Energy Audit Report: Rajkot Dairy, Rajkot

Conducting energy audit & dissemination activities in Gujrat

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
CO_2	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
HMST	Homogeneous milk storage tank
PMST	Pasteurized milk storage tank
RMST	Raw milk storage tank

Conversion Table

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

PwC is thankful to Gujarat Cooperative Milk Marketing Federation Limited (GCMMF) for extending support for this assignment. We are also thankful to Mr. P. K. Sarkar and his team for giving full support during the energy audit. We would like to thank Mr. Falgun Pandya, Cluster Leader - Gujarat, GEF-UNIDO-BEE Project for providing on-field support during the energy audit.

We would also like to acknowledge the support, valuable inputs, co-operation and guidance provided by Mr. A. C. Sinha, Managing Director and Mr. Dilip Hirpara (Manager - Engineering) during field measurements at Rajkot dairy, Rajkot.

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. In this respect, refrigeration system energy audit of Rajkot dairy was one of the plants wherein 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.

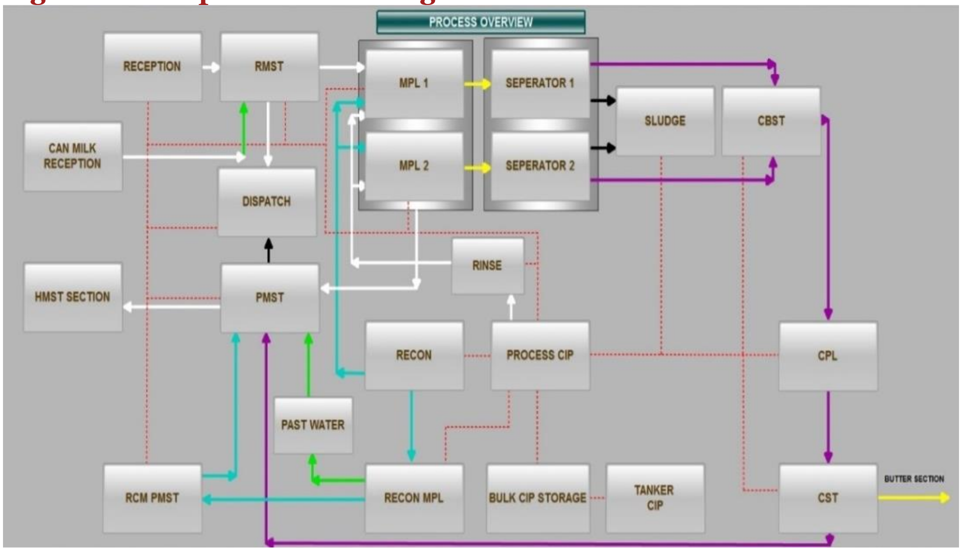
1.3 About Rajkot dairy

The Rajkot dairy is located on the Dudh Sagar Road in Rajkot city. Milk is collected from 600 villages near Rajkot district. Dairy receives milk directly from farmers and also from six chilling centres located at different locations of the Rajkot district. The Dairy plant is 50 years old and has undergone many technological upgrades, revamps to improve milk quality and reduce energy consumption. Presently, plant is manufacturing milk, butter milk and ghee.

Process flow:

Plant processes about 250,000 L of milk every day. Out of which 150,000 L milk is received from different chilling centres at 10°C and about 100,000 L from farmers directly through milk cans which is at ambient temperature. Detailed process flow diagram is as follows.

Figure 1: Milk process flow diagram



Tanker Reception/Cane Milk Reception: It is milk receiving area in new plant, where milk is received at 10 °C from chilling centres in new plant and at ambient temperature from cans in old plant.

Raw milk storage tank (RMST): After milk is received it is cooled in raw milk chiller up to 4 °C and stored in the raw milk storage tank (RMST) for further process.

Pasteurised milk storage tank (PMST): After raw milk is chilled and stored in RMST, it is sent for the pasteurisation process. Where in pasteurisation process milk is heated up to 75 °C and again cooled to 4 °C then stored in the Homogeneous milk storage tanks (HMST) and sent for packing section.

Packing section: After milk is processed completely, it is stored in HMST tanks and sent to packing machine for packing through HMST chillers to maintain milk temperature of 4 °C before packing. Milk is packed in packets of different sizes and stored in the cold storages before loading to trucks.

CIP (Cleaning in Progress): Cleaning is the integral part of dairy process and it is done on regular basis as per the standards.

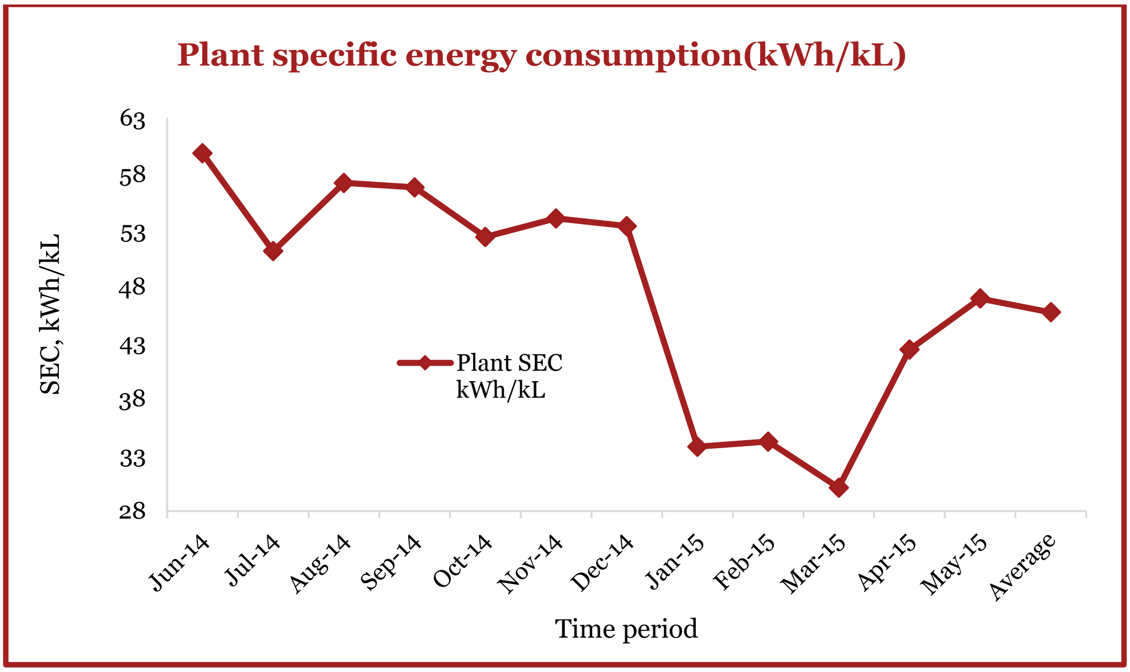
1.4 Present energy scenario & specific energy consumption

Plant uses electricity as the main energy inputs to operate. The electrical energy consumption of the entire plant is tabulated and compared with the quantity of milk processed to find the average electrical energy spent on processing each litre of milk. The same is tabulated below.

Table 1 : Present energy consumption scenario and plant specific energy consumption

Months	Milk handled (L/month)	Electricity consumption (kWh/month)	Plant SEC (kWh/kL)
June -14	8,976,894	537,160	59.8
July-14	10,011,220	511,900	51.1
August-14	9,418,544	538,880	57.2
September -14	9,749,744	553,920	56.8
October-14	9,608,212	503,520	52.8
November-14	9,411,894	508,720	54.1
December-14	9,503,964	507,180	53.4
January-15	15,850,234	534,540	33.7
February-15	14,083,049	481,320	34.2
March-15	14,930,834	449,080	30.1
April-15	13,197,205	558,960	42.4
May-15	11,720,923	549,880	46.9
Average	**11,371,893**	**519,588**	**45.7**
Total	**136,462,717**	**6,235,060**	

Figure 2: Plant specific energy consumption



- Plant is spending on an average 45.7 kWh of electrical energy for processing every one kL of milk.
- The total energy consumption of the plant from June, 2014 to May, 2015 was 6,235,060 kWh and the milk processed during same time period was 136,462,717 L.

1.5 Refrigeration annual energy consumption

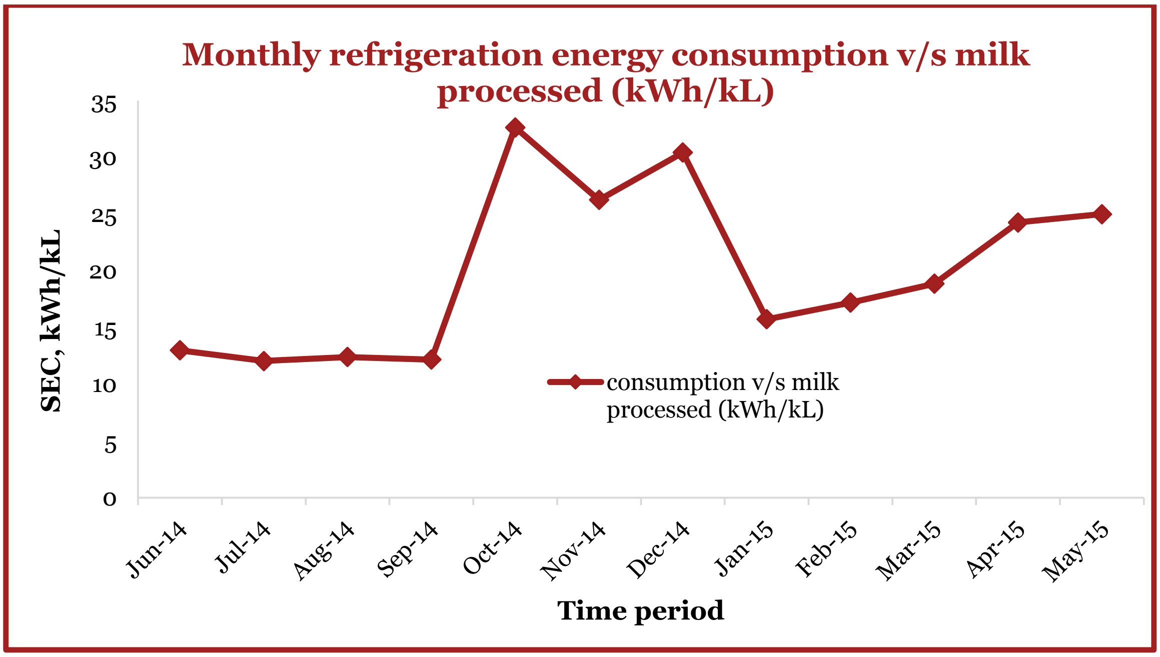
Refrigeration is the one of the major loads in the dairy plant and it is consuming about 55 % of the total energy consumption. Refrigeration system runs continuously throughout the year. The annual electrical energy consumption of the refrigeration system is as below on monthly basis.

Table 2 : Refrigeration annual energy consumption

Months	Refrigeration energy consumption (kWh/month)	Milk handled (L/month)	Refrigeration consumption v/s milk processed (kWh/kL)
June -14	116,789	8,976,894	13.5
July-14	120,786	10,011,220	12.5
August-14	116,896	9,418,544	12.4
September -14	118,859	9,749,744	12.2
October-14	313,718	9,608,212	32.7
November-14	247,169	9,411,894	26.3
December-14	289,205	9,503,964	30.4
January-15	249,570	15,850,234	15.7
February-15	242,343	14,083,049	17.2
March-15	281,867	14,930,834	18.9
April-15	320,448	13,197,205	24.3
May-15	293,091	11,720,923	25.0

Months	Refrigeration energy consumption (kWh/month)	Milk handled (L/month)	Refrigeration consumption v/s milk processed (kWh/kL)
Average	225,895	11,371,893	19.86
Total	2,710,741	136,462,717	

Figure 3: Refrigeration energy consumption and milk processed comparison



- Monthly average of refrigeration energy consumption is 225,895 kWh/month and average milk processed is 11,371,893 L/month.
- In an average 19.86 kWh of refrigeration system, electrical energy is spent on processing every kL of milk.

1.6 *Plant energy consumption and savings summary*

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

Table 3: Summary of plant energy consumption and energy savings

Particulars	Unit	Values
Annual plant electrical energy consumption	kWh/annum	**6,235,060**
Annual plant electrical energy cost	Rs. lakhs	**479**
Proposed electrical energy saved annually in refrigeration system	kWh/annum	**724,040**
Proposed refrigeration system annual cost saved	Rs. lakhs	**33**
Proposed investment	Rs. lakhs	**27**
Payback period	Months	**10**
Internal rate of return (IRR)	%	**105**
Proposed percentage of total plant electrical energy saved	%	**11.6**
Proposed percentage of total plant cost saved	%	**6.8**

1.7 Summary of proposed energy conservation measures

Table 4: Summary of proposed energy conservation measures

S. No.	Suggested energy conservation measure	Annual energy savings	Annual cost saving	Investment	Payback period
		kWh/annum	Rs. Lakhs	Rs. Lakhs	Months
1	Increase chilled water set point from 0 ºC to 1 ºC during night time after 12 AM up to 6:00 AM	**18,900**	**0.81**	**Nil**	**Immediate**
2	Control door openings in cold room by proper scheduling of truck loading to reduce the load on the indoor units and to maintain required temperature in cold rooms	**86,340**	**3.92**	**Negligible**	**Immediate**
3	Increase cooling water flow from 105 m^3/h to 138 m^3/h and clean condenser tubes to reduce condenser approach which will reduce the compressor power consumption	**464,800**	**21**	**8**	**5**
4	Install VFD on chilled water pumps with pressure control feedback system to vary the flow rate as per the user end heat load requirement	**42,000**	**1.91**	**4**	**25**
5	Install solenoid valve control at all old plant PHE chillers to avoid idle chilled water flow to reduce the unwanted heat pick up by chilled water and chilled water pump power consumption	**112,000**	**5**	**15**	**36**
Total		**724,040**	**33**	**27**	**9.9**

2 Introduction

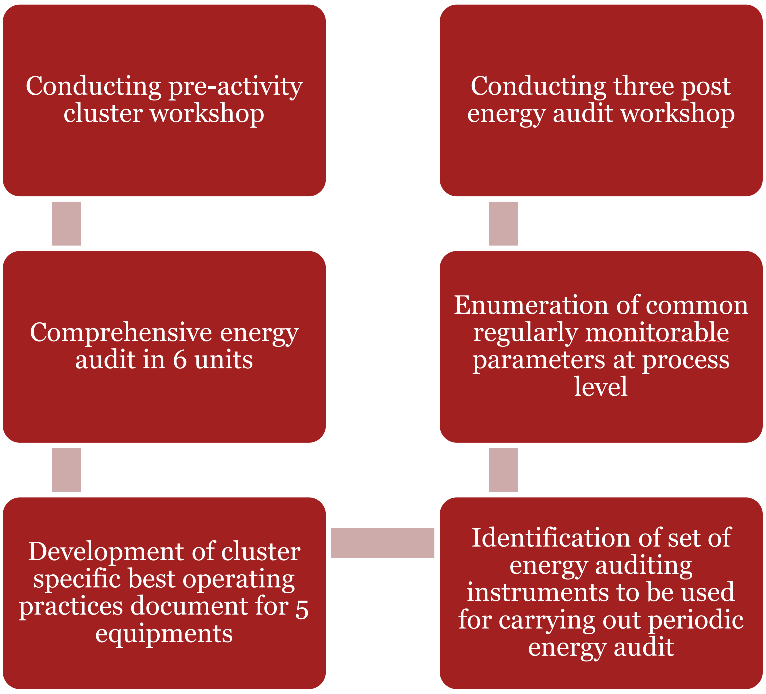
2.1 Introduction

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 Rajkot dairy was one of these 6 audits.

