Energy Audit Report: Amul - Mogar Chocolate Manufacturing Plant (Food complex) A unit of Kaira District cooperative union limited, Village: Mogar, Anand

Conducting activities of energy audit & dissemination activities in Gujrat dairy cluster underGEF-UNIDO-BEE project

March 2016

pwc

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List of Abbreviations and Acronyms

A.C.	Air Conditioning
BTU	British Thermal Unit
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet per Minute
COP	Coefficient of Performance
CO2	Carbon dioxide
DG	Diesel Generator
ECM	Energy Conservation Measure
EE	Energy Efficient
EER	Energy Efficiency Ratio
EPC	Engineering Procurement Construction
FAD	Free Air Delivery
FTL	Fluorescent Tube Light
GWh	Gigawatt Hour
IGEA	Investment Grade Energy Audit
kWh	Kilowatt Hour
LPG	Liquefied Petroleum Gas
LPM	Litre Per Minute
LT	Low Tension
Mkcal	Million Kilo Calories
Mt	Million Tonnes
M&E	Monitoring and Evaluation
O&M	Operation and Maintenance
PV	Photo Voltaic
RE	Renewable Energy
SEC	Specific Energy Consumption
SFC	Specific Fuel Consumption
SPC	Specific Power Consumption
SSE	Solar System Exploration
TOD	Time of Day
TR	Ton of refrigeration

Conversion Table

Unit	Conversion factor
1 kWh	860 kcal
1 Joule	0.24 Calorie
1 m^3	1,000 liters
1 TR	12,000 Btu
1 kWh	0.64 kg CO2
1 Liter (Diesel)	2.7 kg CO2
1 Liter (Furnace Oil)	2.9 kg CO2
1 Liter (Kerosene)	2.5 kg CO2
1 Kg (CNG)	2.8 kg CO2

Acknowledgement

PwC sincerely thank GEF-UNIDO-BEE for associating us in its prestigious project “Energy efficiency and renewable energy in MSMEs” which involves developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Gujarat dairy cluster is also one of these 12 clusters.

We express our sincere gratitude to all concerned officials of PMU of the project for their valuable support and guidance during execution of the project.

Our special thanks to following persons:

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- Mr. Niranjan Rao Deevela, National Technology Coordinator, Energy efficiency and renewable energy in MSMEs
- Mr. Ashish Sharma, Project Engineer, GEF-UNIDO-BEE Project, BEE

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1. Executive Summary

1.1 Introduction

GEF-UNIDO-BEE is developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Gujarat dairy cluster is one of them. The overall motive of this assignment is to improve the productivity and competitiveness of units as well as to reduce overall carbon emissions and improve the local environment. PwC was appointed by GEF-UNIDO-BEE for conducting activities under this assignment in the Gujarat Dairy cluster. The activities in the project includes conducting energy audit in 6 dairy plants and Chocolate plant of Kaira district milk co-operative milk producers union limited – Food complex was one of these 6 plants.

1.2 Objective of energy audit study

The objective of the energy audit is to review the present energy consumption scenario, monitoring and analysis of the use of energy and explore various energy conservation options. It includes submission of five best operating practices & common monitorable parameters in Gujarat dairy cluster. Project also includes the submission of detailed energy audit report containing recommendations for improving energy efficiency with cost benefit analysis and technical specifications for any retrofit options, with the list of suppliers/manufacturers of the recommended energy efficient technologies. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems but also situations which cause load profile variations on both annual and daily basis.

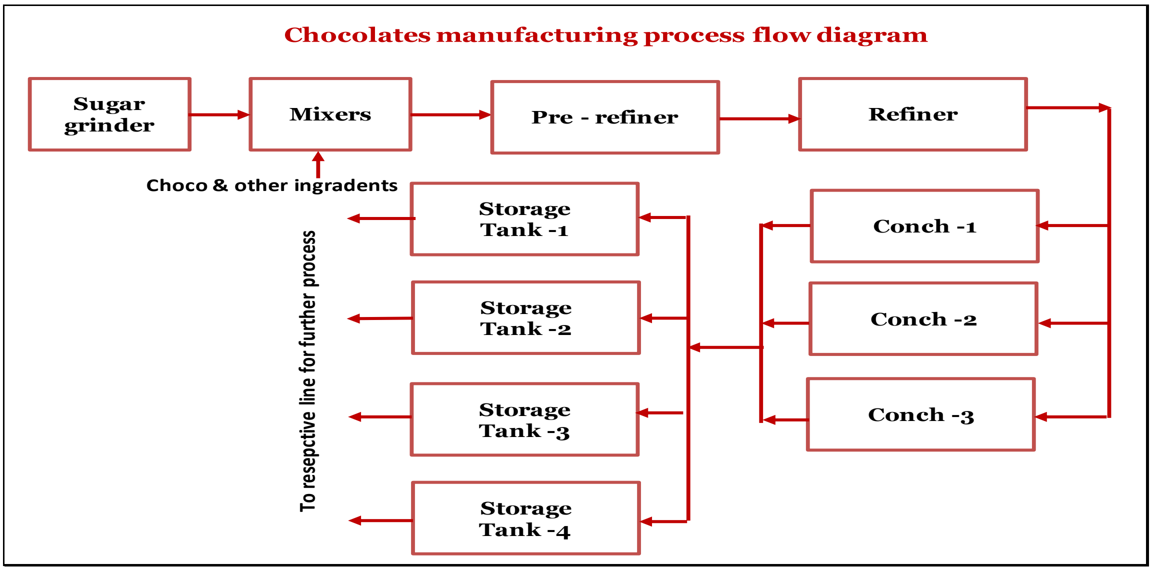
1.3 About Chocolate plant

Kaira district co-operative milk producers' union limited have their food complex in Mogar – Anand. In food complex, there are separate plants manufacturing bread, biscuits, sweets and chocolates under the brand name of Amul. The chocolate plant manufactures different types of chocolates and supplies to entire India. The average daily production capacity of the chocolate plant is 5 TPD. Chocolate plant has a separate building and has its own utilities except for steam, which is taken from main boiler.

Process flow:

The detailed process flow diagram for the chocolate manufacturing is as below.

Figure 1 : Chocolate manufacturing process flow diagram



The chocolate manufacturing process starts with grinding sugar in the grinding machine. After grinding sugar to the required particle size, the process of mixing starts in the mixers. In mixers, all ingredients for chocolates are mixed. After mixing, chocolate is pre refined and refined again then sent to conch machines for further homogeneous mixing and then stored in storage tanks.

The chocolate stored in storage tanks is taken to respective line and chocolates are made by further processing and adding ingredients, then packed in the packing section, and stored in the cold storage before loading to trucks for transport.

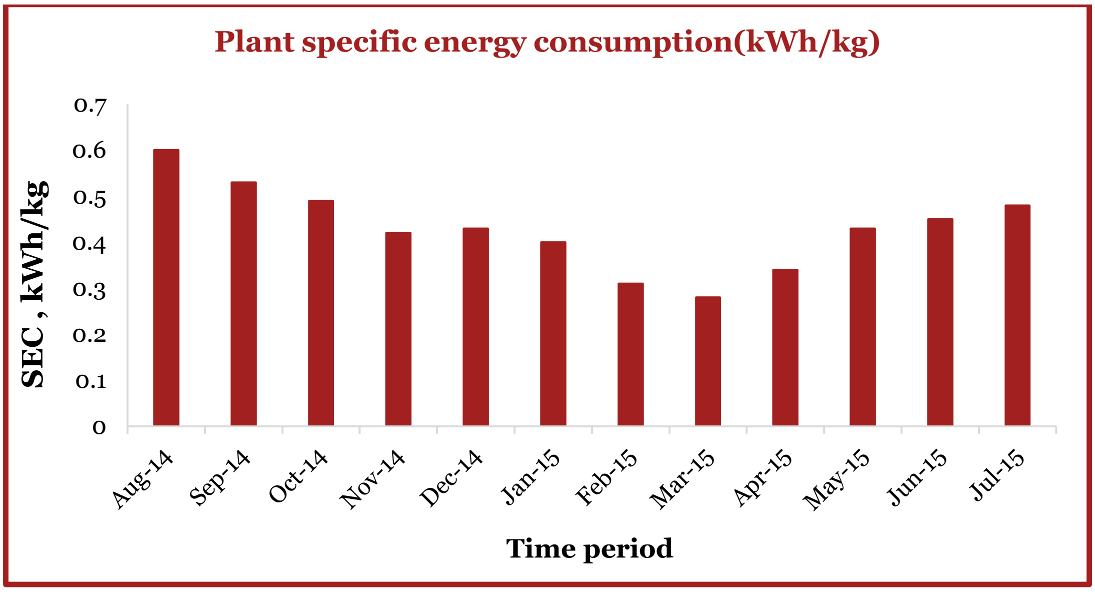
1.4 Present energy scenario & specific energy consumption:

Plant uses electricity and steam as the main energy inputs to operate. The electrical supply is coming from the main substation and steam from main boiler. The data pertaining to electricity consumption of entire chocolate plant from August 2014 till July 2015 was collected during audit and the same is tabulated and compared with quantity of chocolate manufactured to estimate average electricity spent for manufacturing of each kg of chocolate. These findings are tabulated below.

Table 1 : Present energy scenario and specific energy consumption

Months	Chocolate production (kg/month)	Energy consumption (kWh/month)	Raw water consumption (L/month)	Specific energy consumption (kWh/ kg)
August-14	212,200	127,576	277,200	0.6
September-14	220,050	115,928	323,000	0.53
October-14	211,130	103,368	340,000	0.49
November-14	248,100	104,552	442,000	0.42
December-14	219,163	94,612	331,000	0.43
January-15	199,030	79,884	326,700	0.4
February-15	241,215	74,224	312,800	0.31
March-15	306,765	84,560	342,400	0.28
April-15	270,820	92,256	216,800	0.34
May-15	278,810	121,172	459,000	0.43
June-15	235,620	107,128	247,600	0.45
July-15	234,610	112,688	270,100	0.48
Average	**239,793**	**101,496**	**324,050**	**0.43**
Total	**2,877,513**	**1,217,948**	**3,888,600**	

Figure 2 : Plant specific energy consumption month wise



- The average specific energy consumption is 0.43 kWh/kg of chocolate manufactured.
- The maximum specific energy consumption of 0.6 kWh/kg of chocolate was recorded for the month of August 2014 and minimum specific energy consumption of 0.28 kWh/kg was recorded in the month of March 2015.

1.5 *Plant consumption and savings summary*

A summary of plant energy consumption as well as savings is provided in the following table.

Table 2: Summary of plant energy consumption and energy savings

Particulars	Unit	Values
Annual chocolate plant electrical energy consumption	kWh/annum	**12,17,948**
Estimated annual chocolate plant electricity cost	Rs. Lakhs	**55.41**
Proposed annual electrical energy saved	kWh/annum	**236,012**
Proposed annual electricity cost saved	Rs. Lakhs	**10.73**
Investment Required	Rs. Lakhs	**28.8**
Payback period	Months	**32**
Internal rate of return(IRR)	%	**38.1**
Proposed percentage of chocolate plant energy saved	%	**19.3**
Proposed percentage of cost saved	%	**19.3**

The energy conservation measures identified for Chocolate plant are provided in following table.

1.6 Summary of proposed energy conservation measures

Table 3: Summary of plant energy conservation measures

S. No.	Suggested energy conservation measure	Annual Energy savings	Annual Cost saving	Investment	Payback period
		kWh/annum	Rs. Lakhs	Rs. Lakhs	Months
1	Maintain correct required temperature of 21 °C cold storage & 24 °C in packing section as per standards	**21,000**	**0.95**	**Minimum**	**Immediate**
2	Replace old reciprocating chillers in almond line and cold storage with new EE scroll chiller	**74,760**	**3.4**	**10**	**35**
3	Replace all de-centralized cooling water system (including cooling water pumps, cooling tower and fans) with one centralized cooling water system	**61,572**	**2.8**	**8**	**34**
4	Replace all old reciprocating air compressors with new centralized EE screw compressor	**64,680**	**2.94**	**9**	**36**
5	Option -1 : Install lighting energy saver to lighting feeder to save the power consumed by the lighting	**14,000**	**0.63**	**1.8**	**34**
	OR Option -2 :Replace all the different type of lighting fittings in plant with LED lamps	**28,224**	**1.28**	**4.8**	**36**
Total		**236,012**	**10.73**	**28.8**	**32**

2 Introduction

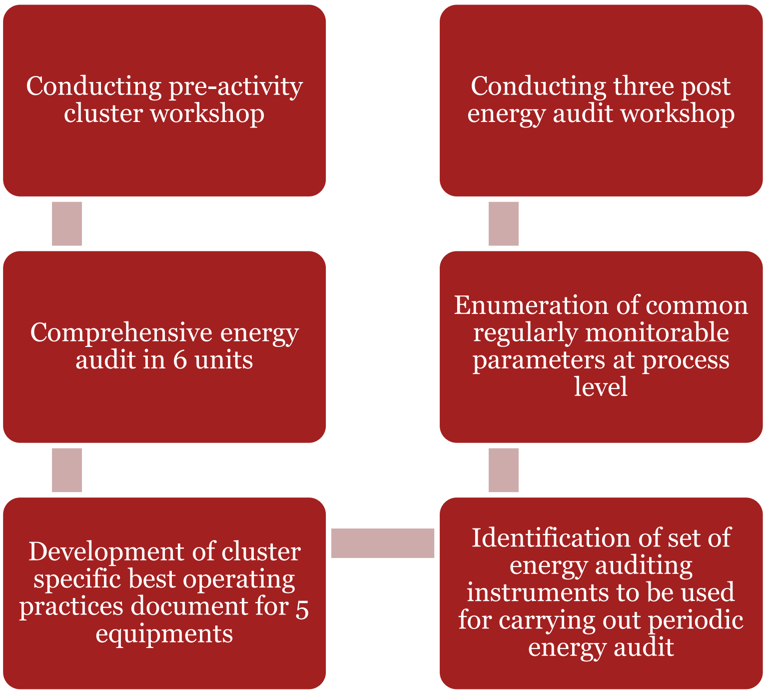
2.1 Introduction

GEF-UNIDO-BEE is developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Gujarat dairy cluster is one of them. The overall motive of this assignment is to improve the productivity and competitiveness of units as well as to reduce overall carbon emissions and improve the local environment. PwC was appointed by GEF-UNIDO-BEE for conducting activities under this assignment in the Gujarat Dairy cluster. The activities in the project includes conducting energy audit in 6 dairy plants and Chocolate plant of Kaira district milk co-operative milk producers union limited – Food complex was one of these 6 plants.

2.2 Scope of services

The scope of this assignment is shown in following figure.

Figure 3: Scope of services



This report has been prepared under the task 2 of our scope of services, which involves conducting comprehensive energy audits in six units in the cluster, where chocolate plant under the Kaira district co-operative milk producers union limited – Food complex, Anand was one of these 6 audits sites.

2.3 Energy audit scope and approach

A detailed energy audit of chocolate plant was undertaken at Kaira district co-operative milk producers union limited – Mogar from August 10 - 13, 2015. The energy audit team of PwC comprised of refrigeration and electrical energy experts. During energy audit, a range of portable energy audit instruments were used to take various measurements at refrigeration system of the plant. In addition, design and operational data were collected from logbooks and equipment manuals. Discussions were held with technical personnel at the plant to fully understand its operations and energy requirements. The energy audit was focused on the study of chocolate plant and the evaluation of operational efficiency/performance of such equipment from the energy conservation point of view.

The following areas were covered during the study:

- ***Chocolate plant***
  - ✓ Refrigeration compressor
  - ✓ Production equipment
    - Grinders
    - Mixers
    - Pre-refiners
    - Refiners
    - Conching machines
    - Storage tanks
    - Cold boxes
  - ✓ Packing section
  - ✓ Cold storages
  - ✓ Air compressors
  - ✓ Cooling water system
- ***Renewable Energy***
  - ✓ Opportunities were identified for use of renewable energy

The study focused on chocolate plant to identify opportunities for energy saving. The analyses included payback and Internal Rate of Return (IRR) calculations to ascertain the financial viability of investment intensive energy conservation measures. The energy audit involved carrying out various measurements and analysis, to assess losses and potential for energy savings in different sections of the plant. A wide array of latest, sophisticated, portable, diagnostic and measuring instruments were used to obtain primary information for energy audit investigations and analyses. The specialized instruments that were used during the energy audit included:

- Power analyzers (Three Phase and Single Phase)
- Digital manometer
- Digital hygrometers
- Temperature loggers
- Ultrasonic flow meter
- Digital pressure gauge
- Others

During the audit, there was continuous interaction between audit team and plant personnel to ensure that recommendations made were realistic, practical and implementable as well as to facilitate possible concurrent implementation measures. On the last day of the field visit, a discussion was held with the plant management on site observations and preliminary findings, to enable the management to take immediate action to conserve energy.

This report presents the field measurements, design and operational data, data analysis, key observations and recommendations to achieve energy savings in each of the major areas that consumed energy and equipment. The recommendations are followed by cost-benefit analysis. Major emphasis is laid on short and medium-term measures. The ultimate aim of this exercise is to help the plant management to understand and prioritize energy efficiency opportunities identified through the study.

2.4 Plant installed load details

A list of major energy consuming process equipment and other utilities at the plant are provided in following table.

