15:9 respectively. The annual energy consumption was 1.87 TJ – for 2008, 1.7 TJ – for 2009, 1.71 TJ – for 2010 and 1.75 TJ – for 2011. The average was 1.76 TJ annually. The average production was 262,222 kg for 2008, 245,902 kg for 2009, 271,920 kg for 2010 and 313,359 kg for 2011. The energy intensities achieved were; 643 KJ/kg for 2008, 589 KJ/kg for 2009, 532 KJ/kg for 2010 and 472 KJ/kg for 2011. The analysis indicates the energy intensity was reducing in the subsequent years. This reflects improved efficiency by TCIL and indicates a higher production demand gives lower energy intensity. This shows it is more costly for low demands of products.

However, it was noted that the energy consumption for auxiliary supplies, lighting and security was 109 GJ, composed of 89.7 GJ – electrical, 460.7 litres of HFO and 90.6 litres of diesel used on monthly basis, which is not directly related to the production. Reduction of this consumption will result in energy saving by the company. The cost of the energy due to the three sources is Kshs.573,702.00 monthly.

Observations and measurements were made of production processes and related energy distribution. The following opportunities were identified and analyzed for energy savings:

- TCIL should consider migration of tariff from CI1 to CI2 which could realize a cost saving of Kshs.61,600.00, monthly, due to reduced kVA demand and kWh costs.
- The pf should be above the required level of 0.9, below which the company is surcharged. TCIL was surcharged Kshs.730,622.00 in November 2009 – March 2010 and this was extra cost on energy. The pf was corrected at a cost of Kshs.345,000.00 with expected payback period of 2 months.
- The peak demand to be reduced by improving starting methods for all motors and improving the efficiencies. Change of operation for the Mineral section to operate at night will reduce the peak demand to approximately 121 kVA, from 260 KVA peak, monthly.
- The light fittings should utilize electronic ballast for starting of fluorescent tubes; this will further improve on energy saving, at approximately 266 kWh, monthly.
- The steam distribution system requires improved maintenance in order to achieve energy saving from exposed steam distribution pipes. Energy due to exposed pipes is approximately equivalent to 3.1 litres of HFO daily or monthly cost of Kshs.6,985.00.

The potential energy saving for the identified opportunities is Kshs.1,127,663.00 and the capital investment to achieve this is Kshs.6,083,400.00, a simple payback period of 5.4 years.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Energy is the main driver of development in all industrialized and developing countries. Energy as a resource in its various natural forms is getting depleted or is inadequate. With increase of technology, energy use is ever increasing and the demand in some countries is outstripping supply. [7, 8]

Examples of the limited natural resources are:- fossil fuels and hydro-generation resource. Energy conservation will reduce the use of these natural resources; delay the need to put up new generation plants for electrical energy and save expenditure on capital for new plants. [7, 8, 13]

The petroleum products and electricity are the main sources of energy, their prices are ever increasing. [8]. The petroleum costs have increased drastically worldwide within the last few months to an ever-high cost of U $ 140 per barrel in 2011. The increase in petrol prices affects the cost of electrical energy; the cost of fuel is transferred to the customers as a fuel cost charge. This has given rise to most industries seeking ways and means to reduce their energy costs. The negative effect of using expensive energy is; the increase in cost of products making them non competitive in the international markets. [12]

The sources of energy that have been developed by other countries are solar, wind, nuclear, geothermal and thermal, amongst others. [14, 15, 16] Renewable energy resources (RE) are currently being promoted for development all over the world, as the current sources of energy cannot sustain the ever increasing demand. Such RE sources are wind, solar, oceanic, and small and Pico hydro generations, pump storage generations, use of hydrogen as a fuel, the challenges facing these RE sources are to have storage facilities for the energy generated for use at a later time. [15, 16]

Kenya is highly dependent on hydroelectricity; the demand in 2010 was 7.4 TWh [2, 14]. The demand has been increasing by an average of 7% per annum for the last 6 years. The contributions of the various forms of energy in 2008 and at March 2012 are:

	2008	2012
• Hydroelectricity	- 56.58%,	49.7%
• thermal	- 32.52%,	34.2%
• geothermal	-10.69%,	12.9%
• cogeneration	- 0.17% and	2.4%
• wind power	- 0.03%.	0.36%

The installed capacity is 1197 MW for 2008 and at March 2012 comprising of:-

	2008	2012
• Hydroelectricity	- 677.3 MW	761 MW
• thermal	- 389.3 MW	525 MW
• geothermal	- 128 MW	198 MW
• cogeneration	- 2 MW	26 MW
• wind power	- 0.4 MW	5.45 MW
• isolated grid		18 MW

In 2008, 6.79 TWh was produced and 5.74 TWh was consumed, exported was 41 GWh and import of 16 GWh. The export and import was within East Africa region. The reliance of Kenya on hydroelectricity results in the system being highly dependent on weather. The contribution of thermal generation is high during long periods of drought. The installed capacity as at March 2012 was 1,533 MW against a peak demand of 1,236 MW. The energy demand forecast for 2010-2030 is estimated to rise from 7.4 TWh in 2009 to 92 TWh in 2030 indicating an annual increase of 12.8%. [2, 13]

The transport sector is the largest consumer of petroleum products (70%) as compared to the manufacturing sector which consumed less than 20% of domestic sales of petroleum products. During peak demand, the electrical supply is inadequate and hence interruptions are planned during load shedding. Customers have installed standby generators to ensure uninterrupted supply to their plants during production when the electrical supply is interrupted. Standby generators are estimated to supply about 22% of required energy in the manufacturing sector and 31% in the furniture related enterprises, while agro-industry, construction industry, machinery, metal and chemical plants will have standby generation to supply total electrical energy requirements. [8, 14]

Twiga Chemical Industries Limited (TCIL) is based in Industrial Area, Nanyuki Road off Lunga Lunga road, Nairobi. The products of TCIL are powders and minerals; mixing of chemicals and packaging of the various products for the agricultural sector, consumers and for other industries. The use of energy by TCIL is shown below for the period:[17]

Year	Electrical (kWh)	Diesel (L)	HFO (L)	Production (T)
2008	391,854	4,575	8,180	3,275
2009	354,811	2,884	8,870	2,950
2010	350,804	1,685	11,070	3,263
2011	349,272	2,900	10,973	3,760

This energy consumption translates to energy intensity for production as 643 KJ/kg, 589 KJ/kg, 532 KJ/kg and 473 KJ/kg respectively. Intermittent disruption of supply has led the company to install a stand by generator which takes up the full demand of the industry during interruptions and is rated at 358 KVA with a power factor of 0.8. The generation of electricity is at 415 Volts. The highest demand was 260 kVA in March 2010 - Appendix1. [17]

1.2 STATEMENT OF THE PROBLEM

Twiga Chemical Industries Limited uses electricity, diesel and HFO fuel for its energy requirements. The energy consumption for the industry was a total of 1.87

TJ for the year 2008, 1.7 TJ for 2009, 1.71 TJ for 2010 and 1.75 TJ for 2011. This indicates a decrease in 2009 and a gradual increase for the consecutive years. The use of HFO fuels has been rising from 286.4 GJ for 2008 to 384.3 GJ for 2011 for steam generation. The cost of electrical energy increases when the power factor is low and results in higher tariff charges and cost of fuel surcharge. The cost of fuels for both diesel and HFO has been on the increase and this implies that the company transfers the production costs to the customers; this makes their products expensive and less competitive in the market. The frequent interruption from the utility has led to use of their standby generator, hence more expensive energy. [12, 17]

Reduction of production costs will lead to lower cost of products for the customers and better competition in the market. [12]

The international guide is that there should be firm capacity (standby capacity) of 15% of the installed capacity. This is to carter for machine outage during maintenance, and customers will not be inconvenienced. Kenya has installed capacity of 1,533 MW and the demand of 1,236 MW as of March 2012; this gives a firm capacity of 19% which is acceptable. This firm capacity will be used up within a year considering annual load growth of 12.8%. [2, 8, 14]

The Kenya Association of Manufacturers' (KAM) is encouraging efficient use of energy and requires manufactures and industries undertake energy audits, to identify opportunities available for energy saving in both petroleum and electrical energy. TCIL was interested in an energy study to determine their opportunities and recommendations for energy saving.

1.3 Objectives

1.3.1 Main Objective

The main objective was to analyze energy used at TCIL, identify saving opportunities, conservation measures and relate consumption to production in view of improving performance and efficiency. [7]

1.3.2 Specific Objectives

The specific objectives of the study were:-

i. Survey of plant and identification of energy use and ascertain the overall consumption within the industry. Establish equipment in use and their condition of operation.
ii. To analyze the historical data and determine the energy consumption with respect to production and compute the energy intensities for the years 2008-2011
iii. To identify the opportunities available for energy saving within the plant
iv. To identify and recommend energy saving measures

CHAPTER TWO

LITERATURE REVIEW

2.1 TWIGA CHEMICAL INDUSTRIES LIMITED (TCIL)

Twiga Chemical Industries Limited produces various products for the agricultural sector, consumers and for other industries. The types of products are in liquid, powder and brick form. These are prepared in various sections; liquids, powders, minerals, and herbicides for both internal and external clients. Clients normally specify their mixing and packaging requirements to TCIL and provide labeled packaging material. The batch numbers, date of manufacture and expiry dates are indicated during the production by TCIL. [17]

Twiga Chemical Industries Limited – Plant layout

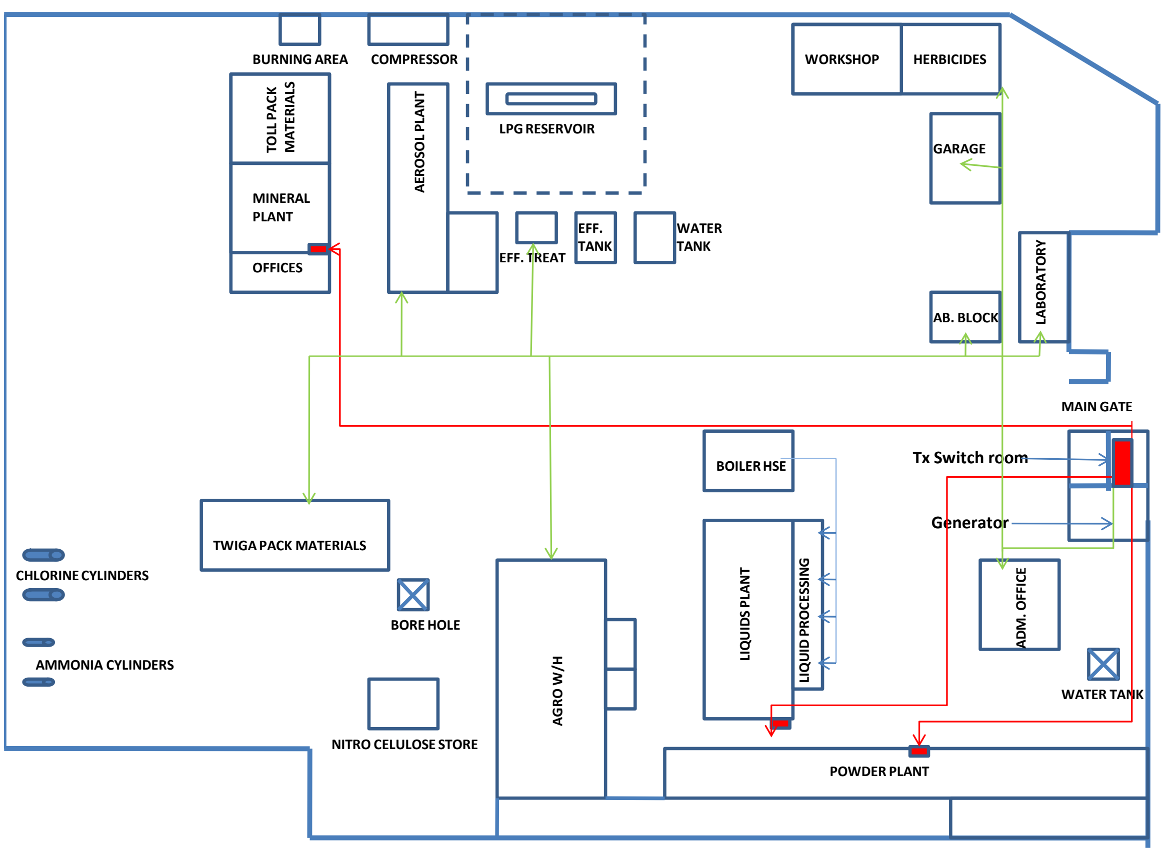

Figure 2.1: TCIL Plant layout

The products manufactured by TCIL are fungicides, insecticides, herbicides and minerals supplements or salts licks. The preparation of the products varies from section to section. The materials for mixing are first weighed out, mixed according to specification of each product. The powders and minerals materials are first crushed to powder, put in mixing tanks/containers and mixed. The crushing is done using disintegrator crusher mill rated 37 kW - 1 number, in powder section; in the mineral section motors used are rated 1 x 22 hp – crusher and 2 x 20 hp - mixers. Mixing of the materials is done using 3 x 25 kW motors in the powder section - Appendix 5. [17]
Other motors within the processing are for: conveyor belts – 3 x 0.75 kW; dust extractors – 6 x 5.5 kW; smaller motors used in the liquid section and for the packaging line – conveyor belts (ranging from 0.37kW – 7.5kW).

The products, after crushing and mixing are then weighed and packaged in packages ranging from 6gm – 50 kg for powders and solids, liquids from 20 ml – 20 liters. Bulk production provided in 1000 liters of liquid and 2000 kg of powder are done for special orders. These products are prepared in different sections of the plant; which are separated per type of products and located such as to avoid contamination.

The demand for the products is determined by the seasons in agricultural sector and the weather patterns. During the rainy seasons, the need for pesticides, herbicides and fungicides increases. The mineral supplement is for the dairy industry as a consumer product, and this is produced for the local and regional market. The mineral supplement is both in powder and brick form and packaged as per client's requirements.

The liquid section has four parts, first- where liquid is prepared in tanks and mixed as required. Some of the raw materials are in the form of solids, and therefore a boiler is used to liquefy the material before mixing and packaging. The other three rooms are for packaging the products in bottles by use of auto filling and semi packaging equipment. The insecticides are packaged in pressurized containers; these undergo a test to check for any leakages after packaging. The gas used as a propellant is LPG gas, this is a flammable substance and therefore the warning of 'Flammable' is indicated on the containers. [17]

2.2 RENEWABLE ENERGY

Solar energy has been utilized by the TCIL in form of transparent roof tiles/sheet for illumination during working hours to this reduces the number of lighting fittings. Solar can be utilized in water heating, to preheat water, or preheat HFO fuel, before steam generation and save on the fuel required for steam generation. [11, 12]. The fuel used by the boiler system Industrial diesel oils (HFO) does not require preheating.

2.3 Electrical systems

2.3.1 Electrical load and Tariff Structure

Energy Regulatory Commission (ERC) is established under the Energy Act, 2006 as the energy sector regulatory agency, with responsibility for economic and technical regulation of power, renewable energy and downstream petroleum sub-sectors. This mandate includes tariff setting and review, licensing, enforcement of standards, dispute settlement and approval of power purchase and network service contracts. [1, 3, 6]

The existing retail tariffs were approved by the then Electricity Regulatory Board (ERB) in June 1999 and came into force on 1st August 1999 simultaneously with the Interim Power Purchase Agreement (IPPA) between KenGen and Kenya Power and Lighting Company (KPLC) which set the base bulk tariff at 2.36 Ksh/kWh.

In order to make the retail tariff more transparent, cost-reflective and simple, a number of new features have been incorporated in the approved retail tariff structure. In conformity with the published ERC's Retail Electricity Tariff Review Policy of 2005, the consumer categories under this policy are as follows:

Consumer Categories

There are five main consumer categories:

i. Domestic Consumers (DC)
ii. The Small Commercial (SC)
iii. The Commercial/Industrial (CI)
iv. The Interruptible (IT) and
v. The Street Lighting (SL).

The DC is applicable to domestic consumers metered at 240V or 415V and whose energy consumption does not exceed 15,000 kWh per month. The energy charge is in three steps based on consumption as follows; 0-50kWh; 51-1,500kWh and over 1,500 kWh.

The Small Commercial (SC) is also metered at 240V or 415V with monthly energy consumption which does not exceed 15,000kWh.

The Commercial/Industrial (CI) Category is subdivided into five sub-categories – CI1, CI2, CI3, CI4 and CI5, all metered at different voltages.

i. CI1 is metered at 415V three phase with monthly energy consumption in excess of 15,000kWh.
ii. CI2, CI3, CI4 and CI5 is metered at 11kV, 33/40kV, 66kV and 132kV respectively with no limitation on energy consumption.

Interruptible Consumers (IT) off-peak is metered at 240V or 415V and with consumption not exceeding 15,000 kWh and the Street Lighting (SL) is metered at 240V.

TCIL is under the Commercial/Industrial (CI) and its sub-category is CI1, as it is metered at 415V three phase with a monthly energy consumption in excess of

15,000kWh. The monthly electricity consumption for the study period ranges between 18880kWh and 43,697kWh. See Annex III. [1]

Under the tariff structure there are four main charges:

i. Energy charge;
ii. Fixed charge;
iii. Demand charge and
iv. Fuel cost charge.

For each consumer category, there is an energy charge rate and a fixed charge. In addition, the demand charge is applicable only to the commercial consumers.

Charges by Consumer category CI:

Commercial/Industrial, CI1

(a) A fixed charge of Kshs 800.00 per month.
(b) An energy charge of Kshs. 5.75 per kWh
(c) Demand charge of Kshs. 600.00 per kVA.

Commercial/Industrial, CI2:

a) A fixed charge of Kshs. 2,500.00 per month.
b) An energy charge of Kshs 4.73 per kWh
c) Demand charge of Kshs 400.00 per kVA.

