Energy Conservation and Auditing of Master Industrial Complex

A Thesis by

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In

ENERGY ENGINEERING

By

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Declaration

I am pleased to announce that substance of the proposal, "Energy Conservation and Auditing of Master Industrial Complex", maker of UPVC Pipes and Fittings, PPRC Pipes and Fittings, Poly-Plastics and clean products, are results of my own data, further the calculations, examinations and no part has been replicated from any distributed source (with the exception of the references some standard tables/ conditions / conventions and so forth.). I further state that this work has not submitted anywhere for honor of some recognition/degree. The University may take some action if the above proclamation is revealed wrong at any stage.

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Abstract

The energy demand is increasing annually by 5% because of the increasing population and industrial expansion in Pakistan. The major source of electrical consumption by industry is 34% in Pakistan. Energy conservation and auditing techniques were applied to Master Industrial Complex, manufacturer of upvc, pprc, sanitary-ware products. Our Aim was to minimize the cost of energy, operational cost, reconstruction and demolishing cost by proper selection of space. The Master Industrial Complex was selected for the proposed solution of the equipment selection and energy efficient equipment. The efficiency of Injection Molding machines and some other machines were determined with the help of old and new machines.

The production is maximized by proper selection of man, machine and material. The different techniques of audit have been conducted by using the walk through audit technique and detail audit technique for the analysis of machines. The financial report and data analysis report has been used for the Master Industrial Complex Project.

Energy flow processes were studied in detail and improvements were suggested for overall energy efficiency gain of system without compromising on operating conditions. For this study walk through interviews, investigation of energy flows and physical inspection of equipment were carried out. The installed capacity of the Master Industrial Complex is 3008 KW. This study analyzes not only the selection for VFD drive systems for compressors, pumps and fans, but also analyzes the energy conservation opportunities for lighting, motors, peak load control. Energy action plan was implemented for PF control as well.

This study suggests the replacement of CFL's (Compact fluorescent light) with LED (Light emitting diode) lamps. It also analyzes the diesel and gas generator exhaust for the waste heat recovery boiler as case study. In this study we observe the impact of energy and cost savings by relocation of factory, also we study the risk assessment of the project. Recommendations are provided to the management of Master Industrial Complex about their energy consumption, which include redefinition of the energy load and installation of solar street lighting for energy conservation and annual energy saving. This study analyzes all types of energy consumption like electricity consumption and production rate per hour, and also analyzes the impact of VFD for the pumps and motors as it saves 30-50 % energy. The VFD were placed on the compressors, pumps and fans where motors have been used. The capacitor bank were used to maintain the PF and save penalty in utility bills.

Key Words: Energy Conservation; Energy Auditing; Energy saving by placing VFD; Energy Conservation by Old and New Machines; Energy Conservation by WHR Boiler; Energy Conservation by Lighting and Solar Street Lights.

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Acronyms and Abbreviations

Q = Flow Rate

S = Cross Sectional Area (m^2)

V = Flow Velocity (m/sec)

ρ = Density (kg/m^3)

C_p = specific heat constant (kJ/Kg °C)

ΔT = Difference of Temperature (°C)

IGBT = Insulated Gate Bipolar Transistors

EPS = Expanded Poly-Styrene

IM= Injection Molding

WHR= Waste Heat Recovery

CO_2 = Carbon Dioxide

VFD = Variable Frequency Drive

WH = Waste Heat

VAR = Volt Amp Reactive

PF= Power Factor

CFL= Compact fluorescent light
V= Voltage

I= Current

HVAC= Heating Ventilation and Air Conditioning

kW = Kilo Watt

VFD= Variable Frequency Drive

HP= Horse Power

EnPI = Energy Performance Indicator.

PA= Phase Advancer

η = volumetric efficiency

THE = Thermosyphone Heat Exchanger

1 Introduction

1.1 Introduction to Master Industrial Complex

This thesis presents the complete study of the energy conversation and auditing of Master Industrial Complex. Our Aim is to minimize the cost of energy, minimize the operational cost, reconstruction and demolishing cost by proper selection of space. Then propose suitable energy efficient equipment. We will determine the efficiency of some machines and also calculate energy conservation in term of energy and cost. We have maximized the production by proper selection of man, machine and material by studying different techniques of production. We have used the walk through audit technique and detail audit technique for the analysis of machines. We have developed a financial and data analysis report for the Master Industrial Complex Project. We analyze the energy conservation opportunities for lighting, motors, peak load control, PF, WHR boiler, compressor and also calculate the old and new machines comparison with respect to energy and production rate. We analyze the diesel generator exhaust for the WHR boiler as the case study. We selected the UPVC 2 unit for the energy auditing and conservation techniques and applied these techniques to conserve energy for the Master Industrial Complex. The total approximate load of Master Industrial Complex is giving in Pie Chart.

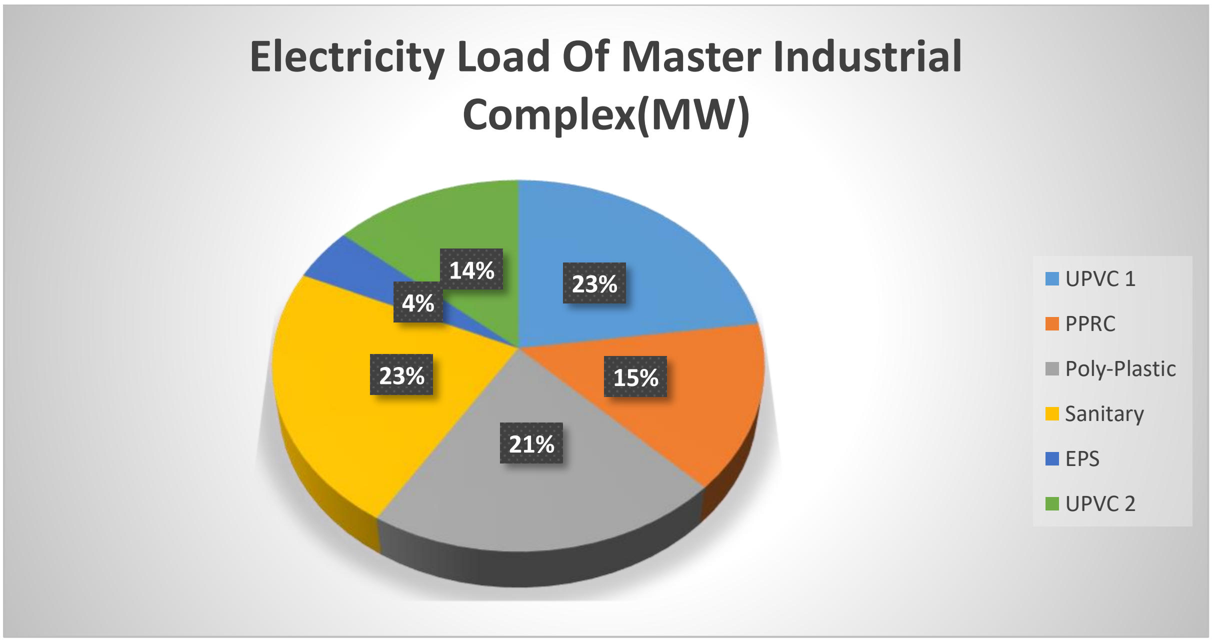


Figure 1.1: Consumption of load by each unit of Master Industrial Complex

1.2 Mass Balance Sheet

Every Industry has their own amount and quantity of waste that is received from the production and can be utilized and energy can be saved from that waste material and also it can be sold so we categorized the waste into solid liquid and gases form.

1.2.1 Solid Waste Mass Balance

Table 1: Mass Balance for Solid Waste

Waste Material	Control Mechanism
Plastics	Selling out as Scrap
Card Board	
Metal Scrap EPS Waste	

Source: Packaging material.

Quantity: Not fixed, varies because of production schedule.

1.2.2 Liquid Waste Mass Balance

Table 2: Mass Balance for Liquids

Area	Waste Material	Discharge	Control
RO / Water Treatment	High TDS RO Rejected Water	2,800 ltr / hr	Primary Treatment through Septic Tank
	Caustic Solution	30 ltr / day	
	Detergents during cleaning and sanitation	-	
Extruder Hall	Waste Water during cooling	2000 gal / hr	
	Drain water from pipe extrusion line as cooling	-	
	Detergents and sanitizers	-	
Injection Molding	Waste Water from mold and dies	8000 gal/hr	
	Drain water from cooling towers	1000 gal/hr	
Furnace Hall	Waste and make up water during operation	800 gal / hr	
	Detergents and sanitizers during sanitation of	-	
Chrome Plant	Disposal of dilute acid during etching process.	200 gal/hr	
	Washing and cleaning	1000 gal/hr	
EPS Hall	High TDS water	200 gal/hr	
	Waste water from dies	100 gal/hr	
UPVC	Detergent waste	-	
Power	Human fecal waste	-	

Source: Different areas of plant

Quantity: Not fixed, may vary because of various factors.

- Please note that all the materials are being discharged in very low quantities. Therefore, the septic tank is being considered as a sufficient mode for controlling at the moment.

1.2.3 Gas Waste Mass Balance

Table 3: Mass Balance for Gases

Area	Waste Material	Discharge	Fuel		Control Mechanism
			Gas (mg/Nm^3)	LDO (mg/Nm^3)	
Steam Boiler	Combustion gases	NOx	400	600	No Treatment Required
		HCl	400	400	
		SO2	400	1700	
		CO	800	800	
		Smoke	< 40%	< 40%	
		Particulate matter	300	300	

Diesel generator exhaust gas we are utilizing in waste heat recovery boiler and saving much amount of energy for EPS plant in Master Industrial Complex.

Source: Combustion of fuel in steam boiler.

Quantity: Detailed chart is attached.

1.3 Process Flow Chart of Organization

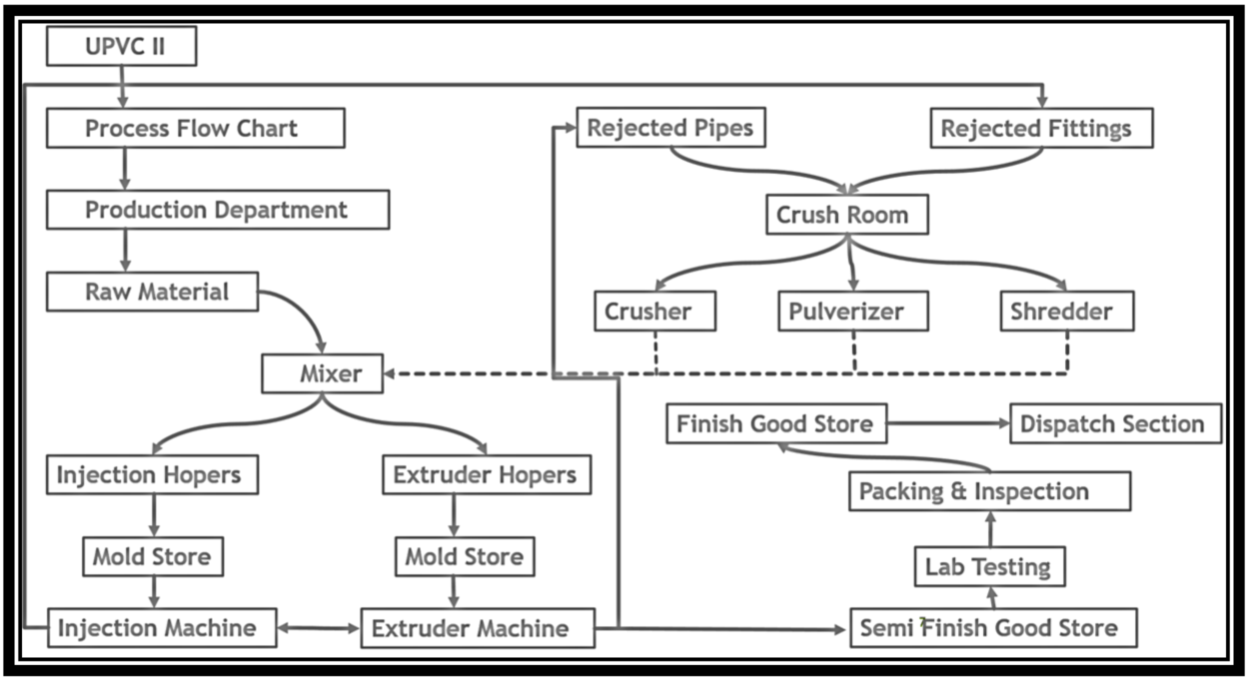


Figure 1.2: Process Flow Chart of UPVC II

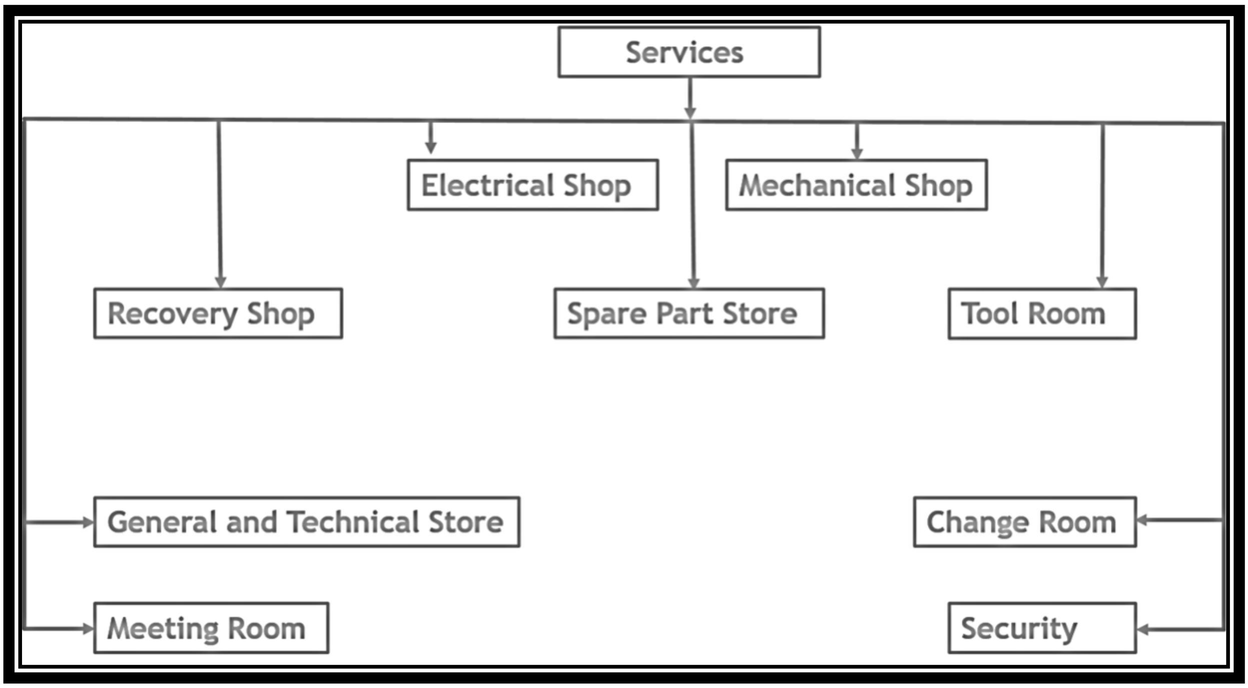


Figure 1.3: Process Flow Chart for Services of UPVC II

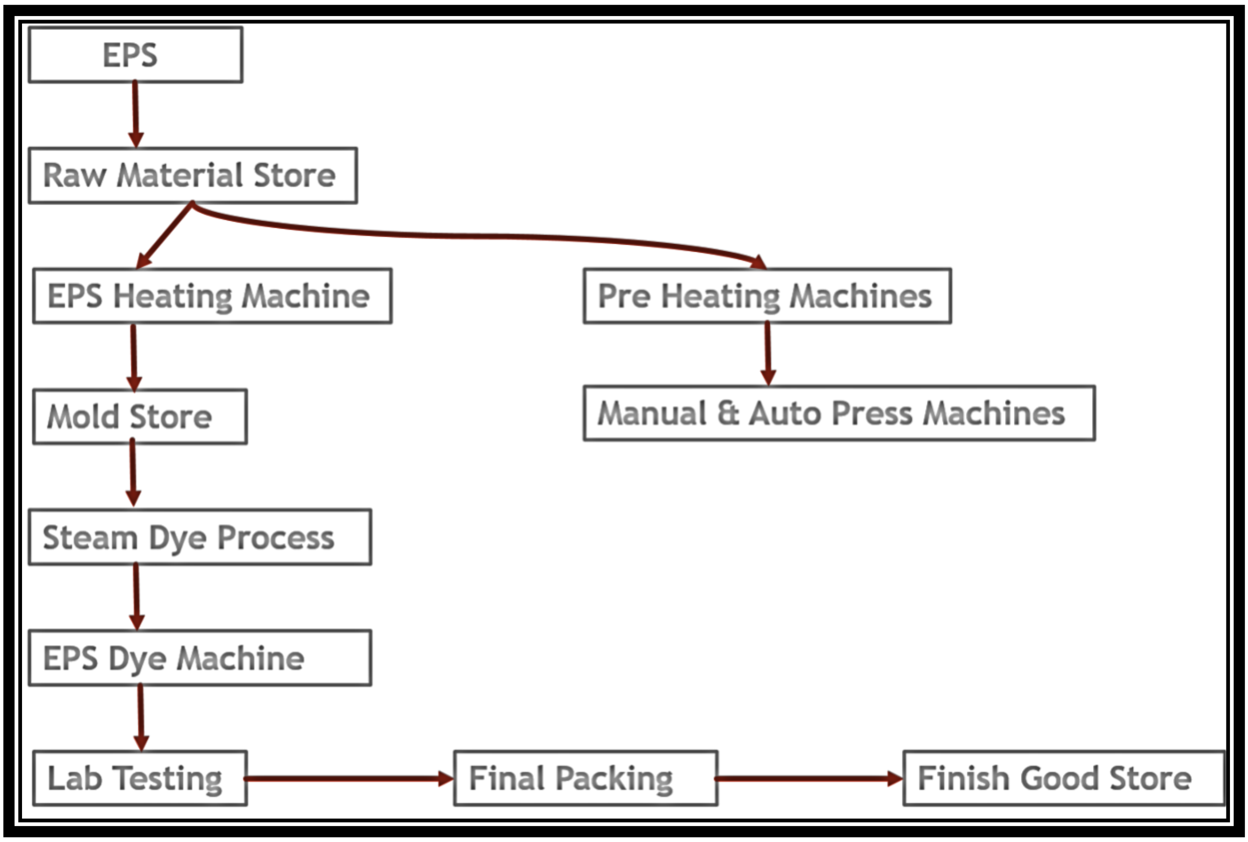


Figure 1.4: Process Flow Chart of UPVC II EPS Section

1.4 Introduction to International Motor Selection and Energy Saving Predictor Software

The software International Motor Selection has wide library of motors with complete detail of cost, efficiency specification, standards and manufacturing brands. It used internationally for the assessment of energy saving and replacement of motor. Comprehensive motor selection and energy saving analysis was carried out by using this software and net saving energy in motors was assessed for this study. Software equipped with international standards of electric motor; software provided comprehensive details of parameters that were required in the selection of a motor. The software Energy Saving Predictor “Yaskawa” and Energy Saving Estimator “WEG” software has wide ranges to estimate the energy saving by the VFD drive system for motor and fans. It has wide library of VFD with complete detail of cost, efficiency specification and also calculate their payback period, energy usage, CO_2 savings and graphs for essential values.

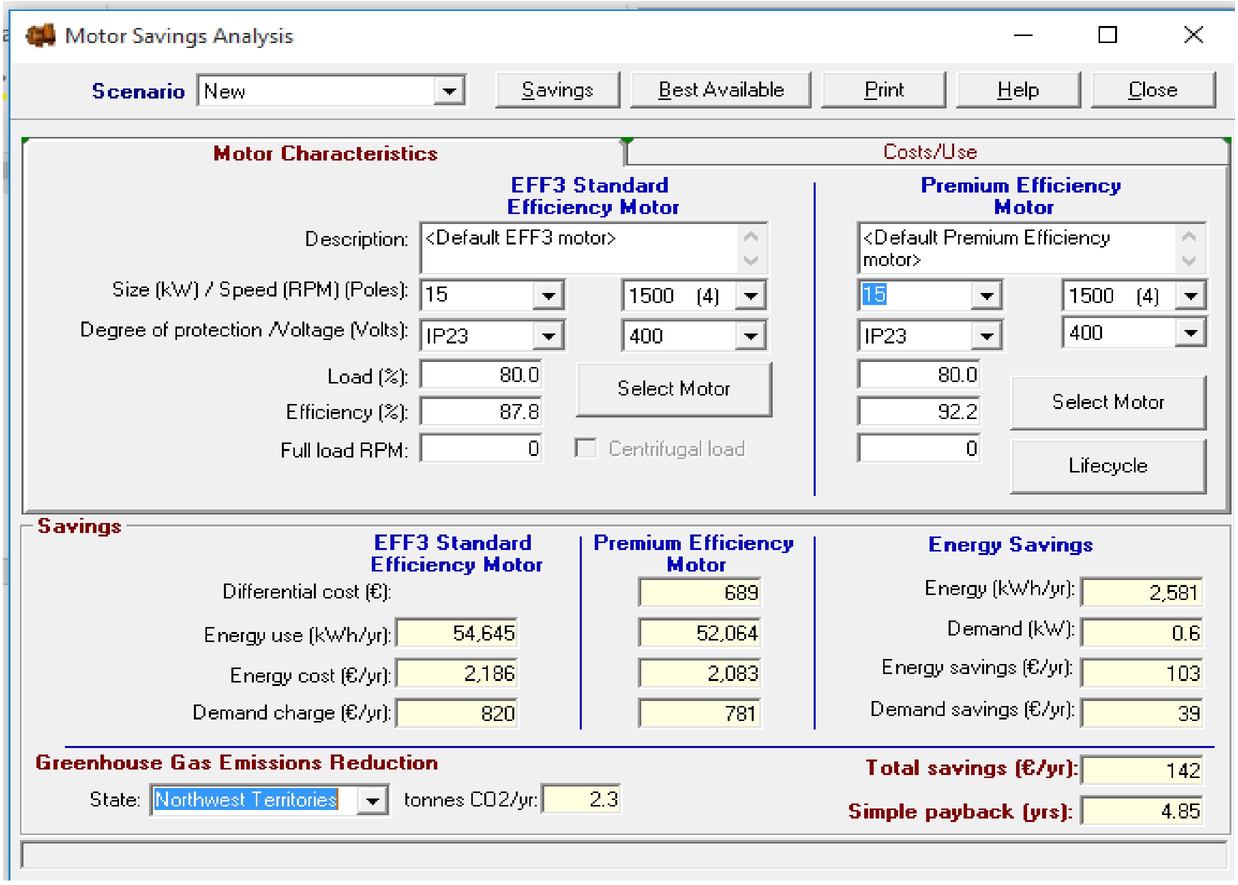


Figure 1.5: Dialogue Box Window of IMSSAS software

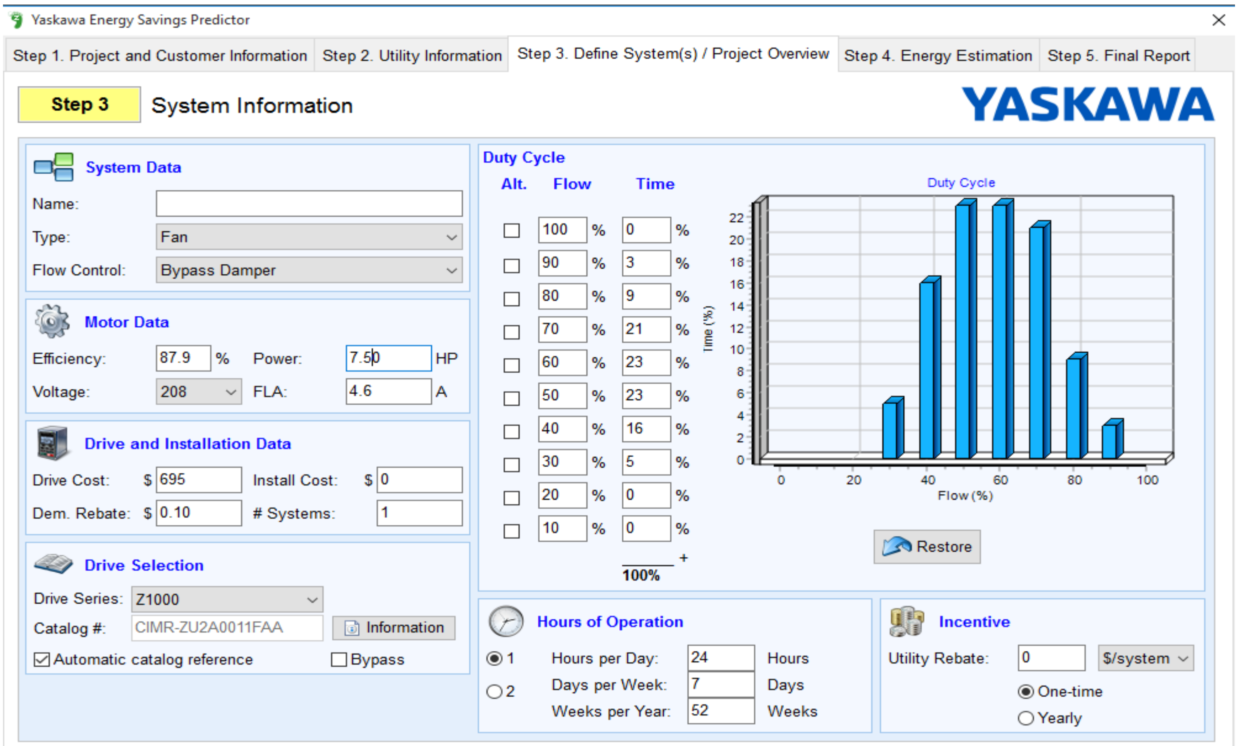


Figure 1.6: Dialogue Box Window of Yaskawa Energy Saving Predictor

1.5 Introduction to Machines

1.5.1 Injection Molding Machine

The most important machine that can be used for making the fittings of UPVC pipes is Injection Molding Machine. The IM machine consist of three major sections.