Table 4 : List of major energy consuming equipments in the plant

Section	Machine Type	Quantity
Chocolate plant	Grinders	2
	Mixers	1
	Pre –Refiner	1
	Refiner	1
	Conching machines	3
	Storage tanks	5
	Processing lines	4
	Cold storages	1
	Packing section	1
	Air compressors	3
	Electric heat pump	1
	Hot water pumps	1
	Chilled water pump	2
	Refrigeration units	5
	Cooling towers	3
	Cooling water pumps	3

3 Observation and Analysis

Kaira district co-operative milk producers union limited have their food complex in Anand, which manufactures all type of Amul branded foods like bread, biscuits, sweets and chocolates. All these food-making plants are under one campus. The detailed energy audit was conducted in the chocolate plant to identify energy saving opportunities. The measurement taken, observations were made on each equipment and result of the analysis is discussed below.

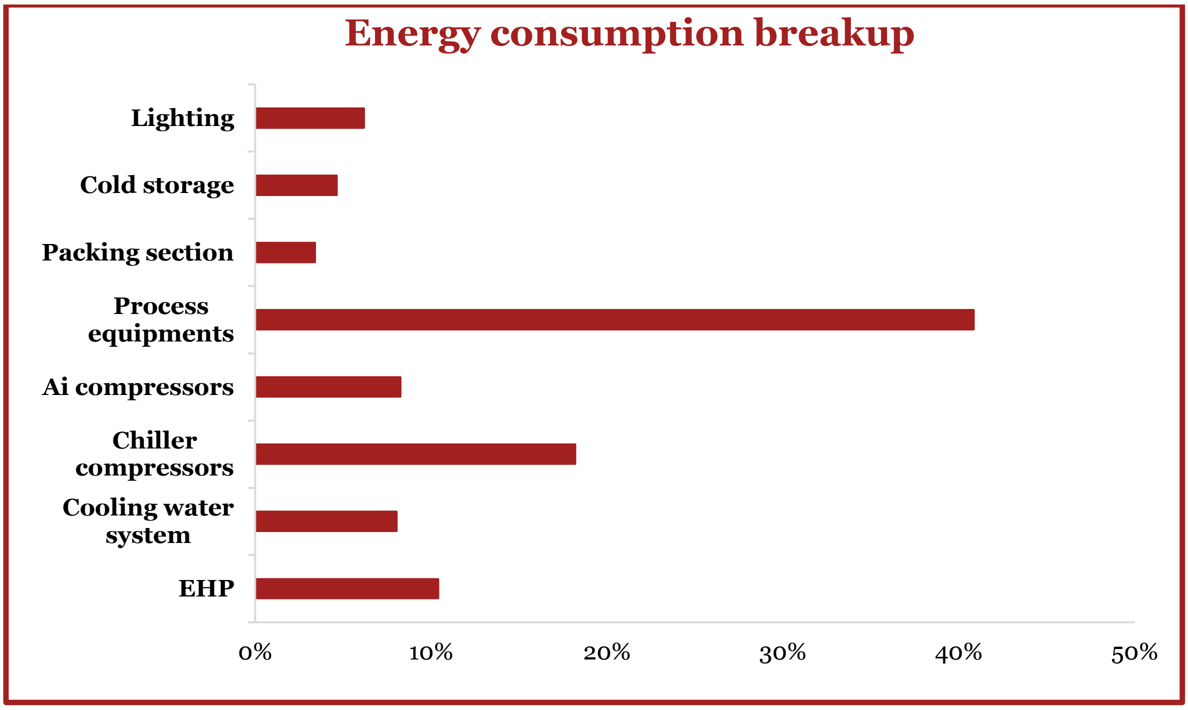
3.1 Energy consumption breakup

Detailed electrical measurement was done on all energy consuming equipment in chocolate plant and energy consumption breakup was derived which is tabulated below.

Table 5 : Energy consumption breakup

Description	Power consumption (kW)	Energy consumption (kWh/day)	Percentage of consumption (%)
Electric heat pump	28	336	10%
Cooling water system	13	260	8%
Chiller compressors	42	588	18%
Ai compressors	14.8	267	8%
Process equipment	132	1,320	41%
Packing section	5.5	110	3%
Cold storage	7.5	150	5%
Lighting	10	200	6%
Total	**253**	**3,231**	**100%**

Figure 4 : Chocolate plant - Energy consumption breakup



- The major energy consumer in the chocolate plant is the process equipment, which consumes about 41% of the energy consumption followed by chillers, electric heat pump, cooling water system and others.
- Chocolate plant works for 24 hours a day and manufactures an average of 5 tons chocolate per day.

3.2 Main incomer power profile

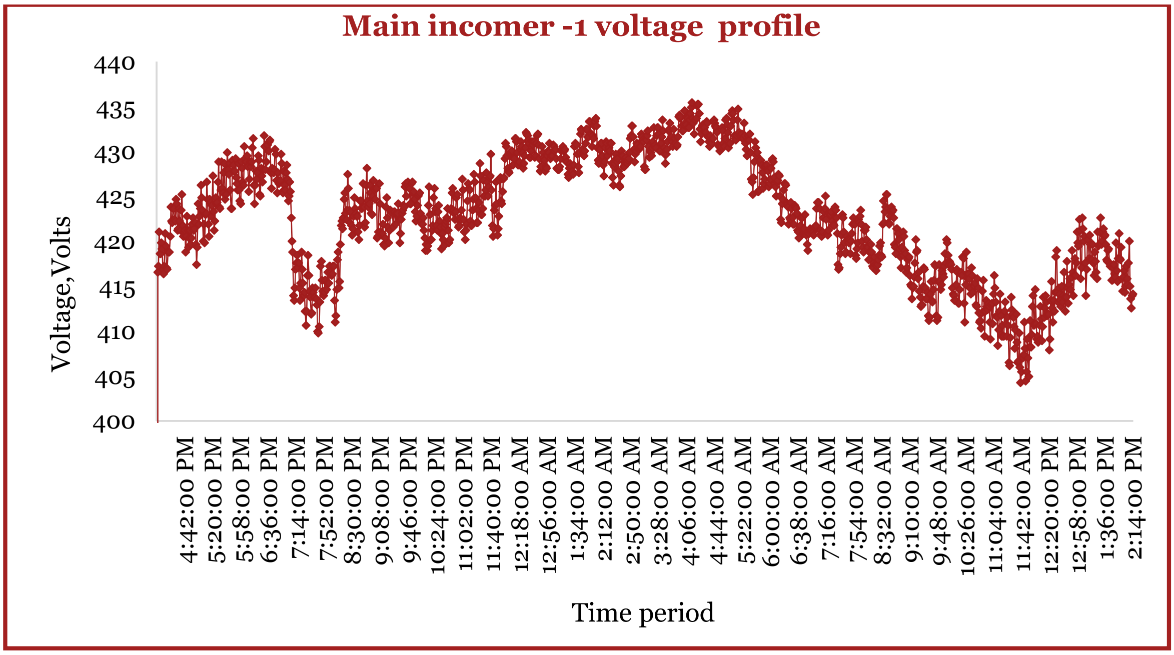
There are two feeders installed to feed power to chocolate plant, these feeders are taken from main substation. Chocolate plant consumption reading is recorded on shift basis in the main substation. The power consumption profile for the feeder -1 was recorded during audit whereas power profile of feeder -2 was not recorded due to lack of provision. The details of the power profile recorded for feeder -1 is as follows.

Feeder -1

Voltage profile:

The voltage profile was recorded for main incomer feeder -1 at the LT side from 12-08-15 @04:44 pm to 13-08-15 @ 2:00 pm and is presented below.

Figure 5 : Chocolate plant main incomer -1 voltage profile

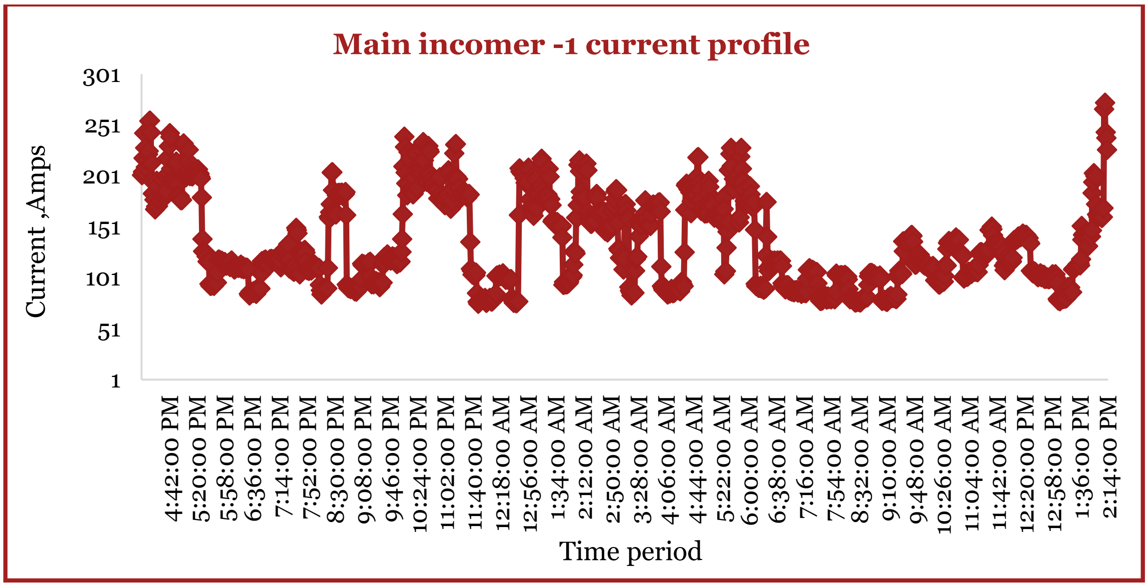


The maximum voltage recorded during this period	=	435 volts
The minimum voltage recorded during this period	=	405 volts

Current profile:

The current profile was recorded for main incomer feeder -1 at the LT side from 12-08-15 @04:44 pm to 13-08-15 @ 2:00 pm and is presented below.

Figure 6 : Chocolate plant main incomer current profile

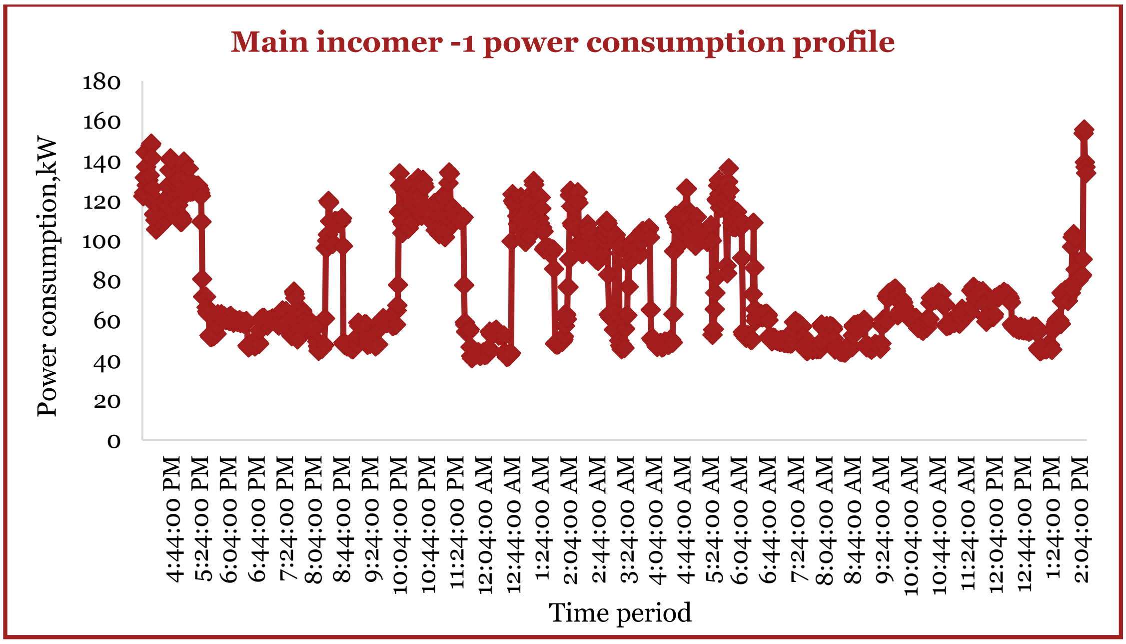


The maximum current recorded during this period	=	260 Amps
The minimum current recorded during this period	=	76 Amps

Power consumption profile:

The power consumption profile was recorded for main incomer feeder -1 at the LT side from 12-08-15 @04:44 pm to 13-08-15 @ 2:00 pm and is presented below.

Figure 7 : Chocolate plant main incomer power consumption profile

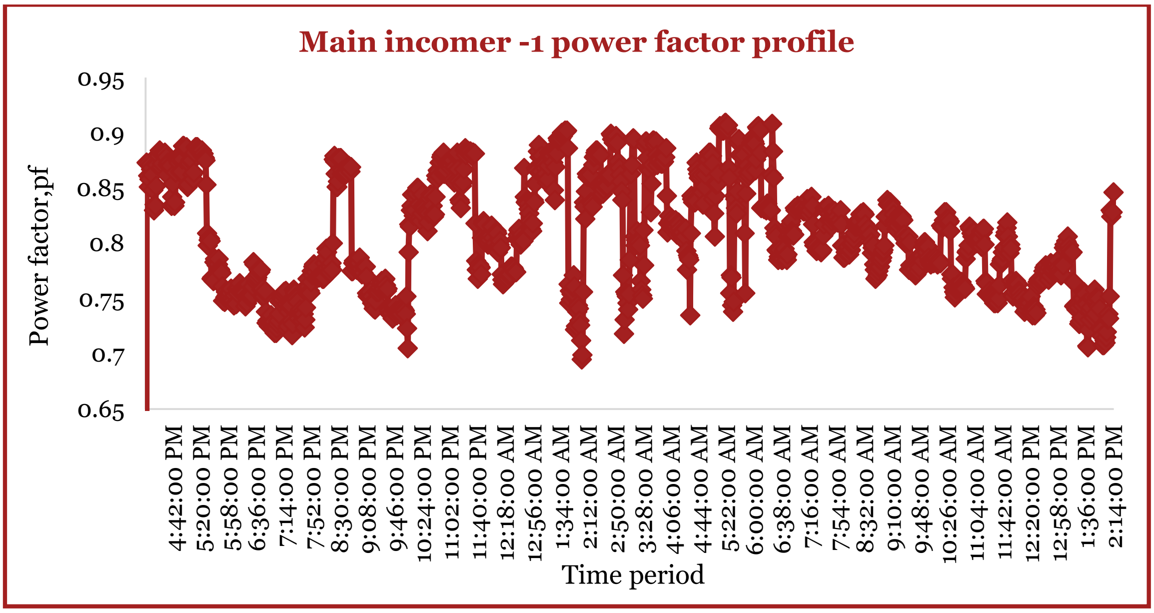


The maximum power consumption recorded during this period	=	160 kW
The minimum power consumption recorded during this period	=	42 kW

Power factor profile:

The power factor profile was recorded for main incomer feeder -1 at the LT side from 12-08-15 @04:44 pm to 13-08-15 @ 2:00 pm and is presented below.

Figure 8 : Chocolate plant main incomer power factor profile



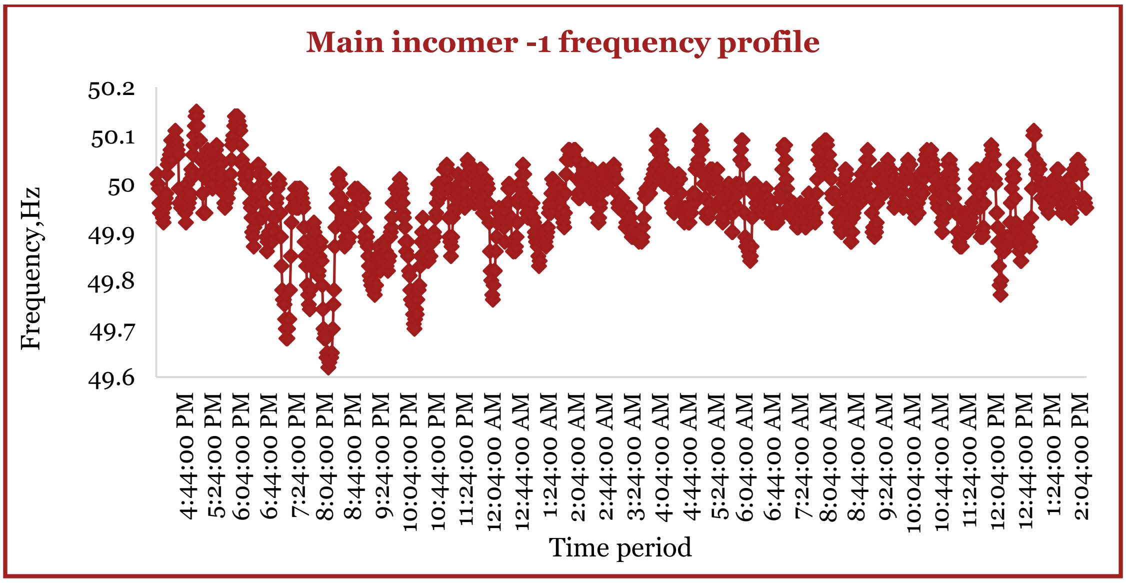
The maximum power factor recorded during this period = 0.92

The minimum power factor recorded during this period = 0.7

Frequency profile:

The frequency profile was recorded for main incomer feeder -1 at the LT side from 12-08-15 @04:44 pm to 13-08-15 @ 2:00 pm and is presented below.