2.2 Scope of services

The scope of this assignment is shown at following figure.

Figure 4: 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 Rajkot Dairy has been selected one of these six.

2.3 Energy audit scope and approach

A detailed refrigeration system energy audit was undertaken at Rajkot Dairy and field work for energy audit was conducted from August 05 -07, 2015. The energy audit team of PwC comprised of refrigeration and electrical energy experts. During field visit, a range of portable energy audit instruments were used to take various measurements at refrigeration system of the plant. In addition, design and operational data were collected from logbooks and equipment manuals. Discussions were held with technical personnel at the plant to fully understand its operations and energy requirements. The energy audit was focused on the study of refrigeration system and the evaluation of operational efficiency/performance of such equipment from the energy conservation point of view.

The following areas were covered during the study:

- ***Refrigeration system***
  - ✓ Refrigeration compressor
  - ✓ IBT Tanks
  - ✓ HP & LP refrigerant receivers
  - ✓ Evaporative cooling towers
  - ✓ Cooling water and Chilled water pumps
  - ✓ PHE Chillers
- ***Renewable Energy***
  - ✓ Opportunities were identified for use of renewable energy

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

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

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

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

2.4 About refrigeration system

The plant process on an average 2,50,000 L of milk every day. Out of which 1,50,000 L of milk is received from six different chilling centres at 10 ^{o}C to the new plant and around 1,00,000 L directly from farmers milk cans, which is at ambient temperature.

Collected milk is first cooled to the temperature of 4 ^{o}C through raw milk chillers and stored in the raw milk storage tanks. Then raw milk is sent to the pasteurisation process and after that pasteurised milk is stored again at the temperature below 4 ^{o}C in the HMST tanks before packing.

Milk is sent for the packing section depending on the market demand and extra processed milk is sent to other nearby packing plants through trucks. Packed milk in the plant is stored in the cold storage and loaded to trucks for distribution.

Refrigeration system is required in the dairy for maintaining the milk temperature of 4 °C. To cater the cooling requirement of the entire plant, dairy is having a centralised refrigeration system, through which refrigeration requirement of old plant, new plant and cold storages are served.

Below list of tables, lists the major energy consuming refrigeration equipment and auxiliaries at the plant.

Table 5 : List of load (Equipments) in the refrigeration system

Section	Name of equipment	Quantity
Refrigeration	Screw compressors	3
	Evaporator condenser water pumps	3
	Liquid ammonia pumps	11
	Chilled water pumps	8
	Evaporator condenser fan	3
	IBT Tanks	2
	HP receivers	3
	LP receiver	1
	Agitators	2
	PHE chillers – Old plant	3
	PHE chillers – HMST	2
	PHE chillers – Refrigeration rooms	1
	PHE chillers – New plant	15

3 Observation and Analysis

Dairy plant is installed with refrigeration system to cater the cooling requirement for milk storage and processing. The refrigeration system is the major load in any dairy plant, which consumes about 55 % of total electrical energy consumption. The detailed energy audit was conducted in the refrigeration system of the plant to identify energy saving opportunities. The observations and measurements taken on each equipment and the result of their analysis is discussed below.

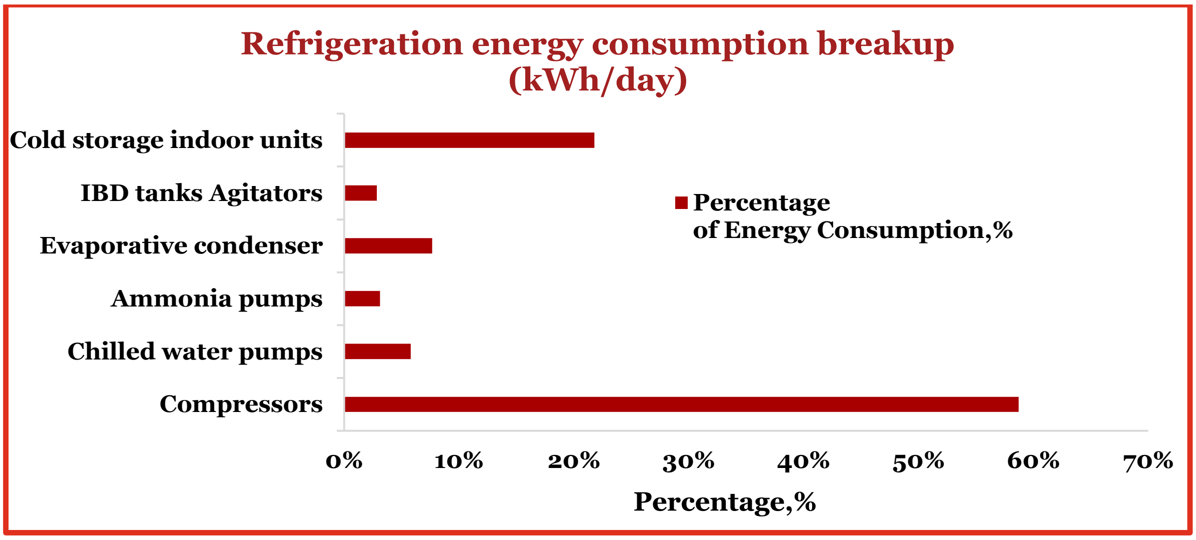
3.1 Energy consumption breakup

Detailed electrical measurement was done on all energy consuming equipment in refrigeration system, and energy consumption breakup is derived and it is tabulated below.

Table 6: Refrigeration energy consumption breakup

Description	Power consumption (kW)	Energy consumption (kWh/day)	Percentage of consumption (%)
Compressors	332	6,640	59%
Chilled water pumps	2	658	6%
Ammonia pumps	15	355	3%
Evaporative condenser	36	868	8%
IBT tanks Agitators	13	324	3%
Cold storage indoor units	112	2,464	22%
Total	**535**	**11,308**	**100%**

Figure 5: Refrigeration energy consumption breakup



- The major energy consumer in the refrigeration system is the compressors, which consumes about 60% of total electricity consumption.
- Refrigeration system runs continuously throughout the year whereas only one compressor runs during night time (after 12 AM to 6 AM).

3.2 Cooling consumption (TR) breakup

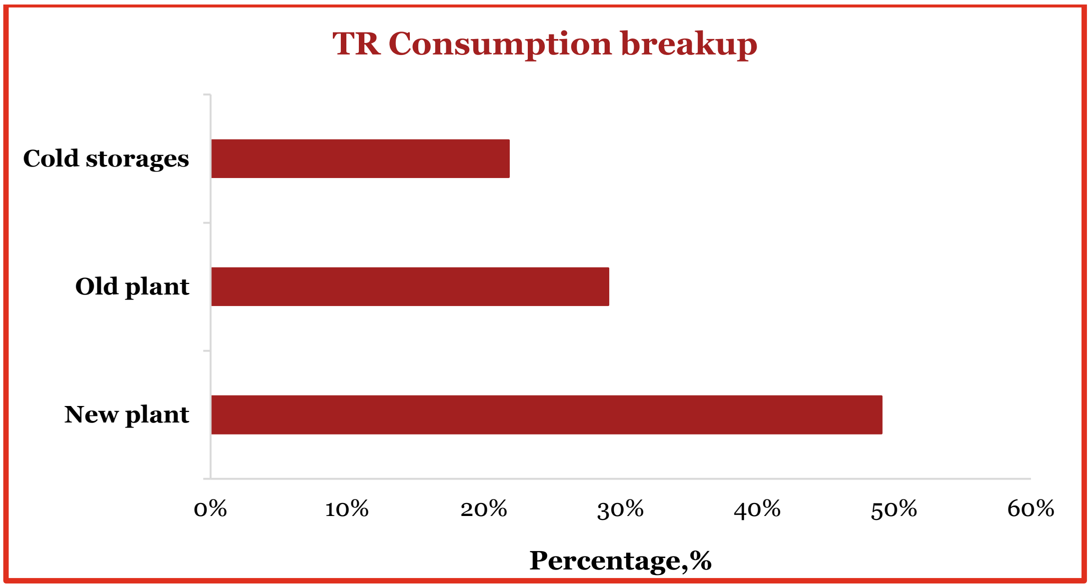
Cooling generation by the refrigeration system is calculated by flow, temperature and power measurement carried out during the audit. The average cooling consumption of each plant is given below.

Table 7: Refrigeration consumption breakup

Description	Cooling consumed (TR)	Percentage of consumption (%)
New plant	135	49%
Old plant	80	29%
Cold storages	60	22%
Total	**275**	**100%**

Note: Cooling generation given in the table is just indicative figure at one instantaneous time in the complete day profile given in section 3.3.2.

Figure 6: Refrigeration TR consumption breakup



- Old plant consumes about 29 % of total cooling load, it receive an average 1 lakhs liters of milk which is cooled up to 4 °C and is then sent to new plant for further processing.
- The new plant consumes about 49% cooling load, it receives an average of 1.5 lakhs liters of milk every day and processes 2.5 lakhs liters of milk.

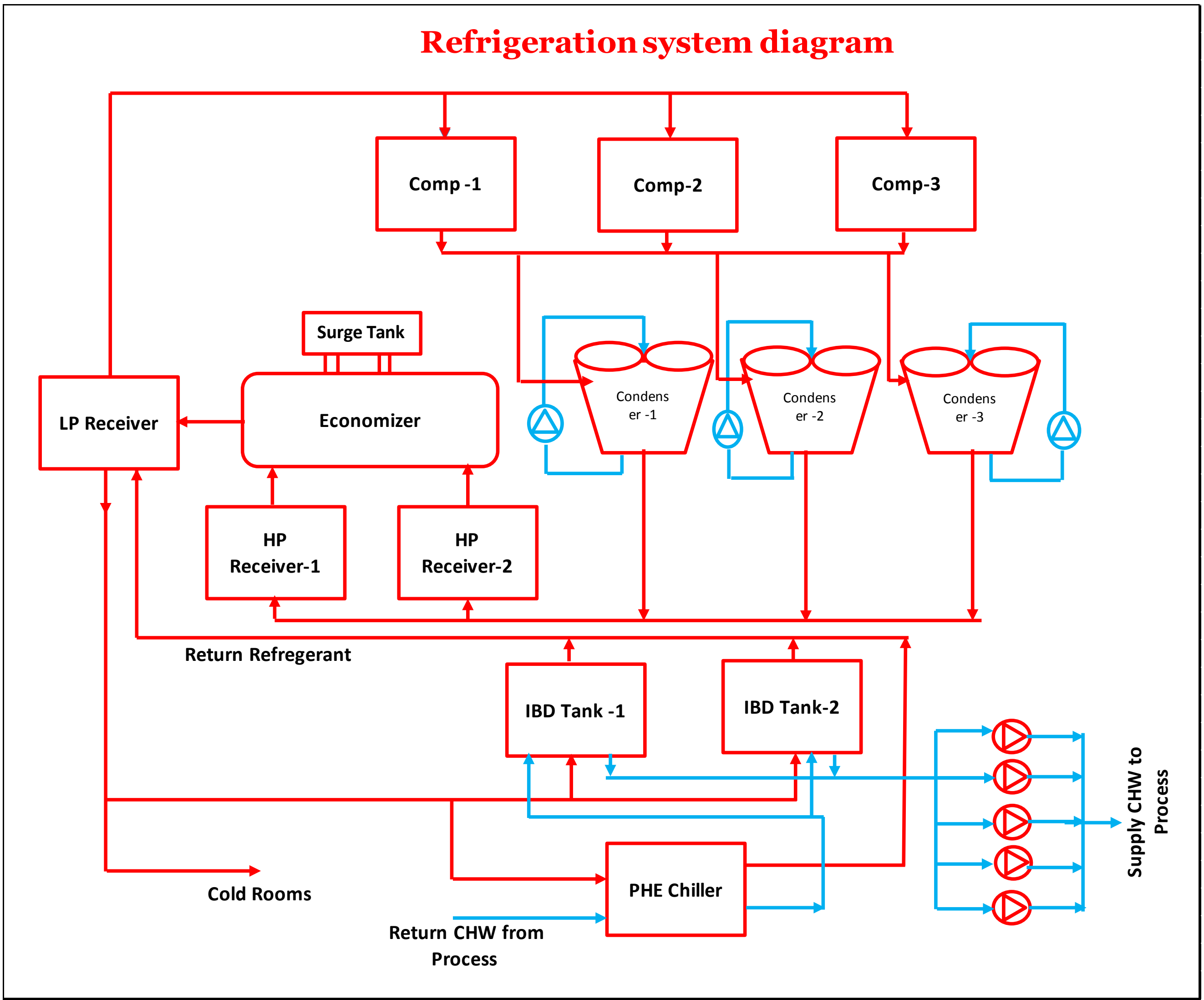
3.3 Refrigeration system – Generation end

The plant is having a centralized refrigeration system wherein chilled water & cooled ammonia refrigerant is generated and sent to following three major users of the plant:

- New Plant - Chilled water user
- Old plant - Chilled water user
- Cold storages - Ammonia refrigerant user

In order to maintain cooling in these areas; plant has installed three refrigeration compressors of 200 TR capacity each. The refrigeration system diagram is as follows.

Figure 7: Refrigeration system diagram



Refrigeration system consists of compressors, evaporative condensers, PHE chillers, chilled water pumps, HP & LP receivers and IBD tanks. All these equipments are working together to deliver the required chilled water temperature. The hot refrigerant from compressors after being compressed goes to evaporative condensers, where it gets cooled and a change of phase from gas to liquid happens. Further, liquid refrigerant goes to HP receiver; and from HP receiver, refrigerant goes to LP receiver and then to IBD tanks through expansion valve. In the expansion valve, refrigerant gets expanded and temperature is reduced further. After expansion valve, refrigerant goes to PHE chiller and IBD tank wherein refrigerant cools return chilled water and picks heat from water and due to heat pickup; refrigerant changes its phase and goes to LP receiver in gaseous form. This gaseous refrigerant goes to compressor again for compression and this cycle continues.

