ANALYSIS OF ENERGY USE AND IMPROVEMENT OPPORTUNITIES AT UNILEVER KENYA LTD

BY

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A Research Project Report Submitted

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UNIVERSITY OF NAIROBI
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Declaration

A. Student's Declaration

I declare that this project is my original work and it has not been submitted to any other college or University for academic credit.

Signed________________________ Date__________________________
John P M Wachira **F56/72807/08**

B. Supervisor's Declaration

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

Signed______________________________ Date____________________________
Dr. A. A. Aganda Project Supervisor

B. Supervisor's Declaration

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

Signed______________________________ Date____________________________
Prof. Felix M Luti Project Supervisor

Dedication

To my wife Phyllis, my daughter Aisha, my parents Wachira and Wangui for their continuous encouragement during the entire study at The University of Nairobi.

Abstract

Fast-moving consumer goods (FMCG) – or consumer packaged goods (CPG) – are products that are sold quickly and at relatively low cost. Examples include non-durable goods such margarine, culinary products, soaps and detergents. As such they have to be manufactured quickly and taken to the consumers within a set timeframe, due to their short shelf life. The absolute profit made on FMCG products is relatively small, but they generally sell in large quantities, so the cumulative profit on such products is be substantial.

Since the profit is low, all the costs associated with the production of the product have to be minimal. Such costs include; labor, energy, repair and maintenance, waste disposal amongst others. Energy cost is a critical factor since the cost is externally determined but the consumption is internally determined. As such Unilever's Nairobi site has experienced an increase in the energy bill over the last 5 years. This has continuously eroded the profit margins on the products. The plant is divided into several subsections which produce different categories of product. These include dry non-Soapery detergents, toilet soaps, personal care products; Vaseline, lady gay, margarine and savoury products.

Unilever Kenya has a maximum demand of 1.8MVA in 2010. The plant operates 24 hours, 6 days a week. The site has centralized utilities systems that serve all the subsections. These include two, 11t/hr, Heavy Furnace oil fired boilers, two 132kW electrical powered compressors for compressed air system, four 1000kVA generators, and centralized water supply system. Consumption in 2010 was 8,844MWh and

consumption per ton of 107kWh/t. This is up from 2007 consumption of 6986MWh, and a unit consumption of 110kWh/t. The site uses about 3.7million litres of HFO to generate energy, both for the powders tower and for the steam generation. Furnace oil contributes 60% of the energy with electricity contributing 36%. Liquefied petroleum gas provides 4%. Motors then use 54% of electrical energy in Savoury factory and 96% of energy in Margarine factory. Product sleeving in Savoury consumes 80% of steam in that factory and water heating in margarine factory consume 80% of the steam. The site has scaled down the operations in the SCC products from 90,000tonnes in a year to 25,000 tonnes. However the utility infrastructure remains the same. The boiler rating, ammonia refrigeration piping sizes still remain that of 90,000 tonnes.

Uses of high consuming energy lights in Savoury stores that consume 400W are installed. One switch controlling an entire floor is also prevalent and is found in Savoury packing floor, stores and powder feeding rooms. Maturation area for Royco beef cube blend is sized with a ceiling which 5 meters high. Standby generators are split in a way they only serve specific factories. They are designed in a way that all of them will come on incase of a power failure.

Areas found to have opportunities to save energy include removing of the high energy saving halogen lamps and replacing them with fluorescent lamps or LED lamps. Synchronising the generators so that they only run as per the load requirement, and with a maximum demand of 1800kVA, this means only two generators are required. All EFF3 motors should be phased out with EFF1 motors. This is on need to buy basis since the difference in running costs cannot justify replacing when the EFF3 motor is still in a working mode.

Acknowledgements

I wish to extend my sincere gratitude to the following, first to the Almighty God for giving me the opportunity to study at The University of Nairobi without which this project would not have been possible. I wish to express my sincere appreciation to my project supervisor Dr. Alex Aganda and Prof. Felix M Luti, for their great guidance and encouragement during the study. I learnt a lot during the interaction with them.

I am greatly indebted to my employer Unilever Kenya LTD, for allowing me to do the project and take off days to do research elsewhere. I also wish to thank Mr. Ephantus Kariuki, Factory manager for his support during the entire project.

Lastly but not least am thankful to my family, my wife Phyllis, and my daughter Aisha for their understanding and support during my studies at the University of Nairobi. I denied them company over the weekends and evenings as I attended classes.

Abbreviations

AC	Alternating Current
BEE	Bureau of Energy Efficiency India
DHACCP	Detailed Hazard and Critical Control Points
EHV	Extra high Voltage
HFO	Heavy Furnace Oil
HPC	Hygiene and Personal Care products
HT	High tension
HV	High Voltage
KenGen	Kenya generating company
KES	Kenya Shillings
KPI	Key Performance indicator
KPLC	Kenya Power and Lighting Company
MPU	Margarine processing Unit
MSG	Mono Sodium Glutamate
PM	Packaging material
RBC	Royco Beef Cube
RM	Raw Materials
R&M	Repairs and maintenance
RMM	Royco Mchuzi Mix
SCC	Spreads and Cooking Category
SKU	Stock Keeping Unit

TDS	Total Dissolved Solids
UKL	Unilever Kenya LTD
UPS	Uninterrupted Power Supply

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Chapter 1

Introduction

1.0 Background

Energy is a key component in day to day operations of every sector. It makes all matter to move from one point to another. However it has to be generated, distributed and then utilised. At every point there are huge costs involved and as such the need to be as efficient as possible to get the maximum output. These costs in the case of manufacturing goods end in the price of the products.

For any business to be competitive, the cost of products must be within the affordable bracket of the customers and consumers. Manufacturing companies then need to reduce the conversion cost of the products. These costs include labour, repair & maintenance, depreciation and energy costs. In Kenya electric power is generated by Kenya Generating Company (KenGen) and then transmitted by Kenya Power and Lighting Company. This power is transmitted country wide to the consumers. The demand in Kenya's demand for power is 1000MW during peak time, and with the country generating 1080MW, power outages have resulted to the need of using standby redundant units [1]. These are generators for industries and UPS's for office electronics. This is an extra cost and the need to utilise this energy optimally thus becomes very critical.

Margarine manufacturing is an energy intensive process. This is due to the need of high pressure pumps varying from 40 bar g to 120 bar g which are required for the process. The heating and cooling of the process from temperatures of 60^oC to 2^oC all indicate the amount of energy required in the process. [2] This energy need to be optimally used so that the cost does not affect the pricing of the product or further erode the profit margins.

Energy efficiency can be an effective strategy to work towards the concept of triple bottom line, which was introduced by the World Business Council on Sustainable Development. For any successful investment in energy efficiency systems, an assessment of how a firm purchases and uses energy is key. This means investigating energy type, quantity and key trends.

In this project, an assessment of energy cost savings in Unilever Nairobi’s Margarine and Savoury factory was done. A survey of energy consuming equipments was done and energy saving opportunities were then identified. Based on the sources of these energies, emissions are released into the atmosphere which includes carbon and sulphur based gases commonly referred to as carbon emissions and $SO_{X.}$

The effect of extra carbon dioxide in the atmosphere is that the overall temperature of the planet is increasing (global warming). Whilst the average global temperature is increasing, on a day-to-day level the climate is changing in unpredictable ways. This can be seen by the extreme weather conditions like the floods Asia, hurricanes in the Americas, heat waves in India and droughts in the horn Africa, all experienced in 2011. To try and reduce the risk of ever more extreme weather, there is a need to reduce emissions discharged to the environment.

1.1 Unilever Kenya

Unilever Kenya Unilever Kenya Ltd. manufactures and markets food, home, and personal care products. The company's products include washing powder, laundry bars, fabric conditioners, margarine, soups, sauces, condiments, toothpastes, toothbrush, body lotions, baby care jelly, face creams, beauty soaps. The brands include Blueband, Royco, Knorr, OMO, Geisha, Lux, Sunlight, Vaseline, Lady gay, Fair & Lovely, and Close up. Unilever

Kenya was formerly known as East Africa Industries Ltd. The company was founded in 1949 and is headquartered in Nairobi, Kenya. Currently Unilever Kenya Ltd. operates as a subsidiary of The Unilever Group.

To make the different products, Unilever Kenya has five factories divided into two broad categories. These are hygiene and personal care products (HPC) and Foods factories. The foods factories are two, split into Spreads and Cooking Category (SCC) and Savoury factory. These plants are all located on one site along Commercial Street, in Nairobi's industrial area.

These plants use different sources of energy to power the operations. These include; electricity from the grid and the generators, gas (Butane) Supplied in small cylinders, furnace oil and diesel oil. Most of these are generated centrally and then distributed to the point of use. On average the site produces 25,000 metric tonnes of margarine and 10,000 metric tonnes of Royco Mchuzi mix in a year. The two plants have employed 250 people directly. The total site uses approximately 1300 tonnes of furnace oil, 7.5 million kWh of electricity, 50 tonnes of diesel for the standby units and 30 tonnes of Butane gas in a year as a supply of energy.

Plant process description; in general, the margarine process comprises of three stages. The first stage involves making of the two margarine phases, the oil phase and the aqueous phase. During the margarine phases the ingredients are dissolved in water and others in oil. The second stage involves mixing the oil phase and the water phase. In this stage cooling is required as water and oil do not mix with ease and the oil has to surround the water molecules. The final stage is packing where the margarine is then put in the containers –commonly referred to as tubs- ready for dispatch and sale. The Royco or Savoury plant consists of raw materials which have been ground to fine powder, which are weighed and then mixed in certain ratios that meet the formulation needed. This is a physical mixing process. From here the product is packed and is ready for sale. The Royco process flow is shown in figure 1-1 while the margarine process is shown in figure 1-2. (DHACCP study)

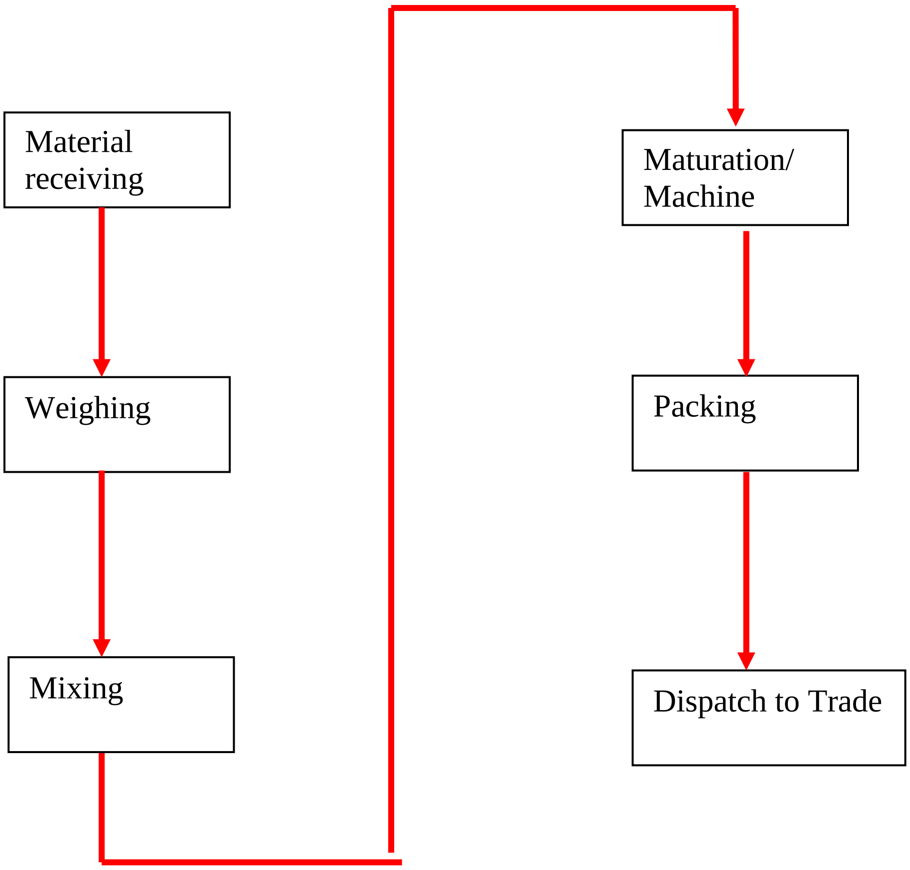


Figure 1-1: Royco Process Flow [13]

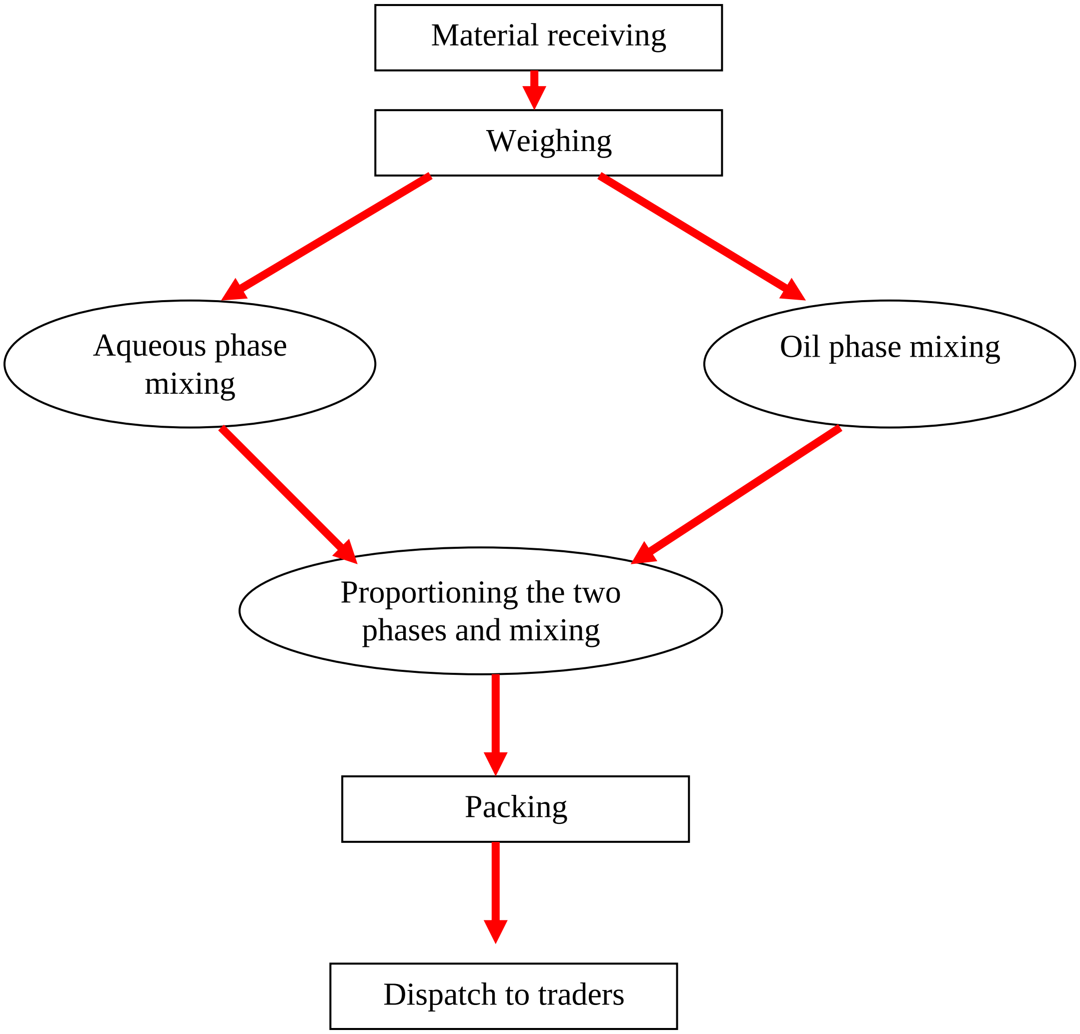


Figure 1-2: Margarine Process [11]

1.2 Problem statement

As noted by Fereidoon Shahidi [3] margarine manufacturing is an energy intensive process notably because of the high energy used in the refrigeration system. These normally consume close to 95% of total energy requirement. Margarine requires about 210kWh/tonne, 2000kgs of steam per tonne of margarine and a further 20m^3 of water for every tonne produced. This justifies the need to use this energy both efficiently and in an optimal way.

In Royco manufacturing, maturation of the blend also requires intense cooling to allow the crystallization of fats. The cooling on average is by 48^{o}C. This means considerable energy use which is also very expensive and is reflected on the cost of the product.

According to Exxon Mobil energy journal [4] outlook for energy a view to 2030, the cost of energy is continuously on the rise. Locally the energy sector's overview of Kenya's economy, a large portion of energy source is renewable, mainly the wood fuel and the Hydro-energy.[5] However the main cost mover in energy generation is on the imported petroleum which is used for transport and generating electricity. This constitutes of 25% of the import bill. This 25% can be used by the country to build other areas of the economy like roads as opposed to purchase of oil.

The current policy emphasizes on providing electricity for every house hold by 2030 and in an affordable manner. The policy emphasizes on renewable sources of energy. Therefore the governments' and private sector resources have been directed towards drilling of more geothermal wells to facilitate this goal. The government has also been increasing the funds to look for oil in the country drilling several wells in the large

Turkana region. This is mainly to supplement the import bill, and increase the export load.

According to current energy bills (appendix 1) the electricity cost in Kenya has changed over the last 10 years moving from an average of KES 5 per unit in 2002 to around KES 16 per unit in 2011. This is about 225% increase in the last 10 years only! With increased energy cost and huge product manufacturing costs, most Kenyan multinationals are opting to produce in other markets while the ones that manufacture in Kenya are becoming largely uncompetitive in the region. These include items like local sugar [6]. This has led to the Kenya Sugar Industry laying a 2010-2014 strategic plan with one of the key objectives of having an efficient and modern milling system which is energy efficient [7]. If the products get increasingly uncompetitive, few people will buy them which eventually lead to job cuts.

The factors that constitute to the cost of production are as follows:

- Raw materials.
- Packaging materials
- Labor
- Repairs and maintenance
- Energy (Utilities)
- Depreciation

RM and PM costs are determined by the law of supply and demand, and as the demand to supply bigger population increases, the prices keep increasing every year. The manufacturing point of the supply chain has no control of these prices but can only switch to cheaper RM and PM, if this does not compromise on the quality of the product. A typical example of price increase is shown on figure 1-1 of palm oil price, which is a raw material making up to 70% of margarine.

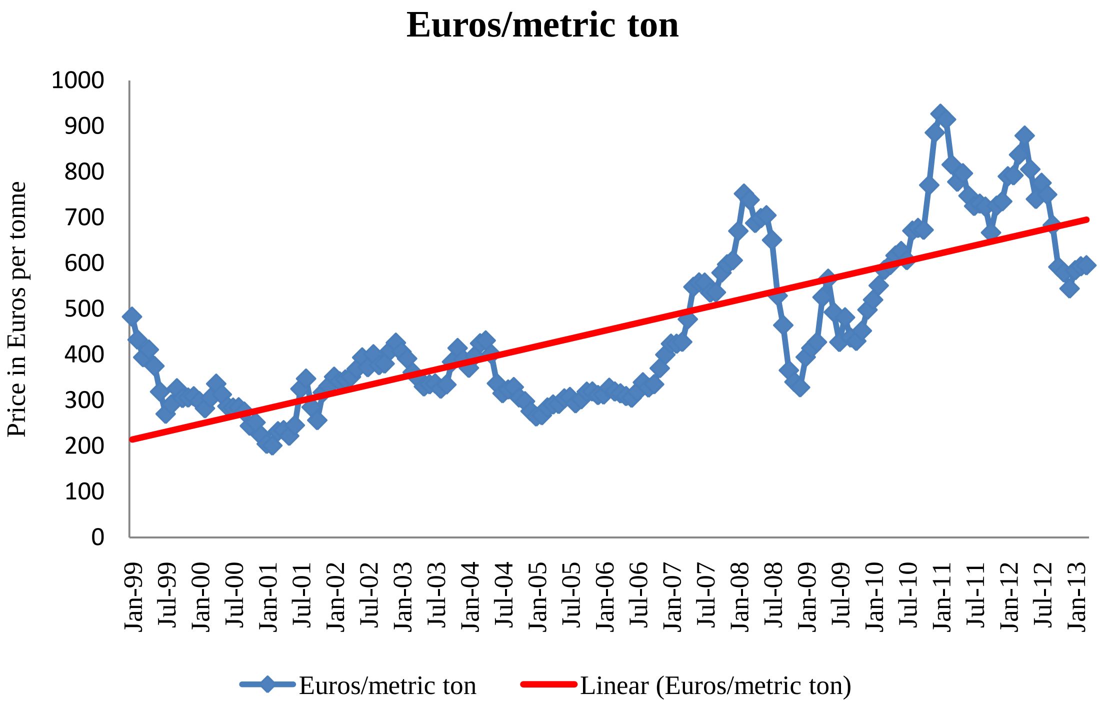


Figure 1-1: Cost of Palm oil

Labor is a function of skills and the level of automation. Flawless production leads to less cost of production because there is no cost associated with rework in terms of labor and energy. To increase on automation, heavy investments have to be done and that depends on the profit margins on the products being manufactured. This also depends on the product portfolio mix i.e. the number of different units the company is making. This then leads to higher depreciation which affects the cost of the product.