Figure 9 : Chocolate plant main incomer frequency profile



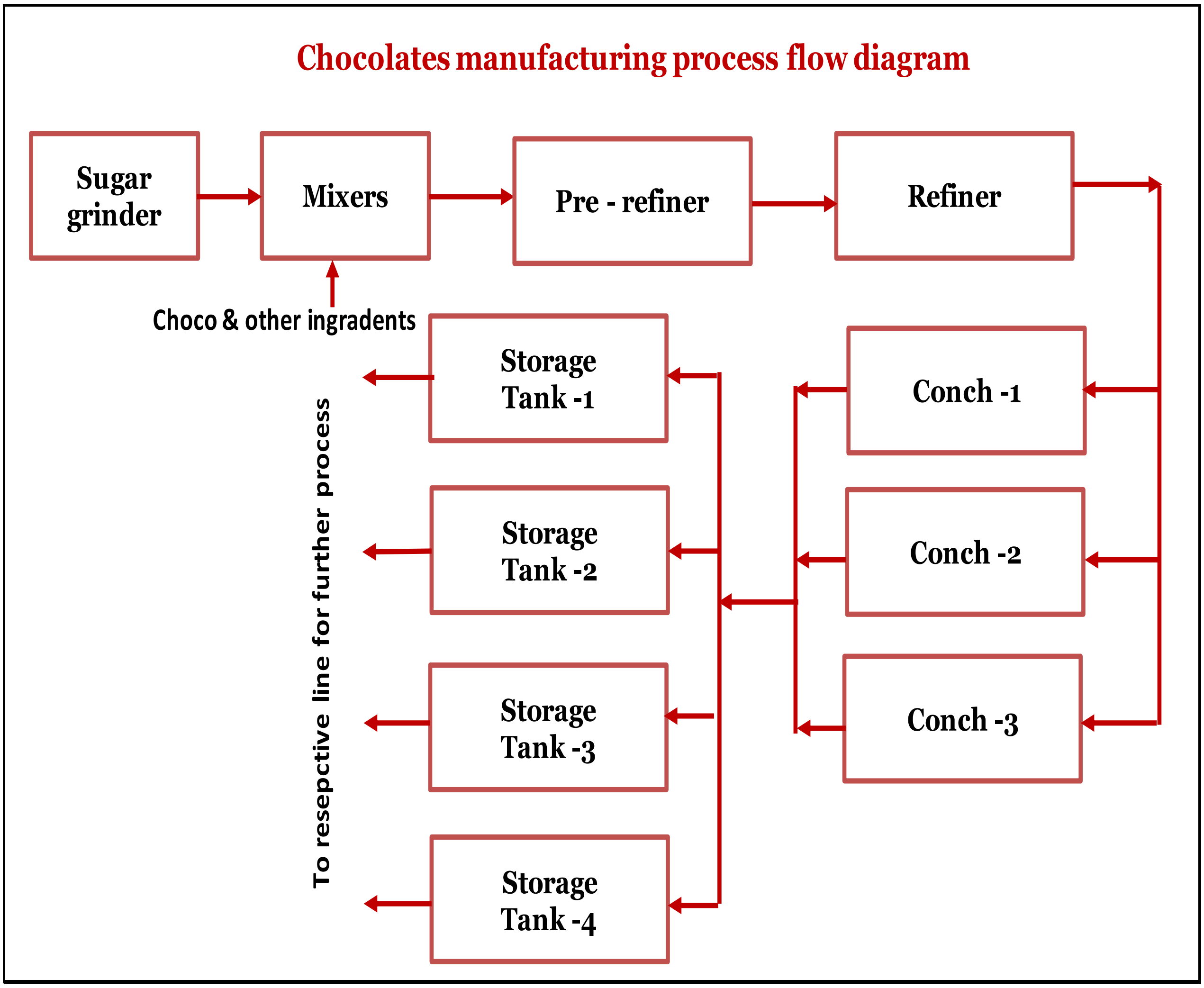
The maximum frequency recorded during this period	=	50.1 Hz
The minimum frequency recorded during this period	=	49.6 Hz

The analysis of various power parameters given above indicates that the overall quality of power received by the plant is good and most of the parameters are within the desired range.

3.3 Process equipment

All energy consuming process equipment in the chocolates manufacturing process were studied during the audit. A detailed process flow diagram for chocolate manufacturing is provided below.

Figure 10: Chocolate manufacturing process flow diagram

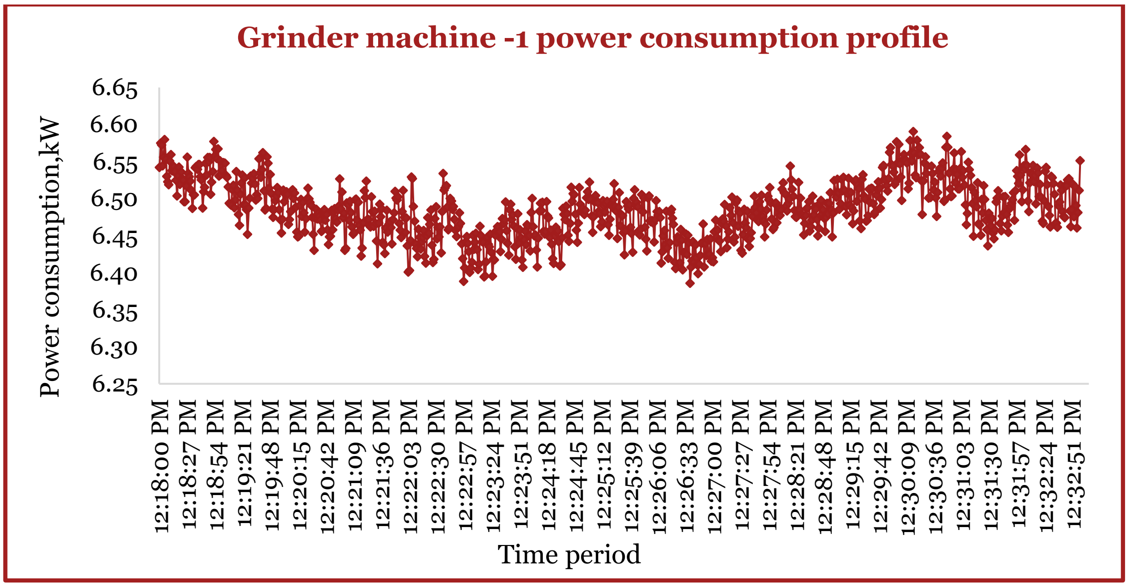


Sugar Grinder:

The chocolate manufacturing process starts from grinding of sugar. Two grinders are installed in the plant of which one is used for grinding sugar for chocolate plant and other is used for grinding sugar for other plants in the food complex. The sugar grinder machines runs only for 3 -4 hours per day.

The power consumption profile for the grinder -1 is machine is as follows.

Figure 11: Sugar grinder machine -1 power consumption profile



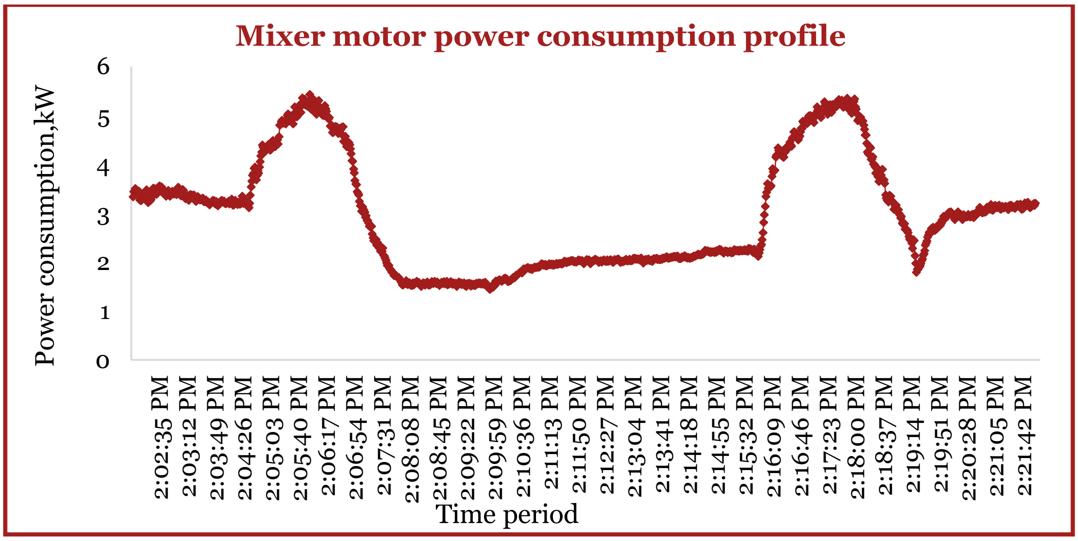
- Rated power consumption of motor = 30 kW
- Power consumption for the grinder machine = 6.5 kW
- Average motor loading = 30 %
- Average sugar grinded per hour = 606 kg/h
- Energy consumption per hour = 6.5 kWh

Mixer:

All the basic ingredients for chocolates are mixed in mixer. Mixer runs for around 15 hours per day. The different type of chocolates and their ingredients are mentioned below.

Milk chocolates	=	Coca powder, low fat, sugar, coca butter
Choco-zoo	=	SMP powder, coca powder, sugar, fat
Dark chocolates	=	Coca powder, coca butter

Figure 12: Mixer power consumption profile



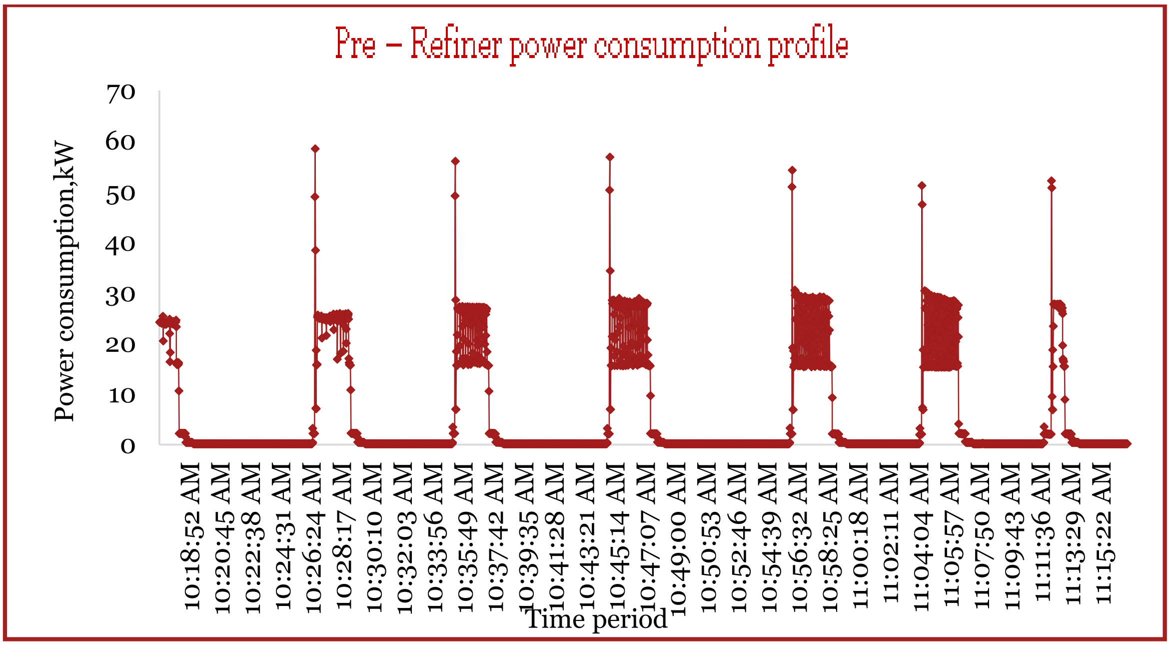
- Rated power consumption of motor = 11.5 kW
- Un load power consumption = 1.562 with 0.22 pf

- Loading power consumption = 5.5 kW with 0.6 pf
- Average motor loading = 50 %

Pre - refiner:

After the mixer, mixed chocolates are sent to pre-refiner for refining. In the process of refining, chocolates are converted to a fine powder and any metal and other impurities are checked thoroughly. Power consumption profile for pre-refiner is as follows.

Figure 13: Pre-refiner power consumption profile



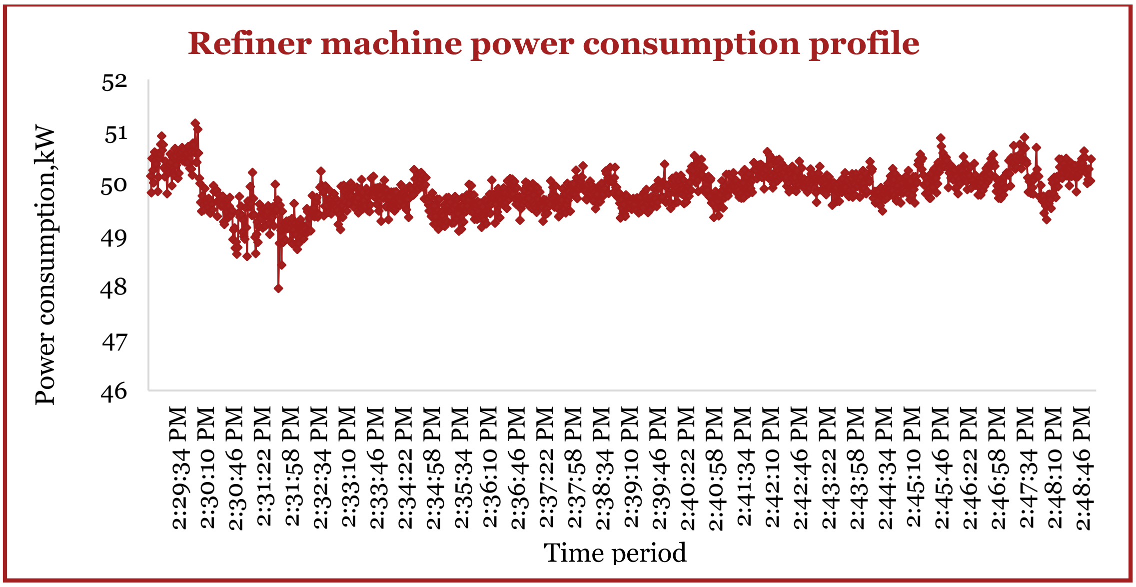
Rated power consumption of motor	=	37 kW
Loading power consumption	=	28 kW
Average motor loading	=	75 %

Refiner:

After pre-refiner, chocolates are sent to refiner machine for further refining. In refining machine, chocolate is further grinded into fine particles by crushing chocolate in between hot rollers. During this process, chocolate is fully refined and converted to fine powder.

Rated power consumption of motor	=	90 kW
VFD frequency	=	36.5 Hz
Loading power consumption	=	50-55 kW
Average motor loading	=	55 %

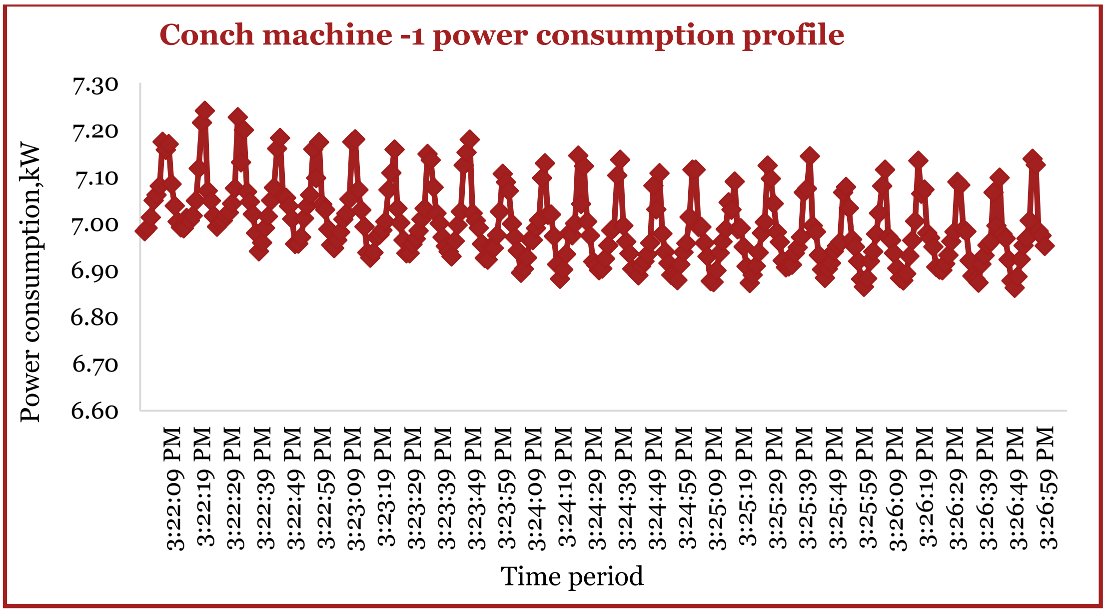
Figure 14: Refiner power consumption profile



Conch Machine -1:

In conch machines, the refined chocolate is mixed with other ingredients in order to make a homogeneous mix of chocolates. The power consumption profile for the conch machine -1 is as follows.