During normal operation, plant runs with following refrigeration equipments to meet the cooling load:

- Number of compressors = 2 numbers
- Number of evaporative condensers = 3 numbers
- Number of chilled water pumps = 2 numbers
- Number of ammonia pumps = 3 numbers
- Number of IBT tanks = 2 numbers

3.3.1 Design details

The design details of the refrigeration system equipment are as follows:

Refrigeration Compressors

Make	:	Frick
Model	:	N 200 USDD – MSX
Capacity	:	192.7 TR @ - 5°c
Capacity	:	223.1 TR @ -1°C
Power consumption	:	200 kW
Design pressure	:	2.6 MPag
Test pressure	:	3.9 MPag
Working fluid	:	Ammonia (NH_3)
Shell side max (WP) design pressure	:	16/90 kg/cm²
Shell side max (WP) design temperature	:	90/100 °C

LP Receiver

Type	:	Horizontal
Shell diameter in mm	:	1,524
Shell length in mm	:	4,878
Material of construction	:	SA 516 Grade 70
Thickness of shell	:	16mm
Thickness of dish end	:	25mm
Design pressure	:	11 bar
Test pressure	:	21 bar

HP Receiver

Type	:	Horizontal
Number of receiver	:	One
Capacity (Holding)	:	5,600
Material of construction	:	SA516 grade 70

PHE Chiller

Capacity	:	544,320 kCal/h
Water flow	:	300 m³/h
Water inlet temperature	:	3.3 °C
Water outlet temperature	:	1.5 °C

Evaporative condenser

Model	:	CATS – 329
Capacity	:	308.5 TR
Condensing temperature.	:	38 °C
Design WBT	:	27 °C
Fan rating	:	15 kW
Pump rating	:	2.2 kW
Water flow	:	138 m^3/h

3.3.2 Specific energy consumption

The specific energy consumption of the refrigeration system is evaluated by measuring the temperature, power consumption and pressure parameters of all refrigeration equipments. This is presented in following table.

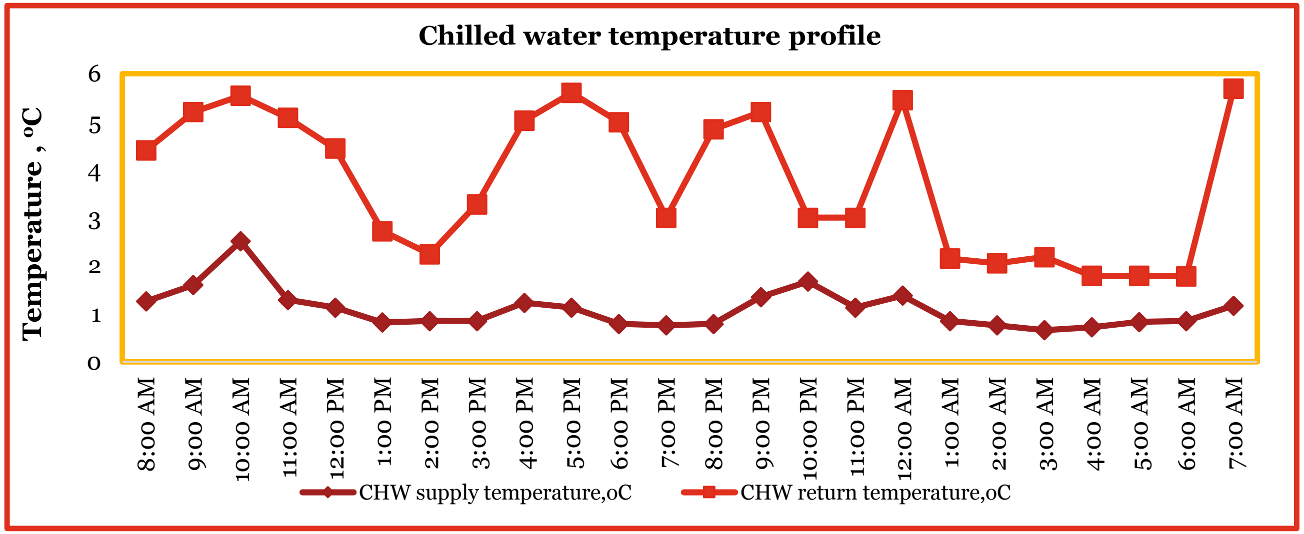
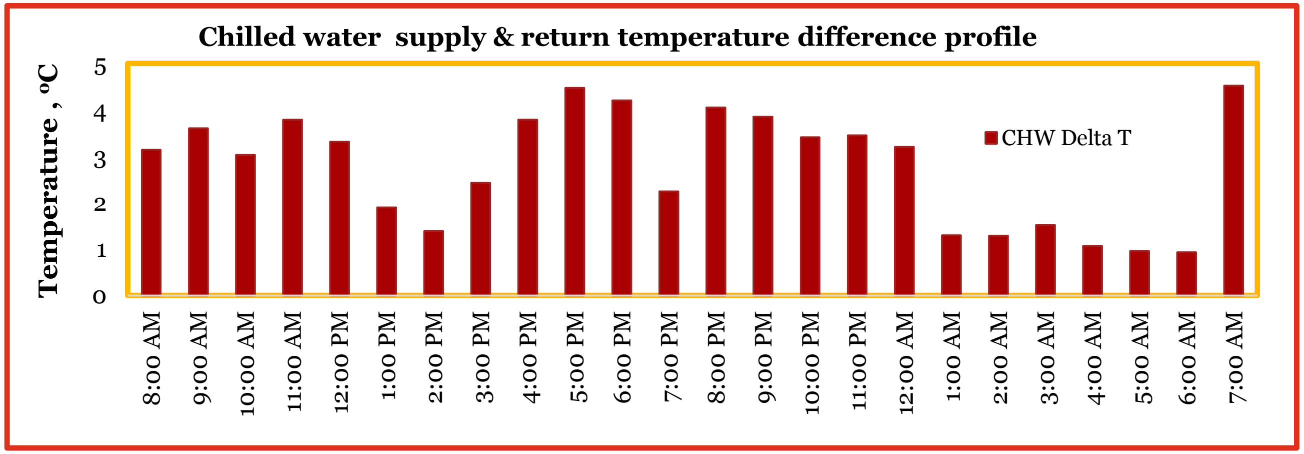
Table 8: Refrigeration SEC

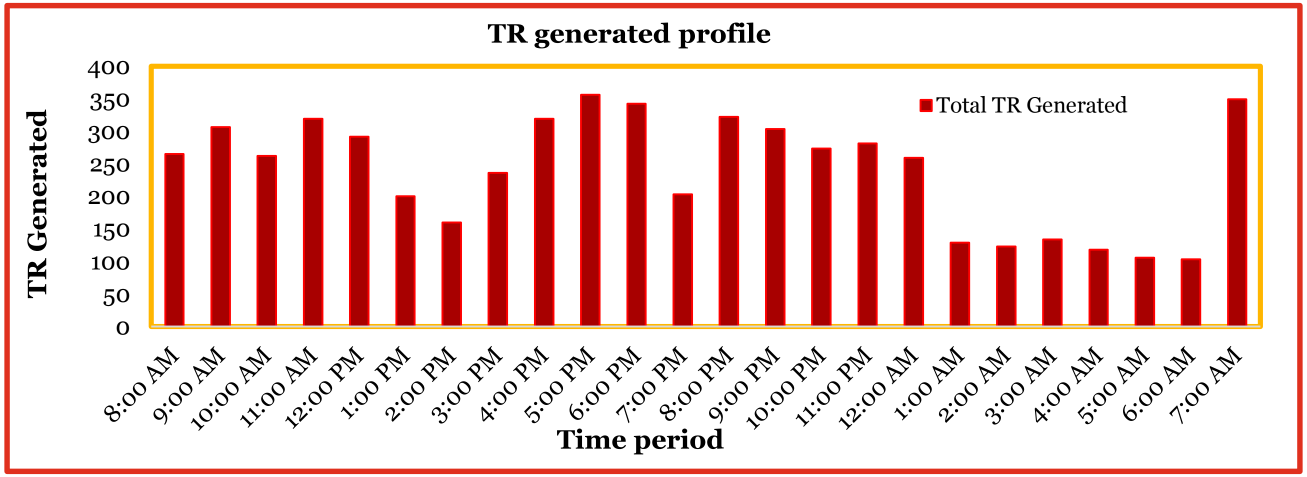
Description	Units	Parameters
Operating parameters		
Capacity of the refrigeration system with one compressor	TR	223.1 @-1°C
Number of compressors installed	Numbers	3
Number of chilled water pumps installed	Numbers	8
Number of IBT tanks	Numbers	2
Number of evaporative condenser installed	Numbers	3
Rated consumption of compressor	kW	200
Rated consumption of chilled water pumps	kW	15
Rated consumption of condenser fan	kW	11
Rated consumption of condenser pump	kW	2.2
Proposed operating parameters		
Number of compressors operating	Numbers	2
Cooling generated*	TR	279
Compressor power consumption	kW	280
Chilled water pumps consumption	kW	29
Ammonia pumps consumption	kW	10.8
Condenser fans	kW	29.4
Condenser pumps	kW	5.4
IBT tank agitators	kW	4.4
Cold storage indoor units consumption	kW	112
Total consumption of refrigeration system	kW	471
SEC of complete refrigeration system	**kW/TR**	**1.69**
SEC of refrigeration system by only considering compressors power	**kW/TR**	**1.0**

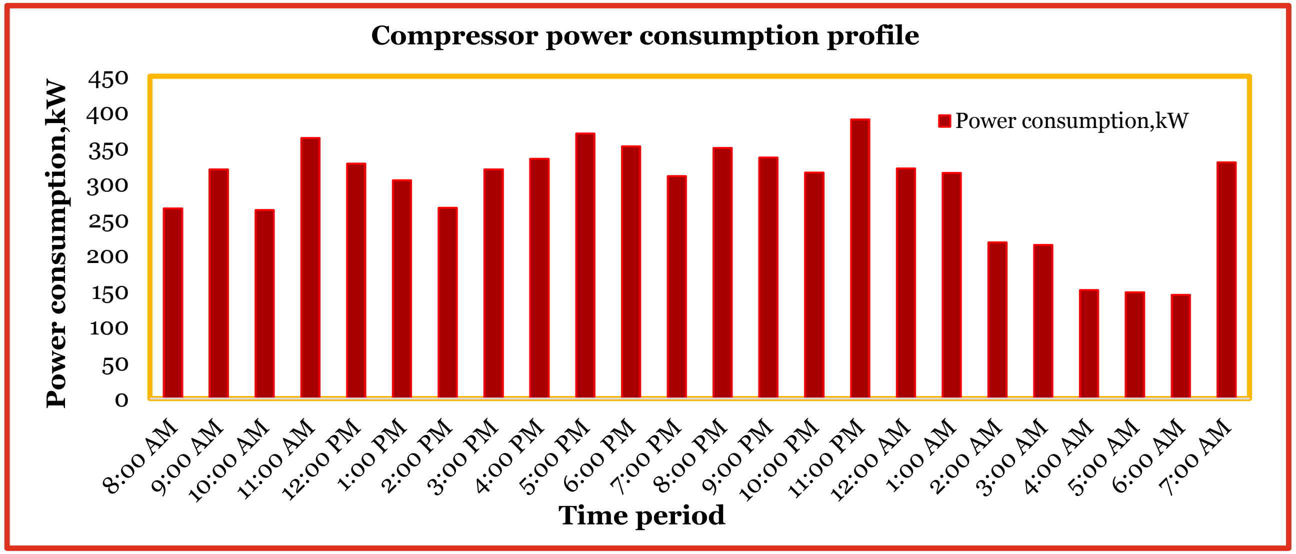
*The cooling load measurement done on 5/08/15 @ 12PM

The specific energy consumption of the refrigeration system (only compressors power) is as per the rated and it shows that the system is running as per the design. The various temperature and power consumption measurement of refrigeration system were carried out during audit to evaluate its performance and it is as follows:

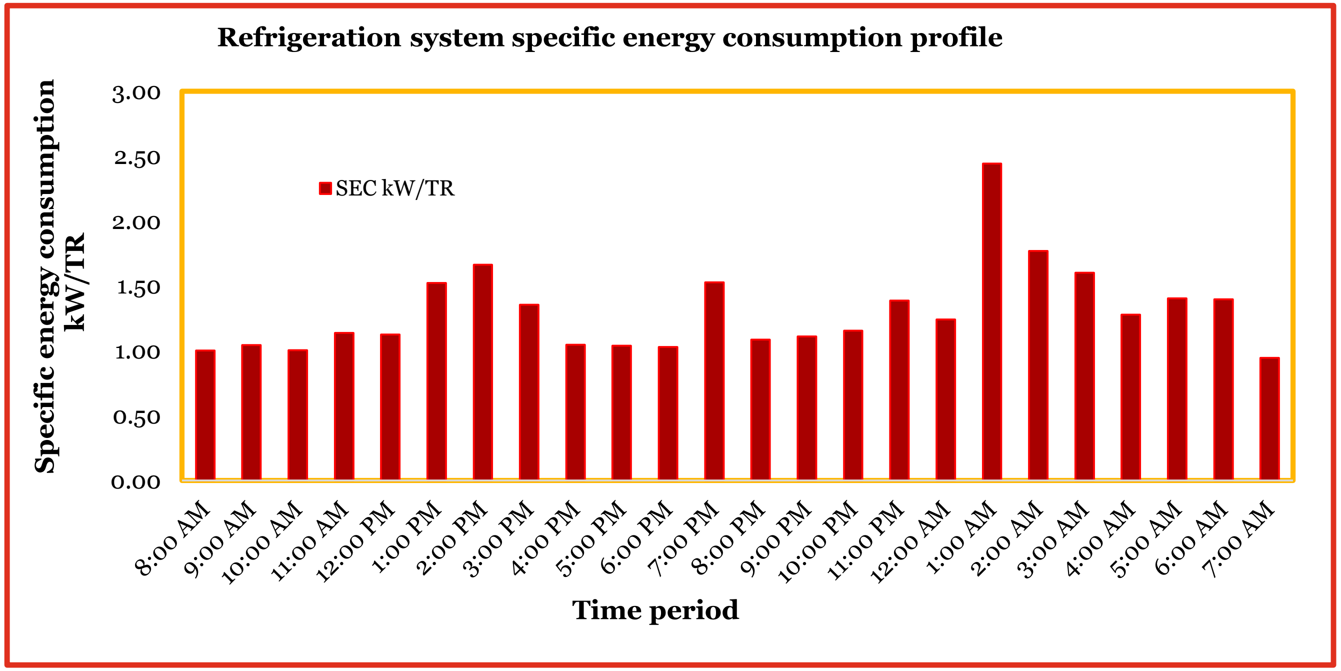
Figure 8: Refrigeration system temperature and power consumption profiles

Temperature & Power Profiles	Remarks
	Chilled water set temperature = 0 ºC Average chilled water supply temperature = 1 ºC Average chilled water return temperature = 3.5 ºC Chilled water flow rate Old plant = 78 m^3/h New plant = 125 m^3/h
	Average chilled water delta T = 2.5 ºC

<table>
<tr><th>Temperature & Power Profiles</th><th>Remarks</th></tr>
<tr><td></td><td>Average TR generated during peak time (6AM to 10AM & 5 PM to 9 PM) = 300 TR

Average TR generated during off peak hours = 200 TR</td></tr>
<tr><td></td><td>Average power consumption during peak time (6AM to 10AM & 5PM to 9PM) = 300 kW

Average power consumption during off peak hours = 200 kW</td></tr>
</table>

Temperature & Power Profiles	Remarks
	The average specific energy consumption of the compressors is = 1.09 kW /TR which is as per the rated

3.3.3 Operating parameters

Compressors:

During normal operation, two compressors operate to meet refrigeration requirement during daytime, however, during nighttime only one compressor is operated to meet the demand. The operating details are as follows.

