Energy Audit Report: Sumul Dairy-Surat

Conducting activities of energy audit & dissemination activities in Gujarat dairy cluster under GEF-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 CO_2
1 Liter (Diesel)	2.7 kg CO_2
1 Liter (Furnace Oil)	2.9 kg CO_2
1 Liter (Kerosene)	2.5 kg CO_2
1 kg (CNG)	2.8 kg CO_2

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:

- Mr. Milind Deore, Energy Economist, BEE
- Mr. Abhishek Nath, National Project Manager, Energy efficiency and renewable energy in MSMEs
- 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 to be executed include conducting detailed energy audit in 6 plants under GCMMF. Sumul dairy - Surat was one of the plant where in detailed energy audit was conducted.

1.2 Objective of the energy audit study

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

1.3 About Sumul dairy

Sumul dairy is located in Surat city and caters to milk and milk product requirement of entire city and district. The plant has milk handling capacity of 15 lakhs litres per day. Along with milk processing and packing, plant also produces Ghee, Curd, Butter milk and Paneer. Plant is about 50 years old and plant has undergone lot of technologies update to revamp milk quality and reduce energy consumption.

Process flow:

Plant is designed to handle around 15 lakhs litre milk. During winter and rainy season, dairy receives higher quantity of milk and during summer season milk received is less.

In milk processing plant, four milk pasteuriser are installed and these runs daily to meet day to day requirement. Milk plant process starts with receiving of milk from tankers, received milk from tankers will be at 4 ^{o}C. Received milk will be first stored in the raw milk silos and then pumped to pasteurization PHEs, where actual pasteurization process takes place (milk is heated up to 73 ^{o}C – 75 ^{o}C and at same time it is cooled to 6 ^{o}C). After pasteurization process, milk is again stored to PMS tanks and then sent to packing section for packing in pouches of 0.5 liter, 1 liter and 5 liter.

Depending on quantity of milk received at dairy and market demand on same day; surplus milk is sent to other sections to produce milk products like curd, butter milk, paneer, ghee and milk powder.

1.4 Present energy consumption scenario:

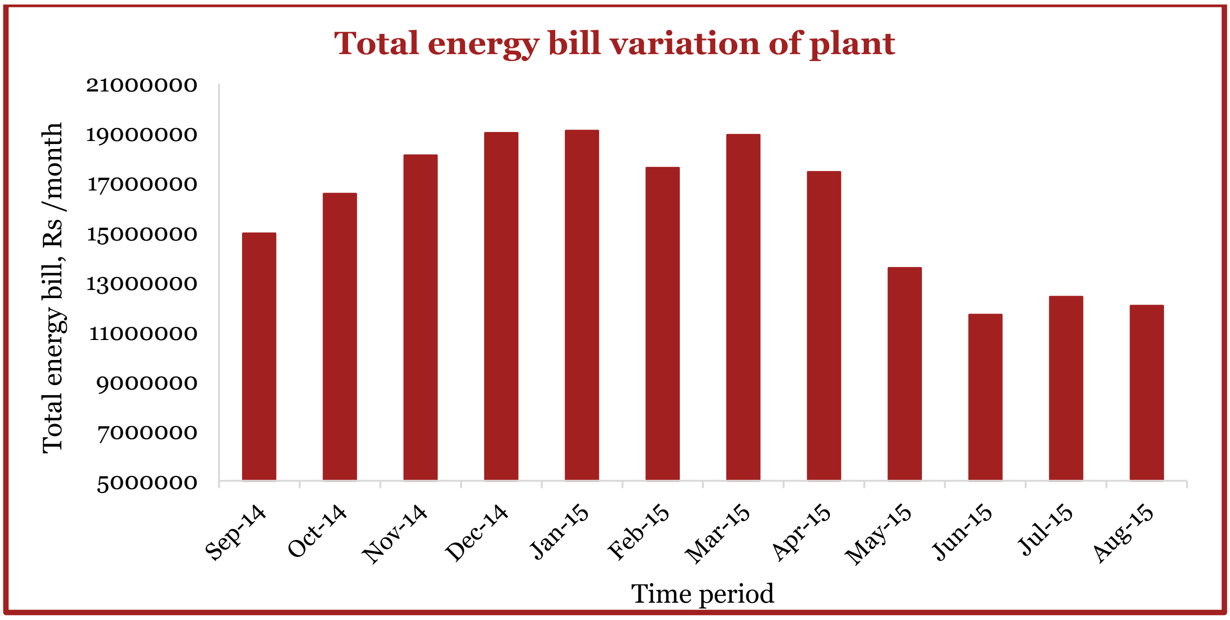
Plant uses electricity and natural gas as main energy inputs to operate. The electrical energy consumption of entire plant along with natural gas consumption is tabulated and presented below.

Table 1: Present energy scenario and plant specific energy consumption

Months	Energy consumption (kWh/month)	Total electricity bill (Rs/month)	Natural gas consumption (SCM/month)	Total Gas bill (Rs/month)	Total energy bill (Rs/month)
Sep-14	1,357,035	8,090,058	162,214	6,879,496	14,969,554
Oct-14	1,410,435	8,468,518	189,297	8,088661	16,557,179
Nov-14	1,389,630	8,306,223	235,640	9,804980	18,111,203
Dec-14	1,351,890	8,102,675	270,630	10,903,683	19,006,358
Jan-15	1,337,940	8,135,416	275,304	10,968,111	19,103,527
Feb-15	1,256,010	7,684,201	246,847	9,925,718	17,609,919
Mar-15	1,455,060	8,886,752	258,928	10,043,817	18,930,569
Apr-15	1,542,330	9,648,543	268,537	7,787,573	17,436,116
May-15	1,594,035	9,230,664	238,753	4,345,197	13,575,861
Jun-15	1,429,425	8,967,620	174,028	2,727,901	11,695,521
Jul-15	1,450,875	9,025,350	184,186	3,389,325	12,414,675
Aug-15	1,430,745	8,874,940	181,174	3,176,922	12,051,862
Average	**1,417,118**	**8,618,413**	**223,795**	**7,336,782**	**15,955,195**
Total	**17,005,410**	**103,420,960**	**2,685,538**	**88,041,384**	**191,462,344**

The following figure captures variation of energy bill in the plant.

Figure 1: Plant energy bill variation



- Average electricity energy consumption dairy per month is 1,417,118 kWh/month with an average electricity bill of Rs. 8,618,413 per month.
- Average natural gas consumption of the dairy per month is 2,223,795 SCM/month with an average gas bill of Rs. 7,336,782 per month.
- Plant energy cost is decreased from April – 15 to Aug – 15 due to reduction in milk receipt because of seasonal variation.

1.5 Plant energy consumption and energy savings

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 plant electricity consumption	kWh/annum	**17,005,410**
Annual plant natural gas consumption	SCM/annum	**2,685,538**
Annual plant energy cost	Rs. Lakhs	**1,914.6**
Proposed annual cost saved	Rs. Lakhs	**70.70**
Proposed investment	Rs. Lakhs	**75.40**
Payback period	Months	**13**
Proposed electricity consumption saved annually	kWh	**542,388**
Proposed plant gas consumption saved annually	SCM	**152,857**
Proposed percentage of plant electrical energy saved	%	**3.18**
Proposed percentage of plant gas consumption saved	%	**5.69**
Proposed percentage of cost saved	%	**3.7**

1.6 Summary of proposed energy conservation measures

Table 3: Summary of proposed energy conservation measures

S. No.	Suggested measure	Annual energy savings	Annual cost saving	Investment	Payback period
		kWh/annum kg/annum	Rs. Lakhs	Rs. Lakhs	Months
1	Maintain proper water flow and temperature at condenser PHE	240,883	11.0	NIL	Immediate
2	Maintain required air flow rate and temperature of 24 °C in yogurt and elaster packing section	36,720	1.68	NIL	Immediate
3	Install VFD in boiler feed water pump	47,520	2.18	2.00	11.0
4	Install milk pre heating PHE to pre heat milk before heating coil in yogurt section	14,000	4.2	4.0	11.4
5	Increase condensate recovery percentage from 60% to 90%	138,857	41.65	40.00	11.5
6	Install VFD on powder plant drier delivery and exhaust fans with header pressure feedback control to vary frequency as per requirement	93,312	4.29	8.10	22.2
7	Install VFD on powder plant drier IFBD and EFBD fans with header pressure feedback control feedback to vary frequency as per requirement	9,560	0.43	1.30	35.2
8	Replace reciprocating buttermilk compressor with new energy efficient screw compressor	114,393	5.26	20.00	45.5
Total		542,388 / 152,857	70.70	75.40	13

2 Introduction

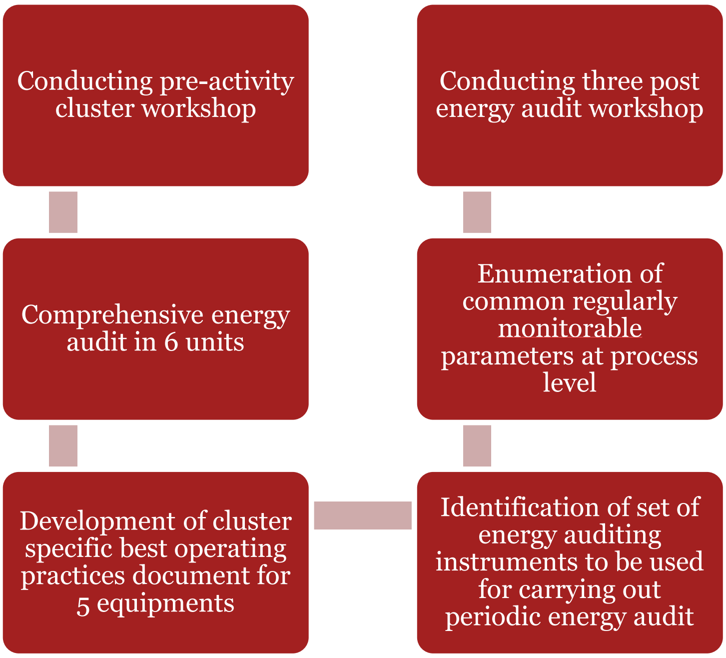
2.1 Introduction

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. Carrying out energy audit in 6 dairy plants is one of the activities of the assignment. Energy audit of Sumul dairy plant - Surat was one of these 6 audits.

2.2 Scope of services

The scope of this assignment is shown at following figure.

Figure 2: 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 Sumul dairy plant has been selected one of these six.

2.3 Energy audit scope and approach

A detailed energy audit was undertaken at Sumul dairy plant – Surat from 01 to 10 October 2015. The energy audit team from PwC comprised of thermal and electrical energy experts. During energy audit, a range of portable energy audit instruments were used to take various measurements of all energy consuming equipments/systems of the plant. In addition, design and operational data was collected from logbooks and equipment manuals. Also, 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 Sumul dairy and evaluation of operational efficiency/performance of each equipment from energy conservation point of view.

The following areas were covered during the study:

- ***Sumul Dairy Plant***
    - Production
        - Dairy plant (Pasteurization)
        - Butter milk plant
        - Curd plant
        - Butter plant
        - Sweets
        - Milk powder plant
    - Refrigeration
        - Compressors
        - Condenser PHE
        - Chiller PHE
        - CW and CHW pumps
        - Cooling towers
    - Other utilities
        - Air compressors
        - Boiler and steam distribution
        - Water pumping system
- ***Renewable Energy***
    - ✓ Opportunities were identified for use of renewable energy

The study focused on identifying opportunities to save energy in Sumul dairy plant. 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 the audit team and plant personnel to ensure that the 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.

3 Observation and Analysis

Sumul dairy is located in Surat city and caters to milk and milk product requirement of entire city and district. The plant has milk handling capacity of 15 lakhs litres per day. Along with milk processing and packing, plant also produces Ghee, Curd, Butter milk and Paneer. In order to operate all its process equipment and utilities, plant uses electricity and natural gas as energy inputs. Major energy consumer in the plant is the refrigeration plant followed by the other utilities. Detailed energy audit was conducted in Sumul dairy plant to identify energy conservation measures.

3.1 Electricity bill analysis

Plant receives electricity from Torrent power through 11 kV supply line and there are three transformers operating in plant out of which two are having capacity of 1,000 kVA each and one is having capacity of 2,000 kVA to step down the voltage from 11 kV to 440 volts. Along with Torrent power supply, plant has a DG set of 500 kVA capacity to supply power when Torrent power fails.

Tariff details:

Supplier = Torrent

Tariff code = HTMD - I

Contract demand = 2,200 kVA

Billing demand = 85 % of CD

Demand charges

First 500 kVA of billing demand = Rs.155 per kVA

Above 500 kVA billing demand = Rs.250 per kVA

IF recorded demand in more than contract demand = Rs. 360 per kVA

Energy charges

First 400 kWh = Rs. 4.70 per kWh

Remaining units = Rs. 4.60 per kWh

TOD charges (Timing: 07:00 hrs. to 11:00 hrs. and 18:00 to 22:00)

For billing demand up to 500 kVA = 55 paisa/unit

For billing demand above 500 kVA = 90 paisa/unit

Nighttime consumption (Timing: 22:00 hrs. to 06:00 hrs.)

Units charges concession of = RS. 50 paisa per units

Electricity bill analyzed for the last one year is as follows

Table 4 : Annual electricity bill analysis

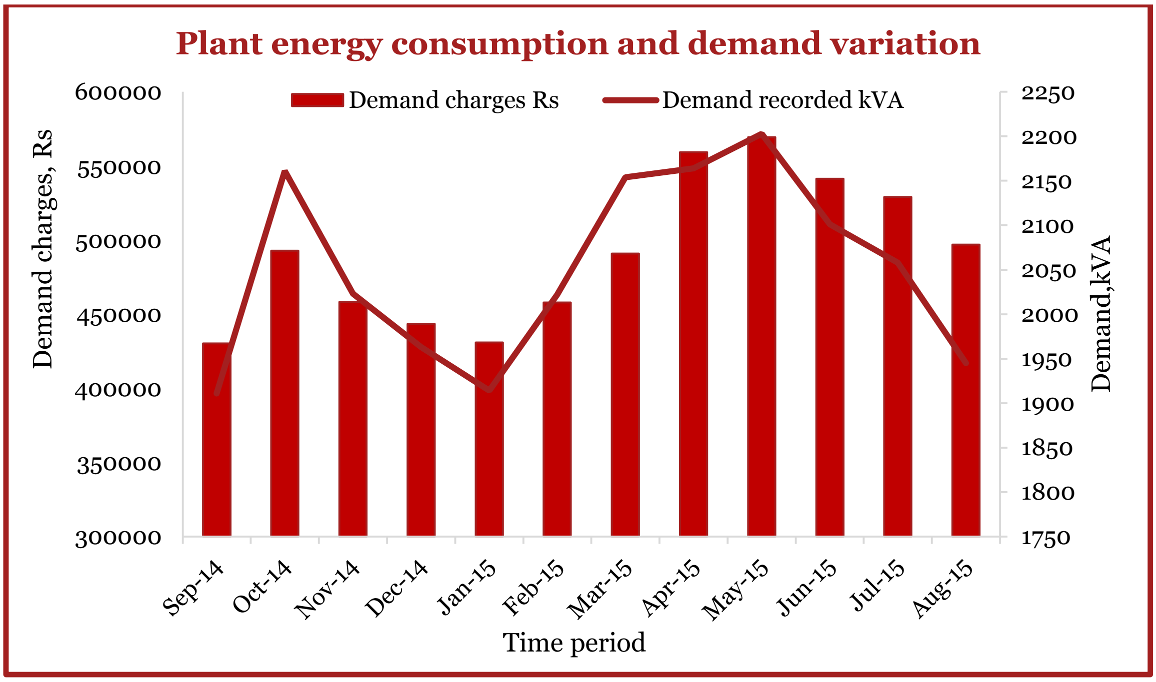
Months	Demand recorded (kVA/month)	Demand charges (Rs/month)	Energy consumption (kWh/month)	TOU energy consumption (kWh/month)	Energy charges (Rs/month)	FPPPA charges (Rs/month)	TOU energy charges (Rs/month)	PF Incentive, (Rs/month)	Total electricity bill (Rs/month) *
Sep-14	1,911	430,250	992,520	364,515	4,642,032	1,865,937	328,063	232,101	8,090,058
Oct-14	2,161	492,875	1,031,565	378,870	4,831,659	1,939,342	340,983	241,582	8,468,518
Nov-14	2,023	458,375	1,016,115	373,515	4,755,069	1,910,296	336,163	237,735	8,306,223
Dec-14	1,963	443,375	992,610	359,280	4,644,546	1,866,106	323,352	232,227	8,102,675
Jan-15	1,914	431,000	984,750	353,190	4,605,582	1,949,448	317,871	230,279	8,135,416
Feb-15	2,022	458,000	920,370	335,640	4,314,582	1,822,332	302,076	215,729	7,684,201
Mar-15	2,154	491,000	1,072,395	382,665	5,019,177	2,123,342	344,398	250,958	8,886,752
Apr-15	2,164	559,382	1139,655	402,675	5,442,958	2,256,516	402,675	272,147	9,648,543
May-15	2,203	569,500	1,177,830	416,205	5,623,941	2,332,103	416,205	281,197	9,230,664
Jun-15	2,101	541,427	1,055,385	374,040	5,044,369	2,089,662	374,040	252,218	8,967,620
Jul-15	2,058	529,030	1,063,245	387,630	5,079,571	2,105,225	387,630	253,978	9,025,350
Aug-15	1,945	496,967	1,049,595	381,150	5,010,916	2,078,198	381,150	250,545	8,874,940
Average	**2,052**	**491,765**	**1,041,336**	**375,781**	**4,917,867**	**2,028,209**	**354,551**	**245,891**	**8,618,413**
Total		**4,076,306**	**12,496,035**	**4,509,375**	**59,014,402**	**24,338,507**	**4,254,606**	**2,950,696**	**103,420,960**

*Total electricity bill also includes electricity duty and meter rent.

- Annual energy consumption of the plant is 12,496,035 kWh and annual electricity bill is about Rs 103,420,960 /-

Demnad recorded in the every month electricity bill is also an major cost component in electricity bill. The demand recorded and money paid towards the recorded demand in the electricity bill is analysed and represented in the graphical form same is as follows.

Figure 3: Energy consumption and demand variation analysis



- Average demand recorded for the last one year is 2,052 kVA and average charges paid as demand cost is about Rs. 491,765 per month.
- Annual cost paid for the demand is Rs. 4,076,306 per annum

3.2 *Gas bill analysis*

Plant is having the gas connection from Gujarat Gas Company. Natural gas is used in the boiler and powder plant as a fuel. The gas bill for the last one month is analysed details are as follows.

Gas contract details:

Supplier = Gujarat gas company

Monthly contracted quantity = 279,000 SCM

Daily contract quantity = 9,000 SCM

Gas bill for the last one year is analysed and tabulated as below.

Table 5 : Annual gas bill analysis

Month	Gas consumption (SCM/month)	Average net Calorific value(NCM)	Average gas cost (Rs/SCM)	Total natural gas bill (Rs/month)
Sep-14	1,62,214	8,380.61	42.41	6,879,496
Oct-14	1,89,297	8,443.14	42.73	8,088,661

Month	Gas consumption (SCM/month)	Average net Calorific value(NCM)	Average gas cost (Rs/SCM)	Total natural gas bill (Rs/month)
Nov-14	2,35,640	8,434.45	41.61	9,804,980
Dec-14	2,70,630	8,487.07	40.29	10,903,683
Jan-15	2,75,304	8,508.76	39.84	10,968,111
Feb-15	2,46,847	8,588.37	40.21	9,925,718
Mar-15	2,58,928	8,537.02	38.79	10,043,817
Apr-15	2,68,537	NA	29.00	7,787,573
May-15	2,38,753	NA	18.20	4,345,197
Jun-15	1,74,028	NA	15.68	2,727,901
Jul-15	1,84,186	NA	18.40	3,389,325
Aug-15	1,81,174	NA	17.54	3,176,922
Average	**223,795**		**32**	**7,336,782**
Total	**26,85,538**			**88,041,384**

- The average gas consumption of the plant per month is 223,795 SCM/month with average bill of about Rs. 7,336,782/month.
- Annual gas consumption of the plant is 26,85,538 SCM/annum per year with annual gas bill of about Rs. 88,041,384 /annum.