The area that the factory team has direct daily control is the energy and R&M. This is because the consumption depends highly on the behaviours of the people and the installations. Looking at the break down of the costs as shown in the figure 1-2, energy and R&M indicate a 21% of the total cost of production.

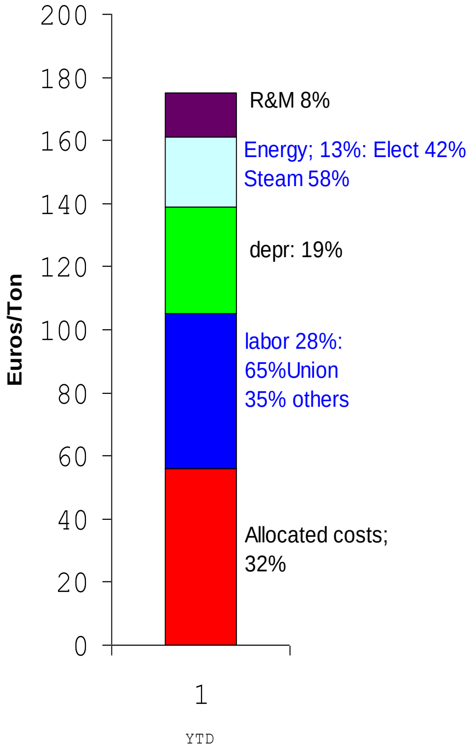


Figure 1-2: Conversion cost break down

From figure 1-2 the energy section is about 13% which is 24euros per tonne of production. With a monthly production of 800T, it translates to about Kes. 8,300,000 a month and this is an amount that if reduced can have a significant impact on the profit margins of the company. Therefore for these products to remain competitive and improve on the profitability the energy cost need to be lowered to the most optimum consumption possible. This project therefore looks at the energy use in the factory to determine any opportunities of reducing this cost.

1.3 Objectives of the study

The overall objective of this project is to assess the energy cost of energy in the manufacturing of margarine and Savoury products in Unilever Kenya and possible savings. The specific objectives of the project are:

i. Analyse energy distribution and use in Royco and margarine factories.
ii. Identify the opportunities for energy usage reduction in Royco and margarine factories.
iii. Assess alternative energy use where cheaper and areas where green energy can be used as a substitute in Royco and margarine factories.

Chapter 2:

Literature Review

2.0 Introduction

Literature review is provided on areas of margarine manufacture, energy generation systems and renewable use of energy in manufacturing.

2.1 Margarine manufacturing process

Margarine is manufactured from vegetable oils and also palm oil mixed with water. Water and oil normally don’t mix as such cooling and mixing is required at the same time to make the molecules mix. To achieve this state, pressure and temperature are very critical parameters in the entire process. The ammonia refrigeration system is used to cool the system so as to achieve the low temperatures. The compressors are run by a 160kW rated motor.

There are two types of margarine, low fat which has 20% oil phase and the high fat content which has 70% oil phase. The oil and aqueous phase are mixed separately. These phases are worked out at a temperature of 55^{o}C to 70^{o}C respectively. The next phase is mixing the two phases and an emulsifier is used. This is done in a votator where temperatures are maintained between 2-6^{o}C. [8]

Energy consumption here can reach up to 960kWh if the start up is done properly. This is because the start up sometimes takes 6 hours before good product that can be taken to the market is achieved. This is also due to the fact that margarine temperature has to move from 70^{o}C to 2-6^{o}C, with a through put of 5.3tonnes/hour. All critical parameters have to be correct otherwise there is no room for reworking a product. These include temperature which has to be between 2-6^{o}C, pressure which has to be between 2.5-3 bar g and a residence time of 6 seconds. The energy consumed depends on the start-up preparation, whether all the machines are started together or a sequential set up, so that peak demand is not high. The surface area of the margarine processing units (MPU), also determine energy use since bigger MPU's have the advantage of economies of scale.

2.2 Royco manufacturing process

Cube blend processing energy use depends on the cube blend going in and out of the maturing room. In Unilever Kenya blend is discharged at 39^{o}C thus necessitating cooling for 36 hours. Companies like Unilever Nigeria, normally sprinkle frozen fat crystals in the cube blend. This means the product is discharged at lower temperatures and thus matures for a very short period of time, 8 hours. However much work is done in crystallizing all the fat needed to produce all the tonnage. [9]

2.3 Electrical systems

To further gain an insight into the energy use of UKL, a review of the electricity billing, electrical load management and maximum demand control, power factor improvement and its benefit, selection and location of capacitors, performance assessment of PF capacitors, distribution and transformer losses.

2.4 Electricity Billing

The electricity billing by utilities for medium & large enterprises, in High Tension (HT) category, is often done on two-part tariff structure, i.e. one part for capacity (or demand) drawn and the second part for actual energy drawn during the billing cycle. Capacity or demand is in kVA (apparent power) or kW terms.

Accordingly, utility charges for maximum demand, active energy and reactive power drawn (as reflected by the power factor) in its billing structure. In addition, other fixed and variable expenses are also levied. The tariff structure for KPLC includes the following components:

- Fixed Charge - This fee helps defray those specific costs not associated with the amount of energy used. Examples include - cost of the meter, cost of reading the meter monthly, maintaining the account, etc.
- Energy Charge - This is the total amount of energy (kWh) used times the charge per kWh for the rate schedule assigned to this account. This is split into two categories, high rate (peak time) and low rate (off peak). This was initially meant to stimulate the companies to be running 24hrs and utilise the night when demand for power is less. However after that was achieved the factories run 24 hours and therefore the prices were standardised. However any bill comes with the two as separate.
- Demand Charge (maximum demand)- Demand (kW) is the greatest 15-minute demand during the billing period, adjusted for 'Power Factor'. Demand is billed to the nearest 0.1 kilowatt. This is meant to ensure the users do not draw too much power at the same time, and later drop to the power they have subscribed to KPLC. This is done by taking the maximum KVA drawn in 15 minutes at any one given time multiplied by a demand charge.
- Reactive (kvarh) - Total amount of reactive power used during this billing period. This reading is used to determine the 'Power Factor'. The total is determined by

taking the difference between the present reading and the previous reading times the meter multiplier.

- Power Factor (pf) - The member/consumer agrees to maintain as near unity power factor as practicable. Should such measurements indicate that the average power factor is less than 90 percent; the demand for billing purposes shall be the demand as recorded by the demand meter multiplied by 90 percent and divided by the percent power factor.

KPLC Rates and Tariffs

The schedule of non-fuel tariffs for electrical energy supplied by the company with the approval of electricity regulatory commission given under section 45 of the energy act, 2006 has set the following schedule of tariffs and rates commencing in the year 2008.

The tariffs to be applied by the company for the supplies of electrical energy from the Interconnected System and also from the Off-Grid Systems, in each billing period shall be as detailed below:

a) METHOD CI1:

Applicable to Commercial and Industrial Consumers for supplies provided and metered by the Company at 415 volts three phase four-wire and whose consumption exceeds 15,000 Units per Billing Period.

i. Fixed Charge of KShs.800.00.
ii. Energy charges of KShs.5.75 per Unit consumed.

iii. Demand charge of KShs.600.00 per kVA.

b) METHOD CI2:

Applicable to Commercial and Industrial Consumers for supplies provided and metered by the Company at 11,000 volts, per Billing Period.

i. A Fixed Charge of KShs.2, 500.00.
ii. Energy charge of KShs.4.73 per Unit consumed.
iii. Demand charge of KShs.400 per kVA.

c) METHOD CI3:

Applicable to Commercial and Industrial Consumers for supplies provided and metered by the Company at 33,000 volts, per Billing Period.

i. A Fixed Charge of KShs.2,900.00
ii. Energy charge of KShs.4.49 per Unit consumed.
iii. Demand charge of KShs.200.00 per kVA

d) METHOD CI4:

Applicable to Commercial and Industrial Consumers for supplies provided and metered by the Company at 66,000 volts, per Billing Period.

i. A Fixed Charge of KShs.4,200.00
ii. Energy charge of KShs.4.25 per Unit consumed.
iii. Demand charge of KShs.170.00 per kVA.

e) METHOD CI5:

Applicable to Commercial and Industrial Consumers for supplies provided and metered by the Company at 132,000 volts, per Billing Period.

- i. A Fixed Charge of KShs.11,000.00
- ii. Energy charge of KShs.4.10 per Unit consumed.
- iii. Demand charge of KShs.170.00 per kVA.

Other charges include; fuel cost charge, Taxes and Levies and VAT at 16% charged to:

1. Fixed Charge
2. Demand Charge
3. Foreign Exchange Fluctuation Adjustment
4. Fuel Cost and Taxable value of electrical energy consumed in a manner required by the Government.
5. Rural Electrification Programme (REP) levy at 5% of revenue from Unit sales.
6. Energy Regulatory Commission (ERC) levy at 3 Kenya cents/kWh.

- a) Maximum demand Charges: - These charges relate to maximum demand registered during month/billing period and corresponding rate of utility.
- b) Energy Charges:- These charges relate to energy (kilowatt hours) consumed during month / billing period and corresponding rates, often levied in slabs of use rates. Some utilities now charge on the basis of apparent energy (kVAh), which is a vector sum of kWh and kVArh.
- c) Power factor penalty or bonus rates, as levied by most utilities, are to contain reactive power drawn from grid.

d) Fuel cost adjustment charges as levied by some utilities are to adjust the increasing fuel expenses over a base reference value.

e) Electricity duty charges levied with respect to units consumed.

f) Meter rentals.

g) Time Of Day (TOD) rates like peak and non-peak hours are also prevalent in tariff structure provisions of some utilities.

h) Penalty for exceeding contract demand.

2.5: Steam system:

2.5.1 Fire tube boilers

The name fire-tube is descriptive. The fire, or hot flue gases from the burner, is channelled through tubes that are surrounded by the fluid to be heated. The body of the boiler is the pressure vessel and contains the fluid. In most cases this fluid is water that will be circulated for heating purposes or converted to steam for process use.

Every set of tubes that the flue gas travels through, before it makes a turn, is considered a "pass". So a three-pass boiler will have three sets of tubes with the stack outlet located on the rear of the boiler. A 4-pass will have four sets and the stack outlet at the front.

Fire-tube Boilers are; relatively inexpensive, easy to clean, compact in size, available in sizes from 175kW to 15,000kW. It also has easy to replace tubes and is well suited for space heating and industrial process applications. For high pressure operations above 30bars, a water tube boiler is used.

2.5.2 Water tube boilers

A Water tube design is the exact opposite of a fire tube. Here the water flows through the tubes and are encased in a furnace in which the burner fires into. These tubes are connected to a steam drum and a mud drum. The water is heated and steam is produced in the upper drum. Large steam users are better suited for the Water tube design. The industrial water tube boiler typically produces steam or hot water primarily for industrial process applications, and is used less frequently for heating applications.

The advantages of water tube boilers availability in sizes that are far greater than the firetube design up to several million pounds per hour of steam. Further the ability to handle higher pressures up to 350bar g, high temperatures and faster recovery when compared to the firetube boilers. .

However the disadvantages include, a very high initial capital cost and cleaning is more difficult due to the design. Additionally they have no commonality between tubes and physical size which may be an issue. Water tube boilers are further categorised by the number of passes where we have single, double/ 2pass and 3 pass boilers.

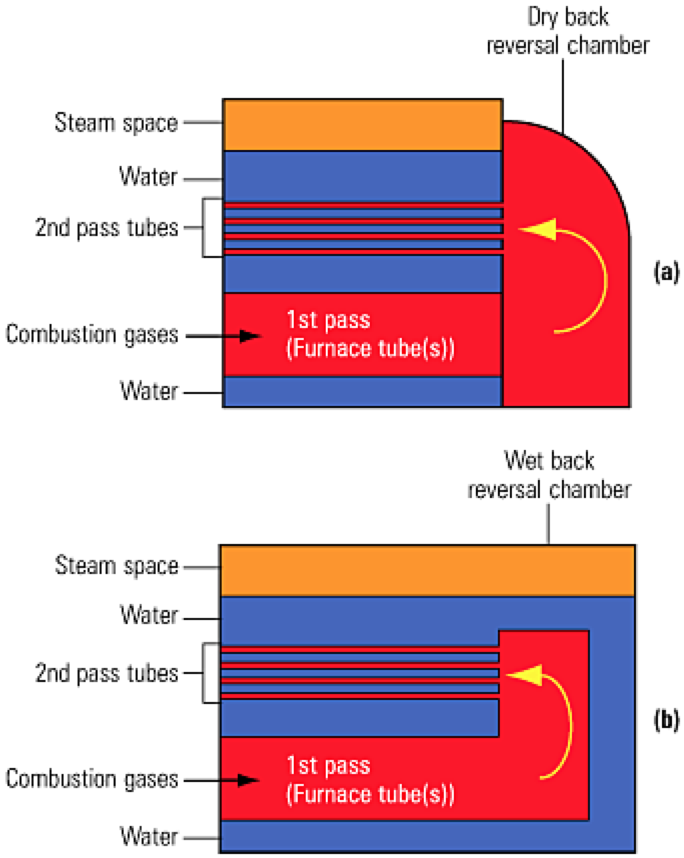


Figure 2-1: Shell boiler - Wet and dry back configurations

Figure 2-1, a more efficient method of reversing the hot gases through a wet back boiler configuration. The reversal chamber is contained entirely within the boiler. This allows for a greater heat transfer area, as well as allowing the boiler water to be heated at the point where the heat from the furnace will be greatest (on the end of the chamber wall.

It is important to note that the combustion gases should be cooled to at least 420°C for plain steel boilers and 470°C for alloy steel boilers before entering the reversal chamber. Temperatures in excess of this will cause overheating and cracking of the tube end plates. The boiler designer will have taken this into consideration, and it is an important point if different fuels are being considered. Below is a history of the initial boilers and how they developed to the ultimate Engineering modern today boilers with very high efficiency levels. [10].

2.5.3 Economic boiler (three-pass, wet back)

A further development of the economic boiler was the creation of a three-pass wet back boiler which is a standard configuration in use today, (see Figure 4.11).

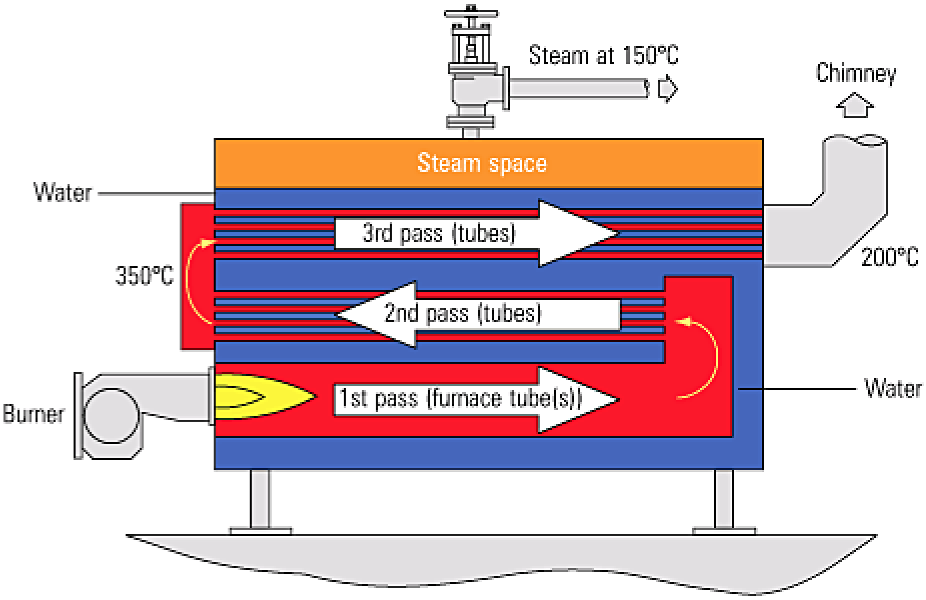
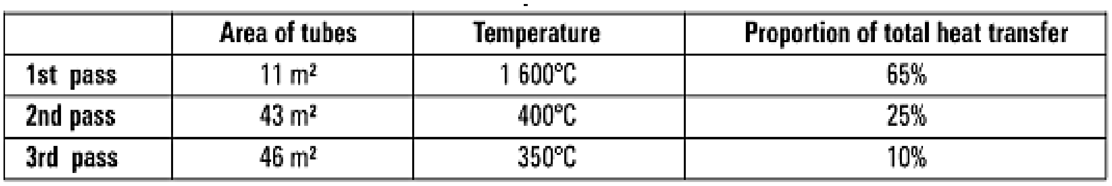


Figure 2-2: Economic boiler (three-pass, wet back)

This design has evolved as materials and manufacturing technology has advanced: thinner metal tubes were introduced allowing more tubes to be accommodated, the heat transfer rates to be improved, and the boilers themselves to become more compact.

Typical heat transfer data for a three-pass, wet back, economic boiler is shown in Table 2.1

Table2.1: Typical Heat Transfer



	Area of tubes	Temperature	Proportion of total heat transfer
1st pass	11 m²	1 600°C	65%
2nd pass	43 m²	400°C	25%
3rd pass	46 m²	350°C	10%

Heat transfer details of a modern three pass, wet back, economic boiler

2.5.4 Packaged boiler: The packaged boiler a complete package with burner, level controls, feed pump and all necessary boiler fittings and mountings. The packaged boiler is shown in figure 2.1 Once delivered to site it requires only the steam, water, and blow-down pipe-work, fuel supply and electrical connections to be made for it to become operational.

Development has also had a significant effect on the physical size of boilers for a given output. Manufacturers wanted to make the boilers as small as possible to save on materials and hence keep their product competitive. Efficiency is aided by making the boiler as small as it is practical; the smaller the boiler and the less its surface area, the less heat is lost to the environment. [11]

Figure 2-3: Unilever packaged boiler (2010)

Unilever boilers are three pass packaged boilers generating 11.5t/hr each.

Boiler efficiency is categorised into two, namely:

Combustion efficiency: This is the total energy contained per unit of fuel minus the energy carried away by the flue gas and unburned fuel exiting the stack. It can also be defined as the amount of heat energy which is converted from a unit of the fuel, be it gas, diesel or HFO. It is dependent on the air available as too much air is will lead to less energy since much of the heat will be used to heat the excess air and too little air means that not all the fuel will be burnt and thus get lower yield. Temperature of the air is equally critical as preheated air will require less energy to heat thus increasing the yield.

An optimum point has to be found and use of online oxygen analyser gets this balance. It checks the amount of unburnt oxygen in the flue gases and gives a feed back to the control system.

Flue gas heat loss is the single largest energy loss in a combustion process. It is impossible to eliminate all flue gas heat loss because the products of combustion are heated by the combustion process. But flue gas heat loss can be minimized by reducing the amount of excess air supplied to the burner.