2.3.2 Electrical Drives

The most commonly used electric motors are induction motors for industrial applications. There are two important attributes of induction motors which are efficiency and power factor. The efficiency is defined as the ratio of the mechanical output at the output shaft to the input power on its terminals. They are also characterized by a power factor less than unity. A good motor should have efficiency and power factor close to unity. The allowed power factor by utility is 0.9. The efficiency of a motor is determined by presence two types of losses;

fixed losses due to magnetic core losses and variable losses due to resistance in current flow in the stator and rotor this is proportional to the square of the current with respect to the wiring material resulting in heat loss. [3, 6, 15]

Energy efficient motors are designed to incorporate thicker wires to reduce current resistance, a longer core to increase active material made from low loss silicon, thinner laminations, smaller air gaps between stator and rotor, superior bearings and smaller cooling fan to reduce mechanical loads, these motors operate at 3-4% higher efficiency than standard motors.

In practice, the motors in industry are overrated in capacity; this will result in under loading. This is a result of original equipment manufacturers designing motors with large safety factor and underutilization in user applications. Under loading of motors is common in industry contributing to lower motor efficiency and power factor. It is recommended to down size motor duty and for the case of high torque requirements at start up, then other options as star delta or soft start can be applied. Other options are replacement with energy efficient motors. [11, 12, 15]

2.3.3 Lighting and luminance

The power consumption on lighting in industry varies from 2-10% depending on the type of industry. Different industrial applications demand different levels of luminance. Lux (lumens/m^2) is a measure of illuminance (lighting levels) and is presented as an example, (30-50-100) where 50 is average, 30 is minimum and 100 is maximum luminance. [5]

The efficacy of lighting lamps is given as the amount of lumens per watt of electricity usage and its rated lamp life. An incandescent lamp is rated at average 14 lux/W with a life of 1000 h while a compact fluorescent lamp is rated at an average of 60 lux/W with life of 8000 to 10000h; which shows that this is superior to incandescent lamp in energy efficiency. Fluorescent lamps are in use at the TCIL rated at average of 50 lux/W with a life of 5000 h. [5]

Fluorescent lamps with high frequency electronic ballast use 35% less energy than those with electromagnetic ballast. Other advantages offered by use of electronic ballast are that its lights instantly, it does not consume power when lamp is faulty and/or flickering, operates well in low voltage load, improvements in power factor and has longer life rating. [5]

2.3.4 Compressed air systems

Compressed air system generally account for a significant amount of energy loss. It is estimated that normally 10-30% of total energy input into a compressor prime mover is used at intended end user equipment as delivered air with the rest lost to unusable heat losses, piping losses, noise and misuse. The efficiency of compressor systems is then important to maximize on positive energy conversion. [15]

The efficiency of an air compressor is affected significantly by the location and the air drawn. The efficiency improves with cleaner, cooler and dryer air at intake. As a rule of the thumb every 4 °C rise in inlet temperature results in higher energy consumption by 1% to achieve an equivalent output. It is good practice to draw intake air from the outside air as the air in the compressor room is normally higher in ambient temperature due to heat generated by compressors during operation and hot exhaust air from compressor radiators.

The relationship between power consumed by a compressor and inlet air temperature is expressed as;

$$W_2 = W_1 \times [1 + 0.00341(T_2 - T_1)] \qquad 2.1$$

Where

W_1 = is power consumed by compressor at air inlet temperature T_1

W_2 = is power consumed by compressor at air inlet temperature T_2

The air intake should be clean to avoid dust getting to the compressor; this can cause abrasion to the compressor moving parts and premature failure in performance. Suitable air filters are recommended to be installed, regularly cleaned and pressure drop across the filter monitored. Every increase in 'pressure drop' of 250mm water gauge across the suction path due to choke filters, the compressor power consumption increases by 2% for the same output. They deliver a range of pressure from loading to unloading point; those delivering at a higher pressure consume more energy while those delivering at lower pressures results in energy savings. A reduction in delivery pressure in a compressor by 1 bar would reduce energy consumption by 6-10%.

It is recommended to generate separately high and low pressure if both are required and the generation should be close to the point of use to minimize in distribution losses. The size and design of piping system can be a source of energy waste due to friction resulting to high pressure drops. Acceptable pressure drops in industrial practice is 0.3 bar at farthest point of main header and 0.5 bar in the distribution system.

Compressed air leakages form a major part of energy losses in industry, as most leakages occur at receivers, relief valves, pipe and hose joints, valves and fittings, quick release couplings, pneumatic tools and equipment due to poor maintenance practices and improper installations. In practice leakage should not exceed 5% of compressed capacity. A 5 mm diameter hole can leak 27 l/s of compressed air at 6 bar wasting 8.3 kW of power used for the generation.

Compressed air leakage can be expressed as

$$\text{Leakage } \% = [(T \times 100)/(T + t)] \quad (2.2)$$

Where

T = time on 'load' in minutes and t = time on 'unload' in minutes

2.4 Boiler and Steam distribution

2.4.1 Fuel system

The most common sources of energy in the industries for steam generation is combustion of fuels in a furnace. The fuels can be solids, liquid or gas. The solid fuels used for boiler steam generation range from coal, wood, coffee and rice husks, sawdust, sugarcane baggasse etc., this depends on the availability at the point of use. [4, 8, 10, 14, 15]

The liquid fuels range from fuel oil, petroleum, kerosene and dirty fuels (used oils, thinners & paint waste amongst others). Gas fuels range from liquefied petroleum gas (LPG) and natural gas. The main combustion components of these fuels are carbon, hydrogen, sulphur, oxygen and ash. In the evaluation of the fuels only carbon and hydrogen are considered. The fuel oils generally consist of carbon at 84% - 90%, hydrogen at 5%-12%, oxygen and nitrogen 3%-4% and sulphur can reach 4% depending on the source.

The heating value is the most important when doing fuel evaluation, this is the quantity of heat generated by combustion of the fuel per unit mass or volume. The lower heating value (LHV) for most fuel oils, range from 35.58 to 41.87 MJ/kg. The higher heating value (HHV) takes into account energy used in the evaporation of moisture in fuel and generation of water from hydrogen and oxygen fuel. This energy can be recovered through condensation of the water vapour in flue gas through heat recovery systems. When fuel has no moisture then the LHV will be equal to HHV.

The relationship between LHV and HHV of fuels can be expressed using the international energy agency (IEA) equation as:- [18]

$$LHV = HHV - (0.2121 x H + 0.2442 x H_2O + 0.0008 x O) \qquad 2.3$$

Where

LHV and HHV are in MJ/kg, and H, H_2O and O are in %

Fuel oils are classified in terms of heating value, viscosity and density in the range of fuel oil number 1 to number 6 (FO1 to FO6). The Kenyan market classifies FO1-FO4 as industrial diesel oils and FO5 – FO6 classified and heavy furnace oil (HFO). Table 1 shows values of the range of LHV, viscosity and preheat temperatures for various fuel oils and the respective classification in Kenyan market. [8]

Table 1: Properties of various industrial fuels

Trade number	Preheat temperature °C	Viscosity Cst. 38 °C	LHV Btu/gal	Comments in Kenyan Market
FO1	Volatile fuel oil	1.6	137,000	HFO hell light
FO2	Moderately volatile	2.7	141,000	HFO amber
FO3	No preheating required			HFO
FO4	No preheating required	15	146,000	HFO black
FO5	75 °C to 105 °C	50	148,000	HFO black
FO6	100 °C to 120 °C	360	150,000	HFO black

The fuels FO5 and FO6 require preheating by either electric heaters or other forms of fuels, gas and light fuels. Steam can also be used through a heat exchanger once the steam has been generated. FO1- FO4 does not require preheating as the fuels are already light and has low viscosity.

The preheating reduces viscosity, improves pumping and allows the attainment of required ignition temperatures. Similarly the mechanical atomization of fuel in the boiler is obtained in the boiler burners for efficient combustion. The heat released during combustion is through chemical processes of combustion of carbon, hydrogen and sulphur and during the reaction of hydrogen and oxygen.

One kg of fuel oil has – 86% Carbon, 12% hydrogen and 2% sulphur; this would require 14.1 kg of air for complete combustion. Sometimes excess air is required to have complete combustion. The amount of excess air varies by the type of furnace and fuel used for combustion. A system using heavy furnace oil (HFO) should aim at limiting the excess air to ranges of 12-15% and oxygen in flue gas to 2-3%.

Heat in flue gas is passed through boiler tubes and passages that run through boiler water to transfer heat from the flue gas to the steam. The efficiency depends on conductivity of the tubes in the boiler, if the tubes are with scales - there is lower heat transfer and high heat loss through high flue gas temperatures. The efficiency of a boiler can reduce by 1% for every 22°C temperature rise in flue gas due to deposits, with a 3mm soot deposit layer causing a 2.5% increase in fuel consumption.

Flue gas should exit at low temperature as possible, high flue gas temperature indicates poor heat transfer in boiler tubes, while low flue gas temperature can lead to sulphur dew point corrosion. Stack temperature higher than 200°C show potential of waste heat recovery. Most boilers operate between 200°C – 300°C flue gas exit temperature. This energy can be recovered through an economizer to preheat feeder water to increase temperatures by 15% and boiler efficiency increase by 3%. The combustion air can be increased by 20°C in an air pre-heater and the boiler efficiency can increase by 1%. [15]

Other heat losses are through the boiler surface radiation where insulation is missing or damaged. The surface radiation expected is 1.5% of gross calorific value for modern boilers.

Boiler efficiency = 100% - (boiler heat loss); this is the direct method.
The indirect method identifies all the losses of heat.
Loses by boiler is due to

- Dry flue gases
- Moisture in fuel and combustion air
- Unburned products
- Heat surface radiation and convection

Flue gas heat loss

= mg x Cp x (Tf-Ta)/kg x HHV x 100 2.4

Where

mg is mass of moisture in flue gas

Cp is specific heat capacity of flue gas

Tf- Ta is the difference in flue gas and ambient temperature

HHV is the higher heating value of the fuel

Combustion of the hydrogen and evaporation moisture

=mg x Cp x (Tf-Ta) + mg x hfg/1kg x HHV x 100 2.5

Where

mg is mass of moisture in flue gas

Cp is specific capacity of stem

Tf-Ta is the difference in flue gas and ambient temperature

'hfg is the enthalpy of stem in flue gas = enthalpy of stem in flue gas – enthalpy of water at ambient temperature

HHV is the higher heating value of the fuel

2.4.2 Water systems

Water is heated to generate steam in the boiler water system. The steam evaporates and impurities remain in the boiler, known as boiler impurities, and their concentration increases with time. The heavier particles settle at the bottom while the lighter particles float at the water surface. To remove the impurities a process known as boiler blow down is used to regulate their concentration. This is done by blowing off some amount of water from the boiler to reduce impurities; feed water is used to make up for the lost water due to blow down. [15]

A slow blow down rate will increase dissolved impurities that will cause deposits and scale formation in the boiler, the scales in the boiler tube will lead to poor heat transfer to the water and will result in heat loss through flue gas and boiler efficiency. The poor heat transfer can also result to overheating of the boiler tubes leading to tube failure. The high impurities at floating at the water surface will result also to forming; that can lead to carry over of water in steam affecting the steam quality.

A high blow down rate will result to excessive loss of heat in boiler water and high heating fuel usage resulting to lower boiler efficiency; more water treatment chemicals will also be required due to increased usage of make-up water.

The maximum recommended by manufacturers for total dissolved solids (TDS) in the boiler water is 3000 parts per million (ppp). To maintain boiler TDS at permissible levels blow down is carried out both at the bottom and at the water surface of the boiler. This can be automated or manually done at regular intervals, after eight hour shift.

The estimated amount of blow down rate can be expressed as

$$\text{Blow down \%} = \frac{\text{Feed water TDS x make up water \%}}{\text{Maximum permissible boiler water TDS}}$$

The effect of impurities in water on boiler efficiency can be reduced by treating feed water both internally and externally. Internal treatment is done to chemically convert scale forming impurities to free flowing sludge that can be removed during blow down. The type of chemicals used varies depending on the type of impurities present in the feed water. These include sodium carbonate, sodium aluminate, sodium phosphates, and sodium sulphites. The external treatment is done to remove suspended, dissolved solids (calcium and magnesium ions responsible for scale formation) and dissolved gases. The external method includes ion exchange, demineralization, reverse osmosis and de-aeration.

A good water system is one that maximizes the use of return condensate from the steam system, this will use less feed water and less impurity introduced in the boiler. [15]

2.4.3 Steam distribution system

The steam generated in the boiler is collected and piped to end user equipment and depending on the steam quality requirements; steam pressure may be lowered using pressure reducing valves installed in the steam distribution system. During steam distribution energy is lost by heat transfer in the pipes resulting to steam condensation. The heat loss is a result of high temperature steam heating cold pipe line to working temperature and thereafter steady heat loss happens through radiation and convection. The condensate formed must be removed through steam trapping to avoid risk of lowering steam quality and water hammer. A 100 mm well lagged pipe of 30 m length carrying steam at 7 bar can condense 10 kg of water in one hour unless it is removed by trapping. Steam piping should then run with a fall of no less than 12.5 mm in 3 m in the direction of flow to allow condensate to flow out. Condensate should be drained out every 30-50 m at the lowest point of pipe network.

The three main designs of steam traps are mechanical type which operates using density differences between condensate and steam/air; thermostatic type which operates using temperature differences between condensate and steam and thermodynamic (disc/orifice) type which operates using flow differences between condensate and steam. Steam traps also help in removal of gasses trapped in the steam by automatic venting, especially during start up. A good steam trap should have a steam separator and a strainer to prevent dirt and scale in trap upstream of the trap. Steam traps require regular monitoring and maintenance to ensure all part move freely and avoid trap stuck in closed or open position. These should be installed to individual condensate source as group trapping is less efficient. [4, 10, 15]

Steam lines require to be lagged to avoid loss of heat energy. Common lagging materials include asbestos, magnesia asbestos, corrugated asbestos, fibre glass, aluminum foil, and mineral wool and slag wool. The use of asbestos in industry is currently discouraged due to health risk. A 5 inch pipe at a temperature of 400 °C and ambient temperature of 21 °C will save heat loss by up to 95% if lagged with fiber glass. Steam system lagging should include steam line accessories and flanges to reduce heat loss. One uncovered flange is the equivalent of 0.6 metre of its bare pipe. A 0.15 metre diameter steam pipe with 5 unlagged flanges will result in heat loss equivalent to 3000 litres of oil in a year.

Heat loss due to surface heat transfer to air can be expressed using the following relationship

$$\text{Heat } Q = hA(T2 - T1) \qquad 2.6$$

Where

h = Heat transfer coefficient in W/m^2K = 15 for steel

A = Total surface area in m^2

T2 – T1 = Temperature difference between surface and air in K

Condensate trapped from the steam system should be recovered as much as practically possible and pumped back to the boiler feed water tank. The main benefit for condensate recovery is heat energy recovery in the condensate as preheated boiler water. Condensate at 7 bar contains 721 KJ/kg of energy which is 26% of original energy contained in steam of 2769 KJ/kg at the same pressure. A 60 °C rise in boiler feed water can result to 1% saving in boiler fuel. The other benefits include reduced usage of makeup water and less impurity in boiler water, reduced chemical treatment of boiler water and reduced blow down rates.

Steam leaks and flash steam are other losses of energy. It is estimated that 3 mm hole on a steam pipe carrying steam at 7 bar can leak steam equivalent to 33,000 litres of fuel oil in a year. Condensates at high pressure releases flash steam when released at atmospheric pressure. The flash steam contains residual energy that can be recovered. This can be achieved in waste heat recovery systems. Waste heat recovery systems vary in design and application depending on the source of waste heat. Typical waste heat recovery system efficiency range is of the order 60-80%.

CHAPTER THREE

METHODOLOGY

3.1 AUDIT REPORTS

The energy study will be the first report on energy use for TCIL. [7, 17]

3.2 Plant Survey and observations

A walk through the industrial plant was done to determine the type of energy in use, energy resources, gas, electricity, solar, and fossil fuels and the specific type of energy in use at each section or unit. It was observed that the energy in use is electrical, diesel, solar and heavy fuel oils (HFO). Diesel fuel was used for a standby generator for the industry, while HFO was used by a steam generation boiler in the industry.

The various energy types that are used at the company were analyzed separately and the overall energy consumption provided. The types of products were separated in to liquids and powders, the liquids covered the insecticides, aerosol (use of compressor and LPG gas to package) and pesticides, while powders cover the minerals and herbicides. These vary in type of products, sizes of packages of the products and production levels of each as per the client orders.

The plant survey, also indicated the possible highest users of energy, electrical, as the powder and Mineral sections. This was done by establishing the equipments and appliances within each section. The motors, the heaters, fans, air conditioners, lighting fittings and lighting levels in offices for each section of the industry were identified as per Appendix 5. The motors were checked for their type, capacity, rating, operation time and efficiency, similarly heaters, fans, AC equipments. Lighting fittings were noted as florescence tubes with magnetic ballast, these have been analyzed to consider their efficiency, life span and installed time. [15, 17]

3.3 Historical Data

The energy consumption and production levels for the industry were obtained from their records for the period under consideration, 2008-2011. The production data was obtained from the Production Manager, and were recorded on weekly and monthly summary productions for both liquids and powders. The electrical energy consumption data was obtained from the electricity bills for TCIL for the same period. The diesel and HFO fuels were obtained from the fueling cards record and consumption level records for the same period. The capacity of the generator and boiler were obtained from the respective name plates.

3.4 Measurements and observations

The industry was observed to have a peak demand of 260 KVA and has installed a diesel generator to supply electrical power of 358 KVA with a power factor of 80% in mitigation of power outages from the utility supply. The standby generator is able to take up the full load of the industry when in operation. The two sections identified as the main users of electrical energy are the powders and minerals sections. Measurements were made using hand held energy analyzer equipment with clamp on CT's to determine the demand of each. The two sections contribute about 73% of the total electrical energy used. Sub meters were installed in September 2011 to monitor their performance. The measured results were down loaded on 11th January 2012 for analysis. The installed meters will remain in the industry for continuous monitoring.