Two Compressor operating	-	6 AM to 12 AM	-	18 hours/ Day
One compressor operation	-	12 AM to 6 AM	-	6 hours/Day

During night, the refrigeration load gets reduced due to shut down of old and new plant and during this time, only cold storages will be working.

Compressor -1:

Suction pressure	-	32.4 psig
Suction temperature	-	27.7 °C
Discharge pressure	-	188.4 psig
Discharge temperature	-	65.2 °C
Oil pressure	-	25 psig
Oil temperature	-	48 °C

Compressor -2:

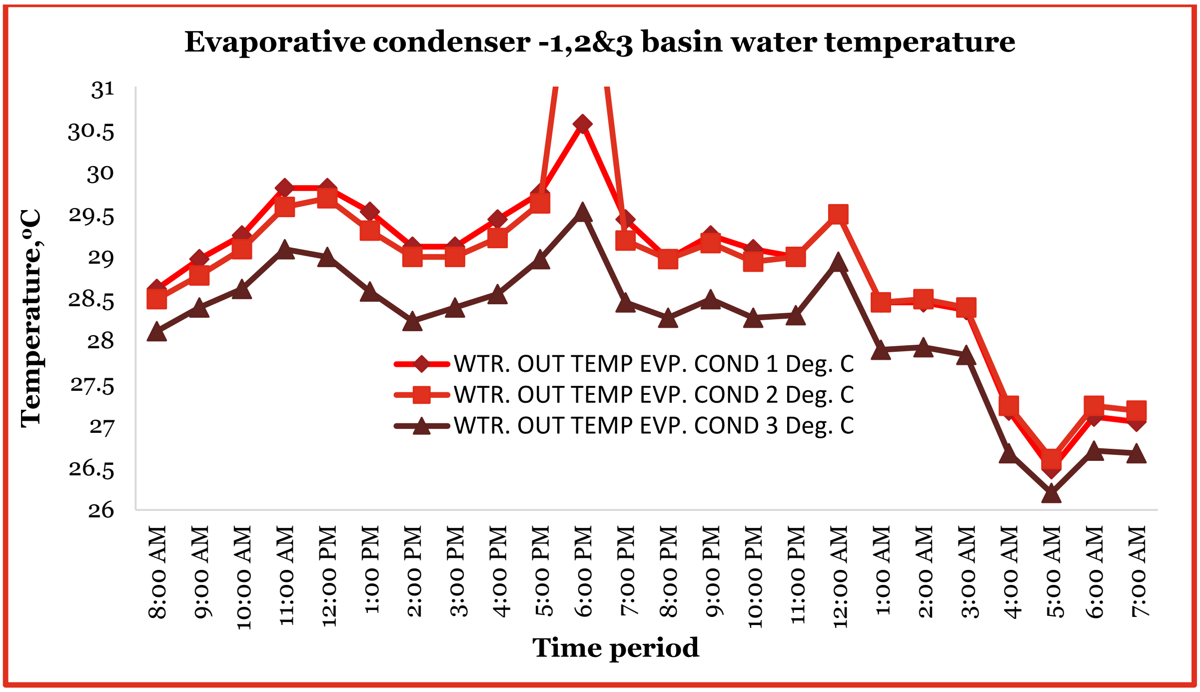
Suction pressure	-	30.7 psig
Suction temperature	-	- 4.6 °C
Discharge pressure	-	181.4 psig
Discharge temperature	-	65.2 °C
Oil pressure	-	23 psig
Oil temperature	-	45.2 °C

Evaporative condenser:

Three evaporative condensers have been installed and each has a capacity of 308 TR. All three condensers are operating during normal operation to meet the requirement. As per design, one condenser should operate for one compressor.

Even though one or two compressors are operated during normal working day but all three condensers will be working all the time irrespective of number of compressor operating and ambient temperature. These condensers are installed with force draft fan and water pumps to cool the ammonia refrigerant. The basin water temperature measured at the condenser is as follows:

Figure 9: Refrigeration system evaporative condenser basin temperature



The average basin temperature measured is	-	28 °C
Rated water flow across one condenser	-	138 m³/h
Actual water flow across one condenser	-	105 m³/h

The actual water flow in the condenser is less as compared to design. Due to less water flow in condenser, refrigerant will not be cooled properly which will result in increase in compressor power consumption.

3.3.4 Chilled water pumps

Eight chilled water pumps are installed in the system, of which two or three pumps are operated to meet the cooling requirement of the plant. These pumps operate at constant speed throughout the day.

Table 9: Chilled water pump efficiency

Description	Units	Parameters
Operating parameters		
Make		Grundfos
Model		CR - 90-2
Flow rate	m³/h	90
Head developed	m	40
Motor rating	kW	15
Overall efficiency	%	76.4
Numbers of pumps installed	Number	8
Proposed operating parameters		
Number of pumps running	Number	2
Flow delivered	m³/h	190
Suction pressure	m	0

Description	Units	Parameters
Discharge pressure	m	40
Head developed	m	40
Power consumption of pump -1	kW	14.5
Power consumption of pump -2	kW	14.5
Total power consumption	kW	29
Overall efficiency	**%**	**71%**

- The efficiency of the pumps was found to be good and it is near to design efficiency.

3.4 *New plant*

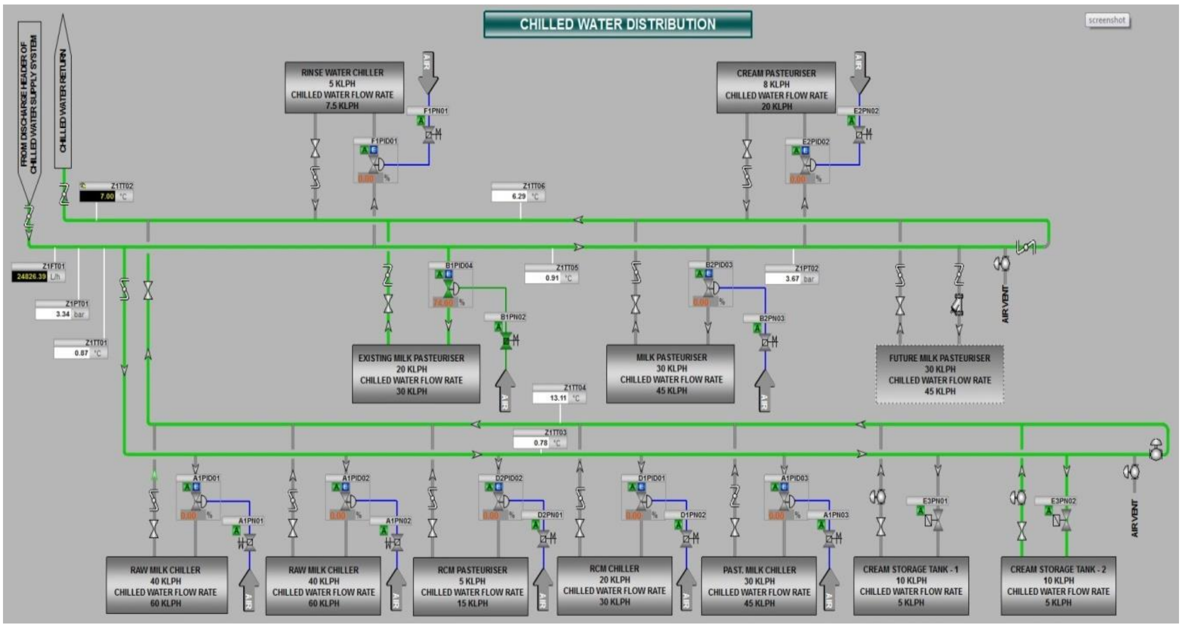
New plant is one of the major consumer of chilled water in the plant. New plant receives milk from nearby chilling centers at an average temperature of 10 °C. The average milk processed daily in this plant is about 2.5 lakhs liters. Plant operates with full capacity during daytime and is shut down from 12 AM to 6 AM daily.

This plant is new and operating from last one year and all new technologies and energy efficient equipments are installed in this plant. The number of PHE chillers installed in this plant are as follows:

Raw milk chillers (40 kL each)	-	2 Numbers
Milk Pasteurization chillers (20 kL & 30 kL)	-	2 Numbers
Rinse water chiller (5 kL)	-	1 Number
Cream pasteurizer	-	1 Number
RCM pasteurizer	-	1 Number
RCM Chiller	-	1 Number

Out of all the installed PHE chillers, only raw milk chillers and milk pasteurization chillers are operated daily whereas all other chillers are operated based on requirement. The SCADA system diagram for chilled water distribution is as follows.

Figure 10: Refrigeration system – chilled water distribution



The major user of chilled water in the plant is the pasteurizers, which uses chilled water to cool the milk after the heating process. Presently two pasteurizers are working in the system and an additional pasteurizer is proposed to be installed shortly to increase the plant capacity. Apart from pasteurizers, major consumers of chilled water are raw milk chillers and packing chillers, which use chilled water to maintain milk temperature of 4 °C in the system.

3.4.1 Chilled water flow and temperature

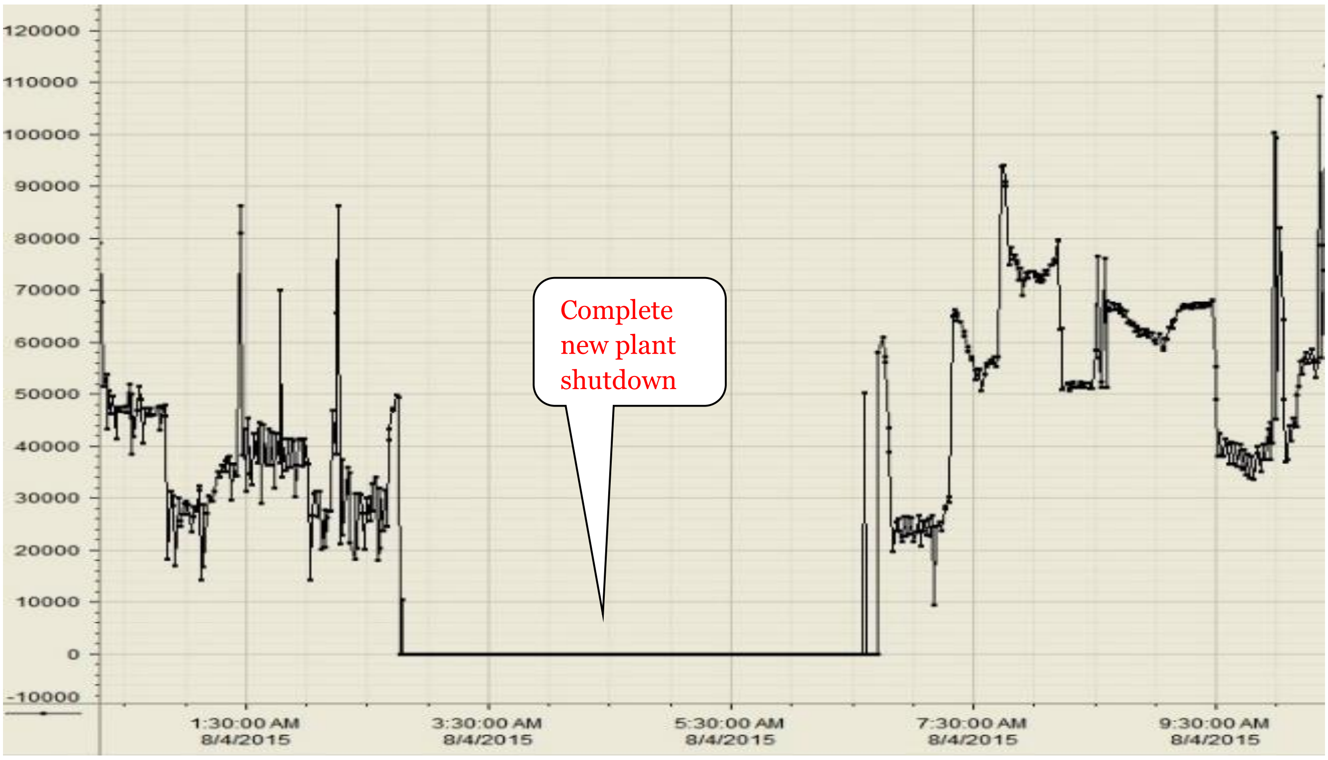
Chilled water generated in the centralized refrigeration system is pumped to new plant and return water after its use in process gets collected back to same system.

The maximum chilled water flow to new plant - 125 m^3/h

Minimum chilled water flow to new plant - 10 m^3/h

Average chilled water flow to new plant - 68 m^3/h

Figure 11: Refrigeration system – chilled water flow profile



The maximum chilled water temperature to new plant - 1.5 °C

Minimum chilled water temperature to new plant - 0.3 °C

Average chilled water temperature to new plant - 0.9 °C

Figure 12: Refrigeration system – chilled water temperature profile

During the nighttime after 12 AM, complete pasteurization will be under CIP and there will not be any requirement of chilled water. During this time, load on refrigeration system reduces drastically as can be inferred from above chilled water temperature profile captured during this time.

3.4.2 *Raw milk chillers*

Two raw milk chillers have been installed in new plant to reduce temperature of received milk from 10 ^oC to 4^oC by use of chilled water. These chillers are PHE chillers, where chilled water flows at shell side of heat exchanger and milk flows at tube side of heat exchanger. After cooling in these chillers, milk is stored in RMST for further processing.

The temperature profile of milk after chilling in raw milk chiller is presented below.