1. Feeding Section: In feeding section raw material mainly consists of resin and calcium carbonate. Some additives are combined to form a feeding material and inserted into hoper of injection machine.
2. Heating Zone: In heating zone material is melted and injected in the mold of the injection machine.
3. Clamping Section: In clamping section of the injection molding machine male and female mold join together with the clamping force.

Figure 1.8: Injection Molding Machine

1.5.2 Extruder

Extruder is the type of machine in which we can extrude the pipe. Its sections are briefly described below:

1. Feeding Section: In feeding section we can insert the raw material after mixing with special type of additive.
2. Heating Section: In heating section mixture of material melts in the heating barrel section.

3. Screw Section: Double screw extrude the material and inserts into the dye and making of pipe starts from that section.
4. Vacuum Tank: The pipe that is formed from the dye goes into the vacuum tank where the water spray nozzles cool down the pipe.
5. Hall-Off Section: In hall-off section pipe stretches through the vacuum tank and cooling tank.
6. Cutter Section: In cutter section pipe can be cut with desired length with the help of encoder.
7. Belling Section: In belling section using heater we can make a socket with the help of a die.

Figure 1.9: UPVC Pipe Extruder

1.5.3 Mixer

Figure 1.10: UPVC Mixer

1.5.4 Crusher and Shredder

The rejected material from the injection molding machines and extruders can be reused after crushing of the upvc pipes and fittings with some addition of chemicals and additives. Hard material of fittings can't be crushed easily so first shredder is used to convert big pieces into the smaller pieces then further they are inserted into the crusher section. Crusher and shredder consist of belt, ventilator, storage tank silo and dust collecting system is available for larger output.

Figure 1.11: Crusher and Shredder for UPVC Pipe and Fittings

1.5.5 Pulverizer

Pulverizer is a sort of machine that is self-developed for the grinding purpose so as compared to the smaller grinders their output is greatly improved about 20 % to 50 % under the same power. It also includes dust collector unit to reduce the dust pollution as compared to the normal grinding machines. Other features include door cover that is required for maintenance purpose and replacement of cutters, which is main requirement for production. Air cooling as well as water cooling systems are added to minimize the working temperature inside the machine body so the grinded material will not suffer from denaturalization

Figure 1.12: Pulverizer for UPVC Pipes and Fittings

1.5.6 Tool Room Machines

The tool room consist of lathe machine, milling machine, table drill machine, radial drill machine, small drill machines, grinders and some other tools to work with. We consider to place the VFD drives into these machine to save power as these machines work at slow or high speed according to the nature of jobs.

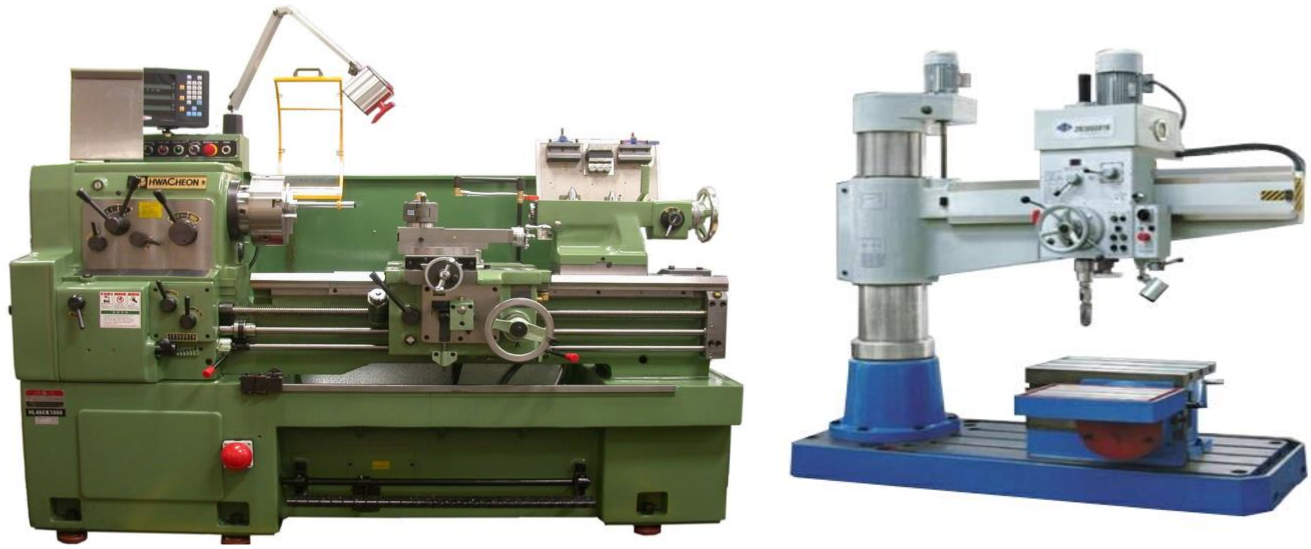


Figure 1.13: Tool Room (Lathe and Radial Drill Machine)

1.6 Problem Statement

- While the shifting of machinery and relocation of factory with the combination of old and new machines, energy auditing and energy saving has to be done.
- Comparing the usage of energy for the new and old machines.
- Estimate the annual energy savings with comparison of solar lights.
- Usage of high energy saving equipment including Screw Compressors, Pumps, Lights with old systems.
- Comparing old and new boilers.
- Calculate the total electrical load and use energy conservation techniques.

1.7 Objective

- Investigate the performance, energy, auditing analysis of Master Industrial Complex with real data collection of power consumption with production rate.
- Energy auditing and conservation of major power consuming devices.
- Compare and provide solution for the power factor penalty of master industrial complex.

2 Theoretical Analysis

2.1 Waste Heat Recovery Boiler

Now in the age of new industrial region every industry has to cut down their energy sufferers. The processes with high energy demands should be improved to cut down their expenses. Now the Industrial plants are searching for WHR methods to reduce energy demands. Energy effectiveness is a major source to reduce cost of any industry. In the short term fuel bills can be minimized and operating cost is also minimized, whereas CO_2 emissions are also reduced. Every industrial process required energy to start and process, some share of energy is required for each process and the excess amount of energy is exhausted to the environment. This energy is exhausted in the form of heat, gas or liquid form. This energy can be recovered WHR methods. The portion of this energy could be utilized in the form of thermal heating, electricity generation and cooling.

2.1.1 Calculation

First we have to know the amount of waste stream that is allowed and recoverable. Secondly the capital project cost should be calculated and economic value should also be known. It is also the breakeven point of the project. The below formula is required to calculate the available waste heat and flow rate.

$$Q = S\,V\,\rho\,C\,p\,\Delta T \text{ ------ (2-1)}$$

Q = Flow Rate of Fluid (m^3/hr)

S = Cross Sectional Area (m^2)

V = Velocity (m/sec)

ρ = Density (kg/m^3)

C_p = Specific Heat Constant (kJ/Kg °C)

ΔT = Difference of Temperature (°C)

'Q' is maximum theoretical flow rate required for the waste heat recovery, however all waste heat could not be recovered. To calculate the optimum value for 'Q' that is required for additional details such as accurate temperatures of the inlet and outlet of water or gas and also the location of process pipes for the exhaust heat. If we want to convert waste heat to the effective energy storage, then it should be such as water or as thermal heat transition fluid. Mostly waste heat are in the form of gaseous state and this is an inefficient energy storage medium because it losses energy swiftly. Liquid have approximately ten times higher heat constant compare to gases.

2.1.2 Calculation of Project Cost from Waste Heat Flow

Firstly we have to know that investment on any project depends upon the rate of return on the investment. The WHR and the re-use energy that is spent is beneficial for the environment. The WHR is also used to maximize the current productivity and spending. If we want to calculate the cost benefit of any company so we have to consider the cost of energy of the existing system and then we have to calculate the energy cost by implementing the WHR system which we have installed.

To calculate the value of WH then the below equation is used:

$$\boldsymbol{Value = Q \; x \; unit \; cost} \text{ ------ } \mathbf{(2\text{-}2)}$$

Q = Waste Heat Flow Rate (kW /hour)

Value = Value/hour of the WH

Q = Maximum amount of WH flow in (kW/hour) (Previous Value)

Unit cost = Fuel cost / Efficiency

Unit cost = m 'Currency' per kW

Fuel cost = Cost for fuel used in currency amount per kW

Other machines used in the factory premises are boiler, compressor, gravity die casting machine, cooling tower, vessel tank, refrigerant dryer etc.

2.2 Variable Frequency Drives

A VFD is device which is used to control the speed of AC induction motor, also the VFD controls the surge and torque load of any induction motor. VFD can control the speed of motor not only during the start and stop cycle but also the speed of induction motor throughout the running cycle.

The main advantage of VFD is to reduce the running cost by controlling the speed. We can also reduce the speed of motor by using belts, sheaves, and gearboxes but the motor quiet run at full speed. The VFD reduces the motor speed and the amps drawn by the motor. Thirdly VFD can also control the variable torque load. For examples centrifugal fans, blowers and pumps. With the help of variable torque the VFD might return the major energy savings.

- Torque is directly changed as the speed is squared.
- Power is directly changed as the speed is cubed.

Efficiency of electrical drive system is represented by:

Motor System Efficiency = (Mechanical Output Power / Electrical Input Power) x 100% ------ **(2-3)**

VFD drive systems are really effective systems. They have mostly an efficiency level of 97 % or even more at full load. When load reduces then the efficiency also reduces. VFDs having capacity 10 HP and above have an efficiency of 90% for the loads greater than 25% at the full load. By placing VFD of 20 HP each at the two running motors of cooling tower we are calculating the annual energy saving by the VFD. We could not calculate the exact amount of energy saving of the system by using VFD in the system. The factors that will affect application of VFD are load change, material characteristic, efficiency, mechanical coupling and the cycle of process. The VFD manufacturers have their own software and also their own formula for energy saving estimation. With the help of VFD, we can save energy by throttle control of ID/FD fans that are used in the boilers and also in the pumps for the pumping of water.

Table 4: VFD Constant Table for Calculation

Fan, 60% of maximum flow*		Pump, 70% of maximum flow*	
Ratio	Method	Ratio	Method
0.28	Variable-frequency drive	0.4	Variable-frequency drive
0.62	Inlet guide vane	0.94	Discharge valve
0.88	Outlet damper	1	Bypass valve
0.88	“Ride the fan curve”	1	No Control
1.0	Bypass damper		

2.3 Power Factor

Power factor is improved by attaching the capacitor in parallel as the additional load. The effect of these two opposite reactance that are connected in parallel takes the total circuit's reactive power close to zero. It cannot change the amount of true power consumed by the load, but it can effect in a considerable reduction of apparent power. Electrical power is the amount of electrical energy that is transferred from one form to other per unit time. 'Power' can be defined as the product of voltage drop through the element and current passes through it. In DC circuits, inductor acts as short circuit and capacitor acts as open circuit in steady state of the system. Later the entire circuit acts as resistive circuit and the whole electrical power is dissipated in the form of heat. The total electrical power is given by:

$Electrical\ Power = Voltage\ across\ the\ element\ x\ Current\ through\ the\ element\ \ldots$ (2-5)

Its unit is Watt = Joule / Sec

If we consider the AC circuits, the inductor and capacitor have stable amount of impedance that is given by:

$$Xc = \frac{1}{2\Pi fC} \qquad \text{------ (2-6)}$$

$$Xc = 2\pi\ f\ L \qquad \text{------ (2-7)}$$

The two major elements are inductor and capacitor, inductor stores electrical energy in the form of magnetic energy and capacitor stores energy in the form of electrostatic energy but they never dissipates energy and there is a phase shift in between the voltage and current. We are considering the whole circuit including resistor, inductor and capacitor. It contains some phase difference between the source voltage and current. The fraction of power is called reactive power. Reactive power does not have a useful work, but it has active work to be done. We represent it with 'Q' and scientifically it is given by:

$$Q = Reactive\ Power = Overall\ Electrical\ Power\ x\ sin\ \varphi \text{ ------ (2-8)}$$

Unit of Q = VAR

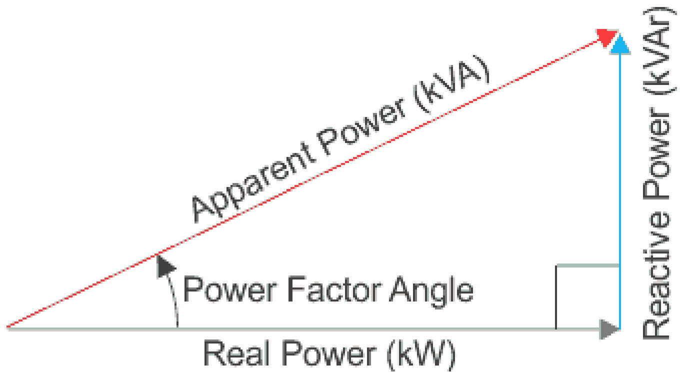


Figure 2.1: PF Triangle

Mathematically it can be represented by:

$$S2 = P2 + Q2 \text{ ------ } \mathbf{(2\text{-}8)}$$

PF = Active power / Apparent power.

$$Cos\ \phi = \frac{Active\ Power}{Apparent\ Power} \text{ ------ } \mathbf{(2\text{-}9)}$$

2.3.1 Requirement of PF Correction

- Real Power is represented by P = V I cosφ. 'I' is inversely proportional to cosφ for transmitting a specified amount of power at fixed voltage. If the PF is near to unity than the current flow is lower. If the 'I' is smaller it need less cross sectional area of conductor so the conductor cost becomes minimized for the 'I' flowing through it.
- When the PF reduces then the losses of current flowing through the copper wire increases. Due to this, voltage drop increases in the alternator, transformer, transmission and distribution lines of system.
- IF the PF becomes high the KVA rating of machines decreases.

$$KVA = \frac{KW}{Cos\ \phi} \text{ ------ } \mathbf{(2\text{-}10)}$$

2.3.2 Methods of Power Factor Improvement

There are three main methods using globally to maintain PF:

- Capacitor Banks
- Synchronous Condensers
- Phase Advancers

2.3.2.1 Capacitor Banks

Power factor is increased by decreasing phase difference between 'V' and 'I'. The common loads that we are using in Master Industrial Complex are inductive loads, they need some reactive power to function. A capacitor bank installed parallel to the loads delivers this reactive power. The capacitor bank act as a source of native reactive power and there is less flow of reactive power in the line. The major role of capacitor banks reduces the phase difference between the 'V' and 'I'.

2.3.2.2 Synchronous Condenser

It is 3 phase 'Synchronous Motor' and having load less with its shaft. The synchronous motor has the ability to operate under any PF, leading, lagging and unity as depends upon the excitation. When the load is inductive in nature than the synchronous condenser will be connected towards the load side and becomes overexcited.

Synchronous condensers sort it perform similar to capacitor. Lagging current is drawn from the supply and it supplies the reactive power.

2.3.2.3 Phase Advancer

The Phase Advancer is basically the AC exciter and it is used to improve the PF of an induction motor. PA is mounted on the motor shaft and connected on the rotor circuit. It increases the PF by providing the exciting ampere that turns to produce the required flux at the set slip frequency. Furthermore, if ampere-turns surges, it could operate at leading PF.

2.3.3 Power Factor Calculation

To calculate the PF, firstly we will measure the 'V' and 'I' by using the Voltmeter and Ammeter correspondingly and secondly the wattmeter is used to calculate the active power.

Now, we know:

$$P = VI\ Cos\ \varphi \text{ ------ } \mathbf{(2\text{-}10)}$$

From this above equation we get the results below.

$$Cos\ \phi = \frac{P}{VI} \text{ ------------ } \mathbf{(2\text{-}9)}$$

$$\frac{Watt\ meter\ reading}{Voltmeter\ reading\ x\ Ammeter\ reading}$$

Hence, we can get the electrical power factor and now we can calculate the reactive power.

$$Q = VI\, sin\varphi\ (VAR) \text{ ------ (2-10)}$$

The amount of specified reactive power cab be provided from the capacitor bank connected in parallel with the load. The reactive power of a capacitors can be calculated by using the below formula:

$$Q = \frac{V^2}{Xc} \text{ -------------- (2-11)}$$

$$C = \frac{Q}{2\pi f\, V^2} \text{ ------------ (2-12)}$$

Table 5: Power Factor Calculation Table

0.750	0.132	0.158	0.184	0.210	0.236	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0.740	0.882
0.760	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0.740
0.770	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673
0.780	0.053	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631
0.790	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553	0.591
0.800	0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519	0.553
0.810		0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487	0.519
0.820			0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453	0.487
0.830				0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.453
0.840					0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398	0.426
0.850						0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370	0.398
0.860							0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342	0.370
0.870								0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315	0.342
0.880									0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289	0.315
0.890										0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.289
0.900											0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235	0.262
0.910												0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209	0.235

0.920													0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183	0.209
0.930														0.000	0.026	0.052	0.079	0.105	0.131	0.157	0.183
0.940															0.000	0.026	0.052	0.079	0.105	0.131	0.157
0.950																0.000	0.026	0.052	0.079	0.105	0.131
0.960																	0.000	0.026	0.052	0.079	0.105
0.970																		0.000	0.026	0.052	0.079
0.980																			0.000	0.026	0.052
0.990																				0.000	0.026
1.000																					0.000

2.4 Cooling Tower Comparison Old & New

In old plant bottle type cooling towers are placed for the cooling of recirculating water. The new plant uses the rectangular type “Induced draft cross flow cooling tower” for higher efficiency and energy saving purpose.

According to the machine details and the water requirement to the all injection molding machines and extruders we have selected 4 cross flow cooling towers of 200 Tons/hr. One is dedicated to extruders and mixers machines and one cooling tower is placed stand by with it. One cooling tower is dedicated to Injection molding machines and crusher section and one cooling tower is placed stand by it.

Table 6: Cooling Tower Comparison Old and New

S.#	Working	Cross Flow	Counter Flow	Remarks
01	Working Principles	Air enters the cooling tower horizontally from the louvers side and water falls down from top plenum, and contact with cross flow.	Counter flow, hot water fall down words and air enter in the tower from bottom and then vertically upward after getting heat of water and cold collected in the Basin.	Efficiency will be same.
02	Contact time	Air and water contact time will be same	As same as cross flow	Heat will be transferred same
03	Power (Kw)	No difference between Fan Motors,	Power will remain same as Counter Flow.	No Difference

04	Pump Head.	Pump head Low	Pump Head Normal high	High pump head increase hp.
05	Filling	Increase air volume	Not much difference in air volume	Almost Same.
06	Air Recirculation	Depend upon the location	Depend upon the location	
07	Area	Much area required	Lesser area required	Better for less space
08	Efficiency	When you design tower for let's say 5000ton/hr, then it will result you same	It will be same as per design Only difference working principles but efficiency will be same.	No difference
09	Maintenance And services,	Maintenance is very easy you can maintenance the tower on half running position.	Big problems for services the tower.	Cross flow easy maintenance
10	Summary	Less energy intake and easy to maintain/ de-scale more deviations of water flow reduced drift drops operating cost.	Higher pump head need higher operating cost. It is difficult to clean and de-scale. There is more piping work needed. Higher suction velocities may pull in trash and drift.	xxxxxxxxxxxx

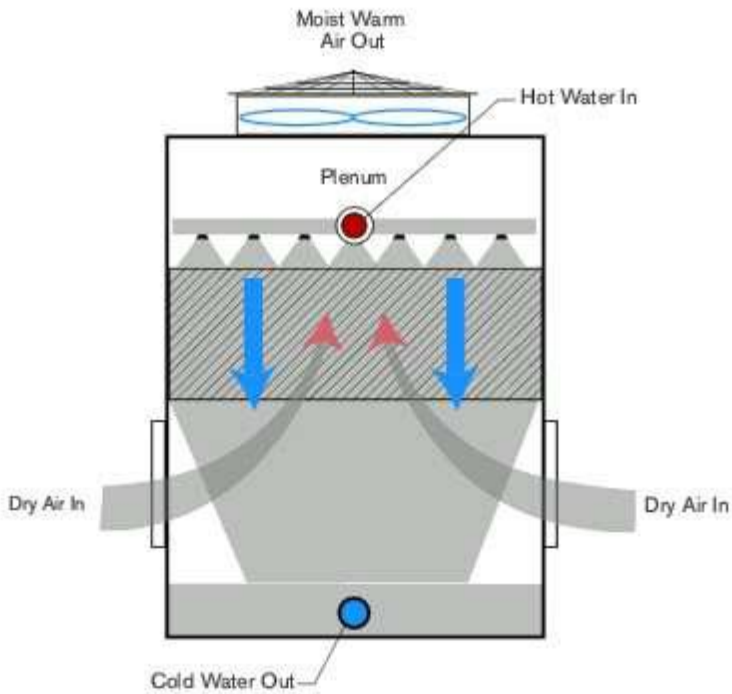


Figure 2.2: Cross Flow Cooling Tower

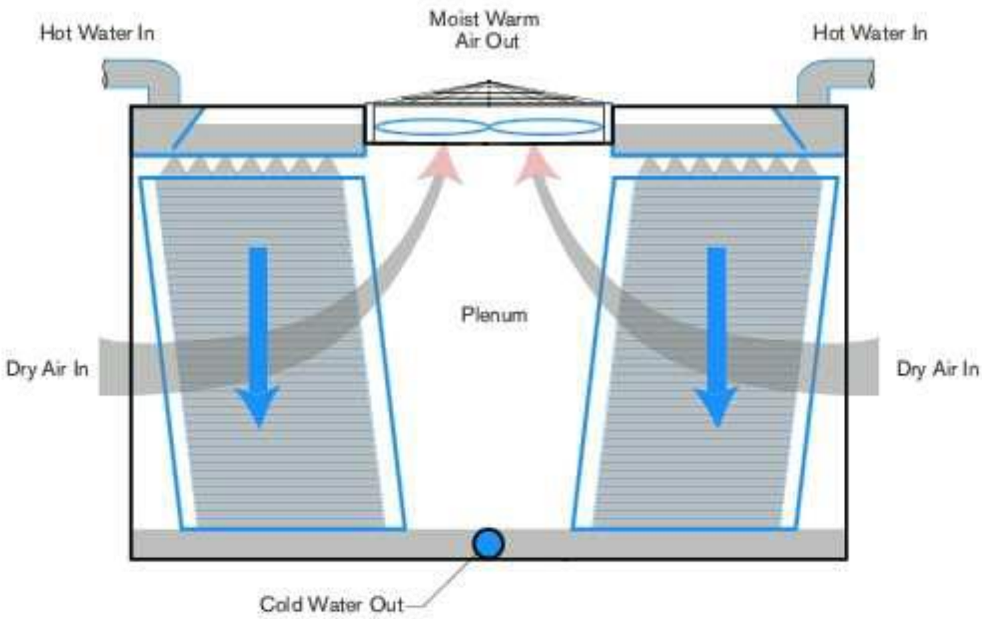


Figure 2.3: Counter Flow Cooling Tower

3 Literature Review

Pakistan has been depend on fossil fuel for their power production for decades. Prices of fossil fuels are increasing day by day due to geopolitical conditions. Paris agreement states that each estate should contribute in decreasing global temperature by 2^{o}C **[1].** The annual growth of electricity demand was increasing and recorded 8% between 2005 and 2010, expected to continue with the same rate until 2035. Either if the electricity growth rate increases with the same speed than the total demand will becomes 474 GW in 2050. **[2].** To cover this demand gap, Pakistan need serious alternative backup energy sources to fulfill the demand gap as well to cover his needs besides coal based power plant, Pakistan need energy potential in solar systems, wind, and biomass plant as well 169 GW, 13 GW, and 15 GW, respectively by 2050 **[2-3].** Pakistan need to increase the annual growth of energy but also need to conserve energy, the fuel mix of electricity generation in 2017-2018 were become 31% by gas, 22% by Hydel, 23% by oil, 8 % by coal, 8% by nuclear, 8% by RLNG. Industry of Pakistan bears output production losses of 12-37% only in Punjab **[4].**
In this research work, Co-Integration method is applied in order to examine the lasting equilibrium linking between energy intake and three descriptive variables to the era from 1980-2013. Moreover, energy setup examination is used for estimating the energy demand of CMI **[5].** The results illuminate that if the government does not cope with the economy, the energy demand of CMI will reach 2558.97 Mtce in 2020 and 2594.18 Mtce in 2030. On the other hand, if the government assigns importance to energy saving and takes necessary actions, energy demand in the industry will shrink to 1113.79 Mtce by 2030, which implies a large energy saving potential for CMI. If China energy problem is resolved it will bring the deterioration of environment issues worldwide and also it will reduce the CO_2 emissions. It also suggests to improve the productivity and competiveness.