3.3 *Energy Consumption breakup*

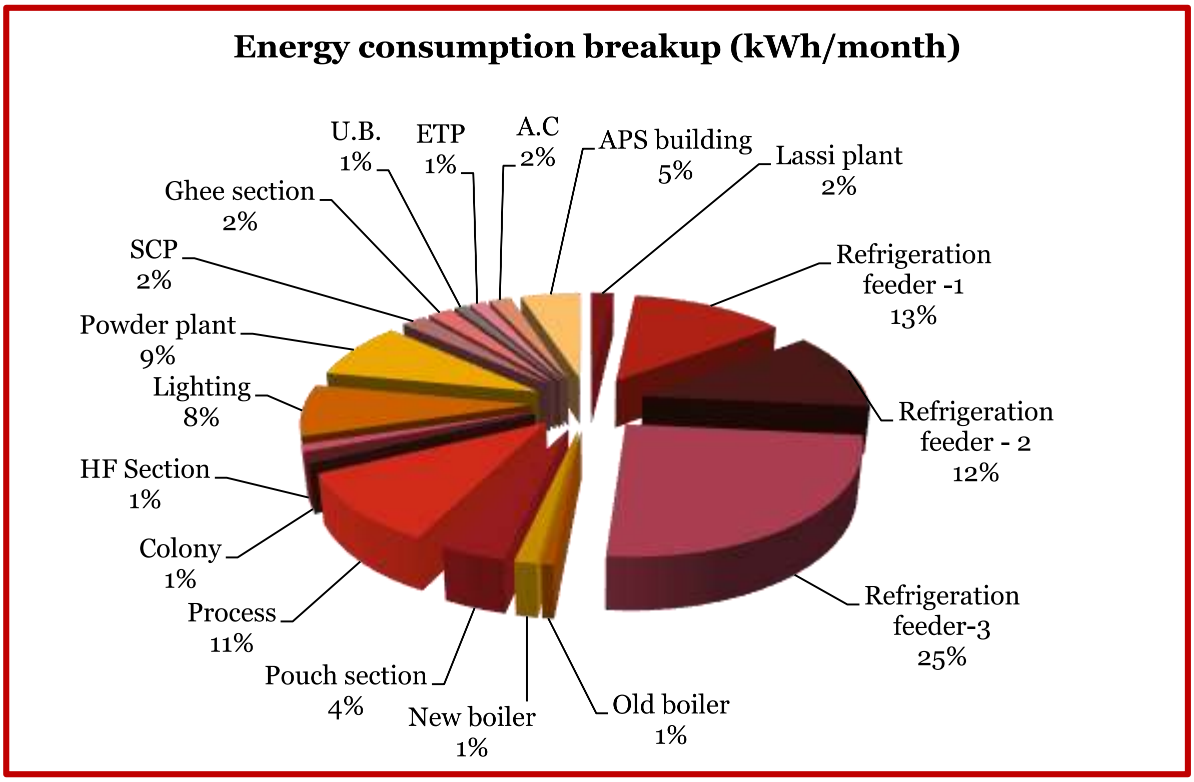
Detailed electrical measurement was done on all energy consuming equipment in entire plant during audit and energy consuming breakup is derived and it is tabulated below.

Table 6: Plant energy consumption breakup

Description	Energy consumption (kWh/month)	Percentage of consumption (%)
Lassi plant	20,077	2%
Refrigeration feeder -1	137,926	13%
Refrigeration feeder - 2	124,379	12%
Refrigeration feeder-3	266,340	25%
Old boiler	7,487	1%
New boiler	14,100	1%
Pouch section	41,026	4%
Process	111,865	11%
Colony	14,725	1%
HF Section	11,236	1%
Lighting	81,780	8%
Powder plant	91,564	9%
SCP	21,883	2%
Ghee section	21,437	2%
U.B.	11,280	1%
ETP	14,370	1%
A.C	19,754	2%
APS building	53,772	5%

Description	Energy consumption (kWh/month)	Percentage of consumption (%)
Total	**1,065,001**	**100%**

Figure 4: Energy consumption breakup



- The major energy consumer in the plant is refrigeration, which consumes about 50 % of the total load
- Average energy consumption of the plant is about 1,065,001 kWh/month

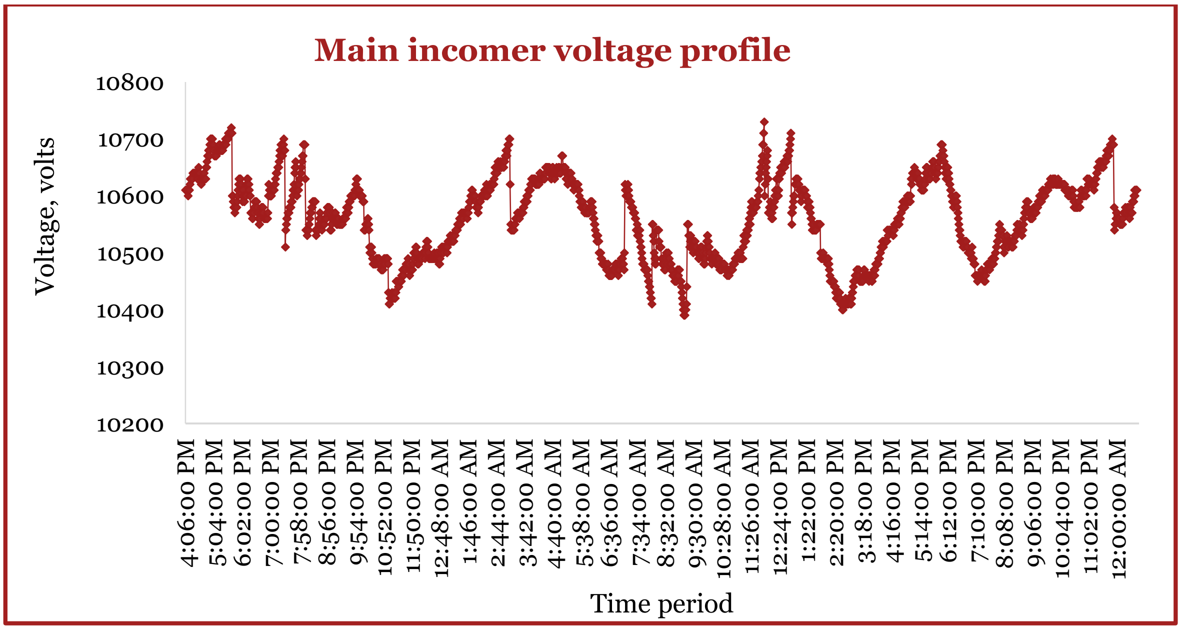
3.4 Load profile

Plant receives electricity from Torrent power through 11kV HT line. Plant is installed with the three transformers, out of three two transformers are 1000 kVA capacity each and one transformer is 2000 kVA capacity. Power profile is recorded at the HT side of the main incomer to assess the total power consumption of the plant and variation in the power parameters, it is discussed below.

Voltage profile:

Voltage profile was recorded at main incomer from 03-10-2015 @ 04:06 PM to 04-10-2015 @ 12:00 AM. The average of three-phase voltage is given below.

Figure 5: Main incomer voltage profile

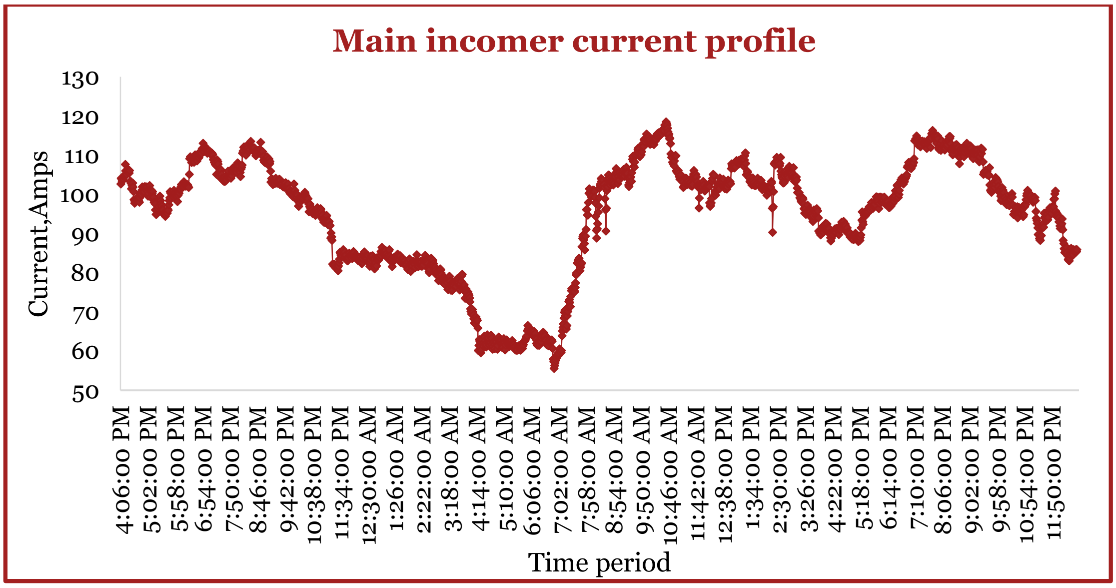


The minimum voltage recorded during the measurement period	=	10,400 volts
The maximum voltage recorded during the measurement period	=	10,750 volts

Current profile:

Current profile was recorded at main incomer from 03-10-2015 @ 04:06 PM to 04-10-2015 @ 12:00 AM. The average of three-phase current is given below.

Figure 6: Main incomer current profile

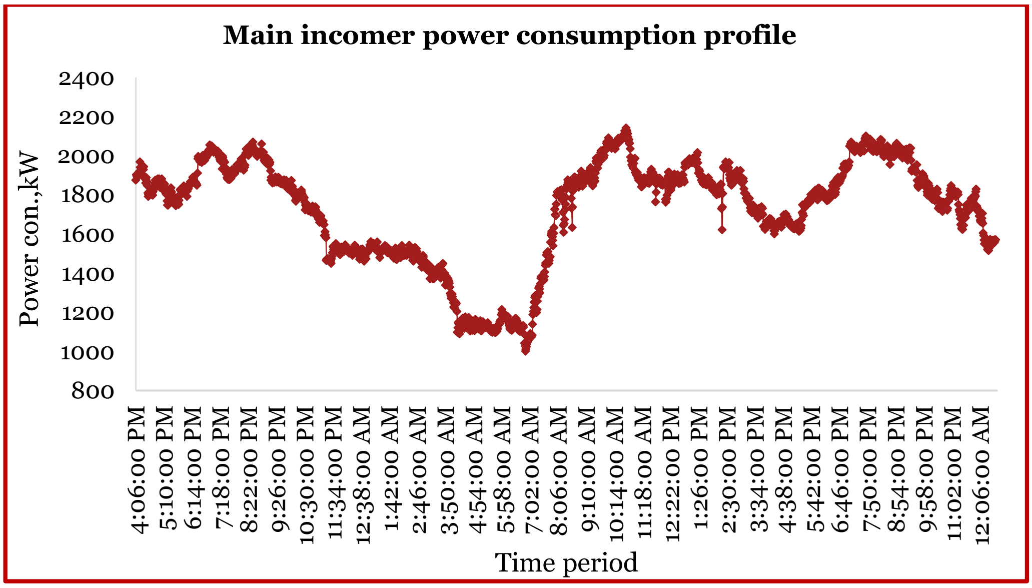


The minimum current recorded during the measurement period	=	55 Amps
The maximum current recorded during the measurement period	=	120 Amps

Power consumption profile:

Power consumption profile was recorded at main incomer from 03-10-2015 @ 04:06 PM to 04-10-2015 @ 12:00 AM. The average of three-phase power consumption is given below.

Figure 7: Main incomer power consumption profile



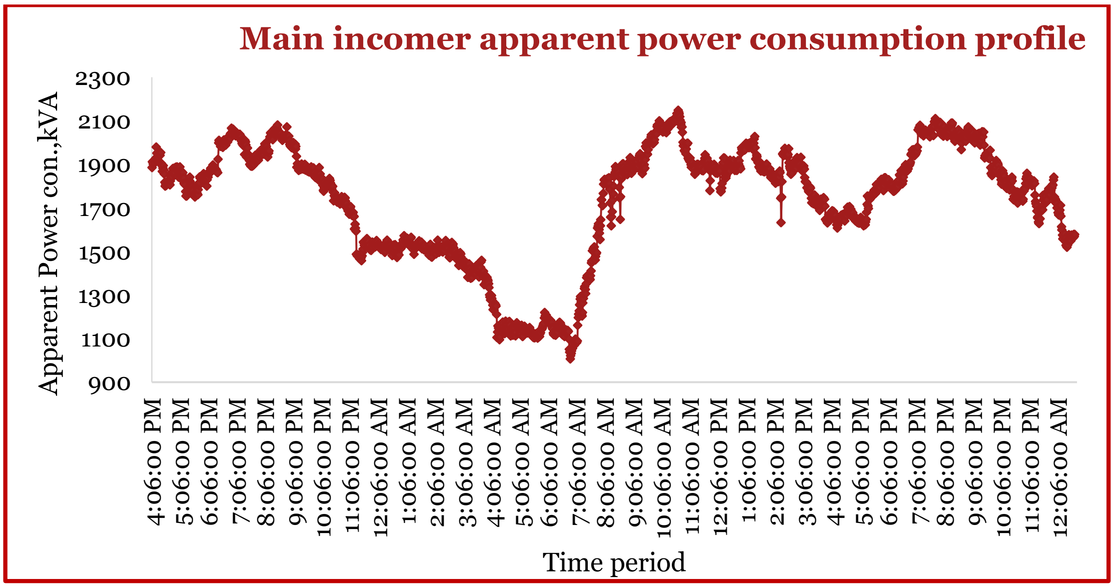
The minimum power consumption recorded during the measurement period = 1,000 kW

The maximum power consumption recorded during the measurement period = 2,100 kW

Apparent power profile:

Apparent power profile was recorded at main incomer from 03-10-2015 @ 04:06 PM to 04-10-2015 @ 12:00 AM. The average of three-phase apparent power is given below.

Figure 8: Main incomer apparent power profile



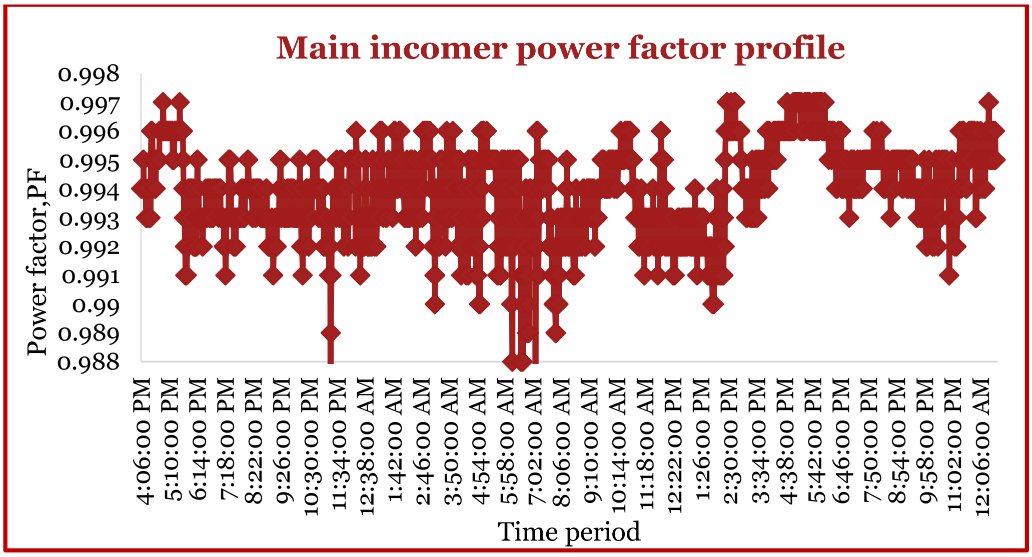
The minimum apparent power recorded during the measurement period = 1,000 kVA

The maximum apparent power recorded during the measurement period = 2,200 kVA

Power factor profile:

Power factor profile was recorded at main incomer from 03-10-2015 @ 04:06 PM to 04-10-2015 @ 12:00 AM. The average of three-phase power factor is given below.

Figure 9: Main incomer power factor profile



The minimum power factor recorded during the measurement period	=	0.988 lagging
The maximum power factor recorded during the measurement period	=	0.997 lagging

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.

3.5 Refrigeration system

Refrigeration is one of the major load in plant, which consumes about 50% of total load. Refrigeration system is a centralized system and serves refrigeration requirement of all sections of the plant. Some of the major users of refrigeration system are listed below.

- Milk pasteurizer
- Buttermilk plant
- Cream pasteurizers
- APS plant
- Cold storages

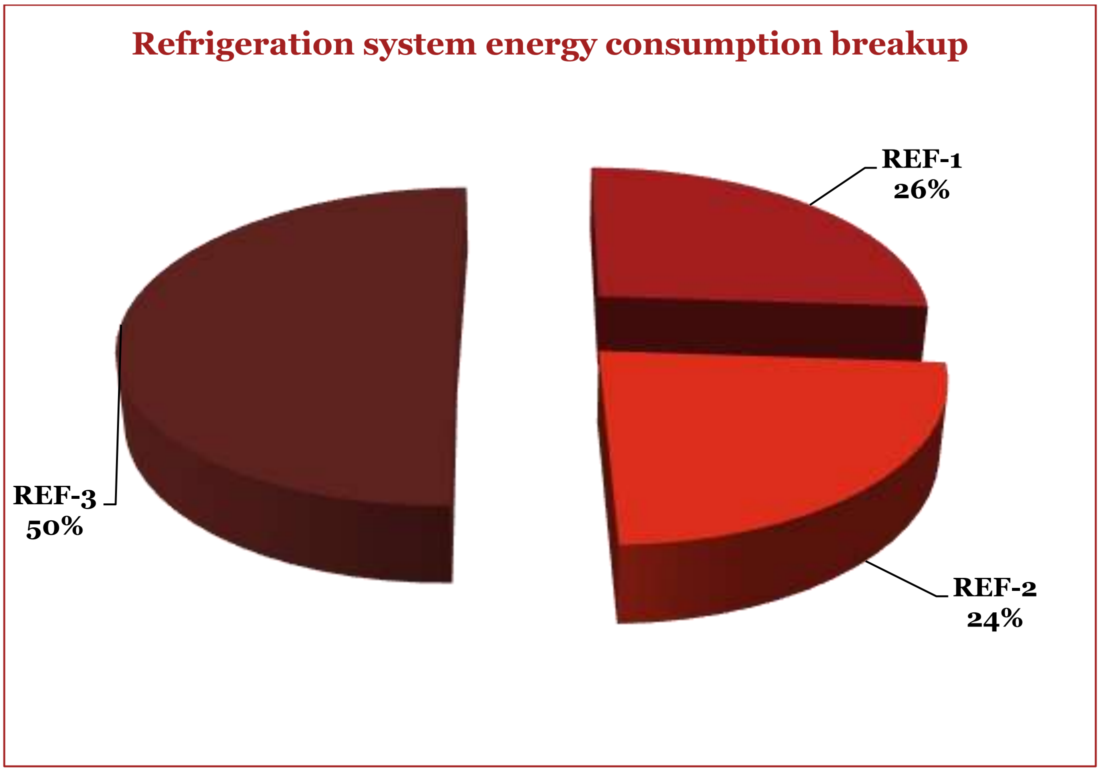
In order to cater the cooling requirement of above sections, refrigeration plant runs 24 hours a day. The energy consumption measurement for all equipments of refrigeration system was measured during audit to derive breakup and the same is discussed below.