Thermal efficiency: This is the amount of heat generated by the combustion process that is transferred to the water through the surface. With proper CO or Oxygen analyser working, stack temperature can be used to know whether enough heat is being transferred across the walls. This is because if the tubes are clogged with soot, then heat transfer may be affected and this means that heat will be lost through the stack. A set point is thus set for the flue gas temperature so that if it exceeds these temperatures then cleaning is initiated.

Overall efficiency: This is product of thermal efficiency and combustion efficiency. It can also be calculated by using the amount steam generated per unit of fuel using the calorific value of the oil.

Other factors that affect the boiler performance include the boiler blow down which is wasted energy. However this can be collected and used to preheat the feed water or even the combustion air.

2.5.5 Boiler feed water and treatment

Oxygen is the main cause of corrosion in hot well tanks, feed lines, feed pumps and boilers. If carbon dioxide is also present then the pH will be low, the water will tend to be acidic, and the rate of corrosion will be increased. Typically the corrosion is of the pitting type where, although the metal loss may not be great, deep penetration and perforation can occur in a short period.

Elimination of the dissolved oxygen may be achieved by chemical or physical methods, but more usually by a combination of both. The essential requirements to reduce corrosion are to maintain the feedwater at a pH of not less than 8.5 to 9, the lowest level at which carbon dioxide is absent, and to remove all traces of oxygen. The return of condensate from the plant has a significant impact on boiler feedwater treatment - condensate is hot and already chemically treated, consequently as more condensate is returned, less feedwater treatment is required. Water exposed to air can become saturated with oxygen, and the concentration will vary with temperature: the higher the temperature, the lower the oxygen content.

The first step in feedwater treatment is to heat the water to drive off the oxygen. Typically a boiler feedtank should be operated at 85°C to 90°C. This leaves oxygen content of around 2ppm. Operation at higher temperatures than this at atmospheric pressure can be difficult due to the close proximity of saturation temperature and the probability of cavitation in the feed-pump, unless the feed-tank is installed at a very high level above the boiler feed-pump. The deaerator in Unilever is placed high up from the pumps to avoid cavitation.

The addition of an oxygen scavenging chemical (sodium sulphite, hydrazine or tannin) removes the remaining oxygen and prevents corrosion. This is dosed on the feed water pipe leaving the deaerator to the boiler feed pump. For plants that need to reduce the amount of chemical treatment, it is common practice to use a pressurised deaerator in figures 2-4 and 2-5.

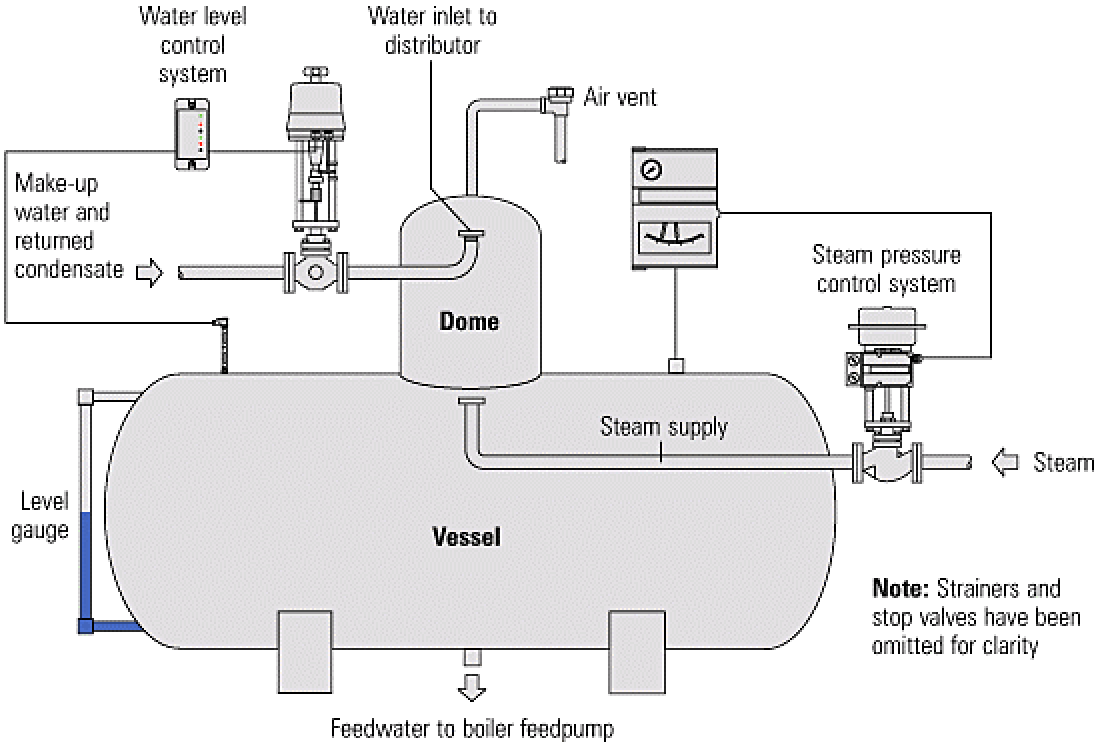


Figure 2-4: Pressure deaerator.

Figure 2-5: Unilever Kenya deaerator

Operating principles of a pressurized Deaerator

If a liquid is at its saturation temperature, the solubility of a gas in it is zero, although the liquid must be strongly agitated or boiled to ensure it is completely deaerated.

This is achieved in the head section of a deaerator by breaking the water into as many small drops as possible, and surrounding these drops with an atmosphere of steam. This gives a high surface area to mass ratio and allows rapid heat transfer from the steam to the water, which quickly attains steam saturation temperature. This releases the dissolved gases, which are then carried with the excess steam to be vented to atmosphere. (This mixture of gases and steam is at a lower than saturation temperature and the vent will operate thermostatically). The deaerated water then falls to the storage section of the vessel. A blanket of steam is maintained above the stored water to ensure that gases are not re-absorbed. Breaking the water up into small drops can be achieved using one of the methods employed inside the dome's steam environment. The operating principles of the pressurized deaerator are illustrated in figure 2-6.

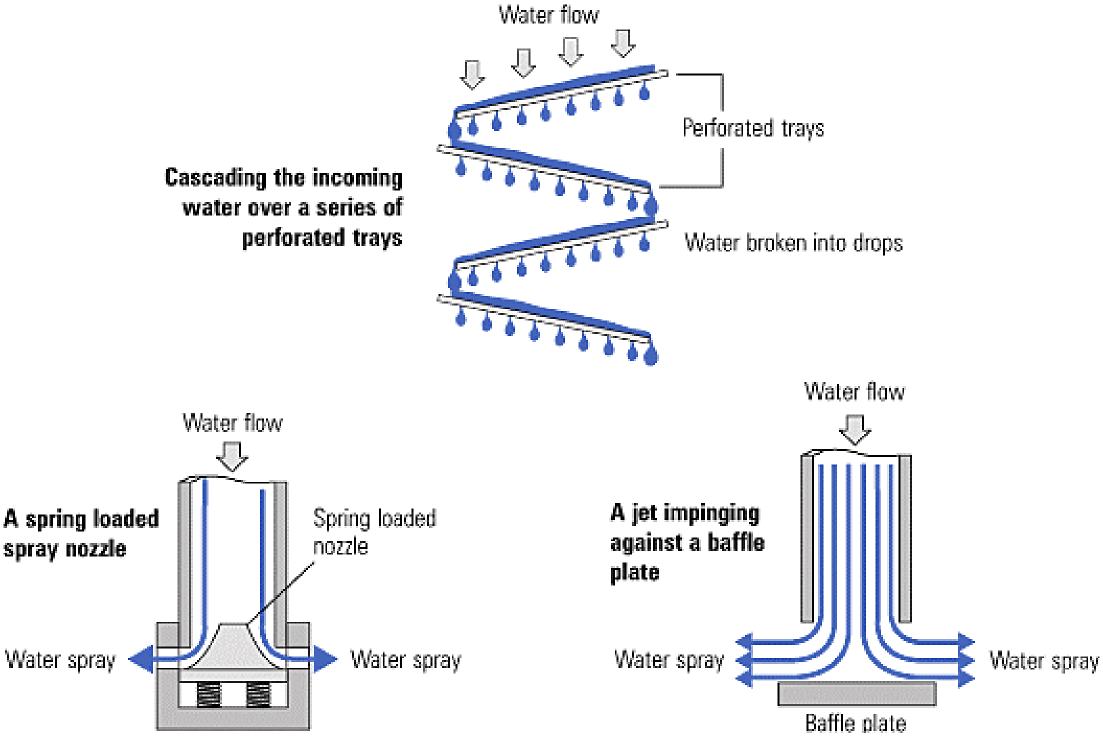


Figure 2-6: Deaerator water inlet options

Spray type is used for industrial applications and is what we use for our dome. It has a total of 24 jets which spray water as the steam moves up heating this water.

Water control

A modulating control valve is used to maintain the water level in the storage section of the vessel. Modulating control is required to give stable operating conditions, as the sudden inrush of relatively cool water with an on/off control water control system could have a profound impact on the pressure control, also the ability of the deaerator to respond quickly to changes in demand. Since modulating control is required, a capacitance type level probe can provide the required analogue signal of water level.

2.5.6 Steam control

A modulating control valve regulates the steam supply. This valve is modulated via a pressure controller to maintain a pressure within the vessel. Accurate pressure control is very important since it is the basis for the temperature control in the deaerator, therefore a fast acting, pneumatically actuated control valve is be used. Notably a pilot operated pressure control valve may be used on smaller applications, and a self-acting diaphragm actuated control valve may be used when the load is guaranteed to be fairly constant.

Figure 2-7: Deaerator steam injection system

The steam injection occurs at the base of the head, and flow in the opposite direction to the water (counter flow), the objective being to provide maximum agitation and contact between the steam and water flows to raise the water to the required temperature as illustrated in figure 4-16. The steam is injected via a diffuser to provide good distribution of steam within the deaerator dome. The incoming steam also provides means of transporting the gases to the air vent and also a blanket of steam required above the stored deaerated water.

Deaerator air venting capacity

If feedwater were heated to the saturation temperature of 100°C in an atmospheric feedtank, the amount of oxygen held in the water would theoretically be zero; although in practice, it is likely that small amounts of oxygen will remain. It is also the case that the loss of steam from a vented feedtank would be quite high and economically unacceptable, and this is the main reason why pressurized deaerator are preferred for higher pressure plant operating typically above 20 bar g.

A pressurized deaerator is often designed to operate at 0.2 bar g, equivalent to a saturation temperature of 105°C, and, although a certain amount of steam will still be lost to atmosphere via a throttled vent, the loss will be far less than that from a vented feedtank. A typical way of controlling the vent rate is to use a duty ball valve of a suitable pressure rating, which can be secured in a part-open condition.

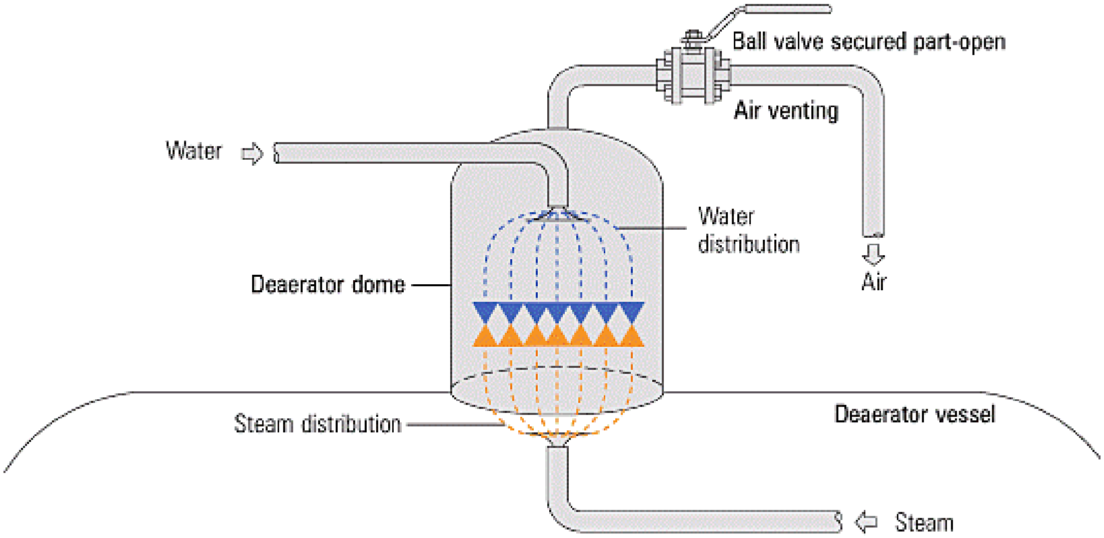


Figure 2-8: Deaerator Dome

Typical operating parameters for a pressurized deaerator

The following information is typical and any actual installation may vary from the following in a number of ways to suit the individual requirements of that plant:

- The operating pressure will usually be approximately 0.2 bar g, which gives a saturation temperature of 105°C (221°F).
- The vessel will contain between 10 and 20 minutes water storage for the boiler on full-load.
- The water supply pressure to the deaerator should be at least 2 bar g, to ensure good distribution at the nozzle.

This implies either a backpressure on the steam traps in the plant or the need for pumped condensate return which an ogdein pump is used.

- Steam supply pressure to the pressure control valve will be in the range 5 to 10 bar g.
- Maximum turndown on the deaerator will be approximately 5:1.

- At flow-rates below this from the process, there may be insufficient pressure to give good atomisation with nozzle or spray type water distributors. This can be overcome by having more than one dome on the unit. The total capacity of the domes would be equal to the boiler rating, but one or more of the domes may be shut down at times of low demand.
- Heating may be required in the storage area of the vessel for start-up conditions; this may be by coil or direct injection.
- However, the type of plant most likely to be fitted with a pressurised deaerator will be in continuous operation and the operator may consider the low There is no additional energy cost associated with operating a deaerator, and the maximum amount of steam exported to the plant is the same with, or without the deaerator, because the steam used to increase the feedwater temperature comes from the higher boiler output.

  However:
- There will be some heat loss from the deaerator (This will be minimised by proper insulation).
- There is the additional cost of running the transfer pump between the feedtank and the deaerator.
- Some steam is lost with the vented non-condensable gases.

Chapter 3

Methodology

3.0 Introduction

This chapter describes the methodology used in this study based on the existing plant machinery and factory design at the time of this project (2011).

To determine the operating conditions of the plant the following procedures were used:

i. Conducted visual plant inspection for the energy distribution network which includes electrical system, steam distribution system and fuel network. The visual inspection would aid in establishing any leaks which would lead to any wastage and thus give opportunities for identifying energy use reduction.

ii. Reviewed equipment manuals for the mixing machines, ammonia compressor and the operating points, conditions and optimum parameters.

iii. Reviewed process parameters which include temperature & relative humidity in the maturation room, pressure and temperature in the ammonia compressor Vs the design optimum process energy requirements. This is because the margarine process uses the old system that was used to produce cooking fat at a capacity of over 2000 tons per week to the current 600ton of margarine per week.

iv. Reviewed historical data records. These are electricity bills and production reports for the year 2010-2011.

v. Analysed power meter readings in KWH for the same period as (iv) above.

vi. Costs saving opportunities were cited, and energy savings calculated.

vii. In areas where investment was required, simple payback was calculated.

viii. Energy use per ton of production was calculated to give the trends.

ix. Relooking at energy requirements to access whether alternative means of energy supply can be realised, e.g in the security lighting and office lighting.

3.1 Historical utilities data

This is centrally stored for the entire Nairobi factory site. Data from this location was used to give a detailed view of the current and previous set-up. It also gave an indication of the type of source of energy used more and the environmental impact from that source. Information on the emissions is also calculated and tabulated. This was important as it gives direction incise two forms of energy are equally efficient, which one to choose.

3.3 Monthly company reports and publications

These are the reports the company sends to the global team for evaluation in terms of carbon footprint. These are found in the company website http://os-env.unilever.com/ which has all the energy usage for all the sites in the world. The units reported include carbon oxygen demand, water consumption, carbon emissions, sulphur emissions, and total energy consumption in GJ per Ton of production.

3.4 Observation

This was used especially where quantification was difficult. These are areas like people behaviour and mannerisms. Behavioural aspects such as Examples being how people respond to putting off lights and water taps when not in use. Can the operators and other factory employees put off the light voluntarily or does it have to be under supervision? This was an important aspect as the behaviour of the employees determines the usage of energy and the wastage levels within the Savoury and SCC factories.

Chapter 4

Results and Discussion

4.0 Introduction

The chapter discusses the details of the energy sources, electricity use in Unilever, the factory installations, furnace oils and the energy improvement opportunities. The discussion is based on the margarine and savoury factories.

4.1 Energy Sources

Unilever has four primary sources of energy that are used to run the operations. These include; electricity from the generators and the national power grid, Gas (Butane) Supplied in 13kg cylinders, furnace oil and diesel oil. This energy is then used to either generate secondary means of energy or used directly. The secondary energies available include steam, compressed air, vacuum and refrigeration system.

The following proceeding section discusses each of these sources in detail, from generation, distribution and use and the possible energy saving opportunities available. Metering is also factored in per factory.

4.2 Electricity-Total Site

4.2.1 Generation

Electricity from KPLC is sold to Unilever Kenya at 11kV. This is then stepped down to 415V 3-phase and 240V single phase and used in the various parts of the factory at the voltage required. KPLC provides a centralised meter and the factory has installed meters for sub metering at different parts of the factories. Billing is done for the total site and the company then allocates the cost to various factories based on the consumption.

4.2.2 KPLC Electricity Bill

These factors are important because they determine the efficiency of the transformer installed. The power factor is controlled using capacitor banks which have been installed at each factory. A look at the company bills shows the different categories as explained above which show in the appendix 1, Unilever KPLC electricity bills, gives a clear indication on billing method and where much of the money is used. The following section discusses each of the above factors to further understand what each parameter of the power costs. The analysis on table 4.1 is for the year 2010. The bills show that Unilever pays an average of KES 700,000 per month as a demand charge. Power factor is always above 0.9 meaning that the company is not charged for power factor.

Table 4-1: KPLC bill analysis 2010

bills analysed.xlsx

4.2.3 Diesel Installed Generators

There are four 1MVA generators installed on site. These run different sections of the factory. The total installed power is 4MVA. Incise of power failure all the generators come on at the same time, pumping 4MVA to the factories. Based on the maximum demand the maximum demand is 1.8MVA leaving a surplus of 2.2MVA.