Figure 15: Conch machine -1: power consumption profile

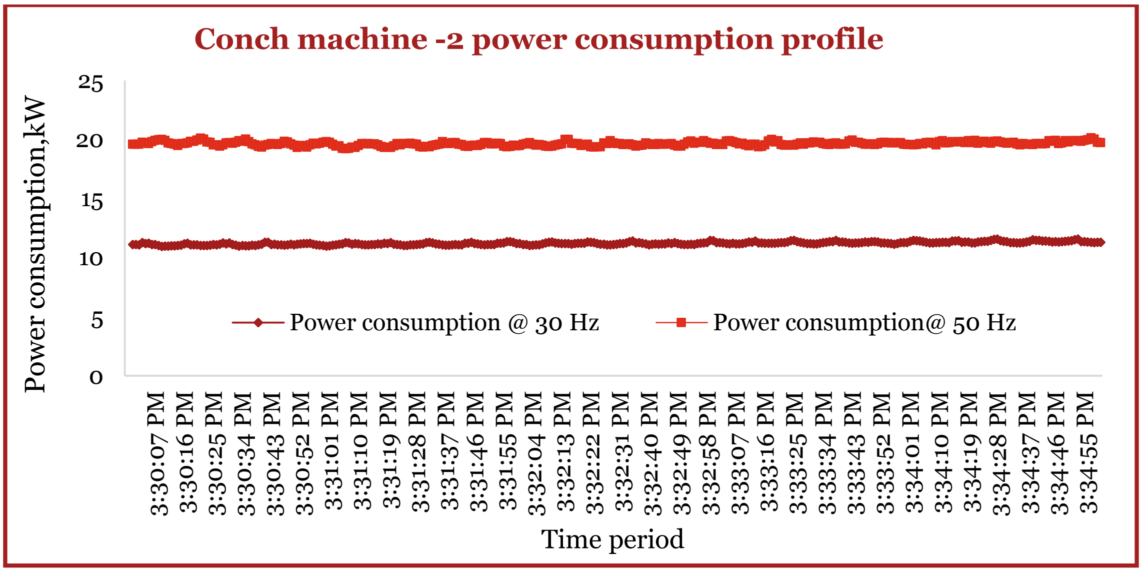


- Rated power consumption of motor = 22.5 kW
- VFD frequency = 30 Hz
- Loading power consumption = 7.1 kW
- Average motor loading = 31 %
- Chocolate temperature = 59 ^{o}C

Conch Machine -2:

In conch machines, the refined chocolate is mixed with other ingredients in order to make a homogeneous mix of chocolates. The power consumption profile for the conch machine -2 is as follows.

Figure 16: Conch machine -2: power consumption profile

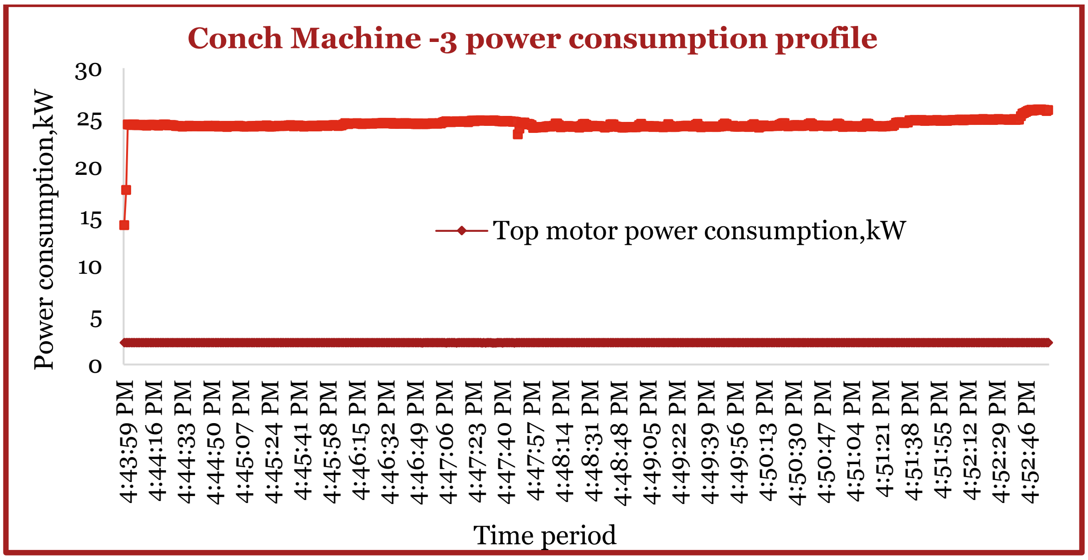


• Rated power consumption of motor	=	22.5 kW
• Loading power consumption	=	11 kW @ 30 Hz
• Loading power consumption	=	22 kW @ 50 Hz
• Average motor loading	=	48% @ 30 Hz
• Average motor loading	=	98% @ 50 Hz
• Chocolate temperature	=	54 ºC

Conch Machine -3:

Conch machine -3 is also used for same purpose as other two conch machines but it has higher capacity. There are two motor installed in this machine, one at the top and other at the bottom. The power consumption profile for the conch machine -3 is as follows.

Figure 17: Conch machine -3: power consumption profile

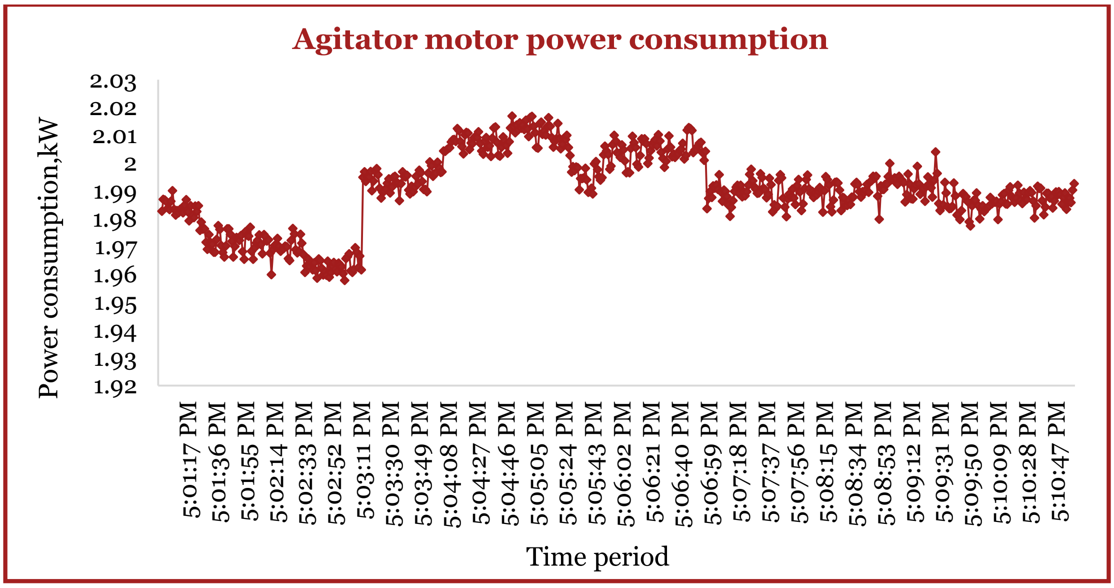


- Rated power consumption of top motor = 55 kW
- Rated power consumption of bottom (Agitator) motor = 11.5 kW
- Actual power consumption of top motor = 25 kW
- Actual power consumption of bottom (Agitator) motor = 6.5 kW

Storage tanks:

After processing the chocolate in conch machine, it is stored in the storage tanks for further processes in respective lines. There are five tanks to store chocolate of different quality. All these tanks are installed with agitator motors at the top for keeping the chocolate homogeneous. The power consumption profile for one agitator motor out of five is measured on sample basis. This has been presented below.

Figure 18: Agitator motor power consumption profile



Maximum power consumption recorded = 2.02 kW

Minimum power consumption recorded = 1.96 kW

3.4 Refrigeration system

Plant is installed with refrigeration system to keep temperature of chocolate under desirable range to maintain the quality. The refrigeration system is one of the major load in the plant, which consumes about 18% of total chocolate plant load. The design details of the refrigeration compressors and actual parameters measured are as follows.

3.4.1 Design details - Cave Mill, Choco -zoo, packing and Wafer line:

Type of compressor = Scroll

Model = ACWCUS028DMN2X1

Water-cooled condenser test pressure

Shell side pressure = 375 psig

Tube side pressure = 150 psig

Air cooled condense test pressure

Tube side pressure	=	412 psig
Compressor motor	=	13.62 kW for each compressor
Nominal capacity	=	42,300 kCal for each compressor

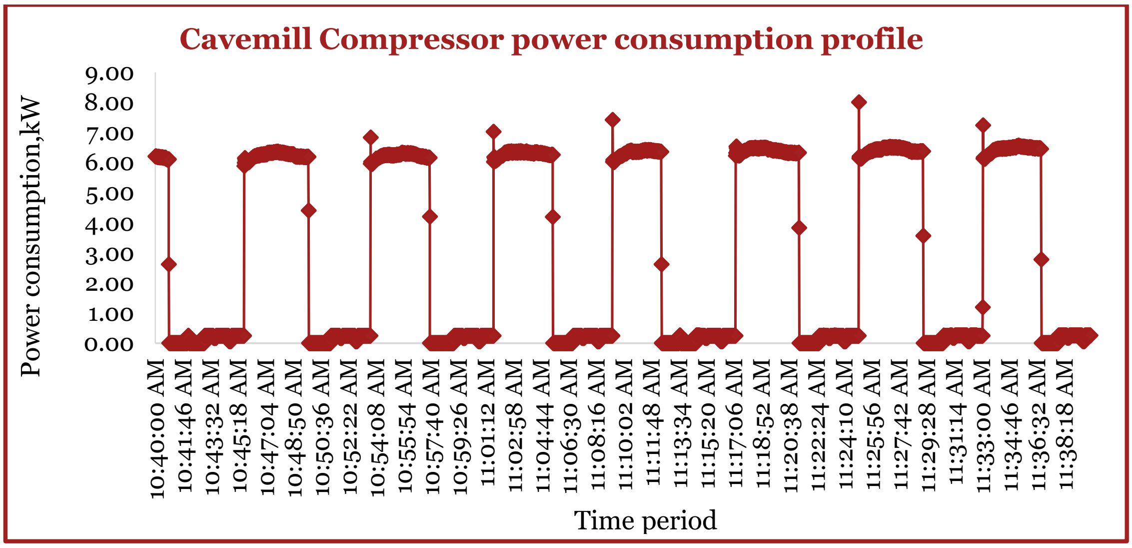
3.4.2 *CaveMill chiller :*

Cave mill chiller is used to keep the chocolate cooled after chocolate is made and before packing. The temperature to be maintained in cooling box is 7-10 °C.

Compressor type	=	Scroll
Number of compressor installed	=	3
Compressor power consumption	=	13.6 kW *3
Rated capacity	=	42,300 kCal*3
Rated SEC	=	0.97 kW/TR

Actual temperature measured at the line-cooling box is 8 °C.

Figure 19: Cave mill compressor - power consumption profile



Number of compressor running	=	1
Highest power consumption	=	6.3 kW

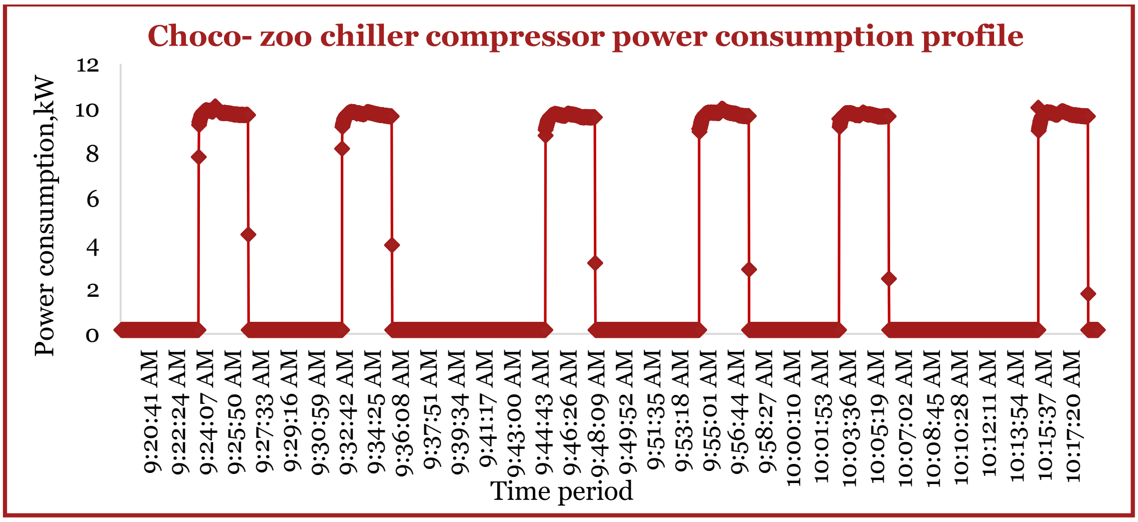
3.4.3 *Choco -zoo chiller :*

Choco-zoo chiller is used to keep the chocolate cooled after choco-zoo chocolate is made and before packing. The temperature to be maintained in the cooling box is 7-10°C.

Compressor type	=	Scroll
Number of compressor installed	=	3
Compressor power consumption	=	13.6 kW *3
Rated capacity	=	42,300 kCal*3
Rated SEC	=	0.97 kW/TR

Actual temperature measured at the line-cooling box is 8 °C.

Figure 20: Choco-zoo chiller compressor - power consumption profile



Number of compressor running	=	1
Highest power consumption	=	10 kW

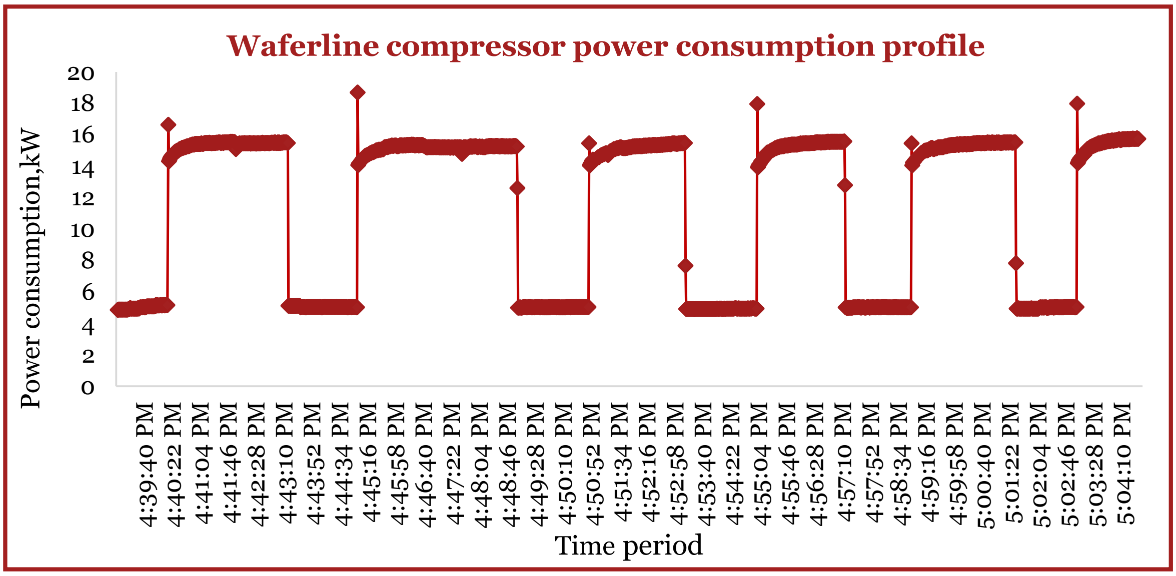
3.4.4 Waferline chiller:

Waferline chiller is used to keep chocolate cooled after chocolate is made and before packing. The temperature to be maintained in the cooling box is 7 °C.

Compressor type	=	Scroll
Number of compressor installed	=	1
Compressor power consumption	=	24 kW
Rated capacity	=	25 TR
Rated SEC	=	0.97 kW/TR

Actual temperature measured at the line-cooling box is 7 °C.

Figure 21: Wafer line chiller compressor - power consumption profile



Number of compressor running	=	1

Power consumption during load condition	=	16 kW
Power consumption during unload condition	=	5 kW

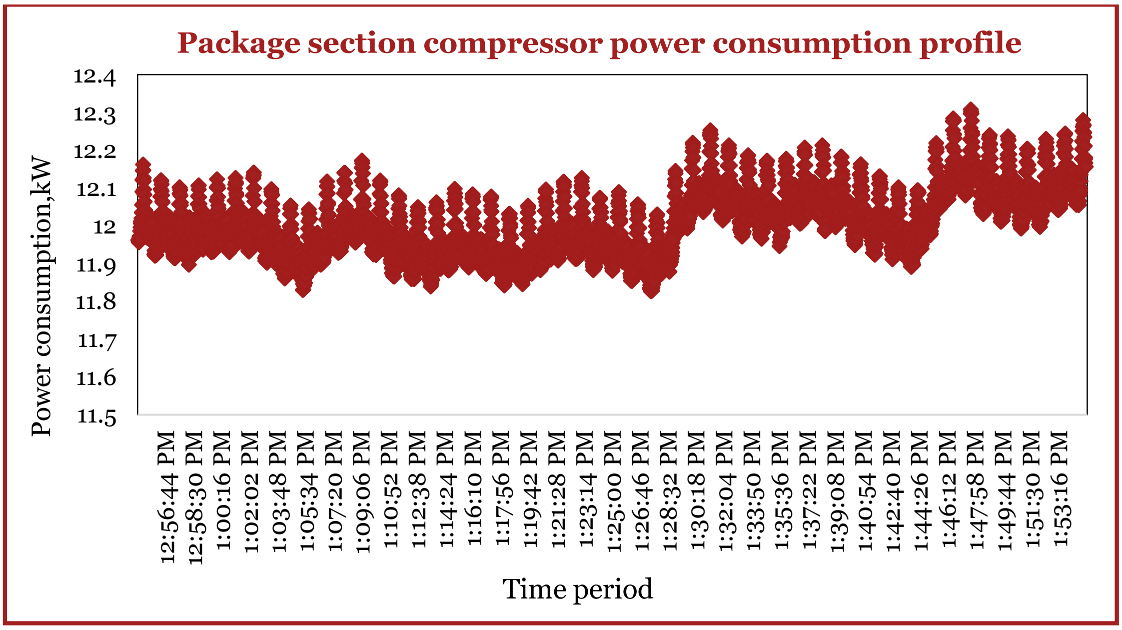
3.4.5 *Packing line chiller:*

Packing line chiller is used to keep the chocolate cooled after chocolate is made and before packing. The temperature to be maintained in the cooling box is 21 °C.