Table 7 : Plant refrigeration system energy consumption breakup

Description	Energy consumption kWh/month	Percentage of consumption %
Refrigeration system – 1	137,926	26%
Refrigeration system- 2	124,379	24%
Refrigeration system – 3	266,340	50%

Description	Energy consumption kWh/month	Percentage of consumption %
Total	**528,645**	**100%**

Figure 10: Refrigeration energy consumption breakup



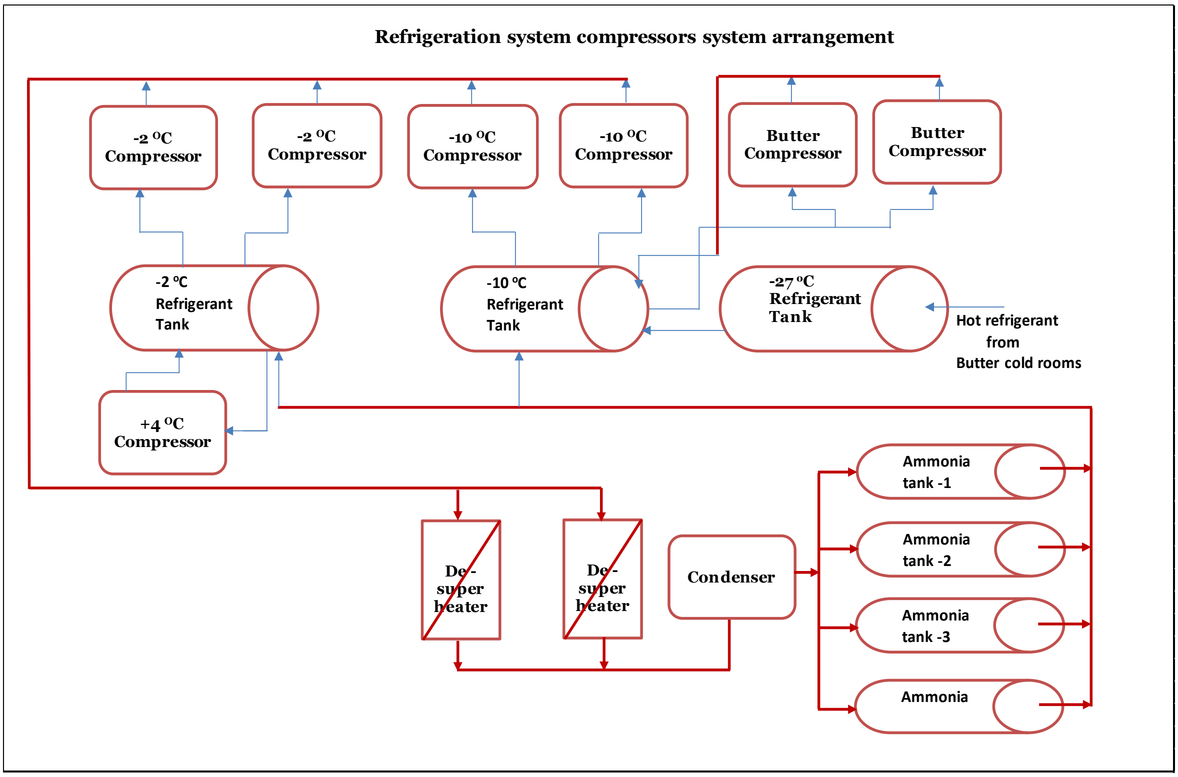
- Refrigeration system consumes about 528,645 kWh/month, which constitutes about 50 % of total plant energy consumption.

3.5.1 Refrigeration system- compressors

There are two stages of compression in the refrigeration system. The first stage of refrigeration system is called as -2 °C stage and other stage is called as -10 °C stage. Along with this system, there are also butter compressors, which operate only during nighttime. Two -2°C and -10 °C compressors are installed in each plant, out of which one compressors in each system will be running to meet load requirement. Whenever there is an increase in the refrigeration load, plant operates second reciprocating compressors as back support to handle higher load. During nighttime, butter compressor operates for average of eight hours to supply cooling requirement of butter cold store room.

The refrigeration system compressors and refrigerant flow diagram is as follows.

Figure 11: Refrigeration system – Compressor system arrangement layout



The design and operating details of these compressors are as follows.

-2 °C compressors:

There are two compressor installed in this system; out of two, one will be working to meet heat load. This compressor compresses refrigerant in first stage, after first stage of compression refrigerant is sent to second stage of compression to – 10°C compressors. The rated parameters and operating parameter collected during the audit is as follows.

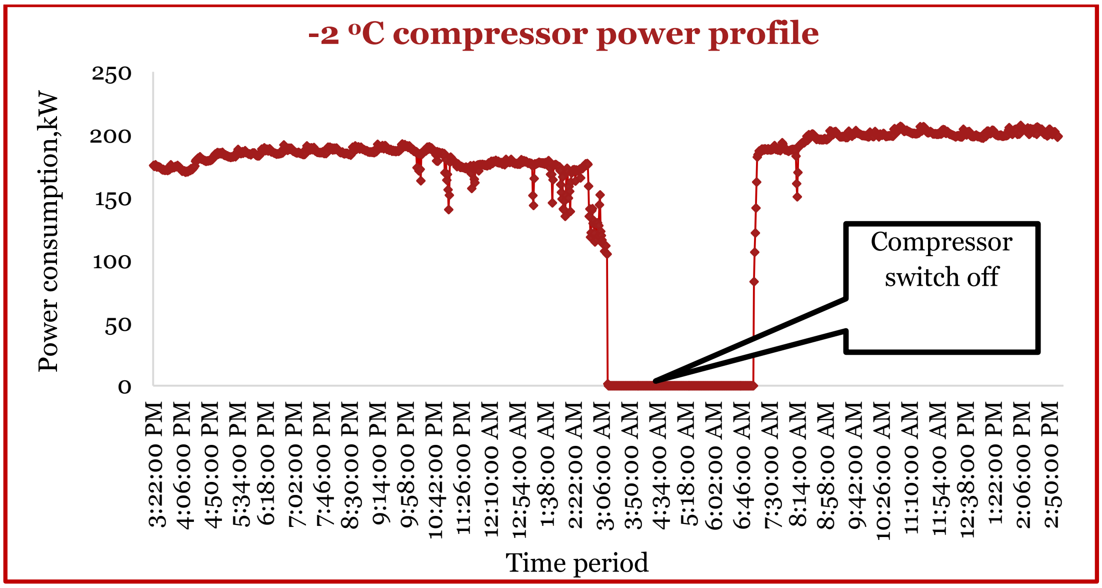
Table 8 : -2 °C compressor design and operating parameters

Description	Units	Parameters
Rated parameters - Compressor		
Make		Mycom
Type		Screw
Model		N200MUD – V
Capacity with economizer	TR	198 @ -10 oC
Capacity with economizer	TR	266 @ -2 °C
Power consumption with economizer	kW	194.4 @ -10 °C
Power consumption without economizer	kW	198.7 @ -2 °C
Condensing temperature	°C	40
Accumulator		
Process fluid		Ammonia
Working pressure	kg/cm²	3
Design pressure	kg/cm²	14
Design temperature	°C	50
Radiography	%	100
Design code		IS 2825

Description	Units	Parameters
Hydraulic pressure	kg/cm²	21
Operating parameters		
Suction pressure	kg/cm²	2.92
Discharge pressure	kg/cm²	12.8
Suction temperature	°C	-7.5
Discharge temperature	°C	75.5
Power consumption	kW	200
Oil pressure	kg/cm²	15.2
Oil temperature	°C	36.8
SV position	%	100

Power consumption measurement done on the operating compressor during the audit is as follows.

Figure 12: -2°C compressor power consumption profile



The average power consumption of the compressor	=	190 – 200 kW
Energy consumption of the compressor per day	=	3,701 kWh/day

-10 °C compressors:

There are two compressor installed in this system; out of two compressors one will be working to meet the heat load requirement. This compressor compresses the refrigerant in the second stage. The rated parameters and operating parameter collected during the audit is as follows.

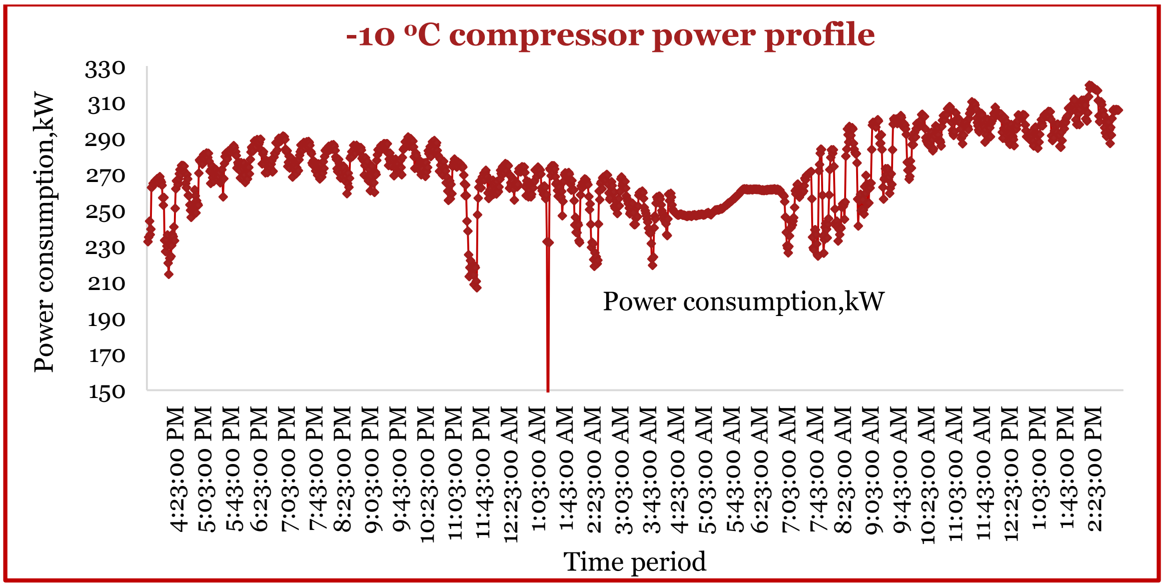
Table 9 : -10 °C compressor design and operating parameters

Description	Units	Parameters
Rated parameters – Compressor		
Make		Grasso Screw compressor
Model		TR – T365-28
Refrigerant		Ammonia
Sweat volume	m³/h	1,465
TR Capacity	TR	257.9 @ -10 °C without economizer

Description	Units	Parameters
	TR	299.71 @ -10 ^{o}C with economizer
	TR	351.4 @ -2 ^{o}C without economizer
	TR	396.3 @ -2 ^{o}C with economizer
Absorbed kW	kW	307.9 @ -10 ^{o}C without economizer
	kW	307.9 @ -10 ^{o}C with economizer
	kW	297.9 @ -2 ^{o}C without economizer
	kW	316.9 @ -2 ^{o}C with economizer
Speed	rpm	2950
Evaporation temperature		-10 ^{o}C and -2 ^{o}C
Condensing temperature	^{o}C	40
Specific energy consumption (SEC)	kW/TR	0.799 @ -2 ^{o}C
Super heat	^{o}C	5
Oil input temperature	^{o}C	50
Oil cooler capacity	kW	162.7
Economizer rating	kW	166.7
Discharge temperature	^{o}C	80
Condenser load	TR	487 @ -2 ^{o}C with economizer
Accumulator		
Process fluid		Ammonia
Working pressure	kg/cm^2	2
Design pressure	kg/cm^2	14
Design temperature	^{o}C	50
Radiography	%	100
Design code		IS 2825
Hydraulic pressure	kg/cm^2	21
Operating parameters		
Suction pressure	kg/cm^2	3.1
Discharge pressure	kg/cm^2	13.8
Suction temperature	^{o}C	-2.9
Discharge temperature	^{o}C	163
Average power consumption	kW	240

The power consumption measurement done on the -10 ^{o}C compressors is as follows.

Figure 13: -10°C Compressor power consumption profile



The average power consumption of the compressor	=	210 – 310 kW
Energy consumption of the compressor per day	=	6,339 kWh/day

-27 °C compressors:

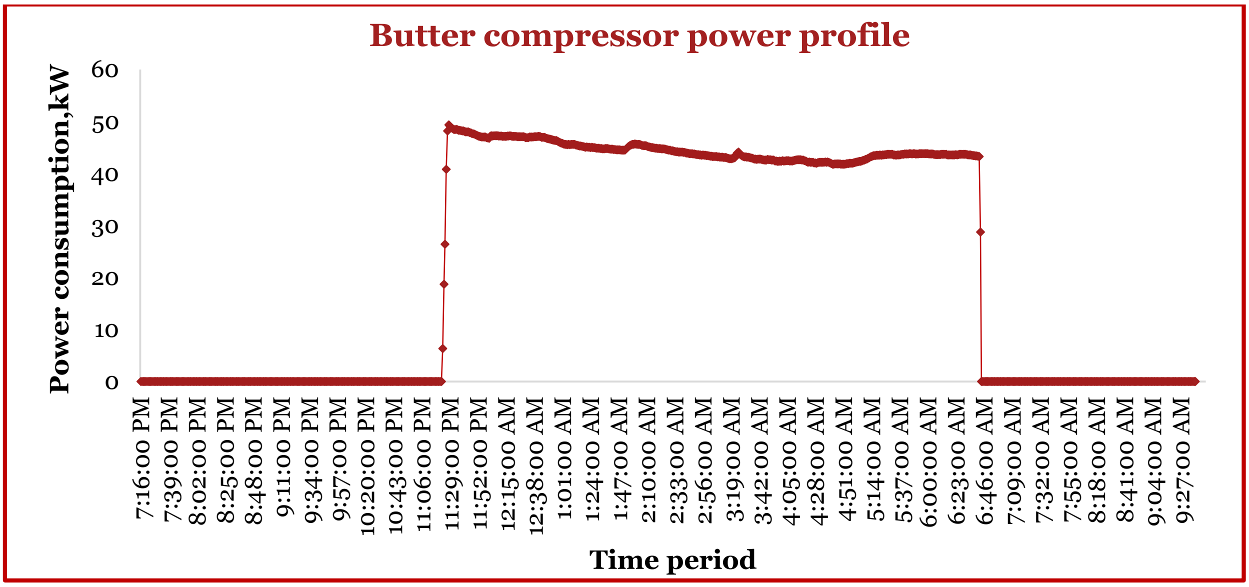
These compressors are running to feed cooling to the butter cold storages. Temperature required to maintain at these cold rooms is -27 °C and these compressors are running only during nighttime for 8 hours. There are two compressors installed, out of which one will be working to meet the cooling requirement.

Table 10 : -27 °C compressor design and operating parameters

Description	Units	Parameters
Rated parameters – Compressor		
Make		GRASSO
Type		Screw
Refrigerant		Ammonia
Sweat volume	m³/h	863
TR capacity	TR	89.2 @ - 27 oC with economizer
		53.3 @ - 27 oC without economizer
Speed	rpm	2,950
Evaporation temperature	°C	-27
Condensing temperature	°C	-2
Specific energy consumption	kW/TR	0.59
Oil cooler capacity	kW	9
Discharge temperature	°C	-6
High stage load	TR	108 @ - 2 oC without economizer
Operating parameters		
Suction pressure	kg/cm²	1.5
Discharge pressure	kg/cm²	4.0
Average power consumption	kW	45

The power consumption measurement done on the -27 °C butter compressors is as follows.

Figure 14: Butter compressor power consumption profile



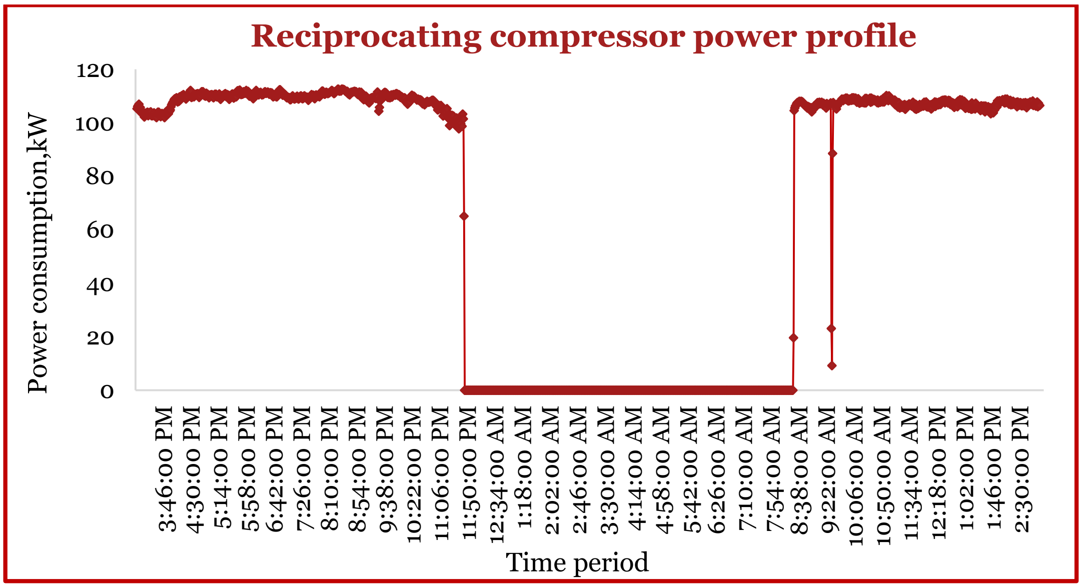
The average power consumption of the compressor = 42 - 50 kW

-4 ºC compressors (Buttermilk compressor)

There is a reciprocating type compressor of 90 TR to supply cooling when buttermilk section is operating. This compressor is backup equipment for the refrigeration system. When buttermilk in butter milk section, it is needed to be cooled from 45 ºC– 47 ºC to 4 ºC resulting in huge cooling requirement due to this refrigerant load increases.

The power consumption measurement done on the -4 ºC buttermilk compressors is as follows.

Figure 15: -Reciprocating compressor power consumption profile



The average power consumption of the compressor = 100-115 kW

3.5.2 Refrigeration system - Chilled water distribution

The chilled water system is generated by two stages of cooling in the plant refrigeration system. In the first stage, return water from process is cooled by -2 ºC PHE chiller using the refrigerant from -2 ºC compressor. In the second stage, chilled water is cooled in ice tank by -10 ^{o}C compressor refrigerant. Due to two stage of cooling system, plant is achieving chilled water temperature of 0 ^{o}C to 0.5 ^{o}C.

Chilled water is supplied to the following PHE's for process cooling

Milk pasteurizer PHE No -1	: 30 kL
Milk pasteurizer PHE No -2	: 30 kL
Milk pasteurizer PHE No -3	: 30 kL
Milk pasteurizer PHE No -4	: 30 kL
Buttermilk PHE	: 20 kL
Cream pasteurizer	: 10 kL
APS building PHE	: Not available

The chilled water distribution diagram is as follows.