Total site metering layout shown in figure 4-1:

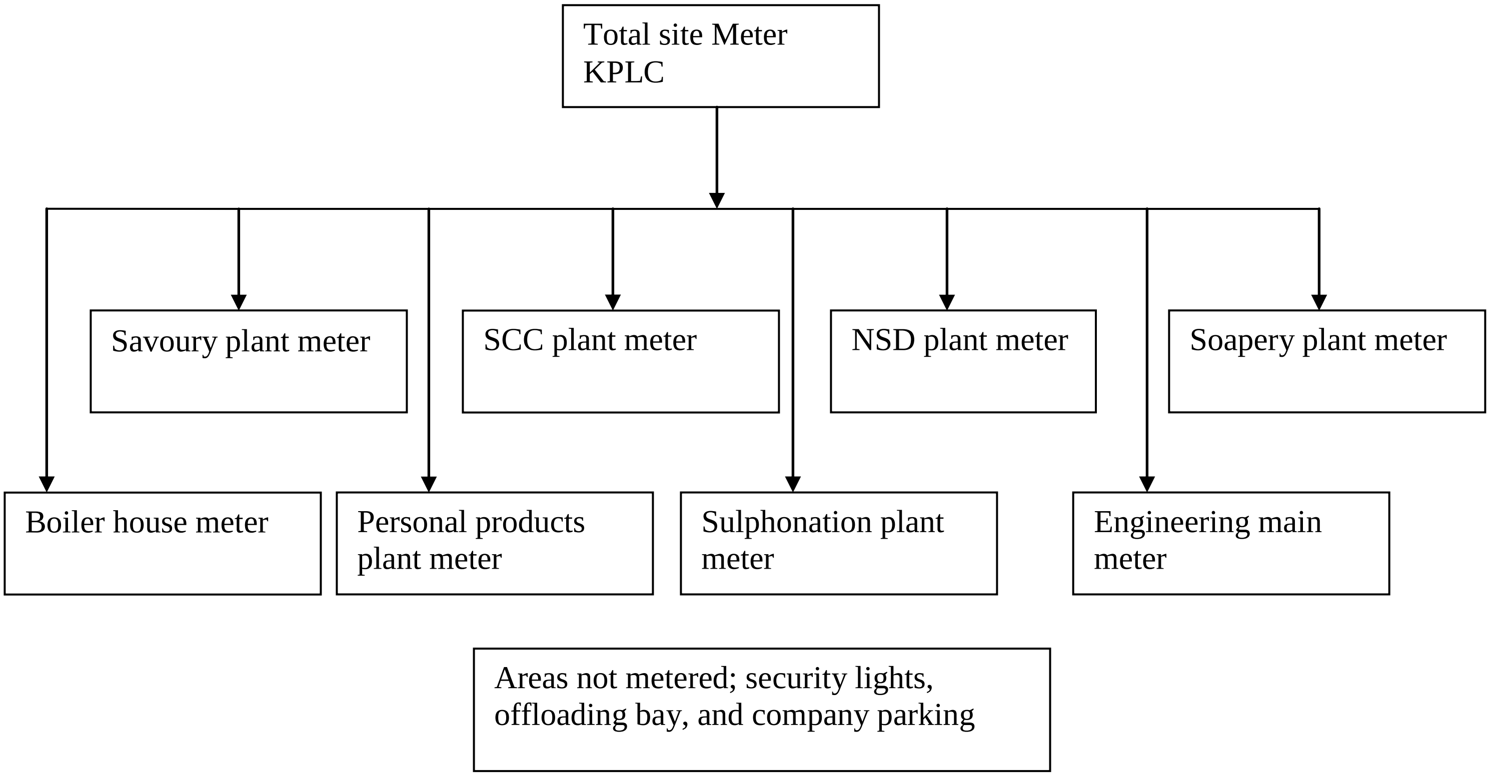


Figure 4-1: Total Site layout on sub-metering process

4.2.5 Factory billing;

The site is sub-divided into different areas which are then given the term factory as they manufacture different products. The Spreads and cooking category, manufacturing margarine and the Savoury factory manufacturing Royco are thus considered as two distinct factories. Every factory has a sub-meter which is used to meter consumption of that particular section. The total cost is divided by total metered units to get cost per unit. This value is then multiplied by the number of units for each factory to get the cost per factory.

The following table shows the billing for the two factories for the period between January 2010 and January 2011. From the main supply this power is then fed to the factory independently as per the layout above. Table 4-1, shows the monthly electricity consumption in 2010 for both plants.

Table 4-1: Average Unit Bill at Site Level and sub- Metered Factory Level.

2010	Royco		Blue band			
Month	Units (kWh)	cost (kes)	Units (kWh)	cost (kes)	Average unit cost	Average site bill unit cost
January	55,239	939,612	220,807	3,755,913	17	16
February	43,261	744,784	204,506	3,520,786	17	16
March	47,035	504,089	197,515	2,116,830	11	16
April	44,283	822,055	176,760	3,281,316	19	15
May	56,133	756,343	232,731	3,135,846	13	13
June	47,468	700,762	202,547	2,990,166	15	11
Month	Units (kWh)	cost (kes)	Units (kWh)	cost (kes)	Average unit cost	Average site bill unit cost
July	39,116	556,529	44,072	2,049,808	14	11
August	44,501	388,223	184,318	1,607,976	9	11
September	36,236	418,215	161,851	1,867,992	12	11

October	43,157	410,005	194,228	1,845,226	10	11
November	44,675	563,262	205,330	2,588,800	13	12
December	45,444	489,193	196,622	2,116,587	11	12

Key thing to note here is that the total bill despite having numerous classes, such as maximum demand, power factor, this is not taken into account when billing individual factories.

On average, the unit cost for the site bill is lower than the factory bill. This is as per the following equations.

–

If the sum of individual units measured from the factories is y’ then the billing unit cost is;

–

If y>y’ then the factory billing is higher than the actual cost. This means that the factories are charged for extra units that are consumed by the areas that are not metered. Factors that can contribute to this scenario as shown in the data for the last one year includes some areas are not metered.

4.3 Factory installations

From the supplies the power is then fed to different factories to be used. Here further metering is done. Different factories have different machinery and power to each is also metered differently. Electricity in these factories is used for these broad categories which include heating, lighting driving motors and office use.

The two factories-margarine and savoury are described separately.

4.4 Royco factory

The energy consumption for the factory against the production is calculated and analyzed in the table 4-2 below.

The graph of production and consumption per ton of electricity is shown below, which shows that the higher the production the lower the consumption per ton.

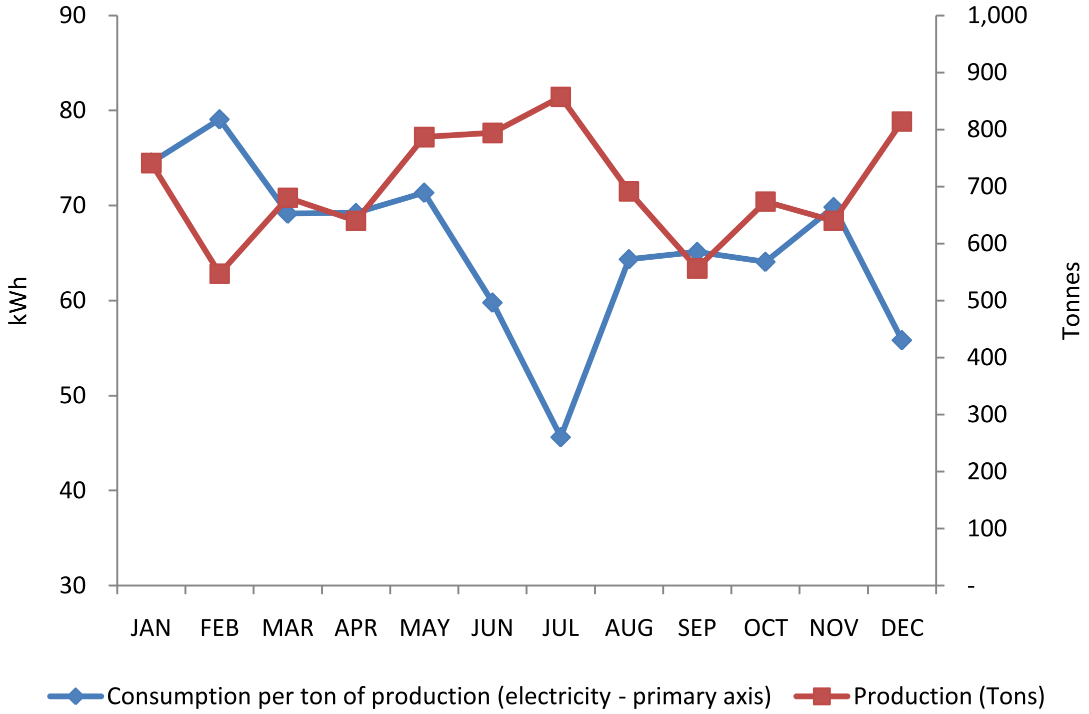


Figure 4-2 Electricity consumption per ton and total production.

Figure 4-2shows a profile that indicates the close link of production with energy consumption. In the month of July there was a huge drop of energy use per ton and this is because the production is also the highest. When the production is low, the consumption per unit production is high and vice versa. Since this presents a scenario that the two units are related, a correlation and eventually regression analysis was done as shown in figure 4-3.

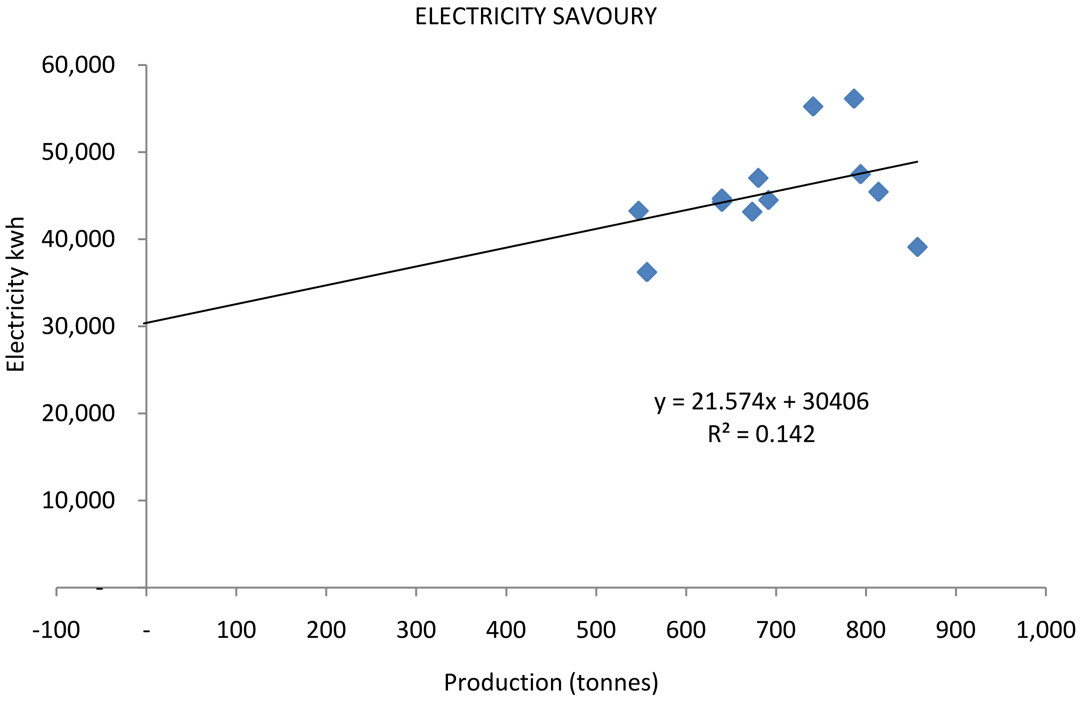


Figure 4-3. Regression graph for Savoury electricity consumption.

This gives a correlation coefficient of 14% which means there is a very low influence of production on the consumption of electricity. This means that consumption is not driven by machines that are directly involved in production but largely on other operations. these include, lighting, air conditioning and heating. By looking at figure 4-4 lighting is 25% and heating is 19%. The base consumption is at 30,406kWh which substantially high. This means that with zero production, 30,406kWh must be consumed and this is due to the lighting, and cold room that run throughout.

Royco factory has a total electrical installed capacity of 222.6 KW which is shared on the different factory installations detailed in figure 4-4.

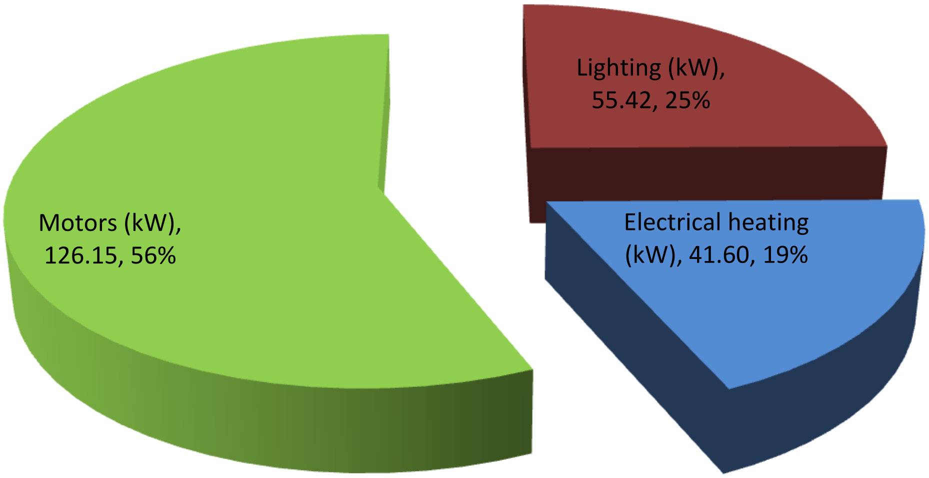


Figure 4-4: Installed capacities for the different process areas in Savoury

Motors have the highest energy consumption with up to 56% of the total power. This represents the biggest impact in terms of energy savings opportunities. However opportunities for energy reduction will be checked across all the units. All this power is metered together as one consumer unit.

4.4.1 Electrical Heating

This includes all the heaters installed on machines. The elements vary in sizes 0.2 to 1.1kW. This is because the packaging material is in multiple layers ranging between 2 and 3 ply layers. The 3 ply layers need more energy to heat. These heaters are used to seal the packaging material.

4.4.2 Lighting

Light intensity is measured in lux levels. 1 lux is equivalent to 1 lumen/m^2. Different areas and different operations need different light intensities, varying from as low as 20 lux to 20,000 lux. Table 4-2, shows a general lux level requirement for different operations;

Table 4-2: Light Requirements for different sections [12]

Lux	**Area**
40 Lux	Corridors
	Passageways
80 Lux	Warehouses involving search & retrieval tasks
	Stairs
160 Lux	Entrance halls
	Foyers
	Waiting Rooms
	Canteens
	Machine shop general work bench
240 Lux	Counters
	Kitchens (food preparation area)
320 Lux	Offices
400 Lux	Machine shop high tolerance work bench
600 Lux	Electronic assembly work

This indicates the light intensity needed for many areas. All the areas are broadly categorized into the following 6 groups:

i. Packing floors which would fall under counters requiring 240 lux
ii. Palletizing area which would fall under warehouse requiring 40 lux.
iii. Machine feeding and tipping which would fall under warehouse requiring 40 lux.
iv. Machine shop requiring 400 lux.
v. Warehouse requiring 40 lux.
vi. Offices requiring 320 lux.

4.4.3 Motors

Motors consume the highest amount of energy. This is because of their intense use in the following areas, driving packing machines operations, driving machine feeding systems, driving Bitzer compressors for air conditioning of maturation room driving conveyors and also driving the mixers.

The first two conveyors after the machine are automated and only run when there is product in the system to be packed. Conveyors; the factory has 13 conveyors, 11of which are primary conveyors with motor ratings of 1kW and 2 are secondary conveyors with a motor rating of 3kW. The primary conveyors are as illustrated in the figures 4-5 and 4-6;

Figure 4-5: Primary conveyors

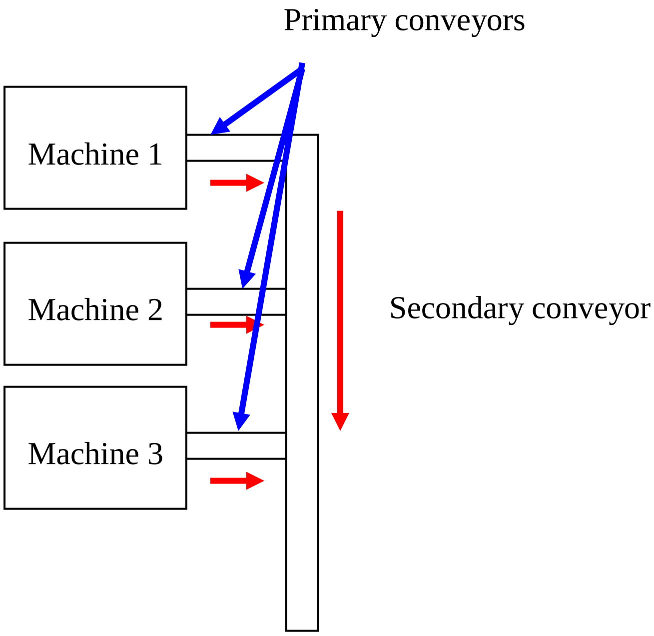


Figure 4-6: Primary and secondary conveyors mechanism

Mixers:

There are two types of mixers:

Nauta mixer: figure 4-7shows, a slow moving mixer with a capacity for 1.5T of beef cube powder and 1.7T of Mchuzi mix powder. It has a total motor capacity of 8.1 kW

Figure 4-7: Nauta mixer

A batch in this mixer takes 45 minutes. Calculating the energy consumption per batch we have:

I batch has 1.5tons of powder so:

Lodidge mixer:

The Lodidge mixer is a high speed plough-shear mixer as shown in figure 4-6 is used only for cube powder. It has a capacity of 0.5t and this takes 10 minutes.

Figure 4-8a: High speed plough mixer (Lodige)

This mixer has three motors with a total rating of 41kW.The mixer produces half (½) a tone per batch which should take about 10 minutes.

Power per batch:

41kW X (10/60) hrs= 6.8kWh/batch

1 batch is 0.5T so power consumption per ton is:

6.8kWh/0.5t= 13.67kWh/ton

This means the second mixer uses 3.4 times more energy per unit production and as such it is more economical to use the Nauta mixer.

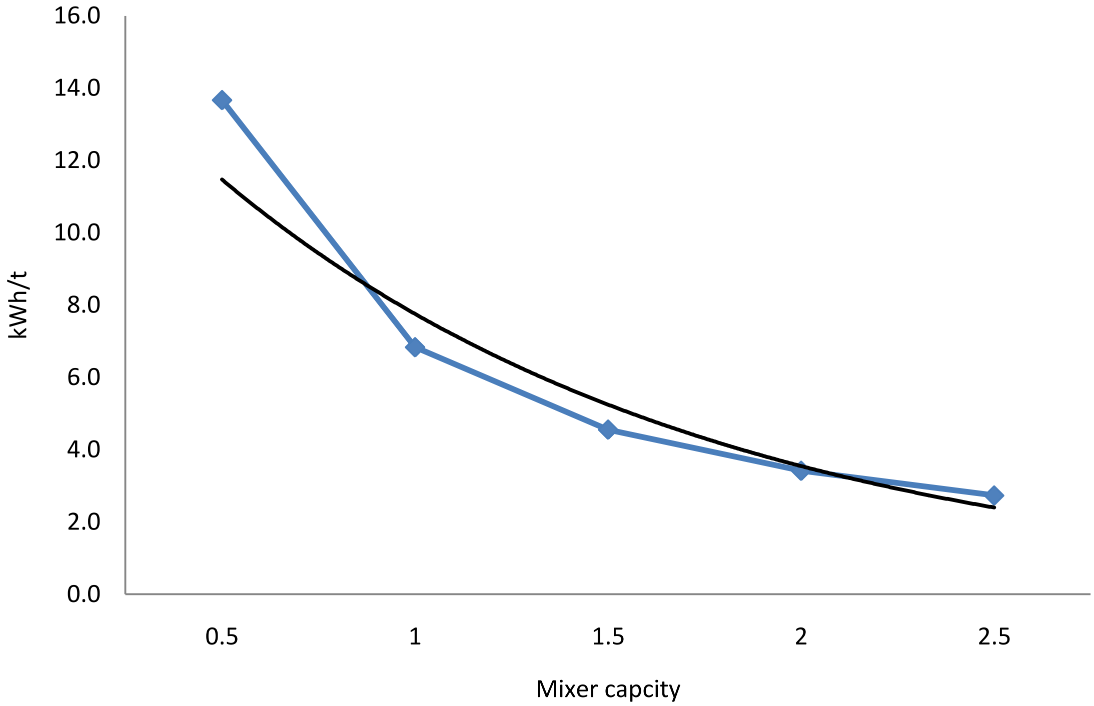


Figure 4-8b: Lodige capacity and energy consumption.

As the capacity of the mixer increases, the energy consumption decreases as shown n figure 4-6b with a 2t mixer consuming 25% of the energy that would be consumed by 0.5t mixer.