Compressor type	=	Scroll
Number of compressor installed	=	2
Compressor power consumption	=	13.6 kW *2
Rated capacity	=	42,300 kCal*2
Rated SEC	=	0.97 kW/TR

Actual temperature measured at the line-cooling box is 22 °C.

Figure 22: Packing section chiller compressor - power consumption profile



3.4.6 *Almond bar chiller:*

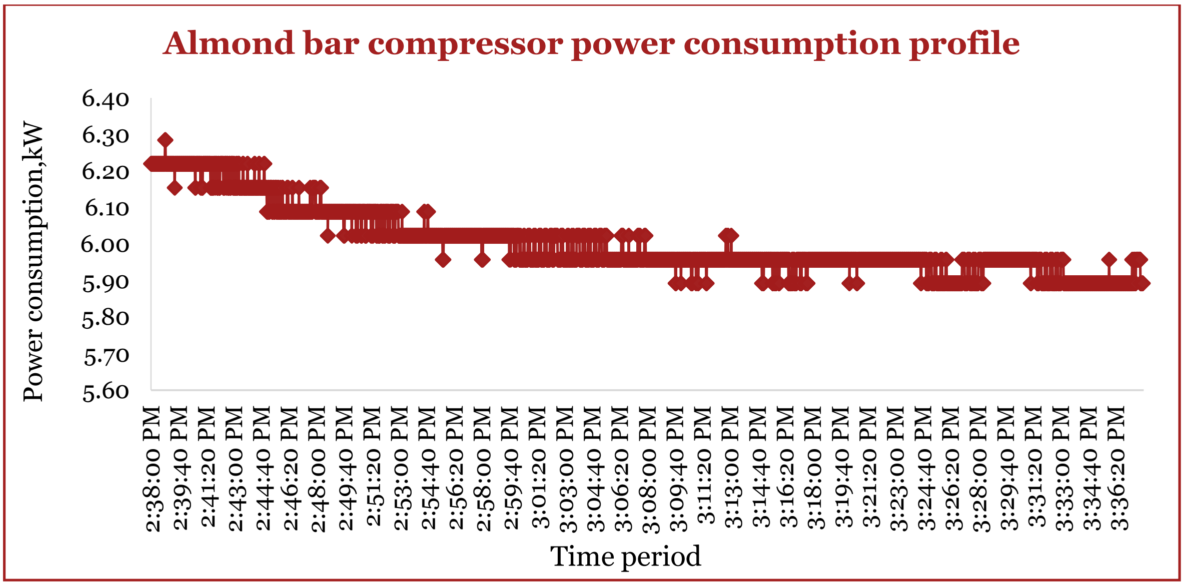
Almond bar chiller is used to keep the chocolate cooled after chocolate is made and before packing. The temperature to be maintained in the cooling box is 12 °C. The almond bar chiller is reciprocating type and is very old.

The chiller compressor design details are as follows.

Compressor type	=	Reciprocating
Capacity	=	5 TR
Power consumption	=	5.5 kW
Rated SEC	=	1.1 kW/TR

Actual temperature measured at the line-cooling box is 10-12 °C.

Figure 23: Almond bar chiller compressor - power consumption profile



Number of compressor installed in chiller	=	1 Number
Average power consumption	=	6 kW

The specific energy consumption of almond bar chiller is evaluated , same is as follows.

Table 6 : Reciprocating chillers SEC for almond line

Description	Units	Parameters
Number of reciprocating chillers installed in almond bar line	Number	2
Actual number of reciprocating chillers operating	Number	1
Capacity of storage chillers	TR	5
Actual TR delivered by storage chiller	TR	3.8
Actual power consumption these chillers	kW	6
Average SEC of reciprocating chillers	kW/TR	1.57

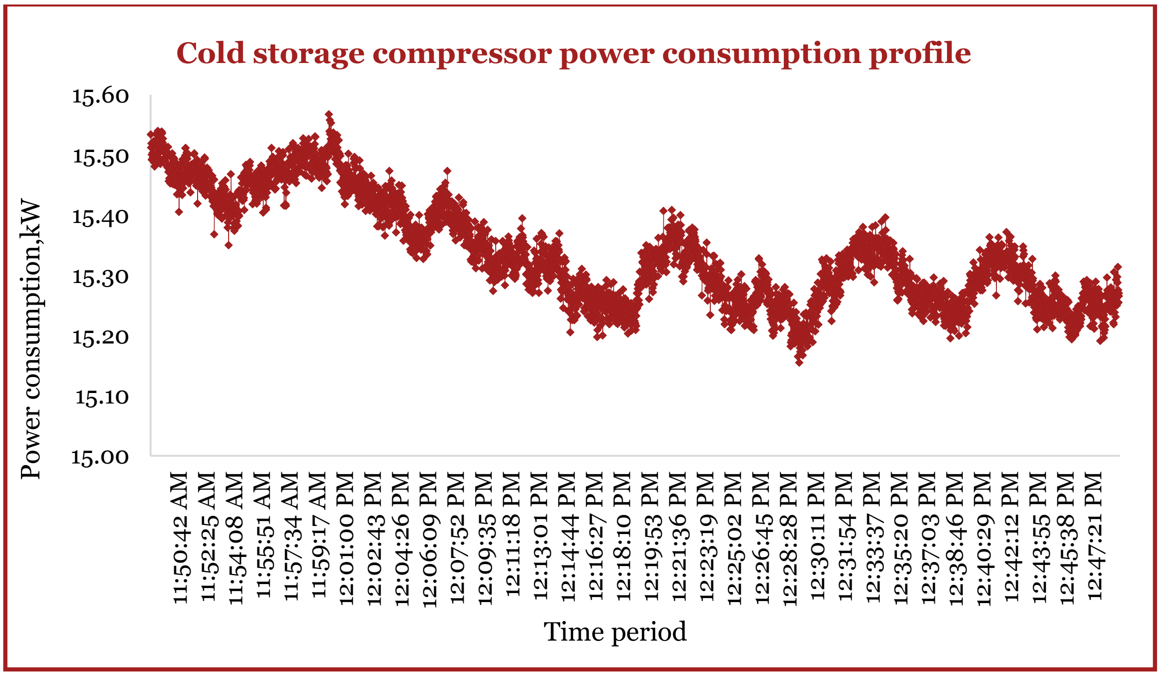
3.4.7 Cold storage chiller:

Cold storage chiller is used to keep the chocolate cooled after packing. The temperature need to maintain in the cooling box is 20 °C. This chiller is reciprocating type and very old. The chiller compressor design details are as follows.

Compressor type	=	Reciprocating
Capacity	=	20 TR
Power consumption	=	18.5 kW
Rated SEC	=	0.92 kW/TR

Actual temperature measured at the line-cooling box is 17-18 °C.

Figure 24: Cold storage chiller compressor - power consumption profile



Number of compressor installed in chiller	=	1 Number
Average power consumption	=	15.4 kW

The specific energy consumption of chillers is evaluated,same is as follows.

Table 7 : Reciprocating chillers SEC for cold storage

Description	Units	Parameters
Actual number of reciprocating chillers operating	Number	1
Capacity of storage chillers	TR	20
Actual TR delivered by storage chiller	TR	10
Actual power consumption these two chillers	kW	15.5
Average SEC of reciprocating chillers	kW/TR	1.55

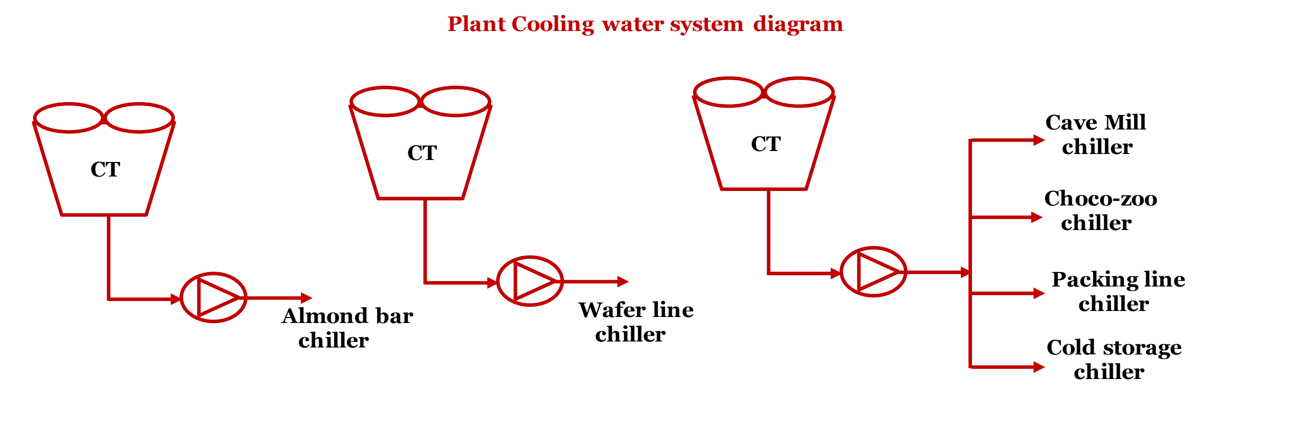
3.5 Cooling water system

Plant has separate cooling water system to supply the cooling water for refrigerant chillers. There are three cooling towers installed and all these cooling tower are working. The capacity of the cooling towers are as follows.

Almond bar CT	=	40 TR, 1.5 kW fan motor
Waferline CT	=	40TR, 1.5 kW fan motor
Cavemill,chocogo,packingline &cold store CT	=	80TR, 7.5 kW fan motor

The cooling tower system diagram is as follows.

Figure 25: Refrigeration system cooling water system diagram



There are three pumps installed for three cooling tower to pump cooling water to chillers. The performance analysis for each pump is done and same is as below.

Table 8 : Cooling water pump - efficiency estimation

Description	Units	Almond bar cooling water pump	Wafer line cooling water pump	Cave mill, choco - zoo, packing line &cold store cooling water pump
Cooling water supply temperature	oC	28.5	29	29
Cooling water return temperature	oC	31	31.5	31
Delta T across CT	oC	2.5	2.5	2
Pump flow rate	m^3/h	5.76	12.96	16.56
Pump suction pressure	kg/cm^2	0	0	0
Pump discharge pressure	kg/cm^2	3.5	3.7	3.6
Total head developed	M	35	37	36
Power consumption	kW	1.2	3.1	3.5
Overall efficiency	**%**	**46%**	**42%**	**46%**
Pump efficiency @90% of motor efficiency	**%**	**51%**	**47%**	**52%**

- The efficiency of the pumps are found to be on lower side may be due to mismatch between operating and design parameters and these pumps are also found to be old and are ideal for replacement.

3.6 Air compressor

There are three reciprocating air compressors installed in the plant to cater to the compressed air requirement of the plant. All the compressors are running to meet the compressed air demand during normal working day. The design details of the compressors are as follows.

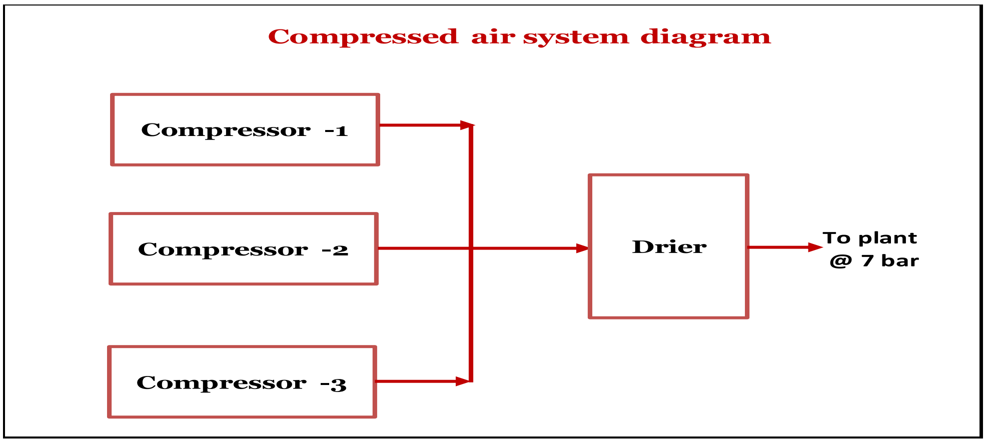
Compressor -1 = 22 cfm, 10 kg/cm^2 @ 3.7 kW

Compressor -2 = 28 cfm, 10 kg/cm^2 @ 5.5 kW

Compressor -3 = 32 cfm, 12 kg/cm^2 @ 9.7 kW

The air compressor system diagram is as follows.

Figure 26: Plant air compressor system diagram



The parameters measured and analysis done is as follows.

Table 9 : Air compressor specific energy consumption estimation

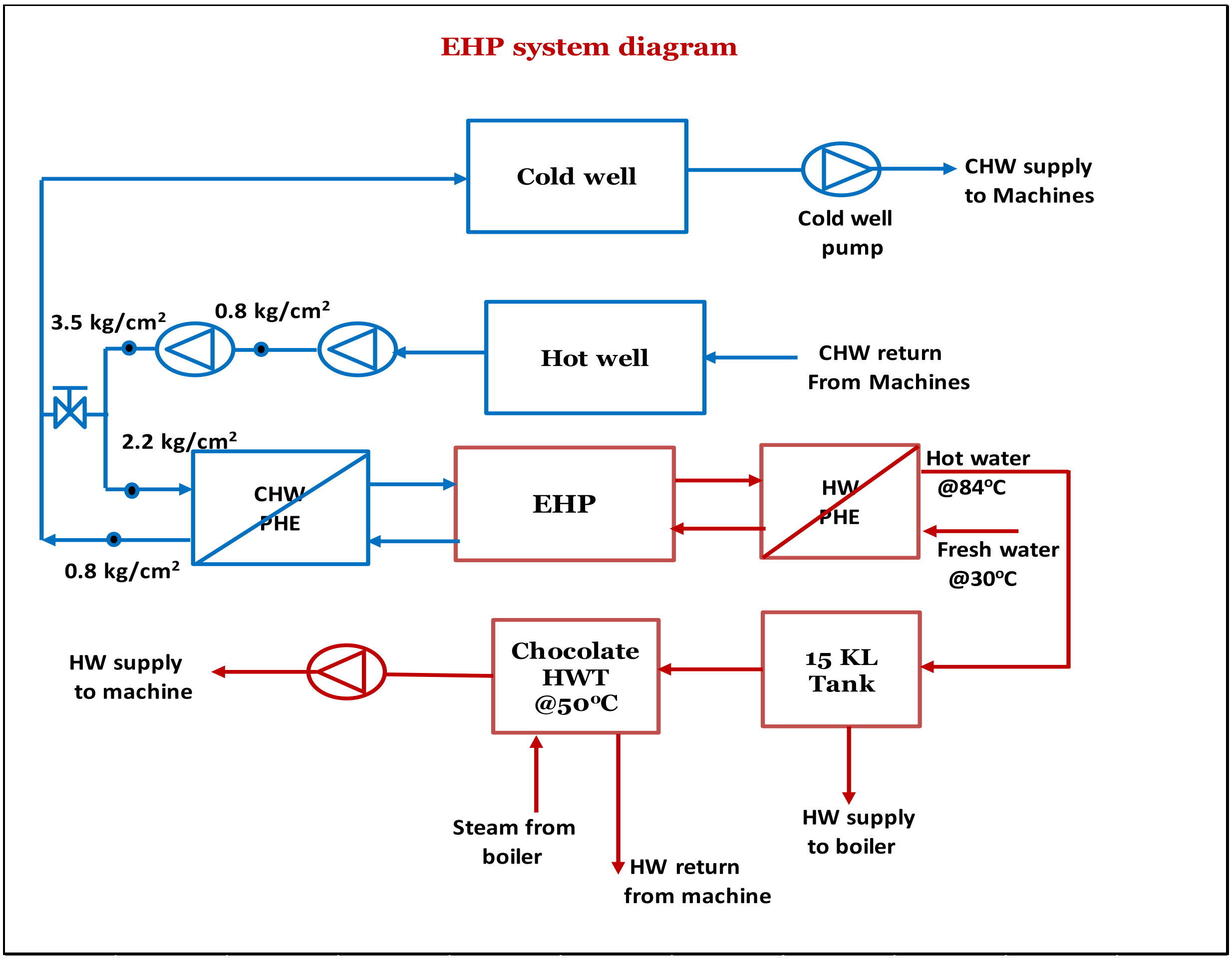
Description	Units	Comp-1	Comp-2	Comp-3
Rated parameters				
Type of compressor				Reciprocating
Rated flow rate	cfm	22	28	32
Rated pressure	kg/cm²	10	10	12
Power consumption	kW	3.7	5.5	9.7
Actual parameters				
Pressure measured	kg/cm²	7.5	7.5	7.5
Flow rate delivered	cfm	12	18	28
Power consumption measured	kW	3.7	5.5	10
SEC	**kW/cfm**	**0.31**	**0.31**	**0.36**

- The actual specific energy consumption measured is found to be very high due to poor maintenance of these compressors.
- During the audit, it was observed that suction filters of these compressors are chocked.
- Since these compressors are reciprocating type and old; these compressors are ideal for replacement.