Sha Yu evaluated; that the development in the building sectors and effects of building energy policies in India, which helped the state to approve ECBC and uplift building energy efficiency plans. Without implementing building structure energy plans, building in Gujarat would grow by 15 times in commercial buildings and 4 times in city residential buildings among 2010 and 2050 **[6].** ECBC revolutionizes energy savings in commercial buildings and could reduce building electricity consumption in Gujarat by 20% in 2050, related to the no strategy situation.

Implementing energy codes for the commercial and residential buildings would result in surplus 10% energy conservation in electricity usage. To achieve these projected conservations, it is serious to form capacity building and develop association for dynamic code and operation.

L. Aditya examined that the cost of energy can be reduced by using proper and efficient insulation material and it is useful in the heat loss and heat gain section for the air conditioning systems **[7]**. In this paper data has been collected on the recent progresses on buildings thermal insulations used for heating and cooling in the building. He also discussed about the life cycle study and discussed that by using the proper insulation materials NOx and CO_2 emissions can also be minimized. These techniques can be applied to the residential, commercial as well as industrial buildings and that the thermal insulation material have high characteristic of thermal resistance and have the ability to decrease the heat flow rate.

The importance of this study is to study involves the energy efficiency improvements and studying the assistances that have been achieved by using the case studies and energy audit features to achieve the results. This paper has discussed the following things: (i) Methods of energy audit for energy savings, (ii) Energy Audit tools, (iii) Energy auditor skill required for the energy audit. Use of some methods and define the structure for energy consumption and carbon emission reduction for industry **[8].** The results have shown the energy conservations by 30%, 13%, 70%, 14%, 10%, and 5% correspondingly for directed procedures used for energy conservations. The energy conservations measures and investment plans were carefully calculated by keeping in mind the ground realities for the return on investment period less than 2 years. He also demonstrated the audit frame work and kept in confidence the operation manager and maintenance manager during the assessment and energy conservation measures applied during the energy audit.

N. Kampelisa et al **[9].** Studied Energy efficiency, progressive controls and renewable energy systems for the industrial sector, residential and commercial building for the design of zero energy and operational setup and also discovered the performance gap. Renewable energy sources which we can use with the smart metering system are also discussed and all commercial applications of systems like photovoltaic systems and wind power to save the cost were discussed with analysis to minimize the utilization of power from the grid system.

Fabrizio has conducted situ surveys that include infrared thermography and also the measurement of U-values for modeling the building that were based on the numerical base study **[10].** In this study he has analyzed high energy demand which is mainly for the space heating and cooling. Secondly study has been conducted for the economical energy retrofit. The analysis evidenced high-energy demands, mainly for the space heating and cooling.

The energy conservation work presents the outcomes of introductory energy audit conducted on 8 large industrial constructions of a well-known car manufacturing divisions in Italy **[11].** The work points out the global warming effect on the world in future and discussed the IEA proposed solution to battle with greenhouse gas emissions. The claim of heating is varied from 6 to 74 kWh/ m^3 per year among the buildings at site. The energy audit techniques are the methods which are used for the corrective actions and measure to conserve the energy for any industrial sector. This paper proposed that by using the VFD drive system we could save up to 60% energy. The energy audit empowered to build a precise factory energy model which has been used in order to analyze the impact of various energy saving actions on the key energy intakes of the site. It has been established that the present HVAC systems can control a reduction of gas intake equal to 15% per year, simple pay-back time of the projected thermal retrofitting is nearly to be 6 years. In this paper he analyzed the factory located in Emilia Romagna, energy audit was conducted with the EU directives to retrofit actions in industries and also it promotes for energy savings, it mitigates the environment impacts and also reduces energy cost. The steps that have been used for the energy audit process by national technical recommendation are given below:

1. Complete the energy analysis of the system.
2. Identification of energy wastes.
3. Retrofitting plan for energy conservation.
4. Systematic plan for the development of energy saving projects.

The paper present the energy consumption of large scale automotive industry and data have been collected for the period of 6 months from June 2012 to January 2013. The collected data is based on the thermal and electrical data, historical trend of factory energy consumption data and finding the energy cost by bills of utilities and with flow meters to calculate the natural gas consumption. It has been confirmed that in this definite case the upgrading of building envelopes and the optimization of the performances of the current HVAC systems can result in a reduction in gas consumption up to 15% per year and the entire pay-back time of the planned thermal retrofitting is assessed to be less than 6 years.

A.Boharb analyzed the characteristics of the energy that would be saved for the improvement of the DPF (Displacement Power Factor) to a value of 0.98, by achieving DPF 0.98 the industry could save 52758.74 US$ annually. Interior lighting load has been a portion of load that is utilized with the load factor of 24 hours and the improvement with efficiency is performed. It is proposed that by implementing action plan the electricity consumption has reduced by 35.3% and also the air conditioning unit efficiency is increased by 31%. The main finding of energy audit report of Moroccan city Fez was that by targeting the factory of cattle fed, energy losses are caused by the mismanagement of electrical energy usage. Apprehensive the voltage regulation and has the possibility of reducing 13.6% of the lighting energy**[12].** Also, harmonic action was taken by connecting passive filters for VSD (variable speed drives).

Yi Jin., et al., stated that the Energy and Water are the key factors for the economy and social development of China. Both the "11th Five-Year" Plan and "12th Five-Year" Plan was established r conservations in a controlled manner. The "13th Five-Year" Plan presents that by implementing the desired action plan so we can could conserve and maintain the GDP growth rate to 6.5%. This paper explains that for the production of oil, gas, oil and electricity required significant amount of water. Energy can be obtained from the wind and thermoelectric power generations so it can not reflect the whole synergetic effect. This study calculates the synergistic results between energy saving and water conservation that has been reached by energy divisions in China from 2007–2012 period. The research results propose that energy segments have completely comprehended 12.40 × 108 m^3 water conservation through energy conservation and 1.12 × 106 tce through water saving **[13].**

The plastic that is consumed by any industry is directly linked with the economic growth of any country. The plastic consumption of India is equivalent to 2% of the total worldwide production of plastic material. 3-5% of the total energy required for the processing is utilized in the drying and precondition of material. It also contain Sankey diagram for the air heated conventional air dryer. Plastic process industry mainly consist of extrusion, injection and blow molding machines and approx. all require preheating, for example if 1 KW energy is supplied for above process than drying process required 1 to 3% of the total energy **[14].** This paper advised that the solar thermal energy would be the best option for pre-conditioning, dehumidification for solar energy drying technology. The experimentation involves the pre conditioning of Nylon-6 and PP by natural convection base solar dryer and economic study is also performed.

In this research Andersson, et al, claims that in order to improve the energy efficiency of industries the government should subsidized the companies on the basis of energy audit and energy efficiency gap could be covered **[15].** The data has been gathered and categorized for the performance indicators. Energy efficiency measures have been taken for the end users and the standards have been made for the large enterprises as well as for medium and small enterprises. Energy efficiency program helps to decrease the CO_2 emissions and also gives the comparison studies of energy audit for the countries and region. Study involves the methods of cost effectiveness and energy saving program.

This paper presents the overview of the Swedish industrial energy audit features, as 80 % of total energy is from the fossil fuel and 33% used by the industry. Industrial energy management measures are the key factors to overcome the energy deficiency and energy management gaps. The case study helps industrial managers to overcome the gap between the operation procedures and the management skills with reduction in their energy costs while their process becomes energy efficient. This paper reviews 10 years of research from an environmental point of view, reduced use of energy remains a corner stone in global greenhouse gas mitigation. However, without full internalization of exterior costs, greenhouse gas reduction as such may not be highly arranged among business. Rather, it is the scale of production costs and ultimately the size of market revenue that pronounces success or disappointment for business. In this paper, a review of ten years of realistic research in the field of industrial energy controlling in Swedish industry is obtained **[16].**

The energy potential could be analyzed through the application of energy benchmark, it is recognized as the effective methodology for the energy consumption and these methods are applied on the chemical industries, buildings and environment **[17].** The US Department of energy and China’s top quality officials issued national standards by providing policy supports for the establishment of energy benchmark. It also discussed the energy benchmark for the injection molding machines with the comparative evolution for energy saving. It explain that 74.7% of energy is consumed by the mechanical processes in manufacturing industry having the energy saving less than 30%. It explain that for energy benchmark it is essential to consider the time and cost factor for the several production processes so it explains the novel method for development of multi-objective energy benchmark based on the forecast and integrated assessment.

In this research the major sources of energy inefficiencies are presented in form of water supply system and its energy auditing is carried out to conserve the energy. The case study applied to this particular system is based on the Águas do Sado water utility system. The operation cost to run the water supply system is 30-40% of operational cost. By implementing the energy audit techniques we could not only reduce Operation and Maintenance cost but also reduce the Carbon emission and Green House Gas effects. The major equipment used in this system is treatment supplied water and pump for supply of water. This presents an energy auditing merged in the Portuguese National Initiative for the controller of water losses and follows the ISO 50001, ISO 55000/55001/55002 standards and identifies the energy improvement solution **[18].**

Ramana and Baskar proposed that VFD is the choice of system in industry where we can control the speed of drives through the frequency **[19].** VFD consist of rectifier-inverter induction motor. Inverter is usually build through the IGBT and the PWM used to reduce harmonics and VFD also reduces the initial current drawn in start-up of any motor. According to the IEEE 60-65% of induction motors are used for the pumps, compressors and fans. He proves that the energy can be conserved by using the VFD in compressors. The factors that affects the performance of any compressor are the speed of rotation, suction pressure, discharge pressure and the fluid flow as a refrigerant. In typical setup the motor runs the compressor at the full speed regardless of the load requirement. The study involves things that we can regulate the speed according the load and 20% reduction in speed can save the energy up-to the 50% and by applying VFD, voltage and frequency can easy be regulated.

Pandey and Prakash studied the energy management prospects in the pulp and paper industries, according to them this industry consumed about 6% of the total energy intake that is being used worldwide. The definite electrical and thermal energy intake was projected and the finding of this is around 91.85 KWH / ton for a 1619 MJ/ton paper. He emphasize to use the waste heat energy, use of by-product material and also use of renewable energy system such as solar system for the lighting purpose and method adopted to reduce the carbon dioxide emission **[20].**

To facilitate the operators for quality check and sorting of tiles with naked eye; 120 numbers of compact fluorescent lamp CFL were installed in the production line **[21].** Basic parameter for the quality of light was its spectrum. Complete component of spectrum supported detection in variation of colors.

It focuses on the carbon emission regulation and explains the procedure of energy audit for an individual company which belongs to production sector. Almost every industry have their loop holes to overcome and following the ECOs and detail energy audit techniques. The steps are as follow: 1. Data Collection, 2. Data Processing, 3. Analysis of results, 4. Recommendation for the improvement, 5. Economic foundations **[22].** The pattern of energy usage could be found to observe the pattern of energy conservation and focus on the main energy consumptions like heating, ventilation, air conditioning, lighting, hot water, plug load, production movers. The previous data gathered by the previous bills. It explain the importance of benchmarking and Sankey diagram shows the inflow and outflow of all the energy content into the system.

M. N. Zaidi and A. Ali suggest to improve the PF by Automatic power factor compensation device. The demand of the electricity is increasing day by day in Malaysia and electrical power is the most expensive source of energy in Malaysia because of generation, distribution and transmission cost. The demand in energy is varying from time to time in industrial and commercial sector as these two sectors are the major power consumption sources. Capacitor bank could be installed to the load side of the metering equipment. These capacitor bank supply the reactive power required by the plant, as power factor is improved, the transmission loses are also improved. It describes that the power factor is the ratio between the true and the apparent power. In inductive circuits, the current lags behind the voltage and the power factor is lagging power factor. In Capacitive circuits, the current leads the voltage and the power factor is leading power factor. As concluded that the 15% reduction can be possible in network losses by improving the PF to 0.95 **[23].**

Sandra Backlund, et al., explain the energy policy 20-20-20. EU adopted the Energy Services Directive (ESD) as to reduce the energy use in EU by 9% in EU on all non-trading parts of economy and targets to improve energy efficiency in all sectors of economy by 20% in 2020. It focuses mainly on the industrial and commercial sector, targets to improve energy in medium and small enterprises **[24].** European Commission estimated the technical energy saving by 25% in manufacturing, 30% in commercial building and 26% in private households and to achieve these goals high implementation rates are required. He suggested some measures for overcoming the energy efficiency barriers are white certificates, voluntary agreement and long term agreement, financial aid program and also subsidies are given to implement the plan. There is a plan to increase the price of energy and also focus on the areas to remove the greenhouse gas emissions.

Y. Li et al., perform the energy audit technique on the float glass plant in China and also perform the energy analysis for energy conservation measures **[25].** He emphasizes to use the simulation software to view the practicality of audit measures. The energy auditing procedures include energy management and statistical data required to improve production line as well as energy measures. As the energy consumption was 2.58 tons of coal equivalent which accounts to 10,000 Yuan output value and 2.17 tce HVE (Heat Value equivalent). The percentage of cost reduced from 51.19% in 2007 and 46.48% in 2008 by applying the energy audit techniques.

S. H. Noie, M. Lotfi, and N. Saghatoleslami explain that the waste heat recovery is most important for the cost saving of any industry, with the help of waste heat recovery primary energy and carbon dioxide production is reduced. Thermosyphon Heat Exchanger (THE) is being used for the waste heat recovery for the industrial plant. The benefits to use 'THE' are compactness and minimum maintenance requirement and it is used for the preheating of air from exhaust of boiler. It is installed on the exhaust of 7 Ton boiler and is used to the pre-heat the incoming air of boiler and thermal effectiveness obtained from the computer simulation was obtained to be 100 KW. It payback period is less than two years. Its performance is based on the effectiveness of NTD and LMTD method to find heat transfer characteristics. The thermosyphon heat exchanger has saved 143,560 m^3 of natural gas and 281,990 kg production of CO_2 has reduced per year. It reduces the exhaust gas temperature from 240 to 125 ^oC and pre-heat the incoming ambient air to 25 from 100 ^oC **[26].**

I. H. Ibrik and M. M. Mahmoud stated that to conserve and improve energy efficiency in industrial, commercial, and residential sectors utilities played a vital role **[27].** The energy consumption is increasing day by day in developing countries, it is important to use such techniques which will not affect living standards. This paper explain that the percentage of energy consumption in Palestine are 50% residential, 15% Industrial, 10% commercial, and 15% for the pumping stations. Energy conservation by utilizing the solar water heater is discussed, I. H. Ibrik and M. M. Mahmoud estimated that the 25-17% of energy could be saved in lighting, 10-20% for the motors and 10-30% for electrical losses in the distribution network. This paper explain the usage of thermosyphone SWH (Solar Water Heating). By implementing the energy audit and energy conservation plan we could save considerable amount of electricity and fuel cost.

The cements plants are the most energy consuming plants in the world and their energy expenditure is 50-60% of the direct production cost. Cement dry process consumes less energy as compare to wet production process. It was estimated that 40% of the total energy was lost through hot flue gases, cooler stack, and kiln shell. One of the best method to reduce energy consumption is co-generation power plant which utilizes waste heat to produce electrical energy with no additional fuel consumption and also reduce the CO_2 emissions. The plants which use waste heat recovery are single flash steam cycle, dual-pressure steam cycle, ORC and the Kalina cycle. Suspension preheater and clinker cooler discharge and exergy analysis could be done for each cogeneration power plant and Kalina cycle had achieved better performance in terms of exergy efficiency **[28].**

Pareshkumar and Purnanand **[29]** energy conservation practice program was done for centrifugal pumps for pumping and their framework. The air compressors volumetric efficiency was established to be poor and there was a gap to recover their efficiency for development. Thus, their losses were just because of air leakages in the pipe lines. PID controller was used with several fixed points, the maintenance work of compressor had to be followed. Very less cost is required to improve the efficiency and their payback period was less than three months.

Dongellini et al. **[30]** was projected to find the energy losses in small and medium industries. Through the survey it was established that energy intake for HVAC systems in industries fluctuates from 6 to 74 kWh/m^3 a year. Investment to maintain standards were suggested only if payback period was less than 6 years. By installing a standard insulations for HAVC systems, we could save energy wastages as maximum.

The quality of the waste heat were determined by the temperature of the exhaust gases. If the temperature ranged <230 ^oC so it was considered as low quality and (230^{o}C– 650^{o}C) were medium range and could be utilized for WHR systems **[31].** The method that were used to save energy from an industry is WHR system, firstly we have to know either we invest on any project or not was depend upon the rate of return on investment. The WHR and the re-use energy that was spend were use as advantage to the ‘green credential’ for industry and also their environmental control. The WH was also used to maximize the current productivity and spending **[32].** If we want to calculate the cost benefit of any company so we have to consider the cost of energy for existing system and then we have to calculate the energy cost by implementing the WHR system which we had installed and also it reduces the CO_2 emissions in the environment **[33].**

4 Methodology

4.1 Energy Auditing

The first step to save and conserve energy could be achieve by the Energy Audit. A primary summary of the elementary steps involved in directing an effective energy audit is provided here. This audit report primarily addresses the procedures in an industrial or across-the-board commercial audit, and not all of the measures defined in this section are mandatory for all type of audit.

The audit procedure begins by gathering information about a space for operation and about its previous records of utility bills. The collected data is then examined to get a picture of how the selected space uses and probably wastes energy, energy auditor learn and getting help to evaluate the energy and finding the ways to reduce the energy cost. Specific changes termed Energy Conservation Opportunities (ECOs)—are acknowledged and assessed to regulate their benefits and their cost-effectiveness. These ECOs are evaluated in terms of their costs and benefits, and their cost-effective relationship is made to overgrown their various ECOs. In conclusion, an Action Plan is shaped where convinced ECOs are selected for execution, and the original process of conserving energy and saving money starts.

4.2 Instrument Used for Auditing and Data Collection

4.2.1 Tape Measures

The utmost basic measuring device required for measuring length is tape meter. The wide range of tape meters are available in the market for the desired usage like a 25-feet measuring tape l" wide and a 100- feet tape are used to check the measurements of walls, ceilings, windows, doors and determining the length of a pipe and tubes for transporting waste heat from one place of equipment to the other one.

4.2.2 Wattmeter/Power Factor Meter

The wattmeter/Power factor meter is used to find the power and also help in determining the power factor and it can be used to find the power factor of inductive motors and also for the inductive devices. The wattmeter meter usually has a clamp-on system which is used to find the current in the current carrying conductor, its probes are used to find the voltage. The wattmeter or PF meter have a true RMS meter for high precision value and to give accuracy where there are some harmonics have been involved.

4.2.3 Voltmeter

The voltmeter is used to determine the operating voltage of any electrical equipment and the voltmeter is essentially useful when the name plate of any electrical device have worn off, unreadable or missing. The best multipurpose instrument is a united volt-ohm-ammeter with a clamp-on feature for determining currents in conducting wire that are easily accessible. Above type of multi-meter is suitable and comparatively low-cost. Any type of voltmeter, multi-meter have a true RMS value for precise accuracy where harmonics could be involved.

4.2.4 Clamp On Ammeter

The Ammeter is very useful device to measure the current in a wire which is without having to make a live electrical connections. To use an Ammeter firstly the clamp is opened and put around the insulated conductor, so the Ammeter reads the current in the conductor. Clamp on Ammeter have a true RMS value to precise reading and for level of harmonics in different facilities.

4.2.5 Steam Flow Meter

Steam is a major source of energy in Polystyrene Unit so it should be measured properly. Without the proper measurement of steam, an organization can't define its significant energy. By using machines which is a necessary part of Energy Auditing and also necessary for setting goals and targets. We observed that most of the industries even don't know that which type of steam flow meter is suitable for their application.

There are mainly two types of steam flow meters which are easily available at lower prices in market;

i. Orifice type steam flow meters

ii. Vortex type steam flow meters

Orifice Type technology is very old, it has a lot of disadvantages which includes:

- Pressure drop across orifice
- Calibrations are required frequently.

- Very precise installation required
- Wear & tear of orifice plate with time
- Lesser turn down ratio

Turn down ratio is a very important factor in selection of a meter. Turn down ratio means the minimum and maximum reading which a meter can read accurately. For orifice type, the turn down ratio is 5:1 which means it can read five times to its lower limit. As steam consumption is not smooth in EPS machines and is continually varying from minimum to maximum and in most cases maximum consumption of steam is 8-10 times of the minimum consumption. So, orifice type will not be suitable for such applications.

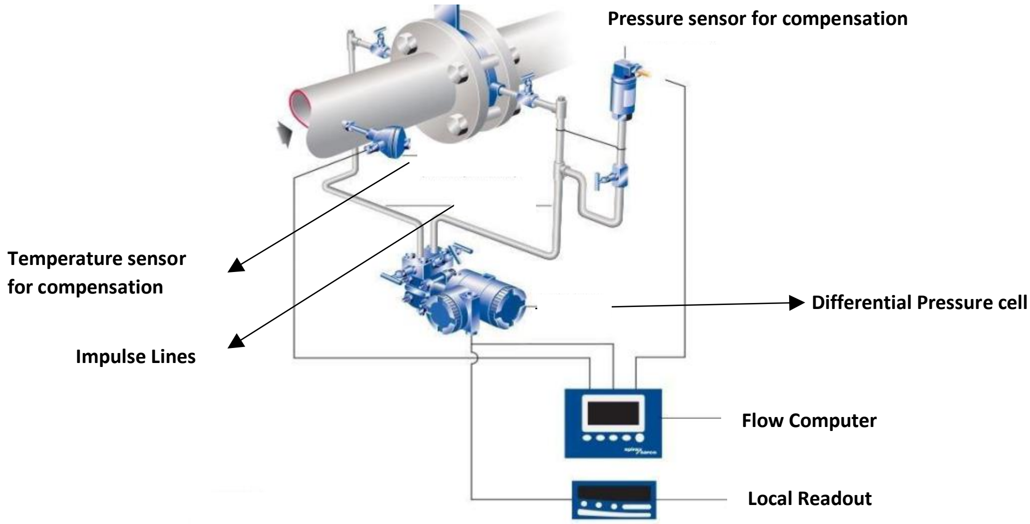


Figure 4.1: Orifice Plate Flow Meter Installation

The complex installation of orifice type meter, it's very important that impulse lines are parallel to each other and no dirt come into those lines which often in practical is not possible. Moreover, differential pressure sensor should be of premium quality for accurate reading.
Vortex Type on the other hand are good meters due to many reasons.

- Easy installation
- Higher turndown ratios up to 20:1
- Calibration not often required
- Lesser space required for installation
- No wear tear with time

4.2.6 Magnetic Flow Meter

Magnetic flow meter is extra more accurate than turbine type flow meter and reading can be easily taken from these types of flow meter. The cost of these meters are high but where the accuracy is required these flow meter can be used like at the inlet of the boiler this flow meter should be installed.

In the Master Industrial Complex water flow meter are installed for the below mention applications:-

1. At the outlet of the turbines to calculate their efficiencies and also to calculate the how much water is being extracted in a day.
2. At the inlet and outlet of the softening plant to calculate the amount of water being recovered.
3. At the inlet of boiler to calculate the amount of water that is feed into the boiler and how much condensate is being recovered through the boiler.
4. At the discharge of cooling tower and production machinery pumps.

4.2.7 Water Flow Meter

Water flow metering is very essential in any processing industry, particularly at boilers it is very important to calculate the blow down of boilers, water and steam losses etc. Although there are a number of flow meters for water metering but mostly two types of flow meters are used in Master Industrial Complex. Which are:

- Turbine Flow Meter
- Magnetic Flow Meter

4.2.8 Turbine Flow Meter

Turbine flow meter is easily available and a cheap flow meter. Water temperature and pressure are main factor in the selection of material of the meter. While installing a turbine type flow meter it should be installed in a horizontal line not in vertical line so that vertical line pressure may not disturb its reading.