3.5 Results and analysis of Data

The electricity bills were analyzed to establish the total electrical energy used annually, similarly the records obtained for diesel and HFO fuel used for the period 2008-2011 were analyzed. The combined energy consumption is provided in Chapter 4. The electricity bills, indicated the meter readings and the electricity demand, units consumed on monthly basis, the taxes, levies and the power factor during the period. The liquefied petroleum gas has not been considered as energy for production but as a propellant in some of the products for insecticides. The generator has a meter and therefore the monthly use was expected to be obtained from the meter reading, but there was no data that TCIL kept as readings from the meter. In the absence of the readings the received fuel data was used in the analysis. [17]

The analysis has indicated the energy intensities on monthly basis per product and deviations noted within the period. This has been used to determine whether any energy saving measures were put in place; whether they are operational or out of service and when it was restored. This was obtained by having graphs of energy against production, preparing a CUSUM table and graph to confirm any deviation or performance of the company. [7]

The power factor for the industry was obtained from the main meter during routine checks and also from the utility bills. It was observed that for a period of five months, from November 2009 to March 2010, the power factor was low, the corrective action taken for the improvement of the p.f. has been presented. Energy conservation opportunities have been identified, through analysis of data, identifying equipments in each section and identification of measures to be put in place to achieve the savings and efficiency of the company. Analysis has been done for the following:-

i. The energy sources and the total annual energy consumption for the period of study, the relationship of the production and energy consumption, the energy intensities on monthly basis for each year.
ii. The appliances and equipments that use energy, motors, heaters, fans, extractors fans, air conditioners, light fittings and lighting levels in offices and working areas.
iii. The energy conservation opportunities available were identified with economic analysis in terms of cost of losses to the company.
iv. The energy conservation measures to be put in place have been identified and the economic analysis done in each case.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Energy

4.1.1 Energy sources

TCIL has the following energy sources in use:-

i. Electricity ii Diesel fuel iii Industrial diesel oils

Electrical energy is the- primary source of energy for TCIL. A diesel generator (358 KVA) is on standby for use when this primary source is not available. The electricity can be interrupted when the utility has a planned outage for maintenance or new customer connection. Other interruptions could be caused by line faults which trip the feeder and an alternative feeder is not available. During these interruptions the generator is able to take up the full load of the industry as its capacity is 358KVA with a pf of 0.8., while the peak KVA for the industry from the utility bills is 260 KVA. The Generator uses diesel fuel for its operation. Figure 4.1 shows total annual energy for the period 2008 – 2011. [2, 8, 13, 15]

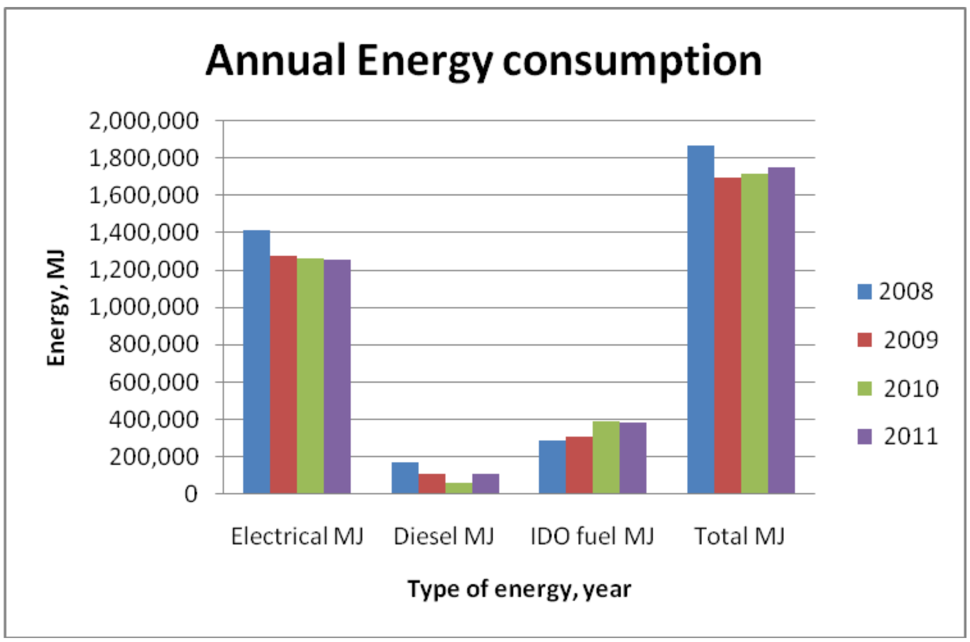

Figure 4.1: Annual energy consumption for the period 2008-2011 and sum total of electrical, diesel and HFO energy sources.

Twiga Chemical Industries Limited has chemicals that are first steamed, in order to change their physical state from solid (frozen) to liquid state before mixing and packaging. A boiler is used to generate steam for the purpose. In previous years, they had a closed steam bath tab, which was used, in the event the pressure becomes too high, it could give way (explode) and hence they changed to an open hot water bath tab for defrosting the chemicals. The boiler uses industrial diesel oil (HFO) as a source of energy, it is used when necessary, the use ranges from once a week to daily as per the attached appendix of fuel consumption, Appendix 2. [14, 15]

4.1.2 Energy Consumption

The various sources of energy used is given in table below on annual basis and represented by the bar chart – Figure 4.2, and the pie charts Figure 4.3 to Figure 4.6 for the last four years.

Table 4.1: Annual energy consumption

Year	Electrical MJ	Diesel MJ	HFO fuel MJ	Total MJ
2008	1,410,674	170,117	286,464	1,867,255
2009	1,277,320	107,239	310,627	1,695,186
2010	1,262,896	62,655	387,671	1,713,222
2011	1,257,379	107,834	384,274	1,749,487

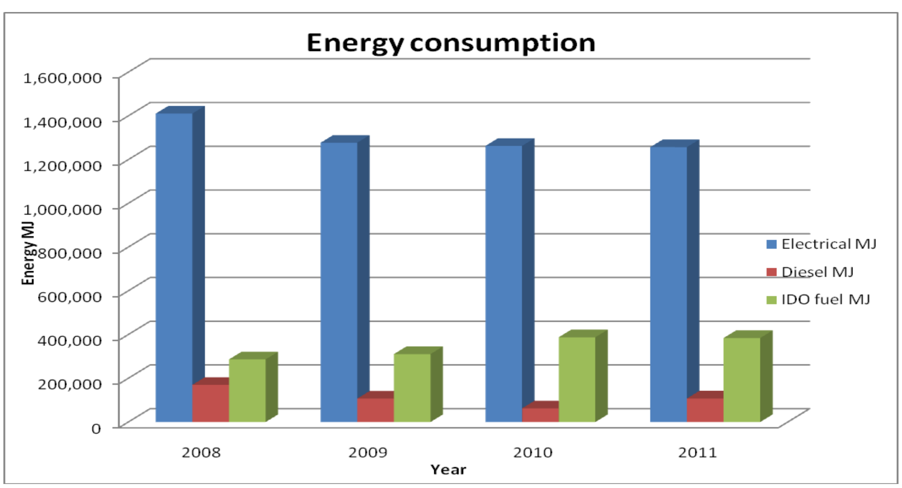

Figure 4.2: The electrical, diesel and HFO fuel used for the period 2008-2011.

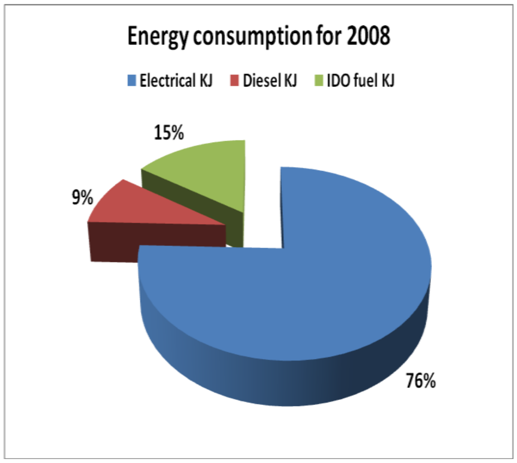

Figure 4.3: Energy consumption for 2008

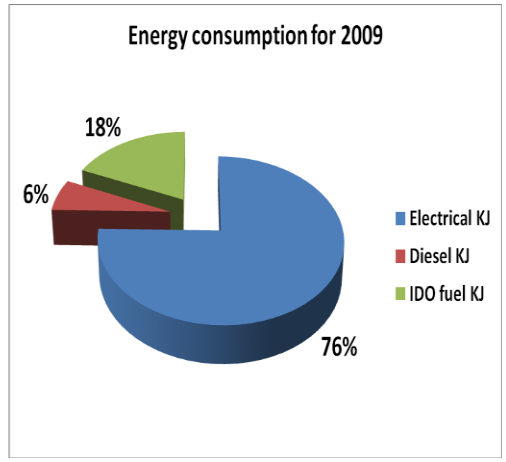

Figure 4.4: Energy for the year 2009

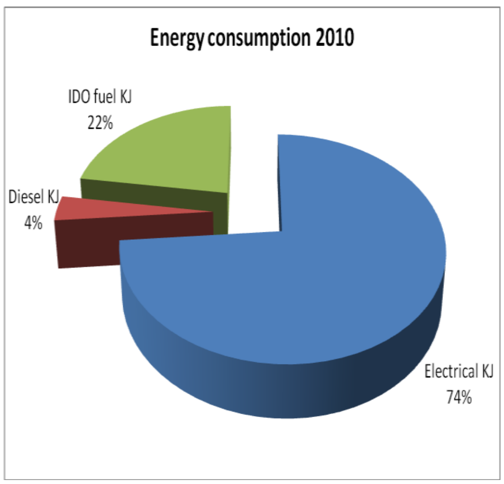

Figure 4.5: Energy consumption for 2010

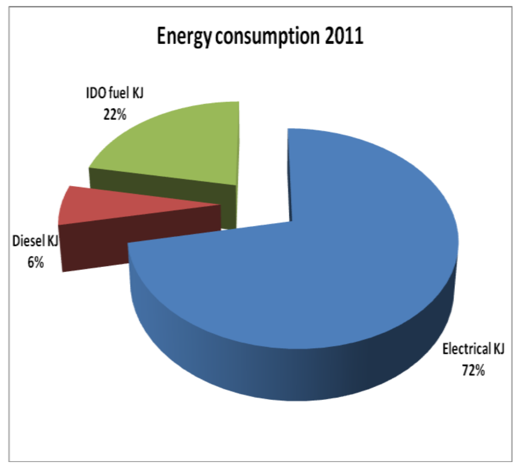

Figure 4.6: Energy consumption for 2011.

4.2 Tariff Structure

One option in reduction of electricity cost is the change of tariff by commercial/industrial customers, depending on the consumption. The next commercial/Industrial tariff CI2 has the charges as follows: [1, 3, 6]

Table 4.2: Comparison of tariffs CI1 and CI2

Cost difference for Minimum 15000kWh	CI1	CI2	Kshs CI1	Kshs CI2
Demand kVA	240	240		
A fixed charge of Kshs. per month.	800.00	2,500.00	800.00	2,500.00
An energy charge of Kshs. per kWh	5.75	4.73	86,250.00	70,950.00
Demand charge of Kshs. per kVA	600.00	400.00	144,000.00	96,000.00
Total costs Kshs.			231,050.00	169,450.00
Saving Kshs.				61,600.00

Cost Saving Opportunity - 1

The comparison of the two tariff structures is given in Table 4.2 above. The analysis indicates the TCIL can make a saving of Kshs.61,600.00 per month, Kshs.739,200.00 per annum, with a change of tariff from CI1 to CI2. [1, 6, 9]

Cost Saving Measure - 1

The choice in tariff has an effect on the costs of electrical energy, to change from one tariff to another; the metering voltages will also change. TCIL can change from being metered at 415V to 11kV which shall mean changing the transformer size to 1MVA with associated control and protection equipment and at a cost to the company. The cost of migration is approximately Kshs.4.0 million, which will translate to a return of investment within six years, as a total of Kshs.739, 200.00 will be saved annually.

4.3 Power Factor

From the start of the data collection in 2009, the power factor (pf) was noted to be low for the periods of November- 2009 to March 2010, less than 0.9and a surcharge was levied by the service provider. Low power factor is caused by inductive loads such as transformers, electric motors, and high intensity discharge lighting. Unlike resistive loads that create heat by consuming kilowatts, inductive loads require the current to create a magnetic field, and the magnetic field produces the desired work. The total apparent power required by an inductive device is a composite of the following:

i. Real power – measured in kilowatts, KW
ii. Reactive power, the nonworking power caused by the magnetizing current, required to operate the device – measured in kilovars, kVar.

The reactive power required by inductive loads increases the amount of apparent power in the distribution system. The increase in reactive and apparent power causes the power factor to decrease.

4.3.1 Benefits of improving power factor, pf.

i. The utility bill will be lower with a higher pf. A low power factor requires an increase in the electric utility's generation and transmission capacity to handle the reactive power component caused by the inductive loads. The industries are expected to operate with pf of 0.9-1.0
ii. The electrical distribution system's capacity will increase. Uncorrected pf will cause power losses in the distribution system, voltage drops are experienced as power loss increase. Excessive voltage drops can cause overheating and premature failure of motors and other inductive equipment.

Energy Saving Opportunity – 2

The TCIL during the period of November 2009 - March 2010 the p.f., was poor and was surcharged as shown below, Table 4.8.

Table 4.8: Power factor

	Month	Kilowatts KW	KiloVoltAmpere KVA	Power factor pf.	Cost of Surcharge Kshs.
1	November 2009	185	222	0.833	43,286.63
2	December 2009	169	196	0.862	22,089.74
3	January 2010	167	194	0.86	20,142.24
4	February 2010	170	196	0.867	17,124.48
5	March 2010	13	260	0.05	627,979.22
6	April 2010	163	166	0.98	0
Total Surcharge on poor pf. Kshs.					730,622.31

4.3.2 Analysis and Corrective measure

The following analysis was done for the month of November 2009, with a pf of 0.833. The pf as a requirement by the utility is to be above 0.9. Hence, the minimum pf of 0.9 is considered. Indicated below is the minimum expected reactive power correction:-

The energy required kW is185 kW, this shall be the constant factor as shown by the following Figure 4.7.

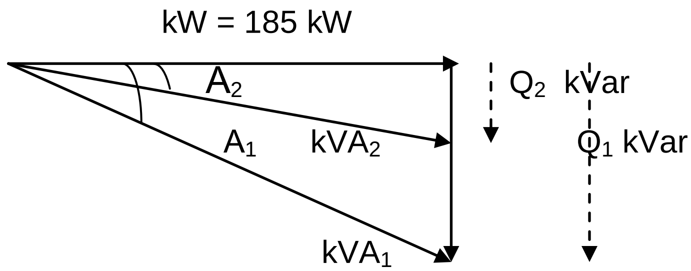

Figure 4.7: Power factor correction.

The pf is derived from the following:

Demand Power, kVA x cos A = kW,

Therefore, pf (cos A) = kW/kVA.

For a pf of 0.9, we shall assume kW of 185 kW, therefore the kVA is given as;

$kVA_2 \times \cos A_2$ = 185 kW

kVA_2 = 185/0.9

= 205.55 KVA

Reactive power is given by:

Cos A_1 = 0.833, A_1=33.59^0

Cos A_1 =0.9, A_2=25.84^0

$kVA_2 \times \text{Sin } A_2 = Q_2$ kVar

kVA_1 = 222 kVA,

Initial reactive power was:

$kVA_1 \sin A_1 = Q_1$ kVar =222 x 0.5532 kVar =122.81 kVar

kVA_2 = 205.55 kVA

Final reactive power becomes:

$kVA_2 \text{ Sin } A_2 = Q_2$ kVar = 205.55 x 0.4358 kVar = 89.58 kVar

The compensated minimum reactive power is:-

$Q_1 - Q_2$, 122.81 - 89.58 = 33.23 kVars,

And this must be done to achieve pf of 0.9. The compensation put in place in March 2010 gave a pf of 0.98. During the same month all the compensation was removed and the pf for the month was 0.05, which reflects failure or removal, to achieve a pf of 0.98 the reactive power compensation which was done was as follows:

’pf = 0.98, Cos A_2 = 0.98, A_2 = 11.480,

Sin A_2 = 0.199, kVA_2 = 166 kVA,

kW_1 = 163 kW

Q_2 kVar = kVA_2 Sin A2 = 166 x 0.199 kVar

= 33.032 kVar.

The capacitor banks installed to achieve 0.98 pf was 200kVAr, the reactive power therefore; Q = 33.032 + 200 kVar

Q = 233.032 kVar

kVA = $\sqrt{(kVar^2 + kW^2)}$

= $\sqrt{(233^2 + 163^2)}$

= 284.35 kVA

The system pf is therefore

kVA cosQ = 163 kW

284.35 x cos Q= 163 kW

Cos Q = 0.573

System pf = 0.573.

The total compensation done by the industry:

Reactive power compensated = Q_1 - Q_2 = 233- 33.00 kVar

= 200 kVar.

The industry proceeded to install capacitor bank that is able to provide pf of 0.98 by replacing the old capacitor banks with a new set of capacitor banks in the month of March 2010. Figure 4.8 and Figure 4.9 shows the installed capacitor banks.

The Figure 4.10 (a) and Figure 4.10 (b) below represent the connection of capacitor banks with respect to the utility meter and customer load. The figures illustrate a system without a capacitor bank for compensation and the flow of the kilowatts and kilovars within the system.

Figure 4.8: New capacitor banks for pf correction.