3.7 Electric heat pump

There is an electrical heat pump installed in the plant to generate hot water and chilled water for process. The chilled water generated is used in chocolate plant and hot water is sent to boiler. The detailed system diagram of electrical heat pump is as follows.

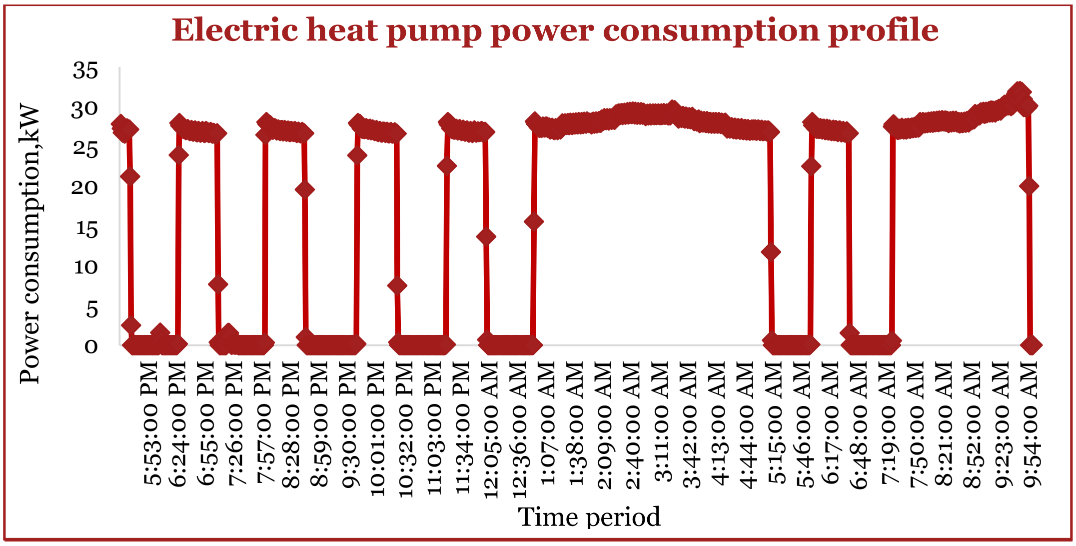
Figure 27: Electric heat pump system diagram



Temperature of the chilled water from electric heat pump	=	5 – 10 °C
Temperature of the hot water from electric heat pump	=	80 - 85 °C
Temperature of hot water required in chocolate plant	=	85 °C
Temperature of chilled water supply in chocolate plant	=	6 °C

The power consumption of electric heat pump compressor logged for one complete day is as follows.

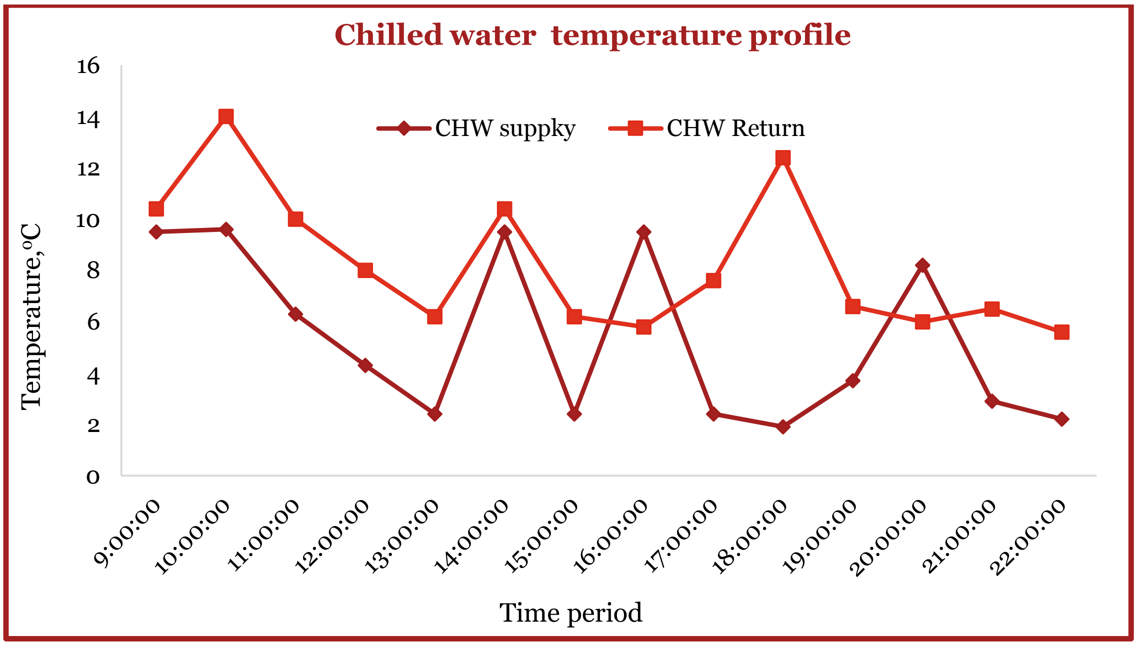
Figure 28: Electric heat pump power consumption profile



Power consumption of the electric heat pump compressor = 28 kW

Chilled water temperature measured at the electric heat pump side is as follows.

Figure 29: Electric heat pump chilled water temperature profile

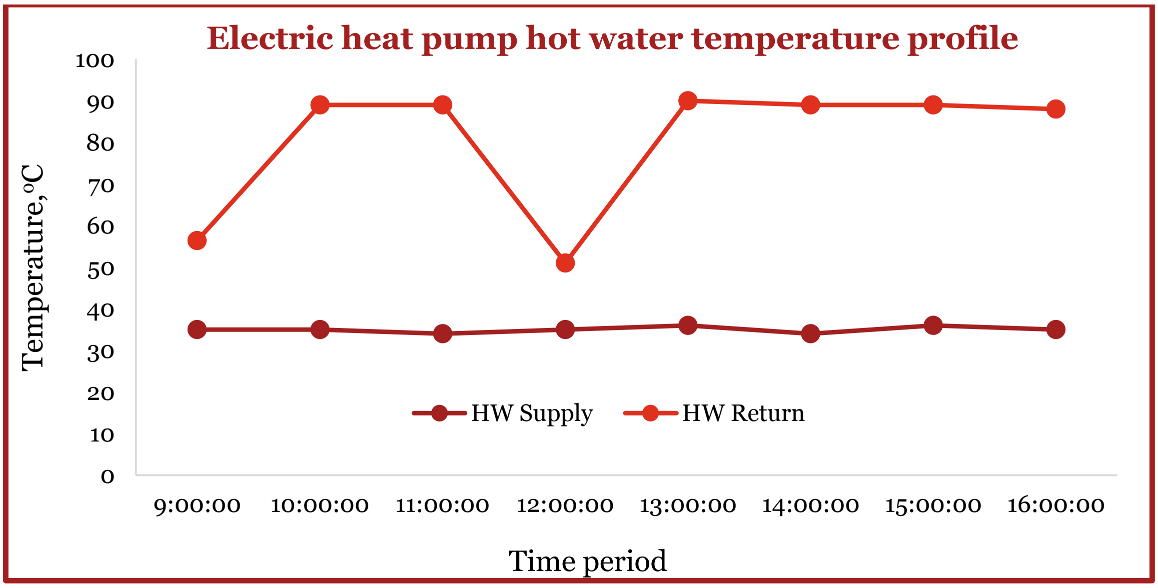


Chilled water supply temperature = 2 – 10 °C

Chilled water return temperature = 6 – 12 °C

Hot water temperature logged at the electric heat pump side is as follows.

Figure 30: Electric heat pump hot water temperature profile



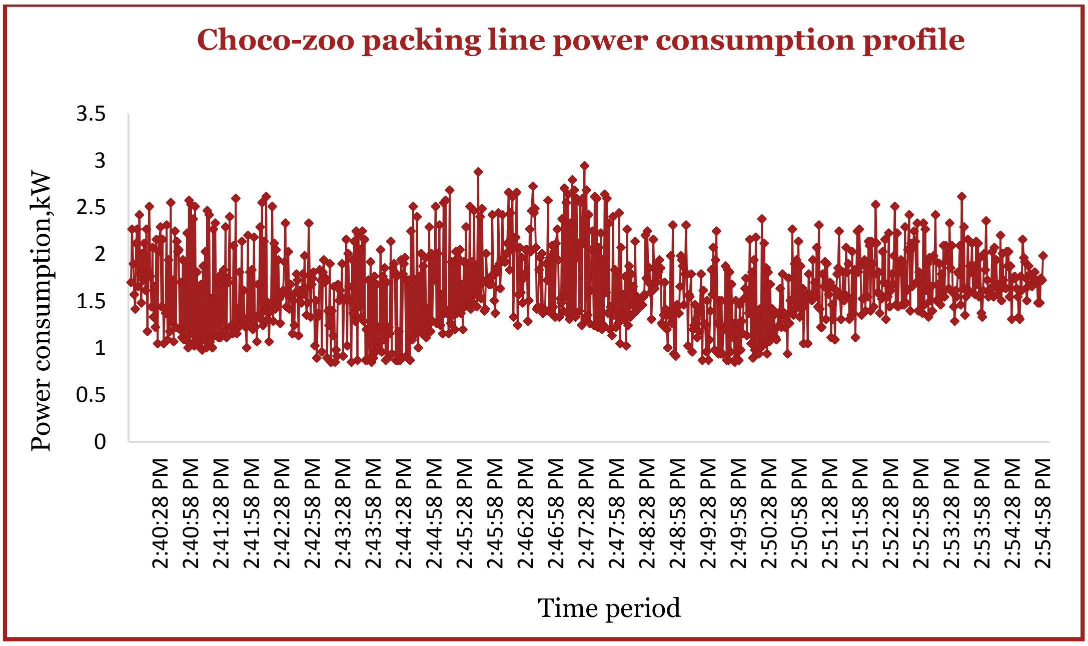
Hot water supply temperature = 90 °C

Hot water return temperature = 35 – 38 °C

3.8 Packing section

There are five packing machines installed and are operated depending on chocolates available for packing. The power consumption measured for packing machines in sample basis is as below. Power consumption profile for Choco –zoo chocolate packing machine is as follows.

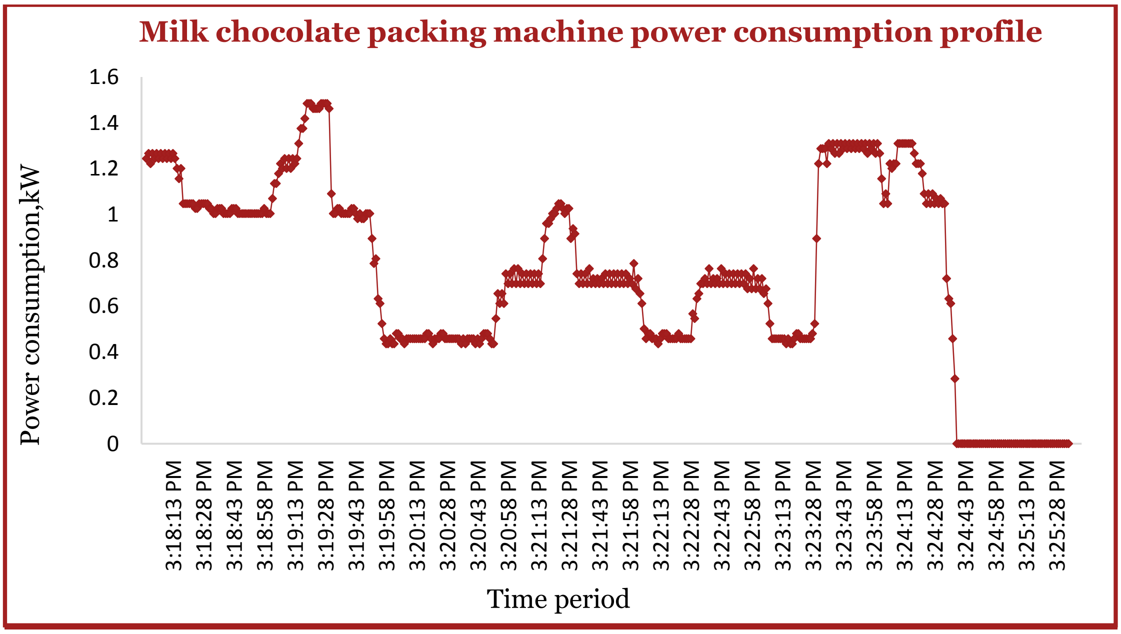
Figure 31: Choco –zoo packing line power consumption profile



Average power consumption of the machine - 2 kW

Power consumption profile for milk chocolate packing machine is as follows.

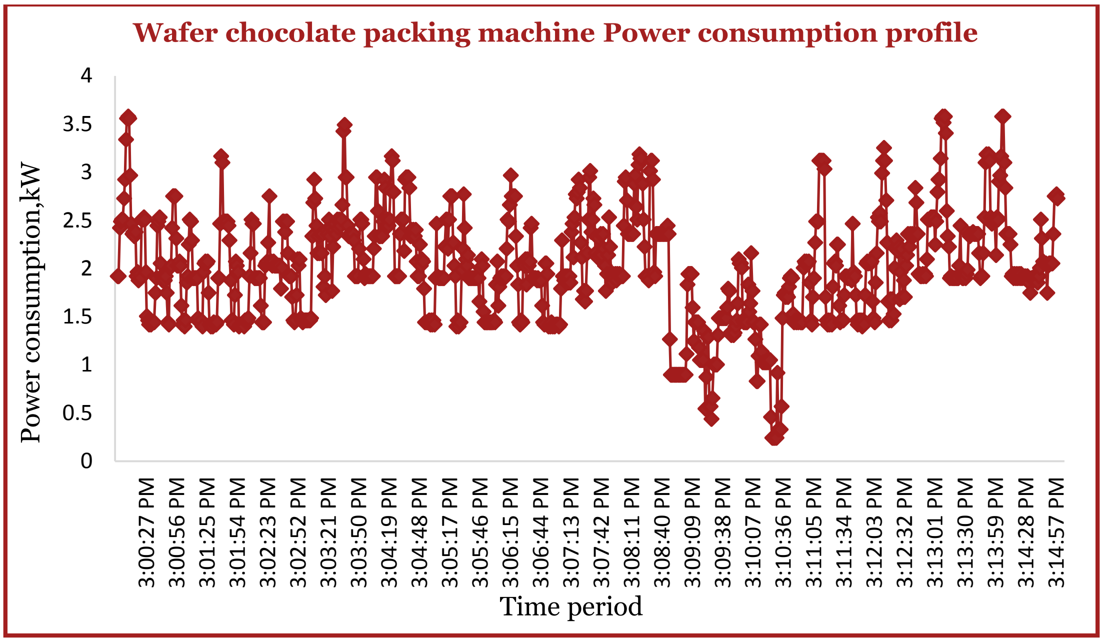
Figure 32: Milk chocolate packing line - power consumption profile



Average power consumption of the machine - 0.8 kW

Power consumption profile for wafer chocolate packing machine is as follows.

Figure 33: Wafer chocolate packing line - power consumption profile



Average power consumption of the machine - 2 kW

Air handling units

AHU is installed in the packing section to maintain the temperature in the section. This AHU is working throughout the day to maintain the temperature. The parameters measured at AHU during the audit are as follows.

Actual measured temperature at the AHU supply side	=	17.5 °C /85 %RH
Actual measured temperature at the AHU return side	=	21 °C /65 %RH
Temperature at the room display	=	23 °C
Actual airflow rate delivered by AHU	=	25,500 cfm
AHU motor power consumption	=	4.3 kW

The actual temperature maintained in the packing section is found to be low, as per the standard; the temperature need be maintained around 24 °C, which will meet the human comfort requirement and save the power consumption of chiller compressor.

3.9 *Cold storage*

There is a cold storage in the plant to keep the packed chocolate before it is dispatched through trucks. The parameters measured at AHU during the audit are as follows.