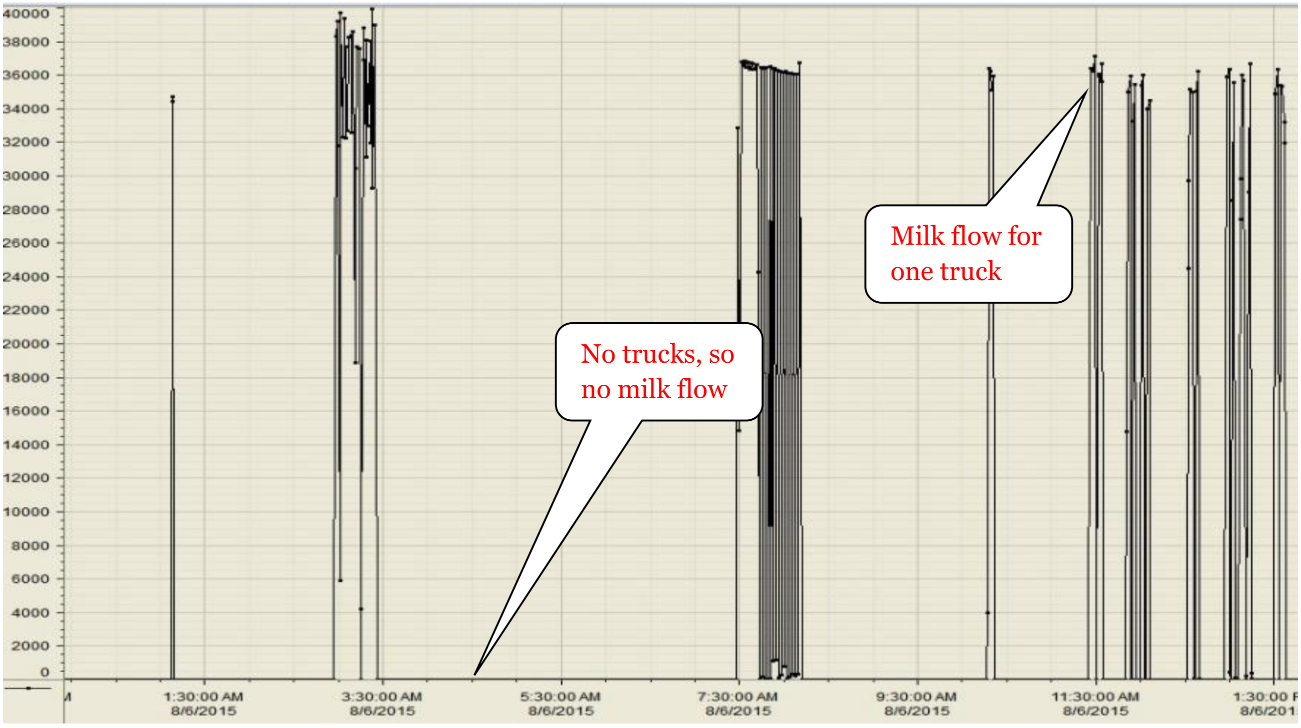
Figure 13: Refrigeration system raw milk temperature profile

Temperature of the milk at the start of batch - 2.5 °C

Average temperature at the end of batch - 4.5 °C

Milk flow rate from tanker to chiller for cooling:

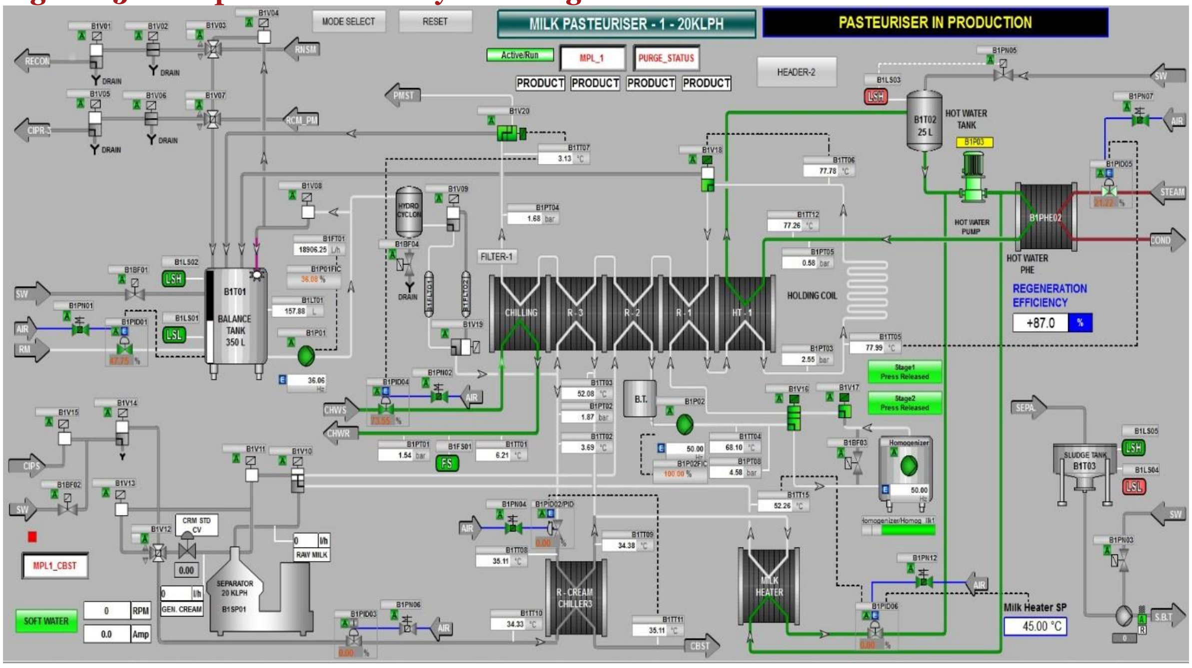
Figure 14: Refrigeration system – milk flow rate from tanker to chiller



3.4.3 Milk pasteurization chillers

There are two pasteurization chillers of capacity 20 kL and 30 kL installed in the plant. These chillers are used for milk pasteurization process. In the pasteurization process, both hot water and chilled water is used and detailed SCADA system diagram of the same is as follows.

Figure 15: Milk pasteurization system diagram



Pasteurization process consists of heating and cooling of the milk to its saturation temperature for removing all bacteria in the milk.

The heating temperature of milk in pasteurization process - 75 °C

Chilling temperature of milk in pasteurization process - < 4 °C

In this process, milk is extracted from raw milk storage tank to pasteurization PHE in a stage-wise manner as mentioned below:

At R-3 stage - Milk gets heated up to 52 °C

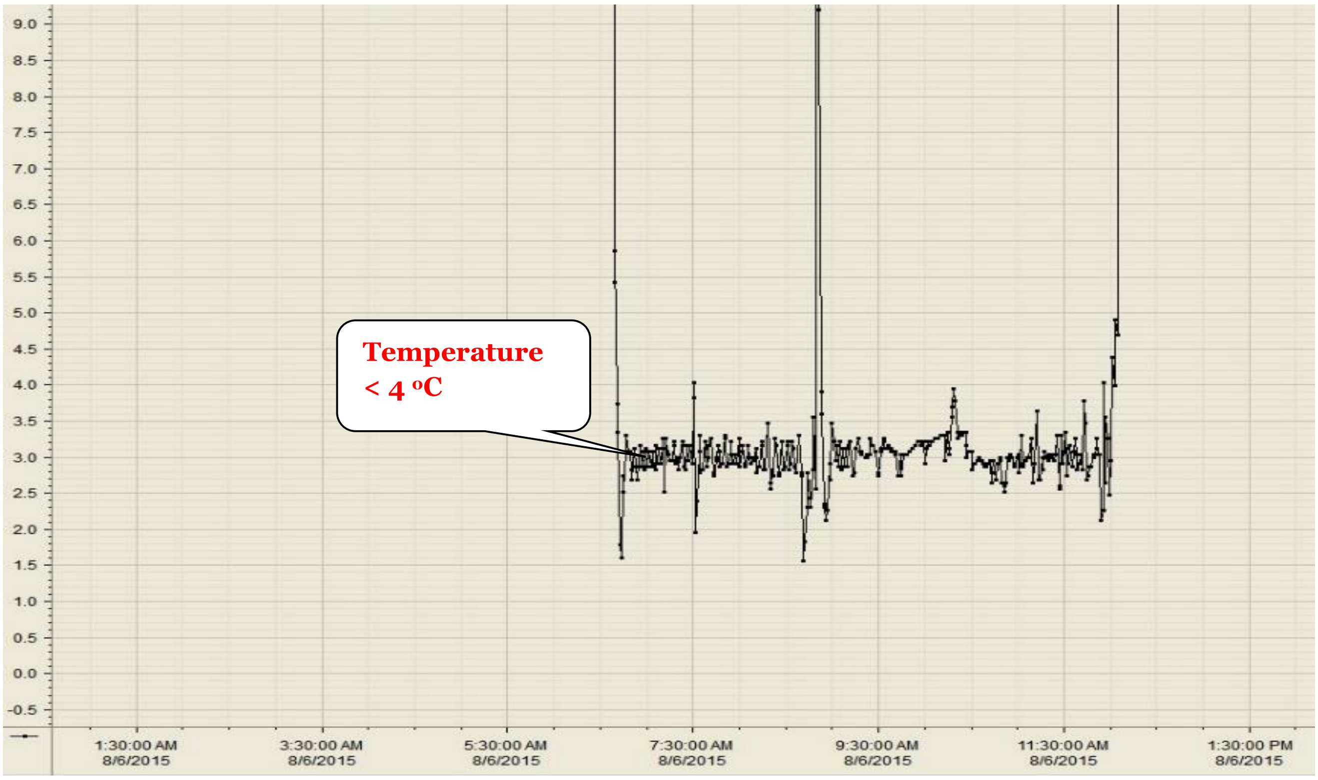
At R-2 stage - Milk gets heated up to 68 °C

At R-1 & HT stage - Milk gets heated up to 75 °C

At Chilling stage - Milk gets cooled to < 4 °C

The temperature profile of milk after pasteurization process is presented below.

Figure 16: Temperature of the milk after pasteurization process



- Temperature of around 4 °C needs to be maintained after pasteurization process as per the standards. The actual temperature measured for one sample day during the audit indicates that temperature is going much lesser than required standard temperature of 4 °C. This should not happen as lower milk temperature will increase refrigeration load in the plant and subsequently increase power consumption of the plant.

3.5 Old plant

Old plant receives milk directly from farmers in milk cans at ambient temperature which is then cooled up to 4 °C and is then sent to new plant for storing and further processing. Completely processed milk from new plant is pumped back to old plant for storing and packing in old plant. Since this plant is old, therefore there are no auto control system or SCADA controls; so all the operations are done manually.

The number of chillers installed in this plant are as follows.

Raw milk PHE chiller (20 kL & 30kL)	-	1 each
Butter milk PHE chiller (5 kL)	-	1 Number
HMST PHE chillers (20 kL)	-	2 Number

Raw Milk PHE chiller: Out of two raw milk chillers, usually 20 kL chiller is operated during normal day. As the mils is received during 4 hours in morning and 4 hours in evening; so during this time chiller operates at its full capacity and during rest of time, this chiller is used to cool the rejected milk during packing (which is very less in quantity).

Average flow rate of the chilled water to old plant	-	78 m^3/ h
Average chilled water temperature	-	0.5 – 1.5 ^oC

Butter Milk PHE chiller: This chiller is used to maintain the temperature of buttermilk and its capacity is of 5 kL. Buttermilk section processes buttermilk for only for around 8–9 hours daily but this chiller runs on an average for about 20 hours daily without any control.

Average chilled water temperature - 0.5 – 1.5 ^oC

HMST Milk PHE chiller: This chiller is used to maintain the temperature of fully processed milk before packing. The complete milk processed in new plant is stored in old plant HMST section for packing. Milk packing section runs for about 22 hours per day and for rest 2 hours; packing machines are cleaned.

Average chilled water temperature - 0.5 – 1.5 ^oC

3.6 Cold storages

There are five cold rooms in dairy and these cold rooms are used for storing milk before loading to trucks. The average temperature that needs to be maintained in these cold rooms is 4^oC. The list of cold rooms, temperature maintained and number of units installed are mentioned in following table.

Table 10: Set and actual temperature in cold storages with number of units installed

Description	Set temperature (^oC)	Average actual temperature(^oC)	Number of units Installed
MS-1	4	10.2	3
Old MS-1	4	11.6	2
Old MS-2	3	5.7	2
Butter milk	3	4.6	1
Ghee	24	25.3	1

The indoor units installed in the cold rooms are using ammonia refrigerant from centralized refrigerant plant for cooling the cold rooms. These indoor units are installed with temperature controllers and are controlled through centralized SCADA. The design details of the cold room indoor units are as follows.