Figure 4.9: Set of Capacitor Banks installed

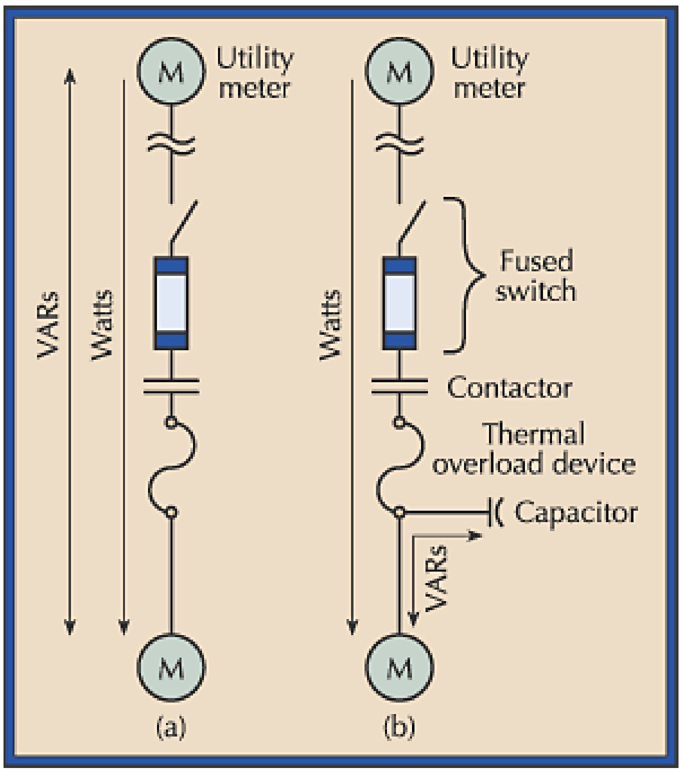

Figure 4.10(a) system without capacitor bank and Figure 4.10(b) System with capacitor bank. (Source: http:www//Google, search – induction motors and reactive power)

Energy Saving Measure – 2

The system pf after failure of the capacitor bank was 0.573. The utility surcharge for this value is approximately Kshs 211,264.00 which would be costly for the utility. The TCIL therefore is having a saving in electrical energy costs that could have been due to the pf, by the reduction/removal of the pf surcharge and also reducing the KVA demand due to the same. The cost of the installation was Kshs.345,000.00. The simple payback period for this is two months.

4.4 Energy consumption Total

The monthly energy data is given in the Appendix 1 and Figure 4.1 which shows the total energy consumed by TCIL after considering all the sources in use, electrical, diesel and industrial fuel HFO.

4.4.1 Electrical

The average demand for the electrical power is 188 KVA with a peak demand of 260 KVA in March 2010. The operation of TCIL is from 8.00 am to 4.30 pm with a tea break and lunch break. The time of peak period was noted to be between 11.00am and 2. 40 pm these are periods that are immediately after the breaks. During the, tea and lunch breaks, the main motors for crushing and mixers are left operating, preparing products. These peaks were noted to occur at metered sections of Powders and Minerals and are shown in Figure 4.20 and Figure 4.21.

Opportunity to reduce demand – 3

The maximum demand is a contribution of the peak loads of each section during peak hours, the induction motors have efficiencies ranging from 60-80%, all the major motors of 10kVA and above are started on star delta methods to reduce on starting currents;

Starting current for motors (I_{st}) connected direct on line is:-

$$I_{st} = 7 \times \text{Rated current}, 7I_{rated}$$

Big motors fitted with Soft starting or star – delta starters, the starting current will be:-

$$I_{st} = (1 \text{ to } 2.5) \times \text{Rated Current}, < 2.5 \times I_{rated},$$

The Demand $= \sqrt{3} \times I_{st} \times V$, VA

Energy saving opportunity – 3

A reduction on the demand will translate to a reduction in the electricity bill by ksh.600 per KVA. TCIL pay monthly KVA demand charges as required on the bills, for 260 KVA the cost was Kshs. 156,000.00 in March 2010. By reducing the monthly demand to as low as 132 KVA, the demand cost was Kshs. 79,200.00 indicating a saving of Kshs.76,800.00 monthly. This translates to an annual saving of Kshs.921,600.00.

4.5 Production

Appendix 2, shows the total production for the period under study, 2007-2011.

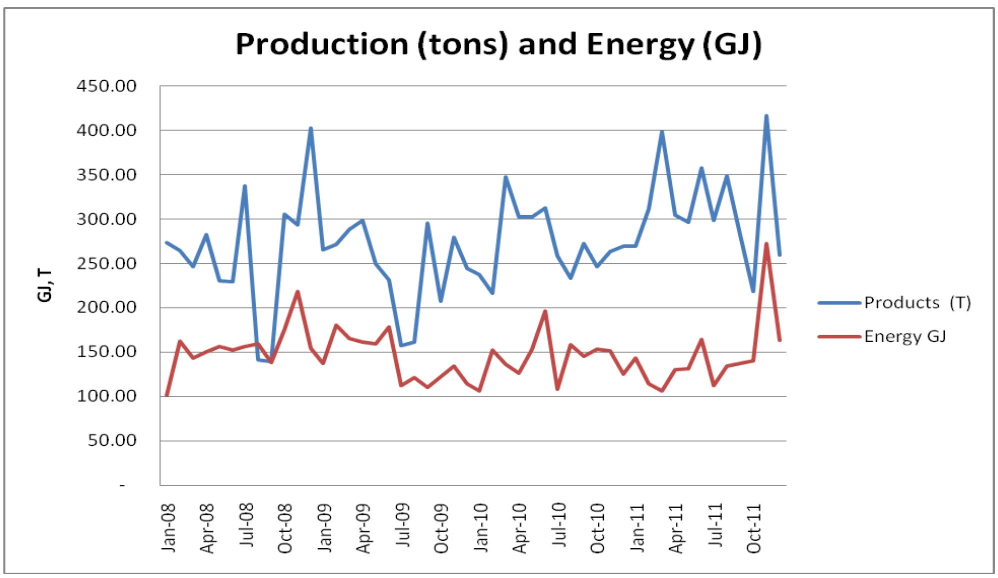

Figure 4.11: Energy and production graph.

The data for production was available from 2007, but the energy data for 2007 was not available, hence the period was not analyzed.

Figure 4.11 indicates that the energy used is tracking the production; with the increase of production the energy required also increases. Where the two are close would mean higher energy intensity during production. The analysis on energy against production graph, as seen in the Figure 4.12, a trend line is obtained as Y = MX + C, gives us the relationship between the production and energy consumption. R^2 shows the best fit for the data provided; best fit should be $R^2 > 0.8$.

The energy consumed for the period, Y = M x Production of the same period + C ,

Where,

M = Energy consumption is directly related to production levels

C = this is the base load - energy consumption for lighting, heating/cooling and general auxiliaries services that are not affected by production levels.

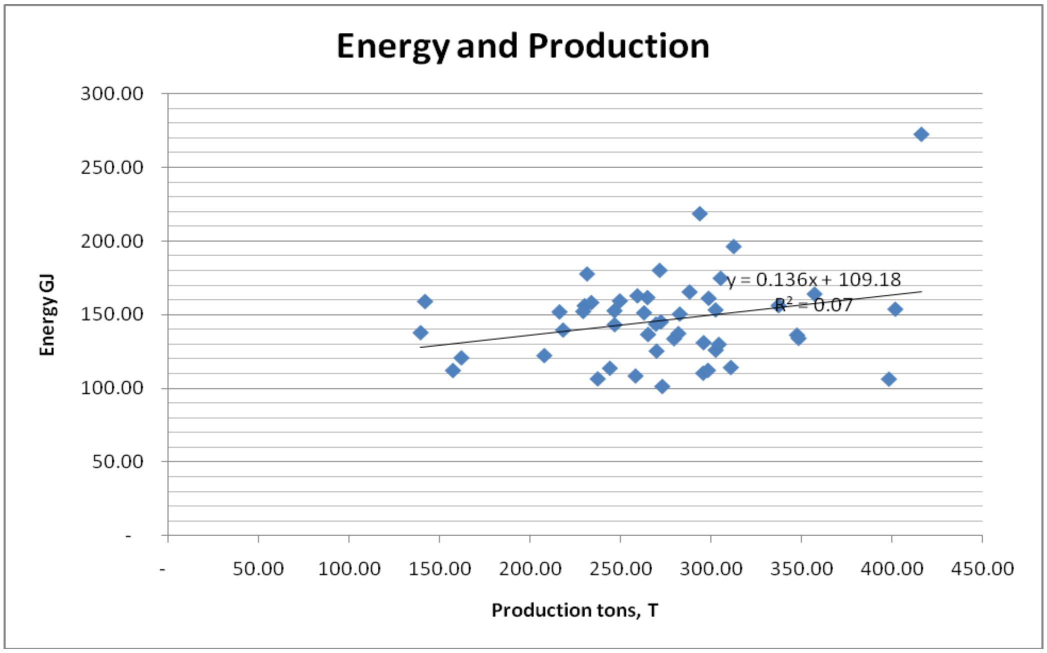

Figure 4.12: Trend line for Energy verses Production.

The trend line obtained from Figure 4.12 was:-

Y= 0.136X + 109.18, M=0.136

The trend line equation obtained from the graph was used for further analysis by working out the expected energy against the actual products, and getting the variation between the two energy obtained, as E - actual and E –calculated. From the calculations a CUSUM graph has been obtained. Appendix 4 shows the calculated values of expected energy consumption from the above equation. Though the best fit R^2 = 0.07, is poor the results have been used to prepare a CUSUM calculations and graph, as in clause 4.6.

Note*: When the best fit R^2 is less than 0.8 it does not represent a true picture of the relationship of energy and production. The various products do not go through the same processes. Each product has separate plants with different processes. The energy use by each plant is different, some plants use much less while have high energy intensity due to the processes. TCIL has five sections each with different plants, processes and energy consumption. The production records combined all products in two groups, liquids and Powders. The liquids products utilize the HFO fuel, while electricity and diesel is common to all products. R^2 = 0.007 is a poor fit for comparison of energy and production.*

4.6 CUSUM

The result of Appendix 4 has been used to prepare a CUSUM graph which as seen below, indicates the deviations from the normal behavior of the energy consumption pattern on the historical data of the industry. The CUSUM graph indicates:-

i. The first months of 2008; TCIL was doing poorly as there are signs of loss due to increase of energy use.
ii. In November 2008, use of 65 KW compressor was stopped and a 30 KW used for a short period till January 2009, when it was put back in use.
iii. In June 2009 the 65 KW compressors was removed from operation as the 30KW was confirmed to be adequate for use. The rise in energy loss increased to about 240 GJ by June 2009. The utilization of the 30 KW compressor resulted in energy savings.
iv. The capacitor banks stopped working properly in November 2009 and finally failed in March 2010 when low pf was experienced. This resulted in increase of electrical energy used and subsequent increase in cost.
v. High demand for liquid products led to increase of use of HFO fuels during January 2010 to January 2011.
vi. From January 2011 the use of diesel generator was minimized as there were less interruptions and this led to energy savings.
vii. The total savings therefore was 126 GJ by September 2011; this was eroded immediately in October-December 2011, due to use of standby generator and the boiler. Use of HFO and diesel fuels increased in Oct-Dec 2011 due

to increased production demand (highest production demand was in November 2011) and electricity supply interruptions.

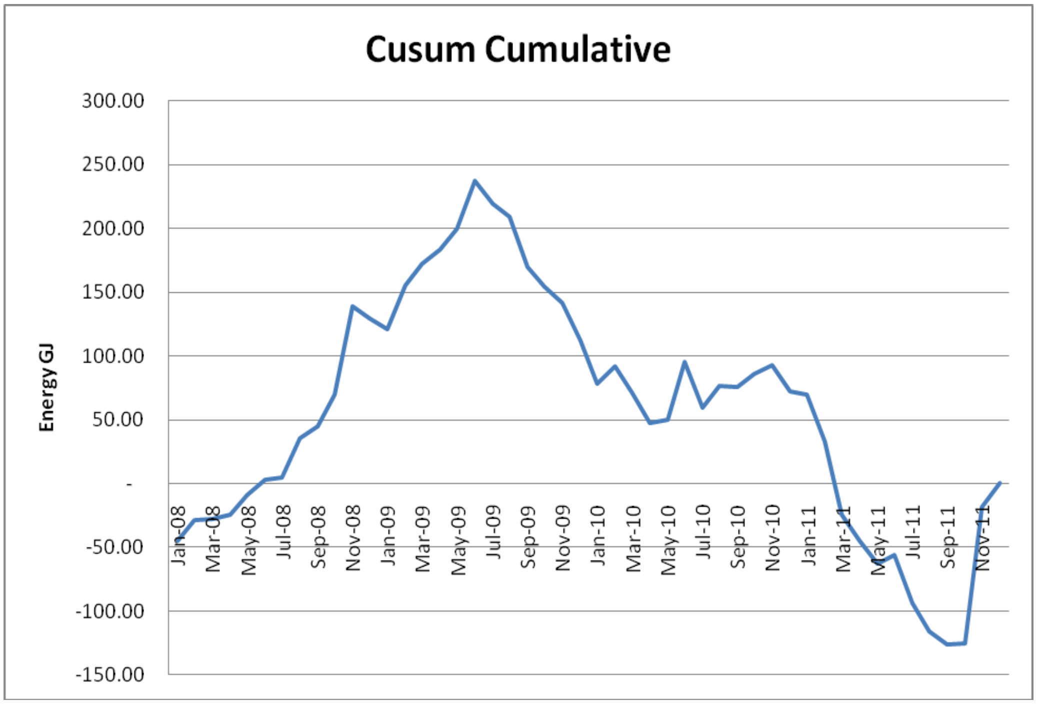

Figure 4.13: CUSUM GRAPH

Opportunity to Conserve Energy – 4

The company is able to save energy during its operations. There was loss of energy due to use of 65 kW compressors instead of 30 kW in June 2009. The loss was about 240 GJ in total. Other contributors to the energy losses are poor housekeeping, production levels management, energy waste due to idle running machines, low power factor, and poor efficiencies for the induction motors. This is equivalent to 66,666.7 kWh which translate to Kshs.1, 400,000.00 in terms of electrical energy.

Measures for Energy Conservation – 4

The company to institute the measures put in place in June 2009 in order to realize the savings that were initially lost and improve on its efficiency, by use of the smaller compressor of 30 kW instead of one of 65 kW. Other measures to put in place are housekeeping and production management. Motors due for replacement to be replaced with those with higher efficiencies and reduce idle time; reduce operating with low loads to improved motor efficiencies. The energy saving measure put in place had a saving of 126 GJ - an equivalent in electrical energy of 35,000 kWh and at Kshs.21/kWh, the savings is Kshs. 735,000.00 over the period of 8 months.

4.7 Energy Intensities

4.7.1 Total Energy intensity

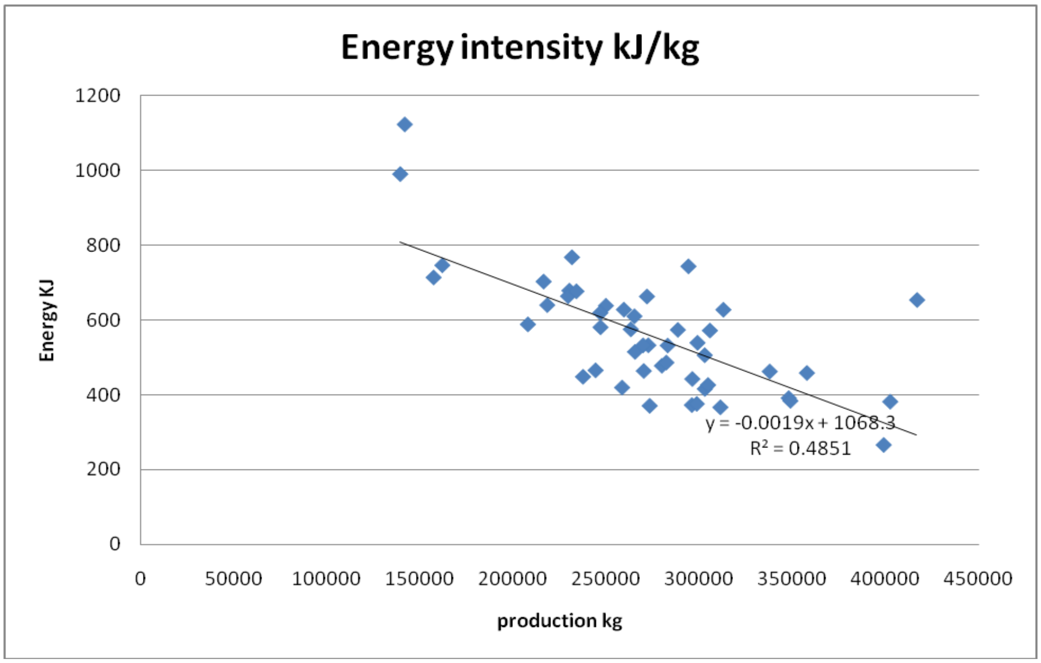

Figure 4.14: Relationship between energy intensity and production.

Figure 4.14 illustrates that total energy intensity reduced with increase in production. With increase of production the energy intensity reduces and indicates that it is more economical to process more products.

4.7.2 Electrical energy and production

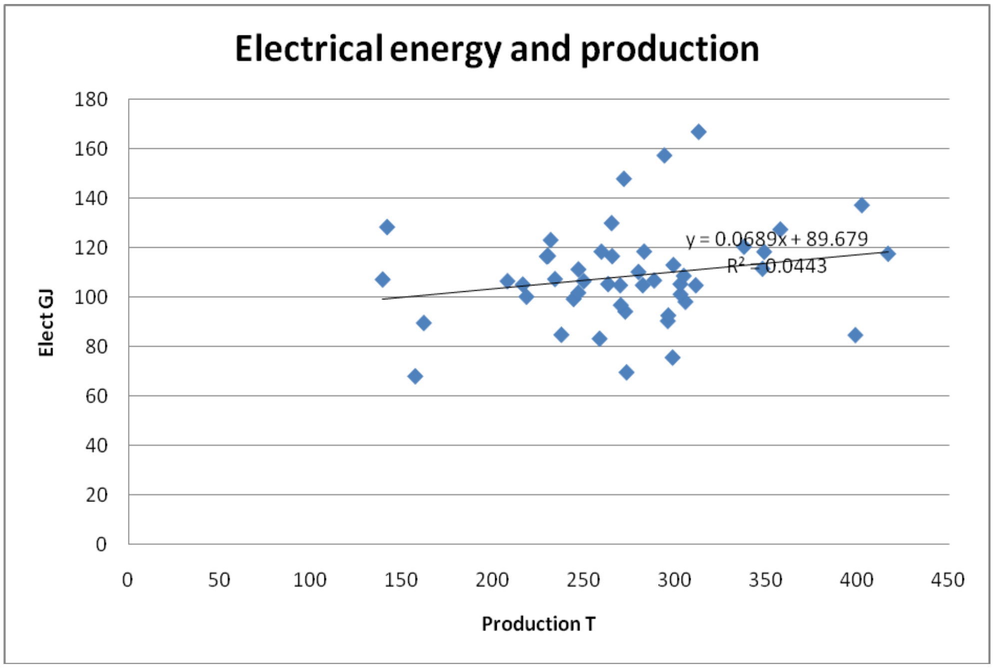

Figure 4.15: Electrical energy and production

Note: R^2 < 0.8 – this does not illustrate the best representation of the data as the processes are different for each section. Each section has a different plant and processes. Some products have higher energy intensity and others much much lower.