4.2.9 Thermal Camera

Steam, hot thermal oil and hot water lines should be insulated properly to avoid heat losses. But it is not possible to see the heat loss through naked eye. To check that either the insulation which we have done is appropriate or not so the infrared thermal camera can be used. Although there are many models available in market but at Master Industrial Complex we used Fluke thermal camera which was not too much costly but reliable and efficient.

Thermal graphic analysis of whole plant was done. Some of the pictures are shown here:

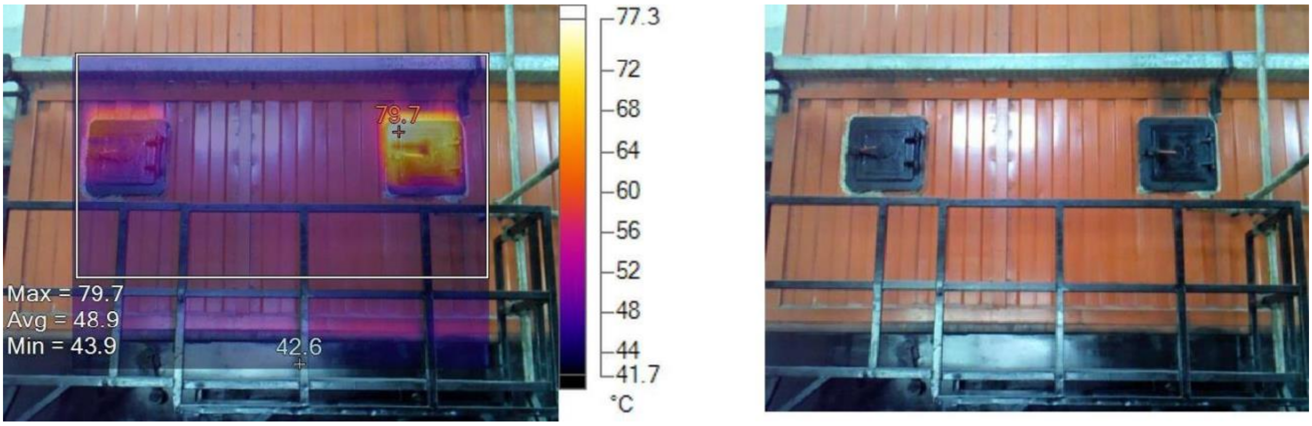


Figure 4.3: Thermal Camera Image

Thermal Camera Image. IS2 **Visible Light Image**

Visible Light Image

9/6/2018 10:45:17

Left Side Door of HFO Boiler

4.3 ANALYSIS:

The above picture in is taken at the left side of a boiler, left hand is through thermal camera while right hand picture is in visible light. You can see in visible light or through naked eye no one can see that heat is losing through one of the doors but thermal camera shows that the refractory of one door is damaged and permanent heat loss is occurring.

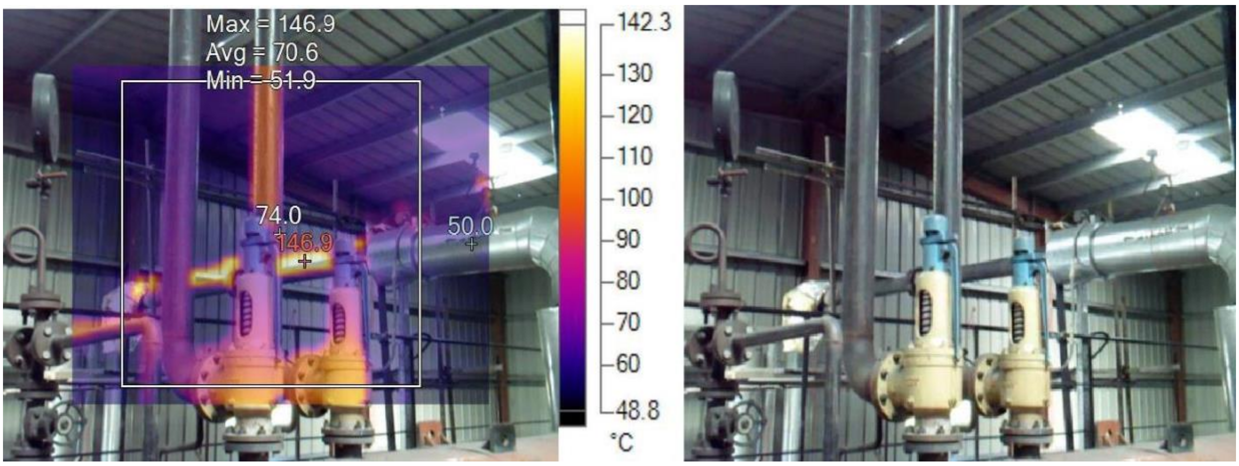


Figure 4.6: Thermal Camera Image (Damaged Part)

Thermal camera image.IS2 **Visible Light Image**

10/10/2018 10:53:01 AM

4.4 Valve at Boiler:

4.4.1 Analysis

The above picture in is taken at the top of a boiler where safety valves are installed. If we see through naked eye nothing can be seen, everything looks normal but when we see it thorough camera we can see that steam is passing from one of the safety valve and its venting it in air which is a continuous heat loss and also shows the fault in the safety valve which should be addressed at earliest.

4.4.1.1 Lux Meter

Lux meter is used to measure the intensity of light. Light standards are available easily on internet and light of different places was checked and adjusted according to it.

Some other equipment's used for the energy conservation and audit are given

- Tape Measures
- Light Meter
- Thermometer
- Infrared Cameras
- Voltmeter
- Airflow Meter
- Safety Equipment
- Miniature Data Logger

4.4.1.2 Flue Gas Analyzer

Flue gas analyzer is used to test the combustion gases of boilers, engines and oil heaters etc. it can be used to analyze any flue gases after combustion. The instrument will tell you the percentage of carbon mono oxide which is a direct measure of how efficiently fuel is burnt. If fuel is efficiently burnt, then in exhaust carbon dioxide should be present instead of carbon mono oxide. Also, the instrument will give the percentage of excess air. Certain quantity of excess air is required for lean burning of fuel.

Table 7: Gas Flue Analyzer Report for HFO Boiler

S.No	Emission Parameters	Value	Units
1	Excess Oxygen O_2	9.7	%
2	Carbon Mono Oxide (CO)	650	Mg/Nm^3
3	Carbon Dioxide (CO_2)	10.9	%
4	Temperature of flue gases	210	^oC
5	Temperature of Ambient Air	33.8	^oC
6	Excess Air	85.2	%
7	Nitric Oxide (NO)	132	Mg/Nm^3
8	Nitrogen Dioxide (NO_2)	01	Mg/Nm^3

Above table shows the emission analysis of a boiler. It was observed that CO & temperature of flue gases were high. For proper burning, it's necessary that carbon monoxide should be converted into carbon dioxide and CO should be less than 200 mg/Nm3. One of the reason found for higher CO was the open doors of furnace and quality of fuel. Target was set and action plans were made to reduce these values which will be discussed in next chapter. After implementation of those projects, it was calculated that huge saving is achieved in terms of reduced HFO consumption per ton of steam generation. The graphical analysis of the table is given below in the graph.

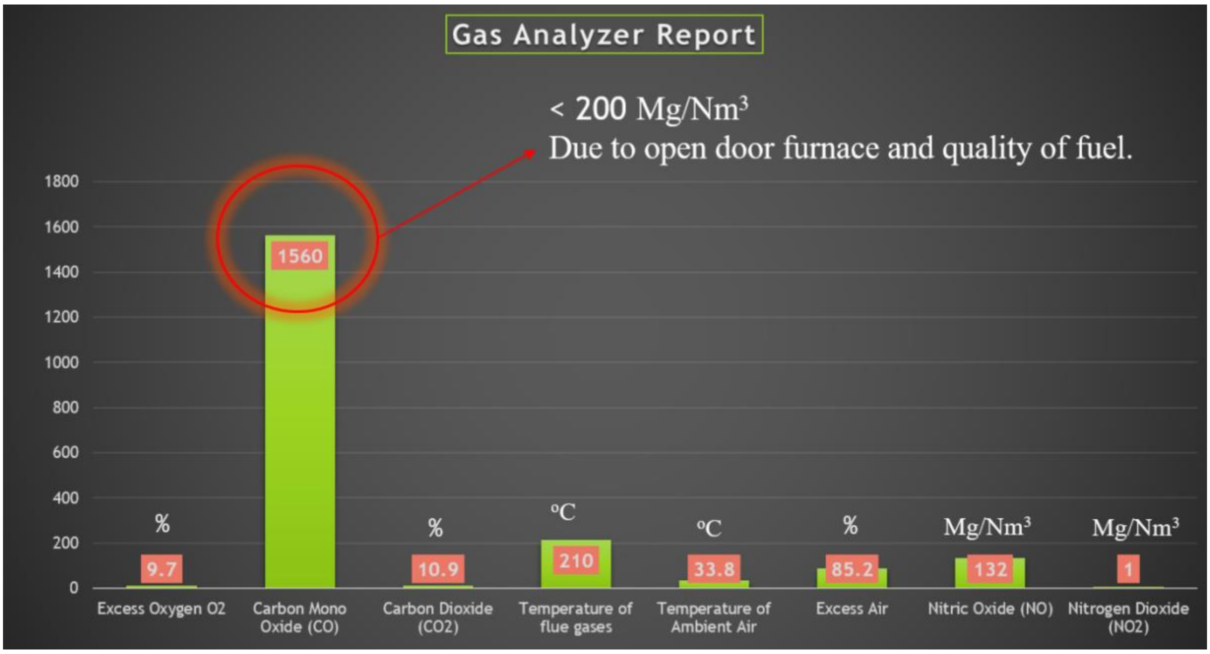


Figure 4.7: Gas Flue Analyzer Report

4.5 Safety Considerations

Safety is essential part of any energy audit. The audit individual or team should be carefully directed on safety equipment and procedures, and would never place themselves in a place where they could harm themselves or other persons at the premises. Satisfactory safety equipment might be damaged at all appropriate times. Auditors and energy managers could be enormously careful by taking any measurements on electrical systems, or on extremely high temperature equipment such as boilers, heaters, cookers, etc. Electrical gloves or asbestos gloves should be worn out as suitable.

The energy manager would be cautious when investigating any operating piece of machine, particularly those with open drive shafts, belts or gears, or any type of rotating machinery. The machine operator or controller should be informed that the energy auditor is going to observe at that part of machine and would require to get data from some part of the device. If essential, the energy manager could want to response when the machine is idle as in order get the data. The energy manager must never inspect any machine without the machinist or controller to be notified first [24].

4.5.1 Safety Checklist

1. Electrical

a. One should never work on a live circuit.

b. Before working on any piece of equipment circuits must be lock off.

c. To prevent from the cardiac arrest while working on live circuits one must keep their one hand in pocket.

2. Respiratory

a. Wear full face respiratory mask having satisfactory filtration particle size.

b. Wear mask having carbon cartridges while working around low concentration of noxious gases.

c. When working in a toxic environment than use a self-contained breathing apparatus.

3. Hearing

a. While working around the loud environment must use foam plugs to reduce sound level u to 30 decibel.

After the detail audit of Master Industrial Complex so we will determine the Energy Conservation opportunities and how many ways and take possible steps to cut down the energy consumption and save annual cost.

4.6 Energy Management ISO 50001

In this study we have used qualitative methodology with case study of Master Industrial Complex as a study work. As we know according to ISO 50001, the energy conservation system was recognized on the idea of quality management system that have four major parts which are PLAN, DO, CHECK & ACT, normally identified as PDCA cycle. PDCA cycle is constructed on the frequent development outline which includes energy management in the everyday organizational carry out. Seven clauses of ISO 50001 standard can be summarized in PDCA cycle as:

4.6.1 Plan

Following the establishment of commitment to a policy, the following planning requirements should be addressed:

- Legal Necessities
- Energy Appraisal
- Energy Reference Point & Baseline.
- EPI (Energy Performance Indicators).
- Objectives & Targets
- Energy Management Action Plans

Plan covers the first four clauses of standard.

4.6.2 Do

The implementation and operation of the system includes:

- Competence, Training and Awareness
- Communication
- Documentation
- Operational control
- Design
- Procurement

DO covers the fifth clause of standard.

4.6.3 Check

Checking and corrective action includes:

- Monitoring, measurement and analysis
- Evaluation of compliance with legal and other requirements

- Internal audit
- Non-conformities, correction, corrective and preventive actions
- Control of records.

4.6.4 Act

The organization have taken into place for the correction and corrective actions to report any insufficiency in the system and leads preventive actions to report any possible problem. The entire purpose of this is to frequently improve the efficiency of the EnMS. A periodic review is required by management to establish the basis for the next PDCA cycle.

4.7 Energy Planning

EP (Energy Planning) is the most serious part of energy management system. The process of the Energy Planning is given below:

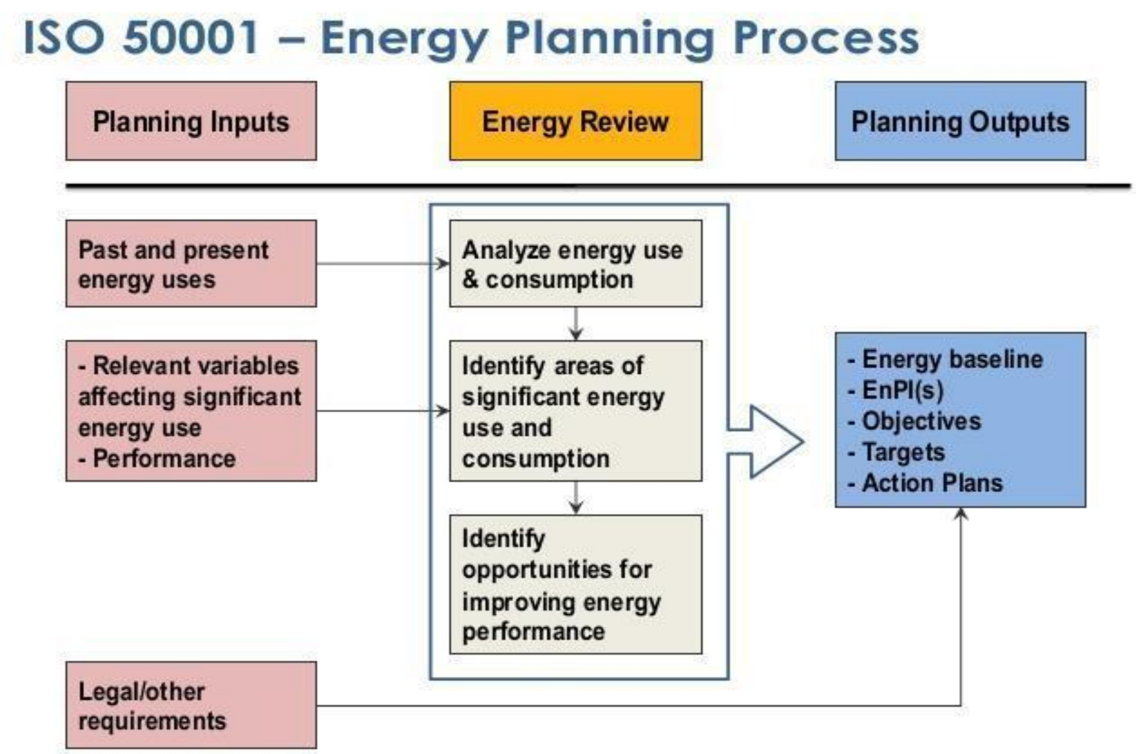


Figure 4.8: ISO 50001 – Energy Planning Process

The above table shows the general energy planning process which mainly consists of Inputs, review and outputs. The whole energy system depends upon the energy planning and planning itself depends upon the inputs and if the inputs to system are not accurate then credibility shows the general energy planning process which mainly consists of Inputs, review and then outputs. The whole energy system depends upon the energy planning and planning itself depends upon the inputs and if the inputs to system are not accurate then credibility of whole system will be at risk. For inputs, energy used data is collected through various energy measuring and testing equipment's which are described below in detail.

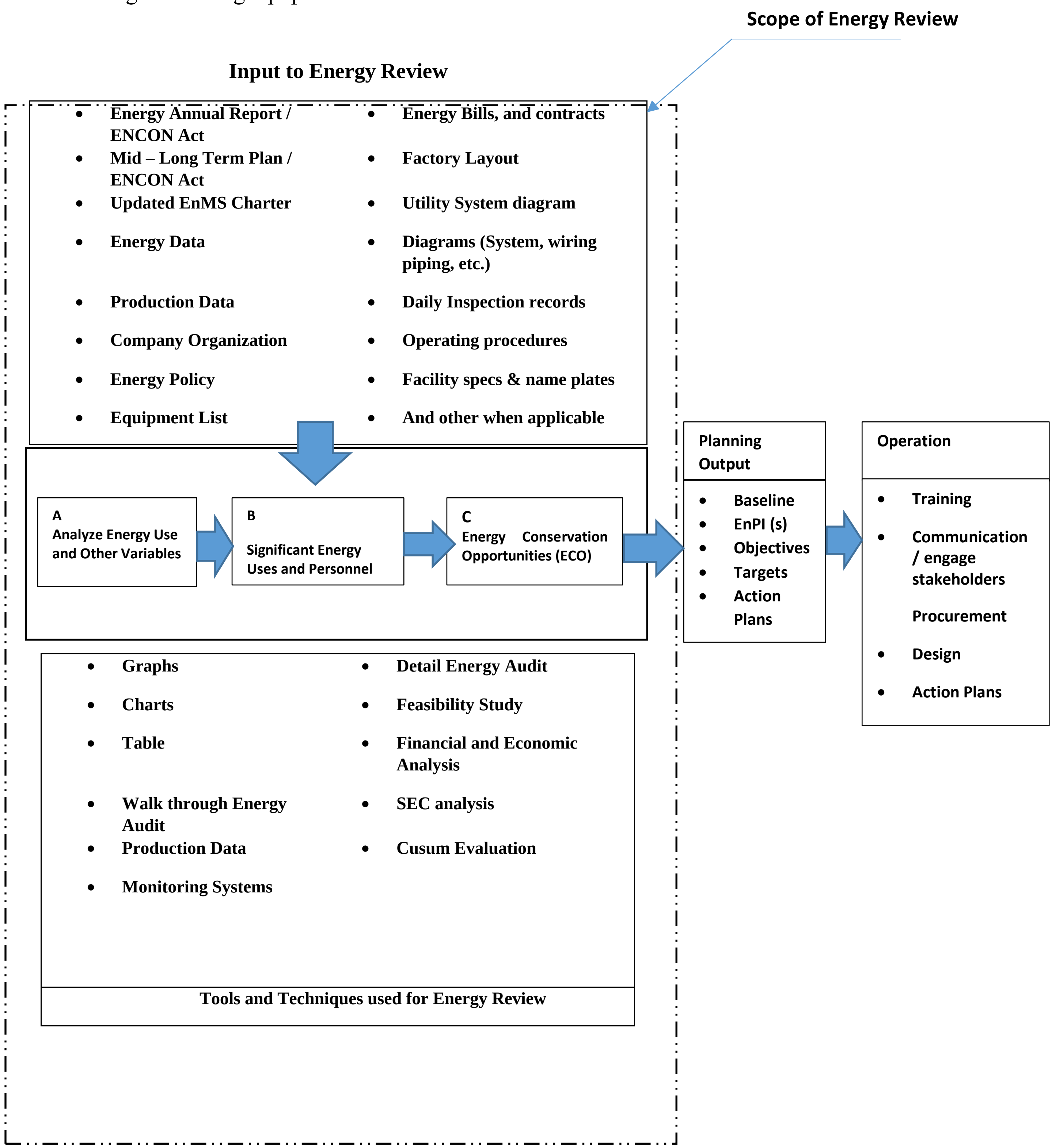


Figure 4.9: Energy Review Measures

4.8 Brief Description of How Research Work Will Be Completed

The Definition energy management given by Cape Hart, Turner and Kennedy is "The judicious and effective use of energy to maximize profits (minimize cost) and enhance competitive position". Also it can be said as the scheme of correcting and improving energy by using systems and processes to decrease energy requirements per unit of productivity while holding constant or sinking total cost of making the output from these structures"

4.8.1 The Basic Components of Energy Audit

To obtain the best energy audit in the Master Industrial Complex we have used the appropriate tools to measure the current, voltage, temperature, pressure, velocity, flow, combustion analyzers, watt meter, light intensity capturing meter, meter tape. We are taking different sections of units as discussed in the introduction so now we were taking UPVC section combined to measure the machine electricity loads and the power factor as whole for combined machine halls.

In UPVC section total load taking from GEPCO is 1260 KVA and the total load of the factory with five Extruders and eighteen Injection Molding machines having four mixing units for Injection and extruders, five Crushers, five Pulverizers, four Shredders. Some of the load for the lab machines and packing machines. Total load o the UPVC 2 section is 2925 kW approx. for the all such machines for the UPVC section recently shifted from Gujrawala to Sadhhoki plant unit. To control the lighting load in the building the area has lot of windows to get natural sun light and all procedures can be easily workable in day time and all the lighting load goes to the GEPCO supply only in the night time. There is two primary and one stand by diesel generator of 1200 KVA each for dividing the load on GEPCO as well as on the generator By dividing loads sometimes on machines only 10 Injection molding machines, 3 Extruders, 2 Crusher, 2 Pulverizer and shredder is running at a time. One of the method in energy management system is to reduce waste material and rejected material from production and reutilize it again but it cause additional cost of electricity consumption so the method to check that the recycle material is usable or not so we have to compare it with market price of the material. The utilities used for the UPVC Pipe and fittings are electricity, water, air which is used for pneumatic valves that are used in all machines including packing and production machines. Pumps are also the main source of electricity consuming equipment which are running all day and night for production purpose and it consume load up to 97 KW constantly. As an energy management engineer we have suggest to make an overhead tank up to that height from which we can get pressure up to 1.5 Bar as machines required for the proper operation but the problem occurred for the recirculation water system. To reduce the cost as well as environment friendly recirculation of water has taken place from machinery to recycle tank and then goes to the cooling tower to drop down the temperature of water but for reusing of water than it is necessary to maintain the TDS, PH, and also other parameter should be checked and dosing of different chemical take place to get soft water used in the machines and also to get long mold life in injection and extrusion machines and with this we can also reduce scale formation in the process pipe lines. We can also reduce pressure losses in the lines. The report is also placed in the reference for discussion. One of the recommendation given by our team is to place doing pump beside cooling tower and also place water softening plant for the make-up water in supply as well as recycle tank as well.

- Redefine new energy loads.
- Examine the efficiency of new machines with old machines
- Data Analysis of lighting, machines, HVAC, loads
- Space and load analysis for the relocation of machines.

Following parameters will be calculated daily:

- Temperatures
- Pressures
- Flow Rates
- Current & Voltage

Lab Experimentation

Data have to be carried out to analyze and link the performance of several kinds of machines and schemes used in Master Industrial Complex. Different apparatus will use in this experiment which is available in our lab and industries. Major apparatus includes,

- Hydraulic Pipe Testing Machine
- Impact Testing Machine
- CFM Meter
- Digital Multi-Meter DMM for the accurate measurement of current and voltage.
- Thermometers for the measurement of working temperature.

- Weather station for the measurement of wind speed and humidity.
- Other electronic circuitry.

5 Results & Discussion

5.1 Energy Conservation by Compressors

Master Industrial Complex was using previously reciprocating compressor with no storage tank attached with the compressor and after shifting this unit to new setup, screw compressors used and it was running day and night, load shifted on 2 compressors. The electricity consumed by the two compressors yearly becomes:

Total Load of Two Compressors =37 KW + 75 KW = 112 KW

Electricity Consumption by running 75 KW compressor = 75 x 24 x 30 = 54000 KWH/Month

Total Amount of Electricity Consumed Per Month = 54000 KWH x 15 = 810,000 PKR

(Without placing vessel tank with the compressor)

By placing vessel tank and removing leakages from the pipe lines the compressor will trip after making pressure up to 8 bar and save up running cost to approx. 4 hours a days.

TOTAL OF ELECTRICITY SAVED = 75 X 4 X 30 = 9000 KWH

(9000 KWH energy saved per month by the compressed air)

Total Amount of electricity saved = 9000 x 15 = 135,000 PKR

Total reduction of bill in form of compressor = 810,000 – 135,000= **675,000 PKR**

By placing VFD into the 75 KW compressor

1. (100 x 1) x 0.746 = 75 KW
2. 0.28*75 = 21 KW
3. 0.58* 75 = 43.5 KW
4. 43.5 – 21 = 22.5 KW
5. 22.5 × 6570 hr × 15 PKR per kwh = 2,217,375 PKR (annual savings)

30% energy saving.

By placing VFD into the 37 KW Compressor

1. (50 x 1) x 0.746 = 37 KW
2. 0.28*37 = 10.36 KW
3. 0.58* 37 = 21.46 KW
4. 21.46 – 10.36 = 11.1 KW
5. 11.1 × 730 hr × 15 PKR per kwh = 121,545 PKR (Annual Savings)

30% energy saving from the 37 KW Compressor

By calculation it is not feasible to place VFD in 37 KW compressor because duty factor is 2 hours per day and its payback period is larger.