Figure 16: Refrigeration system – chilled water system diagram

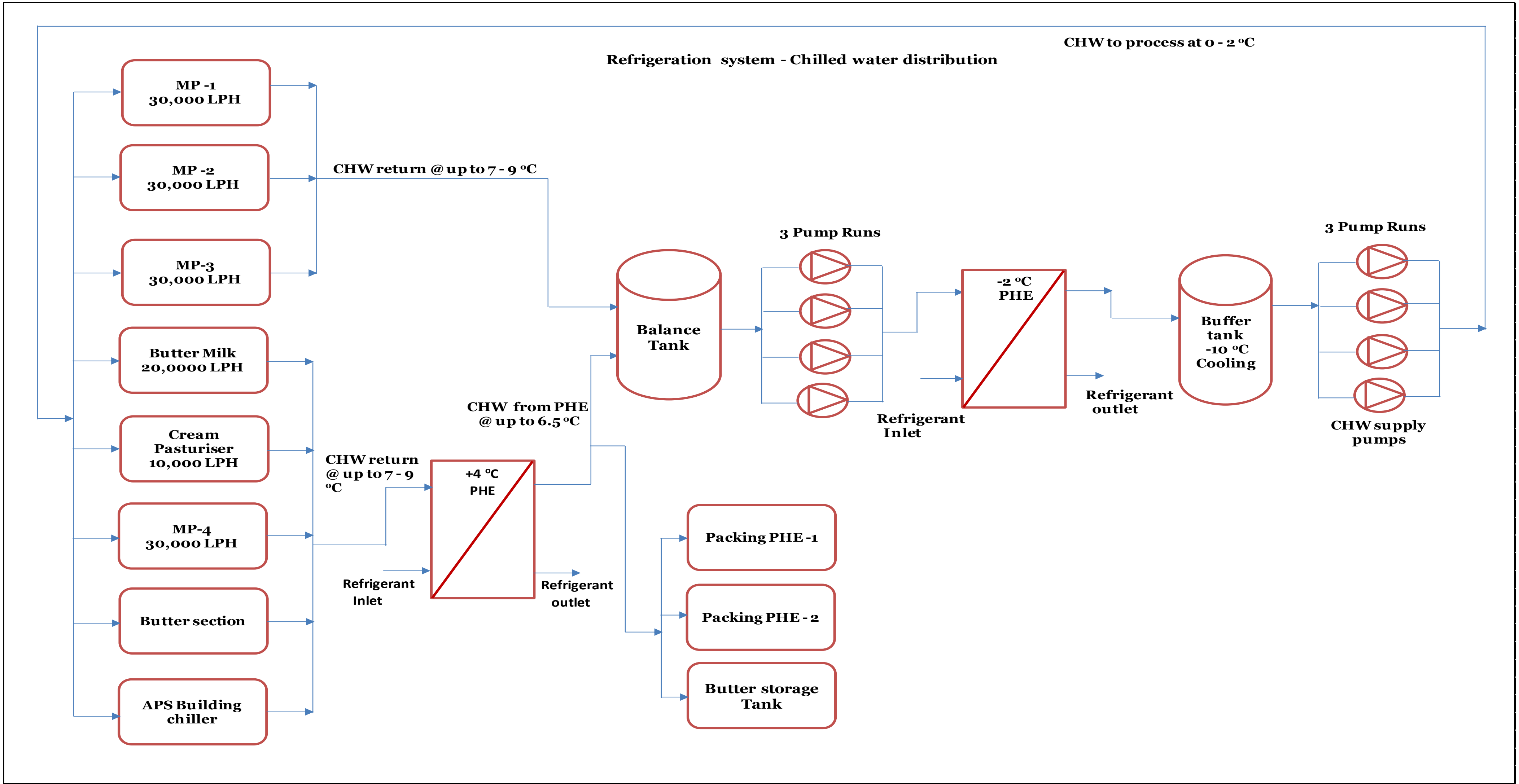
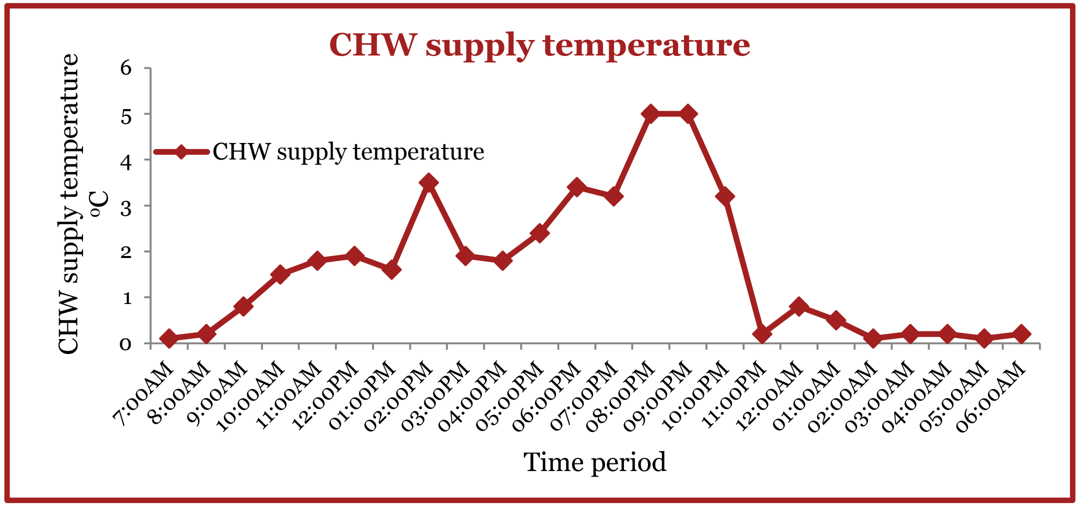
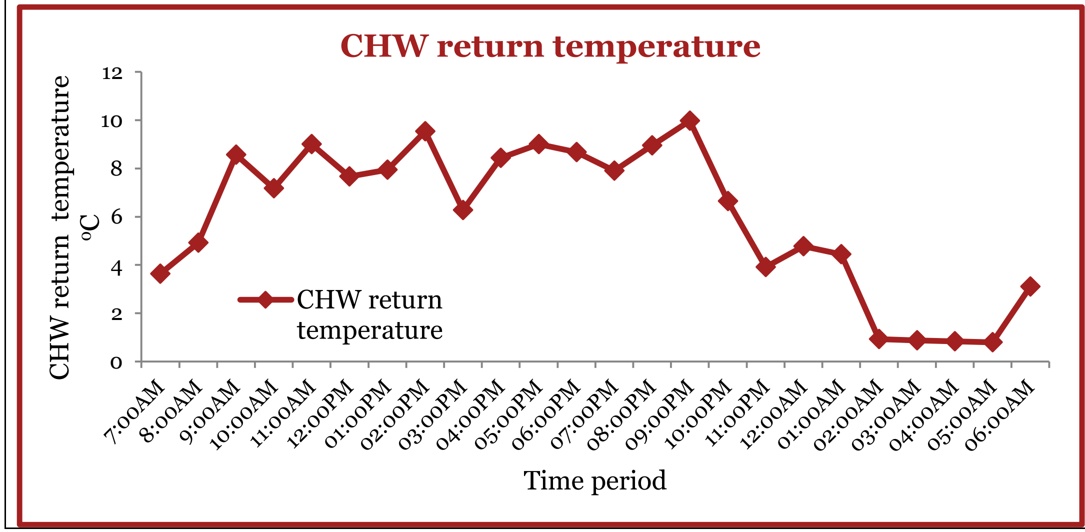
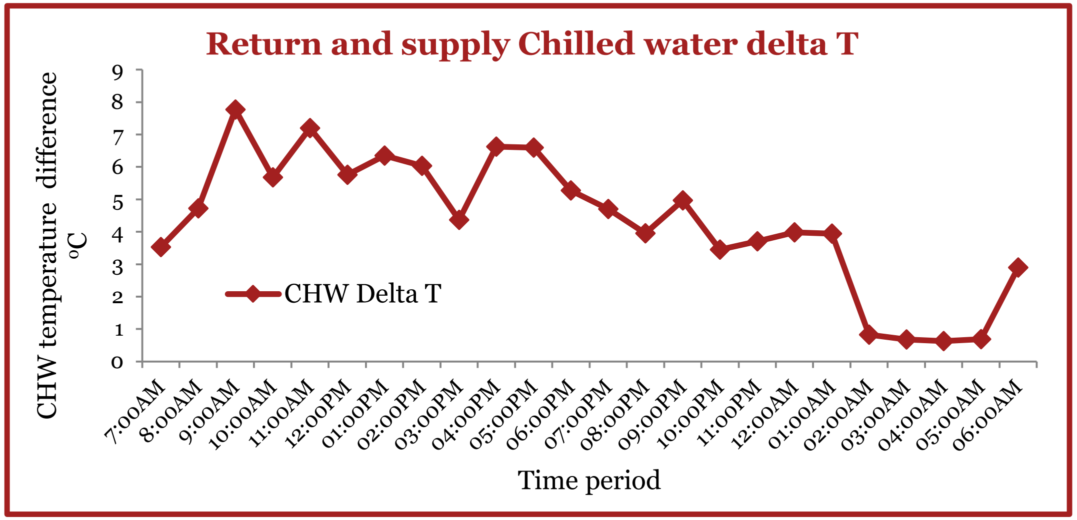
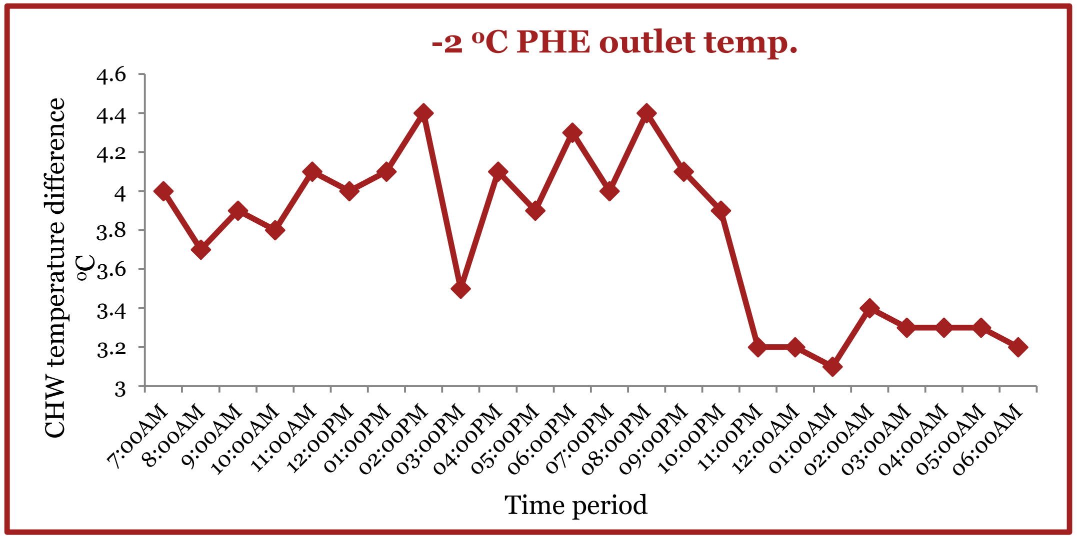


Figure 17: -Refrigeration system – Temperature and power profile

Temperature profiles	Observations
	Chilled water supply temperature is the actual temperature of the water pumped to process. The supply temperature is gradually increased from 2 °C to 5°C from 3PM to 9PM due to the increase in milk receiving during this (Evening time) time. After 9PM fresh milk receiving will reduce, so the temperature of the chilled water also decrease and its near to 0 °C Maximum supply water temperature recorded = 5 °C Minimum supply water temperature recorded = 0 °C
	Return chilled water temperature is the temperature of the chilled water returning from all the process to the refrigeration plant. Return water temperature completely depends on the heat load at the process end. Maximum return water temperature recorded = 10 °C Minimum return water temperature recorded = 0.5 °C

<table>
<tr><th>Temperature profiles</th><th>Observations</th></tr>
<tr><td>
</td>
<td>Chilled water delta T is the temperature difference between the supply and return water temperature. Delta T indicates, how much is the heat load is present in the user end.

Maximum CHW delta T (Temperature difference) recorded = 8 °C
Minimum CHW delta T (Temperature difference) recorded = 0.8 °C</td></tr>
<tr><td>
</td>
<td>Return chilled water is cooled in the two stage, first stage in -2 °C PHE then in -10 °C PHE. -2 °C PHE receives chilled water directly from user end. Graph represents the temperature difference between the -2 °C PHE inlet and outlet chilled water.

Maximum temperature of CHW outlet recorded = 4.4 °C
Minimum return water temperature outlet recorded = 3.1 °C</td></tr>
</table>

3.5.3 Specific energy consumption

Specific energy consumption of the refrigeration system evaluated by measuring temperature, power consumption and pressure parameters of the all refrigeration equipments, the same is tabulated as follows.

Table 11: Refrigeration SEC

Description	Units	Parameters
Capacity of -2 °C PHE	TR	420
Capacity of -10 °C Ice tank	TR	-
Capacity of -2 °C compressor with economizer	TR	266
Capacity of -10 °C compressor with economizer	TR	299.71
Number of compressors installed in each type	Numbers	2
Number of chilled water pumps operating	Numbers	3
Number of buffer tanks	Numbers	1
Rated consumption of -2 °C compressor	kW	198
Rated consumption of 0 - 10 °C compressor	kW	307.9
Rated consumption of each CHW pumps	kW	15
Number of compressors operating in each type (-2 °C & -10 °C)	Numbers	1 each
Cooling generated	TR	468
Compressor power consumption	kW	450
SEC of refrigeration system by only considering compressors power*	**kW/TR**	**0.96**

*The specific energy consumption derived is only for the refrigeration compressors.

3.5.4 Chilled water pumps

There are eight numbers of chilled water pumps installed in the refrigeration system. Out of which two or three pumps will be working to meet the cooling requirement. These pumps are working with constant speed throughout the day.

Table 12: Chilled water pump efficiency

Description	Units	Parameters
Operating parameters		
Make		Grundfos
Model		NB – 65-160/149
Flow rate	m^3/h	100
Head developed	M	35
Motor rating	kW	15
Number of pumps installed	Number	5
Proposed operating parameters		
Number of pumps running	Number	4
Flow delivered	m^3/h	250
Suction pressure	M	0

Description	Units	Parameters
Discharge pressure	M	38
Head developed	M	38
Power consumption of pump -1	kW	12.5
Power consumption of pump -2	kW	15
Power consumption of pump -3	kW	15
Total power consumption	kW	42.5
Overall efficiency	%	**61.5**
Pump combined efficiency @ (95% of motor efficiency)	%	**64.8**

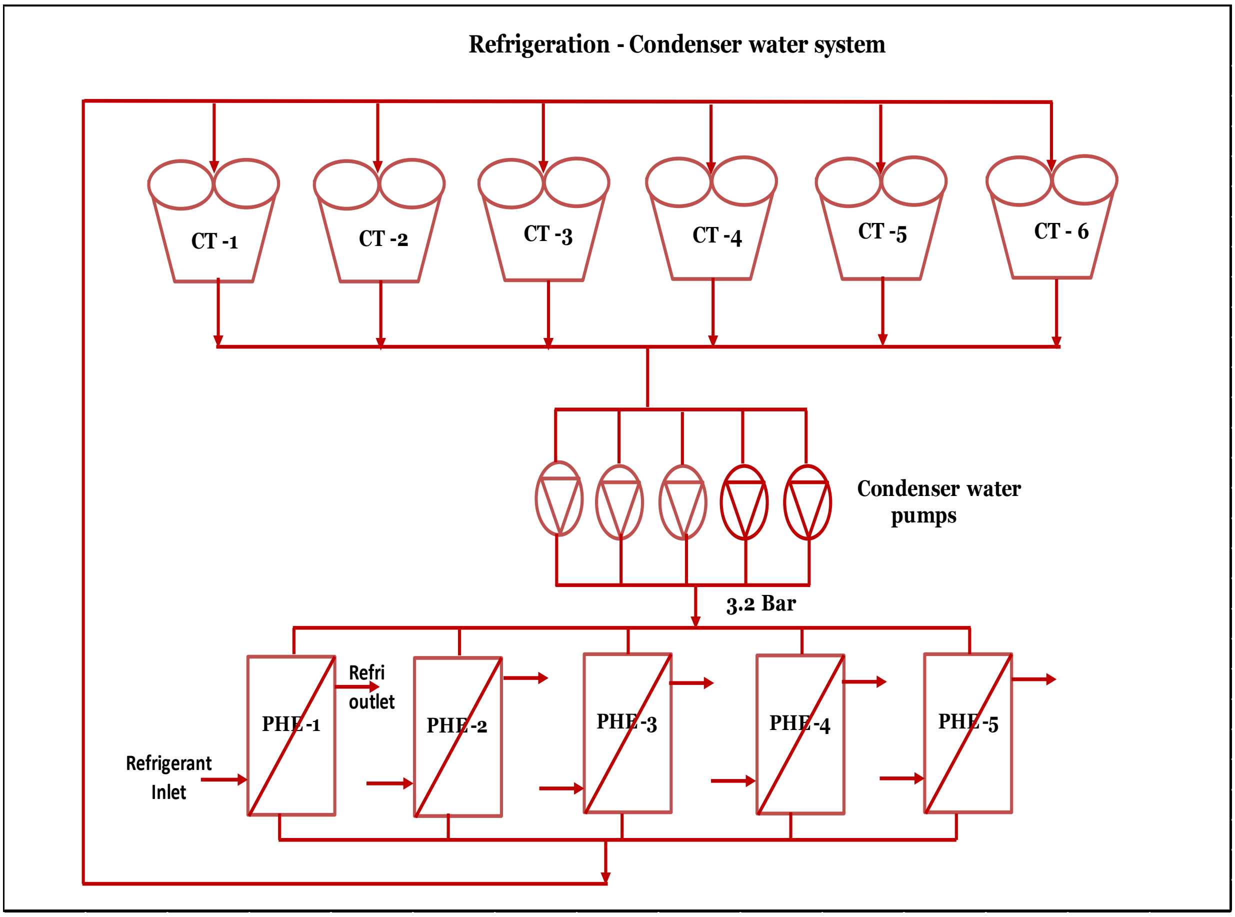
- Efficiency of chilled water pumps are found to be good and it is as per the rated efficiency.

3.5.5 Condenser water system

Refrigeration system is having PHE type of condenser to cool the hot refrigerant coming from the compressor. The condenser water system is having cooling towers, water pumps and PHE. Along with these equipments there is a de-super heater PHE to recover heat from hot refrigerant coming from compressor to pre heat the water which is used for milk crate washing. De-super heater is working only during summer season, since refrigerant temperature will be on higher side due to ambient conditions.

During the normal working hours, there are four cooling towers, three CW pumps and four PHE will be working to meet the cooling demand. The condenser water system block diagram is as follows.

Figure 18: Refrigeration – condenser water system layout



3.5.5.1 Cooling towers

There are six cooling towers installed in the system, out of which four cooling towers are running during normal working hours to meet cooling demand. These cooling towers are force draft type and have FRP blades in fans to suck air from ambient to tower for cooling the water.

Table 13 : Cooling tower operating parameters analysis

Description	Units	Parameters			
Rated parameters		**Tower -1**	**Tower -2**	**Tower -3**	**Tower -4**
Make				MIHER	Paharpur
Model				F1120	Series 20K QF CT
Type				cross flow	cross flow
Power consumption	hp			12.5	
Speed	rpm			2400	2400
Cooling capacity	TR			400	350
Water flow rate	m³/h			350	
Return water temperature	ºC				35.5
Supply water temperature	ºC				31.5
Design WBT	ºC				28
Actual parameters					
Return water temperature	ºC				32.4
Supply water temperature	ºC	29.8	29.9	30.1	30
Condenser water delta T	ºC	2.6	2.5	2.3	2.4
Ambient WBT temperature	ºC	25.5	25.5	25.5	25.5
Approach	ºC	5.3	5.4	5.6	5.5
Effectiveness	ºC	33%	32%	29%	30%

- Condenser water temperature difference (difference between supply and return water) is found to be very less compared to design of 5ºC. A lot of dust deposition was observed on cooling tower fills during audit, due to dust deposition there will not be proper heat transfer between water and air, which causes higher basin temperature. These cooling tower fills need to be cleaned regularly for better performance.

3.5.5.2 Cooling water pumps

There are six water pumps installed in condenser water system out of which three pumps will be running during the normal working hours. Operating parameters of these pumps like flow, pressure and power consumption were measured to estimate efficiency and the findings are as follows.

Table 14 : Condenser pumps efficiency estimation

Description	Units	Parameters
Rated parameters		
Make		Grundfos
Model		NB 100-160-170
Capacity	m³/h	265
Head developed	m	27

Description	Units	Parameters
Power consumption	kW	30
Speed	rpm	2,950
Number of water pumps installed	Number	6
Operating parameters		
Number of water pumps operating	Number	3
Water flow delivered by three pumps	m³/h	634
Head developed	m	32
Power consumed by three pumps	kW	84
Overall efficiency	**%**	**65.7**
Pump combined efficiency @96% of motor efficiency	**%**	**68.4**

The operating efficiency of these pumps is around 60%, which is as per pump design.