Design details for the Ghee, Butter, Old MS-1, 2 cold rooms units

Make	-	Frick
Model	-	SHA – 140608 – 2

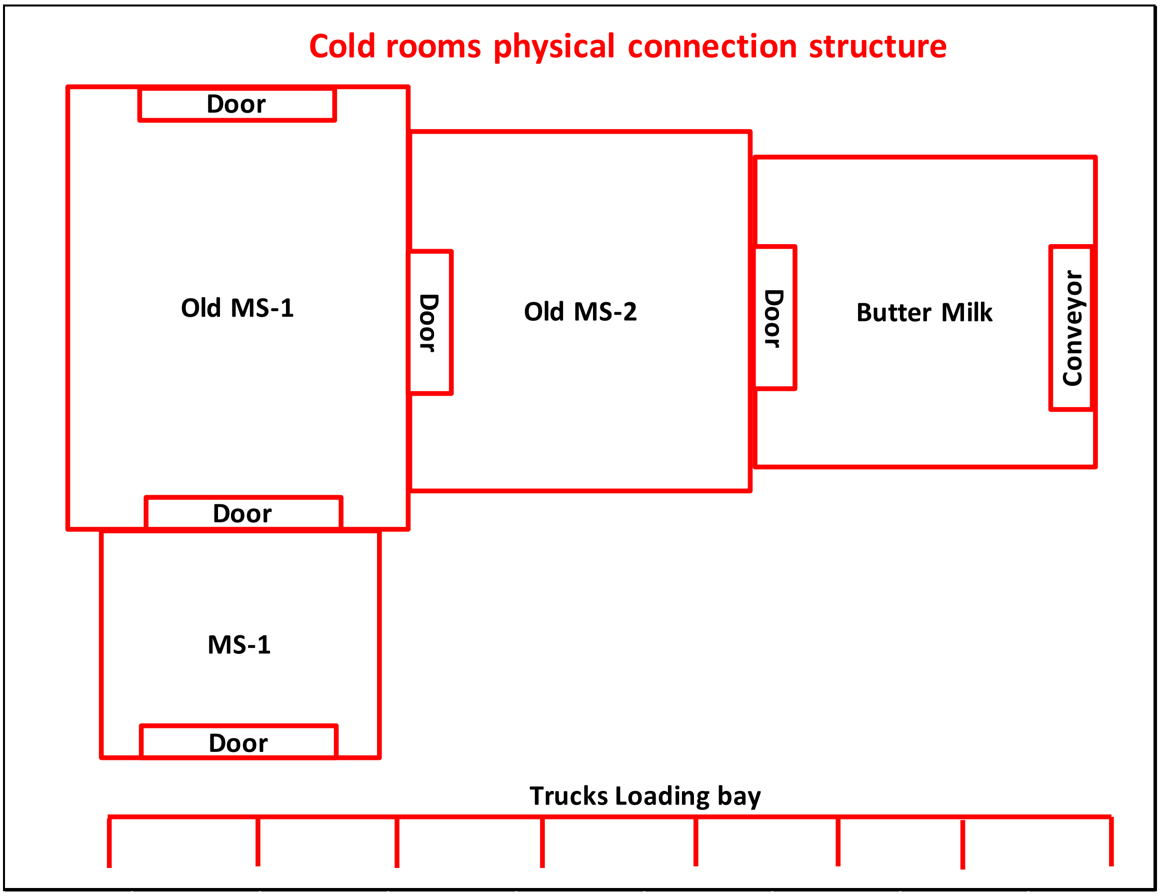
Design temperature	-	0 – 2 °C

Design details for the MS-1, 2 and 3 cold rooms units

Make	-	Frick
Model	-	SHA – 140608 – 2
Design temperature	-	2 – 4 °C

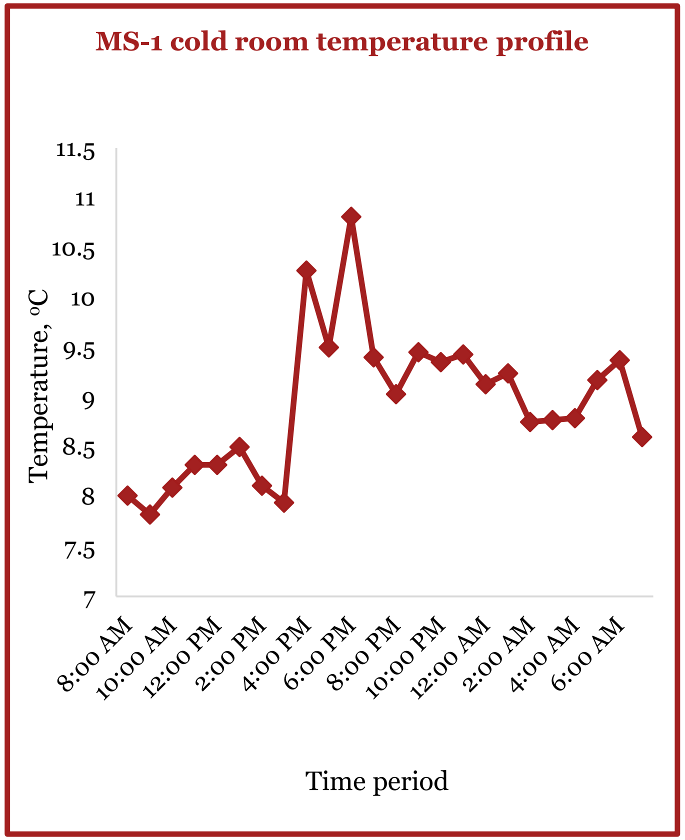
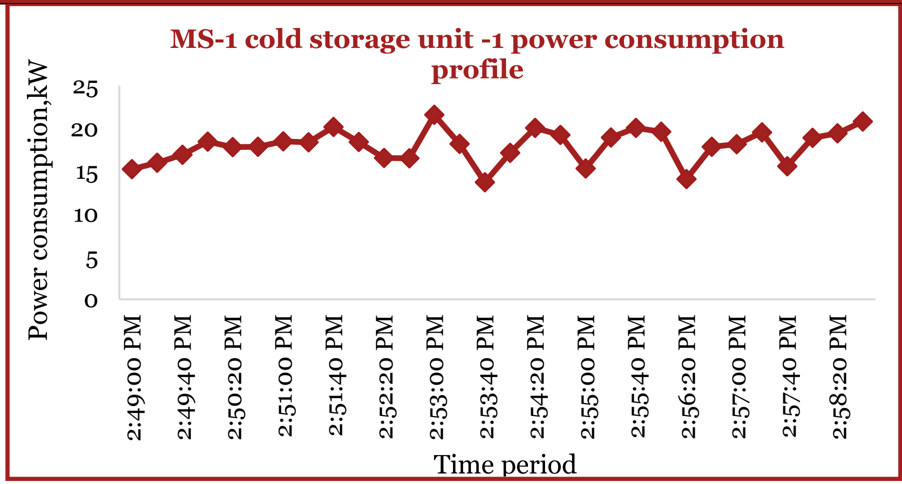
All cold rooms are at one place in old plant and are inter - connected to each other except Ghee cold room. The truck-loading bay is also near to these cold rooms. The milk is loaded to trucks manually and loading take place on an average of 22 hours in a day. The cold room physical connection structure is as follows.

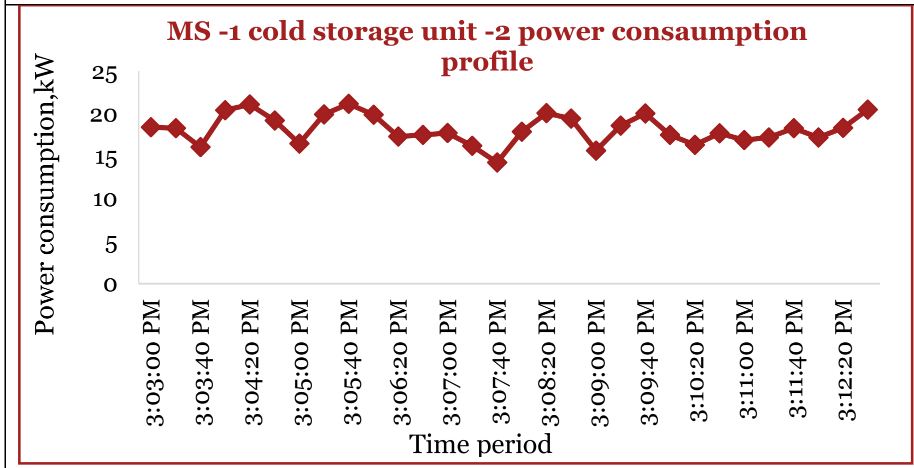
Figure 17: Cold room physical connection structure



The temperature maintained in the cold rooms and power consumption of the indoor units measured during the audit is as below.

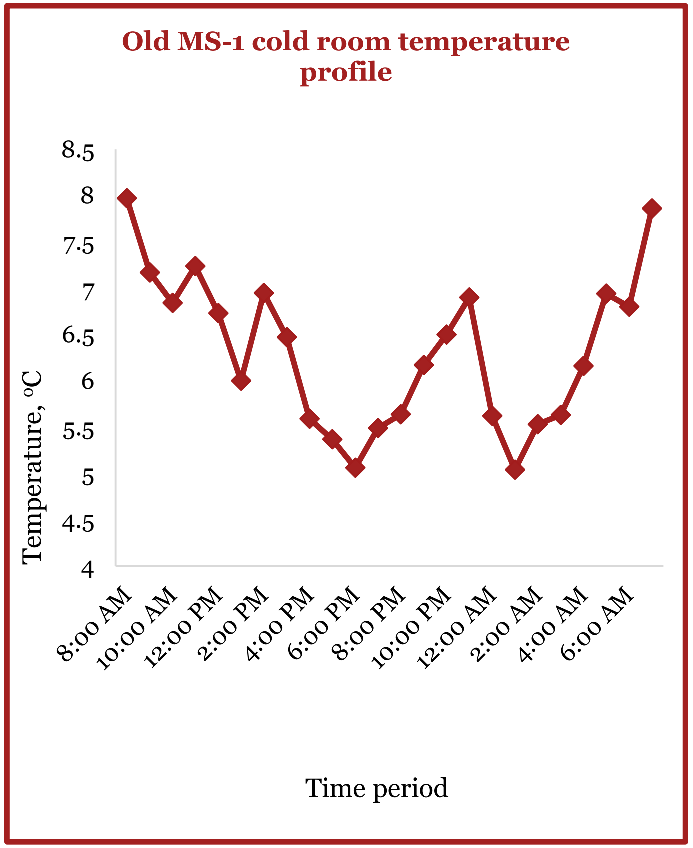
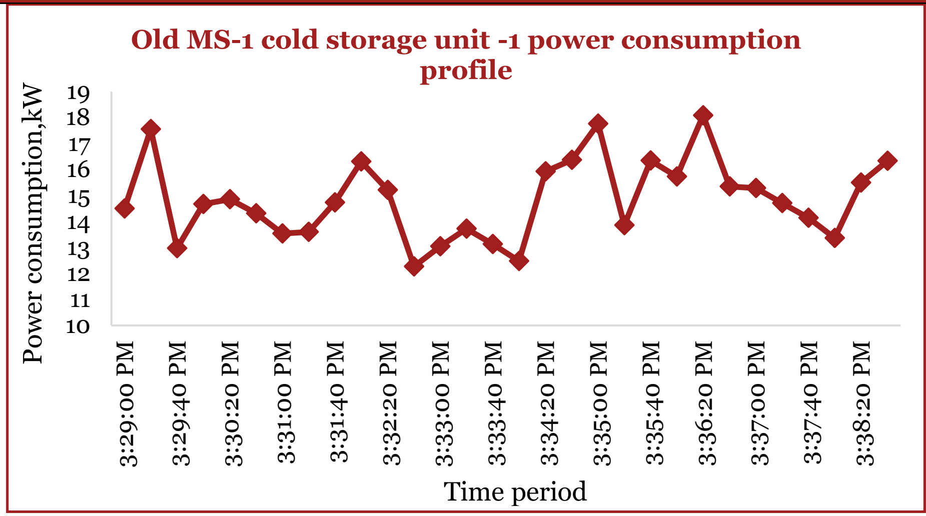
Figure 18: Cold room temperature profile

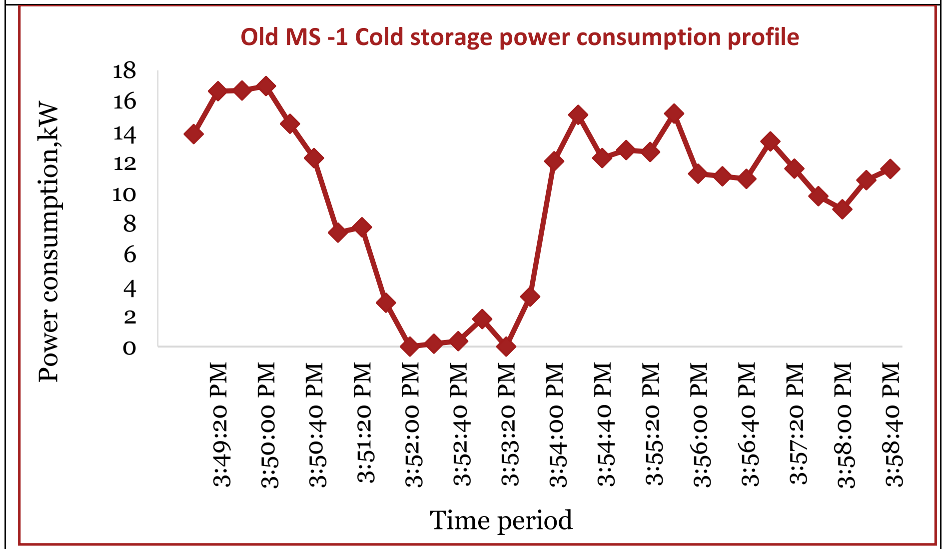
<table>
<tr><th>Temperature profile</th><th>Power consumption(Operating load) profile</th><th>Remarks</th></tr>
<tr>
<td>
</td>
<td>


</td>
<td>The average temperature = 9 °C

The average power consumption of unit -1 = 17 kW
The average power consumption of unit -2 = 17 kW
The average power consumption of unit -3 = 17 kW

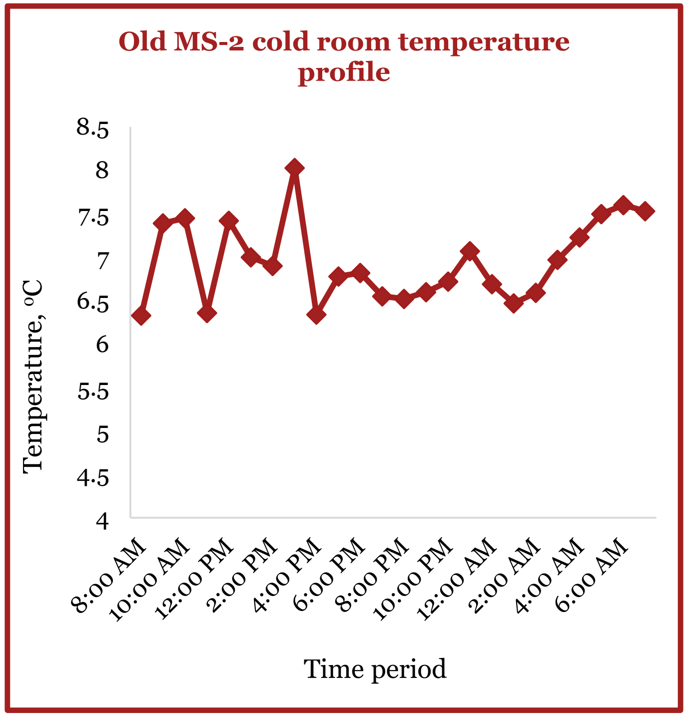
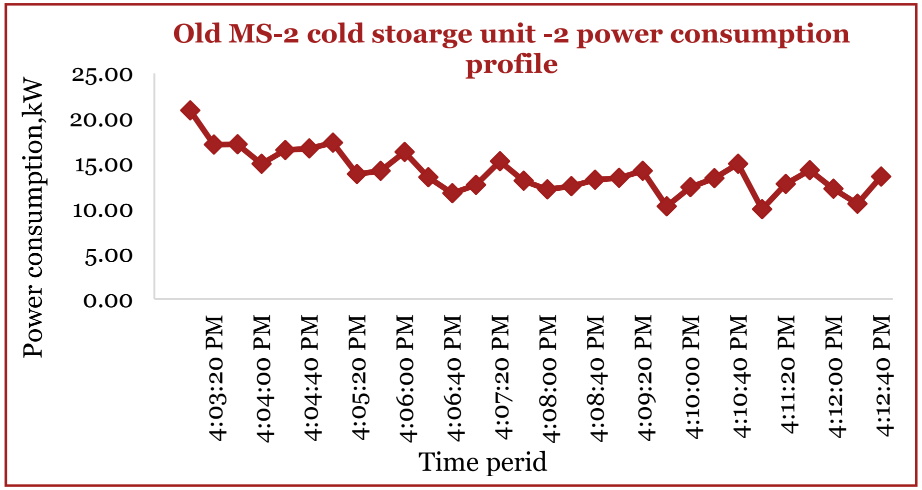
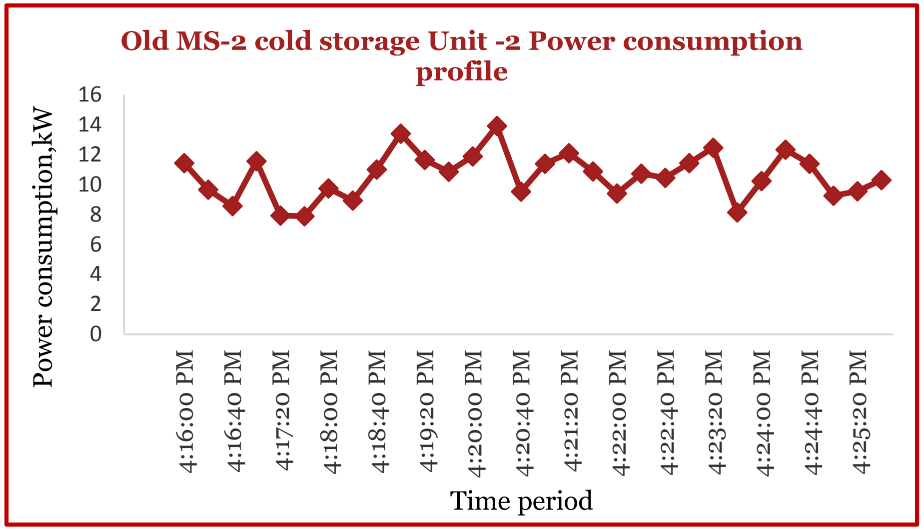
Finding: Since cold rooms doors are always open and there are no air curtains, these units runs on continuous load and consumption is also at higher side</td>
</tr>
</table>