Air conditioning system:

Air conditioning is used in different sections for achieving the standard operating parameters of the air. These include, dehumidifying and cooling. Different sections of the factory need different air grades. These include;

Royco Beef Cube packing floor:

Royco beef cube packing hall has the following occupancy at any one given time, 16 personnel, 7 packing machines a heating load of 13.2kW and a lighting load of 6.235kW [appendix 2]. The air is filtered and pumped in the factory to replace used air. Air is pumped instead of suctioning to prevent dust and foreign particles from getting into the factory. This also keeps the room under pressure above atmospheric blocking any unfiltered air that may get in through the cracks. Cooling air is also supplied due to the numerous heating loads in the room. The average temperature in this packing floor without any external air pumped in averages at 27 degrees.

Royco Mchuzi Mix packing floor

Royco Mchuzi mix packing hall has the following occupancy at any one given time, 17 personnel 9 packing machines, a heating load of 26kW and a lighting load of 6.235kW. [Appendix 2]. The room requires cooling or extraction of this heat. The installed system currently pumps air at ambient temperature. Clogged filters can cause energy waste as the impeller pushes the air through the dust. Cleaning procedures need to be adhered to. The temperature in the room can also be synchronized with the speed of the impeller using a variable speed drive. The high the temperature in the room, the higher the speed of the impeller and the close the temperature in the room is to external temperature the lower the speed of the impeller.

RBC feeding floor

RBC feeding room has the following installed air conditioning systems; Trane air conditioning system: which uses R407c/R134a as a refrigerant. It has two compressors which operate at 28 bar g. There is a dehumidifier which is used only when the RH is too high. This is because the dehumidification process includes using a desiccant gel, which absorbs the water. To remove that water from the gel so as to re-use the gel hot air is passed through. The gel becomes hot and has therefore a tendency of heating the air as it dehumidifies. This means the air has to be cooled again after dehumidifying. The maturation process is optimum when the following conditions are met:

i. An average room temperature of 13^{o}C.

ii. Relative humidity of 45%-55%

The following are main sources of the heat in the room:

In the maturation room, raw powder is taken into the room at 31 degrees since the oil added in the product is added at 75^{o}C and taken though the maturation process for at least 24 hours at 15^{o}C degrees. Given that there are 100 RBC trolleys, each carrying 400kg of RBC, this contributes considerably to the heat load in the room. This is given by using the following heat equation: $Q=mc\ (t_1-t_2)$ where m is the specific heat capacity of the individual components as in table 4-3:

Table 4-3: Major constituents in a 434kg Batch [6]

Component	Mass per 434kg batch	Specific heat capacity
Sugar plantation	22.4kg	0.31cal/gk
Local salt	240.6kg	0.88kj/kgk
post hard	35.4kg	3.77kj/kgk
MSG	53.2kg	2.8kj/kgk
Corn starch	53.2kg	3.1kj/kgk

During these processes there is heat transfer through walls. Heat is transmitted through to the inside of the room and this need to be removed.

4.5) Margarine factory

Figure 4-9 shows how energy is distributed between heating, lighting and motors in the margarine factory. This shows that motors consume about 96% of total energy in that factory.

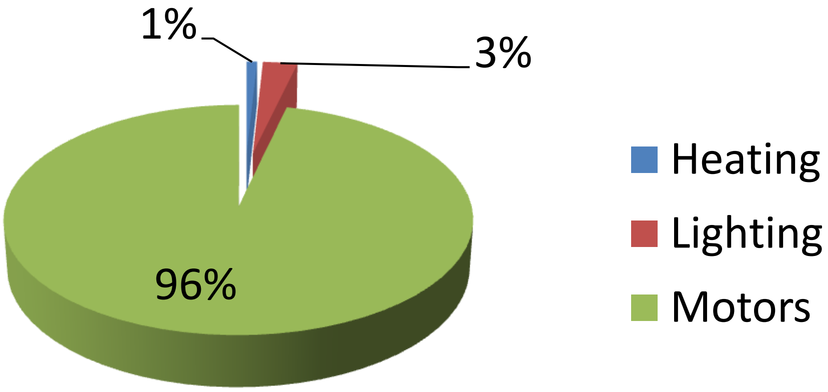


Figure 4-9: Load Distribution in margarine Factory (For details check appendix 3)

4.5.1 Heating

This includes all the heaters installed on machines. The elements vary in sizes 0.2 to 2.6kW.Machines in this factory operate in the same principal as those in the Savoury factor and some highlights include, there are a total of four final packing machines where two of them pack in tubs while two pack in sachets. The sachet machines have two lanes whereas the tub machines have 4 lanes and 2 lanes respectively.

The tub machines have heat seals which are used for putting foil on the margarine seals with the sachet lines having to heat to seal the wrapper/ packaging material. As long as the machine is running the heaters come on. Part of the possible energy saving opportunities, would be dependent on switching the lines off during meal time and proper shutdown procedures at the end of the day. Meals take 1.25 hours in a day and by switching off the heaters the savings as detailed in figure 4-7 can be realised.

The tub machines would have their heating capacities reduced by ensuring when not in use they are switched off. Proper preventive maintenance programs on these lines would ensure that we have single pass production without stoppages. The level of waste levels from this section is as per the detailed information section 4.4.5:

4.5.2. Lighting

The lighting intensity is as shown from the table 3.5:

This is quite similar with savoury and so areas of improvement will be discussed in the discussion section.

4.5.3. Motors

Motors in the margarine factory have the highest energy load. This is about 96% of the total load as seen in figure 4-10.

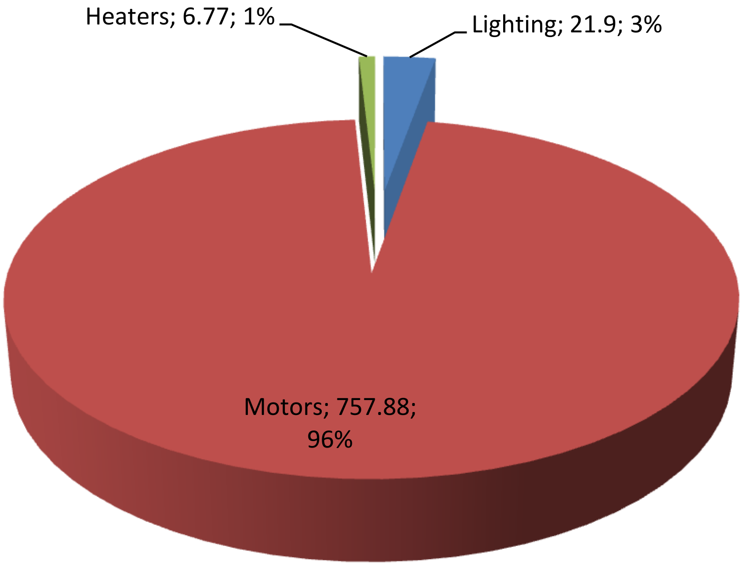


Figure 4-10: Energy use distribution (kWh)

Rating the motors from the highest to the lowest gives us the following palleto figure 4-11 shows the motors as the biggest energy consumers:

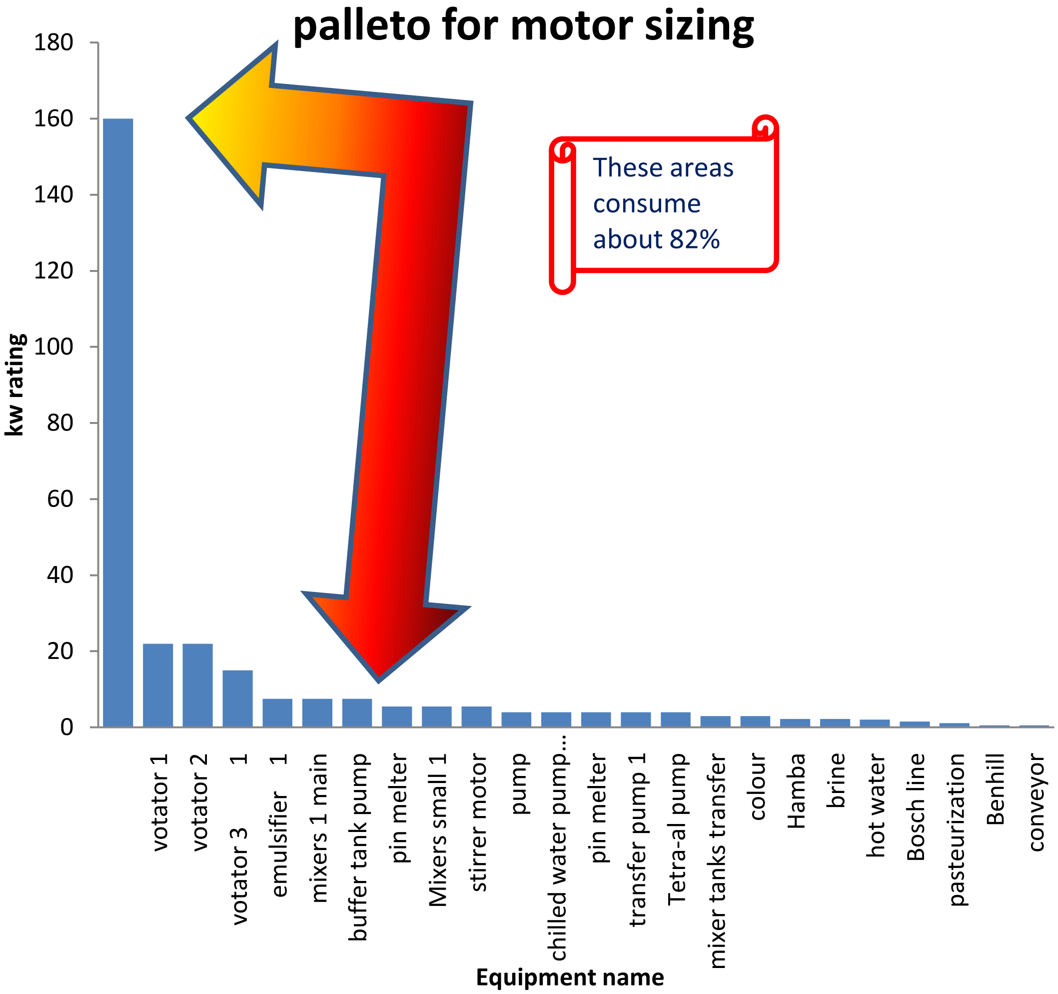


Figure 4-11: Palleto showing biggest energy consumers

Figure 4-11gives a broad perspective of how the ratings are distributed. The design of the product is such that once the equipments start running any stoppage leads to loss of product in the system or hours of start up. Therefore the factory should run without stoppage in the process areas. By looking at table 4-4, 82% of motor loading is in the process and thus run continuously. This is where the highest improvement opportunity lies.

4.6 Ammonia refrigeration system

This system is used to cool margarine and is run by a 160kW motor. This motor alone consumes 54% of the total motor energy in the plant which is also equivalent to 51.8% of total plant power as shown in table 4-4.

Table 4-4: Cumulative energy use for vessels using 80% of the power

Motors	**Motor rating**	Cumulative	Cumulative %
Ammonia Compressor	**160**	**160**	**54%**
Votator 1	22	182	62%
Votator 2	22	204	69%
Votator 3 1	15	219	74%
Emulsifier 1	7.5	226.5	77%
Mixers 1 main	7.5	234	80%
Buffer tank pump	7.5	241.5	82%
Pin melter	5.5	247	84%
Mixers small 1	5.5	252.5	86%
Stirrer motor	5.5	258	88%
Pump	4	262	89%
Chilled water pump 1	4	266	90%
Pin melter	4	270	92%
Transfer pump 1	4	274	93%
Tetra-al pump	4	278	95%
Mixer tanks transfer	3	281	96%
Colour	3	284	97%
Other motors	10	294	100%

The motors that consume up to 97% of the total motor energy are in the process areas. This means that these machines run continuously, stopping only when the entire factory has been shut down. Also based on their rating, every start-up means a huge power demand since all the machines are started at the same time. The ammonia system is a refrigeration system that cools the margarine during the manufacturing process to ensure that we get homogeneity in the crystallization process. A typical Refrigeration System diagram is shown in appendix 4. [5]

4.7 Furnace Oil.

This is one of the major leading energy sources in Unilever Kenya. Furnace oil is used to generate steam in the boilers which is then distributed across site. This is by using a three pass, rotary cup boiler. From the table below, 4-6, this represents 64% of the total energy.

Table 4-5: Cumulative energy use for vessels using 80% of the power

Fuel	**GJ**	
Electricity	55,382	33%
HFO	108,227	64%
LPG	10	0%
Diesel	4,340	3%
Total energy	167,959	

Based on the type of fuel used, boilers can be categorized as multi-fuel fired, gas fired boilers, coal fired boilers, oil fired boilers, biomass fired boilers, and industrial waste fired boilers.

4.7.1 Steam generation

Steam is generated using two 11.5t/h boilers. One boiler is always on standby mode while the other is running. Boilers can use solid, liquid or gas fuel. However in Unilever Kenya only oil fired boilers are used. The steam pressure requirement is 10bar. Steam at 10 bar

70% dry, contains 2181kJ/kg. The energy needed to move water to 100^{o}C is given by the equation where h is the enthalpy at the final temperature which is t_2, C_p specific heat capacity of water and t_1 is the initial temperature or feed water temperature. The energy from 100^{o}C is calculated from the steam tables and the following is an extract.

Table 4-6: Specific enthalpy of water and steam

Feed water temp		Saturation Temperature	Dryness	Specific Enthalpy of Water (h_f)	h_{fg}	Specific Enthalpy of Wet Steam (h)
°C	**kJ/kg**	**°C**	**%**	**kJ/kg**	**kJ/kg**	**kJ/kg**
55	230.3	100	70	419.098	1579.66	1998.76
60	251.188	110	70	461.372	1560.95	2022.33
65	272.11	120	70	503.813	1541.69	2045.5
70	293.044	130	70	546.441	1521.8	2068.24
75	313.992	140	70	589.279	1501.21	2090.49
80	334.96	150	70	632.351	1479.84	2112.2
85	355.951	160	70	675.685	1457.61	2133.3
90	376.969	170	70	719.316	1434.42	2153.74
95	398.017	180	70	763.283	1410.17	2173.46

If the feed water temperature is high, then less energy will be required to convert the water to steam. This is shown by table 4-7.

Table 4-7: heat needed to generate steam

Feed water temp	Initial energy	Final energy	Injected energy
°C	**kJ/kg**	**kJ/kg**	**kJ/kg**
55	230.3	2181.4	1951.2
60	251.2	2181.4	1930.2
65	272.1	2181.4	1909.3
70	293.0	2181.4	1888.4
75	314.0	2181.4	1867.4
80	335.0	2181.4	1846.5
85	356.0	2181.4	1825.5
90	377.0	2181.4	1804.5
95	398.0	2181.4	1783.4
100	419.1	2181.4	1762.3

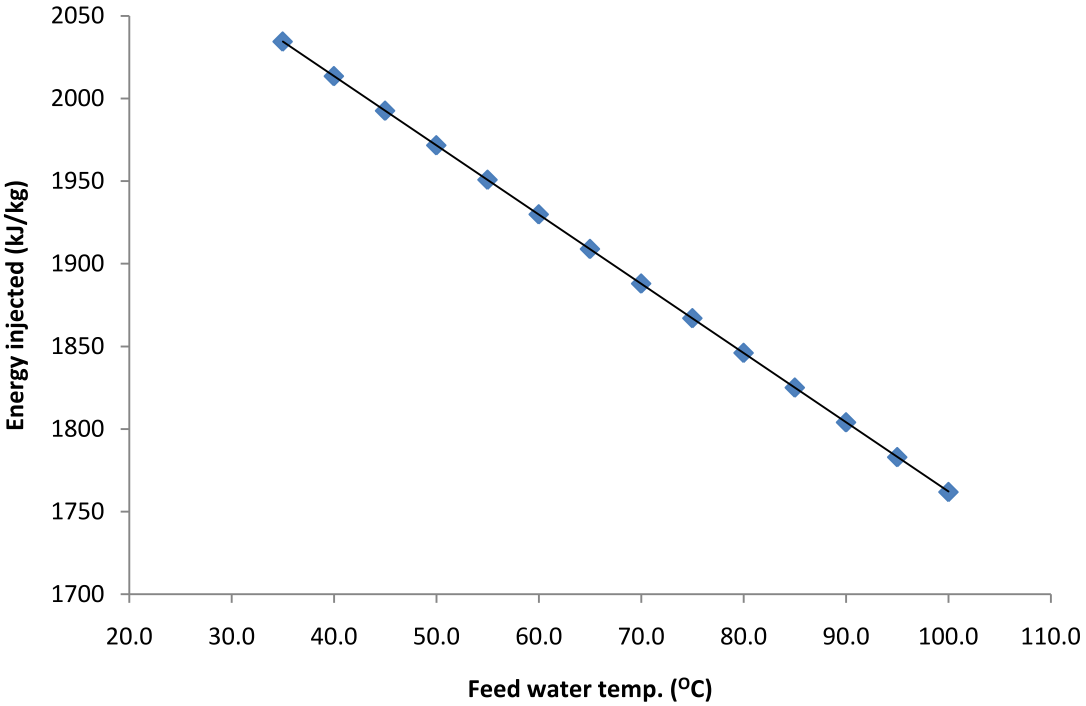


Figure 4-12 Energy needed to convert water to steam

As the temperature of the feed water increases, the energy needed decreases. Different ways of raising the feed water temperature include:

- ✓ Use of a heat exchange to utilise the energy from blow down steam.
- ✓ Return of condensate to the deaerator.
- ✓ Use of steam to raise the temperature-this should be the last option since steam is useful but condensate and blow down is all wasted energy that can be re-used.

Furnace oil has a calorific value of 43,310 kJ/kg. [appendix 9]. With varying feed water temperatures, the amount of steam that can be generated varies slightly as table 4-8 shows. With the equation:

Where for temperature up to 100^{o}C

and

h_g = Total enthalpy of saturated steam (Total heat) (kJ/kg)

h_f = Liquid enthalpy (Sensible heat) (kJ/kg)

h_{fg} = Enthalpy of evaporation (Latent heat) (kJ/kg)

Alternatively the formula where *x* is the dryness factor.

Table 4-8: kg of steam generated from 1 kg of oil.

Feed water temp	Initial energy	Energy ,h, at 10 bar 70% dryness fraction	Injected energy	kg of steam per kg of oil
°C	kJ/kg	kJ/kg	kJ/kg	kg
35.0	146.7	2,181.0	2,034.3	21.1
40.0	167.6	2,181.0	2,013.4	21.4
45.0	188.5	2,181.0	1,992.5	21.6
50.0	209.4	2,181.0	1,971.6	21.8
55.0	230.3	2,181.0	1,950.7	22.0
60.0	251.2	2,181.0	1,929.8	22.3
65.0	272.1	2,181.0	1,908.9	22.5
70.0	293.0	2,181.0	1,888.0	22.8
75.0	314.0	2,181.0	1,867.0	23.0
80.0	335.0	2,181.0	1,846.0	23.3
85.0	356.0	2,181.0	1,825.0	23.6
90.0	377.0	2,181.0	1,804.0	23.8
95.0	398.0	2,181.0	1,783.0	24.1
100.0	419.1	2,181.0	1,761.9	24.4

This indicates that 1 kg of furnace oil can generate up to 24kg of steam at 100% efficiency. However the boiler has numerous losses due to the design and chemical factors.

Boiler losses:

- Stack losses- these are losses due to the hot gases leaving the stack. Temperature of the flue gas must be above 170°C. By the time SO_3 reaches the stack, most of it react with water and form H_2SO_4.
- This has to be maintained as a gas because when it reaches the dew point it corrodes the stack. This design loss amounts to 18% to 22% of the boiler loss.
- Blow down losses. This is due to total dissolved solids. This varies between 1%-3%.
- Radiation and convention heat loss from the body of the boiler. This varies between 1% - 4%.

All these constitute to thermal efficiency of the boiler which is between 71% to 80%. Combustion efficiency is the amount of heat the boiler will generate and this is between 78%-81%. (Appendix 10)

The product of the two gives the overall efficiency of the boiler. So this would then range between 55% - 65%. Applying this on table 4-8, steam output per kg of oil is as per the table 4-9 below.