Figure 5.1: Air Consumption Report with and without VFD

Air Consumption Report					
UPVC - 2					
Date	**Keyser Compresor**	**Atlas Copco (37 KW)**	**FAD M^3 / Hr**	**KWH/Day Without VFD**	**KWH/Day With VFD**
	Running Hours	**Running Hours**			
01-Apr-	18	2	15400	1424	996.6
02-Apr-	18	2	13860	1424	996.6
03-Apr-	18	2	14168	1424	996.6
04-Apr-	18	2	13552	1424	996.6
05-Apr-	18	2	13090	1424	996.6
06-Apr-	18	2	14014	1424	996.6
07-Apr-	18	2	14322	1424	996.6
08-Apr-	18	2	11704	1424	996.6
09-Apr-	18	2	15400	1424	996.6
10-Apr-	18	2	13860	1424	996.6
11-Apr-	18	2	14168	1424	996.6
12-Apr-	18	2	13552	1424	996.6
13-Apr-	18	2	13090	1424	996.6
14-Apr-	18	2	14014	1424	996.6
15-Apr-	18	2	14322	1424	996.6
16-Apr-	18	2	11704	1424	996.6
17-Apr-	18	2	15400	1424	996.6
18-Apr-	18	2	13860	1424	996.6
19-Apr-	18	2	14168	1424	996.6
20-Apr-	18	2	13552	1424	996.6
21-Apr-	18	2	13090	1424	996.6
22-Apr-	18	2	14014	1424	996.6
23-Apr-	18	2	14322	1424	996.6
24-Apr-	18	2	11704	1424	996.6
25-Apr-	18	2	15400	1424	996.6
26-Apr-	18	2	13860	1424	996.6
27-Apr-	18	2	14168	1424	996.6
28-Apr-	18	2	13552	1424	996.6
29-Apr-	18	2	13090	1424	996.6
30-Apr-	18	2	13860	1424	996.6
Total	**540.00**	**60**	**414260**	**42720**	**29898**

Above table shows that by placing VFD with the compressor 30% of the energy has been saved from the system.

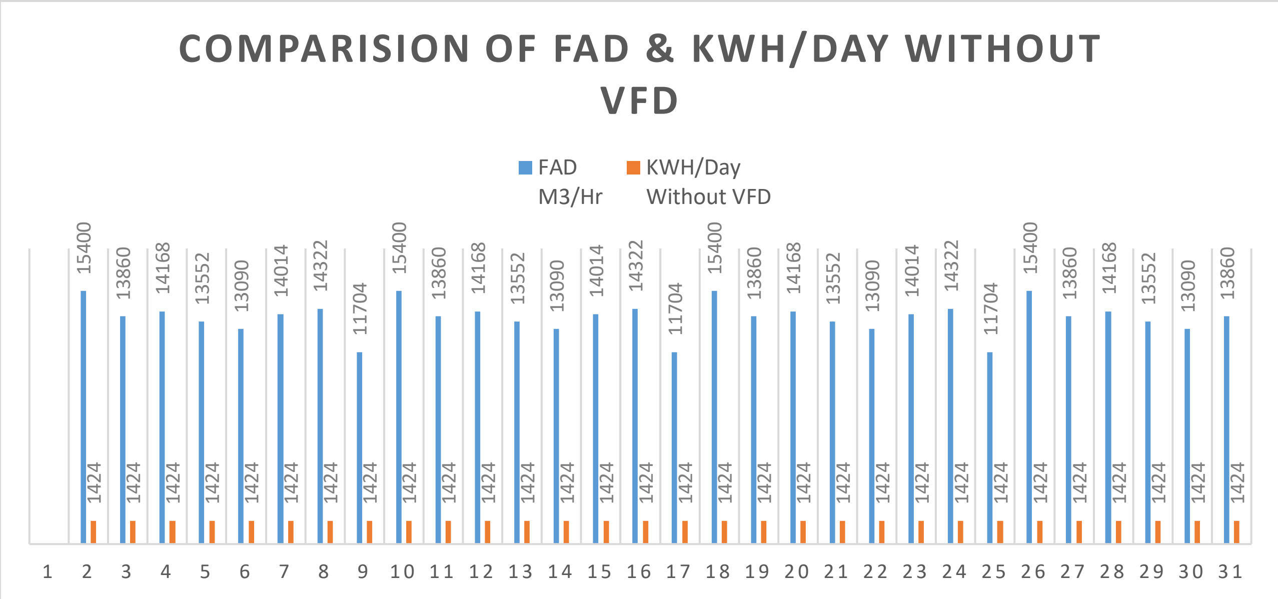


Figure 5.2: Comparison of FAD and KWH/Day of Screw Compressor without VFD in October, 2018

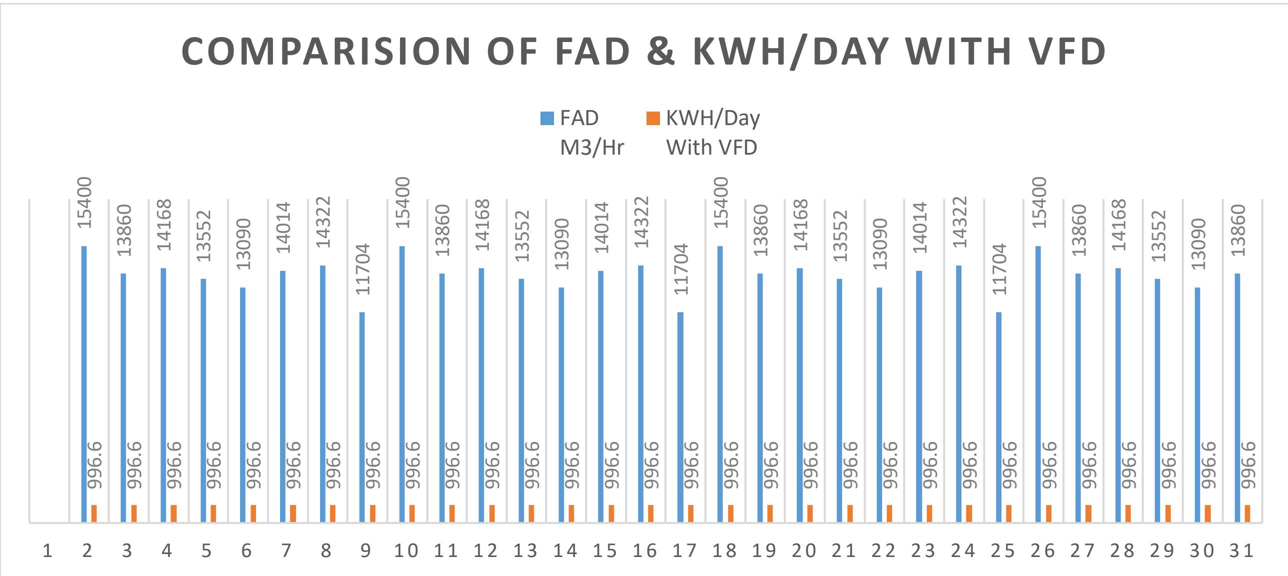


Figure 5.3: Comparison of FAD and KWH/Day with VFD

The above two graphs shows the comparison between FAD and KWH/Day of 75 and 37 KW screw compressor, as it shows that with the same FAD but having the VFD installed in it consume less KWH per day. Table 5.1 shows that the monthly electricity consumption of compressors without VFD is 42720 KWH/Month and the electricity consumption having the VFD 29898 KWH/Month. The total electricity saved per month is 12822 KWH/Month.

5.2 Energy Conservation by Solar Systems

There are two main areas where we are suggested to place and solar panels with minimum cost and suitable efficiency to attain the desired output power for the street lights and only power ventilator and evaporative coolers that are placed on the roof of the UPVC 2.

The progressive cell processing expertise & automatic manufacturing facilities produce a greatly efficient crystal-like PV module. The exchange efficiency of the solar cells spreads up to 20.1%. These cells are condensed between a hardened glass cover and an EVA (Ethylene Vinyl Acetate) strong with back sheet to offer maximum safety from the simplest environmental situations. The complete laminate is fixed in an anodized aluminum frame to deliver structural power and comfort in installation.

We are using JA solar (China Brand 16.77 % panel efficiency and 325 W Of each Panel). Master Industrial Complex has selected system for their roof top Solar Panels.
There are 110 No. of street light in whole Master Industrial Complex site and the management decide to install solar street light.

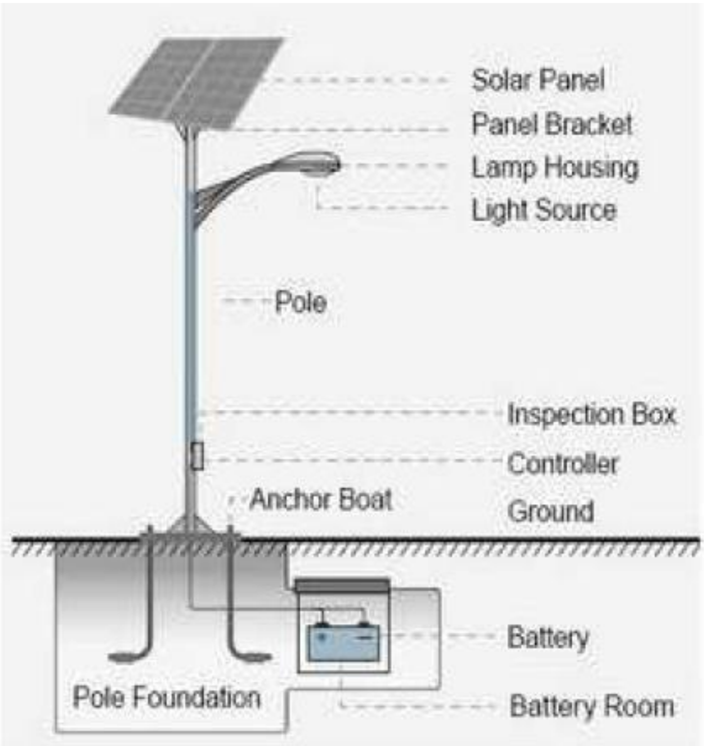


Figure 5.4: Arrangement for Solar Panel of Street Lights

Street lights can be used from 7:30 pm to 5:30 am normally on average basis in year so 9 hours a days and 3285 hours a years.

Each Light = 100 W each

Total = 110 x 100 = 11000 W or 11 KW

Total Consumption / day = 11x 9 = 99 KWH / Day

Total Consumption / month = 99 x 30 = 2970 KWH/ Month

Total Cost = 2970 x 15 = 44,550 PKR/Month (Average for peak and off peak hour)

Total No of power ventilators having electricity consumption 1.1 KW = 6

Total Power Consumption = 6 x 1.1 = 6.6 KW

Total No of Evaporative Coolers having electricity consumption 3 KW = 5

Total Power Consumption of Evaporative Coolers = 5 x 3 = 15 KW

Assuming 10 Hour for solar day.

Total Power = 15 + 6 = 21 KW

Total Consumption per day = 21 x 10 = 210 KWH/Day

Total Consumption per Month = 210 x 30 = 6300 KWH/Month

Total Cost = 6300 x 15 = 94,500 PKR/Month

5.3 Energy Saving By Mean of Natural Sunlight by Using Building Envelope

The unit of building orientation has made to save electricity consumption by mean of artificial light for the working environment in the production hall for the production of pipes and fittings in UPVC unit so by benefiting day light up-to 11 hours and save electricity up-to 3 KW if 30 Numbers of light bulbs of 100 Watt to light up in day time.

Monthly Electricity saving = 3 x 11 x 30 = 990 KWH

Total Amount = 990 x 15 = 14850 PKR/Month

5.4 Energy Conservation from WHR Boiler

WHR boiler has been selected for installation which run from the exhaust of two 1 MW diesel generators.

Technical Data of Waste Heat Recovery Boiler:

1.	Boiler Steam Capacity	02 Ton / hr
2.	Boiler heating surface area	2800 ft^2
3.	Steam Boiler working pressure	7 bar

The boiler is used to supply of saturated steam to the EPS in UPVC 2 Unit. The exhaust of diesel generator was using to operate the boiler and getting the saturated steam from the boiler to deliver saturated steam.

5.4.1 Fuel Comparison

Fuel consumption of boiler if using natural gas as fuel / Month = 2754 x 2 x 24 x 30= 3,965,760 CFT

In Pakistan gas is calculated on the basis of CMT while the bill is calculated on the basis of MMBTU

3,965,760 CFT = 112297.8 cubic meter

280744/100 = 112.297 hectometer

GCV = 933

MMBTU = 112.297 x 933 = 104,773.1/281.734 = 372

Total Amount = 372 x 1470 = 546,682 PKR/Month

Annual fuel saving cost = 1367100 x 12 = 6,560,172 PKR (From the Natural Gas)

Fuel consumption of boiler if using HFO as fuel / Month = 71 x 2 x 24 x 30 = 102,240 Kg

Cost of fuel / kg = 93.6 PKR/kg

Total Cost / Month = 102,240 x 93.6 = 9,569,664 PKR / Month

Annual fuel cost = 114,835,968 PKR

Installation of WHR boiler from the exhaust of two Cummins Generators of capacity 1 MVA having model number KTA 50-G3 C1400 D5. We were collected data from the exhaust of both diesel generators that was essential for the feasibility of WHR boiler and the data which was collected were given below:

Table 8: Data for Calculation of WHR Boiler

S.No	Data	Value
1	Boiler Steam Capacity	02 Ton / hr
2	Boiler heating surface area	2800 ft^2
3	Steam Boiler working pressure	7 bar
4	Exhaust gas flow rate	11,170 Kg/hr
5	Exhaust Gas Temperature (Outlet)	550 ^{o}C
6	Steam Generation from the WHR boiler	1800 kg/hr

The WHR boiler was used to supply saturated steam to the EPS section in UPVC II Unit. The exhaust of diesel generator was using to operate the boiler and getting the saturated steam from the boiler to deliver in EPS section. For selection of WHR boiler as the main source of steam generation system. The fuel consumption of boiler from different types of fuel were necessary for comparison. The comparison were calculated on the basis of two types of fuels; one is Natural Gas and other was HFO.

Table 9: Energy Conservation by using Different fuels for 2 Tons of Saturated Steam Boiler

S.No	Boiler Type	Natural Gas Consumption/ Month	HFO Consumption/ Month	Rate	Monthly Cost
1	Gas Fired Boiler	372 MMBTU	-	1470/MMBTU	PKR 6,562,080
2	HFO Fired Boiler	-	102240 Liter	93.6 / Liter	PKR 114,835,968

Above table shows the monthly consumption of natural gas and HFO per month which 372 MMBTU and 102240 Liters and their monthly cost were 6,562,080 PKR and 114,835,968 respectively. In Pakistan natural gas were calculated on the basis of CMT while the bill is calculated on the basis of MMBTU. HFO Based Boiler**,** furnace oil is used as fuel in HFO boiler.

5.4.2 HFO Based Boiler

Furnace oil is used as fuel in HFO boiler and at furnace burners for ignition. There is HFO tank of 10000 Liter for the storage. There are two supply pumps for supplying the furnace oil to furnace burner of 280ltr/min capacity. There are two decanting pumps of 280 ltr/min capacity to unload the furnace oil from tanker. Boiler feed water is continuously prepared following chemicals are used to prepare boiler feed water.

The chemical recommended for boiler feed water are as follow:

- 77225 O_2 scavenger 0.6 kg/day
- 19P PO_4 base for Ca, Mg hardness 0.5 kg/day
- 2813 amines for steam side film layer 0.35 kg/day

Sample of boiler feed water were tested by the Lab. The results of test are provided to the boiler house personnel. There are two pumps installed for the feed water which is installed at the discharge of condensate tank of 18 gpm and 1.5 HP power motor for the transportation of feed water into the boiler and one pump is installed for the make-up of the same capacity to filled the condensate tank comes from the softening plant.

Table 10: Steam Generated (Tons/Day)

Steam Generated (Tons/Day)				
Day	Waste Heat Boiler	HFO Boiler	HFO/Day	Amount PKR/Day
1-07-18	40.8 Ton/Day	-		
2-07-18	-	37 Ton/Day	2923 Ltr/Day	283,531
3-07-18	39.6 Ton/Day	-	-	-
4-07-18	40.8 Ton/Day	-	-	-
5-07-18	41.04 Ton/Day	-	-	-
6-07-18	38.88 Ton/Day	-	-	-
7-07-18	39.84 Ton/Day	-	-	-
7-07-18	38.88 Ton/Day	-	-	-
8-07-18	38.16 Ton/Day	-	-	-
9-07-18	38.64 Ton/Day	-	-	-
10-07-18	39.12 Ton/Day	-	-	-
11-07-18	34.8 Ton/Day	-	-	-
12-07-18	-	38.4 Ton/Day	3033.6 Ltr/Day	294,259
13-07-18	-	36 Ton/Day	2844 Ltr/Day	275,868
14-07-18	40.8 Ton/Day	-	-	-
15-07-18	40.8 Ton/Day	-	-	-
16-07-18	40.32 Ton/Day	-	-	-
17-07-18	40.8 Ton/Day	-	-	-
18-07-18	40.8 Ton/Day	-	-	-
19-07-18	40.32 Ton/Day	-	-	-
20-07-18	40.8 Ton/Day	-	-	-
21-07-18	39 Ton/Day	-	-	-
22-07-18	39.7 Ton/Day	-	-	-
24-07-18	38.2 Ton/Day	-	-	-
25-07-18	37.9 Ton/Day	-	-	-
26-07-18	39 Ton/Day	-	-	-
27-07-18	-	39 Ton/Day	3081 Ltr/Day	298,857
28-07-18	-	40 Ton/Day	3160 Ltr/Day	306,520
29-07-18	-	38 Ton/Day	3002 Ltr/Day	291,194
30-07-18	37.5 Ton/Day	-	-	-
31-07-18	38.2 Ton/Day	-	-	-
Total	984.7 Ton/Month	228.4 Ton/Month	18043.6 Ltr/Month	1,750,229 PKR

From the above table 81.2% of steam was using from WHR boiler and 18.82% steam was using from HFO base boiler. This table is recorded in the month of July. By using the WHR boiler we saved 69914 Liters of HFO per month from the above table and it has cost up to 6543922 PKR so with the WHR boiler Master Industrial Complex have saved 6543922 PKR per month.

The total cost of the project for installing WHR boiler up to operational condition is 19,150,000 PKR. This is highly favorable as the back pack period of the project is less than 4 months.

The energy can be conserve by using diesel generator and use its ¾ Load and ½ Load on other generator for saving of fuel from the diesel generators. The data table is given below:

Table 11: Diesel Consumption of Diesel Generator (Liters/Days)

Diesel Consumption (Liters/Day)				
Day	Generator 1 ¾ Load Ltrs	Generator 2 ½ Load	Total Diesel Consumption (Ltrs)	Amount PKR/Day
1-07-18	4752	3312	8064	913,167
2-07-18	4650	3320	7970	902522.8
3-07-18	4720	3310	8030	909317.2
4-07-18	4690	3295	7985	904221.4
5-07-18	4730	3325	8055	912148.2
6-07-18	4715	3312	8027	908977.5
7-07-18	4696	3305	8001	906033.2
7-07-18	4670	3280	7950	900258
8-07-18	4625	3100	7725	874779
9-07-18	4650	3200	7850	888934
10-07-18	4670	3210	7880	892331.2
11-07-18	4710	3310	8020	908184.8
12-07-18	4612	3300	7912	895954.9
13-07-18	4500	3100	7600	860624
14-07-18	4430	3400	7830	886669.2
15-07-18	4512	3320	7832	886895.7
16-07-18	4675	3450	8125	920075
17-07-18	4600	3450	8050	911582
18-07-18	4420	3245	7665	867984.6
19-07-18	4500	3310	7810	884404.4
20-07-18	4290	3567	7857	889726.7
21-07-18	4800	3120	7920	896860.8
22-07-18	4760	3321	8081	915092.4
24-07-18	4421	3656	8077	914639.5
25-07-18	3321	3100	6421	727114
26-07-18	4756	3005	7761	878855.6
27-07-18	4552	3149	7701	872061.2
28-07-18	4320	3276	7596	860171
29-07-18	4756	3210	7966	902069.8
30-07-18	4754	3188	7942	899352.1
31-07-18	4756	3433	8189	927322.4
Total	**142013**	**101879**	**243892**	**27618330**

From the above table it is concluded that the 243,892 liters of diesel consume for the running of two primary diesel generators so by running diesel generator its running cost is 30.68 PKR/KWH.

5.5 Energy Conservation from Cooling Tower

There are 4 Nos. of Induced draft cooling tower of capacity 200 Tons/ Hr as they was running two at a time. The capacity of motor was 7.5 HP for the axial fan.

After discussion with GM Technical of Master Industrial complex we have decided to place VFD with high electricity consumption pump of cooling towers and cooling tower fans.

Circulating Water Flow Rate =250 M3/hr

Entering Water Temperature = 42^{o} C

Outer Water Temperature =32^{o} C

Ambient Wet Bulb Temperature =29 ^{o} C

Approach: 03^{o}C

Temperature Drop (Delta t) = 10^{o} C

Evaporation Loss = 0.01%

Drift Loss @ circulating flow = 0.0005%

Water Conditions: Good

PH-TDS = 7.5~8.00/≤400

Electrics Motors

Number of Cells = 04 Cells

Rated HP/kW = 7.5/5.5

Full Speed rpm, volts = Hz: 1460, 400, 50

Phase/Origin =3/China

Insulations Class = IP-55/Y-3 Series

Fans

Type of Fan: Axial Flow Adjustable Blades

Per Cell Fan Diameter: ϕ1574mm

Air Flow CFM/Cell: 48000cfm

Drive: Belt-Driven

5.5.1 Energy Saving By VFD Placement with Pumps

Two pumps were continuously running for the cooling towers having 20 hp each motor with the pump as they are highly energy consuming so VFD has placed with the cooling tower pumps as their payback period is less than 2 years.

From table 2.2.1

(20 x 2) x 0.746 = 29.84 KW

0.4*29.84 = 11.93 KW

0.94* 29.84 = 28.04 KW

29.84 – 11.93 = 17.91 KW

17.91 × 8,760 hr × 15 PKR per KWH = 2353374 PKR

(Annual energy consumption with VFD)

40% of energy is conserve by installing VFD with the pumps of Cooling Towers.

5.5.2 Energy Saving By VFD Placement with Cooling Tower Fan Motors

From table 2.2.1

(7.5 x 4) x 0.746 = 22.38 KW

0.28*22.38 = 6.266 KW

0.88*22.38 = 19.64

22.38-6.266 = 16.114 KW

16.114 x 8760 hr x 15 PKR per KWH = 2,117,379 PKR

(Annual Energy Consumption by Placing VFD)

28.5% of energy is conserve by placing VFD with the cooling tower fan motor. To run the facility of UPVC unit we have built the two tanks having capacity to store water is 18000 Gallon each and from these two tanks one is used as a supply tank and the other is used as a recycle tank. These two tanks are made to save water and used recycling of water. Water has been supplied to the Injection molding machines, Extruders, Mixers, and crusher section at desired pressure and after used by the machinery, the discharge water from the machines goes to the recycle tank but it’s temperature becomes high and this hot water is not suitable to feed machines again so we place pumps at the recycle tank and drops the temperature of water through cooling tower up-to 10^{o}C and the discharge of the cooling tower goes toward the supply tank with the desired temperature and then again feed that water to the machinery. By recycling that water again and again this water needs chemical treatment to soften the water and the dosing pumps have been placed for chemical treatment of water to attain desired PH and TDS and also requires make-up water that feeds from the turbine. We have made a schedule of changing water completely after 15 days.

The total requirement of water for all sections of machinery is approx. 340 gpm so we have placed two pumps of 220 gpm each which will run continuously to the cooling tower to cool down the water for the production machinery. The soft water is supplied to all sections after water treatment the following chemicals are used:

Table 12: Water Parameter Range for Water of Cooling Towers

PARAMETER	LIMIT
PH	8~9.5
COND	1500~2000
TDS	750~1000 ppm
M alk	300~600 ppm

The above parameter have to be maintain to reduce scaling in pipe lines and also reduce scale formation the cavities of injection and extrusion machines molds and also in other equipment's. We have used some chemicals with the help of dosing pumps which is placed outside the cooling towers and also we insert some chemicals in the supply and recycle tanks as well to maintain the desired values. If we maintain the above mention parameter, the make-up water that is inserted into the supply tank through the turbine from underground water is to be minimized and the cost and plenty that to be sanction by the government is also to be minimized and also save water.