3.5.5.3 Condenser PHE's

There is condenser PHEs installed in the system to cool the hot refrigerant by using cooling water. There are six PHE's installed, out of which four PHE are working during normal working condition. The various parameters measured at the PHE's are as follows.

Table 15 : Condenser PHE operating parameters analysis

Description	Units	Parameters				
Rated parameters						
Make		IDMC		GEA Eco flex		SONDEX
Type				LWC 150 S - B-16		5W - 59
Total surface area	m²	97.4				122
PHE type		Condenser		Condenser		
Heat exchanged	kCal/h	1058400				
	TR	350				
		Hot fluid	**Cold fluid**	**Hot fluid**	**Cold fluid**	
Flow		4,020 kg/h	266,510 lph	4,020 kg/h	266510 lph	
Pressure drop	MWc		5		5	
Inlet water temperature	°C	90	32	90	32	
Outlet water temperature	°C	39	36	39	36	
Design pressure	kg/cm²	18	6	18	6	16
Design temperature	°C			100	100	120
Hydraulic test pressure	kg/cm²	24	8	24	8	20.8
Actual parameters		**PHE -1**	**PHE -2**	**PHE -3**	**PHE -4**	**PHE -5**
Actual water flow	m³/h	132.6	186	182.5	134	
Inlet water pressure	kg/cm²	2.6	2.5	2.55	2.6	
Outlet water pressure	kg/cm²	2.2	2.2	2.2	2.2	
Pressure drop across PHE	kg/cm²	0.4	0.3	0.35	0.4	
Water inlet temperature	°C	28.5	28.5	28.5	28.5	
Water outlet temperature	°C	32.5	32	32.5	32.5	
Water delta T across PHE	°C	4	3.5	4	4	

The detailed analysis of PHE condensers indicates that water flow across all PHEs is less than design value. Due to lower water flow to condenser, refrigerant will not be cooled properly which will in turn increase compressor power consumption.

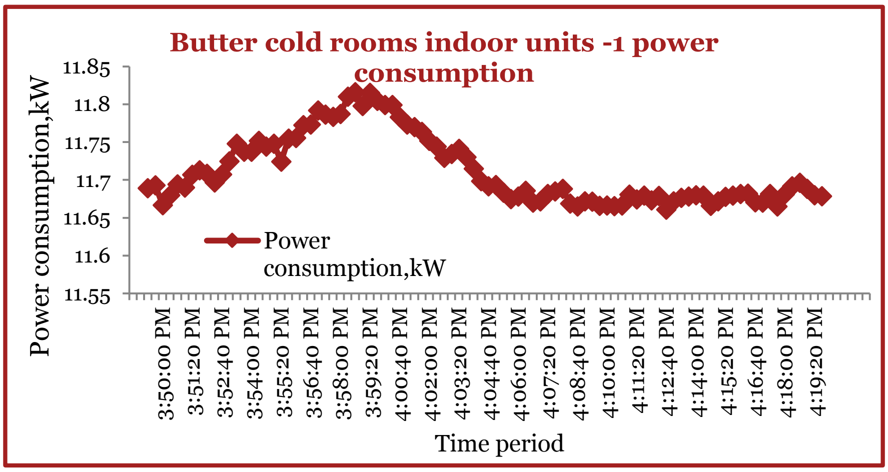
3.5.6 Cold rooms

There are cold rooms in the dairy plant to store final product before being dispatched from plant. Different cold rooms and set temperature in each of the cold room are as mentioned below.

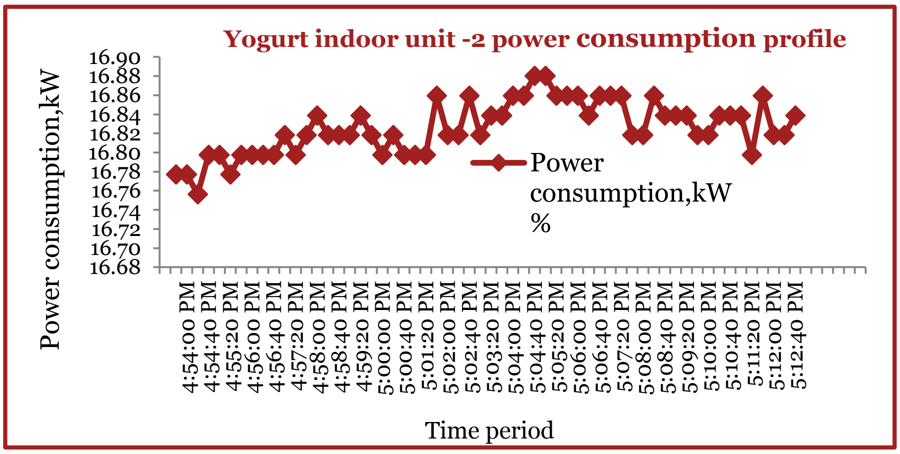
Butter deep freezer	=	-27 °C
Milk cold rooms	=	up to 4 °C
Sweet cold rooms	=	-2 °C & 0 °C
Butter cold rooms	=	-2 °C to -4 °C
Paneer cold rooms	=	4 °C
Yogurt cold rooms	=	4 °C

These cold rooms get cold refrigerant from centralized refrigerant system and indoor units are fitted inside cold rooms. The actual temperature and power consumption of indoor units measured on sample basis during audit are as follows.

Figure 19: Cold room power consumption profile

<table>
<tr><th>Power profile</th><th>Observation</th></tr>
<tr><td>


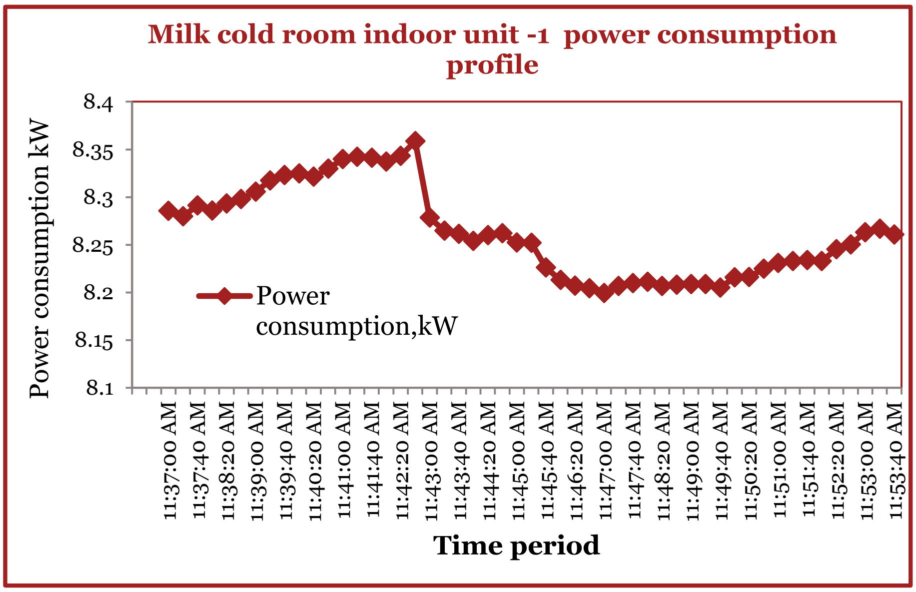
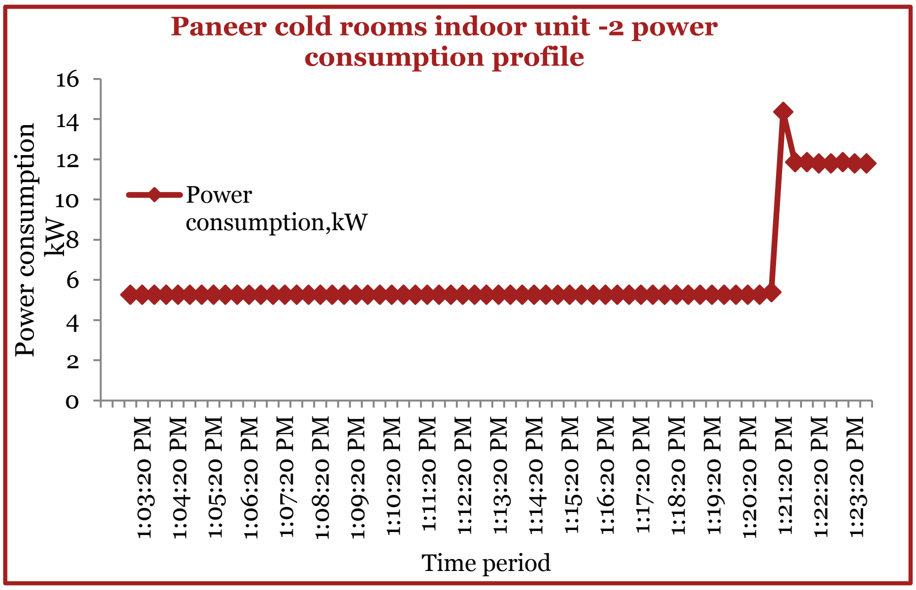
</td><td>There are four indoor units installed and one was working during audit.

The actual temperature measured at cold room = -2 °C
Average power consumption = 11.7 kW</td></tr>
<tr><td>


</td><td>There are four indoor units installed and all were working during audit.

The actual temperature measured at cold room is = 5 °C

Average power consumption = 16.8 kW</td></tr>
</table>

Power profile	Observation
	There are six indoor units installed and all were working during audit. The actual temperature measured at Cold room unit -1 is = 8.3 °C to 9.1 °C Cold room unit -2 is = 6.7 °C to 10.7 °C Cold room unit -3 is = 4.4 °C to 8.9 °C Cold room unit -4 is = 4.4 °C to 9.1 °C Cold room unit -5 is = 4.7 °C to 9.2 °C Cold room unit -6 is = 6.2 °C to 12.3 °C Average power consumption = 8.2 kW
	There is one indoor units installed and it was working during audit. The actual temperature measured at Cold room unit is = 4 °C to 5 °C Average power consumption = 5 kW

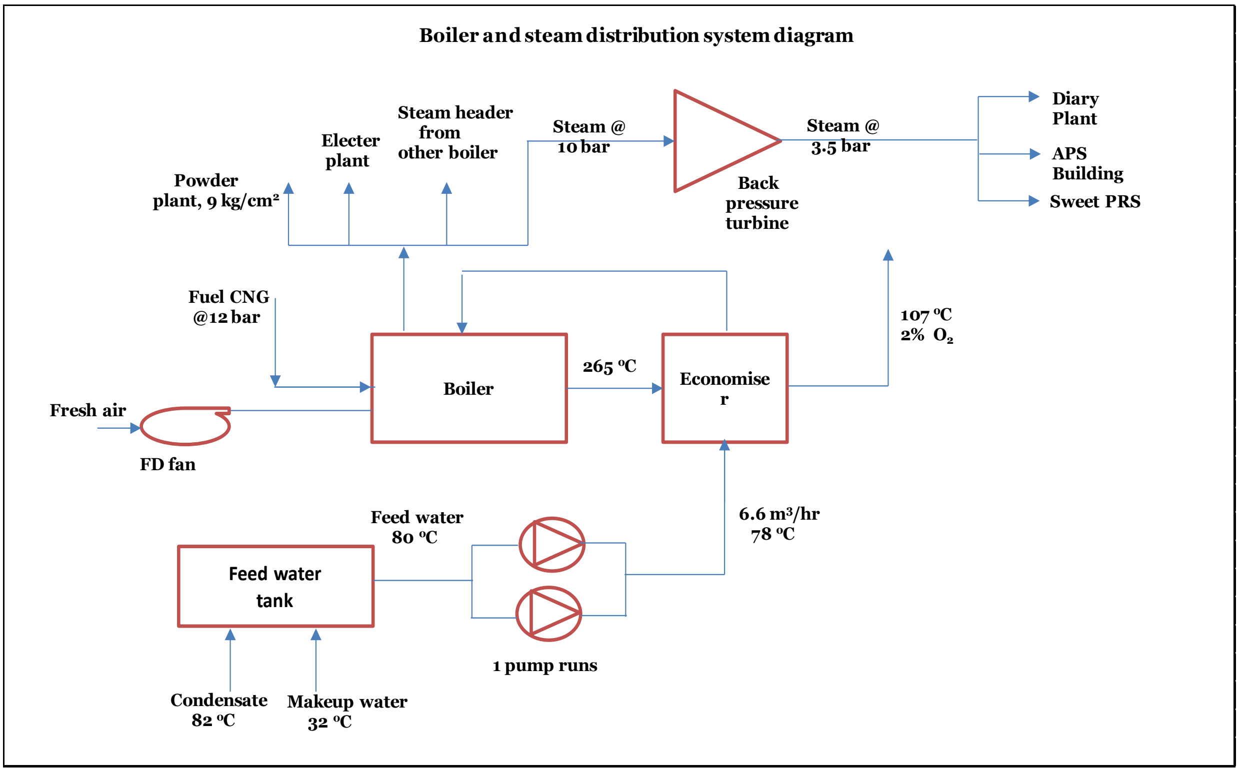
The power consumption and temperature measurement done on the indoor units indicates that actual temperature measured is higher than set temperature. During the audit, it was also observed that cold rooms door opening and closing was not properly managed and most of air curtains were not working. Due to this, cold room air was coming out and mixing with ambient air. Since cold air is coming out of cold room, heat load in cold rooms was always at higher side; due to this, indoor units were operating without unloading. So, it is recommended to control cold room door opening and closing and make sure that air curtains are always in working condition.

3.6 Boiler and steam distribution

There is a boiler of 10 TPH in plant to generate steam required for various processes. Boiler is a natural gas fired and generates steam at a pressure of 17.5 kg/cm².

The boiler and steam distribution diagram is as follows.

Figure 20: Boiler and steam distribution diagram



The parameters measured in the boiler system during energy audit are as follows.

Table 16 : Boiler efficiency estimation

Description	Units	Parameters
Boiler feed water temperature	ºC	84
Boiler steam temperature	ºC	140
Feed water temperature at economizer input	ºC	84
Feed water temperature at economizer output	ºC	120
Ambient temperature	ºC	36
Boiler flue gas temperature at economizer inlet	ºC	270
Boiler flue gas temperature at economizer outlet	ºC	110
Condensate temperature	ºC	80
Gas flow rate measured	SCM	460
Boiler feed water flow rate	m^3/h	7,756
Steam flow rate	TPH	7.7
Process steam flow rate	kg/h	3,275
Powder plant steam flow	kg/h	1,162
APS steam flow	kg/h	470
Feed water TDS	TDS	26
Blow down TDS	TDS	680
Oxygen percentage at the economizer outlet	%	3
CO level at the economizer outlet	ppm	75
Boiler efficiency without economizer	**%**	**87**

Description	Units	Parameters
Boiler efficiency with economizer	%	**89.5**

The efficiency of the boiler without economizer is 87% and with economizer is 89.5 %, which is found to be good and working as per the design.

Boiler is generating steam at a pressure of 17.5 kg/cm² and steam is being used in different processes at different pressure. Since there is a big gap between generation and usage steam pressure so in order to utilize pressure energy; the plant has installed backpressure turbine to generate electrical energy by using the steam pressure. The generation and user end pressure requirement in different processes are listed below.

Steam generation pressure = 17.5 kg/cm²

Powder plant = 8 kg/cm² and 3 kg/cm²

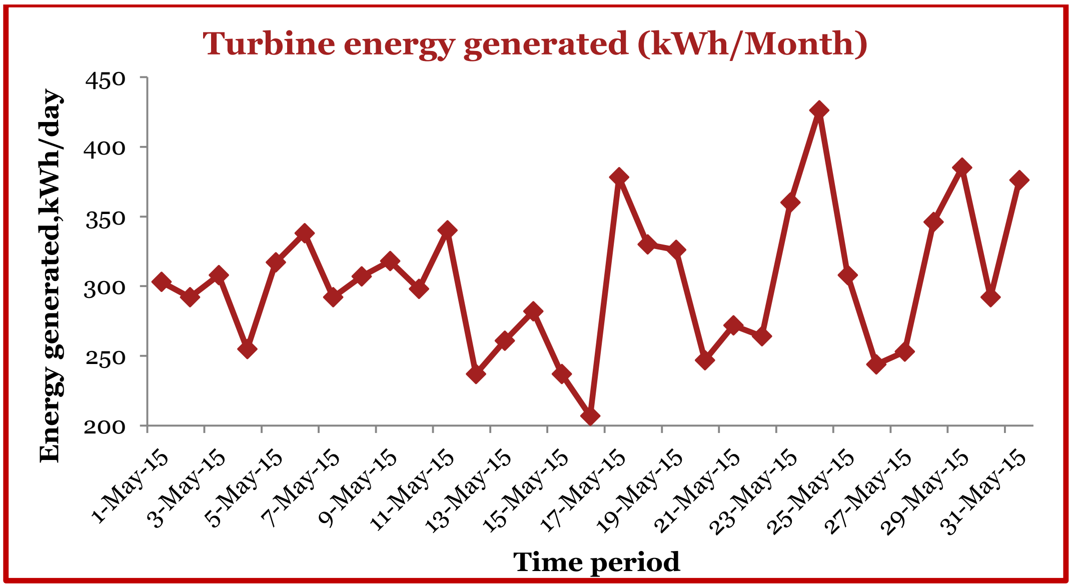
APS building = 3.5 kg/cm²

Elaster plant = 8 kg/cm²

Plant process (Milk section) = 3 kg/cm²

Since there is a big difference between generation and usage steam pressure, the plant has installed backpressure turbine in low-pressure process steam line (10.5 kg/cm²) header to produce electricity and reduce steam pressure to 3 kg/cm². A profile of electricity generation from back pressure turbine is shown below.

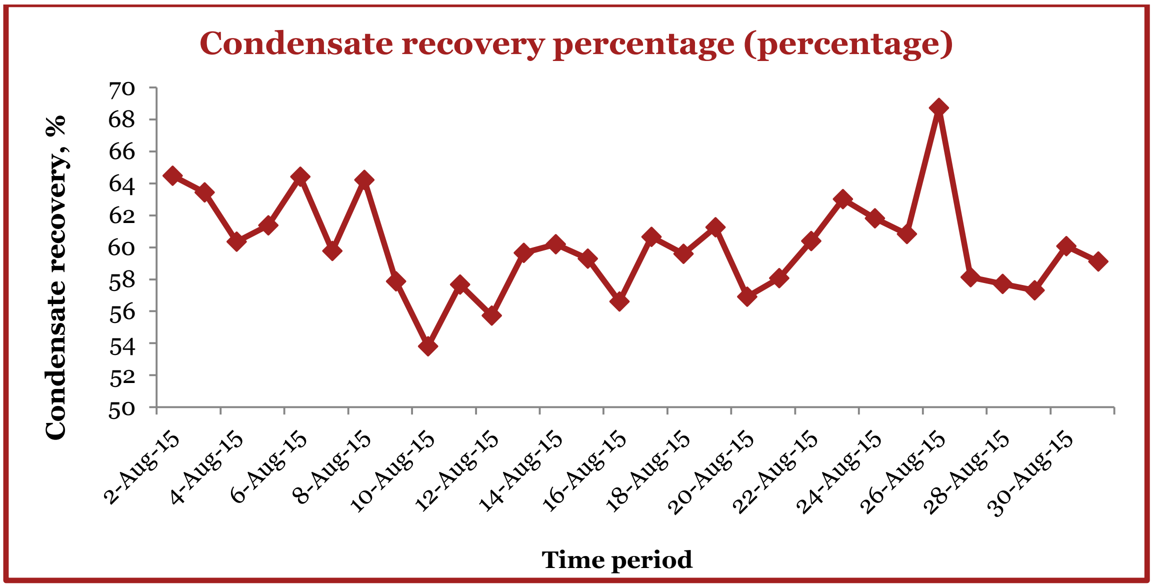
Figure 21: -Back pressure turbine energy generation profile



Steam is used in the process for heating purpose and in most of heating processes; heating is done by indirect heating method. After heating, complete steam is converted to hot water or condensate. The condensate collected after process heating needs to be pumped back to boiler for being used as feed water to boiler.