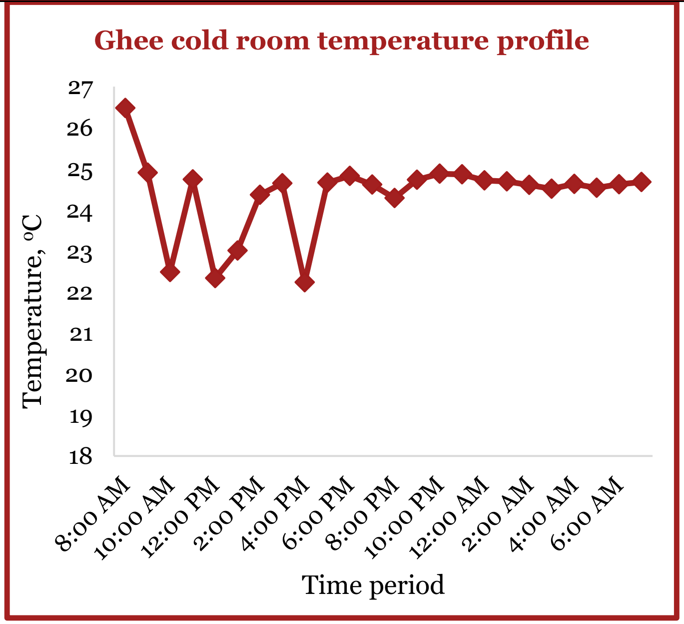
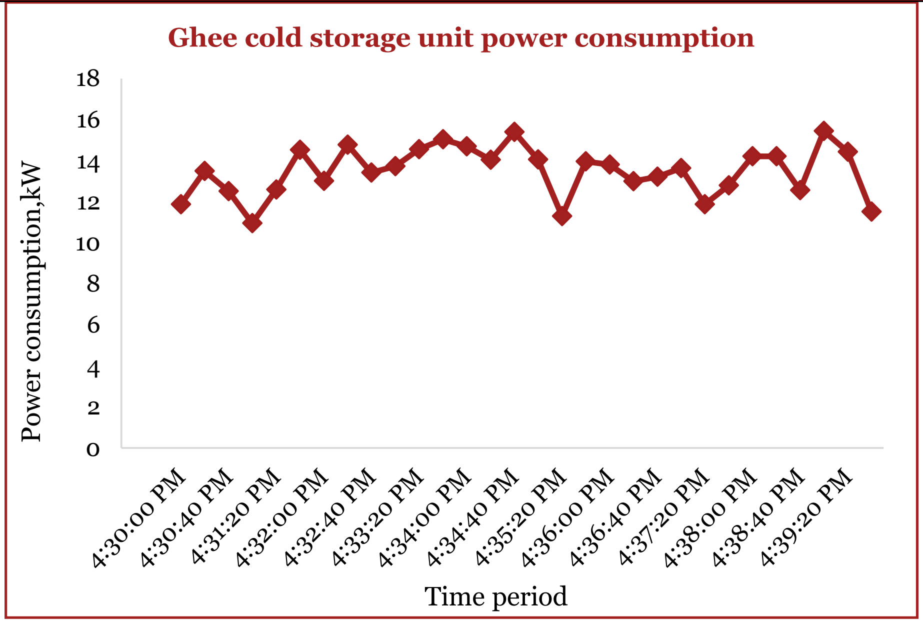
<table>
<tr><th>Temperature profile</th><th>Power consumption(Operating load) profile</th><th>Remarks</th></tr>
<tr>
<td>
</td>
<td>


</td>
<td>The average temperature = 6 °C

The average power consumption of unit -1 = 14 kW
The average power consumption of unit -2 = 10 kW

Finding: Since cold room doors are always open and there are no air curtains, these units run on continuous load and consumption is also at higher side.</td>
</tr>
</table>

Temperature profile	Power consumption(Operating load) profile	Remarks
	 	The average temperature = 7 °C The average power consumption of unit -1 = 15 kW The average power consumption of unit -2 = 12 kW Finding: Since cold room doors are always open and there are no air curtains, these units run on continuous load and consumption is also at higher side.

Temperature profile	Power consumption(Operating load) profile	Remarks
		The average temperature = 24 °C The average power consumption of unit -1 = 14 kW

4 Energy Conservation Measures

4.1 Refrigeration system – Generation end

The detailed analysis of entire refrigeration system at the generation end and user end was carried out during the audit and energy conservation measures identified in refrigeration are as follows. It is suggested to implement the energy conservation measure as one after another in step wise to realize full energy reduction.

1. Step -1 : Install VFD in chilled water pumps with header pressure based feedback control system
2. Step – 2 : Separate the chilled water supply and return water tank instead of mixing both in one tank
3. Step -3: Increase the cooling water flow to 138 m3/hr. and clean condenser tubes to reduce the compressor power consumption
4. Step -4 : Increase the chilled water set point from 0 °C to 1 – 1.5 °C
5. Step -5 : Check and replace the damaged chilled water insulation in pipelines

4.1.1 Install VFD to chilled water pumps with header pressure based feedback control system

Background

There are eight number of chilled water pumps installed in the refrigeration plant to pump chilled water to old plant and new plant. Out of eight pumps, two or three pumps operate daily to meet refrigeration requirement. Each pump is designed to operate at water flow of 90 m3/h @ 40 m head with consumption of 15 kW each.

Findings

In the new plant all chillers are having solenoid valves in place so that once required temperature of milk is achieved; chilled water gets cut off. This will increase pressure in chilled water header on pump side. During this condition, pump speed can be reduced to save pump power consumption, but presently pump operate with same speed.

In old plant, all the valves are manual, chillers operates with full load during peak hours, and during off peak hours; all chillers will have lower refrigeration requirement. After replacing all manual valves with solenoid valve, as per Recommendation in section 4.3.1, this recommendation will give additional saving benefits.

Recommendation

Install VFD in chilled water pumps with header pressure feedback control system and maintain header pressure of 3.5 kg/cm2 instead of presently maintained pressure of 4 kg/cm2

Energy & financial savings

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

Table 11 : VFD installtion saving potential

Description	Units	Parameters
Operating parameters		
Number of pumps installed	Number	8

Description	Units	Parameters
Number of pumps operating	Number	2 or 3
Present discharge pressure	kg/cm^2	4
Present power consumption pump-1	kW	14
Present power consumption pump-2	kW	14
Chilled water flow	m^3/h	190
Number of IBT tanks installed	Number	2
Average temperature of supply water recorded	^{o}C	0.8
Average temperature of return water recorded	^{o}C	3
Proposed operating parameters		
Number of pumps operate	Number	2
Discharge pressure	kg/cm^2	3.5
Pump flow rate	m^3/h	190
Power consumption saving in pump by running @ 3.5 bar after VFD installation	kW	5
Number of operating hours per day	Hours	24
Annual operating hours	Hours	8,400
Annual energy saving by VFD operation	**kWh**	**42,000**
Energy cost	Rs./kWh	4.55
Annual cost saving	**Rs. Lakhs**	**1.91**
Investment for VFD, Pressure sensor	**Rs. Lakhs**	**4.0**
Payback period	**Months**	**25**

4.1.2 Increase the cooling water flow to 138 m³/h and clean condenser tubes to reduce compressor power consumption

Background

There are three evaporative condenser installed in the plant having capacity of 308 TR each. These condensers are design to operate such that one condenser operates during operation of one compressor. Each condenser is having one cooling water pump of 2.2 kW and a force draft fan of 11 kW.

Findings

The water flow measurement done across condenser shows that water flow across condenser (105 m^3/h) is less than designed flow 138 m^3/h. This reduction in water flow across condenser will not cool refrigerant fully and this will increase discharge pressure across compressor and will result in increased compressor power consumption.

The physical observation of the condenser tube (where refrigerant ammonia flows) indicated that there is lot of deposition in the tubes and due to this, heat exchange between water and refrigerant will not happen properly. This leads to increase in power consumption of compressor and it was found during discussions that the plant has not cleaned condenser tubes since its installation.

After cleaning condenser tubes and increasing water flow across condenser, the plant can operate two condensers for two compressors operation instead of three condensers which are being operating presently.

Recommendation

Increase water flow across condenser by rectifying/replacing water pump in condenser and clean ammonia refrigerant tubes by bullet jet cleaning method or by chemical cleaning.

Energy & financial savings

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

Table 12: Increase cooling water flow and clean condenser tube recommendation saving

Description	Units	Parameters
Operating parameters		
Number of compressor installed	Numbers	3
Number of compressor in operation	Numbers	2
Number of condenser in operation	Numbers	3
Average number of hours of operation of two compressors	Hours	18
Average number of hours of operation of one compressor	Hours	6
Average suction pressure of compressor	Psig	180
Average discharge pressure of compressor	Psig	30
Estimated energy consumption of both compressors per day	kWh	6,640
Present water flow across each condenser	m^3/h	105
Rated water flow across condenser	m^3/h	138
Each condenser pump power consumption	kW	2.25
Each condenser fan power consumption	kW	9.8
Proposed parameters		
Number of compressor in operation	Numbers	2
Number of condenser in operation	Numbers	2
Proposed water flow across condenser	m^3/h	138
Proposed discharge pressure across compressor	Psig	160
Estimated energy consumption after cleaning and increasing flow rate	kWh	5,312
Estimated energy consumption saving	kWh	1,328
Annual operating days	Day's	350
Annual energy saving	**kWh**	**464,800**
Energy cost	Rs/kWh	4.55
Annual cost saving	**Rs. Lakhs**	**21**
Investment required	**Rs. Lakhs**	**8**
Payback period	**Months**	**5**

4.1.3 Increase chilled water set point from 0 °C to 1- 1.5 °C

Background

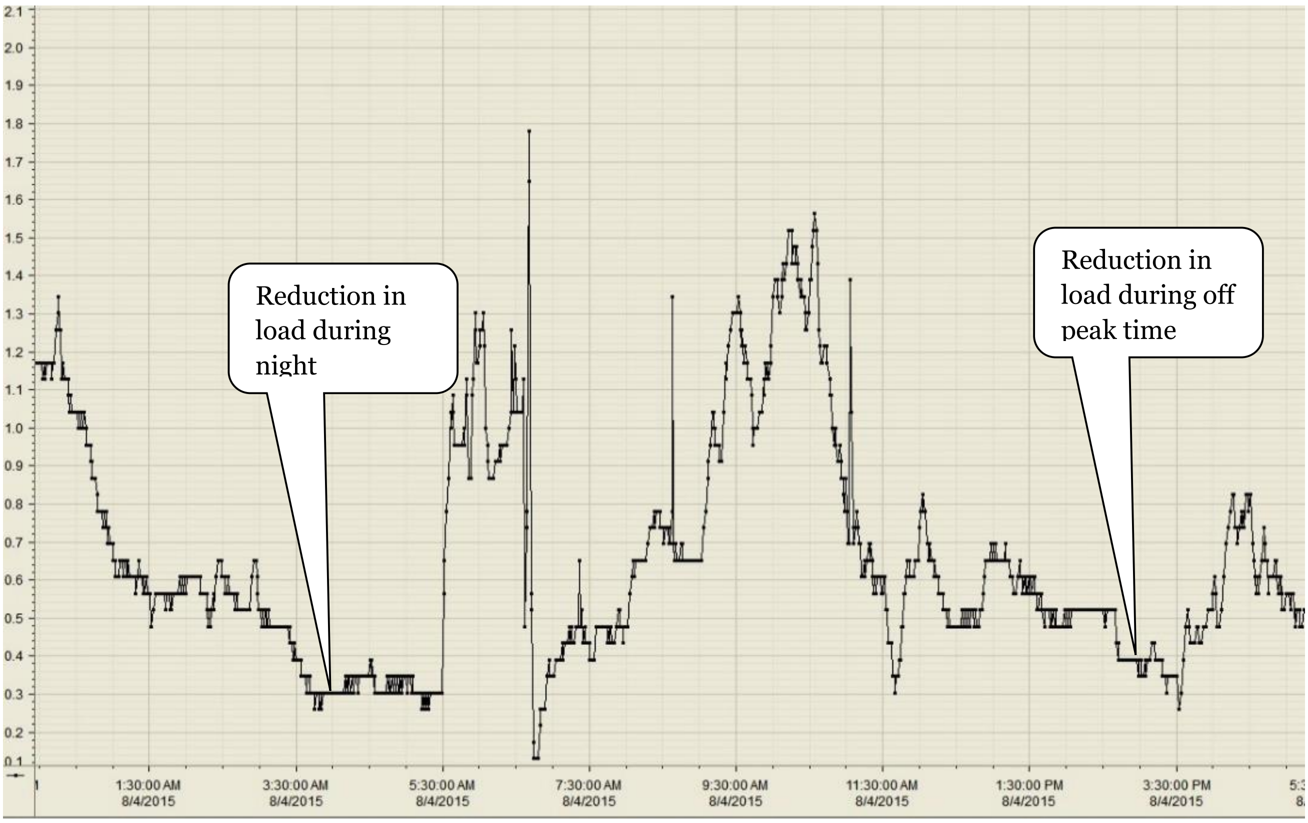
The chilled water set point for the refrigeration is at 0 °C and plant is not changing this set point as per day/night, temperature-wise, season wise or load wise.

Findings

Since there is variation in heat load in plant as heat load will be more during morning 06:00 AM to 10:00 AM and evening 05:00 PM to 09:00 PM, rest of the time plant will be under minimum load. During nighttime from 12:00 AM to 06:00 AM, new plant and old plant will not be operating so there will be operation of cold rooms only. The load requirement of cold storages is less as compared to rest of the plant.

The same effect of the heat load variation can be observed from the below chilled water supply temperature.

Figure 19: Chilled water temperature profile



The entire PHE chiller in the plant is designed with chilled water inlet temperature of 1.5 °C but presently all PHE chillers are getting the chilled water at lesser than rated which is not required.

Recommendation

Step -1: Increase the chilled water set temperature from 0°C to 1 or 1.5°C (whichever is possible for comfort operation) during night time after 12 AM or when new and old plant heat load reduces.

Step -2: Increase chilled water set temperature from 0 °C to 1 °C (any temperature more than 0 °C which is possible with comfort operation) for entire day during winter and rainy season (about 8 months) and only night time during summer season.

There is a sudden increase in the chilled water return temperature up to 8-10 °C during early morning time due to sudden increase in load (due to milk arrival) this can be resolved by following methods.