Table 4-9: kg of steam generated from 1 kg of oil at 55% and 65% efficiency.

Feed water temp	Initial energy	Enthalpy ,h, at 10 bar 70% dryness fraction	Injected energy	kgs of steam per kg of oil	55% efficiency	65% efficiency
°C	kJ/kg	kJ/kg	kJ/kg	kgs	kgs	kgs
35.0	146.7	2,181.0	2,034.3	21.1	11.6	13.7
40.0	167.6	2,181.0	2,013.4	21.4	11.7	13.9
45.0	188.5	2,181.0	1,992.5	21.6	11.9	14.0
50.0	209.4	2,181.0	1,971.6	21.8	12.0	14.2
55.0	230.3	2,181.0	1,950.7	22.0	12.1	14.3
60.0	251.2	2,181.0	1,929.8	22.3	12.3	14.5
65.0	272.1	2,181.0	1,908.9	22.5	12.4	14.6
70.0	293.0	2,181.0	1,888.0	22.8	12.5	14.8
75.0	314.0	2,181.0	1,867.0	23.0	12.7	15.0
80.0	335.0	2,181.0	1,846.0	23.3	12.8	15.1
85.0	356.0	2,181.0	1,825.0	23.6	13.0	15.3
90.0	377.0	2,181.0	1,804.0	23.8	13.1	15.5
95.0	398.0	2,181.0	1,783.0	24.1	13.3	15.7
100.0	419.1	2,181.0	1,761.9	24.4	13.4	15.9

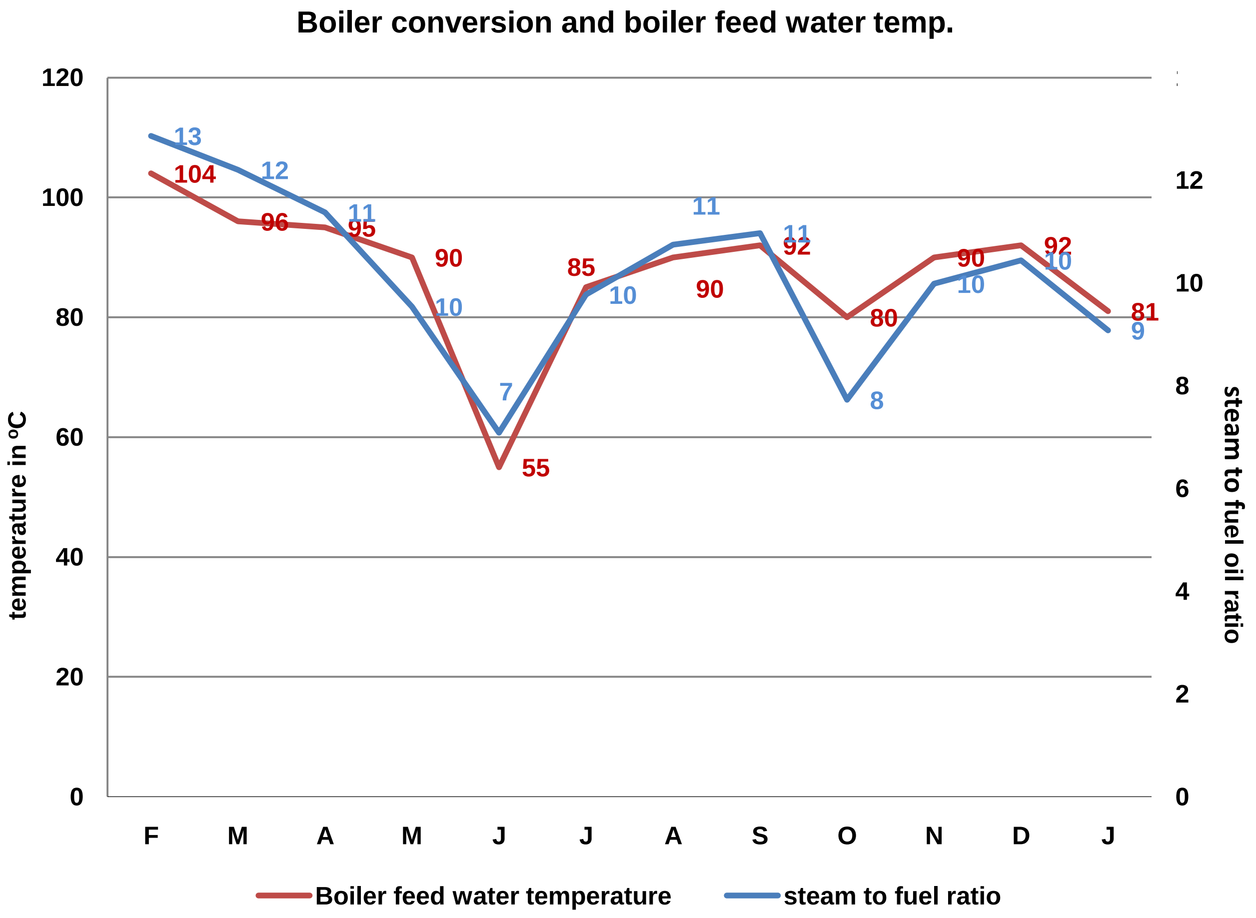


Figure 4-13 boiler conversion and feed water temperature

Figure 4-13 shows that some months had a very good conversion which is 12.87kgs of steam per litre and other very poor at 7.09kgs of steam per litre of fuel. However from the analysis there is a positive correlation of feed water temperature and steam produced per unit of fuel. Boiler efficiency can be broken in two types:

- Thermal efficiency: this is the amount of heat the boiler is able to transfer from the flue gases to the water through the metallic chamber.
- Combustion efficiency: The amount of heat that the flue gases are able to get from the oil/ fuel under combustion.

- Overall efficiency which is the product of the above two or the ratio of energy content in the fuel to that of the steam generated. [7]

In order to attain the conversion of 12kgs of steam and above, the steam going in the boiler need to be heated up-to 105°C consistently. Figure 4-10 clearly shows the relationship between boiler conversions as obtained from Unilever boiler house records. As such the systems that bring back the condensate should be maintained at optimum working conditions, and the steam injected to heat the feed water monitored so that temperatures of 100°C can be maintained. With a conversion of 12.87kgs of steam per kg of oil, this represents an efficiency of 52% from table 4-9 and table 4-10. These losses can also be attributed to unlagged sections of the feed water units as shown in figure 4-14.

Figure 4-14: Unlagged Pipes, Valves and gauges

4.8 Discussion

Diesel Generators

Unilever Kenya had an installed capacity of 4MVA of installed capacity. With a maximum demand of 1680 kVA [appendix 5] only 2 generators of 1000kVA are required. The generators should be interconnected in a synchronized to ensure they run based on the load requirements of the site. i.e. if only two factories are running and you require a load of 800kVA, then only one generator should run. This type of connection where generators run based on demand reduces fuel consumption and consequently carbon foot print reduction. All four generators consume at 150 litres of diesel when on half load and 200 litres on full load per hour. The calculation below shows how much fuel consumption can be reduced for every one hour run:

- 4 generators on half load will consume:
- 2 generators at full load will consume:
- The fuel difference is
- This represents a reduction of 33.33% as shown below.

In 2010 the site used 50,000litres of diesel costing Kes. 3,270,000. [Appendix 6]. This with two generators would have cost the business Kes. 2,180,109 saving Kes. 1,089,891.

An analysis of tariffs in the table 4.10 below shows how much savings would be realised if the company was to move away from the current CI2 tariff. The table describes all the units as described by the KPLC tariff system.

Table 4.10c. Costs associated with tariff CI3 for the same energy consumption

tariffs.xlsx

Table 4-12: Different costs for different tariffs.

Tarrif	Voltage supply	total cost	difference with the current cost
CI1	415V supply	193,387,543	(20,035,725)
CI2	11KV supply	173,351,818	
CI3	33KV supply	164,695,860	8,655,958
CI4	66KV supply	160,435,332	12,916,486
CI5	132KV supply	158,349,619	15,002,199

The analysis indicates the higher voltage supply the better, as demonstrated. If Unilever Kenya can move from tariff C12 to CI5, the factory bill would reduce by 9% equivalent to Kes. 15,000,000 per annum. The setup cost is approximated at Kes. 40,000,000. Calculating the payback period:

=2.6years, or 2years 8 months.

Heating and lighting

By switching off the lines during meal time and proper shutdown procedures, energy consumption can be reduced. Meals take 1.25 hours in a day and by switching off the machines, the heaters can reduce energy consumption by up-to 15000kWh. This is in the savoury plant as detailed in table 4-13.

Table 4-13: Reduction opportunities on the Heating Load by switching off during meals.

MACHINE	Heating loads (kW)	Proposed stoppage time (hrs)	Daily saving (KWH)	Cost
SAPAL 1	2.1	1.25	2.63	39.38
SAPAL 2	2.1	1.25	2.63	39.38
RC 1	3	1.25	3.75	56.25
RC2	3	1.25	3.75	56.25
RC 3	3	1.25	3.75	56.25
UPACK 1	3.2	1.25	4.00	60.00
UPACK 2	3.2	1.25	4.00	60.00
UPACK 3	3.2	1.25	4.00	60.00
SHUBHAM	3.2	1.25	4.00	60.00
Digifil blower motor	0.37	1.25	0.46	6.94
SHRINK WRAPPER	18	1.25	22.50	337.50
TOTAL per day			55.46	831.94
Total per week			333	4,991.63
Monthly savings			1,331	19,966.50
Annualized savings			15,973.2	239,598.00

This is a reduction of up to 16,000kWh in a year which can be up to Kes. 240,000. Further saving opportunities in the margarine factory, are illustrated in table 4-14as follows:

Table 4-14: Lighting Energy Calculation for Margarine factory.

SECTION	NO. OF BULBS	TOTAL WATTS
Staff Entrance	4 @ 36 watts	232
Packing floor	122 @ 58 watt + 6 @ 8 watts	7424
Mini lab	6 @ 58 watts	348
CIP Room	6 @ 58 watts	348
Workshop	2 @ 36 watts +4 @58 watts	304
Compressor Room	10 @ 58 watts	580
Control Room	8 @ 58 watts	464
Day storage area	30 @ 58 watts	1740
Dispatch area	16 @ 58 watts	928
TPM Room	36 @ 18 watts	648
Oil Blending area	3 @ 58 watts	174
Rework pit	4 @ 58 watts	232
Warehouse	132 @ 58 watts	7656
Dairy	28 @ 58 watts	1624
Lift	2 @ 58 watts	118
Security lights	22 @ 58 watts +8 @ 250 watts	3276
Offices	22 @ 58 watts	1276
Totals	471	27,372

TOTAL LOAD IN KW =27.372kW

KW/hr = 27.372

Daily kWh = 27.372 x 24 = 656.928

In a typical day meals take 1.5hrs (45minutes for day shift and 45 minutes for night shift). If lights are switched off during this time, we get 27.372x1.5 kWh which is 41.058kWh per day. This factory runs 7 days a week and thus this would translate to 1,149.62 kWh in a month.

1,149kWh in a month annualized to 13,795.5kWh in a year.

Multiplying this with a unit cost will translate to Kes. 180,000.

Use of strip lighting in the material store where we use halogen lamps can bring the following cost savings:

This multiplied by the unit cost totals to Kes. 1.6 Million Per year.

Table 4-15: Lighting Energy Annualized Savings for both Margarine and Savoury Factories.

Factory Lighting	Lighting load (kW)	Proposed stoppage time (hrs/day)	Daily saving (KWH)	Cost
Savoury	55.42	10	554.20	8,313.00
Margarine	27.37	10	237.7	3,565.50
Total per week			5,543	83,149.50
Monthly savings			22,173.2	332,598.00
Annualized savings			266,076	3,991,140.00

- Light separation- most lights are controlled by one switch. To have more switches so that lighting can be reduced appropriately. This means if only one part of the hall is being used then you can switch on the lights around there to provide the necessary lux level and the other section remains off.
- Switching points: Locating the switches closest to the exit of the users will allow the users to put the power off when they are leaving the rooms. For example warehouse where the switches are on one end leaving the other side without a switch. This can also be achieved by having two way switches in the factories where we have more than one exit. This would reinforce the

behavioural aspect of the employees to put off the light upon exiting the warehouse.

- Use of energy saving lights: The material store has the halogen lamps with a capacity of 400W each. This store has very low activity at night. Because of the location of the switch and the use of halogen lamps this area has the highest energy consumption at in the factory shown in figure 4-15

The balance is as follows;

Reduction;

In a week there can be a reduction by 234kWh annualized to 12,000kWh which is approximately Kes. 195,000.

Figure 4-15: Photo of Halogen Lamps

- Use of strip lighting systems;

This is putting transparent sheet on the roof to ensure natural lighting (figure 4-16) is used during the day. This can be used in all areas that have a roof which are palletizing, warehouse and tipping floor. Currently the palletizing area has strip lighting but probably more would bring better energy saving even on the packing floor.

Figure 4-16: Photo of Strip Lights

The conveying system need to be interlinked so that the motors run only when needed to as discussed here. These conveyors run throughout unless they are stopped manually. These can be interlinked with the machine so that if the machine stops they stop as well. These then feed the main conveyor as seen in figure 4-17:.

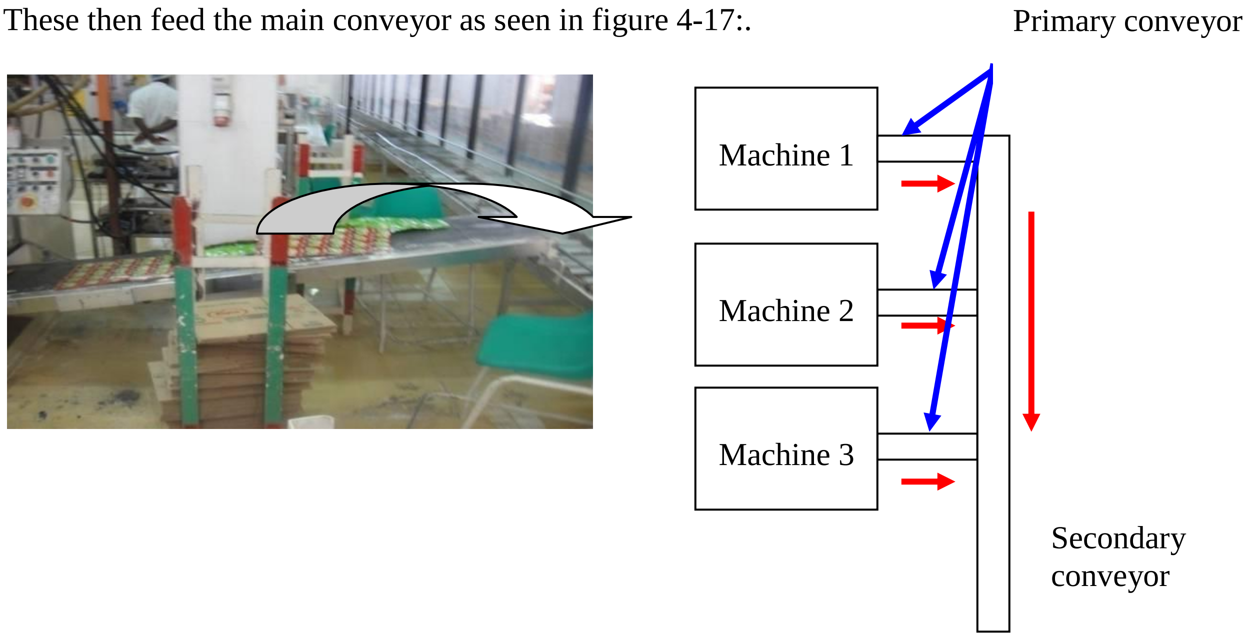


Figure 4-17: Primary and Secondary conveyors.

The cube conveyor (figure 4-18) is driven by three motors and these can be removed and only one motor installed to drive the whole length.

Figure 4-18: Main Cube conveyor

This conveyor also runs throughout and is only stopped manually. This needs a controlling system that only makes it run when there is product. Main conveyor (figure 4-19), which is always off and only put on when the product need to be pushed forward. A similar mechanism should be put to the other primary conveyors to ensure that they run only when there is product.

Figure 4- 19: Main Factory conveyors

When it comes to general air conditioning systems, the key points below can assist in improvement of energy use.

Installing dampers that can close the ducts taking the air to areas that are not in use. Current system is that when it is on it circulates air to all the areas even those that are not occupied. Regular filters cleaning schedule to ensure that there is no dust clogging on the filters. Clogged filters require use of more energy as the motor pushes the air through the resistance of the filter. Shrink sleeving generates a lot of heat and cooling is required to remove this heat. An alternative location can be sought to shrink sleeve the tubs. The maturation room need stringent preventive maintenance and cleaning operations. These include:

- Current design causes localised air circulation currents because the inlet and extraction are positioned close to each other at the top of the ceiling. Hot air should be extracted from the highest point of the room and farthest from the inlet duct.

- Cleaning of the air filters need to be implemented regularly as these cause a pressure drop of the air flowing to the chamber and this. A maintenance checklist should be deployed here. This makes sure that the amount of resistance to air flow is maintained to only that caused by the walls as the air flows.

- The height of the maturation room is 5 metres yet the effective height is only 2 meters. The total volume at 5 metres is (5x10x20) m^3 which $1000m^3$. This can accommodate 40 tonnes of RBC blend. This is $25m^3$per tonne of blend. The with an effective roof of 2m, this would be $400m^{3,}$ resulting to an effectiveness of $10m^3$ per tonne of blend. The other option would be to build a second rack and have the capacity of 70T, and thus a cooling space of $14.2m^3$ per tonne of blend.

The mixer capacity and power rating determines the most optimum usage. The Nauta mixer (figure 4-5) has a usage of 4.05kWh/ton and the Lodidge (figure 4-8a) has a usage of 13.67kWh/ton. This reflects about 3.4 times more. In future purchases, it would be recommended that higher capacity mixers be installed as this has shown to have higher output per kWh. Twin mixers are also available in the market and this has a higher tonnage per kWh. Use of energy efficient motors should also be explored, since this has not been taken to account of any of the items.

Margarine process motors consume a lot of power and since they should never be stopped, then following options should be considered;

- Use of variable frequency drives (VFD) system on the motor.
- Use of energy efficient motors. Use of EFF1 motors. low efficiency motors are labelled EFF3; standard energy efficient motors, EFF2; and high efficiency motors, EFF1
- Ensuring that the heat loss along the system is kept at minimum.

VFD system;

This is a system that first converts the incoming alternating sine wave to a DC and then converts it to an AC wave depending on the speed needed.

Calculating Synchronous Speed of a motor:

AC motors are considered constant speed motors. This is because the synchronous speed of an induction motor is based on the supply frequency and the number of poles in the motor winding. Motor are designed for 60 hz use have synchronous speeds of 3600, 1800, 1200, 900, 720, 600, 514, and 450 rpm.