The plant has a sophisticated condensate recovery system, where collected condensate is pumped back to boiler for using it as feed water. The percentage of condensate collected on daily basis for one complete month is given below.

Figure 22: Boiler condensate recovery percentage



The average percentage of condensate collected is 60 % only, which is very less. Hence, the plant need to improve condensate recovery percentage to up to 90 – 95 % to save boiler fuel consumption.

2.1.1 Steam traps, Insulation and leakage:

Detailed study is done on the steam traps, steam insulation and steam leakage in the plant during the audit, same is discussed below.

Steam traps: Plant is installed with inverted bucket type of steam traps in most of the places in steam distribution network. Detailed physical inspection survey on sample basis is done on the steam traps in plant and it is found that, steam traps are working fine and there was no leakage is observed from it.

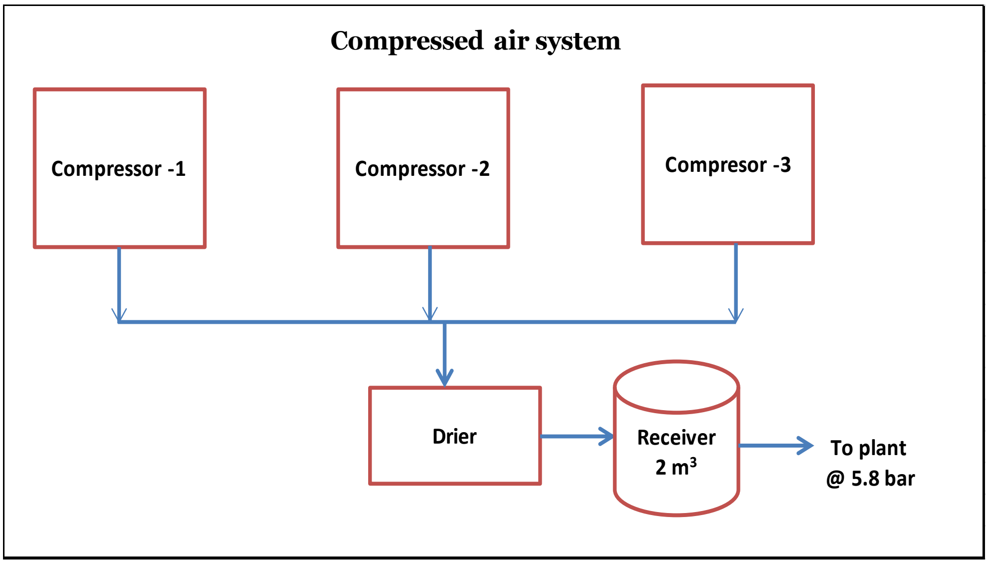
Insulation study: Detailed study is done on the steam insulation by physical inspection and temperature measurement of steam pipeline and it is found that steam insulation was proper and there was no insulation breakage is observed during the study.

Steam Leakage: There was no steam leakage in the plant through live steam lines, steam traps or some other equipments in the plant.

3.7 Air compressors

There are air compressor in the plant to generate the compressed air for process requirement. All compressors installed in the plant are new and screw type and fitted with VFD. The detailed compressed air system diagram is as follows.

Figure 23: -Air compressor system diagram



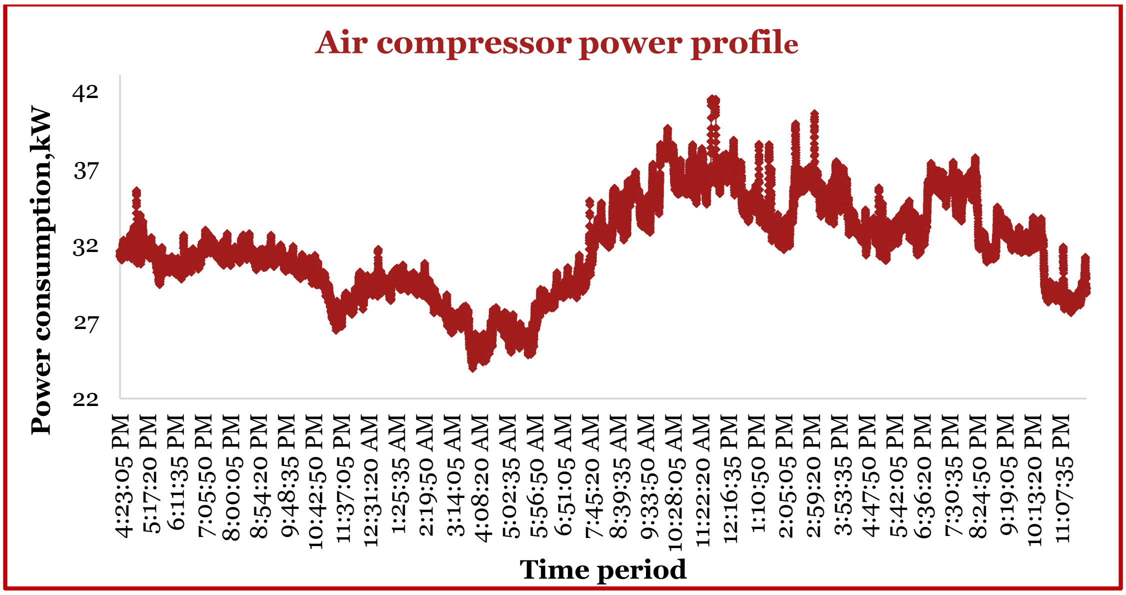
Parameters measured and rated parameters collected for compressors during energy audit are as follows.

Table 17 : Air compressor operating parameter analysis

Description	Units	Parameters
Rated parameters		
Make		Chicago pneumatic
Year of manufacturing		2012
Type		CPC - 50
Rated flow	cfm	220
Power consumption	kW	37.5
Operating parameters		
Number of compressor running	Number	1
Cut in pressure	kg/cm²	5.5
Cutoff pressure	kg/cm²	5.8
Air pressure at receiver	kg/cm²	5.5
VFD frequency	Hz	42.7
Power consumption	kW	30

Power consumption profile recorded at the operating compressor during the audit is as follows.

Figure 24: Air compressor power profile



Power consumption of the compressor	=	25 to 42 kW
Operating frequency	=	42.7 Hz

Since these compressors are new and screw type and fitted with VFD; hence, plant has good compressed air system and this system is working satisfactorily as per design.

3.8 Powder plant

Plant is having powder plant to convert liquid milk to milk powder. Rated capacity of powder plant is 15 tons per day and runs only when surplus milk is available in dairy (when supply is more than demand). The powder plant works for about 8 months in a year whereas during summer seasons (about 4 months) powder plant is shutdown.

Liquid milk is converted to powder by two stage of heat treatment. First stage is called as evaporation process in evaporators and second stage is drying process in drier.

Evaporators:

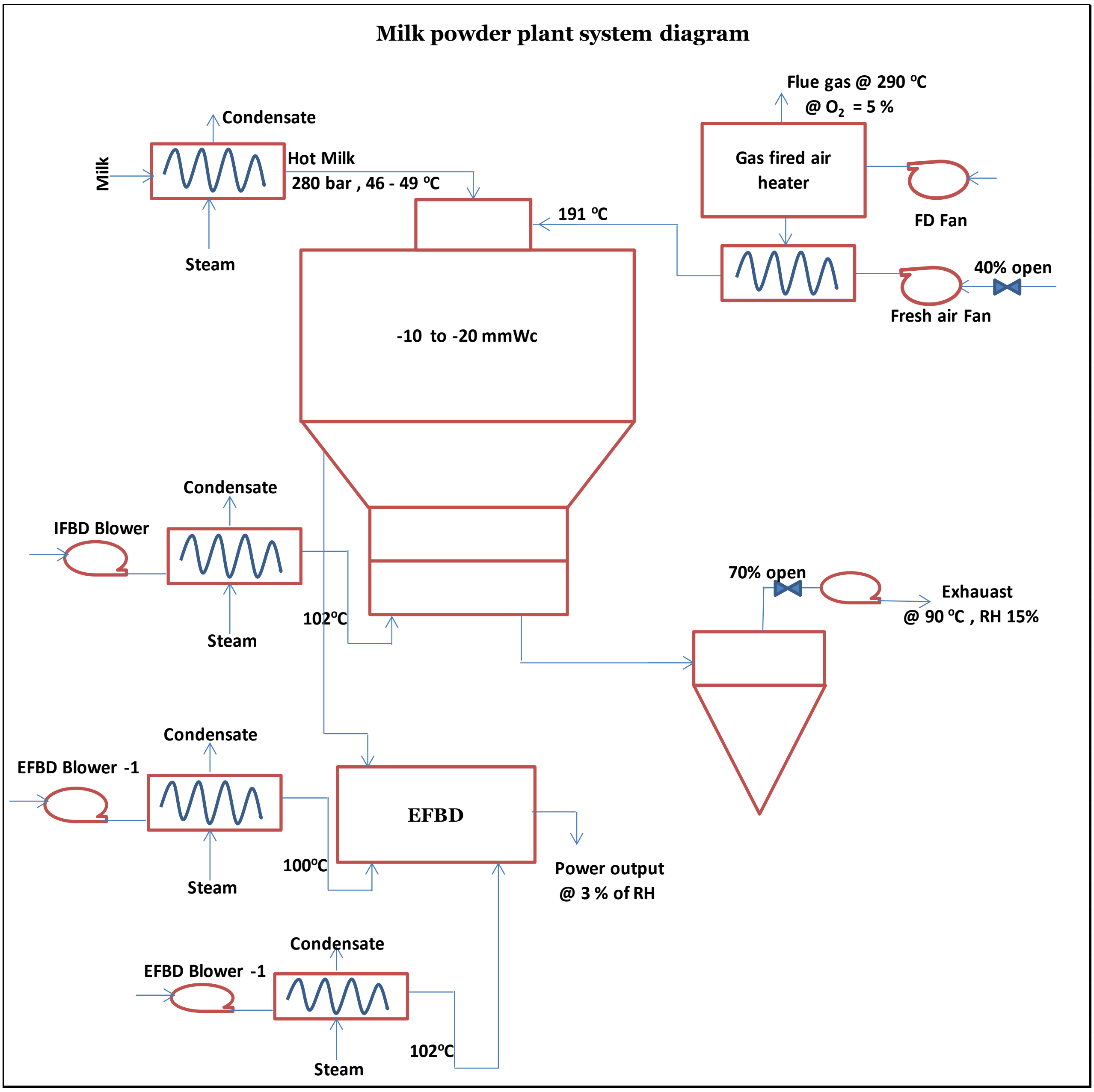
The pasteurized milk from milk processing plant is supplied to this plant for making powder. Evaporation is a multistage heating process, where milk gets heated in multi stages in evaporator columns under vacuum. The milk at end of the evaporation process will have around 48 to 50% solids in it.

Drier:

Milk will be treated in drier in second stage, where milk with 48% solids from evaporation is supplied to drier to make final milk powder. The capacity of the drier is 15 TPD.

Plant milk drier system diagram is as follows.

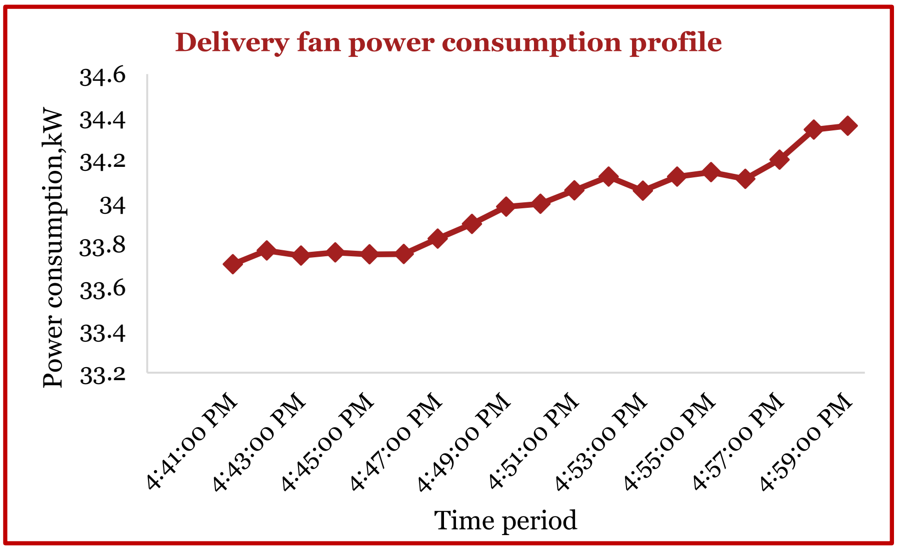
Figure 25: Powder plant drier system diagram

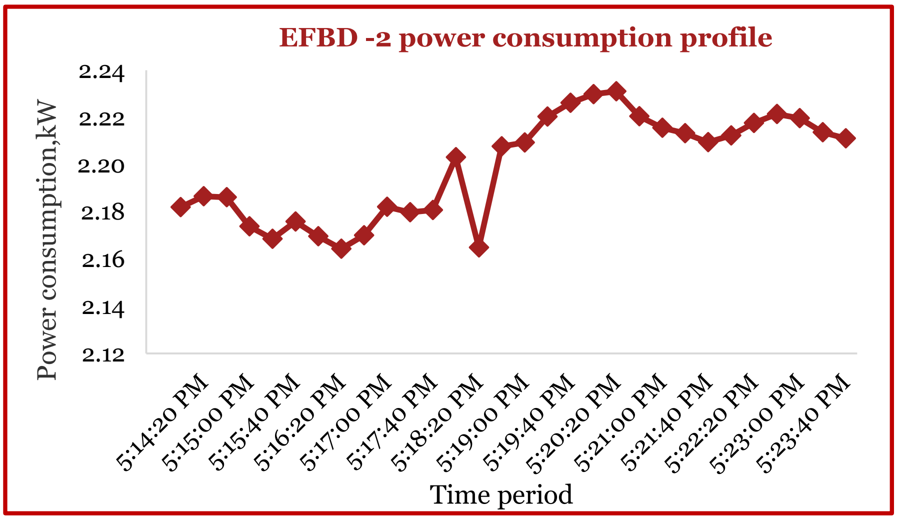


Drier is the one of the major energy consumer in the powder plant and consumes steam, natural gas and electricity. In powder making process, milk is heated up to 45 °C and fed to drier at the pressure of 280 kg/cm² through high-pressure nozzles provided at the top of drier. In drier, milk undergoes heat treatment with hot air delivered from delivery fan. The hot air dries the milk completely and milk powder gets collected in EFBD section of the drier. In EFBD, collected milk powder is further heated to meet required humidity criteria of 3% and then the powder is sent out for packing in packing section.

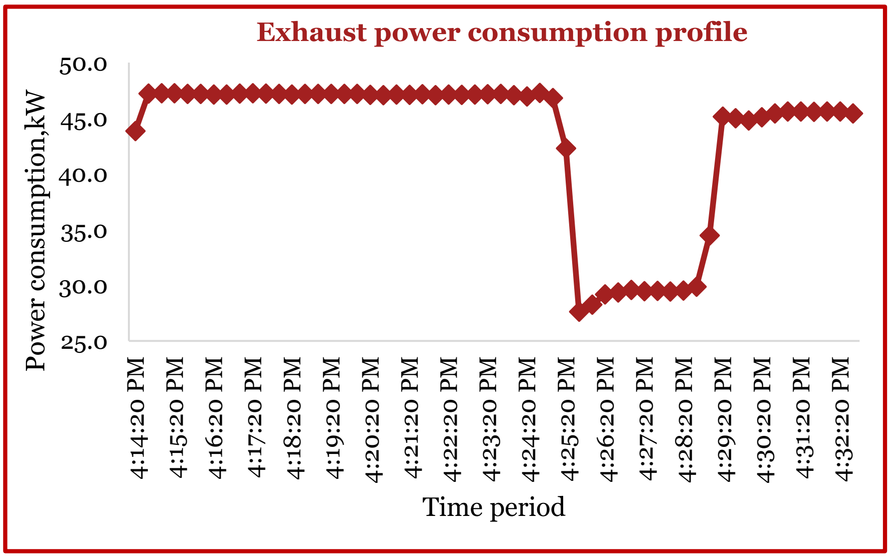
The power consumption profile measured for all the fans in the driers are as follows.

Figure 26: Drier fans power consumption profile

<table>
<tr><th>Power profile</th><th>Remarks</th></tr>
<tr><td>
</td><td>Delivery fan supplies the required fresh air to the drier. This fan is working with 40% throttling condition in the suction side to control the fan pressure and flow rate

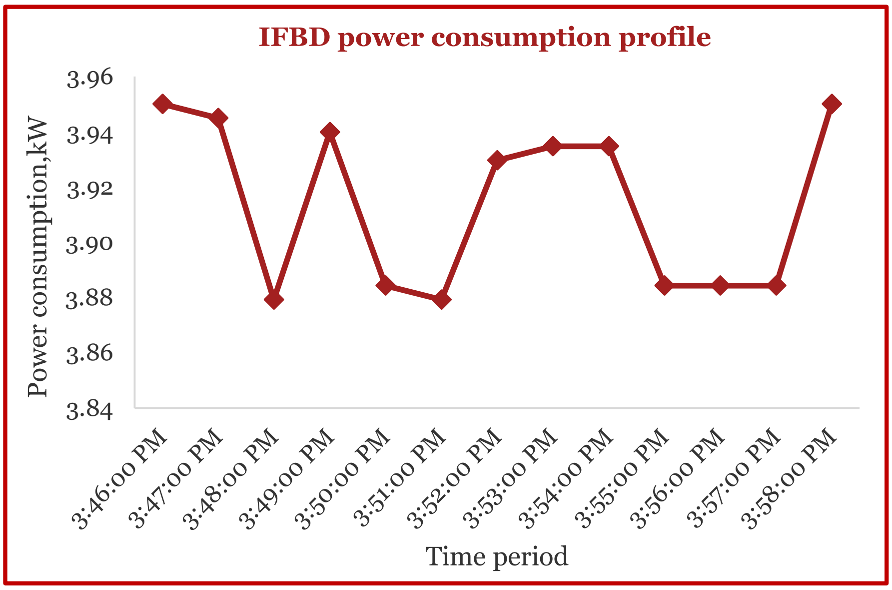
The power consumption of this fan was = 34 kW</td></tr>
<tr><td>
</td><td>There are two EFBD fans installed in the drier and both fans are working. Power consumption profile is recorded for one out of two in sample basis. These fans have steam heater to heat up the air before supplying it to the drier's EFBD section.

These fans were working with 50 % throttling at the delivery side to control fan pressure and flow rate.

The power consumption of this fan was = 2.2 kW</td></tr>
<tr><td>
</td><td>There is an exhaust fan in the drier which exhausts all hot air sent to drier

This fan is also working under throttle condition at the suction side by 30%.