Opportunity to conserve energy – 5

Figure 4.15 shows a value of 89.679 GJ of electrical energy which is used but not relating to the production. This is the energy used for lighting, cooling, security systems which can be reduced to lower levels and improve on energy efficiency. This is equivalent to 24,913 kWh per month of energy.

Measure to conserve energy – 5

The company to institute use of natural lighting mainly in offices, and the relevant lights to be on when necessary. The security lights to have a light sensor that switches off the lights automatically when there is adequate lighting, and avoid manual switching for the security lights. The cost of the energy not related to the production at an average of Kshs 21.00/ kWh is Kshs. 523,173.00 of the monthly electrical energy consumption and bill. A reduction in this electrical energy used in accessories can contribute to a reduction in the overal cost of electricity.

4.7.3 HFO Fuel and Production

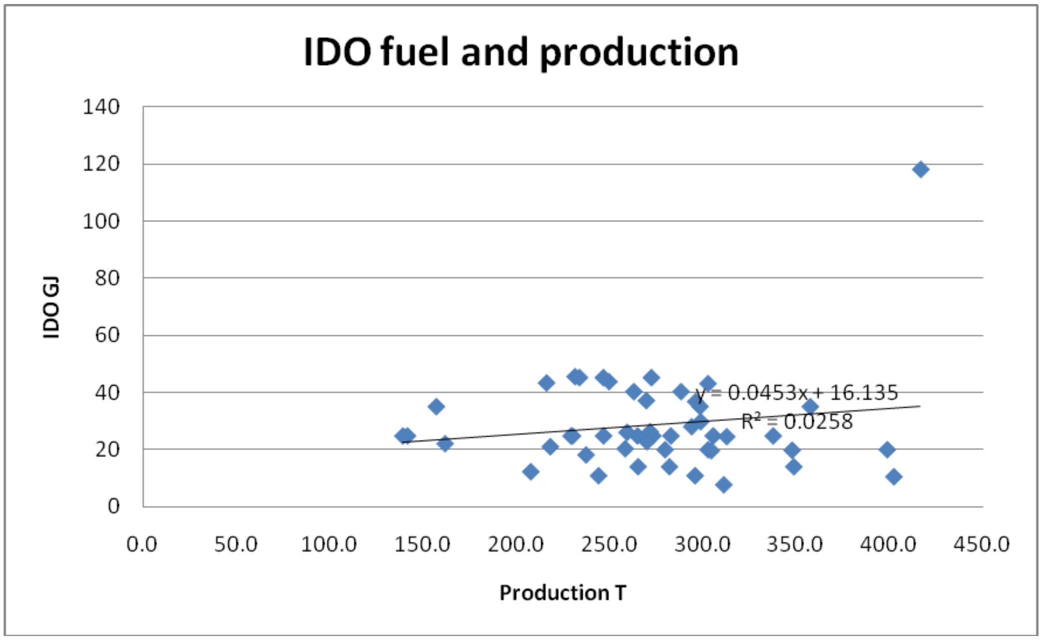

Figure 4.16: HFO fuel and production

Figure 4.16 indicates that the TCIL uses 16.1 GJ of HFO litres which is not directly related to the production. This is equivalent to 460.7 litres of HFO fuel per month used. Table 4.9.

Opportunity to conserve Energy – 6

The company is using - HFO fuel total 460.74 litres which is equivalent to 16.1 GJ that is not related to the production. This is for start up of the boiler, energy lost due to radiations, heat transfers, poor lagging of steam pipes, flash steam, and condensate and cleaning of containers. This is a figure that should be reduced and save on energy consumption.

Measure to conserve Energy – 6

The company to reduce use of HFO fuel by reducing to a minimum fuel used for start up of the boiler and also by instituting proper insulation of the steam distribution lines. Some of the lines are not insulated and are contributing to the total loss of 16.1 GJ which is equivalent to 460.7 Litres of HFO fuel. This loss is due to start up, heating up of cold pipes, radiation losses and losses through sections of pipes which are not insulated. At an average cost of Kshs. 90.00/ litre the industry can save up to Kshs. 41,466.60 monthly.

4.7.4 Diesel and production

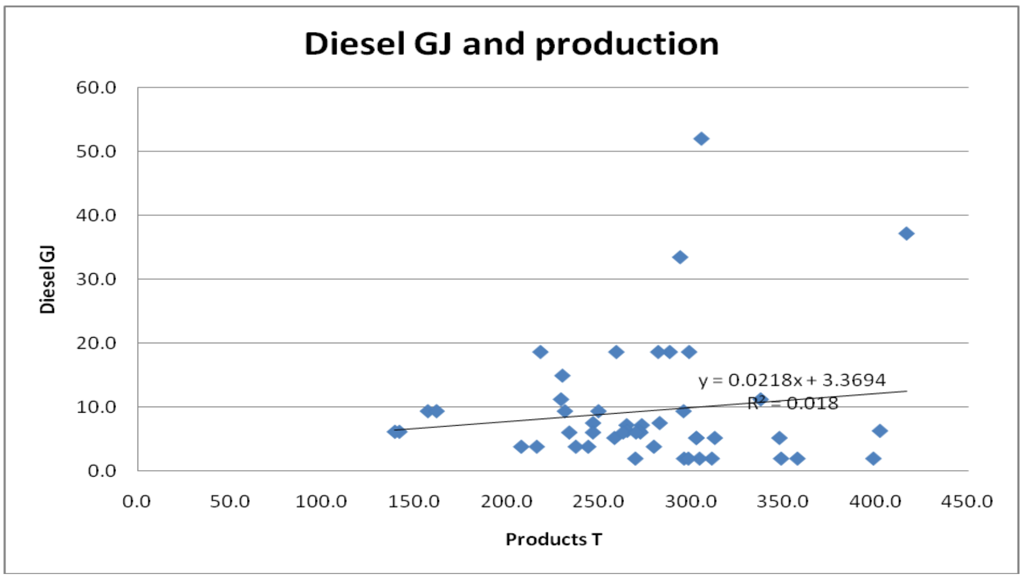

Figure 4.17: Diesel and production

Figure 4.17 indicate the diesel used by the generator has a portion of 3.4 GJ not related to the production. The Generator is used when there is no electrical power, this is the energy for lighting, cooling and other auxiliary supplies required.

Opportunity to conserve energy – 7

A reduction of the auxiliary supplies energy requirement can contribute to reduction of diesel required when the main electrical power is off. The contribution of this energy to the energy used is 3.4 GJ which is equivalent to 90.6 litres of diesel per month.

Measure to conservation – 7

The diesel that is used for other activities can be reduced as this contributes about 90.6 litres, and is not related to the production. The reduction shall contribute to energy savings of Kshs. 9,063.00 per month (Table 4.9).

Table 4.9: Cost of energy not related to production

HFO Fuel	**Energy**	**kJ/kg**	**kg/litre**	**Litres**	**Costs**
Unit	GJ	41,200	0.85		90.00
	16.1	391.6		460.7	**41,466.30**
Diesel fuel	**Energy**	**kJ/kg**	**kg/litre**	**Litres**	**cost Kshs**
Unit	GJ	44,800	0.83		100.00
	3.4	75.2		90.6	**9,063.00**
Electrical Energy	**Energy**	**kJ/kWh**	**KWhs**		**cost Kshs**
Unit	GJ	3,600			21.00
	89.7	24,913.9	24,913.9		**523,173.00**
			Total Cost		**573,702.30**

4.8 Electric drives

Two main sections were noted to be contributing to the major demand of electricity in TCIL, are the Powder Section and the Mineral Section. The two sections were sub metered to monitor the electricity consumption; see Figure 4:17, Figure 4:18 and Figure 4:19.

The downloaded results are shown in Figures 4:20 and Figure 4:21 and indicate the loadings and peak demands of each of them for the months of September – December 2011. The data was recorded and down-loaded on 11th January 2012. The peaks contribute to the maximum demand of TCIL, reduction of these peaks shall lead to energy saving.

Figure 4.17: Distribution Board for Powder section and submeter

Figure 4.18: Down loading of data -Submeter Powder Section

The results obtained was used to analyse the performance and contribution of the two sections.

4.8.1 Mineral & Powder Sections Electrical energy

Figure 4.19: Down loading of data - Mineral Submeter.

Opportunity to conserve energy – 8

The peak demands for each section, Mineral and Powder, was120 kVA and 50 kVA respectively, can be reduced by using soft starting methods for bigger size motors of 10 hp and above. The majority of the big motors have star – delta starting which result in starting current of 2.5 times the rated current. Most of the motors were installed more than 10 years and therefore their operating efficiency is lower. The old motors are proposed to be replaced with motors with higher efficiency and improve their performance.

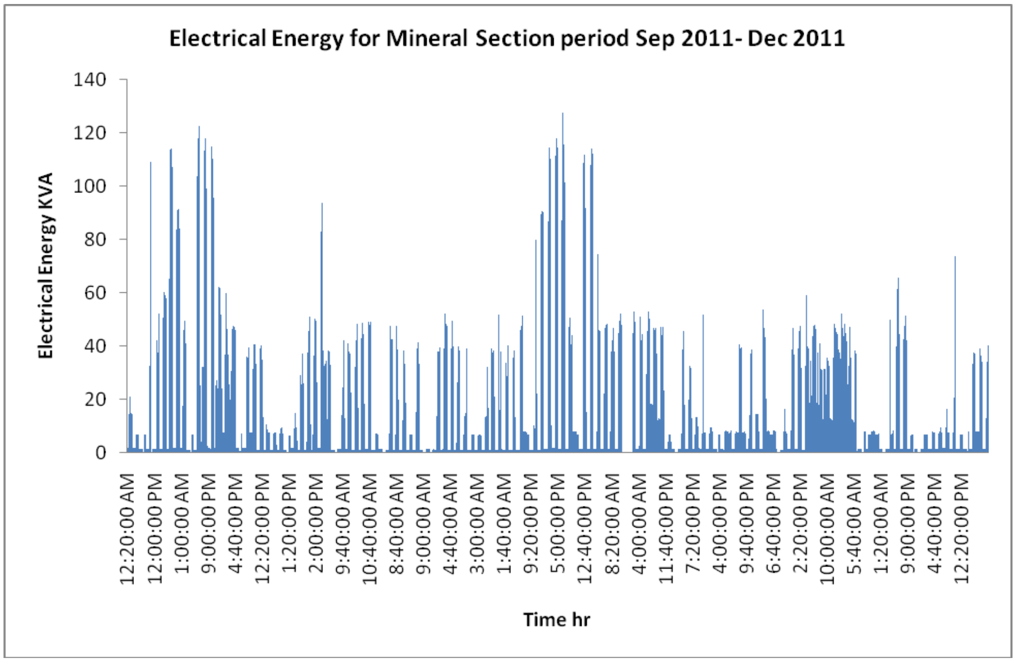

Figure 4.20: Electrical energy for Mineral Section for Sep- Dec 2011

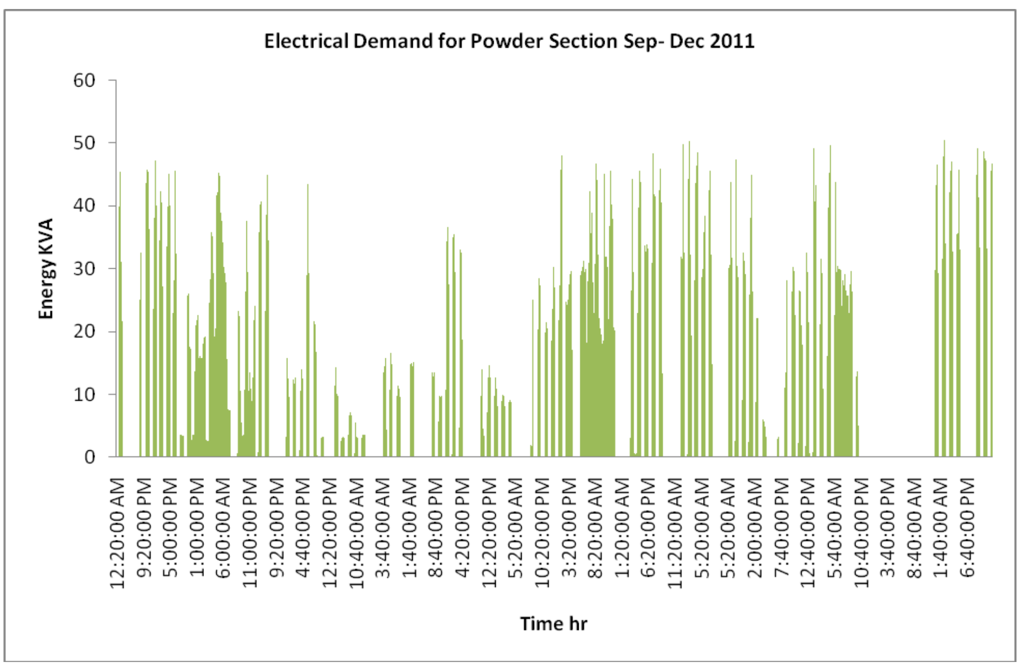

Figure 4.21: Electrical Energy for Powder sections for Sep – Dec 2011

Measure to conserve energy – 8

The company to consider replacing the existing old motors of low efficiency with those with higher efficiency to improve performance. The power factor at the load points are quite low due to the operating conditions such as low loading the powder section has a pf at the load distribution board of 0.4 - 0.67, while the Mineral section has 0.55 – 0.79. The reactive energy that is due to the induction motors for each section is compensated before the utility meter. This can be reduced by using motors with better efficiencies of up to 4% improvement. The savings due to the proposal in peak demand is 17.08 kVA per month. The cost saving is Kshs. 10,246.67 per month on electricity bill. The estimated cost for soft start methods for the bigger motors for nine motor above 20 hp is Kshs. 20,000 each, total of kshs. 180,000.00, the simple payback period is 9 months.

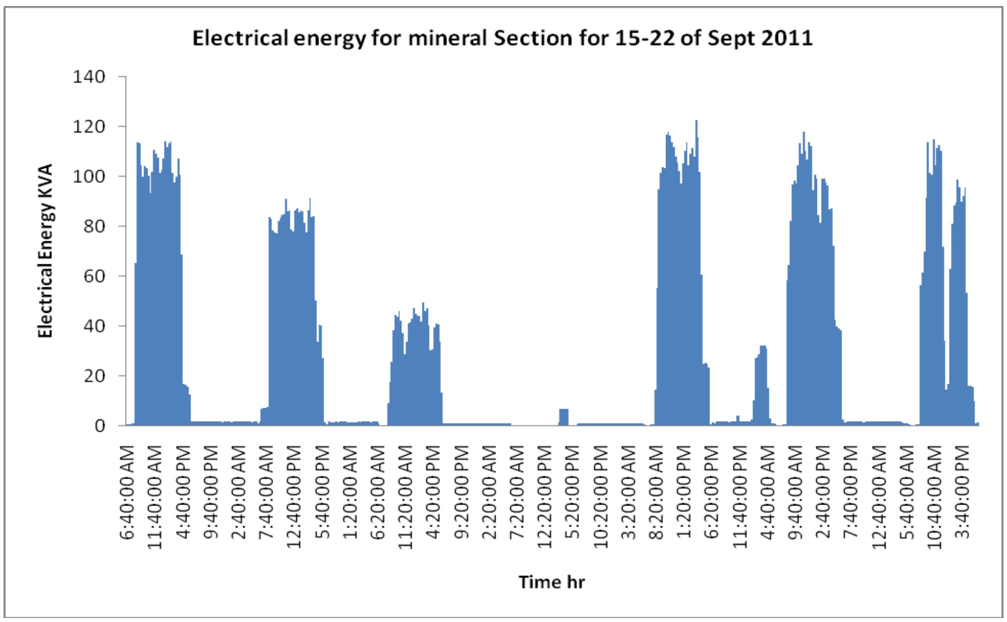

Figure 4.22 : Electrical Energy demand for the Mineral Section period 15-22 Sept 2011

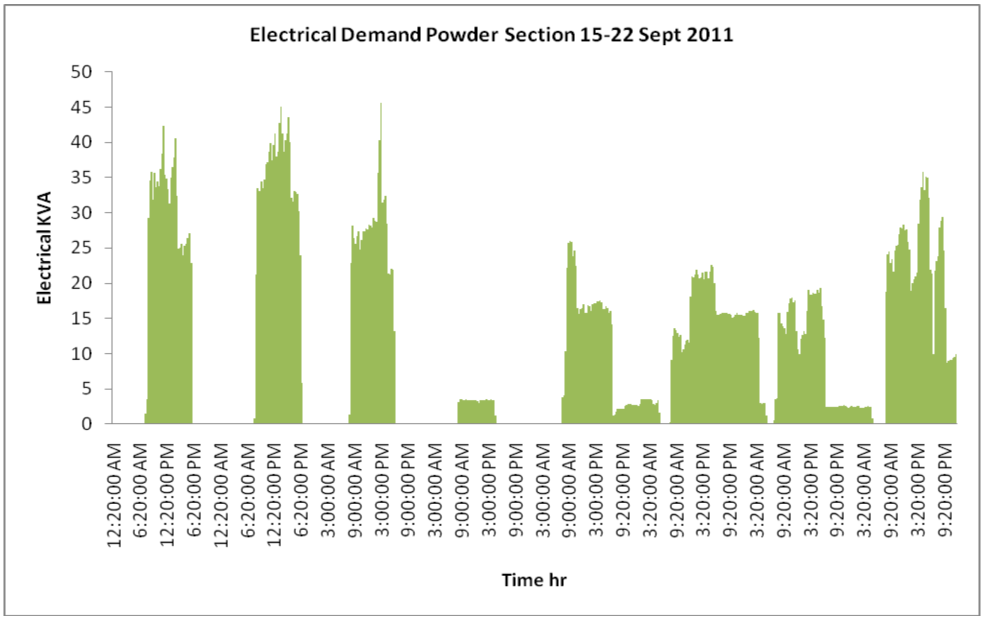

Figure 4.23: Electrical energy demand for the Powder Section period 15-22 Sept 2011

Figures 4.22 & 4.23, shows electrical energy for the two sections and this represents the period when there was a high load demand for the Mineral section, the demand for the powder section for the same period was considered. The two sections had different peaks occurring at different times and days, for the Powder section the highest demand was on 17-9-2011, while for the Mineral section the peak occurred on 19-9-2011. The effective highest demand due to these two section occurred on 15-9-2011 when the demand was 154 kVA, Table 4.10.