5.6 Energy Conservation from the Lighting System

Table 13: Standard Lumen Table for Light Bulbs

Lumen (Brightness)	LED Bulb Watts W	CFL Bulb Watts W	Incandescent Bulb Watt W
400 – 500	6 – 7	8 – 12	40
650 – 850	7 – 10	13 – 18	60
1000 – 1400	12 – 13	18 – 22	75
1450 - 1700	14 – 20	23 – 30	100
2700	25 – 28	30 – 55	150

By using LED lights in offices as well as production areas as compare to CFL and Incandescent lights. The table having all the calculation with the data. To facilitate the operators for quality check and sorting pipes and fitting with naked eye; large numbers of compact fluorescent lamp CFL were installed in the production line so by replacing the CFL lights with LED light huge amount of electricity can be saved annually. Basic parameter for the quality of light was its spectrum. Complete component of spectrum supported the detecting in variation of colors.

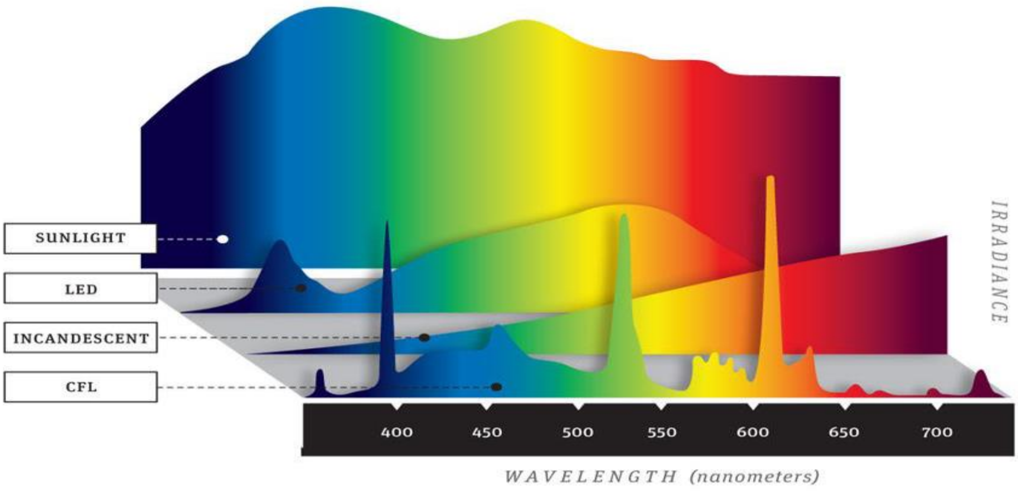


Figure 5.5: Spectrum comparison of Sources of Sunlight, LED, Incandescent and CFL

Table 14: Light Calculation for Facility with LED Bulbs

S.No	Section Name	Area sq m	Roof Height	Required Lumens	Light Type	Lumen/Lights	No of Lights	Total KW
1	Extruder Hall	804	17	259531	LED (100 W)	12000	22	2.2
2	Injection Molding Hall	804	25	346042	LED (100 W)	12000	29	2.9
3	Crusher Hall	175	17	56490	LED (100 W)	12000	5	0.5
4	Mixer Hall (UPVC Pipes)	116.2	20	37509	LED (100 W)	12000	3	0.3
5	Mixer Hall (Injection Molding)	116.2	20	37509	LED (100 W)	12000	3	0.3
6	Compressor Room	175	17	56490	LED (100 W)	12000	5	0.5
7	Electrical Panel Room	58	15	18722	LED (100 W)	12000	2	0.2
8	Generator Room	175	15	56490	LED (100 W)	12000	5	0.5
9	Mould Store	175	15	56490	LED (100 W)	12000	5	0.5
10	Electrical Room	12	15	12912	LED (100 W)	12000	1	0.1
11	Mechanical Room	12	15	12912	LED (100 W)	12000	1	0.1
12	Raw Material Store	175	15	37660	LED (100 W)	12000	3	0.3
13	D.G.M Office	37	11	15925	LED (18 W)	1600	10	0.18
14	Admin Office + Record	58	11	24963	LED (18 W)	1600	16	0.288
15	Kitchen + Sitting	27	11	11621	LED (18 W)	1600	7	0.126
16	Reception	44	11	18938	LED (18 W)	1600	12	0.216
17	Masjid+ Lobby	45	11	9684	LED (18 W)	1600	6	0.108
18	Ablution Area + Lobby	127	11	27330	LED (18 W)	1600	17	0.306
19	Security Room + Wash Room	20	11	4304	LED (18 W)	1600	3	0.054
20	Elevators	6	11	3874	LED (18 W)	1600	2	0.0.036
21	Masjid (M.F)	53	11	22811	LED (18 W)	1600	14	0.252
22	Packing Area (M.F)	249	11	13396	LED (18 W)	1600	8	0.144
23	Store +Ablution Area+ Bath (M.F)	25	11	5380	LED (18 W)	1600	3	0.054
						Total		**10.128**

Table 15: Light Calculation for facility for CFD Bulbs

S.No	Section Name	Area sq m	Roof Height	Required Lumens	Light Type	Lumen/Lights	No of Lights	Total KW
1	Extruder Hall	804	17	259531	CFD (100 W)	7000	37	3.7
2	Injection Molding Hall	804	25	346042	CFD (100 W)	7000	49	4.9
3	Crusher Hall	175	17	56490	CFD (100 W)	7000	8	0.8
4	Mixer Hall (UPVC Pipes)	116.2	20	37509	CFD (100 W)	7000	5	0.5
5	Mixer Hall (Injection Molding)	116.2	20	37509	CFD (100 W)	7000	5	0.5
6	Compressor Room	175	17	56490	CFD (100 W)	7000	8	0.8
7	Electrical Panel Room	58	15	18722	CFD (100 W)	7000	3	0.3
8	Generator Room	175	15	56490	CFD (100 W)	7000	8	0.8
9	Mould Store	175	15	56490	CFD (100 W)	7000	8	0.8
10	Electrical Room	12	15	12912	CFD (100 W)	7000	2	0.2
11	Mechanical Room	12	15	12912	CFD (100 W)	7000	2	0.2
12	Raw Material Store	175	15	37660	CFD (100 W)	7000	5	0.5
13	D.G.M Office	37	11	15925	CFD (18 W)	1100	14	0.252
14	Admin Office + Record	58	11	24963	CFD (18 W)	1100	23	0.414
15	Kitchen + Sitting	27	11	11621	CFD (18 W)	1100	11	0.198
16	Reception	44	11	18938	CFD (18 W)	1100	17	0.306
17	Masjid+ Lobby	45	11	9684	CFD (18 W)	1100	9	0.162
18	Ablution Area + Lobby	127	11	27330	CFD (18 W)	1100	25	0.45
19	Security Room + Wash Room	20	11	4304	CFD (18 W)	1100	4	0.072
20	Elevators	6	11	3874	CFD (18 W)	1100	4	0.072
21	Masjid (M.F)	53	11	22811	CFD (18 W)	1100	21	0.378
22	Packing Area (M.F)	249	11	13396	CFD (18 W)	1100	12	0.216
23	Store +Ablution Area+ Bath (M.F)	25	11	5380	CFD (18 W)	1100	5	0.09
						Total		**16.61**

Table 16: Lighting Calculation Standard Chart

Environment	Footcandle	Lux
Ware House		
Large Items	10	108
Small Items	30	323
Aisles	20	215
Offices		
Private or Open	40	431
Conference Room	30	323
Break Room	15	162
Bathrooms	18	194
Factories		
Assembly – Large Item	30	323
Assembly – Details	100	1076
Exteriors		
Covered Parking	5	54
Urban Parking	1.5	16
Suburban Parking	1	11
Exterior Building	1	11
Gas Station Canopy	12.5	135
Retails		
General	50	538
Department Store	40	431
Displays	3-10x greater than ambient	
Auto		
Shop	50	538
Showroom	50	538
Grocery		
General	50	538
School		
Classroom	40	431
Auditorium	7.5	81
Hallway	25	269

Table 5-6 defines the standard lux level for the each area for the selecting the lumen of lights for each area of Master Industrial Complex specially for the UPVC II unit for the production halls, mold store, offices areas, packing halls, ware house and masjid as well. From Table 5-5 we have calculated total lumens required for the UPVC II units are 1146983.From Table 5-4, total power consumed for generating 1146983 Lumens from CFL Lamps are 16.61 KW and the power consumed for generating 1146983 Lumens from LED Lamps are 10.128 KW. The energy saving is 6.482 KWH.

Monthly energy consumption with LED lights = 10.128*14*30 = 4253.76 KWH/Month

Monthly energy consumption with LED lights = 16.61*14*30 = 6976.2 KWH/Month

2722.44 KWH/Month saves with the installation of LED Lights.

Net Energy Saving in Lighting = $(1-\frac{6.482}{16.61})$ x 100 = 40%

Payback period for installation of LED lights instead of CFL lights is less than 1 year.

5.7 Electrical Load Calculation

To conserve energy of any machine or to compare energy consumption of machine first we have to calculate the total electrical power consumed by the machines as well all utilities.

Table 17: UPVC II Extruder Hall Electrical Load Table

UPVC-2 Machinery Load								
Extrusion Hall								
Sr#	**Machine Name**	**Qty**	**Single Machine (kW)**	**Total kW**	**Running 'A' Single Machine (A)**	**Total Running Current (A)**	**Rated 'A' Single Machine (A)**	**Total Rated Current (A)**
1	Extruder Machines	2	37	74	61	122	71	142
2	Extruder Machines	1	40	40	68.73	68.73	78.4	78.4
3	Extruder Machines	1	37	37	61	61	69.6	69.6
4	Extruder Machines	1	37	37	61	61	69.6	69.6
5	Electrical Panel	5	15	75	25	125	29	145
6	Barrel Heater	20	1.5	30	2.5	50	2.9	58
7	Vacuum Tank Pump	10	4	40	6.5	65	7.6	76
8	Water Tank Pump	10	4	40	6.5	65	7.6	76
9	Hall Off	5	5	25	8.2	41	9.5	47.5
10	Auto Pipe Cutter	5	1.5	7.5	2.5	12.5	2.9	14.5
11	Belling Machine	5	5	25	8.2	41	9.5	47.5
12	Double Speed Crane (5Ton)	2	13	26	21.5	43	24.8	49.6
Total Load				**457**	**333**	**755**	**382**	**874**

Table 18: Tool Room Electrical Load Table

Tool Room								
Sr#	**Machine Name**	**Qty**	**Single Machine (kW)**	**Total kW**	**Running Current Single Machine (A)**	**Total Running Current (A)**	**Rated Current Single Machine (A)**	**Total Rated Current (A)**
1	Lathe Machine	1	5	5	8.2	8.2	9.5	9.5
2	Single Speed Crane (5 Ton)	1	13	13	21.5	21.5	24.8	24.8
3	Table Drill Machine	1	1	1	1.2	1.2	1.4	1.392
4	Radial Drill Machine	1	2	2	2.6	2.6	3.0	3.016
5	Hand Drill Machine	2	1	2	2.4	4.8	2.8	5.568
6	Angle Grinder 4"	2	0.85	1.7	1	2	1.2	2.32
7	Angle Grinder 9"	2	2	4	2.9	5.8	3.4	6.728
Total Load				**18**	**39.8**	**29.7**	**34.3**	**34.3**

Table 19: UPVC II Injection Molding Hall Electrical Load Table

Injection Molding Hall								
1	BL 320 EK	7	58.1	406.7	95.5	668.5	110.05	770.35
2	BL 650 EK	4	98	392	163	652	189	756
3	250 Ton	2	46.7	93.4	77	154	89	178
4	470 Ton	1	28.25	28.25	47	47	54	54
5	530 Ton	1	97.35	97.35	160	160	185	185
6	600 Ton	1	110	110	189	189.2	215.7	216
7	320 Ton	2	65	130	112	223.6	127.5	255
8	Double Speed Crane (10Ton)	2	10	20	18	36.1	21.5	43
Total Load				**1278**	**862**	**2130**	**992**	**2457**

Table 20: UPVC II Crusher Room Electrical Load Table

Crusher Room								
1	Crusher 1	2	18	36	30.9	61.9	35.6	71.1
	Crusher 2	2	13.2	26.4	22.7	45.4	26.1	52.2
2	Conveyer	1	2	2	3.4	3.4	4.0	3.95
3	Cutter	2	1.5	3	2.6	5.2	3.0	5.92
4	Shreder 1	2	7.5	15	12.9	25.8	14.8	29.64
	Shreder 2	2	7.5	15	12.9	25.8	14.8	29.64
5	Pulverizer 1	2	50	100	85.9	171.8	98.8	197.61
	Pulverizer 2	2	34	68	58.4	116.8	67.2	134.37
6	Single Speed Crane (5 Ton)	1	13	13	22.3	22.3	25.7	25.68
Total Load				**278**	**252**	**478**	**290**	**550**

Table 21: UPVC II Mixer Room Electrical Load Table

Mixer Room For UPVC Pipe								
1	Cold Chamber	2	30	60	49.5	99	57	114
2	Hot Chamber	1	75	75	123	123	143	143
3	Hot Chamber	1	110	110	209	209	297	297
4	Elevator	1	10	10	16.5	16.5	19	19
Total Load				**255**	**398**	**447.5**	**516**	**573**

The load calculation of the mixing room is given below:

Table 22: Compressor Room Electrical Load Table

Compressor Room								
1	Compressor	1	37	37	61	61	71	71
2	Compressor	1	75	75	129	129	148	148
Total Load				**112**	**190**	**190**	**219**	**219**

The Electrical Load calculation of the Mixer Room UPVC fittings is given below:

Table 23: UPVC II Fittings Mixer Room Electrical Load Table

Mixer Room For UPVC Fitting								
1	Cold Chamber	2	30	60	49.5	99	57	114
2	Hot Chamber	1	75	75	123	123	143	143
3	Hot Chamber	1	110	110	209	209	297	297
4	Elevator	1	10	10	16.5	16.5	19	19
5	Double Speed Crane (5 Ton)	1	13	13	21.5	21.5	24.8	24.8
Total Load				**268**	**419.5**	**469**	**540.8**	**597.8**

Table 24: UPVC II Auxiliaries Section Electrical Load Charts

Other Auxiliaries								
1	Panel Room	_	_	2	_	11.4	_	12.7
2	Generator Room	_	_	3	_	17.0	_	19.1
3	Mould Store	_	_	2	_	11.4	_	12.7
4	Electrical Room	_	_	2	_	11.4	_	12.7
5	Mechanical Room	_	_	2	_	11.4	_	12.7
6	Raw Material Store	_	_	3	_	17.0	_	19.1
Total Load				**14**	_	**79.5**	_	**89.1**

Table 25: UPVC II Total Electrical Load Table

Total Load UPVC 2 Section		
Total Load	**KW**	**2925**
	A (Running)	**5011**
	A (Rated)	**5948**

We have calculated the above electrical load if we run all machines together. The total load is 2925 KW. We have 1260 KVA of two transformer and 2 diesel generator of 1200 KVA each to run the factory. By the above load calculation we are now able to find our total load requirement and with the help of load management we can run the industry with proper load management.

5.8 Energy Conservation by Selection of Old and New Machines

Master Industrial Complex have a unique sort of work and required planning and management skill because it is shifting from the existing factory which was running in Gujrawala City of Punjab, Pakistan. One of any industrialist could not waste his machinery while shifting from one place to another so keeping in mind to increase the production rate of UPVC 2 unit and also to purchase energy efficient machines as compared to the previous machines and also reduce the cost. The one option decided by the management to buy the used machines to cut down their expenses of new machines but by thinking of long run to reduce the maintenance charges as well as electricity consumption of each machine, Master decided to buy new machines parallel with old machines that are shifted from the previous setup.

The below table and graphs shows the electrical consumption, water consumption and production rate of each machines that can be calculated, this job is really a time taking job also required meeting with the officials and to get on the same point whose investment is on the stack.

Table 26: Electrical Load, Water Consumption and Production Rate Comparison with Old and New Extruders

UPVC Unit 2 (Extruders)							
S.No	**Specification**	**Machine Name**	**Type**	**Machine Capacity (mm)**	**Electrical Load (KW)**	**Water Consumption Gal/hr**	**Production Rate (Kg/hr)**
1	Extruders	Extruder 1 (Single Pipe)	Old	63 - 160	100	1800	250
2		Extruder 2 (Single Pipe)	Old	63 - 160	100	1600	250
3		Extruder 3 (Single Pipe)	New	63 - 160	105	1250	300
4		Extruder 4 (Two Pipe)	New	16 - 63	93	1500	250
5		Extruder 5 (Ron)	New	63 - 160	90	1250	300

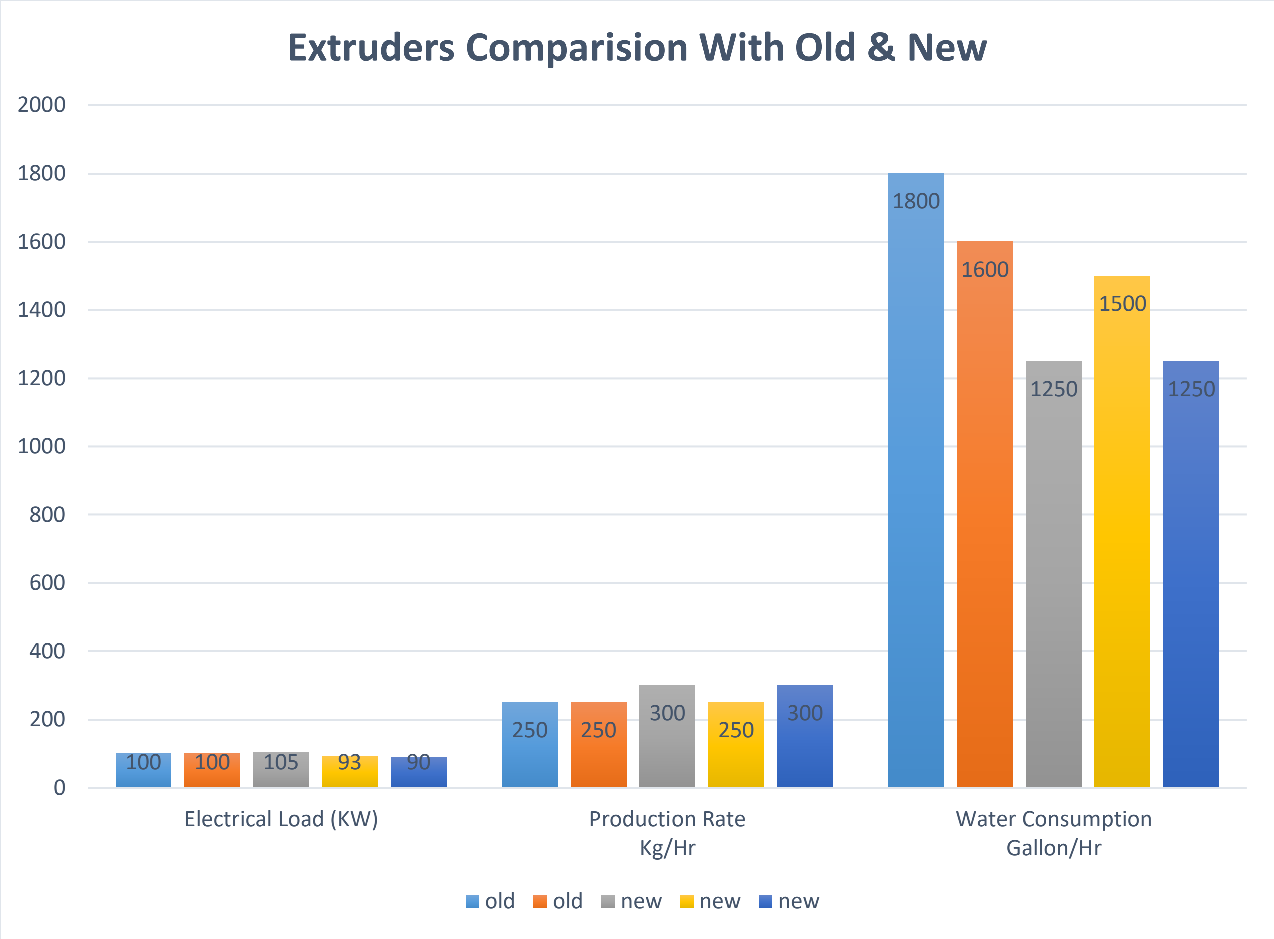


Figure 5.6:UPVC Pipe Extruders Comparison with Old and New

The above graph and table shows that the new extruders consume less amount of water as compared to the old extruders with the higher production rate. The above graph also shows the electrical consumption with the production rate of extruder so the new extruders consume less amount of electrical power and gives higher production rate.

Table 27: Comparison Table of Injection Molding Machine with Old and New from Machine 1-9

UPVC Unit 2 (Injection Molding Machines)							
S.No	**Specification**	**Machine Name**	**Type**	**Machine Capacity (Ton)**	**Electrical Load (KW)**	**Water Consumption (Galon/hr)**	**Production Rate**
1	**Injection Molding Machines**	**Injection Molding Machine 1**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
2		**Injection Molding Machine 2**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
3		**Injection Molding Machine 3**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
4		**Injection Molding Machine 4**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
5		**Injection Molding Machine 5**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
6		**Injection Molding Machine 6**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
7		**Injection Molding Machine 7**	**New**	**320**	**58.1**	**480**	**Depend upon mold and part size.**
8		**Injection Molding Machine 8**	**New**	**620**	**98**	**950**	**Depend upon mold and part size.**
9		**Injection Molding Machine 9**	**New**	**620**	**98**	**950**	**Depend upon mold and part size.**

Table 28: Comparison Table of Injection Molding Machine with Old and New from Machine 10-18

UPVC Unit 2							
S.No	**Specification**	**Machine Name**	**Type**	**Machine Capacity (Ton)**	**Electrical Load (Ton)**	**Water Consumption (Galon/hr)**	**Production Rate**
10	**Injection Molding Machines**	**Injection Molding Machine 10**	**New**	**620**	**98**	**950**	**Depend upon mold and part size.**
11		**Injection Molding Machine 11**	**New**	**620**	**98**	**950**	**Depend upon mold and part size.**
12		**Injection Molding Machine 12**	**Old**	**250**	**46.7**	**450**	**Depend upon mold and part size.**
13		**Injection Molding Machine 13**	**Old**	**600**	**110**	**1000**	**Depend upon mold and part size.**
14		**Injection Molding Machine 14**	**Old**	**530**	**97.35**	**950**	**Depend upon mold and part size.**
15		**Injection Molding Machine 15**	**Old**	**470**	**75**	**850**	**Depend upon mold and part size.**
16		**Injection Molding Machine 16**	**Old**	**250**	**46.7**	**450**	**Depend upon mold and part size.**
17		**Injection Molding Machine 17**	**Old**	**320**	**65**	**610**	**Depend upon mold and part size.**
18		**Injection Molding Machine 18**	**Old**	**320**	**65**	**610**	**Depend upon mold and part size.**

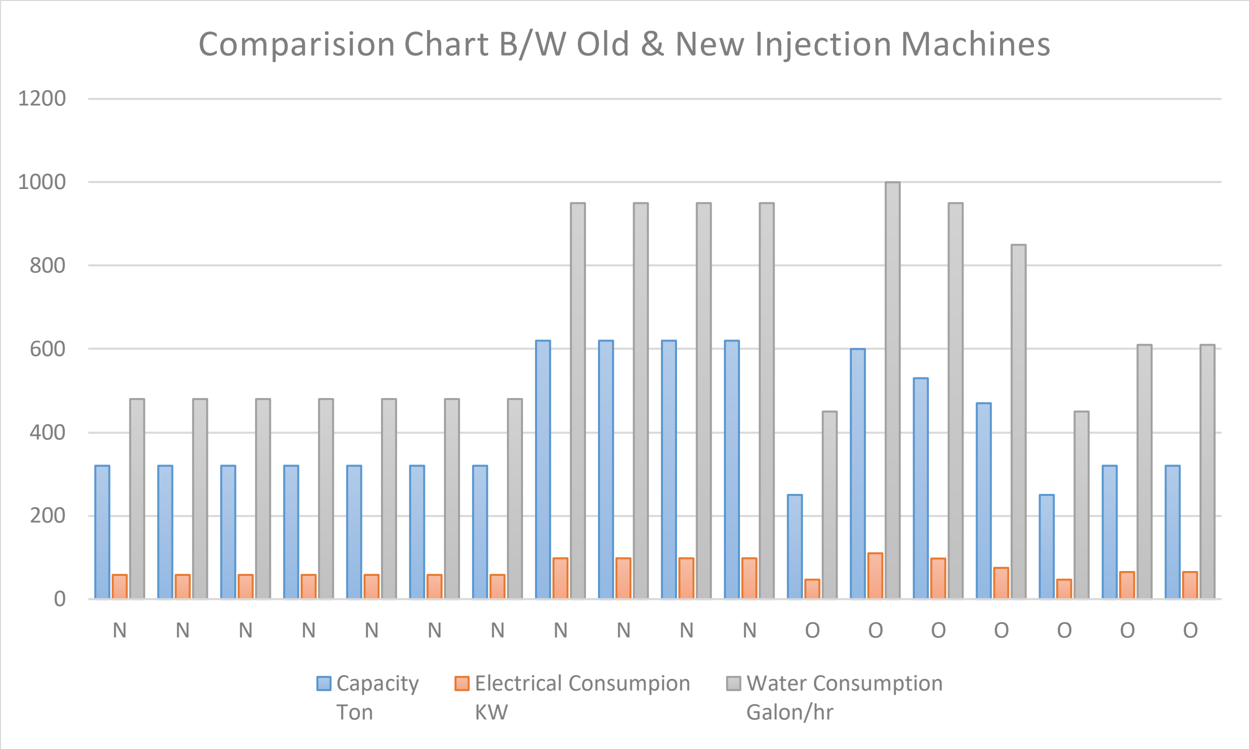


Figure 5.7: Comparison Chart between old and new Injection Molding Machines

The above graph and table shows that with the capacity of machine the new machines consume less electrical power and also consumes less water.