The power consumption of this fan was = 45 kW</td></tr>
</table>

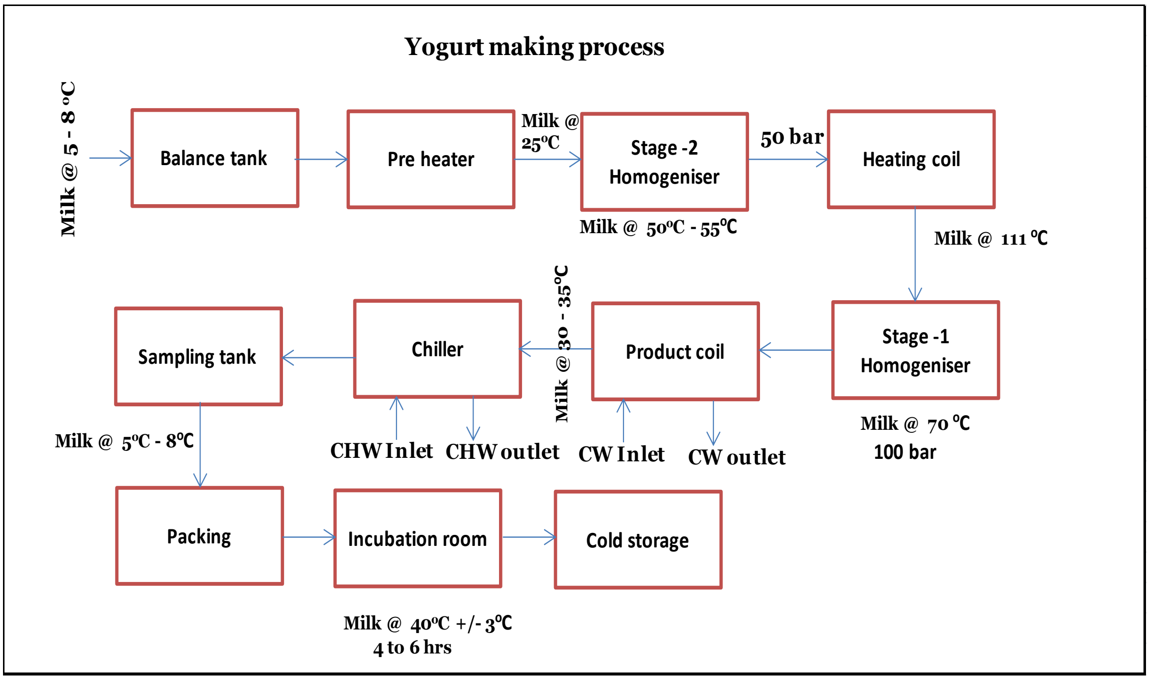
Power profile	Remarks
	IFBD fan supplies hot air at the bottom of drier for powder fluidization. This fan is also working under throttling condition at the delivery side by 50 %. The power consumption of this fan was = 3.9 kW

The entire drier section is under manual control, there is no auto valves provided for any of the equipment. All fans are working under throttling condition. Hence, it is recommended to install proper automation and VFD controls on these fans to save drier power consumption.

3.9 *Yogurt plant*

Yogurt plant is having a capacity of 3,000 liters/h; manufacturing process flow diagram of the yogurt is as follows.

Figure 27: Yogurt making process flow diagram

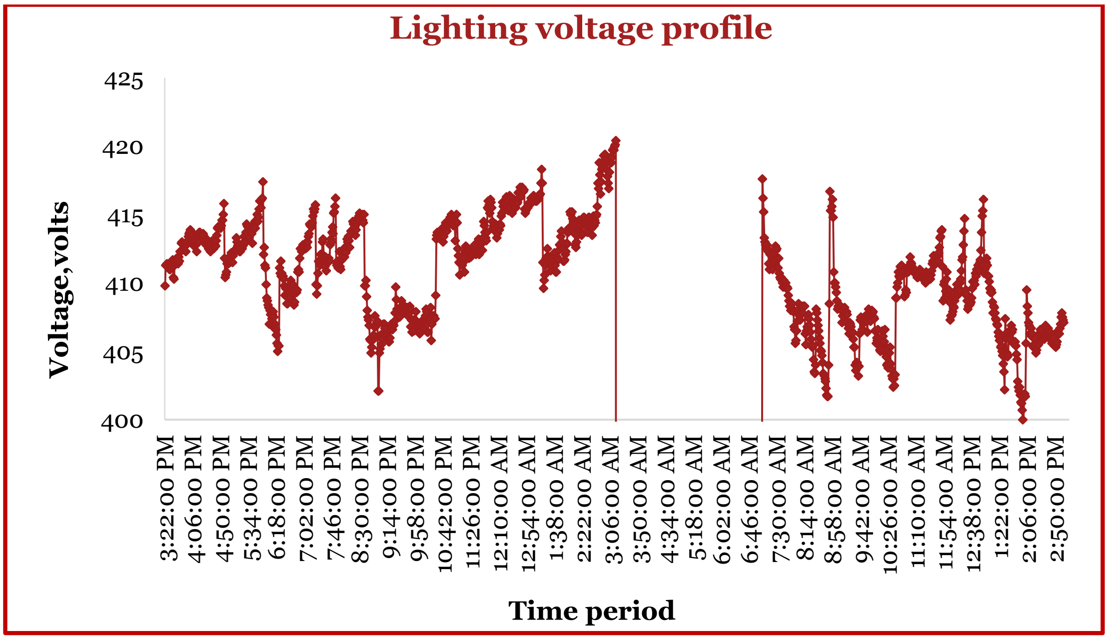


Yogurt making process starts with heating of milk from 5 – 8 °C to 50 – 55 °C using hot water, after heating milk undergoes chemical treatment and then cooled back to the temperature of 5 to 8°C. The yogurt making process consumes steam, chilled water and electrical energy.

3.10 Lighting

Lighting is one of the load in plant which consumes around 8% of plant energy consumption. There is a separate feeder and lighting energy saver to lighting feeder is installed through which power is supplied to all lighting DB's. The voltage and power consumption measurement done on the lighting feeder during the audit is as follows.

Figure 28: Lighting voltage profile

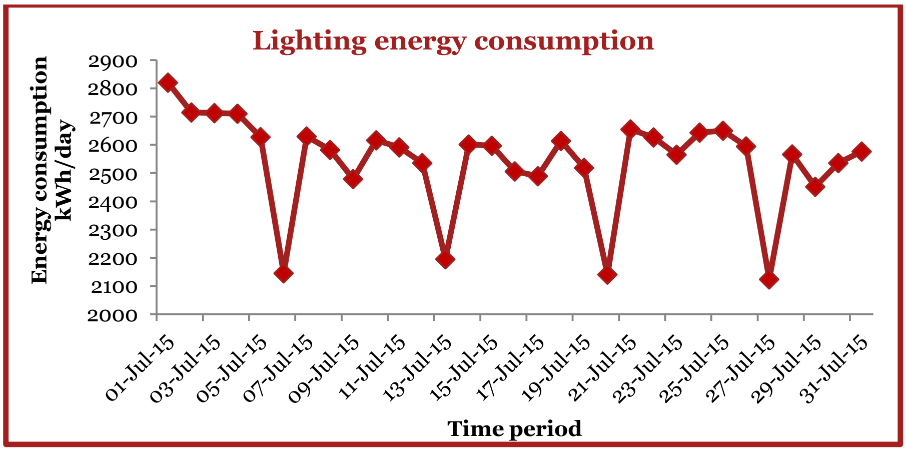


Maximum lighting voltage during the recording period	=	420 Volts
Minimum lighting voltage during the recording period	=	405 Volts
Average lighting voltage during the recording period	=	410 Volts

<u>Lighting energy consumption profile:</u>

Lighting energy consumption profile drawn from plant data for one month on daily basis is as follows

Figure 29: Lighting energy consumption profile



Maximum lighting consumption during the month	=	2,150 kWh/month
Minimum lighting consumption during month	=	2,800 kWh/month

Lux level:

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

Table 18 : Plant lux level measurement

Area	Lux Measured
Engineering office	220,290,200,210,280,300,320,310,320
Refrigeration control room	230,290,300,320,210,230,330,230,290,300
Refrigeration compressor room	120,180,190,200,220,180,160.175
Old boiler area	120,140,150,200,210,190,130,140
New boiler room	200,,230,290,290,300,250
Powder plant	300,230,220,290,190,180,290,300
Milk process plant	300,350,290,280,260,290,280
Yogurt plant	230,300,320,200,320,230,340,320,200
Paneer plant	230,290,280,230,290,300,320,300,320
Elaster plant	200,230,320,210,230,320,290,240
Butter milk plant	290,300,320,320,210,230,240,320,203
Admin building corridor	210,220,230,390,320,310,320,340

4 Energy Conservation Measures

In order to operate all its process equipments and utilities, plant uses electricity and natural gas as the energy inputs. Major energy consumer in the plant is refrigeration plant followed by other utilities. Detailed energy audit was conducted in Sumul dairy plant to find energy saving opportunities, energy conservation part of it is discussed below.

4.1 Refrigeration system

4.1.1 Maintain proper water flow and temperature as per design to condenser PHE

Background

Refrigeration system is having its own condenser cooling system to cool the hot refrigerant coming from compressor. The condenser system has five cooling towers, five CW pumps and five condensers PHE out of which four cooling towers, three CW pumps and four condensers PHEs are working. The design and operating details of these condensers PHEs are as follows.

Table 19: Cooling water flow across condenser PHE

Description	Units	Parameters				
Rated parameters						
Make		IDMC		GEA Eco flex		SONDEX
		Hot fluid	**Cold fluid**	**Hot fluid**	**Cold fluid**	
Flow		4,020 kg/h	266,510 lph	4,020 kg/h	266510 lph	
Pressure drop	MWc		5		5	
Inlet water temperature	°C	90	32	90	32	
Outlet water temperature	°C	39	36	39	36	
Design pressure	kg/cm²	18	6	18	6	16
Actual parameters		**PHE -1**	**PHE -2**	**PHE -3**	**PHE -4**	**PHE -5**
Actual water flow	m³/h	132.6	186	182.5	134	
Inlet water pressure	kg/cm²	2.6	2.5	2.55	2.6	
Outlet water pressure	kg/cm²	2.2	2.2	2.2	2.2	
Pressure drop across PHE	kg/cm²	0.4	0.3	0.35	0.4	
Water inlet temperature	°C	28.5	28.5	28.5	28.5	
Water outlet temperature	°C	32.5	32	32.5	32.5	
Water delta T across PHE	°C	4	3.5	4	4	

Out of five cooling towers installed in the refrigeration system, four number of CT's are working during the normal working hours. The temperature measurement done on the cooling towers indicating that the performances of the CT are at lower side.

Table 20: Cooling tower temperature measurement

Description	Units	Parameters			
CT return water temperature	°C	32.4			
CT supply water temperature	°C	29.8	29.9	30.1	30
CT condenser water delta T	°C	2.6	2.5	2.3	2.4
Ambient WBT temperature	°C	25.5	25.5	25.5	25.5
CT approach	°C	5.3	5.4	5.6	5.5

Finding

All the condenser PHE's are design for cooling water flow of 266.5 m^3/h but actual water flow measured at the PHE -1 is 132 m^3/h, PHE -2 is 186 m^3/h , PHE -3 is 182 m^3/h and PHE -4 is 134 m^3/h. So, the actual water flow across PHE is less as compared to design. Due to reduced water flow, hot refrigerant will not be cooled properly in condenser. If refrigerant is not getting cooled properly in condenser then refrigerant pressure at compressor will increases which in turn will increase compressor power consumption.

The average delta T (Supply and return water difference) across the cooling tower is found to be 2.5 °C, which is found to be very low. These cooling towers are designed for the delta T of 5 °C. A possible reason for poor delta T is due to improper maintenance of CT. A lot of deposition of dust was observed on CT fills during energy audit.

Recommendation

Maintain correct water flow across condenser PHE as per the design. In order to improve water flow across condenser, plant need to operate one more condenser pump. Due to one more condenser water pump operation, power consumption at the pump side will increase, but more amount of energy saving can be achieved on the compressor side due to reduction in specific energy consumption.

Clean cooling tower fills regularly and replaces fills as and when required. Cleaning of cooling tower and fills will result in better heat transfer between water and air.

By implementing above two recommendation, the specific energy consumption of complete refrigeration system can be improved from present value of 0.96 to 0.8 kW/TR.

Energy & financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 21: Savings potential due to increased CW flow and cleaned CT fills

Description	Units	Condenser PHE flow
Design parameters		
Number of CT installed	Number	5
Number of PHE condensers installed	Number	5
Number of CW pumps installed	Number	5
Rated flow rate of each PHE	m^3/h	266.5
Rated flow rate of CW pump each	m^3/h	265
Rated power consumption of CW pump each	kW	30
Operating parameters		
Water flow across the PHE -1	m^3/h	132.6

Description	Units	Condenser PHE flow
Water flow across the PHE -2	m^3/h	186
Water flow across the PHE -3	m^3/h	182.5
Water flow across the PHE -4	m^3/h	134
CT return water temperature	^oC	32.2
CT supply water temperature (average)	^oC	29.2
Delta T across CT (average)	^oC	3.00
The present specific energy consumption of refrigeration system	kW/TR	0.96
Proposed parameters		
Water flow across each PHE	m^3/h	266.5
Extra water flow required	m^3/h	430.9
Extra pumps need to operate (with VFD) to match flow	Numbers	2
Expected extra power consumption by pumps	kW	47
Expected SEC after condenser side revamp	kW/TR	0.8
Saving in the SEC	kW/TR	0.16
Average TR generation	TR	468
Saving in power consumption due to SEC reduction	kW	74.88
Saving in power after extra CW pump power operation	kW	27.88
Annual operating hours	Hours	8,640
Annual energy saving	**kWh**	**240,883**
Power cost	Rs/kWh	4.6
Annual cost saving	**Rs. Lakhs**	**11.08**
Investment	**Rs. Lakhs**	**Negligible**
Payback period	**Months**	**Immediate**

4.1.2 Replace reciprocating butter milk compressor with screw compressor

Background

Buttermilk section has a reciprocating compressor installed in the refrigeration system. The capacity of this compressor is 90 TR. This compressor is old and is used as backup compressor to operate only when there is an increase in refrigeration load. The refrigeration load will increase during buttermilk cooling as once buttermilk is made, it needs to be cooled from a temperature of 45 ^oC to around 8^oC. Since, this reciprocating compressor is used as an back up compressor, operating hours of this compressor are less as compared to other compressors. Typically, it operates for an average of 8 hours per day for around 8 months in an year.

Finding

Since compressor is reciprocating type; the specific energy consumption of this compressor was found to be 1.5 kW/TR which is high as compared to a new energy efficient screw type compressor.

Recommendation

Replace reciprocating compressor with screw compressor to reduce the specific energy consumption.

Energy & financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 22: Replacement of reciprocating compressor with screw compressor recommendation saving potential

Description	Units	Parameters
Rated parameters		
Rated capacity of compressor	TR	90
Rated power consumption of compressor	kW	136.08
Rated SEC of compressor	kW/TR	1.512
Proposed parameters		
Rated capacity of proposed compressor	TR	90
Rated power consumption of compressor	kW	67.5
Rated SEC of compressor	kW/TR	0.75
Saving SEC due to new screw compressor	kW/TR	0.762
Saving in SEC considered for calculation	kW/TR	0.662
Saving in power consumption	kW	59.58
Operating hours of this compressor	Hours	8
Annual operating days	Days	240
Annual energy saving	**kWh**	**114,393**
Power cost	Rs/kWh	4.6
Annual cost saved	**Rs. Lakhs**	**5.26**
Investment for new compressor	**Rs. Lakhs**	**20.0**
Payback period	**Months**	**45.5**

4.1.3 Install auto control valve in chiller PHE at yogurt and elaster section

Background

The plant has SCADA system in place and auto control valves are installed to control and maintain temperature of chilled water temperature in most of the processes. However, there are few sections/processes with still manual control valves and no SCADA control. The list of manual control valve PHEs at following plants chillers are:

Yogurt PHE chiller (20 kL) - 1 Number

Elaster plant PHE chiller (20 kL) - 1 Number

Finding

The chillers are installed at the yogurt and elaster section, which cool the product up to required temperature. Since there is no auto control valve in these sections so temperature of product is less than required temperature which is not desirable.

Since there is no control of chilled water flow as per the requirement, chilled water is flowing through PHE chiller at same rate irrespective of product flow rate and temperature. This will increase the plant heat load and chiller power consumption.

Recommendation

Install solenoid valve control in above yogurt and elaster section chillers PHEs.

Energy & financial savings

Installation of auto control valves at the chiller PHE's will reduce the chilled water consumption and thereby reduce the compressor power consumption.

Since it is not possible to estimate exact possible saving by theoretical calculation (which has to be realized practically); the saving potential is not calculated for this energy conservation measure.

4.2 Boiler and steam distribution

4.2.1 Increase condensate recovery percentage from 60% to 90%

Background

Plant is having boiler of 10TPH to supply steam to all the process in the plant. Steam is used for indirect heating process in plants. Due to indirect heating full steam is being converted to condensate and it should be pumped back to boiler.

Finding

The average condensate recovery percentage observed during the audit is about 60% only (data collected from plant record books). Since plant is generating an average of 7.5 TPH of steam, ideally 90 % of the condensate should be recovered back as per industry standards to boiler for its use as boiler feed water. Lower percentage of recovery indicates that condensate is being drained out in process areas that need to be arrested and the same needs to be pumped back to boiler section.

Recommendation

Revamp complete condensate recovery system in plant to arrest condensate leakage/condensate drain for complete condensate recovery to save boiler fuel consumption.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 23: Condensate recovery potential recommendation saving potential

Description	Units	Condensate recovery
Operating parameters		
Boiler capacity	TPH	10
Average steam generation in boiler	TPH	7.5
Ideal quantity of condensate to be generating in plant	TPH	7.5
Temperature of condensate collected	^oC	95
Present condensate collection percentage	%	60
Present condensate temperature at feed water tank	^oC	90
Condensate quantity at 60% recovery	m^3/h	4.5
Present heat recovery by condensate	kCal/h	270,000
Proposed parameters		
Proposed condensate recovery percentage	%	90

Description	Units	Condensate recovery
Proposed condensate temperature at boiler room	^oC	95
Quantity of condensate at 90% of recovery	TPH	6.75
	m^3/h	6.75
Extra heat recovered by increasing condensate percentage from 60% to 90 %	kCal/h	405,000
Heat energy saved by improving recovery	kCal/h	135,000
Natural gas calorific value	kCal/h	8,400
Fuel consumption saved	SCM/h	16
Annual operating hours	Hours	8,640
Annual fuel consumption saved	**SCM**	**138,857**
Fuel price	Rs/SCM	30
Annual saving potential	Rs Lakhs	41.65
Investment for complete revamp of recovery system	**Rs. Lakhs**	**40.0**
Payback period	**Months**	**11.5**

4.2.2 Reduce BFP discharge pressure by installing VFD control

Background

Plant is having a 10 TPH boiler to generate steam. Steam is generated at pressure of 17.5 kg/cm^2, there is a boiler feed water pump to pump the feed water to boiler for generating steam. The design and operating details of the boiler feed water pump is as below.

Design details:

Make	:	Grundfos
Model	:	CRN – 15-17
Power consumption	:	15 kW
Head developed	:	191.9 m
Flow delivered	:	17 m^3/h

Operating details (During audit)

Head developed	:	212 m
Flow delivered	:	7.5 m^3/h

Finding

It was observed that BFP is developing higher head than the requirement of the system. In any medium sized boiler, the feed water pressure should be 1 to 2 kg/cm^2 more than steam pressure. The higher pressure is required to overcome all static and frictional loss happening in pipes and valves. However, boiler feed water pump is generating more head & flow and it is controlled externally through control valve installed at the discharge side of pump.

Recommendation

The steam generation is varying in the plant throughout the day depending on the plant load. In order to match the feed water pump flow and pressure as per plant demand, it is recommended to install VFD on feed water pump with header pressure feedback control to vary frequency as per requirement.