- During early morning, the entire old and new plant will be under shut down and plant starts at 06:00 AM. Plant officials are starting all PHE chillers at a time resulting in sudden increase in load and increase in power consumption. This can be resolved by switching on PHE chiller one after another instead of starting all PHE chillers at a time (ideally, time between start of each chiller should be 15 to 20 minutes). By use of this method, sudden increase in the chilling load can be avoided.

Energy & financial savings

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

Table 13: Saving potential by increasing chilled water temperature set point

Description	Units	Parameters
Operating parameters		
Number of compressor installed	Numbers	3
Number of compressor in operation	Numbers	2
Number of condenser in operation	Numbers	3
Average number of hours two compressors in operation	Hours	18
Average number of hours one compressors in operation	Hours	6
Estimated energy consumption of both compressors per day	kWh	6,640
Present set temperature	ºC	0
Proposed parameters		
Proposed set point during night time	ºC	1
Number of hours when set point can be increased	Hours	6
Estimated power consumption saving by increasing one degree temperature	%	5
Power consumption of the compressor	kW	180
Estimated power consumption saving	kW	9
Operating hours per day	Hours	6
Annual operating days	Days	350
Annual energy saving	**kWh**	**18,900**
Energy cost	Rs/kWh	4.55
Annual cost saving	**Rs. Lakhs**	**0.86**
Investment required	**Rs. lakhs**	**NIL**
Payback period	**Months**	**Immediate**

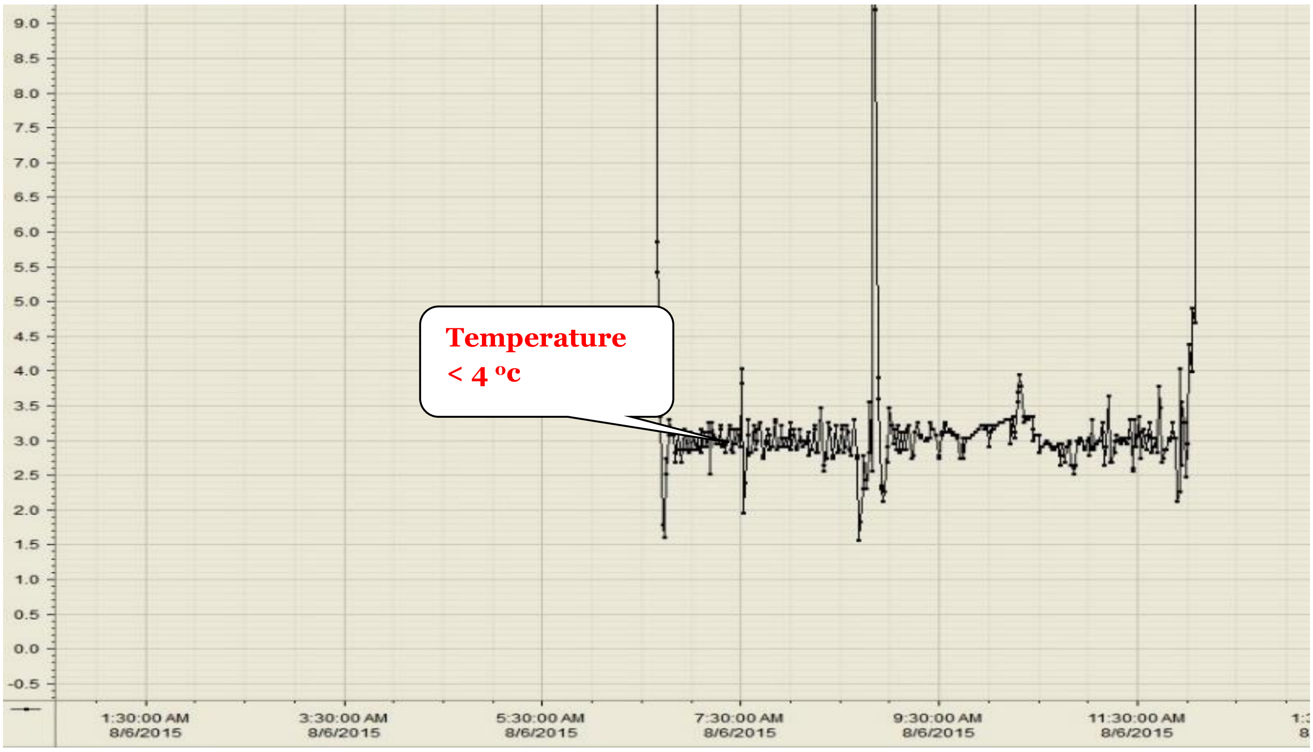
4.2 Refrigeration - New plant

4.2.1 Increase the milk temperature from 3 ºC to 4 ºC

Background

The milk needs to be kept at a temperature of 4 ºC or less to avoid contamination from bacteria. Presently, milk set temperature in all the raw milk chillers and pasteurization milk chillers is at 3 ºC.

Figure 20: Pasteurized milk temperature profile



Findings

Even though milk temperature needs to be kept at a temperature of 4ºC or less; both new and old plant are set with milk temperature of 3 ºC and actual milk temperature maintained is 3.1 to 3.2 ºC and during peak hours milk temperature goes as high as 5 ºC .

Recommendation

Increase the milk set temperature near to 4 ºC (which has to be done on trial and error method to decide exact possible set point).

Energy & financial savings

Increase in the milk temperature near to 4 ºC will reduce chilled water consumption and thereby reduce compressor power consumption.

Since it is not possible to decide exact possible milk set temperature by theoretical calculation (which has to be realized practically); the savings potential is not calculated for this energy conservation measure.

4.3 Refrigeration - Old plant

4.3.1 Replace all manual control valves with solenoid control valve to arrest water flow to non-operating chillers

Background

The old plant receives milk from farmers at ambient temperature which is cooled to 4 ºC and then sends milk to new plant for further processing and it receives completely processed milk in its HMST section to store it before packing.

Old plant is having following PHE chillers

Raw milk PHE chiller (20 kL & 30kL)	-	1 each
Butter milk PHE chiller (5 kL)	-	1 Number
HMST PHE chillers (20 kL)	-	2 Number

Findings

During morning and evening hours, the plant is at full load whereas during rest of time, raw milk chiller and buttermilk chillers do not have any load; but still chilled water flows through these PHE chillers. Presently, there is no auto control of chilled water in this plant.

Since there is no control of chilled water flow as per requirement, so rate of flow of chilled water through chiller is always same. This will increases chiller pump power consumption and increase heat load at compressor.

Recommendation

Install the solenoid valve control in all PHE chillers in old plant.

Energy & Financial savings

Table 14: Saving potential by replacing all manual control valve with solenoid valve in old plant

Description	Units	Parameters
Operating parameters		
Total refrigeration cooling (TR) consumed by the old plant -Instantaneous	TR	80
Chilled water flow to old plant	m^3/h	78
Number of IBT tanks installed	Number	2
Average temperature of supply water recorded	^oC	0.8
Average temperature of return water recorded	^oC	3
Hours in a day that plant will be under full load	Hours	8
Hours in a day that plant will be under partial load	Hours	16
Proposed operating parameters		
Expected energy saving in the compressor power and pump power by auto operation per day	kWh	320
Annual operating days	Days	350
Annual energy saving by VFD operation	**kWh**	**112,000**
Energy cost	Rs./kWh	4.55
Annual cost saving	**Rs. Lakhs**	**5.09**
Investment for VFD, Pressure sensor, Pipeline charges	**Rs. Lakhs**	**15**
Payback period	**Months**	**36**

Note: Estimated investment is for only solenoid valve installation for auto operation.

4.4 Refrigeration - Cold storages

4.4.1 Avoid doors opening in cold rooms to maintain required temperature and reduce power consumption

Background

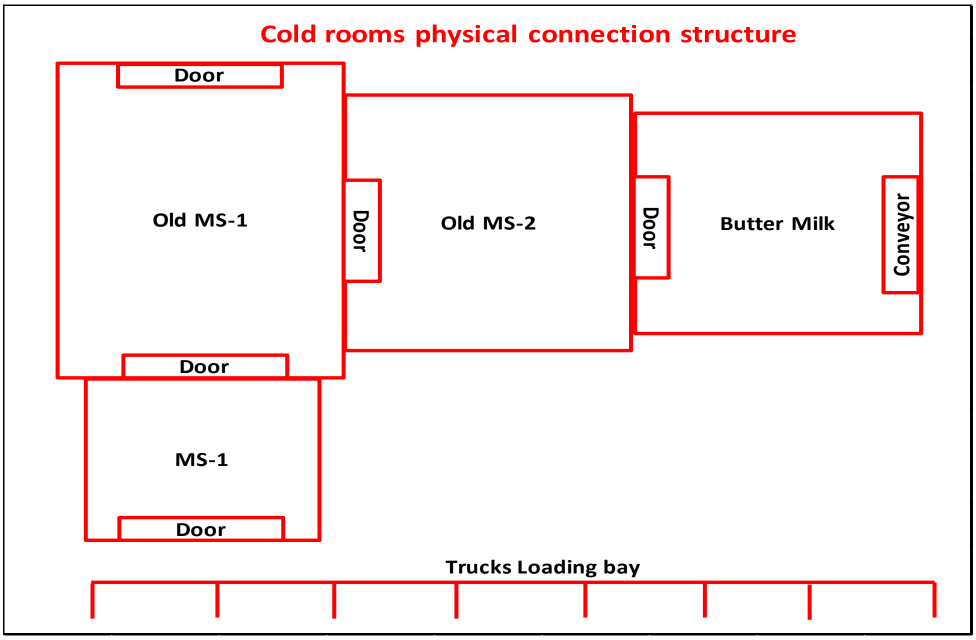
There are four cold storages installed in one area and one cold storage (Ghee storage) is installed separately. Indoor units are kept in all cold storages to maintain temperature. The number of units in each cold storage and actual temperature and set temperature is given below.

Table 15 : Cold storages set temperature and actual temperature

Description	Set temperature °C	Average actual temperature , °C	Number of units Installed
MS-1	4	10.2	3
Old MS-1	4	11.6	2
Old MS-2	3	5.7	2
Butter milk	3	4.6	1
Ghee	24	25.3	1

The physical connection between cold storages is shown below.

Figure 21: Cold rooms physical connection structure



Findings

Even though three units operate in MS -1 and two units in Old MS-1 & MS-2, actual temperature is not even near to actual temperature and this is due to opening in cold storage main door in MS-1 and opening in inner doors in old MS-1 & 2 cold storages.

It was observed that there is no control on door open/close in cold storage and these doors are always open and ambient air enters cold storage. This increases temperature and due to this, indoor units always operate at full load leading to increase in temperature and power consumption.

Recommendation

Control door opening of cold storage by proper planning of trucks loading and installing air curtains or air lock rooms in all cold storage doors.

Energy & Financial savings

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

Table 16 : Saving potential by controlling door opening in cold storages

Description	Units	Parameters
Operating parameters		
Number of cold storage rooms installed	Number	5
Total number of units installed	Number	9
Total power consumption of these units	kW	112
Total energy consumption these indoor units	kWh	2,464
Proposed operating parameters		
Expected reduction in consumption	kWh	246.4
Annual operating days	Days	350
Annual energy saving	**kWh**	**86,240**
Energy cost	Rs/kWh	4.55
Annual cost saving	**Rs. Lakhs**	**3.92**
Investment required	**Rs. Lakhs**	**Negligible**
Payback period	**Months**	**Immediate**

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

Every dairy industry under GCMMF is depending on the electricity and natural gas for running the plant every day. The electrical energy and natural gas is needed for 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. Owing to its geographical location, Gujarat receives over 300 days of sunshine annually and an annual mean daily solar radiation in the range of 5-7 kWh/square meter/day.

CST 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, from 50°C to over 400°C, which can be used in a variety of heat applications. CSTs based on single axis tracking mechanism like Linear Fresnel and Parabolic trough can generate anywhere from 3000-3500 kCal/m^2 of solar concentrator area on a clear sunny day. Technologies based on Dual axis tracking like Paraboloid dish 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 22: Different CST available

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

4.5.1 Solar assessment in Rajkot dairy

For Rajkot dairy in Rajkot area, the details of the solar radiation data is as follows:

Table 17: Physical features of the dairy

Parameters	Unit	Climate data location
Latitude	°N	22.3
Longitude	°E	70.783
Elevation	M	58
Heating design temperature	°C	17.43
Cooling design temperature	°C	35.87

The irradiation information will be of immense help for 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 18: Average monthly insolation data

Month	Daily solar radiation horizontal (kWh/m²/d)	Air Temperature (°C)	Winds Speed (m/s)	Relative Humidity (%)
January	4.64	22.7	2.2	33.20%
February	5.34	24.5	2.3	33.10%

Month	Daily solar radiation horizontal (kWh/m²/d)	Air Temperature (°C)	Winds Speed (m/s)	Relative Humidity (%)
March	6.17	28.1	2.5	35.70%
April	6.7	30	2.7	42.20%
May	6.67	30.4	3.4	53.80%
June	5.8	29.5	3.7	67.90%
July	4.77	28	3.5	77.20%
Aug.	4.58	27.5	2.9	75.80%
September	5.2	28.2	2.4	65.60%
October	5.22	29.6	1.8	44.90%
November	4.66	27.6	1.7	31.10%
December	4.31	24.2	2	31.40%
Annual	**5.34**	**27.5**	**2.6**	**49.30**

4.5.2 Energy and cost parameters for installation of CST modules

On the basis of availability of 2,500 m² roof top area in the Rajkot dairy, a comparison of energy and cost parameters for CST water heaters that can be installed in the dairy is provided below:

Table 19: Energy and cost parameters for solar CST modules

Description	Units	Parameters
Present operating parameters		
Estimated area available for CST installation	m²	2,500
Temperature of water considered in ambient condition	°C	30
Expected temperature of the hot water from CST unit	°C	70
Fuel used in the boiler		Natural Gas
Cost of natural gas per SCM	Rs/SCM	30
Calorific value of natural gas	kCal/kg	8,400
Current boiler efficiency	%	85
Proposed operating parameters		
Expected Cost saved by the CST Installation	Rs./day	21,433
Annual operating days per year	Days	300
Annual cost saving by CST installation	**Rs. Lakhs**	**78.2**
Investment for complete CST installation	Rs. Lakhs	450
Possible subsides from government and other agencies	Rs. Lakhs	200
Net investment required for CST project	**Rs. Lakhs**	**250**
Payback period (Excluding possible subsidy)	**Months**	**69**

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 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 20: 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 plant 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 to the Gujarat dairy sector.

Table 21: Vendor list

Equipment/ Technology	Product	Manufacture/ Brand	Complete Address
Variable Frequency Drive (VFD)	VFD	Danfoss	Danfos India Private Limited No. 502, Abhijeet IV, Behind Pantaloon Showroom Near Law Garden Ahmedabad - 380009
	VFD	Schneider	Schneider electric India Private Limited No. 42A, 4th Floor, Space House, Mithakali Six 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
Solenoid control valve	Valve	Rockwell Automation	Rockwell India Private Limited No. 605, Shri Krishna Complex, Mithakhali Navrangpura, Navrangpura Ahmedabad- 380009
		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

** 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.*