To calculate synchronous speed of an induction motor, the formula below is applicable:

$$\mathbf{rpmsyn} = \frac{\mathbf{120 \times f}}{\mathbf{Np}}$$

rpm_{syn} =synchronous speed (in rpm)

f =supply frequency in (cycles/sec)

Np = number of motor poles

The synchronous speed of a four pole motor operating at 50 hz would be;

$$\text{rpms} = \frac{120 \times 50}{4}$$

=1500rpm

Power is given by the product of torque and angular velocity. Therefore the lower the velocity the lower the power consumed. By altering the frequency the speed and the power consumed can be varied according to the load as illustrated in figure 4-20:

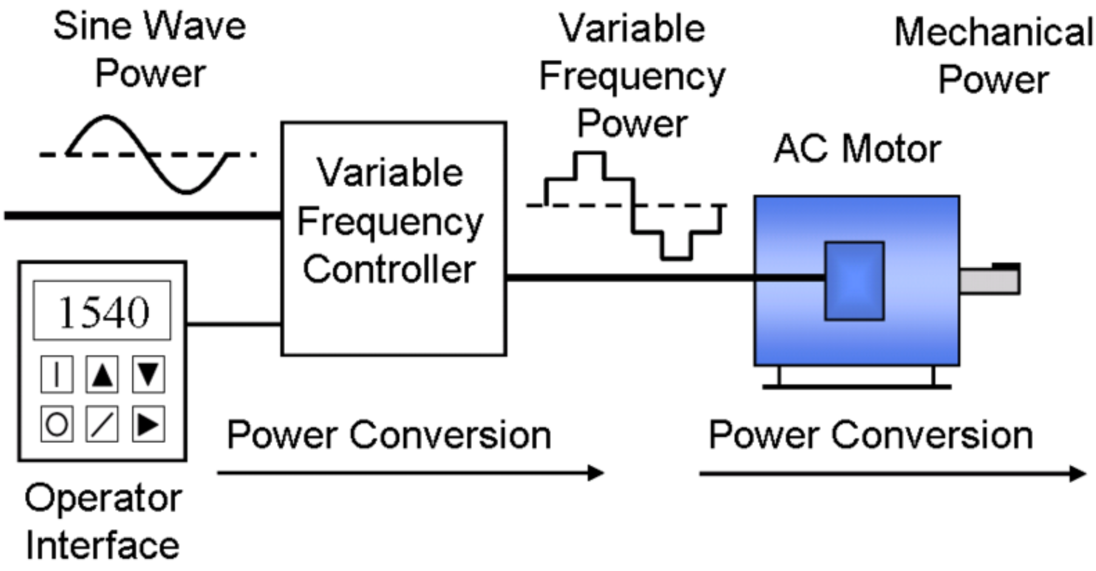


Figure 4-21: Mode of action of VFD.

Use of energy efficient motors

These are classified in three groups: EFF1, EFF2 and EFF3. EFF3 motors are those traditionally standard motors. They have no special qualities that can improve the efficiency of the motor. EFF2 motors are rated second in terms of efficiencies and are labelled to show this. EFF3 motors are not labelled at all as they are considered lowest in price.

Savoury factory has a total number of 55 motors giving a total power usage of 126.2kw [appendix 6] and spreads has a total of 49 motors giving a total of 757kW. These are all EFF3 motors. A typical comparison of these efficiencies is shown in figure 4-23.

Figure 4-22: Typical EFF1 motor

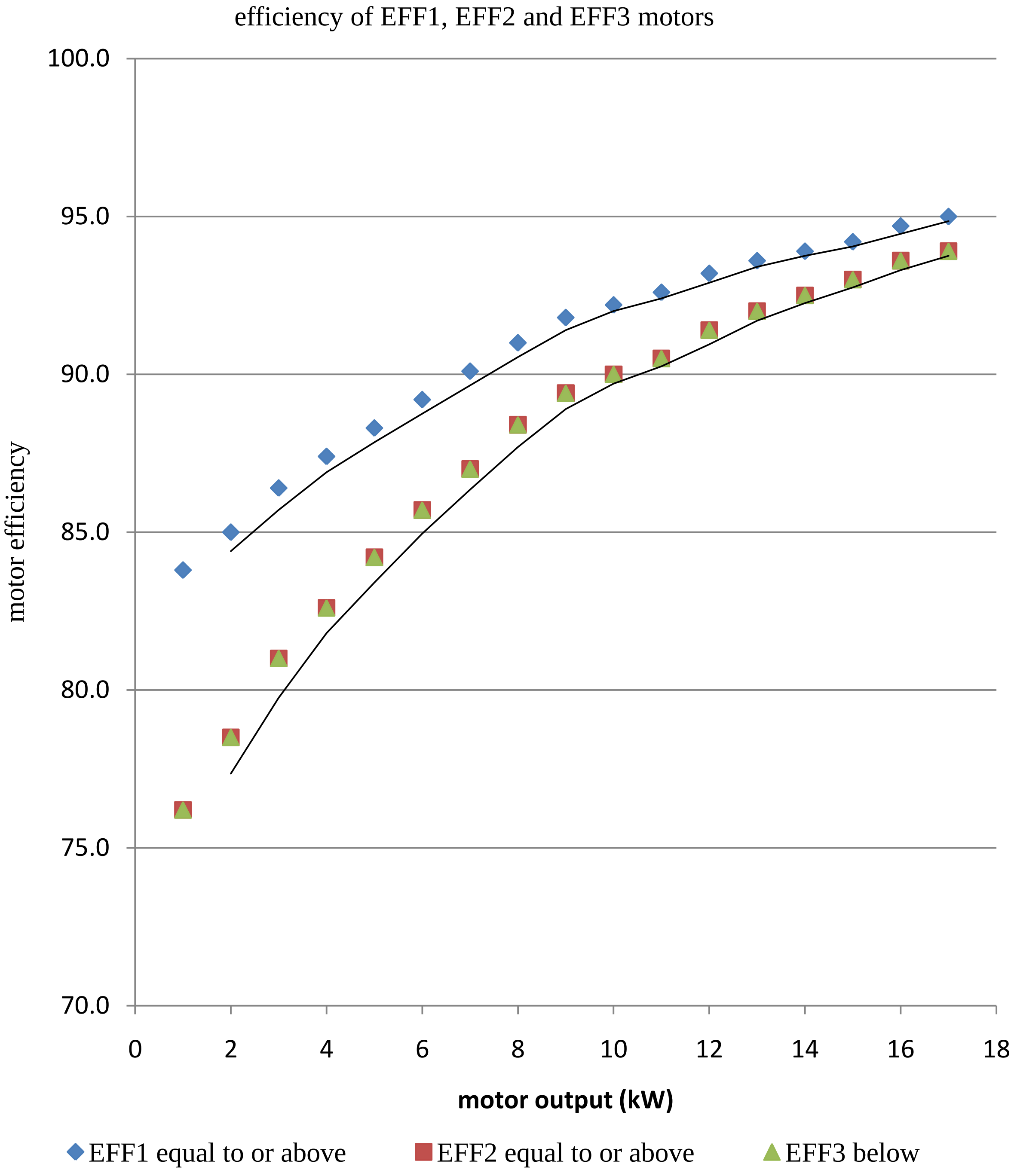


Figure 4-23: comparison of different motor efficiencies [13]

To compute the upgrade efficiency calculation, the following information is required:

- Load factor [%]: the ratio of average motor load/rated motor load for a given period of time.
- Motor power rating: rated motor output in kW or hp
- Annual operating hours
- Motor efficiency
- Electricity cost per kwh. [9]

The ammonia compressor used a 160kW motor which runs 24 hours per day for six days in a week. The loading factor is 90% and is an EFF3 motor. This would give a saving of:

=Kes. 166,204.

The cost of the motor is Kes. 1,440,000. Calculating payback period:

Simple pay back= 1,440,000/166,204

=8.6 years.

This is largely a long time and as such would recommend a phase out approach where every new motor installed for a replacement or new operation is an EFF1 motor. Table 4-16 shows other savings which can be realized in the two factories if EFF1 motors were to be adopted.

EFFI motors as show from table 4-16 can generate savings; however this should be applied on a phasing out schedule as opposed to total motor replacement in one move.

Table 4-16: Savings generated from EFF1 motors.

Motor Use (SCC)	Rating kW	Loading factor	Annual hrs	EFF3	EFF1	Savings in kWh	unit cost	savings in cash
Ammonia compressor 1	160.0	90%	7200.0	93.9	95.0	12785	13	166,204
Ammonia compressor 2	160.0	90%	7200.0	93.9	95.0	12785	14	178,989
Benhill	40.0	80%	6750.0	92.5	93.9	3482	13	45,260
Votator 1:A Unit 3	30.0	85%	7200.0	91.4	93.2	3880	13	50,434
Hamba 1	30.0	80%	6750.0	91.4	93.2	3423	13	44,501
Hamba 2	30.0	75%	6750.0	91.4	93.2	3209	13	41,720
Votator 1:A Unit 1	22.0	60%	7200.0	90.5	92.6	2382	13	30,961
Votator 1:A Unit 2	22.0	60%	7200.0	90.5	92.6	2382	13	30,961
Votator 1:A Unit 4	22.0	60%	7200.0	90.5	92.6	2382	13	30,961
Votator 2:A Unit 1	22.0	60%	7200.0	90.5	92.6	2382	13	30,961
Votator 2:A Unit 2	22.0	60%	7200.0	90.5	92.6	2382	13	30,961
Votator 3:A Unit	22.0	60%	7200.0	90.5	92.6	2382	13	30,961
Votator 4A Unit	15.0	60%	7200.0	89.4	91.8	1895	13	24,635
Main Conveyor	13.8	85%	4500.0	81.0	86.4	4058	13	52,756
Votator 1:C Unit 1	11.0	60%	7200.0	88.4	91.0	1536	13	19,966
Votator 2:C Unit 1	11.0	60%	7200.0	88.4	91.0	1536	13	19,966
Votator 4c Unit	11.0	60%	7200.0	88.4	91.0	1536	13	19,966
Votator 2:C Unit 2	7.5	60%	7200.0	87.0	90.1	1284	13	16,691
Votator 1:Bran Luebbe	7.5	80%	7200.0	87.0	90.1	1708	13	22,210
Votator 1:Bran Luebbe Pump	7.5	80%	7200.0	87.0	90.1	1708	13	22,210
Votator 3 Proportioning Pump	7.5	80%	7200.0	87.0	90.1	1708	13	22,210

Location / Used for	**Kw RATING**	**Loading factor**	**Annual hrs**	**EFF3**	**EFF1**	**Savings in kWh**	**unit cost**	**savings in cash**
Mixer 1 Stirrer	7.5	80%	4500.0	87.0	90.1	1068	13	13,881
Mixer 2 Stirrer	7.5	75%	4500.0	87.0	90.1	1001	13	13,014
Votator 4 Booster Pump	7.5	60%	7200.0	87.0	90.1	1281	13	16,657
Circulation Pump	5.5	80%	7200.0	85.7	89.2	1450	13	18,856
Votator 1:C Unit 2	5.5	60%	7200.0	85.7	89.2	1088	13	14,142
Scrubber Motor	5.0	80%	7200.0	85.7	89.2	1319	13	17,142
Buffer Tank 1 Pump	4.0	70%	4500.0	84.2	88.3	695	13	9,033
Dissolving Pump	4.0	80%	4500.0	84.2	88.3	794	13	10,323
Line 2 Main Drive	4.0	80%	6750.0	84.2	88.3	1191	13	15,485
Line 2 Vacuum Pump	3.8	80%	6750.0	84.2	88.3	1117	13	14,517
Stirrer Choco Dissolving T.	3.0	80%	4500.0	82.6	87.4	718	13	9,335
Stirrer Emulsifier	3.0	80%	4500.0	82.6	87.4	718	13	9,335
Stirrer Colour	3.0	80%	4500.0	82.6	87.4	718	13	9,335
Transfer Pump	2.2	80%	7200.0	81.0	86.4	978	13	12,711
Choco Transfer Pump	2.2	80%	4500.0	81.0	86.4	611	13	7,944
Votator 2 Proportioning Pump	2.2	60%	7200.0	81.0	86.4	733	13	9,533
Hot Water Circulation pump	2.0	85%	7200.0	81.0	86.4	944	13	12,278
Brine Pump	1.5	85%	7200.0	78.5	85.0	894	13	11,625
Bosch Line 3	1.5	85%	6750.0	78.5	85.0	838	13	10,899
Bosch Line 4	1.5	85%	6750.0	78.5	85.0	838	13	10,899
Votator 3 PHE Pump	1.5	85%	7200.0	78.5	85.0	894	13	11,625

Location / Used for	**Kw rating**	**Loading factor**	**Annual hrs**	**EFF3**	**EFF1**	**Savings in kWh**	**unit cost**	**savings in cash**
Feed Pump	1.1	85%	7200.0	76.2	83.8	801	13	10,416
Votator 1:PHE Pump	1.1	85%	7200.0	76.2	83.8	801	13	10,416
Emulsifier Pump	1.1	85%	3600.0	76.2	83.8	401	13	5,208
Hot Water Pump	0.8	85%	7200.0	76.2	83.8	546	13	7,102
Line 1 Outfeed Conveyor	0.6	85%	4500.0	76.2	83.8	250	13	3,255
Line 2 Outfeed Conveyor	0.3	85%	4500.0	76.2	83.8	114	13	1,480
Line 3 Outfeed Conveyor	0.2	85%	4500.0	76.2	83.8	82	13	1,065
Line 4 Outfeed Conveyor	0.2	85%	4500.0	76.2	83.8	82	13	1,065
Votator 1:Bran Luebbe Pump	0.2	85%	7200.0	76.2	83.8	131	13	1,704
Total	**757**			**4,308**		**93,921**		**1,233,764**
Savoury								
Lodidge mixer	41.0	90%	7200.0	92.0	93.6	4936	13	64,174
z arm	15.0	90%	1800.0	89.4	91.8	711	13	9,238
Nauta mixer	8.5	80%	6750.0	87.0	90.1	1815	13	23,598
D-Dust	7.5	85%	7200.0	87.0	90.1	1815	13	23,598
U-Pack 1Main Drive	4.5	80%	6750.0	84.2	88.3	1340	13	17,421
U-Pack	4.5	75%	6750.0	84.2	88.3	1256	13	16,332
Sapal 2	3.0	60%	7200.0	82.6	87.4	862	13	11,202
Sapal 2	3.0	60%	7200.0	82.6	87.4	862	13	11,202
Sapal 1	3.0	60%	7200.0	82.6	87.4	862	13	11,202
Sapal 1	3.0	60%	7200.0	82.6	87.4	862	13	11,202
U-Pack 1Main Drive	3.0	60%	7200.0	82.6	87.4	862	13	11,202

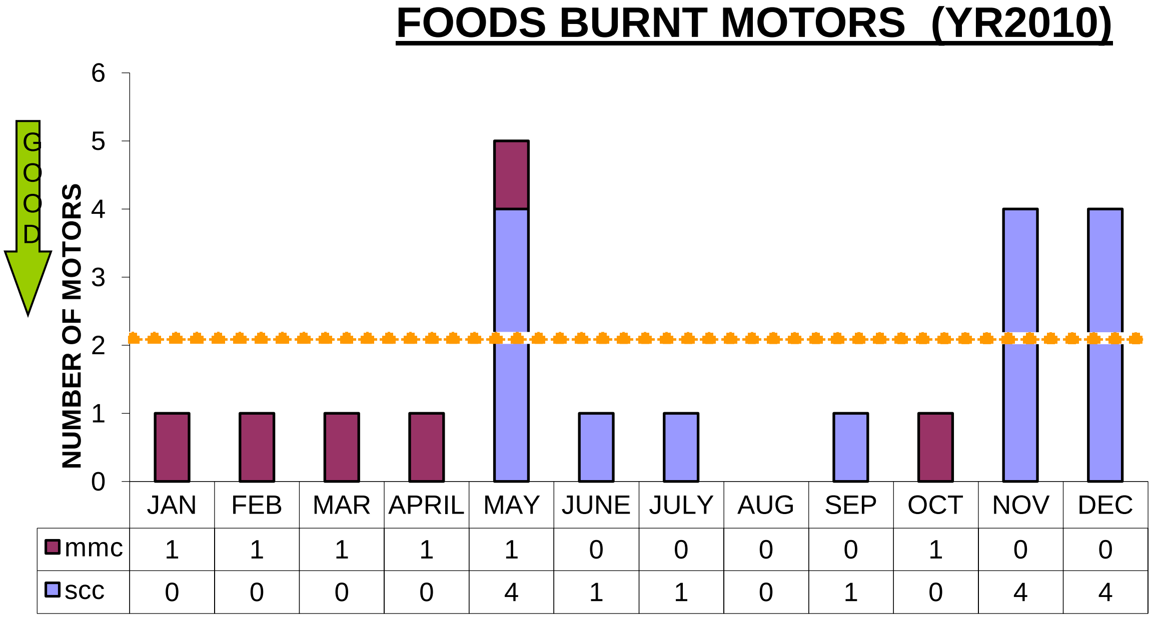
Location / Used for	**Kw rating**	**Loading factor**	**Annual hrs**	**EFF3**	**EFF1**	**Savings in kWh**	**unit cost**	**savings in cash**
Servofill	2.4	60%	7200.0	81.0	86.4	803	13	10,443
Morten mixer	1.8	60%	7200.0	78.5	85.0	757	13	9,847
Aircon	1.8	85%	4500.0	78.5	85.0	671	13	8,719
Aircon	1.8	60%	7200.0	78.5	85.0	757	13	9,847
Aircon	1.8	60%	7200.0	78.5	85.0	757	13	9,847
Palletizing Roller	1.8	60%	7200.0	78.5	85.0	757	13	9,847
Granulator	1.5	60%	7200.0	78.5	85.0	631	13	8,206
Humidifier	1.5	80%	7200.0	78.5	85.0	842	13	10,942
RC1	1.5	80%	7200.0	78.5	85.0	842	13	10,942
Conveyor	1.5	80%	7200.0	78.5	85.0	842	13	10,942
U-Pack Hoist	1.5	80%	4500.0	78.5	85.0	526	13	6,839
Digifill	1.5	75%	4500.0	78.5	85.0	493	13	6,411
Digifill	1.5	60%	7200.0	78.5	85.0	631	13	8,206
Digifill	1.5	80%	7200.0	78.5	85.0	842	13	10,942
Palletizing Case Screw	0.7	60%	7200.0	76.2	83.6	331	13	4,306
Palletizing Case Screw	0.7	80%	7200.0	76.2	83.6	442	13	5,741
U-Pack	0.5	70%	4500.0	76.2	83.6	183	13	2,378
Digifill	0.4	80%	4500.0	76.2	83.6	155	13	2,011
Induction fan	0.4	80%	6750.0	76.2	83.6	226	13	2,936
Induction fan	0.4	80%	6750.0	76.2	83.6	226	13	2,936
Corozza	0.4	80%	4500.0	76.2	83.6	151	13	1,957
U-Pack 1Main Drive	0.3	80%	4500.0	76.2	83.6	125	13	1,631
RC2	0.2	80%	4500.0	76.2	83.6	75	13	979

Location / Used for	**Kw rating**	**Loading factor**	**Annual hrs**	**EFF3**	**EFF1**	**Savings in kWh**	**unit cost**	**savings in cash**
RC3	0.2	80%	7200.0	76.2	83.6	120	13	1,566
RC4	0.2	80%	4500.0	76.2	83.6	75	13	979
RC5	0.2	60%	7200.0	76.2	83.6	90	13	1,174
New Corozza	0.2	85%	7200.0	76.2	83.6	128	13	1,664
U-Pack 1	0.2	85%	6750.0	76.2	83.6	120	13	1,560
U-Pack 1Main Drive	0.2	85%	6750.0	76.2	83.6	120	13	1,560
U-Pack 1Main Drive	0.2	85%	7200.0	76.2	83.6	128	13	1,664
Coding Conveyor	0.2	85%	7200.0	76.2	83.6	128	13	1,664
Shrink Wrapper	0.2	85%	7200.0	76.2	83.6	128	13	1,664
Shrink Wrapper	0.2	85%	3600.0	76.2	83.6	64	13	832
U-Pack	0.2	85%	7200.0	76.2	83.6	128	13	1,664
U-Pack 1	0.1	85%	4500.0	76.2	83.6	40	13	520
U-Pack 1	0.1	85%	4500.0	76.2	83.6	40	13	520
U-Pack 1	0.1	85%	4500.0	76.2	83.6	40	13	520
U-Pack 1	0.1	85%	4500.0	76.2	83.6	40	13	520
U-Pack 1	0.1	85%	7200.0	76.2	83.6	64	13	832
Shrink Wrapper	0.1	85%	7200.0	76.2	83.6	64	13	832
Shrink Wrapper	0.1	85%	7200.0	76.2	83.6	64	13	832
Corozza	0.1	85%	7200.0	76.2	83.6	64	13	832
Sapal 2	0.1	85%	7200.0	76.2	83.6	57	13	739
Sapal 1	0.1	85%	7200.0	76.2	83.6	57	13	739
Total Savoury	**126**					**30,136**		**391,762**
Total Both factories	**883**					**124,057**		**1,625,526**

Motor rewinding

More often than not, when a motor burns the obvious quickest approach is to rewind the motor. If the magnetic core of a failed motor is undamaged and appropriate procedures are followed, a rewound motor will retain its original efficiency. Properly repaired, a “standard” efficiency motor will have its original “standard” efficiency, and an energy-efficient (EE) motor will have its original high efficiency. The drop is normally 0.3% to 1% representing a 0.6% drop on average on first rewinding. [9] This then becomes a quick stop gap as new motors are sought.