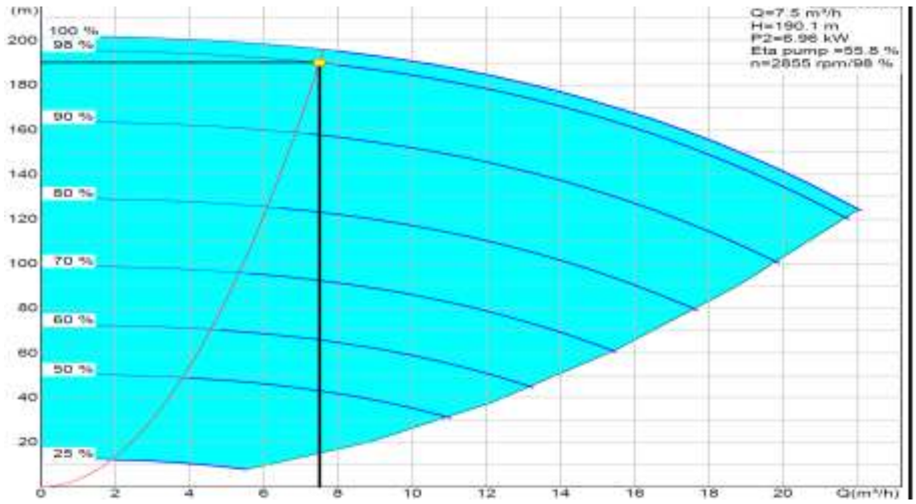
Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 24: VFD installation of boiler feed water pump saving potential

Description	Units	Boiler feed water pump
Design parameters		
Make		Grundfos
Model		CRN – 15-17
Power consumption	kW	15
Head developed	m	191.9
Flow delivered	m^3/h	17
Operating parameters		
Head developed	m	212
Flow delivered	m^3/h	7.5
pump power consumption	kW	12.5
Proposed parameters		
Head developed	m	190
Flow delivered(As per audit period boiler load)	m^3/h	7.5
Power consumption of pump with VFD	kW	7
pump power consumption saved	kW	5.5
Annual operating hours	Hours	8,640
Annual energy consumption saved	**kWh**	**47,520**
Power cost	Rs/kWh	4.6
Annual cost saved	**Rs Lakhs**	**2.18**
Investment for VFD and accessories	**Rs. Lakhs**	**2.00**
Payback period	**Months**	**11.0**

Figure 30: Proposed BFP parameters after VFD installation



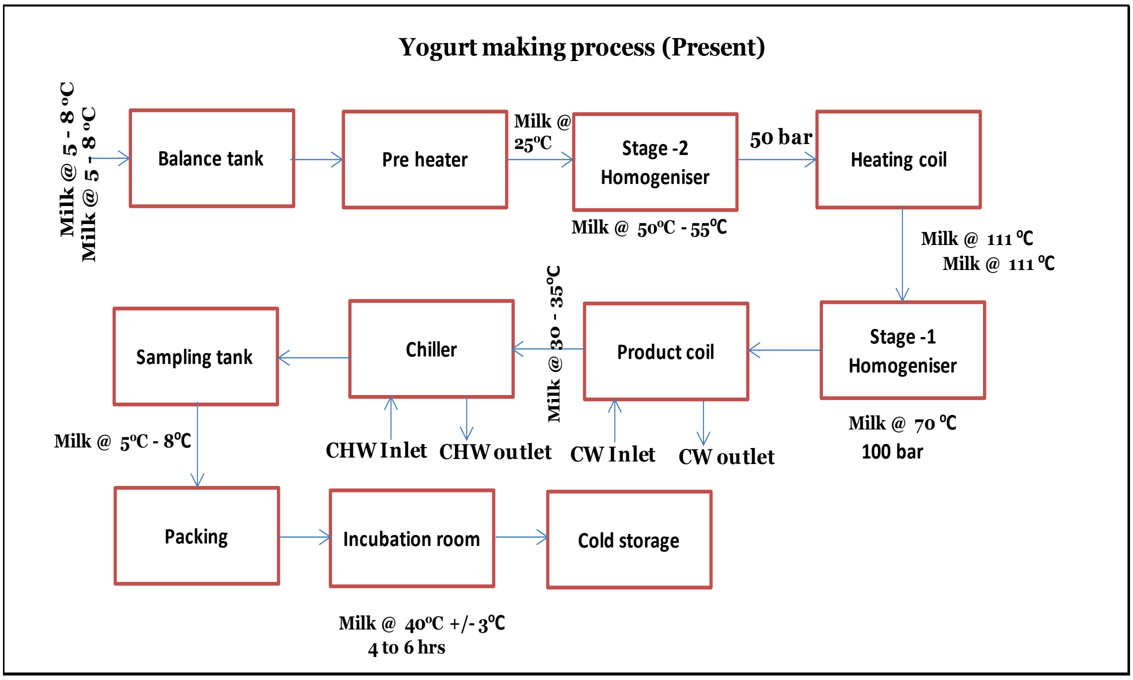
4.3 *Yogurt section*

4.3.1 Install milk pre heating PHE to pre heat milk before heating coil

Background

In the yogurt section, cold pasteurized milk is taken to balance tank and heated up to 111 °C by using multiple heating process. After heating milk, it is cooled again to a temperature of 5 to 8 °C by using CW and CHW water. The present milk heating and cooling process diagram is as follows.

Figure 31: Present yogurt making process flow diagram



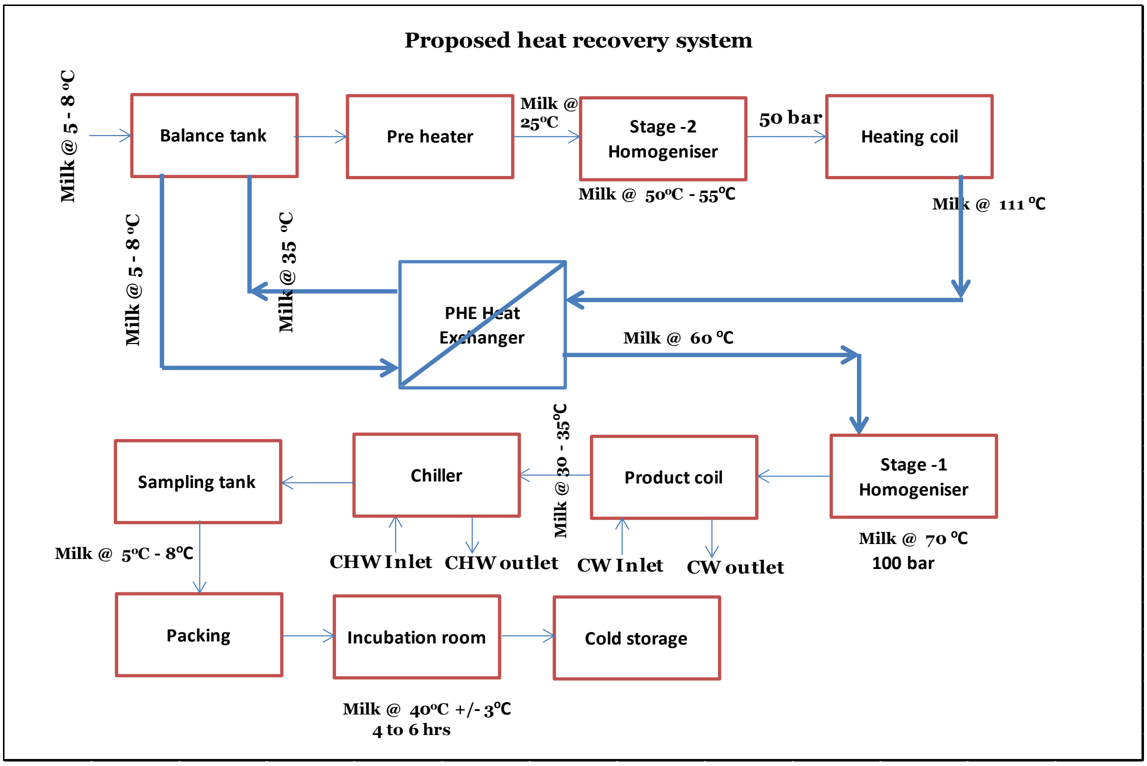
Finding

In the process of yogurt making, milk is heated up to 111 °C and cooled back to a temperature of 5 – 8 °C. This heating and cooling back to same temperature is a process requirement and considerable amount of energy is spent in this regard.

Recommendation

In the process of heating and cooling, there is a possibility of heat recovery from hot milk to cold milk. So, it is recommended to install a PHE to exchange heat between cold milk in balance tank and hot milk from heating coil. PHE installation will preheat cold milk, thereby saving fuel consumption in boiler by consuming less steam in heating the water. Proposed system diagram after PHE installation is as follows.

Figure 32: Proposed yogurt making process flow diagram



Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 25: Recover heat from hot milk in yogurt section to preheat cold milk saving potential

Description	Units	PHE heat recovery
Operating parameters		
Milk flow rate to Yogurt section	L/h	2,500
Milk inlet temperature to balance tank	°C	5 to 8
Milk temperature at the pre heater outlet	°C	25
Heating coil outlet temperature	°C	111
Proposed parameters		
Milk flow rate	L/h	2,500
Cold milk inlet temperature to preheater PHE inlet	°C	5 to 8
Hot milk inlet temperature to preheater PHE inlet	°C	111
Expected cold milk temperature after preheating	°C	35
Expected hot milk temperature after preheating	°C	60
Expected fuel saved due to pre heating	SCM/day	40
Fuel cost	Rs/SCM	30
Cost saved per day	**Rs/day**	**1,200**
Annual operating days	Days	350
Annual cost saved	**Rs. Lakhs**	**4.20**
Investment for PHE and piping	**Rs. Lakhs**	**4.00**

Description	Units	PHE heat recovery
Payback period	**Months**	**11.4**

4.4 *Elaster section*

4.4.1 Maintain required air flow rate and temperature of 24 °C in packing section

Background

An air-handling unit is installed in APS plant to supply air to packing section of yogurt and elaster section. This AHU is fitted with VFD and has a temperature controller to maintain temperature in the packing section. The VFD is set manually to 40 Hz when both packing sections are working and set at 36 Hz when only one packing section is working. The temperature maintained in both packing sections is 22 °C whereas the requirement is of 24 °C.

Finding

Even though total airflow required for both packing section is 30,000 cfm (yogurt section 13,000 cfm and elaster section 17,000 cfm) but AHU is delivering 48,000 cfm, which is very high compared to design requirement.

Also, the actual temperature measured in both of packing sections is 22 °C whereas a temperature of 24°C needs to be maintained as per the standards.

Recommendation

Reduce VFD frequency further down to maintain airflow rate of 30,000 cfm, when both packing sections are working and 13,000 cfm, when only yogurt packing working and 17,000 cfm when only elaster packing section is working.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 26: Control airflow rate and temperature in elaster packing section saving potential

Description	Units	AHU
Rated parameters		
Number of AHU installed	Number	1
AHU flow rate	cfm	64,000
Rated power consumption AHU motor	kW	22
Actual parameters		
Room pressure	mmWc	2
Room temperature	°C	22
VFD frequency	Hz	40
Actual air flow delivered by AHU	cfm	48,000
Actual power consumption of AHU motor	kW	17
Curd section room volume	ft^3	8,098
Elaster section room volume	ft^3	11,704
Air flow required at curd section as per design	cfm	13,000
Air flow required at elaster section as per design	cfm	17,000

Description	Units	AHU
Rated parameters		
Proposed parameters		
Temperature in the both section	^{o}C	24
Air flow rate from AHU	cfm	30,000
Extra air flow rate delivered as of now	cfm	18,000
Corresponding power consumption	kW	10.2
Annual operating hours	Hours	3,600
Annual energy saved	**kWh**	**36,720**
Power cost	Rs/kWh	4.6
Annual cost saved	**Rs. Lakhs**	**1.68**
Investment for Temperature controller	**Rs. Lakhs**	**Negligible**
Payback period	**Months**	**Immediate**

Note: Saving is estimated in above table is for reducing the airflow rate by adjusting VFD frequency only; increasing the set temperature to 24 ^{o}C will further increase the saving potential.

4.5 *Powder plant*

4.5.1 Install VFD in delivery and exhaust fan

Background

Powder plant is having drier, which is fitted with delivery fan to supply fresh air to drier through air heater and exhaust fan to exhaust the air from drier.

Delivery fan is having rated power consumption of 45 kW, exhaust fan is having rated power consumption of 95 kW, and these fans operates whenever drier operates. Both fans are important equipments in milk drying process as these fans maintain airflow rate, pressure and temperature in the drier.

Finding

Both these fans are operating with throttle condition at the suction side. These fans are throttled to maintain required pressure and flow rate delivered to drier. Throttling is a bad practice of maintaining fans/blowers pressure or flow rate since throttling significantly increases power consumption.

Recommendation

It is recommended to install VFD control instead of throttling of these fans and operate at lower frequency to maintain required pressure and flow rate to drier.

It is also suggested to install VFD to delivery fan with header pressure feedback control to vary frequency as per requirement and install VFD on exhaust fan with drier draft feedback control on VFD to vary frequency.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 27: Installation of VFD on power plant drier delivery and exhaust fan saving potential

Description	Units	Delivery fan	Exhaust fan
Present parameters			

Description	Units	Delivery fan	Exhaust fan
Fan rated power consumption	kW	45	95
Damper open percentage at suction side	%	40	70
Damper close percentage at suction side	%	60	30
Damper open percentage at discharge side	%	100	100
Damper close percentage at discharge side	%	0	0
Actual power consumption of these fans	kW	34	47
Proposed parameters			
Damper open percentage at suction side	%	100	100
Damper close percentage at suction side	%	0	0
Damper open percentage at discharge side	%	100	100
Damper close percentage at discharge side	%	0	0
Expected percentage of power saving due to VFD	%	20	20
Power saving	kW	6.8	9.4
Annual operating hours	Hours	5,760	5,760
Annual energy saved	**kWh**	**39,168**	**54,144**
Power cost	Rs/kWh	4.6	4.6
Annual cost saved	**Rs. Lakhs**	**1.80**	**2.49**
Investment for VFD's	**Rs. Lakhs**	**3.40**	**4.70**
Payback period	**Months**	**22.6**	**22.6**

Note: Since there was no provision to measure pressure drop across fan and at throttling damper, saving are estimated in percentage. The above given saving is indicative only, actual saving need to be realized practically.

4.5.2 Install VFD control on IFBD and EFBD fans

Background

There are two EFBD fans and one IFBD fans installed in the drier section. These fans supply fresh air to IFBD and EFBD process. Fresh air from these fans is pre heated by using steam heaters provided at discharge side of each fan.

Rated power consumption of the IFBD fan is 5.5 kW and EFBD fan is 3.7 kW. Both fans are working with throttling at discharge side to control airflow rate delivered to drier. These fans discharge side damper is closed by 50 % and open by 50%.

Finding

Both of these fans are operating with throttling at the discharge side, these fans are throttled to maintain proper pressure and flow rate delivered to drier. Throttling is a bad practice of maintaining fans/blowers pressure or flow rate since throttling significantly increases power consumption.

There is an air preheater installed at the discharge side of these fans, fresh air is getting heated by steam in air heater before sending to drier. Steam flow to air heater is manually controlled by butterfly valve, which is leading to higher air temperature than required.

Recommendation

Instead of throttling, install VFD control on these fans and operate at lower frequency to maintain required pressure and flow rate.

Install auto control valve at the air heater of both IFBD and EFBD blower to control the steam flow rate to maintain correct air temperature.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 28: Installation of VFD on power plant drier IFBD and EFBD fan saving potential

Description	Units	IFBD	EFBD – 1 & 2
Present parameters			
Fan rated power consumption	kW	5.5	3.7
Damper open percentage at suction side	%	100	100
Damper close percentage at suction side	%	0	0
Damper open percentage at discharge side	%	50	50
Damper close percentage at discharge side	%	0	0
Actual power consumption of these fans	kW	3.9	2.2
Proposed parameters			
Damper open percentage at suction side	%	100	100
Damper close percentage at suction side	%	0	0
Damper open percentage at discharge side	%	100	100
Damper close percentage at discharge side	%	0	0
Expected percentage of power saving due to VFD	%	20	20
Power saving	kW	0.78	0.88
Annual operating hours	Hours	5,760	5,760
Annual energy saved	**kWh**	**4,492**	**5,068**
Power cost	Rs/kWh	4.6	4.6
Annual cost saved	**Rs. Lakhs**	**0. 20**	**0.23**
Investment for VFD's	**Rs. Lakhs**	**0.55**	**0.74**
Payback period	**Months**	**32**	**38**

Note: Since there was no provision to measures the pressure drop across the fan and at throttling damper, saving is estimated in percentage. The above given saving is indicative only, actual saving need to be realized practically.

4.6 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/m² 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 33: 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

4.6.1 Solar assessment in Sumul dairy

For Sumul dairy in Surat area, the details of the solar radiation data for site is as follows:

Table 29: Physical features of the dairy

Parameters	Unit	Climate data location
Latitude	˚N	21.17
Longitude	˚E	72.83
Elevation	m	64
Heating design temperature	ºC	18.57
Cooling design temperature	ºC	37.3

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 dairy 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 30: Average monthly insolation data

Month	Daily solar radiation horizontal (kWh/m²/d)	Air Temperature (°C)	Winds Speed (m/s)	Relative Humidity (%)
January	4.66	24.2	2	33.00%

Month	Daily solar radiation horizontal (kWh/m²/d)	Air Temperature (°C)	Winds Speed (m/s)	Relative Humidity (%)
February	5.34	26	2.1	29.40%
March	6.18	30.1	2.3	26.50%
April	6.55	32.2	2.6	31.80%
May	6.54	31.9	3.1	46.10%
June	5.45	29.4	3.3	68.70%
July	4.42	27.4	3.2	80.30%
Aug.	4.38	27.1	2.6	78.20%
September	5.07	28.2	2.1	66.00%
October	5.23	29.6	1.5	43.60%
November	4.69	28	1.4	32.20%
December	4.26	25.1	1.7	33.10%
Annual	**5.23**	**28.3**	**2.3**	**47.40**

4.6.2 Energy and cost parameters for installation of CST modules

On the basis of availability of 2,000 m² roof top area in the Sumul dairy, a comparison of energy and cost parameters for CST water heaters that can be installed in the dairy is provided below:

Table 31: Energy and cost parameters for solar CST modules

Description	Units	Parameters
Present operating parameters		
Estimated area available for CST installation	m²	2,000
Temperature of water considered in ambient condition	ºC	30
Expected temperature of the hot water from CST unit	ºC	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	19,535
Annual operating days per year	Days	300
Annual cost saving by CST installation	**Rs. lakhs**	**71.3**
Investment for complete CST installation	Rs. lakhs	360
Possible subsides from government and other agencies	Rs. lakhs	162
Net investment required for CST project	Rs. lakhs	**192**
Payback period (Excluding possible subsidy)	**Months**	**60**

Note: Energy and cost estimation is merely indicative of the performance of CST modules but the actual generation will be different and will depend upon the technologies and the type of configuration selected by the project developer. The heat delivered by 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 List of 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 32: 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's 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's to the Gujarat dairy sector.

Table 33 : Vendor details for recommended saving solution

Equipment/ Technology	Product	Manufacture/ Brand	Available Location
Refrigeration compressor	Compressors	Mycom	**Adarsh Industries** 307, Shankala Industrial Estate, Gogatewadi, Off Aarey Road, Goregaon East, Mumbai - 400063
Auto control valves	Valves	FlowTek	**FLOW-TEK VALVES & CONTROLS INC.** Plot No. 172-173, Road No. 4, G.I.D.C. Estate, Kathwada, Ahmedabad - 382 430. Gujarat, INDIA. Mobile: +91 - 9824080899
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 Roads Opp. Sri Krishna Centre Ahmedabad - 380009
	VFD	Siemens	**Siemens Ltd** 3rd Floor, Prerna Arbour, Opp. Singapore Airlines, Nr Girish Cold drinks cross roads, Off. C. G. Road, Ahmedabad - 380009 Tel.: +91 (079) 30927600/40207600
Plate heat exchanger	PHE	Alfa Laval	**Alfa Laval India Private Limited** 4, Vasna Road, Shobhna Nagar, Shobhna Nagar, Vadodara, Gujarat 390015

Equipment/ Technology	Product	Manufacture/ Brand	Available Location
APFC	Capacitors	Schneider	**Schneider electric India Private Limited** No. 42A, 4th Floor, Space House, Mithakali Six Road. Opp. Sri Krishna Centre Ahmedabad - 380009

** 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.*