Table 4.10: Electrical Demand for Powder and Mineral Section

Date	Powder	Mineral	Effective
	Peak kVA	Peak kVA	Total Demand kVA
15/09/2011	42.4	114.2	154
16/09/2011	45.1	91.4	135
17/09/2011	45.6	49.4	95
18/09/2011	3.56	6.7	10
19/09/2011	26	122.6	141
20/09/2011	22.6	113.7	130
21/09/2011	19.1	114.9	132
22/09/2011	35.8	62	90

The demand for the month of September 2011 from Table 4.3, Appendix 1, was 166 kVA, this indicates clearly the main contributor to the demand is Mineral Section, followed by powder Section while the other three sections, Fungicides, herbicides, liquids and administration contributed to about 12 kVA of demand for the month of September 2011.

Opportunity to conserve energy – 9

The reduction of demand in the Mineral and Powder sections by use of motors with higher efficiency will contribute to the overall reduction of energy consumption for TCIL.

Energy conservation measure - 9

The company should replace old induction motors, with those with higher efficiency and institute soft start methods for motors of 10 hp and above. The motors with higher efficiency will translate the savings in energy of 15.4 kW, equivalent to 2,582.2 kWh per month. The cost of the electrical energy saving due to efficient motors is Kshs. 113,400.00 –Appendix 5 and Table 4.11 below:

Table 4.11: Energy Savings due to Demand reduction and use of efficient motors.

		Unit cost Kshs	Units	monthly
Demand Savings kVA	15.4	600.00	17.1	10,246.70
Savings kWh	15.4	21.00/kWh	2582.2	54,228.50
				64,472.00

The major motors to be replaced at an estimated cost of Kshs. 1,000,000.00 with energy efficient motors using soft starting methods. This will give a simple payback period of 16 months. The demand and the energy consumption costs will be reduced by Kshs. 64,472.00.

4.8.2 Day Demand – 11 November 2011

Figure 4.24 & Figure 4.25, represent a day in November 2011 for Mineral and Powder section, the peak demands for each occurs at different times of the day, while the total effective peak occur around 11: am – 152 kVA.

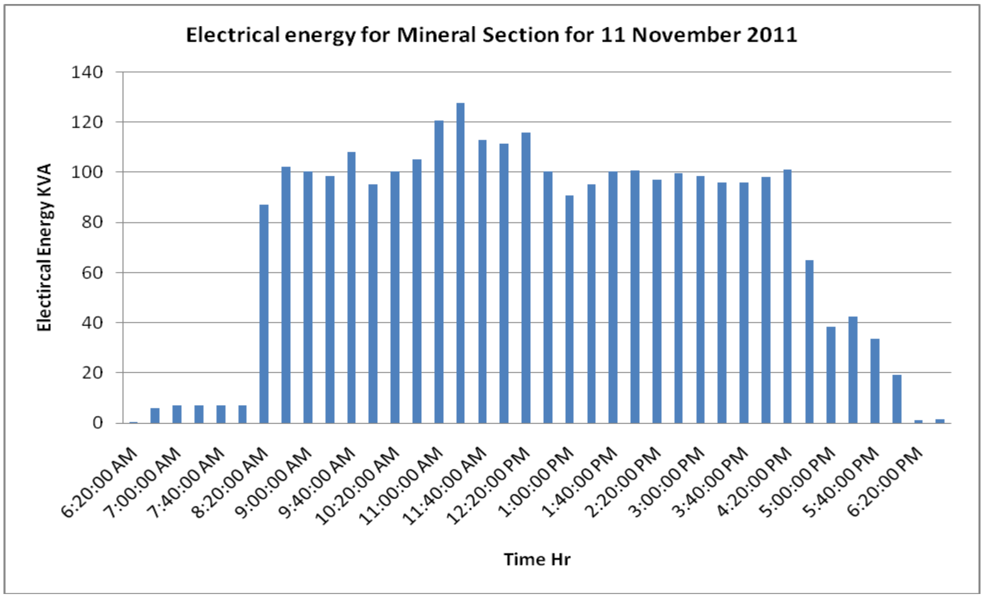

Figure 4.24.: Mineral Section Demand for 11 November 2011

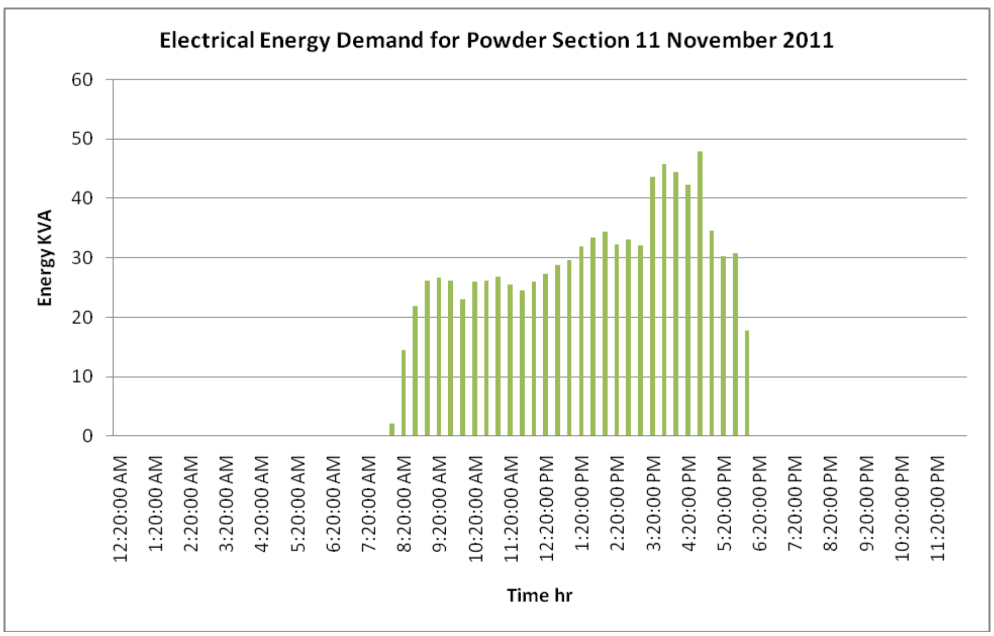

Figure 4.25: Powder Section demand for 11 November 2011

The demand for the month of November 2011 was 206 kVA indicating that these two sections are the major contributors to the overall demand for the industry.

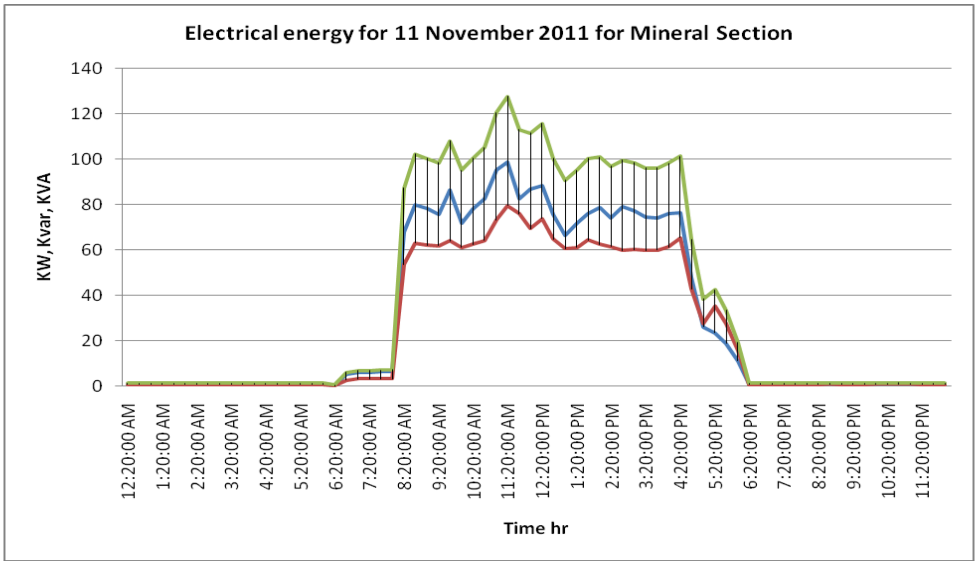

Figure 4.26: Peak load for the Mineral section, 11/11/2011, - kW, - kVar , - kVA.

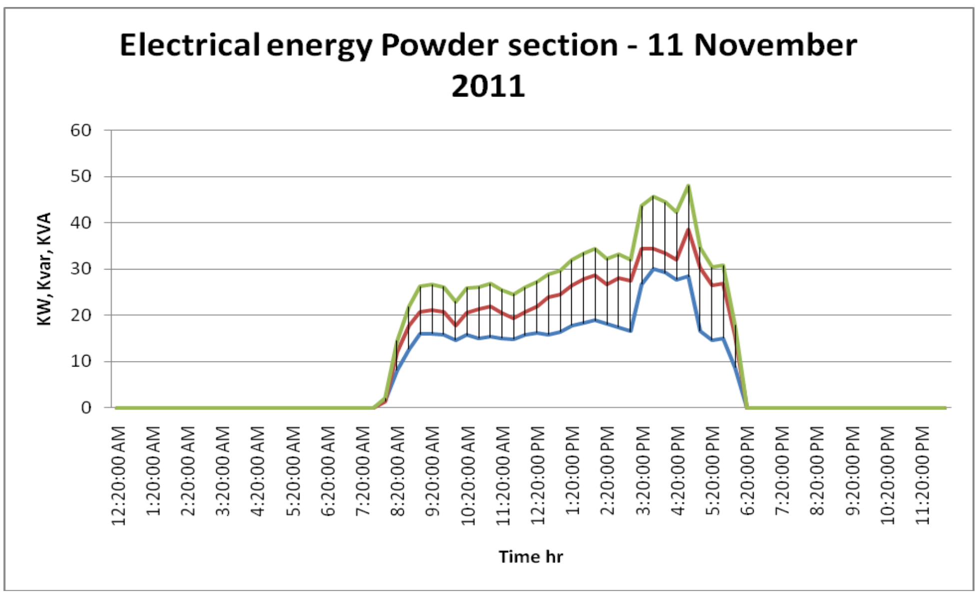

Figure 4.27: Peak load for the Powder section, 11/11/201, - kW, - kVar , - kVA.

Further analysis of the relationship of the kVar, kW and kVA is indicated by Figure 4.26 & Figure 4.27. The Powder section indicates that the reactive/inductive kVar is higher than the kW, hence shall require to be compensated before the meter. This can be improved by increasing loading of motors, which are running with low loads and operating only those that need to operate at the required loading. The Mineral section analysis shows the reactive energy is lower than the real power.

In both instances, managing the production process will be necessary to reduce the reactive power during operating hours and ensure the compensation before the utility meter is always functioning, to avoid having low pf.

Opportunity to conserve energy – 10

The company to change their operations and instead of operating all sections during the day, the Mineral or the Powder section can shift operation to evenings, the demand will reduce to as low as 121.1 kVA per month as seen from Table 4.10. The peak for the day will be low approximately 62 kVA. The demand saving of 85 kVA can be realize; equivalent to cost saving of Kshs.51,000.00 per month, from a peak demand of 206 kVA for the month.

4.9 Lighting

The lighting consist of 40W twin and single fluorescent lights all fitted with electromagnetic ballast. The lighting is supplied in two ways as general high level lighting installed at 6 - 8 meter above the floor level and lighting for product visual inspection installed at 2 – 3 m above the floor level. There are translucent skylights in the roof of the process halls for lighting during the day. The translucent skylights are in the Mineral Section and the ware houses/stores. The Liquid section where the chemicals are mixed has one side of the wall with wire mesh to allow for aeration and escape of fumes. Hence, limited lighting during the day. The packaging area has the lights for visual inspection. The offices are also installed with fluorescent tube lights, most are twin type with electromagnetic starters.

4.10 Illumination

The luminance level was confirmed to be within the required level of 300 lux and above for the working areas. The areas with skylights the lux was up to 2200 lux. Inspection areas were within 300 – 600 lux.

The use of skylights and fluorescent tubes are good initiatives and saves energy use. The fluorescent tubes are energy efficient compared to other type of lights fittings. However the use of electromagnetic ballast results in energy waste as demonstrated in Table 4.12 below.

Table 4.12: Control Lighting

		OTHERS	Agric/W house	Liquids Section	Powder section	Total
General lights	A	82	48		84	214
Product Inspection Lights	B			50		50
Total Tubes	C=A+B	82	48	50	84	264
Power/Tube W	D	40	40	40	40	
Power loss due to magnetic Ballast	E	35%	35%	35%	35%	
Total power /(tube + ballast loss) W	F=D X (1+E)	54	54	54	54	
Power loss to magnetic ballast/Tube W	G=F - D	14	14	14	14	
Electronic Ballast savings						
Ceiling lights						
Power lost due to magnetic ballast	=214 tubes x 14 W			2996	W	
Electronic Ballast savings 20%	=20% x 2996/1000			0.6	kW	
Operation time (Night only)				12	h	
Power Saved due to electronic ballast	=0.3108 kW x 12 h			7.2	kWh/day	
power Savings	= 7.2 X 30 days			215.7	kWh/month	
Inspection lighting						
power lost due to magnetic Ballast	=50 tubes x 14 W			700	W	
Electronic Ballast saving 20%	=20% x 700/1000			0.14	kW	
Time of use h				12	h	
Power per day	=0.14 kW x 12 h			1.7	kW/day	
Savings	=1.7 x 30 days			50.4	kW/month	
Total Savings	=215.7 + 50.4			266.1	kW/month	

Opportunity to conserve energy – 11

All the fluorescent lights in TCIL are controlled by electromagnetic ballast that consumes additional power above actual input to the range of 35%. This amounts to additional 14W extra for every 40W tube. The electromagnetic ballast control gear continues consuming power even when the tube is faulty or flickering resulting in extra energy use. It is proposed to use more energy efficient starting controls to conserve energy for lighting systems.

Measure to conserve energy – 11

Table 4.12 above shows the effects of replacing electromagnetic ballast with electronic control gear. Replacing the electromagnetic ballast will save 20% of the energy currently wasted by electromagnetic ballast. The saving of 266 kWh per month equivalent to Kshs.5,586.00 per month, can be realized. With an investment of about kshs.600.00 per ballast replacement, the simple payback period is 2.4 years.

4.11 Compressed air systems

The company has a compressor used mainly for aerosol – insecticide packaging in compressed air tins. The propellant used is Liquid Petroleum gas (LPG) due to its properties of being liquid under pressure. The disadvantage is that it is flammable and therefore safety concerns have to be put in place during packing, storage and use of the product. The compressor is 30 kW rating and is used daily for eight hours.

There was no data that was obtained for the compressor that could be used to analyze its performance, the intake air and output air temperatures were not taken during operation. The performance is affected by the intake temperature, the cooler the air intake, the better the performance. Other factors that affect the performance are leakages of air through air leaks and misuse during cleaning. All these activities can reduce energy wastage due to the compressor. However, these options were not analyzed in this report. The equipment for monitoring was not in place and was to be done at a cost.

4.12 **Boiler and steam distribution system**

4.12.1 Boiler

The company has one boiler installed at the premises. The details as shown in Table 4.13.

Table 4.13 : Type of boiler and rating

Boiler make		Allen YGNIS
Type		Fire Tube
Burner Make		
Rated pressure	PSI	150
Rated Capacity	PSI	155

The Energy loss due to the boiler surface was not analyzed as measurements for both body, ends and manholes readings during operations were not monitored. The data on fuel analysis as to its composition was not also available. No measurements were taken on the flue gas to note the excess air and temperatures as no monitoring of the same was put in place. The performance of the boiler can be assessed by having information on these parameters. It was not possible to do any analysis in the absence of the measurements. The equipment to do the monitoring and measurements for flue gas was expensive to buy and install, hence lack of necessary data.

4.12.2 Steam distribution system.

Steam from the boiler is distributed to five points within the liquid section of the industry. The steam distribution pipes are of the size 2" diameter steel pipes with 3mm of thickness. The steam lines from the boiler system have valves to reduce the flow and delivery pressure at the required point. The heating system is to four containers used to mix chemicals when a specific product is required. This is indirect form of heating, as the steam is passed within the containers and the condensate is recovered to a tank but is never recycled.

The other use is for defrosting of liquid products which are at solid state at ambient temperatures. A water bath is used with steam pipes passing within the water. The drum of product is immersed in the water bath and steam is passed through for some 2 – 3 hours before removal and putting in the mixing containers, to be mixed at certain temperatures.

Opportunity to conserve energy - 12

The piping system is old and poorly lagged. The effect of nature is also evident, as most of the pipes are exposed, and laggings coming off. There is total exposure of about 5 meters along these pipes. The energy loss through the poorly lugged surface is given in Table 4.14 as 108.72 MJ of HFO fuel, this is equivalent to 3.1 litres of fuel daily. Figure 4.28 and 4.29, shows part of the exposed pipe from the boiler and the lagging peeling off due to age and weather conditions, and the steam distribution system.