Table 29: Comparison Table for Old and New Crusher, Pulverizer, and Mixer

UPVC Unit 2							
S.No	**Specification**	**Machine Name**	**Type**	**Machine Capacity**	**Electrical Load (KW)**	**Water Consumption (Gal/hr)**	**Production Rate (Kg/hr)**
1	**Crusher**	**UPVC Pipe & Fitting Crusher 1**	**New**	**NIL**	**18**	**250**	**300-400**
2		**UPVC Pipe & Fitting Crusher 2**	**New**	**NIL**	**18**	**250**	**300-400**
3		**UPVC Pipe & Fitting Crusher 3**	**Old**	**NIL**	**13.2**	**200**	**150-200**
4		**UPVC Pipe & Fitting Crusher 4**	**Old**	**NIL**	**13.2**	**200**	**150-200**
1	**Pulverizers**	**UPVC Pulverizer 1**	**New**	**NIL**	**50**	**350**	**180-400**
2		**UPVC Pulverizer 2**	**New**	**NIL**	**50**	**350**	**180-400**
3		**UPVC Pulverizer 3**	**Old**	**NIL**	**34**	**250**	**120-200**
4		**UPVC Pulverizer 4**	**Old**	**NIL**	**34**	**250**	**120-200**
1	**Mixers UPVC Pipes**	**Mixer Machine 1 (Extrusion System)**	**New**	**800 L**	**140**	**1000**	**350**
2		**Mixer Machine 2 (Extrusion System)**	**Old**	**600 L**	**105**	**800**	**240**
3	**Mixers UPVC Fittings**	**Mixer Machine 1 Injection Molding Section**	**New**	**800 L**	**140**	**1000**	**350**
4		**Mixer Machine 1 Injection Molding Section**	**Old**	**600 L**	**105**	**800**	**250**

Table 30: Comparison Table for Old and New Shredder and Compressor

S.No	Specification	Machine Name	Type	Machine Capacity	Electric Load (KW)	Water (Galon/hr)	Production Rate
1	Shredder	UPVC Shredder 1	New	NIL	37	200	550 kg/hr
2		UPVC Shredder 2	New	NIL	37	200	550 kg/hr
3		UPVC Shredder 3	Old	NIL	22	200	300 kg/hr
4		UPVC Shredder 4	Old	NIL	22	200	300 kg/hr
1	(Comp)	Compressor 1 (Screw Type)	New	7.5 Bar, 12 m3/min FAD	75	NIL	12.02 m3/min
2		Compressor 2 (Screw Type)	Old	7.5 Bar, 7.8 m3 /min FAD	37	NIL	7.8 m3/min

Table 31: Comparison Table for Old and New Tool Room Machines

UPVC Unit 2							
S.No	**Specification**	**Machine Name**	**Type**	**Machine Capacity**	**Electrical Load**	**Water**	**Production Rate**
1	**Tool Room**	**Lathe Machine**	**Old**	**Depend upon Job**	**3 HP 40 - 750 rpm**	**NIL**	**Depend upon Job**
2		**Radial Drill Machine**	**Old**	**Depend upon Job**	**1.5 HP & 1 HP with 40-3300 RPM**	**NIL**	**Depend upon Job**
3		**Table Drill Machine**	**New**	**Depend upon Job**	**0.75 HP 86 – 1440 RPM**	**NIL**	**Depend upon Job**
4		**Angle Grinder 4”**	**New**	**Depend upon Job**	**850 W, 1100 RPM**	**NIL**	**Depend upon Job**
5		**Drill Machine**	**New**	**Depend upon Job**	**0.75 KW**	**NIL**	**Depend upon Job**
6		**Drill Machine**	**New**	**Depend upon Job**	**0.75 KW**	**NIL**	**Depend upon Job**
7		**Angle Grinder 9”**	**New**	**Depend upon Job**	**2 KW , 6000 RPM**	**NIL**	**Depend upon Job**

Table 32: Comparison Table for Old and New Industrial Elevators and Over Head Cranes

S.No	Specification	Machine Name	Type	Machine Capacity	Electrical Load	Water Consumption	Production Rate
1	Industrial Elevator	Industrial Elevator 1	Old	5 Ton	10 KW	NIL	NIL
2		Industrial Elevator 2	Old	5 Ton	10 KW	NIL	NIL
3		Industrial Elevator 3	New	5 Ton	10 KW	NIL	NIL
1	Cranes	Crane 1 (Single Speed)	Old	5 Ton	13 KW	NIL	NIL
2		Crane 2 (Single Speed)	Old	5 Ton	13 KW	NIL	NIL
3		Crane 3 (Double Speed)	Old	5 Ton	13 KW	NIL	NIL
4		Crane 4 (Double Speed)	New	10 Ton	10 KW	NIL	NIL
5		Crane 5 (Double Speed)	New	10 Ton	10 KW	NIL	NIL
6		Crane 6 (Double Speed)	Old	10 Ton	13 KW	NIL	NIL
7		Crane 7 (Double Speed)	Old	10 Ton	13 KW	NIL	NIL
8		Crane 8 (Double Speed)	Old	10 Ton	13 KW	NIL	NIL

a) Comparison of Old and New Machines On the Basis of Electricity

The above table shows that the old machines consume more electricity consumption with new machines and new machines are energy efficient machines with old machines.

b) Comparison of Old and New Machines On the Basis of Water Consumption

The above tables and graphs shows that the old machines consume more water with compared tonew machines and new machines consume less water and with less water consumption mean that they are energy efficient machines.

c) Comparison of Old and New Machines On the Basis of Production Rate

The above tables and graphs shows that the new machines production rates are higher than the old machines with less energy consumption rate

Table 33: Production Chart of UPVC II unit from 1st to 10th of October, 2018

Date (October)	1	2	3	4	5	6	7	8	9	10
Extrusion (Production Ton)	5.16	5.29	6.31	3.55	3.22	2.45	0.00	2.90	3.30	2.58
Injection (Production Ton)	4.61	5.30	3.92	1.73	2.40	2.97	0.00	1.46	1.61	2.57
Extrusion (Usage Ton)	5.53	6.63	6.26	4.06	3.38	3.05	0.00	3.62	3.68	5.04
Extrusion (Rejection Ton)	0.37	1.34	-0.06	0.50	0.17	0.60	0.00	0.72	0.38	2.46
Injection (Usage Ton)	4.90	5.51	4.45	3.31	3.12	1.56	0.00	2.70	2.03	3.87
Injection (Rejection Ton)	0.28	0.21	0.53	1.58	0.72	-1.41	0.00	1.24	0.42	1.29

Table 34: Production Chart of UPVC II unit from 11th to 20th of October, 2018

Date (October)	11	12	13	14	15	16	17	18	19	20
Extrusion (Production Ton)	3.95	4.65	4.75	0.00	2.99	5.00	5.41	4.66	3.73	0.39
Injection (Production Ton)	4.90	5.54	5.30	0.00	4.92	5.20	4.87	5.44	4.05	2.28
Extrusion (Usage Ton)	4.31	8.25	4.60	0.00	6.64	7.52	6.65	4.90	4.61	1.87
Extrusion (Rejection Ton)	0.36	3.60	-0.15	0.00	3.65	2.52	1.24	0.24	0.88	1.48
Injection (Usage Ton)	5.76	5.43	5.42	0.00	6.31	6.19	6.17	6.00	4.48	3.24
Injection (Rejection Ton)	0.86	-0.11	0.12	0.00	1.39	0.98	1.30	0.56	0.43	0.96

Table 35: Production Chart of UPVC II unit from 21st to 30th of October, 2018

Date(October)	21	22	23	24	25	26	27	28	29	30	31
Extrusion (Production Ton)	0.00	3.72	3.04	4.34	4.54	3.98	**1.84**	**0.00**	**1.93**	**2.72**	**0.20**
Injection (Production Ton)	0.00	3.99	1.77	0.50	1.67	3.36	**1.95**	**0.00**	**1.47**	**1.41**	**0.29**
Extrusion (Usage Ton)	-	5.46	4.83	5.89	4.87	5.61	0.78	-	3.65	1.77	-
Extrusion (Rejection Ton)	-	1.74	1.79	1.55	0.32	1.63	-1.06	-	1.73	-0.96	-
Injection (Usage Ton)	-	4.96	1.72	-	3.67	4.09	-	-	3.66	0.63	-
Injection (Rejection Ton)	-	0.97	-0.05	-	2.00	0.73	-	-	2.19	-0.79	-

Table 36: Monthly Production Report for the Month of October

Production Hall	Total	Percentage
Extrusion (Production)	96.59 Tons	78.23%
Injection (Production)	85.50 Tons	86.21%
Extrusion (Usage)	123.6 Tons	-
Extrusion (Rejection)	26.88 Tons	21.77%
Injection (Usage)	99.17 Tons	-
Injection (Rejection)	13.67 Tons	13.79%

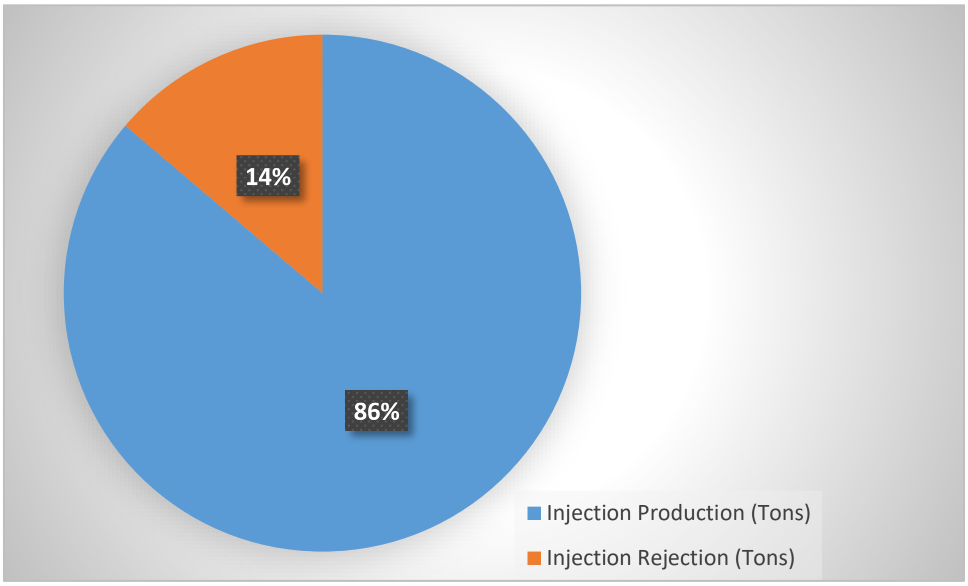


Figure 5.8: Production and Rejection Percentage Chart for Injection Molding Hall

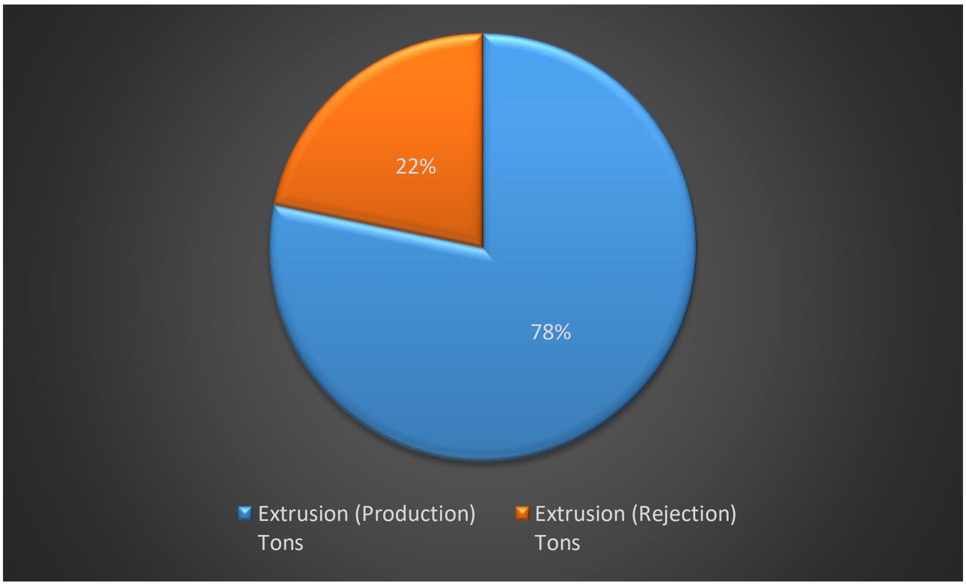


Figure 5.9: Production and Rejection Percentage Chart for Extruders

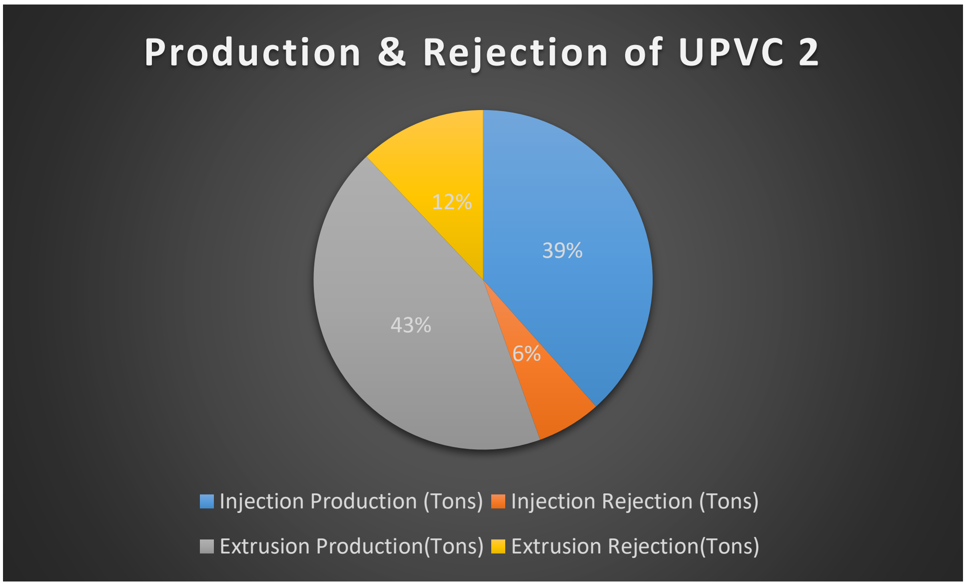


Figure 5.10: Production and Rejection Percentage for UPVC II Unit

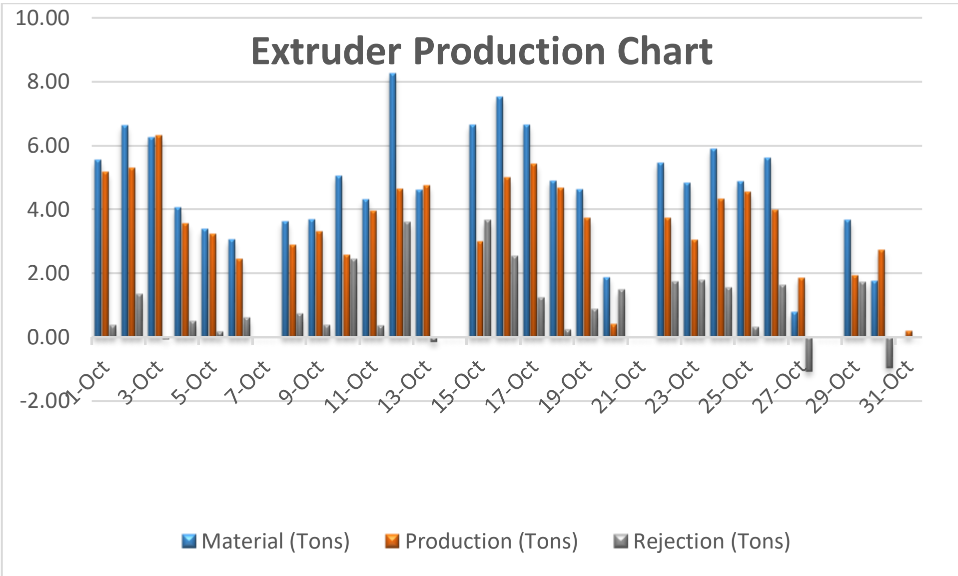


Figure 5.11: Extrusion Hall Monthly Production Chart

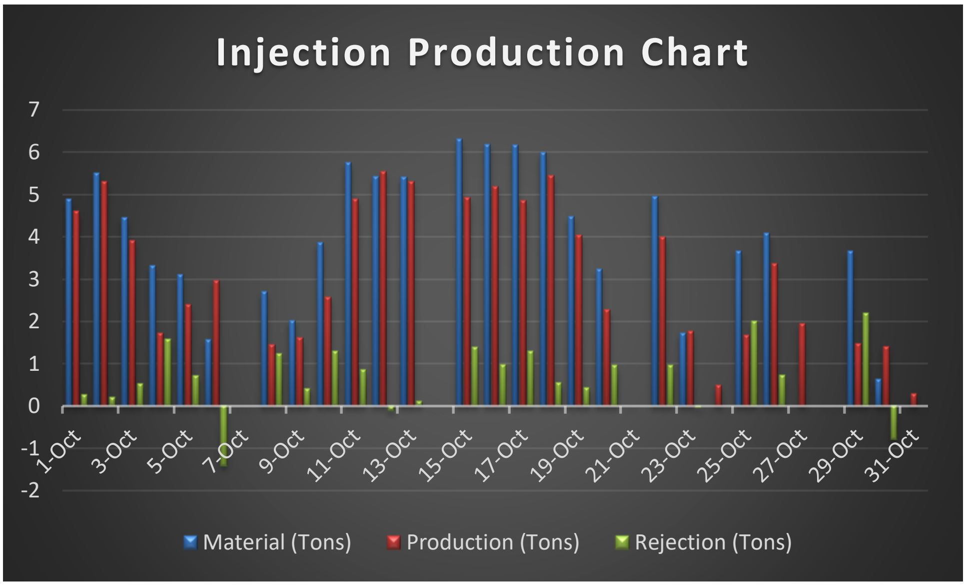


Figure 5.12: Injection Molding Hall Monthly Production Chart

After getting data of daily production from the UPVC 2 unit, it is to be clear, the rejection material must be reduced to enhance the production rate and annual cost saving up to 10%. Method which is used to save the material is to use of pulverized material and also use industrial UPS only for the extrusion unit and injections machines heating barrel section because extruder produce major rejection when it is stopped due to power failure. Pakistani industry need power backup while production. Master Industrial Complex decide to place UPS only for the three extruder and injection molding machines soon the connection are only for the heating barrel section to avoid the extra power usage before starting the prime mover diesel generator

5.9 Energy Conservation by Installation of Industrial UPS

By experimentation and being worked there in UPVC plant as we are facing power short fall, when there is electricity failure from GEPCO, Master Industrial Complex is facing huge amount of loss and also equipment wear and tear there is electricity failure than machines become stopped and material stuck into the twin screw and in die heat. The mold of upvc pipes becomes damaged day by day, so there are two possible solution to place an ATS system into the generator and other is to install an industrial UPS. First we study for the ATS system but due the older model of generator we are unable to install an ATS into the diesel generator and also after placing an ATS system into the Diesel generator if of being new model diesel generator there is a delay of approx. 2 to 3 min to being in an operational side. After concerning with the manufacturer of Extruders and Injection molding machines management decided to place an Industrial UPS unit and makes the connection only to the heating barrel on the mold of extruder and heating barrels of injection molding machines to easy going process and reduce the material wastage and also to save the molds of extruders and save injection molding section.

The calculation for the selection of Industrial UPS are given below:

Table 37: Electrical Load Calculation of Industrial UPS for UPVC II

S.No	Machine Name	Load	Remarks
1	Extruder (Heaters On Screw Barrel & Mold)	18 KW	3 Extruder run each time and total load of heaters on extruder are 18 KW.
2	Injection (Heaters On Screw)	24 KW	15 Injection machines have run on the basis of load management and the total load for the heater of Injection molding machines is 24 KW
3	Hall off (Extruder Unit)	15 KW	3 Extruder can run at the same usually and 15 KW will take by hall off.
	Total Load	57 KW	

For selecting the UPS we have to approximate the load into the KVA so 75 KVA, 3 Phase UPS had selected for the smooth operation of extruders as well as Injection molding machines.

5.10 Energy Conservation by Power Factor Control

To save from the penalties on bill given by the GEPCO so your power factor should be between ranges 0.9 to 1. Master Industrial complex faces power factor penalties due to the huge amount of induction motors used for the production as well as utilities. We have installed two PFI Panels of capacity 250 KVAR each with the capacitor bank method. PFI panel automatically turns “ON” if its power factor drops from 0.95 and with the help of PFI panel bill penalties reduces to zero in the next bill. We have two transformers 0f 630 KVA each so their power to be 1008 KW so the capacitor needed for this load to increase its power factor from 0.75 to 0.92. The calculation is given below:

The connected load to the transformers are 1008 KW approx.

Current Power Factor = 0.75

Desired Power Factor = 0.92

From table 2.3.1

=1008 x 0.453 = 456.6 kVAR

To calculate the capacitor in Farad

C = kVAR / (2 π f V²)

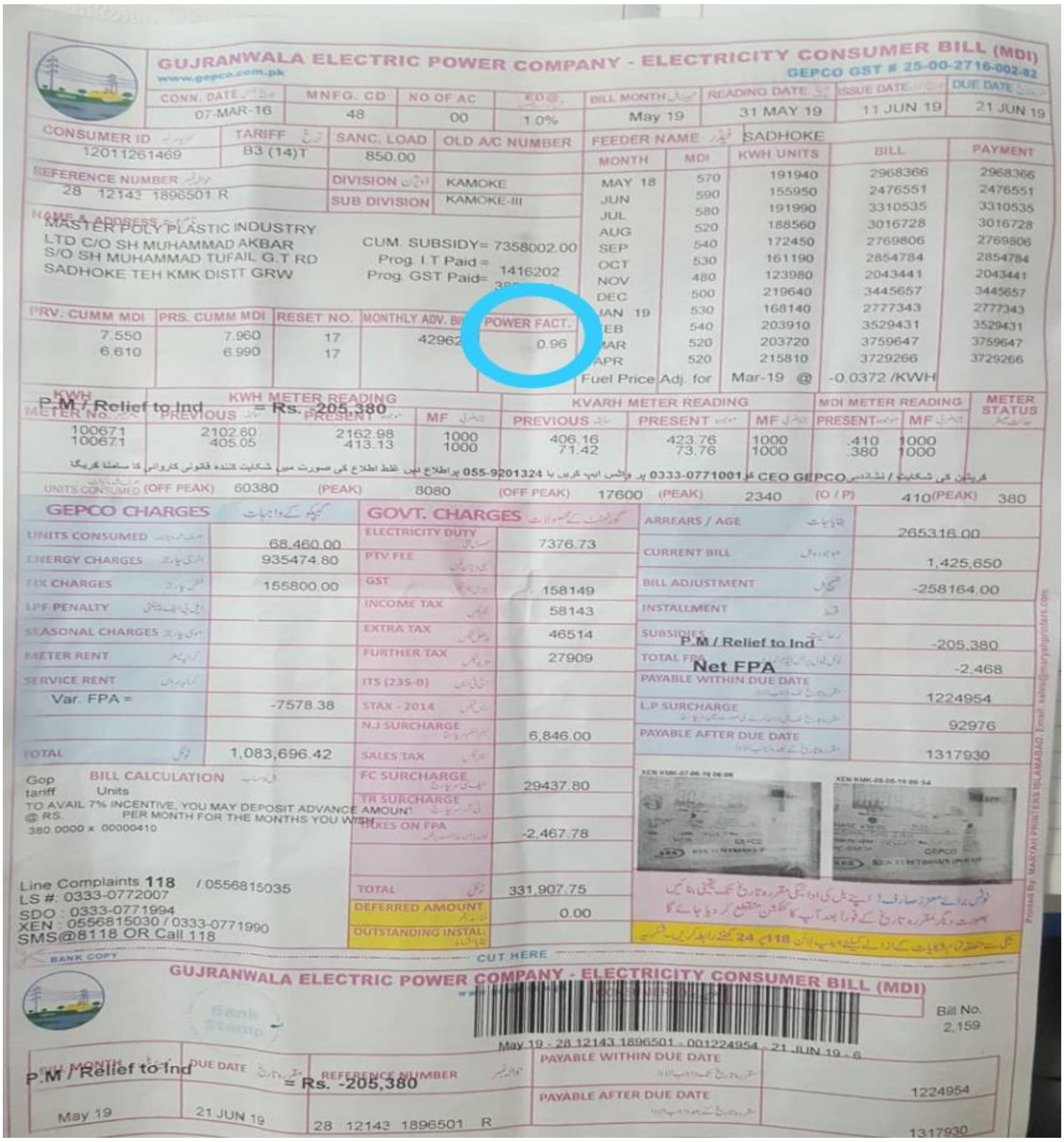
$$C = kVAR / (2 \pi f V^2)$$

$$C = 456.62 / (2 \times 3.142 \times 50 \times 400^2)$$

C=0.009083 Farad

Master installed two 250 kVAR capacitor bank of each 8 stage PFI controller each for 250 kVAR (12.5 x 2 +25 x 3 + 50 x 3)

By installing above PFI panel the power factor increases from 0.75 to 0.9 as shown in the bill attached.


GUJRANWALA ELECTRIC POWER COMPANY - ELECTRICITY CONSUMER BILL (MDI)

www.gepco.com.pk

GEPCO GST # 25-00-2716-002-82

CONN. DATE	MNFG. CD	NO OF AC	ED @	BILL MONTH	READING DATE	ISSUE DATE	DUE DATE
07-MAR-16	48	00	1.0%	May 19	31 MAY 19	11 JUN 19	21 JUN 19

CONSUMER ID	TARIFF	SANC. LOAD	OLD A/C NUMBER
12011261469	B3 (14)T	850.00	

REFERENCE NUMBER 28 12143 1896501 R

DIVISION KAMOKE

SUB DIVISION KAMOKE-III

NAME & ADDRESS MASTER POLY PLASTIC INDUSTRY LTD C/O SH MUHAMMAD AKBAR S/O SH MUHAMMAD TUFAIL G.T RD SADHOKE TEH KMK DISTT GRW

CUM. SUBSIDY= 7358002.00

Prog. I.T Paid = 1416202

FEEDER NAME SADHOKE

MONTH	MDI	KWH UNITS	BILL	PAYMENT
MAY 18	570	191940	2968366	2968366
JUN	590	155950	2476551	2476551
JUL	580	191990	3310535	3310535
AUG	520	188560	3016728	3016728
SEP	540	172450	2769806	2769806
OCT	530	161190	2854784	2854784
NOV	480	123980	2043441	2043441
DEC	500	219640	3445657	3445657
JAN 19	530	168140	2777343	2777343
FEB	540	203910	3529431	3529431
MAR	520	203720	3759647	3759647
APR	520	215810	3729266	3729266

Fuel Price Adj. for Mar-19 @ -0.0372 /KWH

PRV. CUMM MDI	PRS. CUMM MDI	RESET NO.	MONTHLY ADV. BILL	POWER FACT.
7.550	7.960	17	42962	0.96
6.610	6.990	17		

P.M / Relief to Ind = Rs. -205,380

METER No.	KWH PREVIOUS	KWH PRESENT	MF	KVARH PREVIOUS	KVARH PRESENT	MF	MDI PRESENT	MF
100671	2102.60	2162.98	1000	406.16	423.76	1000	.410	1000
100671	405.05	413.13	1000	71.42	73.76	1000	.380	1000

UNITS CONSUMED (OFF PEAK) 60380 (PEAK) 8080 (OFF PEAK) 17600 (PEAK) 2340 (O / P) 410 (PEAK) 380

GEPCO CHARGES		GOVT. CHARGES			
UNITS CONSUMED	68,460.00	ELECTRICITY DUTY	7376.73	ARREARS / AGE	265316.00
ENERGY CHARGES	935474.80	PTV FEE		CURRENT BILL	1,425,650
FIX CHARGES	155800.00	GST	158149	BILL ADJUSTMENT	-258164.00
LPF PENALTY		INCOME TAX	58143	INSTALLMENT	
SEASONAL CHARGES		EXTRA TAX	46514	SUBSIDIES P.M / Relief to Ind	-205,380
METER RENT		FURTHER TAX	27909	TOTAL FPA Net FPA	-2,468
SERVICE RENT		ITS (235-0)		PAYABLE WITHIN DUE DATE	1224954
Var. FPA =	-7578.38	STAX - 2014		L.P SURCHARGE	92976
		N.J SURCHARGE	6,846.00	PAYABLE AFTER DUE DATE	1317930
TOTAL	1,083,696.42	SALES TAX			
		FC SURCHARGE	29437.80		
		TR SURCHARGE			
		TAXES ON FPA	-2,467.78		
		TOTAL	331,907.75		
		DEFERRED AMOUNT	0.00		
		OUTSTANDING INSTAL.			

BILL CALCULATION

TO AVAIL 7% INCENTIVE, YOU MAY DEPOSIT ADVANCE AMOUNT @ RS. PER MONTH FOR THE MONTHS YOU WISH

380.0000 x 00000410

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LS #: 0333-0772007

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GUJRANWALA ELECTRIC POWER COMPANY - ELECTRICITY CONSUMER BILL (MDI)

Bill No. 2,159

BILL MONTH	DUE DATE	REFERENCE NUMBER	PAYABLE WITHIN DUE DATE	1224954
May 19	21 JUN 19	28 12143 1896501 R	PAYABLE AFTER DUE DATE	1317930

P.M / Relief to Ind = Rs. -205,380

Figure 5.13: Facility Bill of UPVC II Unit by GEPCO

5.11 Energy Conservation of Pump Room by Placing VFD

There are 4 Pumps for the extruder Hall, 8 Pumps for the injection molding hall, 4 Pumps for the Mixers section, 2 Pumps for the crusher and pulverizer section. All the pumps are placed into the underground work station to create the positive suction head of all pumps and increase discharge head and maximum flow rate of each pump.

Total Number of Pumps in running condition = 9 Nos.

Total Number of Pumps in Stand by condition = 9 Nos.

Total Power consumed by Pump Room = (10 HP x 2) + (10 HP x 4) + (7.5 HP x 1) + (7.5 HP x 2)

Total Power consumed by Pump Room = 82.5 HP

For 10 HP:

Flow Rate = 100 GPM, 2900 RPM, 4.25 Bar Pressure.

For 7.5 HP:

Flow Rate = 60 GPM, 2900 RPM, 4.25 Bar Pressure

Total Power consumed by Pump Room = 82.5 HP = 61.545 KW

From table 2.2.1

(10 x 4) x 0.746 = 29.84 KW

0.4*29.84 = 11.93 KW

0.94* 29.84 = 28.04 KW

29.84 – 11.93 = 17.91 KW

17.91 × 8,760 hr × 15 PKR per KWH = 2,353,374 PKR (Energy Consumption with VFD)

From table 2.2.1

(10 x 2) x 0.746 = 14.92 KW

0.4*14.92 = 5.968 KW

0.94* 14.92 = 14.024 KW

14.92 – 5.968 = 8.952 KW

8.952 × 8,760 hr × 15 PKR per KWH = 1,176,293 PKR (Energy Consumption with VFD)

From table 2.2.1

(7.5 x 1) x 0.746 = 5.6 KW

0.4*5.6 = 2.24 KW

0.94* 5.6 = 5.264 KW

5.6 – 2.24 = 3.36 KW

3.36 × 8,760 hr × 15 PKR per KWH = 444,501 PKR (Energy Consumption with VFD)

From table 2.2.1

(7.5 x 2) x 0.746 = 11.91 KW

0.4*11.91 = 4.476 KW

0.94* 29.84 = 11.2 KW

11.91 – 4.476 = 7.434 KW

7.434 × 8,760 hr × 15 PKR per KWH = 976,827 PKR (Energy Consumption with VFD)

The payback period of all above VFD's are less than two year so all these VFD's are feasible for the project.

Table 38: Supply and Recycle Tank Storage Capacity Description

S.No.	Description	Gallon / hr.
1	**Present Water Tank**	**30' x 20' x 8' = 02**
2	**Supply Tank**	**15' x 20' x 8'**
3	**Recycle Water**	**15' x 20' x 8'**

Table-37 shows the capacity of water storage area as to store water for the production and recycle tank used for the recirculation of water from the cooling tower and again supplied to the supply tank for the production of pipes and fittings.

5.12 Water Turbines Efficiencies

There are two water turbines installed at Master Industrial Complex; both is of 01 cusec/hr. Flow meters and running meters were installed on these turbines during the implementation of energy management system and data was collected for the month of July. We can see from table that turbines-1 and turbine-2 has almost same volumetric efficiencies. In initial practice, it was set that turbine-1 will be working as primary turbine and turbine-2 will be only operating as a stand by turbine. But after the data collection and analysis it was found that turbine-1 and turbine-2 has almost same efficiency so we suggest to run turbine by 15 days cycle of the month of July to reduce the wear and tear and also reduce the maintenance cost of turbines.

Table 39: Monthly Volumetric Efficiency Table for Two Water Turbines

Water Turbine Volumetric Efficiency										
	Turbine 1					Turbine 2				
Date	**Q M^3/Hr**	**Run Hr**	**Actual Q M^3/Hr**	**Design Q M^3/Hr**	**η**	**Total Q M^3/Hr**	**Run Hr**	**Actual Q M^3/Hr**	**Design Q M^3/Hr**	**η**
1	250	4.8	73	100	72	NIL	NIL	NIL	100	NIL
2	240	4.7	72	100	71	NIL	NIL	NIL	100	NIL
3	280	5.4	71	100	73	NIL	NIL	NIL	100	NIL
4	290	5.48	72	100	74	NIL	NIL	NIL	100	NIL
5	200	3.8	71	100	75	NIL	NIL	NIL	100	NIL
6	300	6	72	100	69	NIL	NIL	NIL	100	NIL
7	225	4.25	73	100	72	NIL	NIL	NIL	100	NIL
8	224	4.4	72	100	71	NIL	NIL	NIL	100	NIL
9	235	4.65	71	100	72	NIL	NIL	NIL	100	NIL
10	265	5.1	72	100	73	NIL	NIL	NIL	100	NIL
11	234	4.5	72	100	72	NIL	NIL	NIL	100	NIL
12	222	4.3	73	100	71	NIL	NIL	NIL	100	NIL
13	220	4.2	74	100	74	NIL	NIL	NIL	100	NIL
14	290	5.2	75	100	75	NIL	NIL	NIL	100	NIL
15	300	5.7	71	100	73	NIL	NIL	NIL	100	NIL
16	NIL	NIL	NIL	100	NIL	260	5.2	69	100	74
17	NIL	NIL	NIL	100	NIL	270	5.5	72	100	69
18	NIL	NIL	NIL	100	NIL	300	5.7	71	100	75
19	NIL	NIL	NIL	100	NIL	230	4.7	69	100	72
20	NIL	NIL	NIL	100	NIL	240	4.8	72	100	71
21	NIL	NIL	NIL	100	NIL	255	5	71	100	72
22	NIL	NIL	NIL	100	NIL	230	4.3	72	100	73
23	NIL	NIL	NIL	100	NIL	240	4.5	73	100	74
24	NIL	NIL	NIL	100	NIL	235	4.4	72	100	73
25	NIL	NIL	NIL	100	NIL	225	4.2	71	100	71
26	NIL	NIL	NIL	100	NIL	220	4.4	68	100	72

27	NIL	NIL	NIL	100	NIL	222	4.2	72	100	73
28	NIL	NIL	NIL	100	NIL	235	4.4	73	100	72
39	NIL	NIL	NIL	100	NIL	243	4.6	71	100	74
30	NIL	NIL	NIL	100	NIL	232	4.35	72	100	75

The energy can be conserve by installing the VFD with turbine by using the programed PLC and connecting the VFD with the turbine motor. Calculation is given below:

= (60) x 0.746 = 44.76 KW

=0.4*44.76 = 17.904 KW

=0.94* 44.76 = 42.0744 KW

=44.76 – 17.904 = 26.856 KW

=26.856 × 142.73 hr × 15 PKR per KWH = 57,497 PKR

(Monthly Electricity Cost with VFD)

=44.76 x 142.73 hr x 15 PKR per KWH = 95,828 PKR

40% of energy is conserved by installing the VFD with the water turbine.

5.13Energy Conservation by Water Filtration Plant

To save the water from drain according to the quality of water for the process. We are suggested to place water softening plant with filtration system. The below table shows that the 2186 Tons of water was entered into water softening plants out of 2186 Tons 1495.76 Tons of water had filtered and 706.47 Tons of water rejected and drained to wastage line. The below table shows that 68.5% of water saved with the help of water softening plant and also reduce the power consumption and natural resource for the Pakistan.

The results of July are given below in the table:

Table 40: Water Recovery and Rejection for water softening plant in month of July

Date	Inlet Tons	Production Tons			Rejection Ton	Recovery %
		Softening Plant 1	Softening Plant 2	Total		
1	90	38	39.4	77.4	12.6	86%
2	86	35	30.36	65.36	20.64	76%
3	78	39	4.68	43.68	34.34	56%
4	80	40	12	52	28	65%
5	78	37	5.9	42.9	35.1	55%
6	88	35	31.88	66.88	21.12	76%
7	85	34	34	68	17	80%
8	78	32	10.12	42.12	35.88	54%
9	80	41	19.8	60.8	19.22	76%
10	76	32	21.96	53.96	22.04	71%
11	78	35	24.28	59.28	18.72	76%
12	67	32	12.89	44.89	38.19	67%
13	79	36	3.5	39.5	39.5	50%
14	92	37	34.76	71.76	20.24	78%
15	82	40	8.9	36.9	45.1	45%
16	72	32	24.16	56.16	15.84	78%
17	78	30	26.94	56.94	21.06	73%
18	67	32	11.55	43.55	23.45	65%
19	56	33	10.68	43.68	12.32	78%
20	45	24	1.2	25.2	19.8	56%
21	30	12	10.8	22.8	7.2	76%
22	71	35	16.83	51.83	19.17	73%
23	66	23	19.9	42.9	23.1	65%
24	75	34	24.5	58.5	16.5	78%
25	67	30	13.55	43.55	23.45	65%
26	50	20	13.5	33.5	16.5	67%
27	83	35	29.74	64.74	18.26	78%
29	56	29	2.92	31.92	24.08	57%
30	86	35	21.76	56.76	29.24	66%
31	67	23	15.19	38.19	28.81	57%

5.14Energy Conservation by Lab Testing

Energy can be conserve by the lab testing, the rejection can be minimized by the lab testing if formulation of the mixing of material is becomes wrong than the whole production has to be rejected so Lab test performs the vital role in energy conservation of material and approximately 5 % of the rejection can be controlled by performing Lab test on the regular basis between the production.

5.15 Energy Conservation by Mass Balance

Energy can be conserve by the mass balance of any industry because every industry has their wastage and these wastages can be utilized in a favorable manner and Master Industrial Complex categorized his wastages into three categories as Solid waste, Liquid Waste and Gases waste. Master Sell their plastic which can't recycled and also sell brass which is extracted from the CNC machining and lathe work. Waste liquid need treatment plant and also sludge non-clogging pump for the disposal of waste water of factory and that grey water after some treatment can be utilized for the plantation area and gardening purpose.

5.16 Energy Conservation by VFD and Payback

Table 41: Energy Saving Potential by Placing VFD with Pumps & Fans

S.No	Equipment	Capacity HP	Energy Saving KWH/Yr	Payback Period Years	VFD Net Cost with Installation
1	Compressor 1	100	147825	0.513	PKR 1,138,000
2	Compressor 2	50	8103	6.58	PKR 800,000
3	Pump 1	20	52998	0.43	PKR 340,000
4	Pump 2	20	52998	0.43	PKR 340,000
5	Pump 3	10	26139	0.58	PKR 230,000
6	Pump 4	10	26139	0.58	PKR 230,000
7	Pump 5	10	26139	0.58	PKR 230,000
8	Pump 6	10	26139	0.58	PKR 230,000
9	Pump 7	10	26139	0.58	PKR 230,000
10	Pump 8	10	26139	0.58	PKR 230,000
11	Pump 9	7.5	19622	0.64	PKR 190,000
12	Pump 10	7.5	19622	0.64	PKR 190,000
13	Pump 11	7.5	19622	0.64	PKR 190,000
14	Pump 12	60	30834	2.05	PKR 950,000
15	Pump 13	1.5	1130	7.64	PKR 130,000
16	Pump 14	1.5	3868	2.2	PKR 130,000
17	Pump 15	1.5	400	54	PKR 130,000
18	Pump 16	5	2256	4.6	PKR 156,000
19	Axial Fan 1	7.5	18469	0.83	PKR 230,000
20	Axial Fan 2	7.5	18469	0.83	PKR 230,000
21	Axial Fan 3	7.5	18469	0.83	PKR 230,000
22	Axial Fan 4	7.5	18469	0.83	PKR 230,000

Table 41 shows that there were 16 pumps used for the UPVC II units out of which (1-2) were utilized for the cooling tower, (3-11) used for utility section of production hall for Injection and Extruder machines, (11) were used for the deep well water extraction pump, (13-14) for the WHR and HFO boiler for feed water and (15-16) were used for the HFO decanting and HFO supply to the HFO fired boiler. VFD were installed with the pumps of cooling towers as they are highly energy consuming and the payback period VFD is less than 2 years. 40% of energy is conserve by installing VFD with the pumps of Cooling Towers. The payback period of all above VFD’s are less than two year so all these VFD’s are feasible for the project. There are two water turbines installed at Master Industrial Complex; both is of 01 cusec/hr. Flow meters and running meters were installed on these turbines during the implementation of energy management system and data was collected for the month of July. We can see from table that turbines-1 and turbine-2 has almost same volumetric efficiencies. In initial practice, it was set that turbine-1 will be working as primary turbine and turbine-2 will be only operating as a stand by turbine. But after the data collection and analysis it was found that turbine-1 and turbine-2 has almost same efficiency so we suggest to run turbine by 15 days cycle of the month of July to reduce the wear and tear and also reduce the maintenance cost of turbines. The energy can be conserve by installing the VFD with turbine by using the programed PLC and connecting the VFD with the turbine motor. 40% of energy were conserved by installing the VFD with the water turbine. 28.5% of energy is conserve by placing VFD with the cooling tower fan motor. Above table also explains that the compressor 2, pump 13, pump 15 and pump 16 did not required VFD with them as their load factor were less and also their payback period is greater than 4 years so VFD should not be installed with those above items.

6 Conclusion & Recommendation

In this study we have done the energy conservation and auditing of Master Industrial Complex which is in the construction phase and machinery is shifting from old operating factory to the new factory and we only take UPVC 2 which is shifted from Master Pipes and fittings to the Master Industrial Complex and rest we have street lights as the whole project so there are huge opportunity for the others departments that are shifting in the next year like PPRC Pipes and fittings, Sanitary, and Poly-Plastic Industries. During energy wastage assessment every minor potential of energy saving was consider and it resulted in valuable volume of annual energy saving .It is recommended to follow the industrial equipment and process standards for authentic assessment and sustainable energy savings. The Pakistani Industry culture is majorly a one man show system from the CEO side and there is difficult to convince to invest money on the energy conservation side and they are willing to invest money on partial basis and not willing to invest in new energy saving equipment's. There is huge amount of side where we can conserve energy like furnace, sand blasting machines, shot blasting machines, CNC and manual lathe milling and machining centers.

The total load of the UPVC II section is almost 2925 KW, Out of 2925 KW extruder hall consume 457 KW, tool room consume 18 KW, injection molding hall consume 1278 KW, crusher room 278 KW, mixer room UPVC pipes consume 255 KW, compressor room consume 112 KW if both compressor runs same time, mixer room UPVC fittings consume 268 KW, auxiliary sections with equipment consumes 14 KW. The combine load of all the sections is 2925 KW. By using the load management system the load is managed by adding the two prime mover diesel generators of 1200 KVA and one stand by diesel generator.

The main equipment used for the utilities in UPVC II are compressors, pumps, cooling towers, boiler, power ventilator and evaporative type coolers. By using the VFD unit in the prime moving compressor of 75 KW compressor and reduce the line leakages we achieve to save energy up to the 40%, 22.5 KWH energy have been saved during each hour by placing VFD in 75 KW compressor and 7% of energy have saved by removing the leakages from piping network of compressor. Boiler is the main source of energy consuming device in every industry where steam is used for the production purpose by comparing the HFO and natural gas as a fuel in boiler so the natural gas is favorable in our region but supply is the issue in winter and sometimes in summer as well therefore Master Industrial Complex decide to run HFO fired boiler as a stand by source and WHR boiler as a prime mover source. WHR boiler produces 984.7 Tons/Month steam from 1213.1 Tons/Months steam which is 81.2% of steam that was producing from the WHR boiler and rest 18.8% of steam produced from the HFO fixed boiler so 81.2% of energy saved from the WHR boiler with the payback period of less than 2 years. Cooling tower is the main part of equipment used for the UPVC pipe and fitting industry, by using the chiller production rate have increased but running cost is also increase by using the chilled water system so by using the cooling tower instead of chiller we have achieved our desired temperature and reduced the running cost of production. In cooling tower we attain the ΔT is equal to 10 ^{o}C which is suitable for the extrusion and injection process and only high thickness fitting only required chillers so we suggest portable type chillers for only two injection machines where high thickness fitting mold usually used. By placing VFD with pumps of cooling tower and with the axial fans of cooling towers. 17.91 KW per hour energy saved from the pumps running with the cooling towers and 16.11 KW per hour energy saved from the axial fans by placing VFD with fans and pumps. Power Ventilators and Evaporative Coolers have run on the solar system as major running hours of power ventilator and evaporative coolers were in day time. With the installation of solar panels on the roof of UPVC II, conservation of energy is 210 KWH/Day and 6300 KWH/Month.

Streets lights are the major source of energy consumption source in any industry and by shifting the system of street lights to solar panels each for each street light and also used LED light to reduce the battery back-up. 99 KWH/Day energy is conserve through the solar street light and 2970 KWH/Month energy conserve through the solar street lights. One of the best technique used to conserve energy was using the building envelope with this we could utilized natural sun light and wind to conserve energy in the form of reducing the running hours of artificial lights and reduce running hours of fans and saves energy up to 30-40% from the share of lightening and fan running hours by using the building envelope. With the help of building envelope energy conservation would be 990 KWH/Month only in the form of lighting and almost double in the form of fans running.

The UPVC II unit in Master Industrial Complex comprises of old and new machines combined. The new machines consume less electrical power and water and their production rate is higher as new extruder produces 14 % higher production than the old extruders with same power consumption and also consume 20% less water for the same production rate and injection molding machine also consume 10% less electrical power and 8% less water consumption as compare to old injection molding machines. Crusher produces 50% more crushed material with only 27% more electrical power and only 20% more water consumption. New Pulverizer produces 50% more pulverized material with only 32% more electrical power as compare to old Pulverizers and 29% more water consumption as compare to the old Pulverizers. The new mixers produces 31.4% more production with only 25% more electrical power and with only 20% more water consumption. The new shredder produces 45.45% more production than the old extruders, difference of production is 550 kg/hr and 300 kg/hr with 40.54% more electrical power and same water consumption rate. The production recorded in the month of October, 2018 for the extrusion and injection section is 96.59 Tons 85.5 Tons respectively and the rejected production is 21.77% for the extruder section and 13.79% for the injection section to overcome this problem we have placed Industrial UPS to reduce the rejection ratio and it reduces up to 5% to 10% of the total production.

The PF of the Master Industrial Complex have reduced from 0.75 to 0.92 by installing the capacitor bank of two 250 kVAR each for controlling the PF from 0.75 to 0.9 and reduce the penalty from the utility bill. There are large amount of areas where we can conserve energy in the future and hope this study will help all the fellow person who want to study the energy conservation systems. Feasibility report can be made for the wind power system for the Master Industrial Complex. Solar system can be installed with dual metering system to sale electricity in day time and consume that amount of electricity in night by GEPCO as it reduces the cost of batteries as must be attached with solar system to utilize energy in night.

40% of the energy is conserve by placing the VFD with the water turbine motor which is 60 HP each for single water extraction source and also 68.5% of water is conserve by using the water softening plant with the recycle tank and water is purified and soften by using the water softening plant attached with the recycle tank of UPVC II unit.

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COMMENTS OF SUPERVISOR:

Signature of Supervisor   Signature of Student

Endst No.UNIV/ENR/MS/   Dated: ________________

The above proposal duly recommended by the department Board of Studies/Post-graduate Studies and Research Committee in it meeting held on 22nd October 2019 is forward to the Director General Research for obtaining the approval of Vice-Chancellor.

CHAIRMAN
Mechanical Engineering Department

DEAN,
Faculty of Mechanical Engineering