Figure 4-24 shows the average number of motors that got the windings burnt in 2010 in both spreads and savoury factories:



	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
🟥 mmc	1	1	1	1	1	0	0	0	0	1	0	0
🟦 scc	0	0	0	0	4	1	1	0	1	0	4	4

Figure 4-24: Burnt motors 2010.

The month of May, November and December seem to have a high motor failure rate in the margarine factory. This may be attributed to the weather conditions and subsequently power fluctuations. Installing uninterrupted power supply back up system will reduce this level of motors burnouts. This is not only to help with issue of motor burnouts but looking at the process, any time there is power fluctuation, margarine solidifies in the crystallization units and this can take hours to unblock.

Opportunities in the Ammonia system

Lagging

Once the ammonia is cooled and is in liquid state ready to be taken to the factory, any heat along the way will be absorbed, using the energy in the way not intended. As such any pipe from the condenser to the evaporator must be fully lagged and sized correctly. The illustration in figure 4-25 shows the need to lag all the pipes from the condenser at the ceiling to the votators where cooling is done.

Figure 4-25: Unlagged Sections.

Un-lagged sections cause a lot of heat absorption near the votators. The work done here to cool the vapour in the atmosphere and cause this level of icing could have been used to cool the product itself. This is energy lost and to avoid heat absorption near the votators lagging need to be done appropriately.

Figure 4-29: Unlagged Sections of the Ammonia Receiver Leading to Icing

At the ammonia receiver the gas is still causing icing (figure 4-29), means either there is lack of complete cooling at the evaporator or the gas is still cooler than the ambient temperature. If there is proper cooling then the gas ammonia receiver need to be lagged so that the gas remains cool and when it is taken for compression then it does not convert to too much heat, requiring more energy at the condensing unit. Heat absorption along the process receivers meaning more work will be done to remove this heat at the condensers.

Pipe sizing

The original design of this factory was for 2-160kW compressors running concurrently. Over the years change of product and innovations has led to the use of only one compressor while the other one remains redundant. However the piping still remains the same size. This has the following several impacts. More ammonia is needed to fill the oversized pipes.

- Since the pipes are bigger and the ammonia needed at the evaporators is less, more energy is lost in the system as the ammonia is left idle in the system. Examples of redundant pipes are shown in figure 4-30 which are filled with ammonia:

Figure 4-30: unused redundant pipes and oversized pipes

Use of Variable frequency drive

Use of the VSD to run the ammonia compressor motor will help reduce the intake current to the current required by the load.

Chapter 5: Conclusion and Recommendations

In conclusion, the following are opportunities for energy use reduction and better energy management. These arise from the use of traditional methods which have high usage and waste. The study demonstrates how and where the use of modern methods provides energy saving opportunities from the design of the structures and the point of purchase of new equipments. The following recommendations are thus made which if applied would greatly improve the energy management and increase the savings:

- Use of natural lighting to light the factories. This is especially so in the Savoury factory packing floor, material store, maturation room and the mixing room.
- Moving from the current CI2, 11kV supply to CI4, supply of 66kV to the site. This would save the company about Kes. 12, 916,486 annually.
- Combine all the generators so that they feed to one grid within the site. With a maximum demand of 1800kVA, only two generators would be required as opposed to the current four. This also increases reliability of the redundant system. This would reduce the running costs of generators by 33.3%.
- Light switching splitting. The switches especially in Savoury plant need to be split so that every switch lights fewer number of lights. An average of 6 per floor with two way stitches should be used. This is in packing floor, powder feeding, maturation, raw material store and tipping rooms.
- Use of less energy consuming bulbs. This involves the removal of 400W halogen lamps in savoury stores and replacing them with 36W fluorescent tubes.

- Switching off the lights during meal breaks at night and when in use during the day. This is for both spreads factory and savoury factory.
- Use solar power for the security lighting.
- Use of economies of scale when buying new machines. In savoury instead of using single and twin lanes for example Rovema which is single lane packing 75g sku and upack 2 which is twin lane packing 15g, purchase should be done for six lanes and above. Use of half tonne mixer units where 1.5tonne or 2 tonne mixers are available should be avoided.
- Sub-metering should be even in the security lighting.
- All the big consumers should have independent meters e.g. the ammonia compressor motors in spreads.
- Resizing systems to fit the demand in cases where we have capacity changes for the ammonia system, boiler systems, compressed air system. The ammonia system piping system still has the capacity of running 90,000 metric tons a year yet the production has gone down to 25,000metric tons. This needs resizing. The boiler which is 11.5t/hr only runs at 3t/hr and as such at 25% capacity utilisation. This is quite in efficient and a smaller boiler needs to replace the 11.5t/hr boiler.
- Creating awareness to the teams about energy savings and opportunities available. This means changing the culture of switching off lights when not in use.
- All EFF3 motors should be gradually phased out with EFF1 motors.

- Further analysis need to be done to get the benefits of installing a UPS for the margarine factory against the cost of the motors that burn out. However the interruptions and subsequent production losses caused by this should also be taken into account.
- Further analysis should also be done in the renewable energy where power can be generated from the sister company Unilever Tea using hydro and then transmitted to Nairobi over the National grid.

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Appendices

Appendix 1 sample of electricity bills:

Oct Elec Bill.pdf

Appendix 2: Savoury electrical installed capacity

SAVOURY ELECTRICAL INSTALLED CAPACITY						
		Running Hrs/day	Lighting KW	Machine name	Heating **(kW)**	Motors(kW)
1	**Packing floor**					
	(a) royco mchuzi mix rmm	24hrs	6.235			
				u pack 1	3.2	0.67
				Rovema	0.8	1.75
				u-pack 2	1.8	1.75
				Shubham	6.6	1.71
				u pack 3	4.4	14.11
				Digifil	_	2.25
	(b) royco beef cubes	24hrs	6.235			
				Sapal 1	2.1	2.59
				Sapal 2	2.1	2.59
				RC 1	2.5	8.07
				RC 2	2.5	8.07
				RC 3	2.5	8.07

		Running Hrs/day	Lighting KW	Machine name	Heating **(kW)**	Motors(kW)
				RC 4	2.5	8.07
				Cramsa	2.5	1.84
	conveyor belt motors	24hrs	_			2.22
2	**processing area**					
	(a) tipping	24hrs	4.32		_	11.25
	(b) maturation	24hrs	4.44		_	26.95
	© rmm/mc feeding	24hrs	5.30		_	4.47
	(d) discharge area	24hrs	4.88		_	_
3	**weighing station**	24hrs	4.28		_	2.39
4	**warehouse**	5	5.36		_	0.07
5	**palletising area**	24	3.62		_	0.26
6	**Offices**	9	5.36		8.1	_
7	**security lighting**	10	3.50		_	_
8	**stair case lighting**	12	1.33		_	_
9	**Shrink tunnel**		0.56			17.00
	Totals		55.42		41.60	126.15
	TOTAL					222.60

Appendix 3: Margarine installed capacity

Section		**Lighting (kW)**	**Motors**	**motor rating (kW)**	**Heaters**	**(kW)**	**Total (kW)**
Ammonia room		0.58	Compressor 1	160			
			Pump	4			
			compressor 2	160			
			Pump	4			
			chilled water pump 1	4			
			" 2	3			
Total		**0.58**		**335**			**335.58**
Packing floor	Packing M/C	3.944					
		0.12	Hamba	2.2,0.18, 0.55,0.75	Spot sealer	0.5	
					sealing heater	1.31	
			Benhill	0.55,3,5.5	Sealing heater	2.66	

Section		**Lighting (kW)**	**Motors**	**motor rating (kW)**	**Heaters**	**(kW)**	**Total (kW)**
			Bosch line 3	1.5	Sealing heater	1	
				0.18	"	0.15	
			Bosch line 4	1.5	"	1	
				0.18			
				0.55	"	0.15	
			conveyor	0.55			
				0.55			
				0.55			
				0.55			
				2.2			
Total		**4.064**		**21.04**		**6.77**	**31.874**
Process							
		2.32	votator 1	22			
		0.04		30			
				22			
				22			
				11			
				5.5			
				1.1			

				7.5			

Section		**Lighting (kW)**	**Motors**	**motor rating (kW)**	**Heaters**	**(kW)**	**Total (kW)**
				0.18			
				7.5			
				0.18			
			votator 2	22			
				22			
				11			
				7.5			
				1.5			
			pin melter	4			
				0.18			
				7.5			
				3			
				5.5			
				5.5			
			votator 3 1	15			
				11			
				7.5			
				22			
				4			

				2.2			

Section		**Lighting (kW)**	**Motors**	**motor rating (kW)**	**Heaters**	**(kW)**	**Total (kW)**
			pin melter	5.5			
			mixer tanks transfer pump	3			
			emulsifier 1	7.5			
			2	3			
			Colour	3			
			mixer 1	7.5			
			mixer 2	7.5			
			New line	3			
				2.2			
				5.5			
				5.5			
Total		**2.36**		**333.54**			**335.9**
Dairy		1.16	Mixer 1	5.5			
			" 2	5.5			
			" 3	5.5			
			stirrer 1	5.5			
			" 2	5.5			
			" 3	5.5			

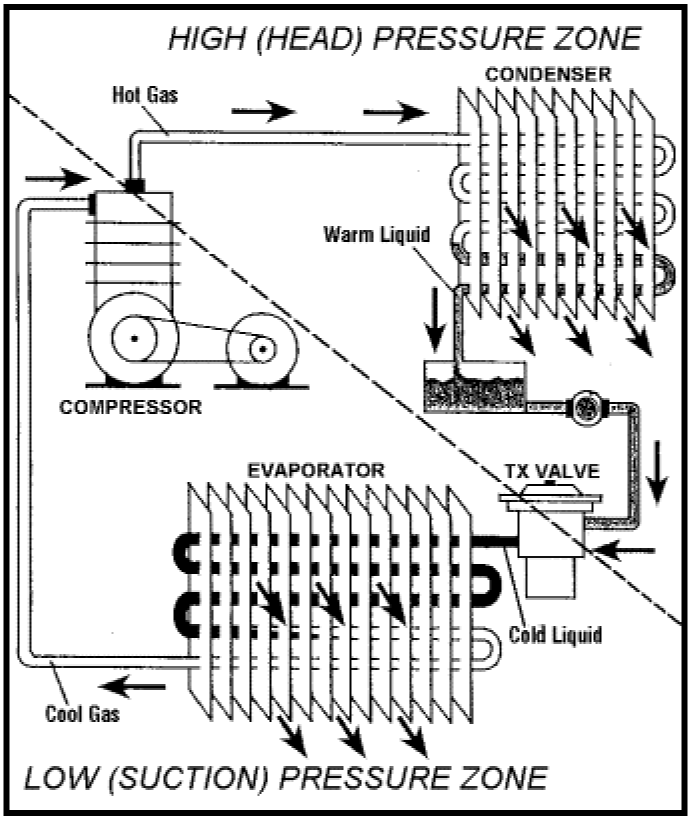
			transfer pump 1	4			
			" 2	4			

Section		**Lighting (kW)**	**Motors**	**motor rating (kW)**	**Heaters**	**(kW)**	**Total (kW)**
			" 3	3			
			" 4	4			
			pasteurization	1.1			
			hot water	2			
			Brine	2.2			
Total		**1.16**		**53.3**			**54.46**
Offices		1.276					
Total		**1.276**					**1.276**
Store		8.352					
Total		**8.352**					**8.352**
Dispatch area		1.508					
		0.12					
Total		**1.628**					**1.628**
Workshop		0.348					
Total		**0.348**					**0.348**
Lab		0.348					
		0.04					

Total		**0.388**					**0.388**

Section		**Lighting (kW)**	**Motors**	**motor rating (kW)**	**Heaters**	**(kW)**	**Total (kW)**
Ground store		0.928					
		0.04					
Total		**0.968**					**0.968**
Entry area		0.232					
		0.04					
Total		**0.272**					**0.272**
Reworks		0.348		3.5			
Total		**0.348**		**3.5**			**4.196**
CIP room		0.116	buffer tank pump	7.5			
		0.04	Tetra-al pump	4			
Total		**0.156**		**11.5**			**11.656**
TOTAL HEAT LOAD							**786.898**

Appendix 4: typical refrigeration system



Appendix 5; Energy breakdown

	High rate	Low rate	total energy (kWh)	Max Demand KVA	Max Demand KW
Jan	645,100	623,800	1,268,900	1,657	1,624
Jan	624,160	623,800	1,247,960	1,652	1,624
Feb	624,160	623,800	1,247,960	1,652	1,624
Mar	384,200	415,560	799,760	1,655	1,622
Apr	397,936	443,040	840,976	1,593	1,561
May	411,280	405,912	817,192	1,596	1,548
Jun	435,208	497,360	932,568	1,615	1,579
Jul	336,384	340,016	676,400	1,707	1,667
Aug	415,368	439,688	855,056	1,711	1,672
Sep	380,040	369,072	749,112	1,738	1,708
Oct	431,032	461,432	892,464	1,706	1,674
Nov	451,576	486,080	937,656	1,766	1,720
Dec	456,072	491,000	947,072	1,777	1,730
Jan	395,508	441,040	836,548	1,695	1,658
Average	**456,287**	**475,829**	**932,116**	**1,680**	**1,644**

Appendix 6: Diesel issues system extract:

DESCRIPTION	ISSUEDATE	QTY	AVGUNITCOST	EXTCOST	NUMISSUETO	NUMCHARGETO
Diesel Oil	10/3/2010	-10000	68.5	-685000	2663	25KC
Diesel Oil	11/13/2010	-10000	63.5	-635000	2663	25KC
Diesel Oil	4/16/2010	-10000	65	-650000	2663	25KC
Diesel Oil	4/20/2010	-10000	65	-650000	2663	25KC
Diesel Oil	4/24/2010	-10000	65	-650000	2663	25KC
Total		50,000		3,270,000		

Appendix 7: Motors in Savoury and SCC factories

SCC				Savoury	
LOCATION / USED FOR	Kw RATING			LOCATION / USED FOR	Kw RATING
Buffer Tank 1 Pump	4		1	Granulator	1.5
Transfer Pump	2.2		2	Lodidge mixer	41
Feed Pump	1.1		3	Nauta mixer	8.5
Dissolving Pump	4		4	Morten mixer	1.8
Hot Water Pump	0.75		5	z arm	15
Brine Pump	1.5		6	Induction fan	0.36
Ammonia compressor 1	160				
Ammonia compressor 2	160		7	Induction fan	0.36
Choco Transfer Pump	2.2		8	Aircon	1.8
Circulation Pump Choco	5.5		9	Aircon	1.8
Stirrer Choco Dissolving T.	3		10	Aircon	1.8
Hot Water Circulation	2		11	D-Dust	7.5
Bosch Line 3	1.5		12	Humidifier	1.5
Bosch Line 4	1.5		13	RC1	1.5
Line 3 Outfeed Conveyor	0.18		14	RC2	0.18
Line 4 Outfeed Conveyor	0.18		15	RC3	0.18
Line 2 Main Drive	4		16	RC4	0.18
Line 2 Vacuum Pump	3.75		17	RC5	0.18
Line 2 Outfeed Conveyor	0.25		18	New Corozza	0.18
Line 1 Outfeed Conveyor	0.55		19	New Corozza	0.18
Main Conveyor (five)	13.75		20	Sapal 2	3
Scrubber Motor	5		21	Sapal 2	3
Votator 1:A Unit 1	22		22	Sapal 1	3
Votator 1:A Unit 2	22		23	Sapal 2	0.08

Votator 1:A Unit 3	30		24	Sapal 1	0.08
Votator 1:A Unit 4	22		25	Sapal 1	3

SCC				Savoury	
LOCATION / USED FOR	Kw RATING			LOCATION / USED FOR	Kw RATING
Votator 1:C Unit 1	11		26	Conveyor	1.5
Votator 1:C Unit 2	5.5		27	U-Pack 1	0.18
Votator 1:PHE Pump	1.1		28	U-Pack 1	0.09
Votator 1:Bran Luebbe	7.5		29	U-Pack 1	0.09
Votator 1:Bran Luebbe Pump	7.5		30	U-Pack 1	0.09
Votator 1:Bran Luebbe Pump	0.18		31	U-Pack 1	0.09
Votator 2:A Unit 1	22		32	U-Pack 1	0.09
Votator 2:A Unit 2	22		33	U-Pack 1Main Drive	3
Votator 2:C Unit 1	11		34	U-Pack 1Main Drive	0.3
Votator 2:C Unit 2	7.515		35	U-Pack 1Main Drive	0.18
Votator 2 Proportioning Pump	2.2		36	U-Pack 1Main Drive	0.18
Votator 3:A Unit	22		37	U-Pack 1Main Drive	4.5
Votator 3 Proportioning Pump	7.5		38	Palletizing Case Screw	0.66
Emulsifier Pump	1.1		39	Palletizing Case Screw	0.66
Stirrer Emulsifier	3		40	Coding Conveyor	0.18
Stirrer Colour	3		41	Shrink Wrapper	0.09
Mixer 1 Stirrer	7.5		42	Shrink Wrapper	0.09
Mixer 2 Stirrer	7.5		43	Shrink Wrapper	0.18
Votator 4A Unit	15		44	Shrink Wrapper	0.18
Votator 4c Unit	11		45	Palletizing Roller	1.8
Votator 3 PHE Pump	1.5		46	U-Pack	0.5
Votator 4 Booster Pump	7.5		47	U-Pack	0.18
Hamba 1	30		48	U-Pack	4.5
Hamba 2	30		49	U-Pack Hoist	1.5
Benhill	40		50	Digifill	1.5
			51	Digifill	1.5
			52	Digifill	1.5
			53	Digifill	0.37
			54	Corozza	0.09
			55	Corozza	0.36
			56	Servofill	2.41
Total	**757**				**126.2**

Appendix 8; comparison of eff1, eff2 and eff3 motors.

2 pole				4pole			
	Efficiences %				Efficiences %		
kW rating	**EFF1**	**EFF2**	**EFF3**	**kW rating**	**EFF1**	**EFF2**	**EFF3**
1.1	82.8	76.2	76.2	1.1	83.8	76.2	76.2
1.5	84.1	78.5	78.5	1.5	85.0	78.5	78.5
2.2	85.6	81.0	81.0	2.2	86.4	81.0	81.0
3	86.7	82.6	82.6	3	87.4	82.6	82.6
4	87.6	84.2	84.2	4	88.3	84.2	84.2
5.5	88.6	85.7	85.7	5.5	89.2	85.7	85.7
7.5	89.5	87.0	87.0	7.5	90.1	87.0	87.0
11	90.5	88.4	88.4	11	91.0	88.4	88.4
15	91.3	89.4	89.4	15	91.8	89.4	89.4
18.5	91.8	90.0	90.0	18.5	92.2	90.0	90.0
22	92.2	90.5	90.5	22	92.6	90.5	90.5
30	92.9	91.4	91.4	30	93.2	91.4	91.4
37	93.3	92.0	92.0	37	93.6	92.0	92.0
45	93.7	92.5	92.5	45	93.9	92.5	92.5
55	94.0	93.0	93.0	55	94.2	93.0	93.0
75	94.6	93.6	93.6	75	94.7	93.6	93.6
90	95.0	93.9	93.9	90	95.0	93.9	93.9

Appendix 9: Fuel oil analysis

Appendix 10: Photo of the boiler display panel showing the combustion efficiency.