Figure 4.28: Poor or no lagging of steam distribution pipes.

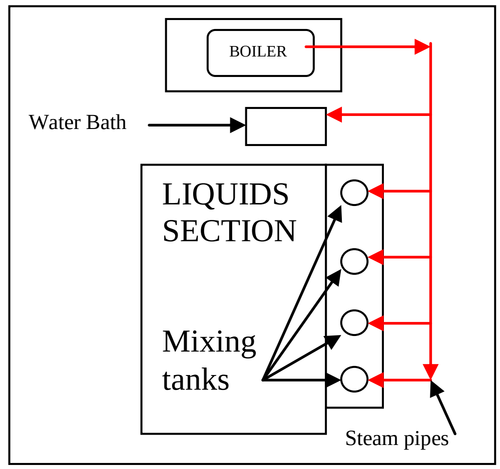

Figure 4.29: Boiler steam distribution

Table 4.14: Energy loss in steam distribution system.

Length of pipe meters (m)	5	operation time hours (h)	8 h
Steam Temperature T2 °K	615.1	time seconds (s)	28800 s
Ambient temperature T1 °K	298	total Energy joules (J)	108720000 J
h (heat resistance of steel) k/sq m	15	Energy in 1kg HFO (kJ)	41200 kJ
Pipe Diameter inches	2	Total kg of HFO	2.64 kg
Pipe Radius inches	1	1 litre of HFO = 0.85 kg	
Pipe Diameter in meters (m)	0.05	litres of HFO = 2.64/0.85	3.10 L
Pipe Radius in meters (m)	0.03	Cost Kshs @90.00/litre	279.40/day
Total Area (sq m)	0.79	Cost/Month Kshs	**Kshs.6,985.00**
Q - heat loss (J)	3775		

Measure to conserve energy - 12

The steam distribution system is poorly maintained and there are no lagging along all the piping systems, approximately 5 meters of pipe is exposed, this includes the bends and valves which are exposed in most area. The exposed piping system is losing energy equivalent to HFO fuel of 3.10 litres, costing Kshs. 279.40 per day. Operating the boiler daily for a month will cost Kshs.6,985.00 per month of energy lost. The approximate cost for the lagging of the exposed steam distribution lines is Kshs 400,000.00, and gives a simple payback period of 4.8 years.

CHAPTER FIVE

DISCUSSIONS AND OBSERVATIONS

5.1 Energy sources

The company uses three main types of energy sources, electrical, diesel and industrial fuel oil. Solar is used in sky-lighting for some of the Sections and warehouses. The main source is electrical energy, 76%; diesel contributes 9% and HFO is 15% of the total energy used.

5.2 Historical data

The average annual energy consumption for the period 2008-2011 was 1.76 GJ. The average energy intensity was ranging from 643.3KJ/kg – 472.5KJ/kg from 2008 to 2011. The four years of analysis indicate there has been remarkable reduction of energy intensity annual average from 643.3KJ/kg to 472.5KJ/kg. The production levels have risen within this period, and reduction of energy intensity is an indication of energy savings.

However the main energy component, electrical, has remained constant the last three years but the use of HFO increased by one third of previous years and diesel requirements has doubled the last year, 2011.

5.3 Energy consumption and production

The analysis shows 109.2 GJ of energy is used for auxiliary supplies, security lighting and cooling systems, which are not related to the production, this is composed of Electrical – 89.7GJ, HFO – 16.1GJ and diesel – 3.4GJ, on monthly basis. This is an opportunity for TCIL to save on energy that is not related to the production. In all the three categories of energy, savings can be accrued through reductions of these consumptions.

5.4 Power factor correction

The pf was noted to be low in the month of November 2009 – March 2010, this was corrected during the period of the study and the pf surcharge had accrued to

Kshs.730,622.00. The replacement was done at a cost of Kshs.345,000.00 by installing capacitor banks of 200 kVar to achieve a pf of 0.98. The payback period was estimated to 2 months, as the average surcharge was approximately Kshs.211,264.00 per month

5.5 Tariff structure

TCIL can consider tariff migration, from CI1 to CI2, as this shall have a cost saving of Kshs. 61,600.00 monthly. The investment however will be costly and is approximately Kshs.4,000,000.00, with a simple payback period of 6 years.

5.6 Electrical Peak demands

The electrical peak demands contribute to the cost in the utility bills. The industry had an opportunity to reduce the peak from the current 260kVA in March 2010 and maintain at lower levels of 132kVA as seen in March 2011, relative production for these two periods were 347,710 kg and 398,695 kg, with energy intensity of 392 KJ/kg and 267 KJ/kg respectively. Maintaining a low demand can be achieved by having the two major sections operate in shifts, one during the day and the other Mineral section, during the night. This will reduce the peak to approximately 121 kVA. The energy costs savings due to demand is estimated at Kshs.51,000.00.

5.7 CUSUM

The CUSUM shows poor performance in the first year 2008, and next half of 2009, with a total loss of 240GJ. In mid 2009, a measure was put in place to reduce this losses, one was to stop the use of 65 kW compressor in the mineral section and use a 30 kW size, others were better housekeeping measures, improve loading of motors, use motors with high efficiency, product monitoring/inspection. A deviation noted in January 2010 was due to the low pf which was rectified in March 2010. There was a total energy saving of about Kshs. 735,000.00 from February 2011 to September 2011 due to measures put in place. The high cost of fuel and the fluctuation of the shilling eroded these savings in the months of October 2011-December 2011.

5.8 Energy intensity

Despite the economic issues that affected the cost of petroleum fuel, TCIL has managed to bring the energy intensity on average for the last year to 472.5 KJ/kg. However, the monthly intensity for the last three months of 2011, were considered to be the highest for the last one year of consideration, with 641 KJ/kg, 655 KJ/kg and 629 KJ/kg.

Figure 4.14 illustrates that the total energy intensity reduced with the increase in production. For low orders of production, the energy consumption is higher per unit product.

5.9 Mineral and Powder Sections

Two sections were metered, Mineral Section and Powder Section, and on analysis were identified as the main contributors to the electrical energy consumption and; contributes 74% to the total demand. The starting methods, for the motors that contribute to the peak demand, to be enhanced, high starting currents contribute to the peak demand, all motors above 10 hp to have soft start methods. The motors with star-delta to be upgraded to soft start methods, and planned program to be put in place for starting of the plants to avoid high surges due to starting currents. The savings on demand and energy reductions due to use of efficient motors for the industry is estimated at Kshs.123,646.00 per month.

5.10 Real, reactive and demand power

The analysis of the relationship between real, reactive and demand was done for a specific day, 11th November 2011. This was for the two sections which have induction motors installed. It was noted that, the pf for each of the sections was lower than required, within the range of 0.4 - 0.8 and an effective pf of 0.6 before the capacitor bank. TCIL to ensure the compensating system is in good working order at all times to avoid having a pf below the required level.

5.11 Lighting

The use of sky lighting is a way of energy saving and also the use of fluorescent tubes. The use of ballast for starting in not an economical method compared to use of electronic ballast starters.

5.12 Boiler distribution system

The boiler distribution system is in dire need of repairs to replace the lagging and rusted pipes that have been affected by exposure to the environment. The replacement of the lagging will cost approximately Kshs.400,000.00, and the simple payback period will be 5 years as the expected savings of Kshs.6,985.00 per month of HFO oil.

5.13 SUMMARY

Table 5.1: Summary of opportunities and measures for energy conservation in TCIL.

	ECO	ECM	Cost Saving due to ECO	Savings per month Kshs.	Investment cost Kshs	Pay Back period (years)
1	Tariff migration from CI1 to CI2 will save energy	migration to the next tariff of CI2	kshs 200.00/kVA and Kshs.1.02/kWh	61,600.00	4,000,000.00	5.5
2	Pf Surcharge due to poor pf	improvement of pf was done to 0.98	Kshs.730,622.00	211,264.00	345,000.00	0.14
3	High peak demand	Reduce peak demand during operation	260 kVA to 132 kVA	76,800.00	-	immediate
4	Consumption savings during operations	reduce comsumption of energy during normal operations	13.07 GJ @ MONTH	76,250.00	-	Immediate
5	Auxiliary energy is high and this is an opportunity to reduce	Reduction of Auxiliary use of energy - electrical	89.7 GJ	523,173.00	-	immediate
6	HFO fuel not related to production	Reduce use of HFO fuel	460.7 litres	41,466.00	-	‘’
7	Diesel use not related to production	Reduce diesel use not related to production	90.6 litres	9,063.00	-	‘’
8	peak demand due to motor starting	reduction of peak demand due to motor starting	17.1 kVA	10,248.00	180,000.00	1.46
9	Energy use due to poor efficiency for the motors	replace old motors with those with higher efficiency	2,582.2 kW	54,228.00	1,000,000.00	1.5
10	Change in operation, reduce demand	Shifts mineral plant to operate in the evenings, the rest during the day	85 kVA saving	51,000.00	-	immediately

11	Magnetic ballast in lighting are not economical	Replace all magnetic ballast with electronic ballast for lighting	266 kWh	5,586.00	158,400.00	2.4
12	The steam distribution system is poorly lagged	The distribution pipes to be properly lagged	3.1 litres of HFO	6,985.00	400,000.00	4.8
	TOTAL			1,127,663.00	6,083,400.00	5.4 years

CHAPTER SIX

CONCLUSIONS AND RECOMENDATIONS

6.1 Conclusions

The energy resources used in TCIL are, electrical, HFO fuel and diesel fuels at the ratio in percentages of 76%:15%:9% respectively. Electricity supply is at 415V, with a peak demand of 260 kVA.

The energy intensity for the production had improved from the first year of study, 2008, from 643.3 KJ/kg to the fourth year, 2011, to 472.5 KJ/kg on average, this indicates improved performance. The monitoring and management of production and proper loading of motors when operating, has provided higher efficiency in the operations. These measures have achieved savings in energy consumption.

The energy that is used by auxiliary supplies, lighting, security and administration that is not related to production is approximately 109.18GJ per month. This indicates an opportunity to realize further saving on energy consumption. The total cost due to the three sources is Kshs.573,702.30.

The pf contributes to the value of peak demand for the factory if below the required value. A surcharge was charged through the electricity bills of Kshs.730,622.00 due to poor pf in November 2009 to March 2010. Capacitor bank was installed at a cost of kshs.345,000.00 end of March 2010 and improved pf of 0.98 was achieved.

The company can migrate from tariff CI1 to CI2 and realize a saving of Kshs.61,600.00 on demand charge and energy costs per month. The cost of investment is approximately Kshs.4,000,000.00 and a payback period of 6 years.

Peak demand contributes to the energy costs in the electricity bill and hence, TCIL has been operating between 132-260 kVA ranges. An option of operating mineral plant at night will contribute to lower demands and hence lower energy costs. The expected demand savings is Kshs. 51,000.00, monthly.

It was noted that two main sections, Mineral and Powder contributes largely to the peak demand of the factory, approximately 74% of the total demand. Reduction of peaks demands for the two sections will contribute to energy savings. The company to consider replacing old motors with those with higher efficiencies and big motors of 10 hp and above to have soft starting methods, to improve efficiency and reduce demand.

It was noted the fluorescent tubes use magnetic ballasts which are not energy saving, it is proposed to change to electronic ballasts that will contribute to the energy savings of Kshs.5,586.00 per month. The factory lighting was found to be sufficient above 300 lux.

The boiler distribution system was noted to be in poor condition and requires urgent repairs to save on energy due to poor lagging of pipes. The savings due to this is estimated to be 3.1 litres of HFO fuel per day.

Several energy conservation measures have been recommended in this study, as follows:

1. Improvement and maintenance of the pf at the required levels of above 0.9 as required by the utility.
2. Reduce peak demands during normal operations when starting of motors and type of starting methods for large motors.
3. Change the operating times for Mineral Plant to evenings instead of day operations to reduce the peak demand.
4. Reduction of energy consumption due to auxiliary use, which is not related to production.

5. Improve the efficiency of motors by replacing old motors with new ones of higher efficiency.
6. The lighting system to have electronic starters to reduce consumption due to lighting.
7. The steam distribution system to be repaired and maintained in a good state to reduce energy loses due to exposed steam pipes and valves.

The cost of the energy saving due to the recommended energy conservation measures is approximately Kshs.1,127,663.00 on a monthly basis. The total estimated investment is Kshs.6,083,400.00 and the simple payback period is 5.4 years.

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APPENDICES

Appendix 1:

Monthly Energy Data for 2008-2011

Month	Max. Demand KVA	Total Energy Electrical KWh	Generator Diesel Fuel Lts	Boiler HFO fuel	Electrical energy in kJ 1KWh = 1*3600 kJ	Diesel 1Lt = 0.83 kg, kJ/kg = 44800 kJ	HFO fuel 1 Lt = 0.85 kg, kJ/kg = 41200 kJ	Total Energy used kJ
Jan-08	220	19321	191	708	69555600	7102144	24794160	101451904
Feb-08	214	36094	191	708	129938400	7102144	24794160	161834704
Mar-08	207	30890	200	708	111204000	7436800	24794160	143434960
Apr-08	210	32892	200	708	118411200	7436800	24794160	150642160
May-08	225	32401	400	708	116643600	14873600	24794160	156311360
Jun-08	238	32347	300	708	116449200	11155200	24794160	152398560
Jul-08	217	33445	300	708	120402000	11155200	24794160	156351360
Aug-08	220	35648	163	708	128332800	6060992	24794160	159187952
Sep-08	160	29756	163	708	107121600	6060992	24794160	137976752
Oct-08	208	27250	1400	708	98100000	52057600	24794160	174951760
Nov-08	241	43697	900	800	157309200	33465600	28016000	218790800
Dec-08	212	38113	167	300	137206800	6209728	10506000	153922528
Jan-09	169	32374	167	400	116546400	6209728	14008000	136764128
Feb-09	245	41067	167	750	147841200	6209728	26265000	180315928
Mar-09	214	29653	500	1150	106750800	18592000	40273000	165615800
Apr-09	205	31383	500	850	112978800	18592000	29767000	161337800
May-09	192	29568	250	1250	106443360	9296000	43775000	159514360
Jun-09	182	34181	250	1300	123051600	9296000	45526000	177873600
Jul-09	170	18880	250	1000	67968000	9296000	35020000	112284000
Aug-09	149	24869	250	630	89528400	9296000	22062600	120887000
Sep-09	169	25093	250	310	90334800	9296000	10856200	110487000
Oct-09	192	29568	100	350	106443360	3718400	12257000	122418760
Nov-09	222	30607	100	570	110185200	3718400	19961400	133865000
Dec-09	196	27569	100	310	99248400	3718400	10856200	113823000
Jan-10	194	23544	100	518	84758400	3718400	18140360	106617160
Feb-10	196	29184	100	1237	105062400	3718400	43319740	152100540
Mar-10	260	30962	137	565	111463200	5094208	19786300	136343708
Apr-10	166	28087	137	570	101113200	5094208	19961400	126168808
May-10	177	29234	137	1230	105241320	5094208	43074600	153410128
Jun-10	166	46351	137	700	166863600	5094208	24514000	196471808
Jul-10	182	23103	137	580	83170800	5094208	20311600	108576608
Aug-10	186	29805	160	1290	107298000	5949440	45175800	158423240
Sep-10	141	26156	160	1290	94161600	5949440	45175800	145286840
Oct-10	141	28270	160	1290	101772000	5949440	45175800	152897240
Nov-10	177	29234	160	1150	105241320	5949440	40273000	151463760
Dec-10	138	26875	160	650	96750000	5949440	22763000	125462440

Jan-11	166	29106	50	1060	104781600	1859200	37121200	143762000
Feb-11	166	29106	50	220	104781600	1859200	7704400	114345200
Mar-11	132	23507	50	570	84625200	1859200	19961400	106445800
Apr-11	139	30158	50	560	108568800	1859200	19611200	130039200
May-11	166	25716	50	1050	92577600	1859200	36771000	131207800
Jun-11	169	35378	50	1000	127360800	1859200	35020000	164240000
Jul-11	156	20981	50	1000	75531600	1859200	35020000	112410800
Aug-11	192	32858	50	400	118288800	1859200	14008000	134156000
Sep-11	166	29106	500	400	104781600	18592000	14008000	137381600
Oct-11	173	27824	500	600	100166400	18592000	21012000	139770400
Nov-11	206	32644	1000	3370	117518400	37184000	118017400	272719800
Dec-11	159	32888	500	743	118396800	18592000	26019860	163008660

Appendix 2:

Monthly production data for 2007 - 2011

Year	**Month**	**Liquids kilogram (Kg)**	**Powder Kilogram (kg)**	**Total kg**
2007	**Jan-07**	45850	184226	**230076**
	Feb-07	46567	160624	**207191**
	Mar-07	51404	106508	**157912**
	Apr-07	86814	132752	**219566**
	May-07	110236	303756	**413993**
	Jun-07	48447	143149	**191596**
	Jul-07	67694	232781	**300475**
	Aug-07	88934	209194	**298128**
	Sep-07	80515	199178	**279693**
	Oct-07	111633	194437	**306071**
	Nov-07	83251	142045	**225296**
	Dec-07	22170	106442	**128613**
2008	**Jan-08**	79935	193149	**273083**
	Feb-08	83275	181602	**264877**
	Mar-08	108668	138018	**246687**
	Apr-08	97539	185210	**282749**
	May-08	72594	157439	**230033**
	Jun-08	69319	159967	**229286**
	Jul-08	90608	246940	**337548**
	Aug-08	38893	102756	**141649**
	Sep-08	37533	101666	**139199**
	Oct-08	125699	179732	**305431**
	Nov-08	69589	224293	**293882**
	Dec-08	57852	344388	**402240**
2009	**Jan-09**	44095	221090	**265185**
	Feb-09	79175	192461	**271637**
	Mar-09	85125	203100	**288226**
	Apr-09	164886	133874	**298761**
	May-09	94593	155001	**249594**
	Jun-09	105349	126055	**231403**
	Jul-09	43760	113338	**157099**
	Aug-09	32501	129288	**161789**
	Sep-09	73645	222097	**295742**
	Oct-09	73189	134526	**207715**
	Nov-09	72886	206743	**279629**
	Dec-09	50641	193407	**244048**

2010	**Jan-10**	54209	183105	**237314**
	Feb-10	50307	165842	**216149**
	Mar-10	87444	260266	**347710**
	Apr-10	123101	179603	**302704**
	May-10	112076	190536	**302612**
	Jun-10	69194	243469	**312662**
	Jul-10	76097	182174	**258271**
	Aug-10	48100	185674	**233774**
	Sep-10	69740	202602	**272342**
	Oct-10	47507	199101	**246608**
	Nov-10	52391	210577	**262968**
	Dec-10	65479	204447	**269926**
2011	**Jan-11**	87519	182057	**269576**
	Feb-11	31844	279233	**311077**
	Mar-11	109024	289671	**398695**
	Apr-11	73630	230802	**304432**
	May-11	102189	193803	**295992**
	Jun-11	148858	208616	**357473**
	Jul-11	83619	214755	**298374**
	Aug-11	101109	247515	**348624**
	Sep-11	48515	233476	**281991**
	Oct-11	78958	139177	**218135**
	Nov-11	94982	321676	**416659**
	Dec-11	73176	186103	**259278**

Appendix 3:

Energy, Production and Energy intensity.

	Month	Total Energy used kJ	Total products kg	Energy intensity kJ/kg	average KJ/kg, annually
2008	Jan-08	101451904	273083	372	
	Feb-08	161834704	264877	611	
	Mar-08	143434960	246687	581	
	Apr-08	150642160	282749	533	
	May-08	156311360	230033	680	
	Jun-08	152398560	229286	665	
	Jul-08	156351360	337548	463	
	Aug-08	159187952	141649	1124	
	Sep-08	137976752	139199	991	
	Oct-08	174951760	305431	573	
	Nov-08	218790800	293882	744	
	Dec-08	153922528	402240	383	**643.26**
2009	Jan-09	136764128	265185	516	
	Feb-09	180315928	271637	664	
	Mar-09	165615800	288226	575	
	Apr-09	161337800	298761	540	
	May-09	159514360	249594	639	
	Jun-09	177873600	231403	769	
	Jul-09	112284000	157099	715	
	Aug-09	120887000	161789	747	
	Sep-09	110487000	295742	374	
	Oct-09	122418760	207715	589	
	Nov-09	133865000	279629	479	
	Dec-09	113823000	244048	466	**589.33**
2010	Jan-10	106617160	237314	449	
	Feb-10	152100540	216149	704	
	Mar-10	136343708	347710	392	
	Apr-10	126168808	302704	417	
	May-10	153410128	302612	507	
	Jun-10	196471808	312662	628	
	Jul-10	108576608	258271	420	
	Aug-10	158423240	233774	678	
	Sep-10	145286840	272342	533	
	Oct-10	152897240	246608	620	
	Nov-10	151463760	262968	576	

	Dec-10	125462440	269926	465	**532.46**
2011	Jan-11	143762000	269576	533	
	Feb-11	114345200	311077	368	
	Mar-11	106445800	398695	267	
	Apr-11	130039200	304432	427	
	May-11	131207800	295992	443	
	Jun-11	164240000	357473	459	
	Jul-11	112410800	298374	377	
	Aug-11	134156000	348624	385	
	Sep-11	137381600	281991	487	
	Oct-11	139770400	218135	641	
	Nov-11	272719800	416659	655	
	Dec-11	163008660	259278	629	**472.54**

Appendix 4:

CUSUM calculations

Month	**Products (T)**	Energy GJ	Energy Calculated, =0.136m+109.18, E-cal GJ	E-act - Ecal GJ	Cusum Cumulative
Jan-08	**273.08**	101.45	146.32	(44.87)	(44.87)
Feb-08	**264.88**	161.83	145.20	16.63	(28.24)
Mar-08	**246.69**	143.43	142.73	0.71	(27.53)
Apr-08	**282.75**	150.64	147.63	3.01	(24.52)
May-08	**230.03**	156.31	140.46	15.85	(8.68)
Jun-08	**229.29**	152.40	140.36	12.04	3.36
Jul-08	**337.55**	156.35	155.09	1.26	4.63
Aug-08	**141.65**	159.19	128.44	30.74	35.37
Sep-08	**139.20**	137.98	128.11	9.87	45.23
Oct-08	**305.43**	174.95	150.72	24.23	69.47
Nov-08	**293.88**	218.79	149.15	69.64	139.11
Dec-08	**402.24**	153.92	163.88	(9.96)	129.15
Jan-09	**265.19**	136.76	145.25	(8.48)	120.67
Feb-09	**271.64**	180.32	146.12	34.19	154.86
Mar-09	**288.23**	165.62	148.38	17.24	172.10
Apr-09	**298.76**	161.34	149.81	11.53	183.62
May-09	**249.59**	159.51	143.12	16.39	200.01
Jun-09	**231.40**	177.87	140.65	37.22	237.24
Jul-09	**157.10**	112.28	130.55	(18.26)	218.98
Aug-09	**161.79**	120.89	131.18	(10.30)	208.68
Sep-09	**295.74**	110.49	149.40	(38.91)	169.77
Oct-09	**207.72**	122.42	137.43	(15.01)	154.75
Nov-09	**279.63**	133.87	147.21	(13.34)	141.41
Dec-09	**244.05**	113.82	142.37	(28.55)	112.86
Jan-10	**237.31**	106.62	141.45	(34.84)	78.03
Feb-10	**216.15**	152.10	138.58	13.52	91.55
Mar-10	**347.71**	136.34	156.47	(20.12)	71.42
Apr-10	**302.70**	126.17	150.35	(24.18)	47.25
May-10	**302.61**	153.41	150.34	3.07	50.32
Jun-10	**312.66**	196.47	151.70	44.77	95.09
Jul-10	**258.27**	108.58	144.30	(35.73)	59.36
Aug-10	**233.77**	158.42	140.97	17.45	76.81
Sep-10	**272.34**	145.29	146.22	(0.93)	75.88
Oct-10	**246.61**	152.90	142.72	10.18	86.06
Nov-10	**262.97**	151.46	144.94	6.52	92.58

Dec-10	**269.93**	125.46	145.89	(20.43)	72.15
Jan-11	**269.58**	143.76	145.84	(2.08)	70.07
Feb-11	**311.08**	114.35	151.49	(37.14)	32.93
Mar-11	**398.69**	106.45	163.40	(56.96)	(24.03)
Apr-11	**304.43**	130.04	150.58	(20.54)	(44.57)
May-11	**295.99**	131.21	149.43	(18.23)	(62.80)
Jun-11	**357.47**	164.24	157.80	6.44	(56.35)
Jul-11	**298.37**	112.41	149.76	(37.35)	(93.70)
Aug-11	**348.62**	134.16	156.59	(22.44)	(116.14)
Sep-11	**281.99**	137.38	147.53	(10.15)	(126.29)
Oct-11	**218.14**	139.77	138.85	0.92	(125.36)
Nov-11	**416.66**	272.72	165.85	106.87	(18.49)
Dec-11	**259.28**	163.01	144.44	18.57	0.08

Appendix 5:

Electrical Equipments

	Powder Section					**70%**	**higher efficiency**
	D5 - Appliances	Rating kW		NO	Total kW	efficiency	74%
1	Disintegrator crusher Mill	37	3	1	37	25.9	27.38
2	Conveyor belts	0.75	3	3	2.25	1.58	1.67
3	Garden Mixer hp	25	3	3	55.95	39.17	41.40
4	Conveyor belts	0.75	3	1	0.75	0.53	0.56
5	Dust Extractors	5.5	3	6	33	23.1	24.42
6	Conveyor belts	0.7	3	1	0.7	0.49	0.52
7	conveyor motors	0.37	3	4	1.48	1.04	1.10
8	Heaters for wrapping	0.38		18	6.84	4.79	5.06
9	Heaters for wrapping	0.38		12	4.56	3.19	3.37
10	fans	0.75		2	1.5	1.05	1.11
					144.03	**100.82**	**106.58**
	powder kVA, kW	**45.74**	**30.11**		**144.03**		**5.76**
	Pf for powder section			0.66			
	kVA demand				**218.80**		
	Reactive power at the powder section kVar			34.43			
	Mineral Section					**70%**	**higher efficiency**
	Appliances	Rating kw		NO	Total kW	efficiency	74%
1	Raw material lift 1 ton, 3 m	9.8 KN			29.4	20.58	21.76
2	motors hp	20	3	2	29.84	20.89	22.08
3	motorshp	5.5	3	2	8.21	5.74	6.07
4	Motor hp	3	3	4	8.95	6.27	6.62
5	motors hp	22	1	1	16.41	11.49	12.14
6	packaging kW	0.9		1	0.67	0.47	0.5
					93.48	**65.44**	**69.14**
7	Compressor	30 kW	3	1	30		
8	hydrolic pressure 200 ton	65 kW	3	1	65		
					188.48	131.94	139.47
							7.54
Others						**70%**	**higher efficiency**
		Rating kW		NO	Total kW	efficiency	74%
	Liquids section						
1	motor kW	2.2	3	1	2.2	1.54	1.63
2	Motor kW	2	3	1	2	1.4	1.48
3	Motor hp	2	3	1	1.49	1.04	1.10
4	Motor kW	4	3	1	4	2.8	2.96

5	motor kW	7.5	3	1	7.5	5.25	5.55
6	motor hp	5.5	3	1	4.10	2.87	3.04
7	Motor hp	0.25	3	2	0.37	0.26	0.28
	Fungicide						
1	Motor kW	7.5	3	1	7.5	5.25	5.55
2	Motor kW	4	3	1	4	2.8	2.96
3	Motor kW	2	3	1	2	1.4	1.48
4	Motor kW	4	3	1	4	2.8	2.96
5	Motor kW	4	3	1	4	2.8	2.96
6	Motor hp	5.5	3	1	4.10	2.87	3.04
7	motor kW	2.2	3	1	2.2	1.54	1.63
8	Motor hp	1	3	1	0.75	0.52	0.55
9	Motor hp	2.2	3	1	1.64	1.15	1.22
					51.86	**36.30**	**38.38**
							2.07
			Total Saving kW				**15.37**

Electricity Bill

Kenya Power

Contract No. / Account No: 0531229-01

KENYA POSTAGE PAID

TWIGA CHEMICAL INDUSTRIES LTD
P O BOX 30172 00100
NAIROBI
NAIROBI GPO

Bill Number: 0531229-01-26/10/2011-1

Maximum Authorised Load (KW): 210

Date of Issue: 27/10/2011

Date Due: 03/11/2011

Method of Charge No.: CI1 (HIGH/LOW RATE, PF) Deposit: KShs. 400,000.00

Supply Location: CHEMICAL FACTORY NANYUKI RD

CONSUMPTION DETAILS

Consumption Type	Meter Number	Previous Reading	Current Reading	Conversion Factor	Consumption
HIGH RATE (C1)	8082748	587096	608325	1	21229
LOW RATE (C1)	8082748	147544	154139	1	6595
DEMAND KVA (C1)	8082748		173	1	173
DEMAND KW (C1)	8082748		167	1	167

BILLING DETAILS

BILLING CONCEPT	AMOUNT IN SHILLINGS
BALANCE BROUGHT FORWARD	671,737.50
FIXED CHARGE	800.00
HIGH RATE CONSUMPTION	122,066.75
LOW RATE CONSUMPTION	37,921.25
FUEL COST CHARGE 840.0 cents/kwh	233,721.60
FOREX ADJ. 274.0 cents/kwh	76,237.76
INFLATION ADJ. 17.0	4,730.08
ERC Levy 3.0 cents/kwh	834.72
REP Levy 5.00 %	7,999.40
MAXIMUM DEMAND KVA	103,800.00
POWER FACTOR SURCHARGE (c/kwh)	0.00
VAT 12.00 %	69,513.29
20111015-CHEQUE PAYMENT	-671,737.50
Round Adjustment	0.05
Total Amount	657,624.90

KVAR/ Mlt:

Consumption Period: 28/09/2011 - 26/10/2011 (Act)

Power Factor: 0.97

The monthly bill is KShs. 657,624.90

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This electricity bill is payable before 03/11/2011.
Notice is hereby given that if this bill is not paid within fourteen days from 03/11/2011, i.e on 17/11/2011, your supply shall be liable to disconnection without any further notice to you.

Should the supply be disconnected, in addition to settling the outstanding amount, you will be required to pay the applicable Reconnection (RC) fee before reconnection.The RC fees are as follows: Sh580 for cut-out RC or Sh3,828 for pole RC or Sh13,920 for service line RC.The said RC fees are inclusive of an 16% VAT charge. In addition, you will also be required to top up your deposit to 2 times your average monthly bill

All enquiries to Customer Service Eng. NAIROBI SOUTH P.O. BOX 30177, NAIROBI TEL. 020-3211547

customercarenairobi@kplc.co.ke

TWIGA CHEMICAL INDUSTRIES LTD P O BOX 30172 00100 NAIROBI

03/11/2011 0531229-01-26/10/2011-1 KShs. 657,624.90

2110

The net balance for the supply as at 27/10/2011 is KShs. 657,624.90. Please pay this amount

AEC885117B9EE67F5FE2C269D29648E716828DE0 1143 02617787 1111121453 ABC06000945

KENYA POWER & LIGHTING CO. LTD

POLYPHASE TEST SHEET No. ....

	MAKE AND TYPE	OWNERS NUMBER	~~MAKERS NUMBER~~	AMPS	VOLTS	100%	50%	10%	5%	100% @ 0.5PF	AT UNITY P.F. PH 1	AT UNITY P.F. PH 2	AT UNITY P.F. PH 3	AT...... ....PF (LAG) PH 1	AT...... ....PF (LAG) PH 2	AT...... ....PF (LAG) PH 3	,SC	CREEP TEST	R/KWH	DIAL TEST @ 100%	
1	ELSTER A1700	04131608	CT= 200/5A	5(10)	3x240/415	-0.22	-0.23	-0.19	-0.23	-0.12	Zero final Reading 4.0kWh						OK	OK	0.2	RSS ERROR:- 95 91 4	-0.93
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					

Tested by: Austin Vita Nyamu

Checked by: F. ONYANGO

Date: 14/9/2010

IF, 126 A . 1000

KENYA POWER & LIGHTING CO. LTD

POLYPHASE TEST SHEET No. ....

	MAKE AND TYPE	OWNERS NUMBER	MAKERS NUMBER	AMPS	VOLTS	100%	50%	10%	5%	100% @ 0.5PF	AT UNITY PF PH 1	AT UNITY PF PH 2	AT UNITY PF PH 3	AT........PF (LAG) PH 1	AT........PF (LAG) PH 2	AT........PF (LAG) PH 3	SC	CREEP TEST	R/KWH	DIAL TEST @ 100%	
1	ELSTER A1700	04131612	N/A	10-100	3x240/415	-0.61	-0.59	0.02	0.78	-0.11	ZERA FINAL READING = 2kWh						OK	OK	500	RSS ERROR:- 80 78 .2	00
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					

Tested by Austin .... Checked by E. Mwangi .... Date 13/9/2010.

IF, 126 A. 1000

ELSTER METER TYPE A1700 REGISTER READING CODES

No	Code	Code description
1	Current Date	Current date
2	Current Time	Current time
3	1.8.0	Positive Active energy - Total kWh (Current) All tariffs
4	H1:1.8.0.1	Positive Active energy - Total kWh (Memory) All tariffs
5	2.8.0	Negative Active energy - Total kWh (Current) All tariffs
6	H1:2.8.0.1	Negative Active energy - Total kWh (Memory) All tariffs
7	9.8.0	Apparent energy - Total kVAh (Current) All tariffs
8	H1:9.8.0.1	Apparent energy - Total kVAh (Memory) All tariffs
9	1.8.1	Positive Active energy - Total kWh (Current) HIGH RATE
10	H1:1.8.1.1	Positive Active energy - Total kWh (Memory) HIGH RATE
11	1.8.2	Positive Active energy - Total kWh (Current) LOW RATE
12	H1:1.8.2.1	Positive Active energy - Total kWh (Memory) LOW RATE
13	1.6.1	Maximum demand (kW) - (Current) HIGH RATE
14	1.6.1	Date & Time of Maximum demand (kW) - (Current) HIGH RATE
15	H1:1.6.1.1	Maximum demand (kW) - (Memory) HIGH RATE
16	H1:1.6.1.1	Date & Time of Maximum demand (kW) - (Memory) HIGH RATE
17	1.6.0	Maximum demand (kW) - (Current) ALL TIME
18	1.6.0	Date & Time of Maximum demand (kW) - (Current) ALL TIME
19	H1:1.6.0.1	Maximum demand (kW) - (Memory) ALL TIME
20	H1:1.6.0.1	Date & Time of Maximum demand (kW) - (Memory) ALL TIME
21	9.6.1	Maximum demand (kVA) - (Current) HIGH RATE
22	9.6.1	Date & Time of Maximum demand (kVA) - (Current) HIGH RATE
23	H1:9.6.1	Maximum demand (kVA) - (Memory) HIGH RATE
24	H1:9.6.1	Date & Time of Maximum demand (kVA) - (Memory) HIGH RATE
25	9.6.0	Maximum demand (kVA) - (Current) ALL TIME
26	9.6.0	Date & Time of Maximum demand (kVA) - (Current) ALL TIME
27	H1:9.6.0.1	Maximum demand (kVA) - (Memory) ALL TIME
28	H1:9.6.0.1	Date & Time of Maximum demand (kVA) - (Memory) ALL TIME
29	Phase A volts	Phase A rms volts
30	Phase B volts	Phase B rms volts
31	Phase C volts	Phase C rms volts
32	Phase A, Amps	Phase A rms Amps
33	Phase B, Amps	Phase B rms Amps
34	Phase C, Amps	Phase C rms Amps