Actual measured temperature at the AHU supply side	=	15 °C/90 %RH
Actual measured temperature at the AHU return side	=	17.5 °C/75 %RH
Temperature at the room display	=	19 °C
Actual airflow rate delivered by AHU	=	22,750 cfm
AHU motor power consumption	=	1.3 kW

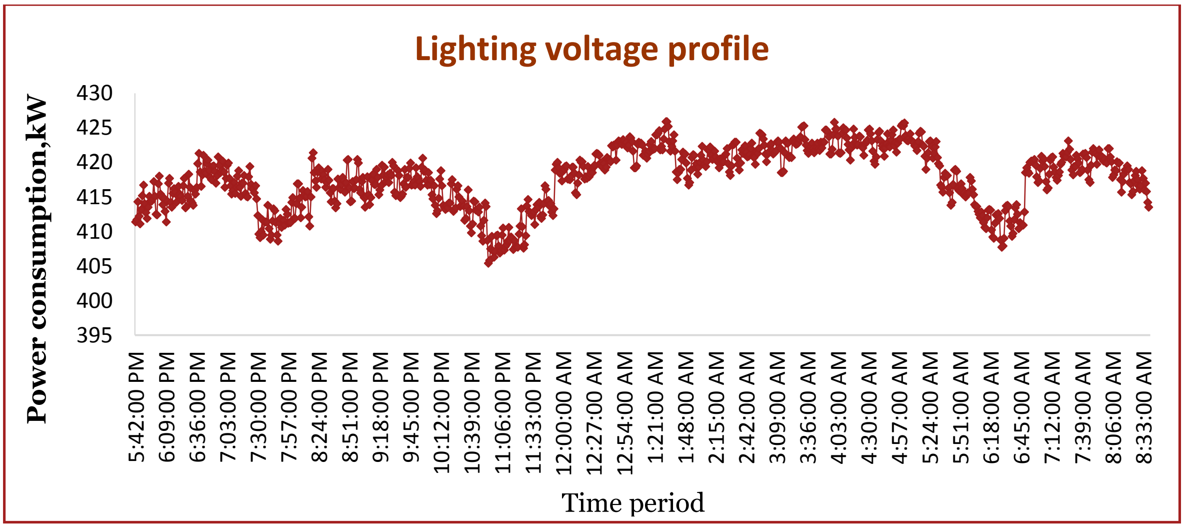
The actual temperature maintained in the packing section is found to be low, as per the standard; the temperature can be maintained around 24 °C, which will meet the human comfort requirement and save the power consumption of chiller compressor.

3.10 Lighting

Lighting is the one of the major load in the plant and consumes roughly 6% of total electricity consumption of the plant. There is a separate feeder installed for lighting through which power is fed to all lighting DB's.

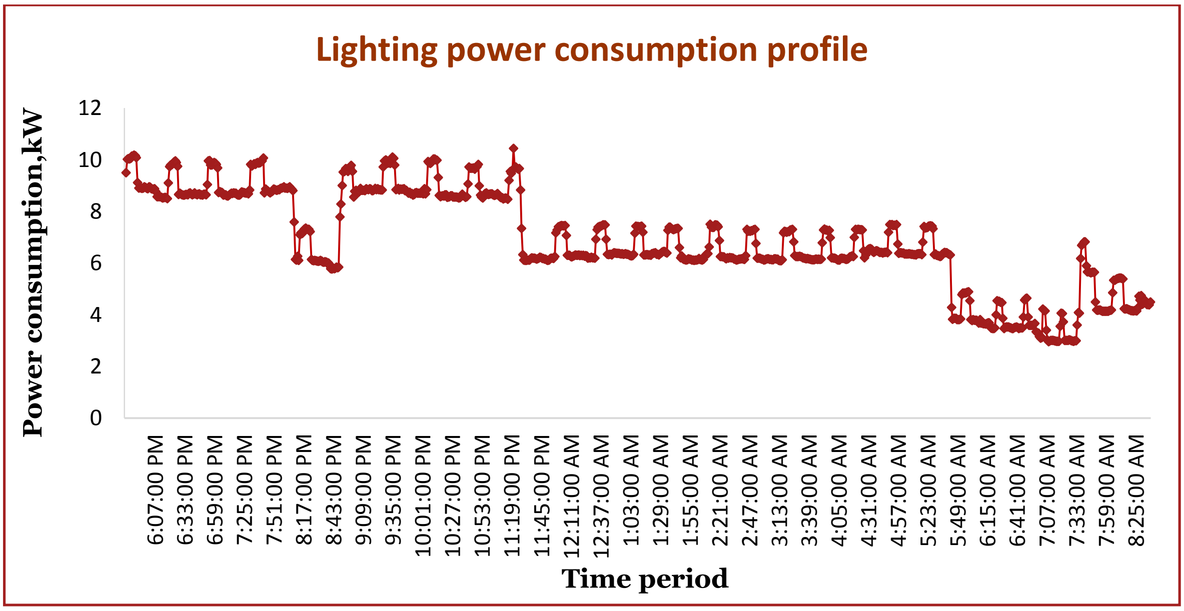
The voltage and power consumption measurements were done on lighting feeder during the audit and the results are presented below.

Figure 34: Lighting voltage profile



Maximum lighting voltage during the recording period	=	425 Volts
Minimum lighting voltage during the recording period	=	405 Volts
Average lighting voltage during the recording period	=	415 Volts

Figure 35: Lighting power consumption profile



Maximum lighting consumption during the recording period = 10 kW

Minimum lighting consumption during the recording period = 3.8 kW

Average lighting consumption during the recording period = 6.5 kW

Lighting inventory details:

Lighting inventory details for chocolate plant are as follows.

Table 10 : Plant lighting fittings details

Location	36W*2 FTL	36W*1 FTL	150W MV	250W MV
Chocolate plant	118	18	14	3

- Plant is fitted with different types of fittings to provide light in shop floor and offices. All these lamps are operating at least 12 hours a day and all days in the year.
- Replacing all these lamps with LED lamps with respective suitable wattage ratings will save the lighting energy consumption.

Lux level:

The lighting lux levels measured during the audit at different places of the plant is as follows.

Table 11 : Plant lux level measurement

Area	Lux Measured
Walkway (Corridor)	242,89,159,189,200
Shop floor (Production area)	89,86,120,190,320,345,234,189
Grinder room	234,290,190,213,220,190,320
Packing area	129,70,170,66,112,293,78,219
Storage area	67,59,44,33,20,290,138,418
Guest receiving area	230,240,180,210,220
Production manager office	210,290,310,200,320,210
Coco processing area	230,290,300,340,320,210

- Lux levels measured at the different places of the plant are found to be good and satisfactory as per the standards.

4 Energy Conservation Measures

Kaira district co-operative milk producers union limited have their food complex in Anand, which manufactures all type of Amul branded foods like bread, biscuits, sweets and chocolates. All these food-making plants are under one campus. The detailed energy audit was conducted in the chocolate plant to identify energy saving opportunities. Energy conservation measures identified in chocolate plant during audit is discussed below.

4.1 Refrigeration system

4.1.1 Replace old reciprocating chillers in almond line and cold storage with new EE scroll chiller

Background

The plant has installed six refrigerant chillers to meet the refrigeration requirement. These six chillers are of following two different types.

Scroll type : Cave Mill, Choco-zoo, Packing and Wafer line

Reciprocating : Almond bar & cold storage

Findings

The performance evaluation of reciprocating chiller shows that these are operating at specific energy consumption of 1.55 kW/TR, which is very high compared to new energy efficient scroll chiller. (The scroll chillers are already operating in other lines of the plant as mentioned before). The new energy efficient scroll chiller will have a specific energy consumption of 0.7 kW/TR. Hence, replacement of existing reciprocating chillers with screw chillers will result in substantial energy savings.

Recommendation

Replace old higher specific energy consuming reciprocating chillers with new energy efficient scroll chillers in Almond line and Cold storages.

Energy & financial savings

Estimated energy and financial savings for the recommendations along with payback period is as follows.

Table 12 : Refrigeration chillers replacement saving and investment estimation

Description	Units	Parameters
Actual parameters		
Number of reciprocating chillers installed	Number	2
Actual number of reciprocating chillers operating	Number	2
Average SEC of reciprocating chillers	kW/TR	1.55
Capacity of cold storage chillers	TR	20
Capacity of almond bar chillers	TR	5
Actual TR delivered by storage chiller	TR	10
Actual TR delivered by almond chiller	TR	3.8

Description	Units	Parameters
Actual power consumption these two chillers	kW	21.3
Proposed parameters		
New scroll chillers capacity required for almond line	TR	5
New scroll chillers capacity required for cold storage	TR	20
Expected SEC of new scroll chiller (Already operating in other lines)	kW/TR	0.97
Actual TR generated by these chillers	TR	13.8
Actual power consumption of new chillers	kW	13.3
Energy savings	kW	8.9
Operating hours per year	Hours	8,400
Annual energy saved	**kWh**	**74,760**
Power cost	Rs/kWh	4.55
Annual cost saved	**Rs. Lakhs**	**3.40**
Investment	**Rs. Lakhs**	**10**
Payback period	**Months**	**35**

4.1.2 Replace all de-centralized cooling water system with one centralized cooling water system

Background

Plant has separate cooling water systems to supply the cooling water for the refrigeration chillers. There are three cooling towers installed and all these cooling tower are working during normal working hours. The capacity of the cooling towers are as follows.

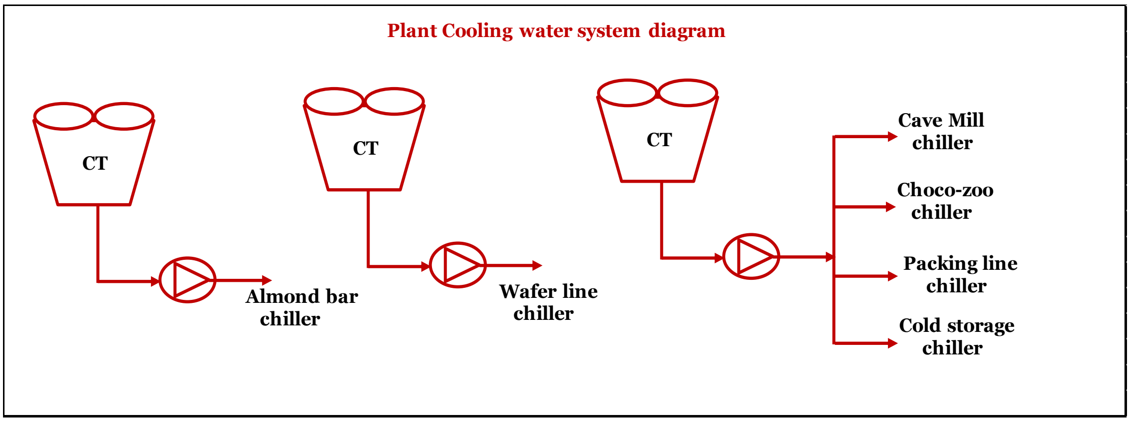
Almond bar cooling tower = 40 TR , 1.5 kW fan motor

Waferline cooling tower = 40 TR,1.5 kW fan motor

Cavemill,choco-zoo,packingline &cold store cooling tower = 80 TR,7.5 kW fan motor

The cooling tower system diagram is as follows.

Figure 36: Plant cooling water system for refrigeration system



Total pump power consumption = 7.8 kW

Total fan power consumption = 6.5 kW

Findings

The performance of cooling water system (cooling tower & cooling water pumps) are found to be very poor due to following reasons:

- There was no even distribution of water in cooling towers. Due to uneven water flow; cooling water was not getting cooled properly.
- The cooling tower fills were not cleaned and there is deposition on these fills resulting in improper heat transfer between air and water.
- The efficiency of the cooling water pumps is found to be very low due to ageing.

Recommendation

Replace all small cooling towers and cooling water pumps with one centralized cooling water system having following features:

- Cooling tower fan with FRP blades
- Cooling tower pump with VFD

Energy & financial savings

Estimated energy and financial savings for the recommendations along with payback period is as follows.

Table 13 : Cooling water system optimization saving and investment estimation

Description	Units	Parameters
Actual parameters		
Number of cooling tower operating	Number	3
Number of cooling tower pump operating	Number	3
Total fan power consumption	kW	6.5
Total pump power consumption	kW	7.8
Total water flow rate	m^3/h	35.5
Head required	m	30
Total CT capacity	TR	160
Proposed parameters		
Proposed CT capacity	TR	160
Fan power consumption	kW	1.5
Proposed flow rate of cooling water pump	m^3/h	96
Pump power consumption @36 m^3/h by VFD	kW	5.5
Power consumption saved	kW	7.3
Operating hours per year	Hours	8,400
Annual energy saved	**kWh**	**61,572**

Description	Units	Parameters
Energy cost	Rs/kWh	4.55
Annual cost saved	**Rs. Lakhs**	**2.8**
Investment for CT, pump & VFD	**Rs. Lakhs**	**8**
Payback period	**Months**	**34**

4.2 Air compressor

4.2.1 Replace all old reciprocating air compressors with new centralized EE screw compressor

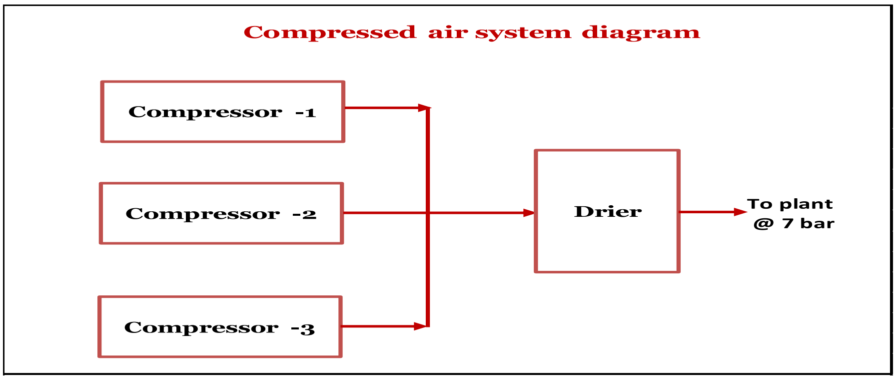
Background

There are three reciprocating compressors installed in the plant to cater the compressed air requirement and all the compressors are running to meet the compressed air demand during normal working hours. The design details of these compressors are as follows.

Compressor -1 = 22 cfm, 10 kg/cm² @ 3.7 kW
Compressor -2 = 28 cfm, 10 kg/cm² @ 5.5 kW
Compressor -3 = 32 cfm, 12 kg/cm² @ 9.7 kW

The Air compressor system diagram is as follows.

Figure 37: Present air-compressor system block diagram



Findings

The FAD test conducted on these compressors revealed that specific energy consumption of compressors are on higher side compared to new energy efficient screw compressors. Measured details and analysis done is as follows.

Table 14 : Air compressor specific energy calculation

Description	Units	comp-1	comp-2	comp-3
Rated parameters				
Type of compressor		Reciprocating		
Rated flow rate	cfm	22	28	32

Description	Units	comp-1	comp-2	comp-3
Rated pressure	kg/cm²	10	10	12
Power consumption	kW	3.7	5.5	9.7
Actual parameters				
Pressure measured	kg/cm²	7.5	7.5	7.5
Flow rate	cfm	12	18	28
Power consumption measured	kW	3.7	5.5	10
Specific energy consumption(SEC)	**kW/cfm**	**0.31**	**0.31**	**0.36**

Recommendation

Since compressor is of reciprocating type, actual specific energy consumption of these compressors is from 0.31 kW/cfm to 0.36 kW/cfm, which is very high compared to new energy efficient screw compressors available in market. New energy efficient screw compressors consumes about 0.15 kW/cfm. Hence, it is recommended to replace all small and old reciprocating air compressors with one centralized energy efficient screw compressor with VFD.

Energy & financial savings

Estimated energy and financial savings for the recommendations along with payback period is as follows.

Table 15 : Centralized air compressor system installation saving and investment estimation

Description	Units	Comp-1	Comp-2	Comp-3
Rated parameters				
Type of compressor		Reciprocating		
Rated flow rate	cfm	22	28	32
Rated pressure	kg/cm²	10	10	12
Power consumption	kW	3.7	5.5	9.7
Actual parameters				
Pressure measured	kg/cm²	7.5	7.5	7.5
Flow rate	cfm	12	18	28
Power consumption measured	kW	3.7	5.5	10
SEC	**kW/cfm**	**0.31**	**0.31**	**0.36**
Proposed parameters				
Proposed capacity of compressor	cfm	82		
Rated discharge pressure	kg/cm²	7.5		
Rated power consumption	kW	12.3		
Actual air flow required	cfm	58		
Actual power consumption with VFD @ 35 Hz.	kW	8.7		
Power consumption saved	kW	11		
Operating hours per day	Hours	24		
Annual operating hours	Hours	8,400		
Annual energy consumption saved @70% compressor loading	**kWh**	**64,680**		

Description	Units	Comp-1	Comp-2	Comp-3
Energy cost	Rs/kWh			4.55
Annual cost saved	**Rs. Lakhs**			**2.94**
Investment for compressor and VFD	**Rs. Lakhs**			**9**
Payback period	**Months**			**36**

4.3 Cold storage & packing section

4.3.1 Maintain correct temperature of 24 °C always in cold storage & packing section as per standard

Background

Two separate AHUs are operating at cold storage and packing section to maintain the required temperature. Parameters measured are as follows.

Packing section

Actual measured temperature at the AHU supply side = 17.5 °C/85 %RH

Actual measured temperature at the AHU return side = 21 °C/65 %RH

Temperature at the room display = 23 °C

Actual airflow rate delivered by AHU = 25,500 cfm

Cold storage

Actual measured temperature at the AHU supply side = 15 °C/90 %RH

Actual measured temperature at the AHU return side = 17.5 °C/75 %RH

Temperature at the room display = 19 °C

Actual airflow rate delivered by AHU = 22,750 cfm

Findings

The actual temperature measured in both section is below the standard, as per standard temperature need to maintain is as below.

For cold rooms = up to 21 °C

For packing section = up to 24 °C

Recommendation

Increase the set temperature to 24 °C as per standards.

Energy & financial savings

Estimated energy and financial savings for the recommendations along with payback period is as follows.

Table 16 : Set temperature increase in cold room saving and investment estimation

Description	Units	Parameters
Actual parameters		
Actual temperature in packing section	°C	21
Actual temperature in cold storage section	°C	17.5
Power consumption of packing section chiller	kW	12
Power consumption of cold room chiller	kW	15.4
Proposed parameters		
Expected temperature in cold storage	°C	21
Expected temperature in packing chiller	°C	24
Power consumption saved	kW	2.5
Operating hours per day	Hours	24
Operating days per year	Days	350
Annual energy saved	**kWh**	**21,000**
Energy cost	Rs/kWh	4.55
Annual cost saved	**Rs. Lakhs**	**0.95**
Investment for temperature control calibration	**Rs. Lakhs**	**Negligible**
Payback period	**Months**	**Immediate**

4.4 Lighting

4.4.1 Option -1: Install lighting energy saver to lighting feeder

Background

Lighting is the one of the major load in the plant and roughly consumes 6% of the total plant electricity consumption. There is a separate feeder installed for lighting through which power is supplied to all lighting distribution boards.

The power consumption measurement done on lighting feeder during the audit is as follows.

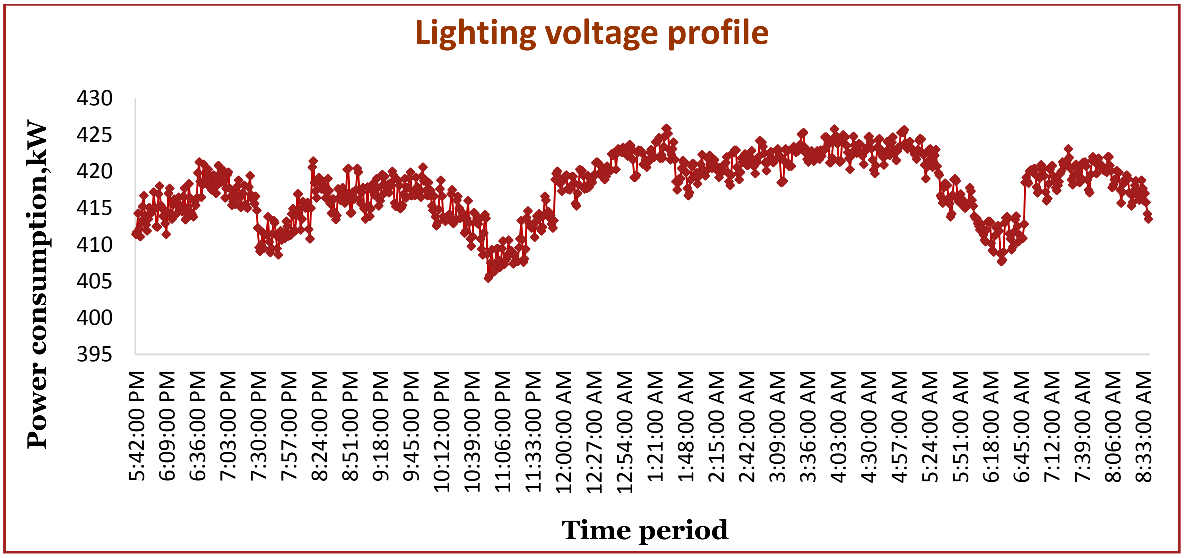
Maximum lighting consumption during the recording period	=	10 kW
Minimum lighting consumption during the recording period	=	3.8 kW
Average lighting consumption during the recording period	=	6.5 kW
Lighting energy consumption per day	=	200 kWh

Findings

The voltage profile recorded in the lighting feeder during the audit shows that lighting is operated with a voltage of 405 volts to 425 volts, which is very high.

The voltage measurement done on the lighting feeder during the audit is as follows.

Figure 38: Lighting voltage profile



The lighting can be efficiently operated at around 370- 380 volts and this reduction in lighting voltage at lighting feeder will have slight impact on the lux level.

Recommendation

Install lighting energy saver to lighting feeder and operate lighting at 370-380 volts instead of 405 – 425 volts.

Energy & financial savings

Estimated energy and financial savings for the recommendations along with payback period is as follows.

Table 17 : Lighting energy saver installation saving and investment estimation

Description	Units	Parameters
Actual parameters		
Actual voltage recorded in lighting feeder	Volts	405-425
Lighting energy consumption per day	kWh	200
Proposed parameters		
Proposed lighting voltage	Volts	370 - 380
Expected power saving by saver	%	20%
Actual energy consumption saving per day	kW	40
Operating days per year	Days	350
Annual energy consumption saved	**kWh**	**14,000**
Energy cost	Rs/kWh	4.55
Annual cost saved	**Rs. Lakhs**	**0.63**
Investment for 36 kVA LES	**Rs. Lakhs**	**1.8**
Payback period	**Months**	**34**

4.4.2 Option -2: Replace all the lighting fittings with appropriate new LED fitting

Background

The plant is fitted with following type of lamps in offices and shop floors to meet the lighting demand.

Table 18 : Lighting fitting details

Location	36W*2 FTL	36W*1 FTL	150W MV	250W MV
Chocolate plant	118	18	14	3

The average energy consumption of the lighting for a complete day is 200 kWh.

Findings

The power consumption of existing lamps can be reduced by replacing these lamps with appropriately sized LED fittings. This replacement of existing lamps with LED lamps will reduce power consumption and maintain same or better illumination levels with higher life and less maintenance.

Recommendation

Replace existing lamps with energy efficient LED lamps of following rating:

- 36 W FTL Replace with 16 W LED
- 150W MV Replace with 70 W LED
- 250W MV Replace with 120 W LED

Energy & financial savings

Estimated energy and financial savings for the recommendations along with payback period is as follows.

Table 19 : Replacement of all plant lamps with LED lamp saving and investment estimation

Description	Units	Parameters
Actual parameters		
Number of 36 W FTL's working in plant	Numbers	254
Number of 150 W MV lamps working in plant	Numbers	14
Number of 250 W MV lamps working in plant	Numbers	3
Total power consumption of these lamps	kW	15
Average number of lamps working	%	70
Actual lighting power consumption	kW	10.5
Proposed parameters		
Power consumption of respective LED lamps	kW	5.4
Actual power consumption with 70% utilization	kW	3.78
Power consumption saved	kW	6.72
Operating hours per day	Hours	12

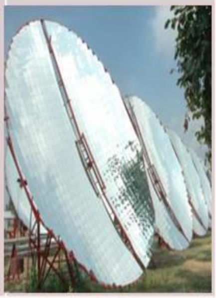
Description	Units	Parameters
Operating days per year	Days	350
Annual energy consumption saved	**kWh**	**28,224**
Energy cost	Rs/kWh	4.55
Annual cost saved	**Rs. Lakhs**	**1.28**
Investment for LED lamps	**Rs. Lakhs**	**4.8**
Payback period	**Months**	**36**

4.5 Renewable energy options – Concentrated solar thermal technology (CST)

Every dairy industry under GCMMF is depending on the electricity and natural gas for running the plant every day. The electrical energy and natural gas is need for the running all equipment and for heating/cooling requirements in the dairy. The same heating and cooling requirement in the plant can be met in an eco-friendly manner using heat from the sun while simultaneously avoiding the hassles related to transportation of fuel and its rising costs. CST technologies used for heating purposes are sometimes considered as boilers with 25 years fuel supply. CST's essentially comprise of reflectors/collectors for reflecting incoming solar radiation onto a receiver, thus concentrating a large area of sunlight onto a single receiver. This principle is similar to how a small lens generates enough heat to burn a piece of paper, except that here the small lens is much bigger to the tune of 100 square meters or more depending on the type of technology. This heat energy received is then used to heat a transmitting fluid depending on the end requirements of the process.

CSTs can produce a range of temperatures, between 50°C and up to over 400°C, which can be used in a variety of these heat applications. CSTs based on single axis tracking mechanism like Linear Fresnel and Parabolic trough can generate anywhere from 3000-3500 kCal/m^2 of solar concentrators area on a clear sunny day (In a region with good solar irradiation like Gujarat, Rajasthan, Tamil Nadu etc.). Technologies based on Dual axis tracking like Paraboloid dish and may have higher heat delivery by approximately 5% in comparison to single axis tracked dishes due to avoided errors in manual North-South adjustments.

Figure 39: Different CST available

	Parabolic Trough	Solar Dish	Linear Fresnel	Scheffler Dish	Non Imaging Concentrators
					
Working Temperature	150-400 °C	Upto 600 °C	Upto 400 °C	100-250 °C	Upto 150 °C
Conversion Efficiency	Around 20%	Around 30%	Around 15-20%	15-20%	Around 15-20%
Concentration Ratio	10-100 Suns	1000-4000 Suns	10-100 Suns	20-100 Suns	5-25 Suns
Commercial Status	Some pilots operational in the country	Commercial	Pre- Commercial	Commercial with many installations in India	Not commercial in India but many installations abroad
Tracking	Single axis	Double axis	Single axis	Single axis	No tracking

4.5.1 Solar assessment in Chocolate plant - Anand

For food complex plant in Anand area, the solar radiation details is as follows:

Table 20: Physical features of the chocolate plant

Parameters	Unit	Climate data location
Latitude	°N	22.556
Longitude	°E	72.951
Elevation	m	76
Heating design temperature	°C	17.13
Cooling design temperature	°C	37.52

The irradiation information will be of immense help for providing solar planners, designers, engineers and renewable energy analysts in providing an initial assessment of a site and estimated returns from a solar project. For plant area, the details of monthly daily solar radiation horizontal kWh/m²/d, air temperature, wind speed and relative humidity as provided by NASA are tabulated below.

Table 21: Average monthly insolation data

Month	Daily solar radiation horizontal (kWh/m²/d)	Air temperature, (°C)	Winds speed (m/s)	Relative humidity (%)
January	4.65	22.8	2.3	33.00%
February	5.28	24.7	2.3	29.00%
March	6.14	29.4	2.5	25.60%

Month	Daily solar radiation horizontal (kWh/m²/d)	Air temperature, (°C)	Winds speed (m/s)	Relative humidity (%)
April	6.61	32.1	2.8	29.30%
May	6.63	32.6	3.4	41.40%
June	5.7	30.2	3.5	63.90%
July	4.52	28	3.1	77.00%
Aug.	4.42	27.7	2.6	74.60%
September	5.11	28.8	2.3	62.00%
October	5.21	29.4	1.7	41.00%
November	4.68	27.1	1.8	30.10%
December	4.25	23.9	2	32.30%
Average	**5.27**	**28.0**	**2.5**	**44.90**

4.5.2 Energy and cost parameters for installation of CST modules

On the basis of availability of 4,500 m² roof top area in the Chocolate plant - Anand, a comparison of energy and cost parameters for CST water heaters that can be installed in the plant is provided below:

Table 22: Energy and cost parameters for solar CST modules

Description	Units	Parameters
Present operating parameters		
Estimated area available for CST installation	m²	4,500
Temperature of water considered in ambient condition	°C	30
Expected temperature of the hot water from CST unit	°C	70
Fuel used in the boiler		Natural Gas
Cost of natural gas per SCM	Rs/SCM	30
Calorific value of natural gas	kCal/kg	8,400
Current boiler efficiency	%	85
Proposed operating parameters		
Expected cost saved by the CST Installation	Rs./day	43,954
Annual operating days per year	Days	300
Annual cost saving by CST installation	**Rs. Lakhs**	**160.4**
Investment for complete CST installation	**Rs. Lakhs**	**810**
Possible subsides from government and other agencies	Rs. Lakhs	318
Net investment required for CST project	Rs. Lakhs	492
Payback period (Excluding subsidies)	**Months**	**60.5**

Note: Energy and cost estimation is merely indicative of the performance of CST but the actual heat generation will be different and will depend upon the technologies and the type of configuration selected by the project developer. The heat delivered by a CST source will depend on solar module rating and insolation level of the location and environmental factors like dust, wind, velocity and temperature of the location. Some of the features of solar technology & environmental factors which influence the performance of the power plant are irradiance or light intensity, temperature of the cells, response of the light spectrum, and orientation of the panel/array, sun hours per day etc.

5 Annexure

5.1 List of Energy Audit Instruments

PwC has multiple energy audit instruments kits. All the instruments are of have high quality, precision and are periodically calibrated. The instruments are capable to cover all electrical and thermal measurements required in the plants. A list of instruments used by PwC during the audit are shown below

Table 23: List of energy audit instruments

S. No.	Name of the Instrument	Make	Quantity
Thermal Instruments			
1	Flue Gas Analyzer (KANE 900+)	Kane (UK)	2
2	Non-contact Infrared Thermometer (Testo-845 and Extech)	Testo (USA),	3
3	Contact type Thermometer (Testo-845 and Extech)	Extech (USA)	3
4	Digital Manometer (Testo-510)	Testo (USA)	1
5	Vane Anemometer (Testo-416)	Testo (USA)	2
Electrical Instruments			
6	3-phase Power Analyzer	Krykard	3
7	1-phase Power Analyzer		3
8	Digital Tachometer (Extech-461995)	Extech (USA)	1
9	Lux Meter (Extech and Testo)	Extech and Text	5
10	Pressure Gauge	Comark (UK)	2
Others			
11	Precision Hygrometer (Testo-625)	Testo (USA)	2
12	Ultra Sonic Water Flow meter - Transit Time type	GE, Micronics	2
13	Ultra Sonic Water Flow meter - Doppler type	Micronics	1

5.2 List of Suppliers

The objective of the mapping of suppliers is to provide guidance to the factory management in understanding the supplier base for the recommended energy efficient technologies and equipment in the energy conservation measures in the report.

PwC team with their experience as well as during the fieldwork stage of the energy audits collected a very wide range of energy consumption related data and gained a thorough understanding of related technologies and practices adopted at dairy plants. These interactions enabled the PwC to understand the current level of awareness among factories about energy efficient equipment and the suppliers of such equipment.

By analyzing, the energy consumption related data collected at the fieldwork stage, the PwC team identified the appropriate energy efficient equipment for each of the audited dairy plants. Following the identification of the most appropriate energy efficient technologies and equipment, the energy audit team gathered information on the suppliers of such technologies and equipment mainly through following steps:

Names and addresses of the suppliers, who have supplied energy efficient equipment and technologies to the factories, which were visiting during field studies, were collected.

Desk Research (internet search etc.) was carried out to identify the established international and local suppliers of energy efficient equipment to dairy plants.

When additional technical and pricing information was required, the suppliers (or agents or representatives in India) were directly contacted by the PwC team, to obtain the required information.

Based on the above-mentioned approach, the following table provides insights into the composition of the current supplier base and identifies preferred suppliers of energy efficient technologies/ equipment to the Gujarat dairy sector

Table 24 : Vendor details for recommended saving solution

Equipment/ Technology	Product	Manufacture/ Brand	Location and address
Variable Frequency Drive (VFD)	VFD	Danfoss	**Danfos India Private Limited** No. 502, Abhijeet IV, Behind Pantaloon Showroom Near Law Garden Ahmedabad - 380009
	VFD	Schneider	**Schneider electric India Private Limited** No. 42A, 4th Floor, Space House, Mithakali Six Road, Opp. Sri Krishna Centre Ahmedabad - 380009
	VFD	Siemens	**Siemens Ltd** 3rd Floor, Prerna arbour, Opposite to Singapore Airlines, Near Girish Cold drinks cross roads, Off. C. G. Road, Ahmedabad - 380009 Tel.: +91 (079) 30927600/40207600
Scroll chiller	Chiller comp	Voltas	**Voltas Limited** 301, Shivalik Corporate Park, 132 Ft Ring Road, Behind IOC Petrol Pump, Satellite city Ahmedabad - 380015
Cooling tower	CT	Advanced CT Pvt. Ltd	**Advanced Cooling towers Private Limited** 405-406, South Avenue, Span Centre,, R. K. Mission Marg, Near Ramkrishna Temple, Santacruz West Mumbai - 400054
		Paharpur	**Paharpur Cooling Towers Limited** Plot No. 132 KV-I, Manjusar - Savli GIDC, Savli. Vadodara - 391775

Equipment/ Technology	Product	Manufacture/ Brand	Location and address
Cooling water pump	Pump	Kirloskar brothers	**Kirloskar Brothers Limited** Shop No. 107, 1st Floor, Swapneel - 5, Near Commerce Six Roads, Drive in Rd, Sarvottam Nagar Society Navrangpura , Ahmedabad - 380009
	Pump	Grundfos	**Grundfos India Private Limited** 11, Mill Officer Colony, Behind La Gajjar Chamber, Ashram Road, Ashram Road, Ahmedabad. Phone : 079 2657 4802
Air compressor	Air compressor	Atlas copco	**Atlas Copco India Limited** Mahatma Gandhi Memorial Building, Netaji Subhash Chandra Road, Netaji Subhash Chandra Road, Mumbai – 400002
Lighting	Lighting energy saver	Schneider	**Schneider electric India Private Limited** No. 42A, 4th Floor, Space House, Mithakali Six Roads, Opp. Sri Krishna Centre Ahmedabad – 380009
		Beblac	**Beblec Energy Systems Pvt Ltd** N3 Part, 1st Floor, 3rd Phase SIDCO Industrial estate, Hosur - 635 126 Phone: +91-4344-276358 / 278658 Mobile: +91-9443376558
	LED lamps	Philips	**Philips India Private Limited** Star House, Near Relief Cinema, Relief Rd, Bhadra, Ahmedabad - 380001 Phone:079 2535 4833
		Syska	**Syska Lighting** 6th floor, Shiromani complex Nehru Nagar, Opposite to ocean park satellite Ahmedabad

** Please note neither PwC nor UNIDO recommends any particular vendor/supplier. The list provided is not comprehensive and is only suggestive to facilitate the unit. If unit has its own vendor /supplier, those can also be contacted for the same.*

DISCLAIMER: