Promoting EE & RE in Selected MSME Clusters in India – Morbi Cluster

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE SP-5: OSHO SANITARYWARE (P) Ltd.

Submitted to

UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

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This **Comprehensive Energy Audit Report** has been originally prepared by **Development Environergy Services Ltd.** as a part of '**Promoting EE & RE in Selected MSME Clusters in India – Morbi Cluster'** activity under the GEF-UNIDO-BEE project 'Promoting Energy Efficiency and Renewable Energy in selected MSME clusters in India'.

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Disclaimer

This **Comprehensive Energy Audit Report** is an output of an exercise undertaken by **Development Environergy Services Ltd.** (DESL) under the GEF-UNIDO-BEE project's initiative for the benefit of MSME units and is primarily intended to assist and build the capability of decision making by the management of MSME units for implementation of EE & RE technologies, BOP etc. While every effort has been made to avoid any mistakes or omissions. However, GEF, UNIDO, BEE or DESL would not be in any way liable to any person or unit or other entity by reason of any mistake/omission in the document or any decision made upon relying on this document.

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1. Mr. Kennit Suresh
2. Mr. Niranjan Rao Deevela
3. Mr. Vamsi Krishna
4. Mr. Vijay Mishra

DESL is indebted to M/s. Osho Sanitary ware (P) Ltd. and their management for showing keen interest in the energy audit and their wholehearted support and cooperation for the preparation of this comprehensive energy audit report, without which the study would not have steered to its successful completion. Special thanks to following members of the unit for their diligent involvement and cooperation.

1. Mr. Alpesh Patel, Director

It is well worthy to mention that the efforts being taken and the enthusiasm shown by all the personnel towards energy conservation are really admirable.

We also acknowledge the support from Morbi Ceramics Association throughout the study.

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ABBREVIATIONS

Abbreviations	Expansions
APFC	Automatic Power Factor Controller
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BOP	Best operating practice
CGCRI	Central Glass and Ceramic Research Institute
CMP	Common monitor able parameters
DESL	Development Environergy Services Limited
ECM	Energy Conservation Measure
EE	Energy efficiency
FI	Financial institutions
FT	Floor tile
GEF	Global Environmental Facility
GPCB	Gujarat State Pollution Control Board
IRR	Internal Rate of Return
LPG	Liquefied Petroleum Gas
MCA	Morbi Ceramic Association
MSME	Micro, Small and Medium Enterprises
NPV	Net Present Value
PG	Producer Gas
PMU	Project Management Unit
PV	Photo Voltaic
SEC	Specific energy consumption
SP	Sanitary ware products
RE	Renewable energy
UNIDO	United Nations Industrial Development Organization
VFD	Variable frequency drive
VT	Vitrified tile
WH	Waste heat
WHR	Waste heat recovery
WT	Wall tile

UNITS AND MEASURES

Parameters	Unit of Measurement (UOM)
Calorific value	CV
Degree Centigrade	^0C
Horse power	hp
Hour(s)	h
Hours per year	h/y
Indian Rupee	INR/Rs.
Kilo Calorie	kCal
Kilo gram	kg
Kilo volt	kV
Kilo volt ampere	kVA
Kilo watt	kW
Kilo watt hour	kWh
Kilogram	kg
Litre	L
Meter	m
Meter Square	m^2
Metric Ton	MT
Oil Equivalent	OE
Standard Cubic Meter	scm
Ton	t
Tons of Oil Equivalent	TOE
Ton of CO_2	tCO_2
Ton per Hour	t/h
Ton per Year	t/y
Voltage	V
Watt	W
Year(s)	Y

CONVERSION FACTORS

TOE Conversion	Value	Unit	Value	Unit
Electricity	1	kWh	0.000086	TOE/kWh
Coal	1	MT	0.55	TOE/MT
Natural Gas	1	scm	0.00082	TOE/scm
Emissions				
Electricity	1	kWh	0.00082	tCO_2/kWh
Coal	1	MT	2.116	tCO_2/t
Natural Gas	1	scm	0.001923	tCO_2/scm

EXECUTIVE SUMMARY

The Bureau of Energy Efficiency (BEE) in collaboration with United Nations Industrial Development Organization (UNIDO) is working on the Global Environment Facility (GEF) funded project titled - 'Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India', which aims to give impetus to the energy efficiency initiatives in the small and medium enterprises (SMEs) sector in India. The objective of the program is development and promotion of energy efficiency and enhanced use of renewable energy in 12 selected energy-intensive MSME clusters, identified on the basis of their total energy utilization and energy-intensity levels. The project will provide solutions to certain technological as well as policy level barriers in implementation of energy efficient technologies in the MSME sector. Development Environergy Services Ltd. (DESL) has been engaged to lend project development support for the Morbi Ceramic Cluster in Gujarat.

The assignment targets ceramic industries in four (4) major product categories viz. sanitary products, floor tiles, wall tiles and vitrified tiles. Based on walk through audit and questionnaire survey of several ceramic manufacturing industries, 20 units have been shortlisted by BEE and UNIDO in consultation and discussion with the Morbi Ceramic Association (MCA) to conduct detailed energy audits.

Home Osho Sanitary ware (P) Ltd. has been selected as one of the 20 units for detailed energy audit. Home decor is a one piece closet manufacturing unit. This report has been prepared as an outcome of energy audit activities carried out in the unit.

INTRODUCTION OF THE UNIT

Name of the Unit	Osho Sanitary ware (P) Ltd
Year of Establishment	2012
Address	Sartanpar Road, NH -27m Morbi - 363642, Gujarat - India
Products Manufactured	One piece closet and other sanitary products
Name(s) of the Promoters / Directors	Alpesh Patel

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

- **Stage 1:** Walk through energy audit of the plant to understand process, energy drivers, assessment of the measurement system, assessment of scope, measurability, formulation of audit plan and obtaining required information
- **Stage 2:** Detailed energy audit- testing & measurement for identification of saving potential, technology assessment and understanding of project constraints
- **Stage 3**: Data analysis, initial configuration of projects, savings quantification, vendor consultation, interaction with unit and freezing of projects for implementation and preparation of comprehensive energy audit report

➨ PRODUCTION PROCESS OF THE UNIT

A brief description of the manufacturing process is given below. The main energy utilizing equipment is the kiln, which operates on natural gas. The temperature maintained in kiln is approximate 1,150 – 1,200°C (in the heating zone). The other equipment installed includes:

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed along with water to form a plastic mass.
- **Agitator:** The plastic mass after mixing in ball mill is poured in to a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Glaze mill:** For producing glazing material used on the product.
- **Kiln:** Moulded sanitary products articles are loaded in kiln car and dried and cured in Tunnel kiln at 1100-1150 deg C temperature.

The main utility equipment installed is:

- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.

The detailed energy audit covered all equipment which was operational during the field study.

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control at kiln: During the study it was found that excess air levels in the NG fired kiln is 6.7% against the desired level of 3%. It is recommended to install an oxygen sensor and PID controller, so that the air flow can be adjusted or automatically.etc according to fuel firing.
- Waste heat recovery from cooling zone: Cooling air is carrying heat from heated product coming out from firing zone and wasted in surroundings. It is recommend to utilize that heat to preheat combustion air from 35°C to 200°C to reduce the fuel consumption in tunnel kiln
- Replacement of conventional motors
- Timer controller at stirrer motor: At present 6 stirrer motors are operated continuously. A timer controller is recommended to be installed so that operating hours of each will reduce up to 12 hour.
- Pressure reduction in air compressor: The pressure at receiver is 8 bar (a) and they require maximum pressure up to 6.5 bars in plant. It is advisable to reduce operating pressure of compressor from 7.5 bar to 6.5 bar
- Replacement of ordinary fans with EE ceiling fans: Average power consumption of conventional fan was 48 W during DEA which can be achieved upto 30 W
- Remove throttling in pre heating blowers: Preheating blower was throttled upto 25% which can be eliminated by adjusting VFD that will save 15% energy as compared to present consumption

- Replacements of Inefficient pump with efficient pump: Bore well pump is meeting the plant water requirement, having low efficiency (25%). It is recommended to replace these with more efficient pumps
- Kiln car replacement with improved design and less weight: The existing kiln car is having mass of 500 kg. At present there are light weight options available which can reduce the heat gain by the car, and enable better utilization of heat for the product. It is recommended to replace the kiln car of mass 330 kg
- Installation of EMS in plant
- Replacement of belt drive to direct drive
- Convert existing V belt to REC belt.
- Replacement of T8 tube lights with EE LED lamps
- Cleaning of chocked filter
- Installation of roof top solar PV system

The following table summarizes the quantity of resource saved, monetary savings, investment and payback period of the measures.

Table 1 Summary of ECMs

Sl. No.	Energy Conservation Measures	Estimated Annual Savings				Annual Monetary Savings	Investment	Simple Payback Period	Annual Emission Reduction
		Electricity	NG	Coal	TOE Equivt.				
		KWh	scm/y	t	TOE/y	Lakh Rs/y	Lakh Rs	Months	tCO_2
1	Excess air control for kiln	28,322	19,368		20	8.29	6.93	10	60
2	Waste heat recovery from hot air		1,10,836		100	36.32	39.60	13	213
3	Kiln car replacement with improved and less weight car		32,109		29	10.5	7.0	8	62
4	Remove throttling in pre heating blowers by VFD	5,355			0.5	0.37	0.22	7	4
5	Cleaning of choked filter	11,350			1	0.8	Nil	Immediate	9
6	Replacement of conventional motors with EE motors	14,993			1	1.03	1.11	13	12
7	Timer controller at stirrer motor	61,446			5	4.23	0.55	2	50
8	Pressure reduction at air compressor	11,837			1	0.81	0.33	5	10
9	Replacement of T8 tube lights with EE LED lamps	83,160			7	5.72	2.44	5	68
10	Replacement of ordinary fans with EE ceiling fans	53,010			5	3.65	8.25	27	43
11	Inefficient pump replacement with efficient pump	17,804			2	1.22	0.92	9	15
12	Installation of EMS in plant	15,596			1	1.07	1.85	21	13
13	Power factor improvement					0.09	0.2	29	
14	Replacement of belt drive with direct drive	1,434			0.1	0.10	0.17	21	1
15	V belt replacement with REC belt	6,783			1	0.47	0.57	15	6
	Total	311,088	162,313		173	74.8	70	11	567

The recommendations, when implemented, will enable the following improvements:

- Reduction in energy cost by 32%
- Reduction in electricity consumption by 39.9%
- Reduction in thermal energy consumption by 40%
- Reduction in greenhouse gas emissions by 31.8 %

FINANCIAL ANALYSIS

Summary of financial indicators of the each recommendation is summarized in the table below. The IRR and discounted payback period has been calculated considering a five-year period.

Table 2: Financial indicators

#	Energy conservation measure	Investment	Internal Rate of Return	Discounted Payback Period
		Lakh Rs	%	Months
1	Excess air control for Kiln	6.93	91	3.88
2	Waste heat recovery from flue gas	39.60	67	4.99
3	Kiln car replacement with improved and less weight car	7.00	112	3.13
4	Remove throttling in pre heating blowers by VFD	0.22	123	2.8
5	Cleaning of chocked filter			
6	Replacement of conventional motors with EE motors(IE# 3) for stirrer	1.11	67	4.95
7	Timer controller at stirrer motor	0.55	563	0.63
8	Pressure reduction at air compressor	0.33	185	1.92
9	Replacement of T8 tube lights with EE LED lamps	2.44	181	2.00
10	Replacement of ordinary fans with EE ceiling fans	8.25	23	10.06
11	Inefficient pump replacement with efficient pump	0.92	101	3.5
12	Installation of EMS in plant	1.85	36.5	7.8
13	Power factor improvement	0.22	36.0	5.78
14	Replacement of belt drive with direct drive	0.17	35.9	7.87
15	V belt replacement with REC belt	0.57	57	5.63

1. CHAPTER -1 INTRODUCTION

1.1 BACKGROUND AND PROJECT OBJECTIVE

The Bureau of Energy Efficiency (BEE) in collaboration with United Nations Industrial Development Organization (UNIDO) is working on the Global Environment Facility (GEF) funded project titled - 'Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India', which aims to give impetus to the energy efficiency initiatives in the small and medium enterprises (SMEs) sector in India. The objective of the program is development and promotion of energy efficiency and enhanced use of renewable energy in 12 selected energy-intensive MSME clusters, identified on the basis of their total energy utilization and energy-intensity levels. The project will provide solutions to certain technological as well as policy level barriers in implementation of energy efficient technologies in the MSME sector.

The objective of the project includes:

- Increased capacity of suppliers of energy efficiency (EE) and renewable energy (RE) based products, service providers and financing institutions;
- Increasing the levels of end-use demand and implementation of EE and RE technologies and practices by SMEs.
- Scaling up of the project to a national level.
- Strengthening policy, Institutional and decision-making frameworks.

1.2 ABOUT THE UNIT

General details of the unit are given below:

Table 3: Overview of the Unit

Description	Details		
Name of the plant	Osho Sanitaryware (P) Ltd		
Plant Address	27- National Highway, Sartanpar Road, Morbi-363642		
Constitution	Private Limited		
Name of Promoters	Alpesh Patel		
Contact person	Name	Alpesh Patel	
	Designation	Director	
	Tel	9099088440	
	Fax		
	Email	alpesh@oshosanitarywares.com	
Year of commissioning of plant	2012		
List of products manufactured	One piece closet and other sanitary products		
Installed Plant Capacity	400-500 pieces/day or 11-12 tonnes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	Not provided		
Net profit	Not provided by the unit		
No of operational days in a year	Days/Year	350	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	

Description	Details		
Number of employees	Category	Number	
	Staff	120	
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	No	
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas (scm)	Yes	Kiln
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
If Yes	Year of energy audit		
	Conducted by		
	Recommendations implemented		
	Type of ECM		
Visit Dates	Visit #1	28-May-18	
	Visit #2	15-Jun-18	
Interested in DEA	Yes		
	Interested		

1.3 Methodology and Approach

The study was conducted in 3 stages:

- **Stage 1:** Walk through energy audit of the plant to understand process, energy drivers, assessment of the measurement system, assessment of scope, measurability, formulation of audit plan and obtaining required information
- **Stage 2:** Detailed energy audit-testing & measurement for identification of saving potential, technology assessment and understanding of project constraints
- **Stage 3**: Desk work for data analysis, initial configuration of projects, savings quantification, vendor consultation, interaction with unit and freezing of projects for implementation and preparation of energy audit report

The following flow chart illustrates the methodology followed for Stage-2 and Stage-3.

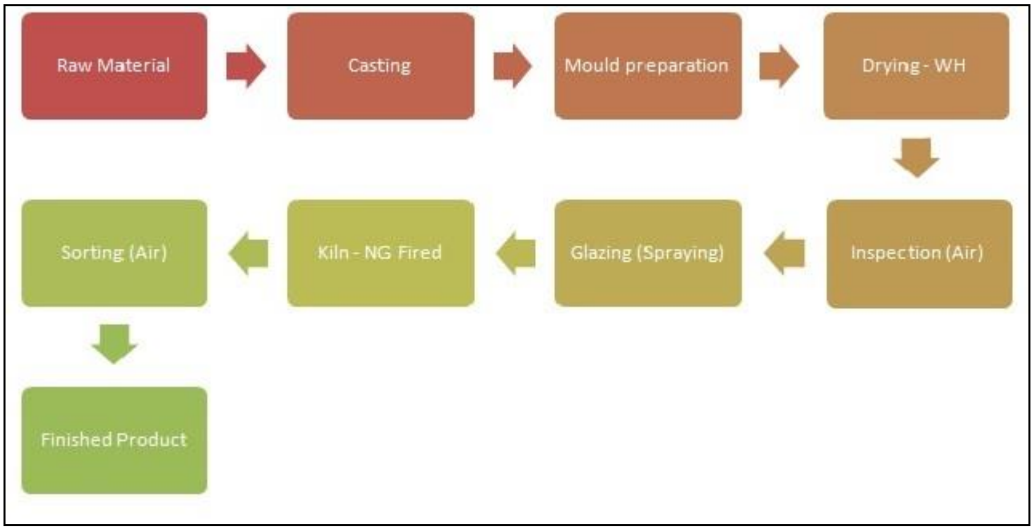

Figure 1 : General methodology

The field work was carried out during 11th to 12th December 2018.

Stage-2: A kick-off meeting was conducted to explain to the unit the methodology of field assessment and map major areas of concern/expectation of the unit. This was followed by a process mapping to understand the manufacturing process based on which field measurement was planned in all major energy consuming areas. Field measurements were conducted as per this plan using calibrated portable measurement instruments. The audit covered all the energy intensive systems and equipment which were working during the field study. Simultaneously, process flow diagram, single line diagram, and data collection were done. At the end of the field study, a debriefing meeting was conducted to discuss initial findings and project ideas.

Stage-3: Post audit off-site work carried out included data compilation, data analysis, calculations for arriving at the savings potential, investment estimate through information available with DESL vendor database and carrying out vendor interactions as required, configuring the individual energy performance improvement actions and preparation of comprehensive energy audit report. The identified energy performance improvement actions (ECM's) normally fall under short, medium and long-term measures.

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit are the following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Parameters Measured
1	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
2	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval

Sl. No.	Instruments	Parameters Measured
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and Flue gas temperature, Ambient temperature
6	Digital Temperature and Humidity Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

This detailed energy audit report has been organized and presented sequentially as follows:

- Executive Summary of the report covers the summary list of projects along with estimated investment & energy and financial saving figures for individual projects.
- Chapter 1 (this chapter) of the report provides a brief background of the project, the scope of work and unit details and the methodology and approach for detailed energy audit.
- Chapter 2 of the report provides a description of the manufacturing process, analysis of historical energy consumption and establishment of baseline.
- Chapter 3 and 4 covers the performance evaluation of major energy consuming equipment and sections, thermal and electrical.
- Chapter 5 covers information on energy monitoring practices and best monitoring practices.
- Chapter 6 covers information on renewable energy assessment in the unit.

2. CHAPTER -2 PRODUCTION AND ENERGY CONSUMPTION

2.1 Manufacturing process with major equipment installed

A simple block diagram of the process flow is shown in the figure below:

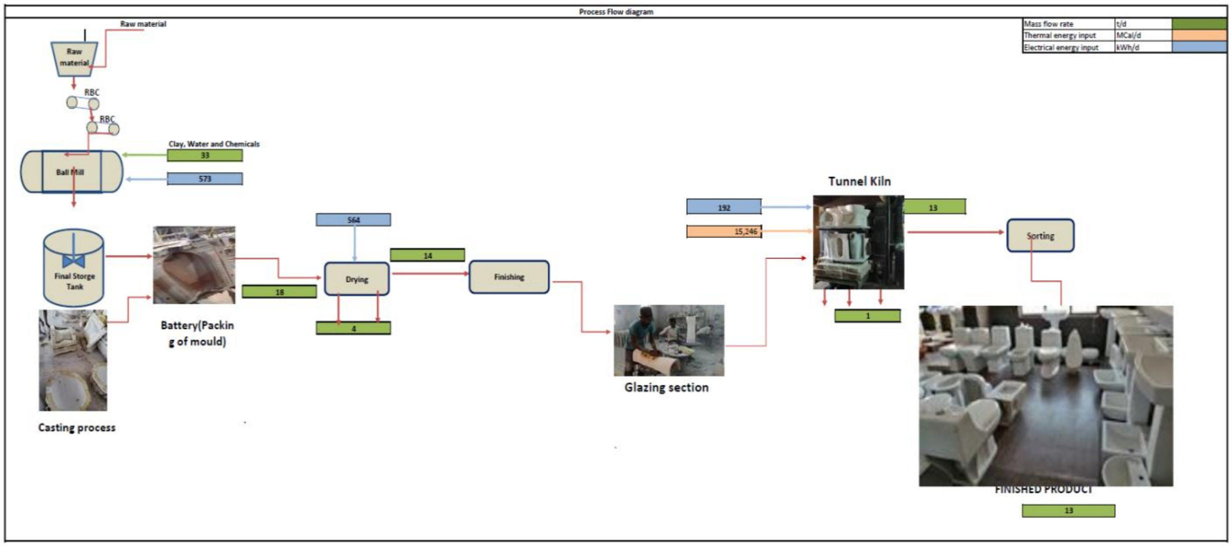

Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is a mixture of china clay, bole clay, Than clay, talc, potash, feldspar and quartz which is mixed along with water to form slurry.

Figure 3: Ball Mill for clay preparation

- The raw materials are mixed and grinded using pebbles together with water in the ball mill for a period of 7.5-9.0 hours. Slurry is then poured into the prepared mould to undergo a casting process and then allowing it to solidify and form a battery of the product

Figure 4: Moulding Battery section

- After this the moisture is reduced from 35-40% to 6% in by evaporative drying using several numbers of ceiling fan air circulation drying process.
- This is followed by the grinding/polishing , glazing process and printing using stickers

Figure 5: Manual printing process

- After this the glazed products make a passage through tunnel kiln at 1100- 1,150oC for final drying and hardening.

Figure 6: Tunnel kiln entry

- Output of kiln is inspected for any possible defect.
- After sorting, various products are packed in boxes or wrapped with dry grass to avoid damage during transportation and then dispatched.

The major energy consuming equipment's in the plants are:

- **Ball mill**: Here the raw materials like clay, feldspar, potash, talc and quartz are mixed along with water to form slurry.
- **Glaze mill:** For producing glazing material used for spraying on various sanitary products.
- **Air Compressor**: Pressurized air is used at several locations in a unit viz. cleaning, finishing, glazing etc.
- **Agitator**: The liquid slurry mass after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing settling of solid particles at the bottom.
- **Tunnel Kiln**: The kiln is the main energy consuming equipment where the product is passed after glazing and printing. The kilns are about 55 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150°C to 1,200°C depending upon the type of the final product. Once the sanitary products come out of the kiln. The materials further go for sorting to find the defected closet and then packed for dispatch.

A detailed mass balance diagram for the unit is included as Annexure-1. A detailed list of equipment is included as **Annexure-2**.

2.2 Production Details

The unit is currently manufacturing one piece closet of the following specifications:

Table 5: Product Specifications

Product	Weight	Pieces per day
	kg/d	
One piece closet	11,500	400-500

The products are mainly sold in domestic market as well as exported. The month wise production details of various products, is given below.

Table 6: Month wise production

Period	Corresponding Mass (MT)
Nov-17	241
Dec-17	204
Jan-18	194
Feb -18	185
Mar-17	212
Apr-17	243
May-17	289
Jun-18	320
July-18	324
Aug-18	277
Sep-18	47
Oct-18	**335**
Average	239

2.3 ENERGY SCENARIO

Both electricity and thermal energy is used in different manufacturing processes. The overall energy usage pattern in the unit is as follows:

- Electricity is supplied from two different sources:
- From the Utility, Paschim Gujarat Vij Company Ltd. (PGVCL)
- Captive backup diesel generator sets for whole plant
- Thermal energy is used for following applications :
- Natural Gas for tunnel kiln

Total energy consumption pattern for the period Nov-17 to Oct-18, from different sources was as follows:

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	TOE	% of total
Grid – Electricity	54.15	23.0	67	11.8
Thermal – NG	181.26	77.0	503	88.2
Total	235.41	100	571	100

This is shown graphically in the figures below:

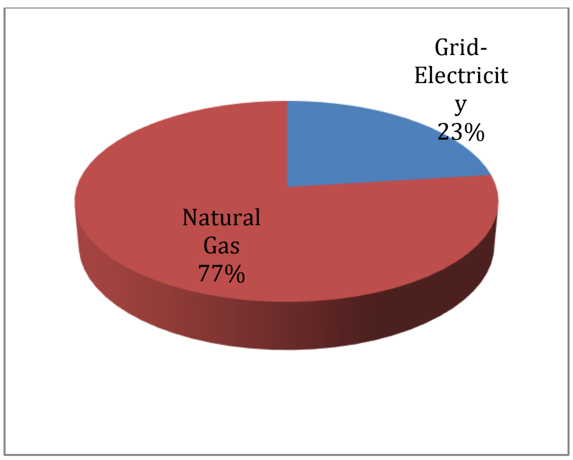

Figure 7 : Energy cost share

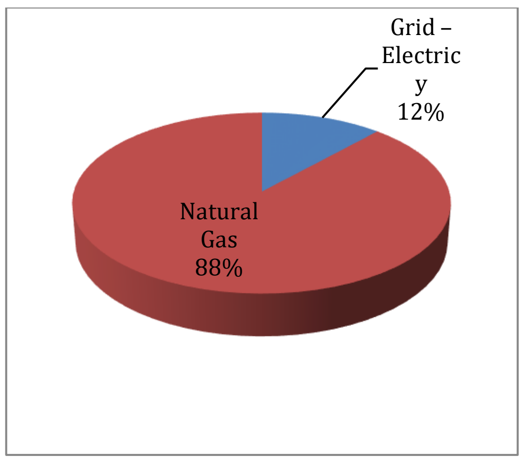

Figure 8: Energy use share

The major observations are as under:

- The unit uses both thermal and electrical energy for the manufacturing operations. Electricity is sourced from the grid as well as self-generated from DG sets when the grid power is not available. However, blackouts are infrequent, due to which the diesel consumption is minimal and records are not maintained.
- Electricity used in the utility and process accounts for the remaining 23% of the energy cost and 11.8% of the overall energy consumption.
- Source of thermal energy is from combustion of natural gas, which is used for firing in the kiln.

- Natural gas used in kiln account for 77% of the total energy cost and 88% of overall energy consumption.

2.3.1 Analysis of Electricity Consumption

2.3.1.1 Supply from Utility

Electricity is supplied by the Paschim Gujarat Vij Company Ltd. (PGVCL). The unit has one electricity connection, details of which are given below:

Table 8: Details of Electricity Connection

Particulars	Description
Consumer Number	32,610
Tariff Category	HTP-I
Contract Demand, kVA	225 kVA
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Electric Tariff structure

Particulars	Tariff structure for Category LTP-1
Demand Charges (Rs./kVA) 1st 500 kVA 2nd 500 kVA Next 297	 150 260 475
Energy Charges (Rs./kWh) Normal Hours Peak Hours Night Time	 4.2 0.85 0.4
Fuel Surcharge (Rs./kVAh) (variable)	0.00
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill from Nov-17 to Oct 18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units consumed kWh	Total Electricity cost Rs.	Average unit Cost Rs./kWh
Nov-17	58,269	4,23,436	7.27
Dec-17	72,933	5,19,331	7.12
Jan-18	82,032	5,82,249	7.10
Feb-18	75,174	5,23,251	6.96
Mar-18	58,155	3,73,720	6.43
Apr-18	62,718	4,40,034	6.22
May-18	55,803	3,55,507	6.37
Jun-18	68,247	4,73,687	6.94

Month	Units consumed kWh	Total Electricity cost Rs.	Average unit Cost Rs./kWh
July-18	65,484	4,56,481	6.97
Aug-18	77,736	5,32,841	6.85
Sep-18	51,051	3,64,497	7.14
Oct-18	52,191	3,70,030	7.09

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 64,983kWh/month and cost is Rs. 4.5Lakhs per month (Nov-17 to Oct-18). The average cost of electricity is Rs. 6.87/kWh, corresponding to the month. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

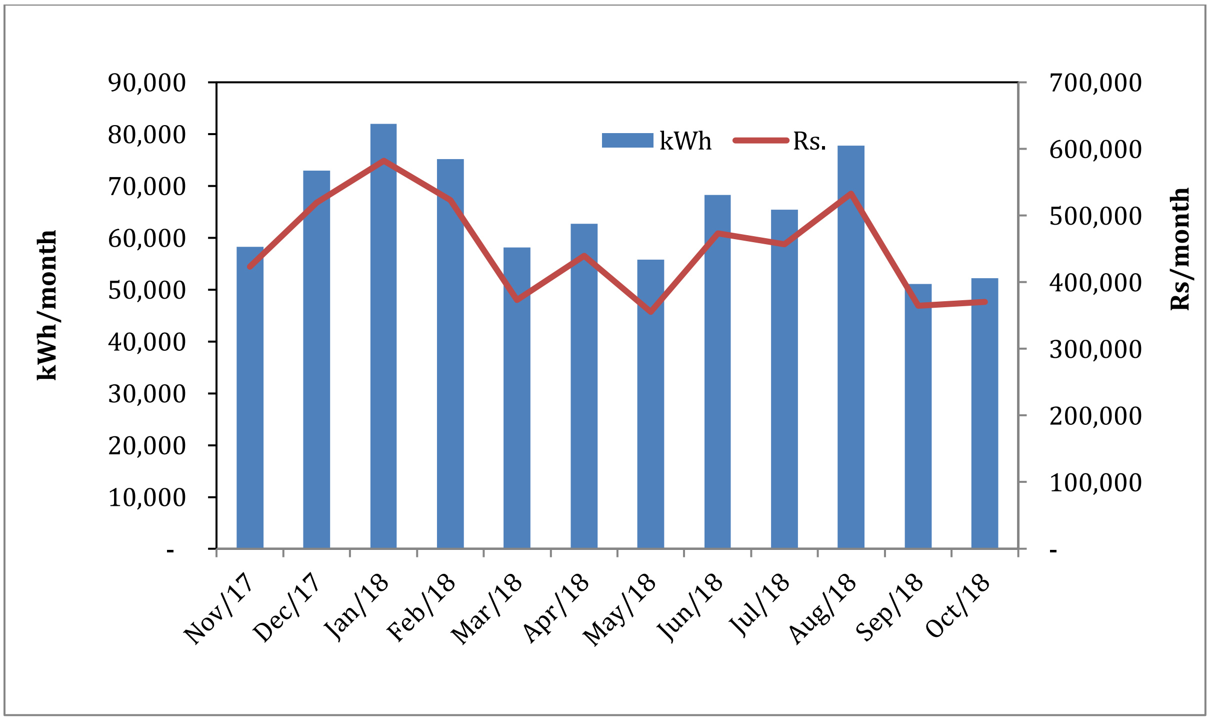

Figure 9: Month wise Variation in Electricity Consumption

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

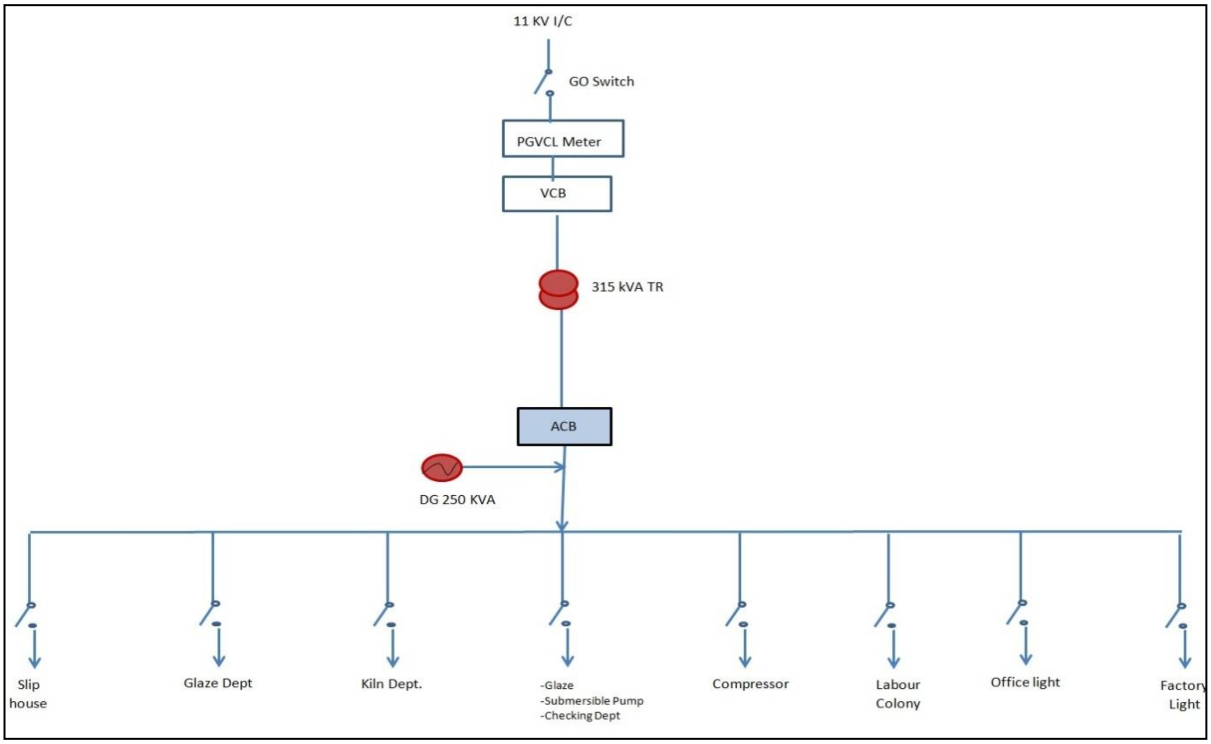

Figure 10: Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 279.5 kW, which includes:

- Plant and machinery load is 155.93 kW.
- Utility load is (lighting, air compressor and fans) about 123.5 kW including the single phase load.

Table 11 : Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Kiln	38
2	Compressor	59
3	Ball Mill	60
4	Agitator tank	22
5	Lightning	33
6	Fans	36
7	AC	32
8	Single phase load	64.52
Total Connected Load		279.5

A pie chart of the entire connected load is shown in the figure below:

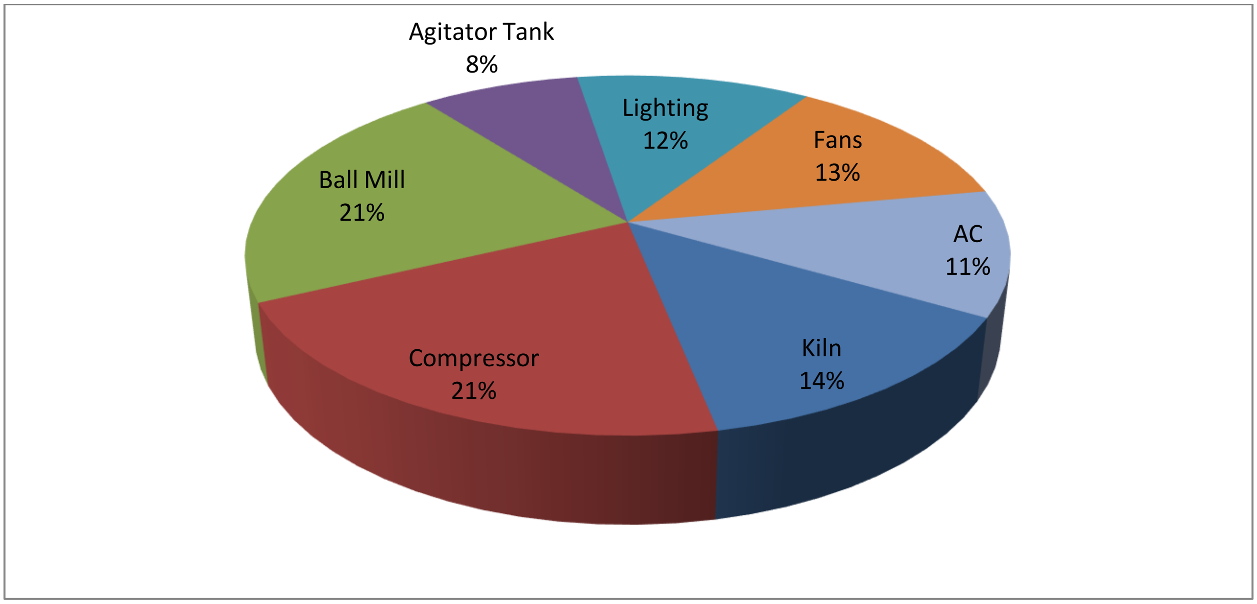

Figure 11: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for ball mill-21%, for the air compressor– 21%, for kiln– 14% , for fans-13% and other loads.

2.3.1.6 Specific electricity consumption

The month wise variation of specific electricity consumption (kWh/t of production) is shown in the figure below:

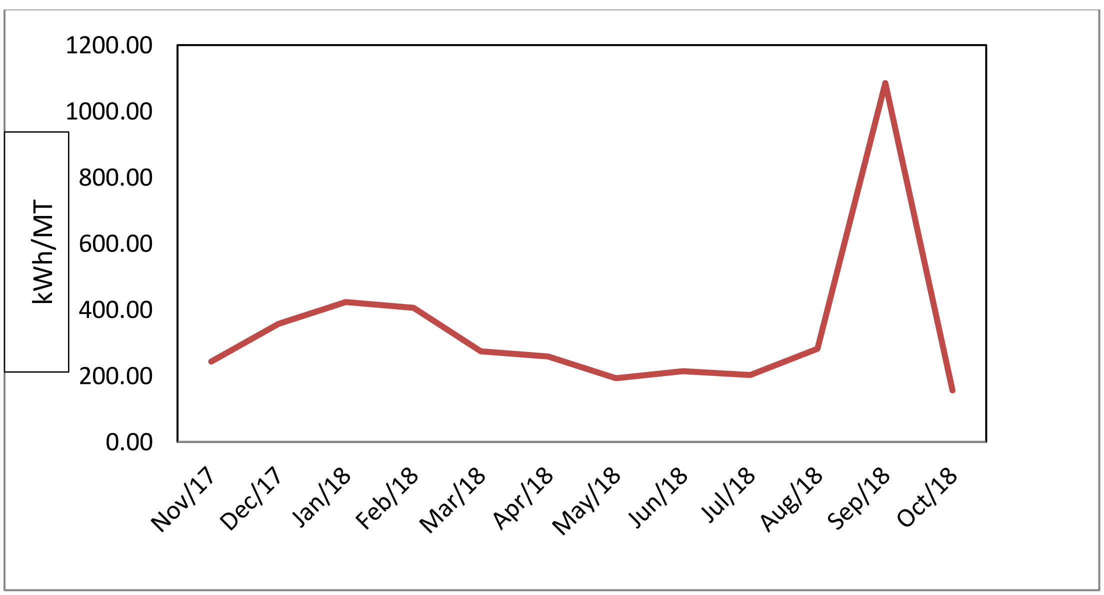

Figure 12: Month wise variation in Specific Electricity Consumption

The maximum and minimum values are within ±25% of the average SEC of 341kWh/t indicating that electricity consumption follows the production. Mostly Plant was in shut down condition in month of

September 18. Month Sep 18 can be considered as outliers since production was least (47MT) and electricity consumption was normal (as other months). Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in ball mill section, glaze mill, utility like compressor, pumps etc.

2.3.2 Analysis of Thermal Consumption

2.3.2.1 Month wise Fuel Consumption and Cost

The thermal consumption area is kiln. Natural gas is used as the fuel for firing in the kiln .Based on the gas bill shared for the month of Nov-17 to Oct-18 annual fuel cost has been derived as under. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	Kiln		
	NG Used	NG Cost	NG cost
	SCM	Rs	Rs./SCM
Nov-17	52,776	1,497,166	28.4
Dec-17	40,210	1,621,742	40.3
Jan-18	55,744	1,545,858	27.7
Feb-18	49,091	1,517,024	30.9
Mar-18	55,619	1,706,841	30.7
Apr-18	34,876	1,366,321	39.2
May-18	53,634	1,738,039	32.4
Jun-18	52,598	1,725,244	32.8
July-18	54,846	1,798,980	32.8
Aug-18	46,426	1,522,799	32.8
Sept-18	7,888	258,731	32.8
Oct-18	55,716	1,827,516	32.8

Observation (for the period Nov-17 to Oct-18)

- Average monthly natural gas consumption is 46,619 scm and average cost is around Rs. 15 Lakhs/month

2.3.2.2 Specific Fuel Consumption.

The month wise variation of specific fuel consumption (SFC- GJ/t of production) is shown in figure below:

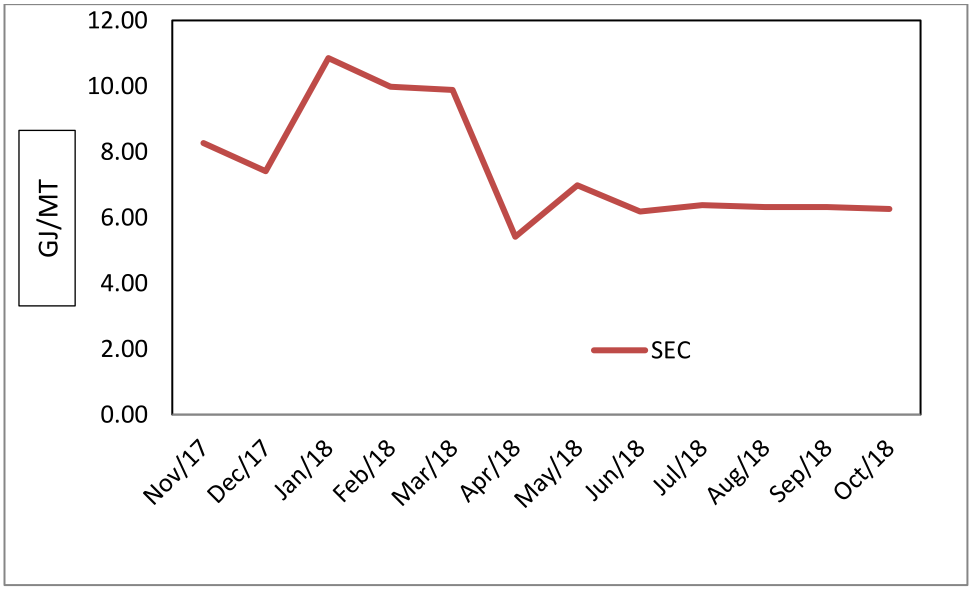

Figure 13 : Month wise variation in Specific Fuel Consumption

The average SFC is 7.5 GJ/MT. SFC is high in the months of Jan-18 (production was 194 MT and thermal consumption was 2,100 GJ) and low in the month of Apr-18 (production was 243 MT and thermal consumption was 1,314GJ). While metering for NG is recorded.

2.3.3 Specific energy consumption

2.3.3.1 Based on data collected during EA.

Specific energy consumption (SEC) on the basis of data collected is shown in below table:

Table 13: Specific energy consumption

Particulars	Units	Value
Average production	kg/h	498
Power consumption	kW	94.8
NG consumption	scm/h	77
Energy consumption	kgOE/h	77.4
SEC of plant	kgOE/kg	0.16

2.3.3.2 Section wise specific energy consumption

Specific electricity consumption section wise (major areas) based on DEA is as follows. This is determined on weight basis, since mass data could be collected at each stage.

Table 14: Section wise specific energy consumption (per unit production)

Particulars	NG	Electricity
	scm/t	kWh/t
Ball Mills		11
Agitator		3.55
Kiln	156	45

The detailed mass balance diagram based on which the above has been arrived at is included as **Annexure-1**.

2.3.3.3 Based on yearly data furnished by unit

Based on the available information, various specific energy consumption (SEC) parameters have been estimated as shown in the following table:

Table 15 : Overall: specific energy consumption

Parameters	Units	Value
Annual Grid Electricity Consumption	kWh/y	779,793
Self-Generation from DG Set	kWh/y	
Annual Total Electricity Consumption	kWh/y	779,793
Annual Thermal Energy Consumption (NG)	scm/y	559,424
Annual Energy Consumption	TOE	571
Annual Energy Cost	Rs Lakh	235
Annual production	MT	2,870
SEC; Electrical	kWh/MT	271.7
SEC; Thermal	GJ/MT	7.34
SEC; Overall	TOE/MT	0.2
SEC; Cost Based	Rs./t	8,201

(Annual data based on the period Nov-17 to Oct-18)

Basis for estimation of energy consumption in terms of tons of oil equivalent are as follows:

Conversion Factors

- Electricity from the Grid : 860 kCal/kWh
- GCV of NG : 9,000 kCal/scm
- CO_2 Conversion factor
- Grid : 0.82 kg/kWh
- NG :0.001923tCO_2/scm

2.3.3.4 Baseline parameters

The following are the general baseline parameters, which have been considered for the techno-economic evaluation of various identified energy cost reduction projects as well as for the purpose of comparison post implementation of the projects. The costs shown are landed costs.

Table 16: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs/ kWh from Nov-17 to Oct-18	6.88
Cost of NG	Rs/SCM	32.4
Annual operating days	d/y	350
Operating hours per day	h/d	24
Annual production	MT	2,870

2.4 WATER USAGE AND DISTRIBUTION

Water usage and pumping efficiencies (including water receipt, storage, distribution, utilization etc.) pump specs, breakdown maintenance etc.

Water requirement is met by two bore well pumps and water is stored in overhead tank. From this overhead water tank, water is distributed to various sections as per requirement through different pumps including workers colony. Water consumption on daily basis is about 165 m^3/day based on measurement.

Water distribution diagram is shown below.

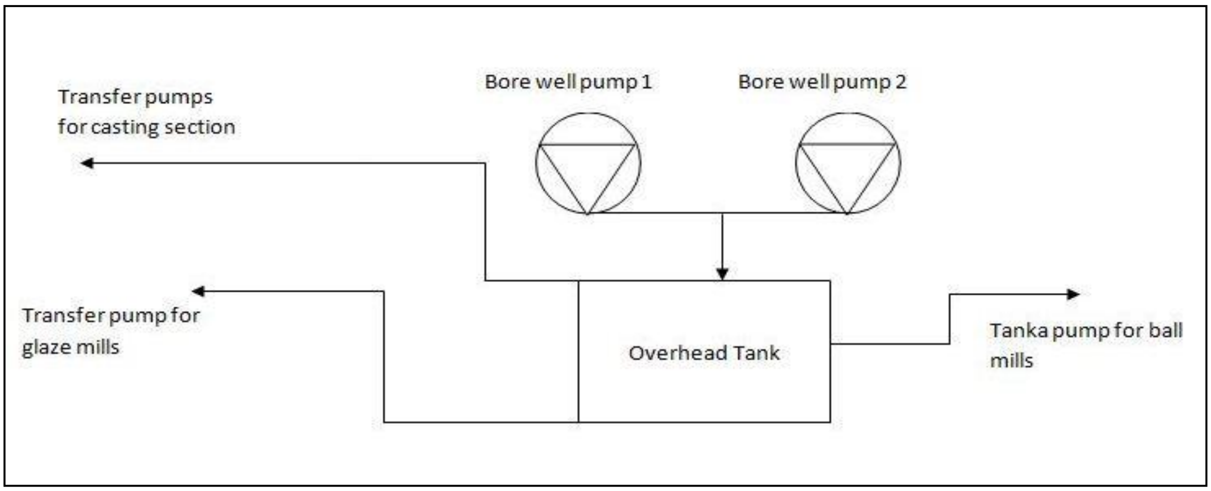

Figure 14: Water Distribution Diagram

Two submersible pumps (only one is in working condition) are installed to meet the water requirements of process (ball mills, glaze mills, casting and domestic use). Installation details of submersible pumps are tabulated hereunder.

Table 17: Submersible pump details

Parameters	Unit	Bore well Pump 1	Bore well Pump 2
Motor rating	HP	15	10
RPM	rpm	2,900	2,900

Unit has installed RO water plant and permit water from RO is utilized for preparation of slurry. It is recommended to install meters, to monitor and control water consumption.

3. CHAPTER -3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Natural gas is used as a fuel in the kiln to heat the closet to the required temperature. The required air for fuel combustion is supplied by combustion blower. Cooling blower is used for cooling the closet after combustion zone to get required closet quality and at the starting point, a preheating blower is installed which preheats the closet before combustion zone of kiln. Kiln consists 51 HP electrical load of which 5 HP is for exhaust blower, 6 HP for preheating blowers, 15 HP for combustion blowers, 15 HP for cooling blowers, 5 HP each for smoke and hot air blower and others load.

Table 18: Kiln Details

Sl. No.	Parameter	Unit	Value
	Make		Local
1	Kiln operating time	H	24
2	Fuel consumption	scm/h	77
3	Number of burner to left	-	
4	Number of burner to right	-	
5	Cycle Time	h	27
6	Pressure in firing zone	mmWC	50
7	Maximum temperature	°C	1,170
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	M	40 x 2.1 x 1
	Firing Zone	M	9 x 2.1 x 1
	Final cooling zone	M	22x 2.1 x 1

3.1.2 Field measurement and analysis

During DEA, measurement of power consumption for all blowers, surface temperature of kiln, flue gas analysis, air flow measurement of blowers and section wise temperature profile of kiln were done. Natural gas generated is used at kiln; therefore, the consumption in kiln has been calculated based on heat load of the kiln during DEA. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 19: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	6.7%
Ambient Air Temperature	35 °C
Exhaust Temperature of Flue Gas	130 °C

From the above table, it is clear that the oxygen level measured in flue gas was high. The inlet temperature of one piece closet in kiln was in the range of 35 – 42°C which was the ambient air temperature. Surface temperature was high, throughout the surface of the kiln as shown in the table below:

Table 20: Surface temperature of kiln

Zone	Temperature (°C)
Ambient Temperature	40.2
Pre-heating zone Average Surface Temperature	56.60
Firing zone Average Surface Temperature	66.60
Cooling zone Average Surface Temperature	55.41

The temperature profile of the kiln is shown below:

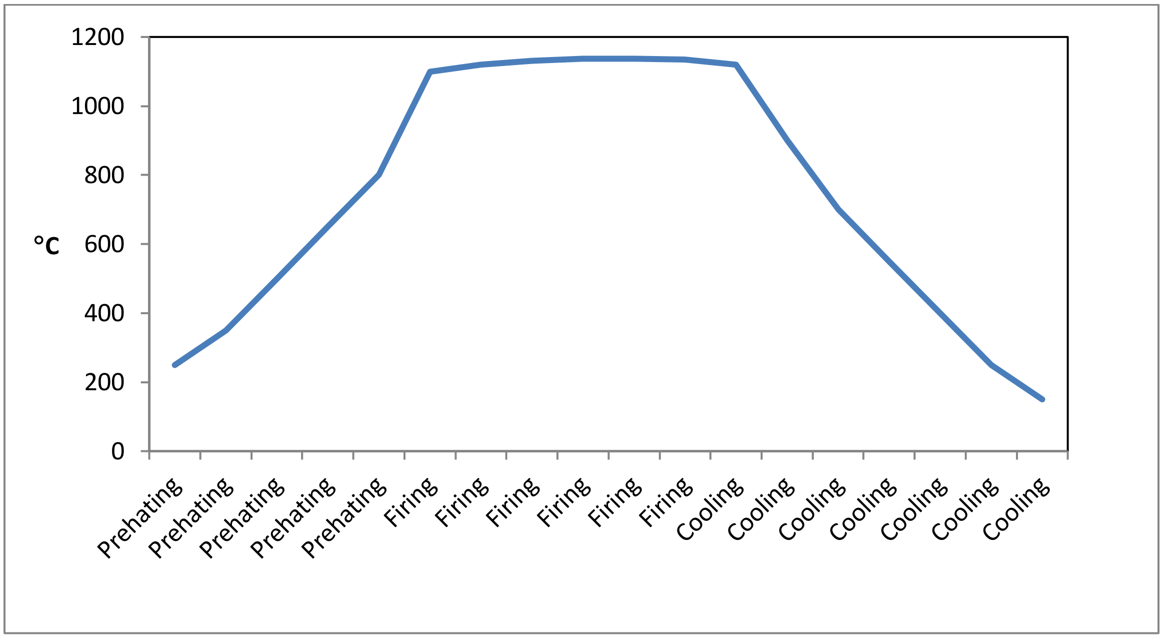

Figure 15 : Temperature Profile of Kiln

Measured data of power for all blowers is given in below table, details are provided in **Annexure-4**:

Table 21 Power measurements of all blowers

Equipment	Average Power (kW)
Preheating Blower 1	2.14
Preheating Blower 2	2.11
Exhaust blower-1	2.41
Combustion Blower-1	2.25
Combustion Blower-2	2.23
Combustion Blower-3	2.34
Cooling Blower-1	1.41
Cooling Blower-2	2.26
Cooling Blower-3	2.03
Smoke Blower	0.63
Hot Air Blower	2.62

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln is 33.3%. Summary of all losses is shown in below figure:

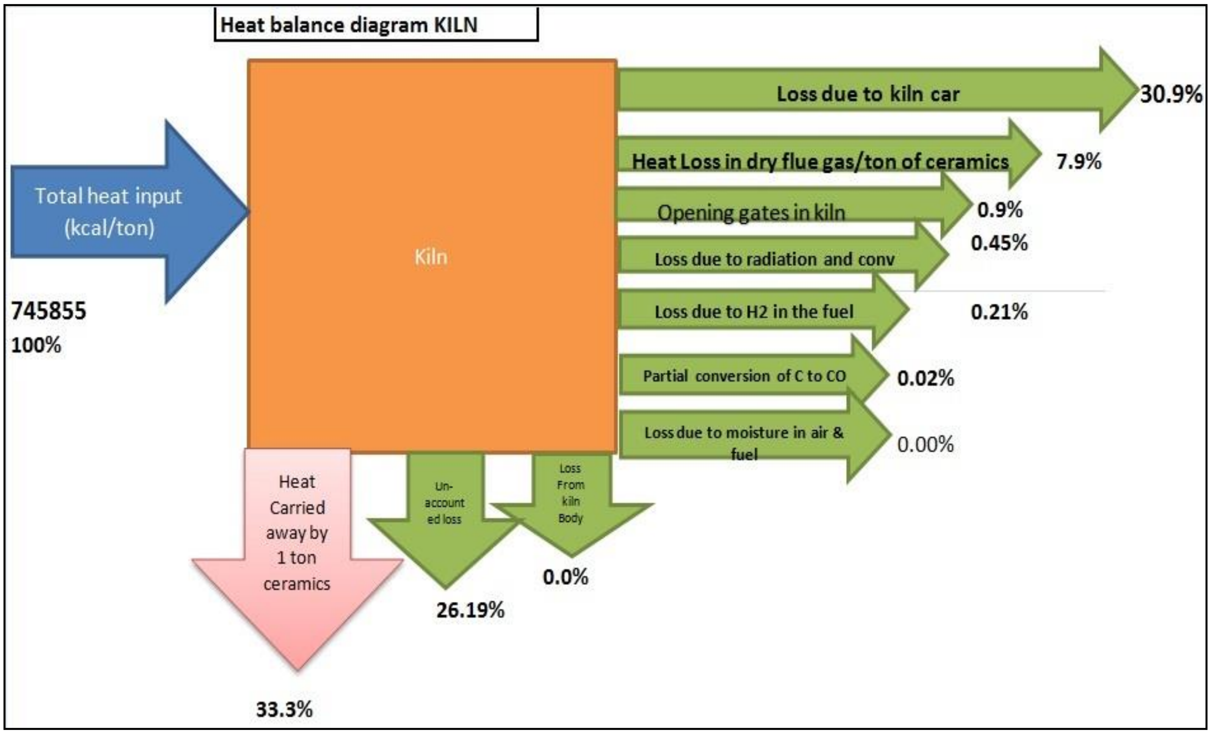

Figure 16: Heat balance diagram of Kiln

Detailed calculation is included in Annexure-5.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln -Excess Air Control

Technology description

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of the fuel. The excess air levels are calculated based on oxygen content in the flue gases. The theoretical air required for combustion of any fuel can be known from the ultimate analysis of the fuel. All combustion processes require a certain amount of excess air in addition to the theoretical air supplied. Excess air supplied needs to be maintained at optimum levels, as too much of excess air results in excessive heat loss through the flue gases. On the other hand, too little excess air results in incomplete combustion of fuel and formation of black colored smoke in flue gases.

In general, in most of the kilns, fuel is fired with too much of excess air. This results in formation of excess flue gases, taking away the heat produced from the combustion and increasing the fuel consumption.

A PID controller, if installed, can measure the oxygen levels in the flue gases at the exit of the kiln and based on that the combustion air flow from FD fan (blower) will be regulated. Subsequently, proper temperature and optimum excess air for combustion can be attained in the kiln.

Study and investigation

At the time of DEA, there was no proper automation and control system installed in the kiln to monitor and maintain optimum excess air levels. Fuel was fired from the existing burner system and no air flow control mechanism was in place for maintaining proper combustion of the fuel. The combustion air and cooling air (through air curtains) were being supplied from the same FD fan. The pressures required for combustion and for cooling air were different, and supplying both the air from one common FD fan was not a good practice.

Flue gas analysis of kiln is given in below table:

Table 22: Flue gas analysis

Parameters	Units	Value
O_2 in flue gas	%	6.7
CO_2 in flue gas	%	8.9
CO in flue gas	ppm	30

Recommended action

Two separate blowers have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. Every reduction in every 10% of excess air will save 1% in specific fuel consumption. The cost benefit analysis of the energy conservation measure is given below:

Table 23: Kiln Excess Air Control (ECM-1)

Parameters	Units	Present	Proposed
A. Fuel Saving			
Oxygen level in flue gas before firing zone	%	6.7	3.00
Excess air percentage in flue gas	%	46.4	16.7
Dry flue gas loss	%	8%	
Saving in fuel (Every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%)	Scm/t	156	151
Saving in specific fuel consumption	scm/h		2.31
Operating hours per day	h/d		350
Operating days per year	d/y		24.00
Annual fuel savings	Scm/y		19,368
Fuel cost	Rs/scm		33
Corresponding monetary savings	Lakh Rs/y		6.3
B. Power saving at combustion blower			
Mass flow rate of air	t/h	1.43	1.43
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	0.3	0.3

Parameters	Units	Present	Proposed
Total pressure rise	Pa	5000	5000
Measured power of blower	kW	6.82	3.45
Motor power	kW	10.3	8.2
Power saving	kW	3.37	
Operating hours per day	h/d	350	
Operating days per year	d/y	24.00	
Savings in electrical energy	kWh/y	28,322	
Cost of electricity	Rs/kWh	6.88	
Savings in terms of energy cost	Lakh Rs/y	1.95	
C. Summary of Savings			
NG saving	scm/y	19,368	
Electricity saving	kWh/y	28,322	
Monetary savings	Lakh Rs/y	8.29	
Estimated investment	Lakh Rs	6.93	
Payback Period	Months	10	
IRR	%	91	
Discounted payback period	Months	3.9	

3.1.4.2 ECM #2: Waste Heat recovery from hot air (generating from cooling zone)

Technology description

Utilization of additional heat content available in hot air (generating from cooling zone).

Study and investigation

It was observed during the field visit that combustion air was supplied at ambient temperature (35°C) and hot air (from cooling zone) was released into surrounding atmosphere which is not advisable. So, to improve efficiency levels of kiln and to save fuel, it is suggested to utilize this additional heat content in the hot air (that is presently being wasted) to marginally increase the temperature of combustion air used in firing zone, thereby also bringing down the cooling air temperatures.

Figure 17: Pre drying and entrance of Tunnel Kiln

Recommended action

It is recommended to decrease the cooling air temperature at kiln so that the combustion air temperature could be increased from 35°C to 200°C, thereby reducing the hot air temperature. This would help to reduce amount of fuel consumption.

Table 24: Recuperator in Smog Line [ECM-2]

Particulars	Units	Value
Combustion air flow	m^3/h	2,448
Density of air	kg/m^3	1.225
Combustion air flow	kg/h	2999
Combustion air temperature in present scenario	°C	35.0
Combustion air temperature after recuperator	°C	200
Heat required	kCal/h	118,752
Heat supply at recuperator input	kCal/h	197,921
Effectiveness of HE-1	%	60.0
GCV of NG	kCal/scm	9,000
NG savings	scm/h	13.2
Operating hours per day	d/y	350
Operating days per year	h/d	24
NG price	Rs./kg	32.8
Annual running hours	h/y	8,400
Annual NG savings	scm/y	110,836
Annual Monetary saving	Lakh Rs/y	36.3
Estimated Investment	Lakhs Rs	40
Payback Period	months	13
IRR	%	67
Discounted payback period	Months	5

3.1.4.3 ECM #3: Replacement of Kiln car with improved and less weight car

Technology description

The existing kiln car consists of refractory bricks and tiles which are very heavy and hence increase the dead weight of the car. The present kiln car also carries away much of the useful heat supplied to the kilns, thus reducing its efficiency. A new material called ultralite[1] can be used in the kiln car construction, replacing the present material, which will help in reducing its dead weight. This will also help in reduction in losses due to useful heat carried away by the kiln car, as this material has lower specific heat.

Study and investigation

[1] Kiln car material by Inter-kiln Industries, Ahmedabad, Gujarat.

Presently, the kiln car used in the unit is made up of HFK bricks, quadrite tiles and pillars. These materials contribute to a dead weight (of kiln car) of 400 - 530 kg. The ceramic materials to be fired are placed on the kiln car on make-shift racks and this kiln car travels all along the length of the kiln from pre-heating zone to firing zone to cooling zone. The kiln car also gains useful heat that is supplied by fuel to heat the ceramic materials and they carry the same with them out of the kiln. The heat gained by kiln car is wastage of useful heat supplied, as the heat is being supplied to heat the ceramic material and not the kiln car. However, this wastage is inevitable, as the materials have to be placed on the kiln cars to travel along the kiln. So, in order to reduce this wastage, it is recommended to select kiln car material that absorbs as minimum heat as possible, so that most of the heat supplied is gained by the ceramic material. This will also help in reducing fuel consumption in the kiln.

Figure 18: Kiln car

Recommended action

It is recommended to replace the present kiln car material with "ultralite" material with a little modification in the arrangement of refractory. This will help reduce its dead weight besides reducing the heat gained by it, and also help in reduction in fuel consumption in the kiln considerably. The cost benefit analysis for the EPIA is given in the table below:

The cost benefit analysis for the EPIA (kiln – 1) is given in the table:

Table 25: Kiln car replacement [ECM-3]

Particulars	Units	As is	To be
Production of the material	t/h	0.50	0.50
Weight of existing kiln car	kg	500	330
Total number of kiln car inside kiln	Nos.	36	36
Initial temperature of kiln car	°C	40.2	40.2
Final temperature of kiln car	°C	1170	1170
Estimated percentage saving by new kiln car material	%	30	
Heat carried away by the kiln material	kcal/h	114,675	80,272
Reduction in the heat carried by the kiln	kcal/h		34,402
Operating hrs of kiln	h	8400	8400
Savings in terms of fuel consumption	scm/y		32,109
NG price	Rs/scm	32.8	32.8
Savings in terms of cost	Rs Lakh/y		10.5

Particulars	Units	As is	To be
Estimated investment of kiln material	Rs Lakh/y		7.00
Payback period	months		8
IRR	%		112
Discounted payback period	Months		3.1

3.1.4.4 ECM #4 Cleaning of chocked suction filter of blowers

Technology description

Frequent cleaning of choked suction filter of all blowers.

Study and investigation

It was observed during the field visit that most of the blowers are having problem of filters chocking which increases the load of blowers

Recommended action

It is recommended to clean all suction filters frequently to reduce loading of blowers. The cost benefit analysis for the ECM is given in the table below:

Table 26: Cleaning of chocked filters [ECM-4]

Parameter	Unit	Values
Existing Blower Flow Rate	m^3/sec	1.9524
Blower Power (Measured)	kW	12.52
Suction Filter Choked	mmWC	37
Existing Static Pressure	mmWC	230
Total Pressure	mmWC	267
Fan Efficiency	%	50
Present Power	kW	12.03
Proposed Power	kW	10.67
Operating Days	d	350
Operating Hours	y	24
Saving Potential	kWh/y	11,350
Saving Potential	INR/y	78,051
Investment	INR	Nil
Simple payback period	months	Immediate
IRR	%	
Discounted payback period	Months	

3.1.4.5 ECM #5 Remove throttling in pre heating blowers

Technology description

Throttling in blowers is to be removed through VFD

Study and investigation

It was observed during the field visit that preheating blower was throttled by 25%.

Recommended action

It is recommended to adjust RPM of VFD with preheating blower so that throttling can be eliminated by varying speed of blower as per requirement. The cost benefit analysis for the ECM is given in the table below:

Table 27: Installation of VFD with preheating blowers [ECM-5]

Parameters	Units	As Is	To Be
Average power consumption of blower	kW	4.25	3.61
Operating hours/day	h/d	24	24
Operating days/year	d/y	350	350
Annual energy consumption	kWh/y	35,700	30,345
Annual energy saving	kWh/y		5,355
Unit cost of electricity	Rs/kWh		6.88
Annual monetary savings	Lakh Rs/y		0.37
Estimated Investment	Lakh Rs		0.22
Payback period	Months		7.3
IRR	%		127
Discounted payback period	Months		2.8

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 BALL MILLS

4.1.1 Specifications

Ball mills produce slurry by mixing clay, water and chemicals SMS and STPP. Ball mills take 5 to 6 hours for slurry preparation. The specifications of ball mills and its accessories are given below:

Table 28 : Specifications of ball mills

Particular	Units	Value
Numbers of ball mills	#	2
Capacity of each ball mill	t/batch	8
Water consumption in each ball mill	t/batch	3
Water TDS	ppm	1100
Nos. of batch per day		3

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all ball mills

All power profile is included in Annexure-4. Average power consumption & PF are given in below:

Table 29: Average power consumption and PF of ball mills

Equipment	Average Power (kW)	PF
Ball Mill	15.6	0.92

Slurry preparation from ball mill is calculated by using daily batch production and slurry preparation in each batch (as mentioned in specification)

4.1.3 Observations and performance assessment

Mass balance of Ball mill #1 Based on measurements is given below:

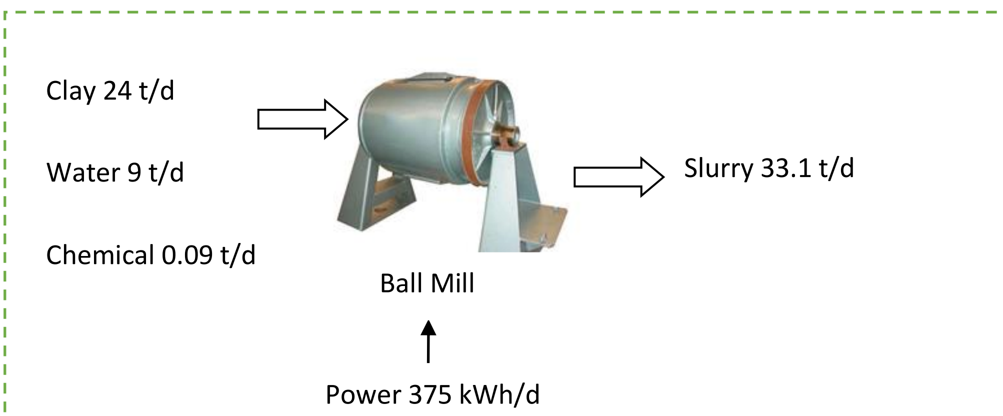

Figure 19: Energy and mass balance of Ball Mill

Performance of ball mills measured in terms of specific energy consumption (power consumed for preparation of 1 ton of slurry). Based on observations during DEA, the specific energy consumption of coal was 11kW/ton. TDS of water is maintained as unit is using RO water in ball mills.

4.2 Agitator Motors

Figure 20: Vertical Agitator

4.2.1 Specifications

Slurry stored in agitation tank after preparation in ball mills where agitator motors (stirrer) were rotating continuously. Stirrer avoids settling of solid particles from slurry. The specifications of agitator motors are given below:

Table 30: Specifications of agitators

Particular	Units	Value
Numbers of agitators tanks	#	3
Capacity of each agitator motor	kW	3
Number of motors	#	6

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

Power consumption of all agitator motors (stirrer) are given in below table:

Table 31: Power consumption and P.F. of agitator motors

Equipment	kW
Stirrer-1	2.4
Stirrer-2	2.38
Stirrer-3	2.43
Stirrer-4	2.44
Stirrer-5	2.47
Stirrer-6	2.51

4.2.3 Observations and performance assessment

During DEA it is observed that all motors operate same time. It is suggested that all motor should operated by timer control. Slurry prepared in ball section is considered same for SEC calculation of agitator also

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry). Based on observations during DEA, the specific energy consumption of agitator motors were 3.55kW/ton.

4.2.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.2.4.1 ECM #6: Timer Controller for stirrer motor

Technology description

A number of agitators are running only to maintain homogenous of the slurry. A timer-based control can help save energy. A number of units have implemented timer based control where two agitators in same tank are made to operate 30-45 minutes each based on time control.

Study and investigation

It was observed that all the agitators are equipped with DOL (Direct online) starter and all agitators are in continuous operation throughout the day.

Recommended action

It is recommended to install timer based control for agitators to save energy. Timing of agitators can be decided based on requirement and configuration of agitators. The cost benefit analysis for this project is given below:

Table 32: Stirrer Time Controller [ECM-6]

Particulars	Unit	AS IS	TO BE
No of agitator stirrer	Nos.	6	6
No of agitator stirrer running	Nos.	6	6
Rated power of agitator stirrer motor	kW	3	3
Running of each stirrer motor	h/d	24	12
Operating power of stirrer motor	kW	2.4	2.4
Annual operating days	d/y	350	350
Annual power consumption	kWh/y	122,892	61,446
Annual energy saving	kWh/y	0	61,446
Cost of Electricity	Rs./kWh		6.80
Annual energy cost saving	Lakh Rs./y	4.23	
Estimated investment	Lakh Rs.	0.55	
Payback Period	Months	1.57	
IRR	%	563	
Discounted payback period	Months	0.6	

4.2.4.2 ECM # 7 –Replacement of conventional motor with IE3 stirrer motor

Technology description

It was observed that stirrer motor is consuming much higher power than EE motor (IE3)

Study and investigation

Power consumption of stirrer motor is recorded and compared with latest EE motors (IE#3) and found less efficient

Recommended action

It is recommended to replace existing conventional motor with EE motor (IE#3 motor)

Estimated cost benefit is given in the table below:

Table 33: Saving and cost benefit by using improved water quality [ECM-7]

Particular	Unit	AS IS	To Be
Rated power of motor	kW	22	22
Existing efficiency of motor	%	85.5	87.8
Existing power consumption	kW	14.63	12.85
Energy loss in motor	kW	2.1	0.3
Estimated energy saving	kW		1.8
Operating days/year	d/y	350	350
Operating hours/day	h/d	24	24
Annual energy consumption	kWh/y	122,892	107,899
Annual energy savings	kWh/y	14,993	
Unit cost of electricity	Rs/kWh	6.88	
Annual monetary savings	Lakh Rs/y	1.03	
Estimated Investment	Lakh Rs	0.13	
Payback Period	Months	1.5	
IRR	%	67	
Discounted payback period	Months	5	

4.3 GLAZING

4.3.1 Specifications

Ceramic glaze is an impervious layer or coating of a vitreous substance which is fused to a ceramic body through firing. Glaze can serve to color, decorate or waterproof an item. It also gives a tougher surface. Glaze is also used on stoneware and porcelain. In addition to their functionality, glazes can form a variety of surface finishes, including degrees of glossy or matte finish and color. Glazes may also enhance the underlying design or texture unmodified or inscribed, carved or painted.

Glazes need to include a ceramic flux which functions by promoting partial liquefaction in the clay bodies and the other glaze materials. Fluxes lower the high melting point of the glass formers silica, and sometimes boron trioxide. These glass formers may be included in the glaze materials, or may be drawn from the clay beneath.

Figure 21: Glaze section

Raw materials of ceramic glazes generally include silica, which will be the main glass former. Various metal oxides, such as sodium, potassium, and calcium, act as flux and therefore lower the melting temperature. Alumina, often derived from clay, stiffens the molten glaze to prevent it from running off the piece. Colorants, such as iron oxide, copper carbonate, or cobalt carbonate and sometimes opacifiers like tin oxide or zirconium oxide, are used to modify the visual appearance of the fired glaze.

The specifications of glazing mills are given below:

Table 34: Specifications of glazing machine

Particular	Units	New sizing
Numbers of glazing mills	Nos.	3
Capacity of glazing mills	HP	7.5

Glazing mills were not in operation during DEA so measurement and observation are not given in report

4.4 AIR COMPRESSORS

4.4.1 Specifications

Two air compressors are installed in plant. The specifications of compressors are given below:

Table 35: Specifications of compressors

Particular	Units	Venus Compressor	ELGI compressor
Power rating	HP	50	30
Maximum pressure	Bar (a)	8	7
Rated capacity	m^3/min	6.53	3.85

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all compressor
- Air flow measurement of all compressor

Average power consumption and air flow rate of the compressors is given below:

Table 36: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)
Venus Compressor	33	0.94	6.53

FAD of compressors could not be conducted as there was only one receiver for whole plant.

4.4.3 Observation and performance assessment

Existing compressor is equipped with VFD and average power consumption is 33.0kW.

4.4.4 Energy conservation measures (ECM) - ECM #8: Pressure Reduction at air compressor

Technology description

When the generation pressure of compressed air is reduced by 1 kg/cm^2, there is reduction in energy consumption of compressor by 6% as per BEE.

Study and investigation

During DEA, it was found that the compressed air was generating compressed air at 7.5 kg/cm^2 and the pressure requirement at the end utilities were around 6.5 kg/cm^2.

Recommended action

It is recommended to reduce the generation pressure of compressed air and thereby achieve energy savings. The cost benefit analysis for this project is given below:

Table 37: pressure reduction of compressor [ECM 8]

Parameter	Units	As is	To Be
Operating pressure required	kg/cm²	7.5	6.5
Cut off pressure	kg/cm²	8	8
Reduction in pressure	kg/cm²	-	1
% of energy saving	%	-	6%
Average load	kW	33.2	31.17
Operating hours/day	h/d	17	17
Operating days/year	d/y	350	350
Annual energy consumption	kWh/y	197,278	185,441
Annual energy savings	kWh/y		11,837
Unit cost of electricity	Rs/kWh		6.88
Annual monetary saving	Lakh Rs/y		0.81
Estimated Investment	Lakh Rs		0.33
Payback period	Months		4.86
IRR	%		190
Discounted payback period	Months		1.9

4.5 Water Pumping System

4.5.1 Specifications

Pumping system comprises of a bore well pump.

4.5.2 Field measurement and analysis

During DEA, the following measurements were done for the bore well pump:

- Power consumption of bore well pump (other pumps are having smaller size and internal corrosion problems)
- Flow measurements for same pump

Total head, flow and power for pump is given in below table:

Table 38: Operating details of pump

Particulars	Unit	Value
Measured flow	m^3/h	13.8
Total head	M	50
Actual power consumption	kW	9

4.5.3 Observation and performance assessment

Based on observations during DEA, the pump efficiency is determined as 25%.

4.5.4 Energy conservation measures (ECM) - ECM #9: Replacement of inefficient pumps with efficient pump

Technology description

The old pump is running at lower efficiency and is recommended to be replaced with new high efficiency pump.

Study and investigation

The old pump is running throughout the day as per requirement. Pump is operating for about 10-12 hours/day to meet the water requirement.

Recommended action

Recommendations have been given to refurbish/replace submersible pumps with energy efficient pumps. Additional water meters have also been recommended. Measured parameters and the derived efficiency of the pumps are mentioned hereunder.

Table 39: Replace inefficient pump by energy efficient pump [ECM-9]

Particulars	Unit	Present	Proposed
Measured Data			
Flow rate Q	m^3/h	13.8	13.8
Suction Pressure	kgf/cm^2 (a)	0.0	0.0
Discharge Pressure	kgf/cm^2 (a)	7.0	7.0
Motor Input Power	kW	9.0	4.42
Calculated Data			

Flow rate Q	m^3/s	0.00383	0.00383
Pressure Difference	kgf/cm^2 (a)	5.0	7.0
Total Head/head developed	M	50	70
Liquid Horse Power	kW	1.9	2.6
Motor Input Power	kW	9.0	4.42
System Efficiency	%	20.9	59.5
Motor Loading	%	120.6	59.3
Pump Efficiency	%	24.6	70
Operating hour per day	h/d	12	
Annual operating days	d/y	350	
Annual power savings	kWh/y	17,804	
Cost of Electricity	Rs./kWh	6.88	
Annual Monetary savings	Lakh Rs/y	1.22	
Estimated investment	Lakh Rs	0.92	
Payback Period	Months	9	
IRR	%	98	
Discounted payback period	Months	3.5	

4.6 LIGHTING SYSTEM

4.6.1 Specifications

The plant lighting system includes:

Table 40: Specifications of lighting load

Particular	Units	Fluorescent tube light T8	Fans	LED	Exhaust Fan	AC
Power consumption of each fixture	W	36	56	9	150	3500
Numbers of fixtures	#	660	550	149	23	9

4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 41: Lux measurement at site

Particular	Units	Value
Office	$Lumen/m^2$	160
Kiln control room	$Lumen/m^2$	110
Kiln area	$Lumen/m^2$	60
Ball mill and agitators	$Lumen/m^2$	70

4.6.3 Observations and performance assessment

Adequate day lighting is used wherever possible. There is scope to replace luminaries with more energy efficient types which are currently available.

4.6.4 Energy conservation measures (ECM) - ECM #10: Replacement of inefficient light with EE LED lamps

Technology description

Replacing conventional lights like T8 tube lights with LED lights helps reduce the power consumption and also results in higher illumination (lux) levels for the same power consumption.

Study and investigation

The unit is having 660 tube lights.

Recommended action

It is recommended to replace the above mentioned light fixtures with energy efficient LED lamps, which will result in reduction of present lighting energy consumption. The cost benefit analysis for the ECM is given below:

Table 42: Replacement of T12 tube light with EE LED lamps [ECM-10]

Particulars	Units	Present	Proposed
Fixture		T8	EE LED tubes
Power consumed by T12 Tube lights	W	36	18
Operating hours	h/d	12	12
Operating days	d/y	350	350
Energy Used per fixture	kWh/y	202	76
Cost of Electricity	Rs./kWh	6.88	6.88
No. of Fixture	Unit	660	660
Power consumption	kWh/y	133,056	49,896
Operating cost	Rs. Lakh/y	9.15	3.43
Electrical savings	kWh/y		83,160
Annual Monetary saving	Rs. Lakh/y		5.72
Investment per fixture of LED	Rs		0.004
Estimated Investment	Rs. Lakh		2.44
Payback Period	months		5
IRR	%		176
Discounted payback period	Months		2

4.7 ELECTRICAL DISTRIBUTION SYSTEM

4.7.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415V) by step down transformer (0.315 MVA). Automatic power factor correction system is installed in parallel to main supply. There was one DG (capacity of 100 KVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeders which are shown in Figure 8.

4.7.2 Field measurement and analysis

During DEA, the following measurements were done:

- Whole plant load measurement by installing power analyzer at new and old plant main incomer feeder

4.7.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **193.121kVA** at the plant feeder.

The voltage profile of the unit is satisfactory and average voltage measured was **422.15 V.** Maximum voltage was **435.33 V** and minimum was **403.17 V**.

Average total voltage and current Harmonics distortion found to about **6%** & **19%** respectively during power profile recording.

There is only one electricity meter in the plant at the main incomer, with no sub-metering.

It is observed that some of the power factor is maintained in all the feeders. Poor power factor leads to cable losses (I^2R) in the electrical distribution system.

4.7.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.7.4.1 ECM #11: Replacement of conventional fans with EE fans

Technology description

All fans were conventional fans in which were consuming more power than EE ceiling fans

Study and investigation

During DEA, it was found that each fan was consuming 48 watt as compared to 30 watt (EE ceiling fan)

Recommended action

It is recommended to replace conventional fans with EE ceiling fans
The cost benefit analysis for the ECM is given below:

Table 43: Cost benefit analysis of EE ceiling fans [ECM 11]

Particulars	Units	AS IS	TO BE
Number of fans in the facility	Nos	550	550
Run hours per day	H/d	15	15
Power consumption at Maximum speed	kW	0.048	0.03
Number of working days/year	d/y	350	350
Tariff for Unit of electricity	Rs/kWh	6.88	6.88
Fan unit price* (use '0' for ordinary fan if replaced)	Rs/piece		1,500
Electricity consumption:			
Electricity demand	kW	26.60	16.50
Power consumption by fans in a year	kWh/y	139,635	86,625
Savings in terms of power consumption	kWh/y	53,010	
Savings in terms of cost	Rs Lakh/y		3.65
Estimated investment	Rs Lakh/y		8.25
Payback period	months		27.15
IRR	%		23
Discounted payback period	Months		10

4.7.4.2 ECM #12: Energy monitoring system

Technology description

Installation of energy monitoring system at unit level will monitor the energy consumed by various machines. From this, the benchmark energy consumption can be set with respect to production for the machines. If an increase in energy consumption is noticed for any machine, then the reasons for the increased consumption can be diagnosed and proper remedial actions can be taken.

Study and investigation

It was observed during the audit that online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed at kiln like on-line flow-meters.

Recommended action

It is recommended to install online electrical energy monitoring systems (smart energy meters) on the main incomer and on the various electricity distribution panels and fuel monitoring system. This measure will help in reduction in energy consumption by approximately 3% from its present levels. The recommended locations for the energy meter are:

- Kilns
- Ball mills
- Agitator motors
- Compressor
- Glaze line and kiln line

The cost benefit analysis for this project is given below:

Table 44: Cost benefit analysis [ECM-12]

Parameters	Unit	As Is	To Be
Energy monitoring saving for electrical system	%		2.00
Energy consumption of major machines per year	kWh/y	779,793	764,197
Annual electricity saving per year	kWh/y		15,596
Unit Cost	Rs/kWh		6.88
Annual monetary savings	Lakh Rs/y		1.07
Number of equipments	Nos.	-	4.00
Estimate of Investment	Lakh Rs	1.85	
Annual monetary savings	Lakhs Rs/y	1.07	
Number of energy meters	Nos.	4.00	
Estimated Investment	Lakhs Rs	1.85	
Payback Period	months	21	
IRR	%	38	
Discounted payback period	Months	7.6	

4.7.4.3 ECM #13: Power factor improvement by installing capacitor bank

Technology description

The average power factor of the unit during DEA found 0.97 as per measurement by power analyzer during DEA while 1.0 in the utility bill.

Study and investigation

The power factor of the unit as per utility bill is shown below in the figure:

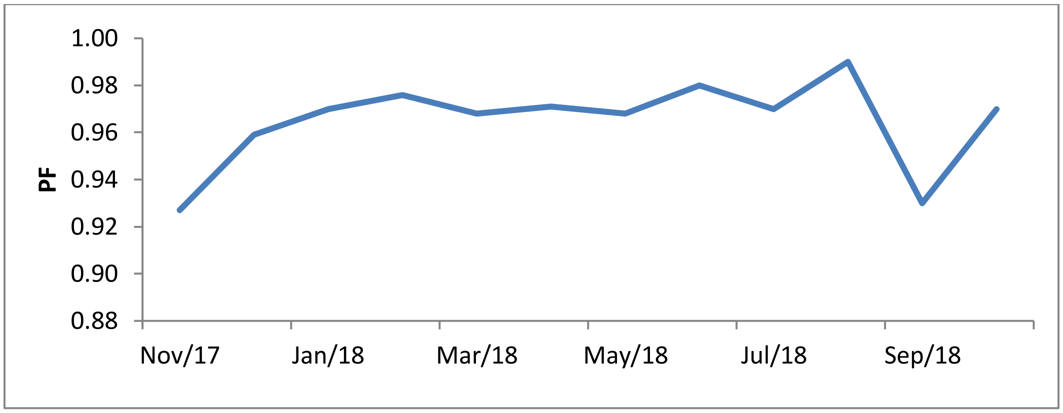

Figure 22: PF variation

Recommended action

It is recommended to improve it to 1.0 by installing additional capacitor. Proper modification in wiring to be done so that capacitor bank is also connected to load while DG sets are in operation

Saving Assessment

The cost-benefit analysis of the energy conservation measure is as shown in the table below:

Table 45: Cost benefit analysis [ECM-13]

Parameters	Units	As Is	To Be
Actual Maximum Demand in last one year	kVA	227	220
Power Factor	Cosϕ	0.97	1.00
Rebate availed in Electricity Bills	Rs	60,200	77,979
Present Load in kW	kW	220	220
Total Energy Charges last one year	Rs	3,119,172	
Capacitor required to improve power factor	kVAr		56
Net PF rebate saving	Rs/y	17,779	
Total Saving	Rs Lakh/y	0.18	
Estimated Investment	Rs Lakh	0.22	
Simple Payback Period	months	15	
IRR	%	55	
Discounted payback period	Months	5.8	

4.8 Belt Operated Drives

4.8.1 Specifications

There are 5 drives operated with V Belt of total capacity of locations includ:

- Kiln blowers (4)
- Ball mill (1)

4.8.2 Field measurement and analysis

During DEA, power consumption of all v belt driven equipment was measured.

4.8.3 Observations and performance assessment

Maximum belts in plant are v belt which are not energy efficient

4.8.4 Energy conservation measures (ECM) - ECM #14 Replacement of belt drive to direct drive

Technology description

Replacement of horizontal agitator belt drive to vertical direct drive for two of the agitators.

Study and investigation

It was found that more slippage loss occurs in belt drive which can be avoided. Two of agitators were having horizontal belt drives which are inefficient as compared to vertical drive

Recommended action

It is recommended to replace two of the agitator drive which are having horizontal belt drive system. Cost benefit analysis of energy conservation measures (ECM) is given below:

Table 46: Replacement of belt drive with direct belt [ECM-14]

Particular	Unit	AS IS	To Be
Rated power of motor/blower	kW	7	7
Existing power consumption	kW	4.9	4.7
Assumed: Energy loss in transmission	%	5	2
Power loss in transmission	kW	0.24	0.07
Operating hours per day	h/d	24	24
Operating days per year	d/y	350	350
Annual energy consumption	kWh/y	40,964	39,530
Annual energy savings	kWh		1,434
Unit cost of electricity	Rs/kWh		7
Annual monetary savings	Lakh Rs/y		0.10
Estimated Investment	Lakh Rs		0.17
Payback Period	Months		21
IRR	%		36
Discounted payback period	Months		7.8

4.8.5 Energy conservation measures (ECM) - ECM #15: V Belt replacement with REC belt

Technology description

Replacing conventional belt (V belt) with energy efficient belt REC (raw edged cogged) belt. REC belts transmit more power as compared to V belts, hence deliver rated RPM and more air supplied.
Benefits of Cogged belts & Pulley over V belts:

- The cogged belts by design, is having 30% power carrying capacity for the same V belt.
- The cogged belts run cooler, 50% more longer hours, and occupy less space in pulley.
- The narrow and cogged belts operate higher speed ratios using smaller diameter pulleys.
- Hence the existing pulley needs to be replaced with 20% lighter weight pulley.

Study and investigation

The unit is having about 5 belt driven blowers in plant

Recommended action

It is recommended to replace the above conventional belt with REC belt for energy savings. Cost benefit is given below:

Table 47: Cost benefit analysis of replacement of conventional belt with REC belt [ECM-15]

Parameters	Units	AS IS	TO BE
Name of the belt driven blower	#	V belt driven blowers	
Rated power of blower	kW	37.8	37.8
Energy Saving	%		3.60%
Measured power the blower	kW	22.4	21.6
Operating hours per day	h/d	24	24
Operating Days per year	d/y	350	350
Annual energy consumption	kWh/y	188,412	181,629
Annual energy saving	kWh/y		6,783
Unit cost of electricity	Rs/kWh		6.88
Annual monetary savings	Lakh Rs/y		0.47
Estimated Investment	Lakh Rs		0.57
Payback Period	Months		14.53
IRR	%		57
Discounted payback period	Months		5.6

5. Chapter -5 Energy consumption monitoring

5.1 Energy Consumption Monitoring

In order to monitor the overall energy performance, the installation of a basic energy monitoring system has been proposed for the unit (ECM #11).

5.2 Best operating practices

Unique operating practices which were observed in the unit include the following:

Table 48: Unique operating practices at the unit

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Ball mill	VFD for energy saving. Timer control system
3	Press	PRV installed for regulating usage of compressed air
4	Glaze ball mill	Timer control in each ball mill.
5	Kiln	VFD with each blower, waste heat used in combustion air preheating. PID control system for controlling chamber temperature in firing zone. Air is controlled by sensing fuel flow
6	Lighting	LED lights installed in some areas

5.3 New & Emerging Technologies for consideration:

5.3.1 HIGH ALUMINA Pebbles for Ball Mills

Ball mills performance is greatly affected by quantity and quality of grinding balls / Pebbles used. There are different qualities of pebbles used in Morbi cluster:

a. Local pebbles from river
b. Imported pebbles from China
c. High Alumina Pebbles from EU

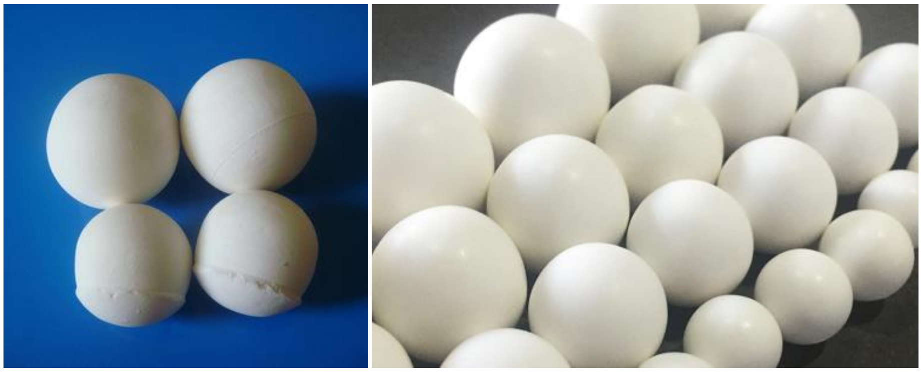

Figure 23: - High Alumina pebbles for Ball mill

The cost and quality of each pebble is different and has major impact on energy consumption of ball mill as described below:

a. Local pebbles: The local river pebbles are used mainly for economic reasons as they are cheap but its sizes vary irregularly and wears out very fast resulting in longer grinding time which increases the energy consumption.
b. Imported Pebbles: Chinese pebbles are available in different quality and variable working life span. This quality is also widely used by ceramic units which gives better performance as compared to local pebbles.
c. High Alumina Pebbles: The third quality is High alumina pebbles from Spain/ EU origin which are having very high Alumina percentage ranging from 80-92 % which gives very long life. As per one feedback from unit during audit, it was learnt from production team that local pebbles are worn out in 8-10 grinding batches where as high alumina pebbles last 8-10 times longer (90-100 batches) which reduces energy consumption and running time of ball mill. The fineness and residue percentage of RM used are also affected with local /poor quality pebbles which are not the case in high alumina pebbles. The cost is relatively high which restricts the use of high alumina pebbles, but if the running cost, productivity and energy consumption is taken in to account, the high alumina pebbles are proven better.
d. Replacement of pebbles is a coniferous process as this is consumable. Only a few units in Morbi cluster are already following this practice, there is a scope for wider adaption of the recommended practice.

5.3.2 Use of Organic deflocculant in Ball Mill grinding Process

In the tile manufacturing process different raw materials which include one or more clays are mixed in specific Ratio (Clay Body). Clay body is subjected to wet grinding in a ball mill to get required density and viscosity. For efficient grinding, inorganic dispersants like STPP, SHMP or sodium silicate are used. These can be replaced either partially or fully by organic deflocculant (Brand name FLOSPERSE[2]) to prevent the solid particles of slip to settle.

Purpose of using deflocculants is to avoid increase in the viscosity of the slurry due to thixotropy. Lower viscosity during wet-grinding makes the grinding operation faster, thus reducing power consumption. Lower viscosity also prevents choking of pipelines. Deflocculants allows for achieving higher slurry density (more solids loading per litre of slurry) without increasing viscosity. For drying operation, achieving higher slurry density is important since more solids in slurry, less water to be evaporated in drying and less time required, making the operation faster.

In water, the deflocculant ionizes to cation and anion. The anion absorbs on the particle imparting it a negative surface charge. Thus the electric double layer on the particle surface is expanded (as opposed to coagulation, where the double layer is compressed) leading to increased repulsion and lower viscosity.

Estimated savings from use of deflocculants for **Partial Replacement of STPP/Sodium Silicate include**

- STPP dosage is reduced by more than 50%

[2] Product brochure of M/s SNF (India) Pvt. Ltd. Vishakkapattanam–Subsidiary of SPCM SA-France

- For the same treatment cost as STPP alone, by using FLOSPERSE in combination, a higher density slip can be achieved at the same viscosity thus saving much more time in moisture evaporation and drying.
- Since this is a new product, a small scale pilot is recommended to ascertain the cost and benefits.

5.3.3 Use of Organic Binder in Porcelain Manufacture

In ceramic bodies where highly plastic clays are used, sufficient green and dry strength is achieved due to the inherent binding ability of the clays hence the use of external binders is not necessary. However, in the manufacturing process of porcelain/sanitary products, almost 75 % of raw materials are non-plastic in nature which contributes very less to green and dry strength. Organic binders like FLOBIND[3] can be used very effectively to increase the green and dry strength as well as edge strength of the tiles. The working principle of the binder is as follows:

- During wet grinding, the binder gets uniformly mixed through the body and inter-particulate bonds are formed which remain intact even after physically combined water is removed during the drying stage. Thus, green and dry strength is imparted.
- Conversely, during each process stage, if water is absorbed, there is loss of strength. Organic binders ensures that sufficient strength is maintained to withstand all the process stages thus reducing rejections due to cracks, damaged edges and breakages.

Advantages of using Binder for Vitrified tiles include:

- Lower dosage or effective binder cost.
- The product is non-fouling which is not susceptible to bacteriological contamination during slip storage; hence no need to use biocides.
- Minimum or no adverse effect on the rheological properties of slip (The rheological behavior of non-Newtonian fluids such as cement paste, mortar, or concrete is often characterized by two parameters, yield stress, $\tau 0$, and plastic viscosity, μ, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.
- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost
- Since this is a new product, a small scale pilot is recommended to ascertain the cost and benefits.

5.3.4 Direct blower fans instead of belt drive

- There are several numbers of fans used in ceramics industry which are using belt drive system
- The application of majority fans is in kiln heating, cooling, recovery of air, exhaust / flue air etc. There are also some applications like FD and ID fans on Hot Air Generators.
- In most of these applications, the air temperature is high and overall system is working in handling high temperature air with whole mechanical structure including fan and shaft are at higher temperature compared to atmospheric air temperature.

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[3] Source: Product brochure of M/s SNF (India(Pvt. Ltd., Vishakkapattanam, India

- The fans are working with heavy inertia load of fan impeller and air flow which continuously create stress on V-belts resulting in belt elongation and slippage.
- To avoid energy loss in belt drive slippage, direct mounted fans on motor shaft eliminates the slippage issue and depending upon size and application, @ 3-5 % of energy loss can be reduced using direct motor mounted fans along with Inverter drive for speed control.
- There are units like Sanskar Johnson Unit No.2 in Morbi cluster using direct drive fans

Figure 24: Direct drive blower fan

6. Chapter -6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA.

The RCC roof top space available is 50 m^2 and corresponding solar power potential will be 5kW. Other roof areas are sloping structures, where structural enhancement is required for solar PV installation. There is no ground space available for solar PV installation.

6.1.1 Energy conservation measures (ECM) - ECM #15: Installation of solar PV system

Technology description

The RCC roof top space available in plant is 50m^2 under office admin and administrative building.

Study and investigation

During DEA, it was found that plant is having solar potential which will help to reduce GHG emission.

Recommended action

It is recommended to install solar PV system to meet plant energy requirement. The cost benefit analysis for this project is given below:

Table 49: Installation of solar PV system [ECM-16]

Parameters	Units	Value
Available area on roof	m^2	50
Capacity of solar panel	kW	5
Energy generation from solar panel	kWh/d	24
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	8,760
Electricity Cost	Rs/kWh	6.9
Annual monetary savings	Rs Lakh/y	0.6
Estimate of Investment	Rs Lakh	2.6
Simple Payback	Months	52
IRR	%	1
Discounted payback period	Months	17.3

7. ANNEXES

7.1 Annex-1: Process Flow Diagram

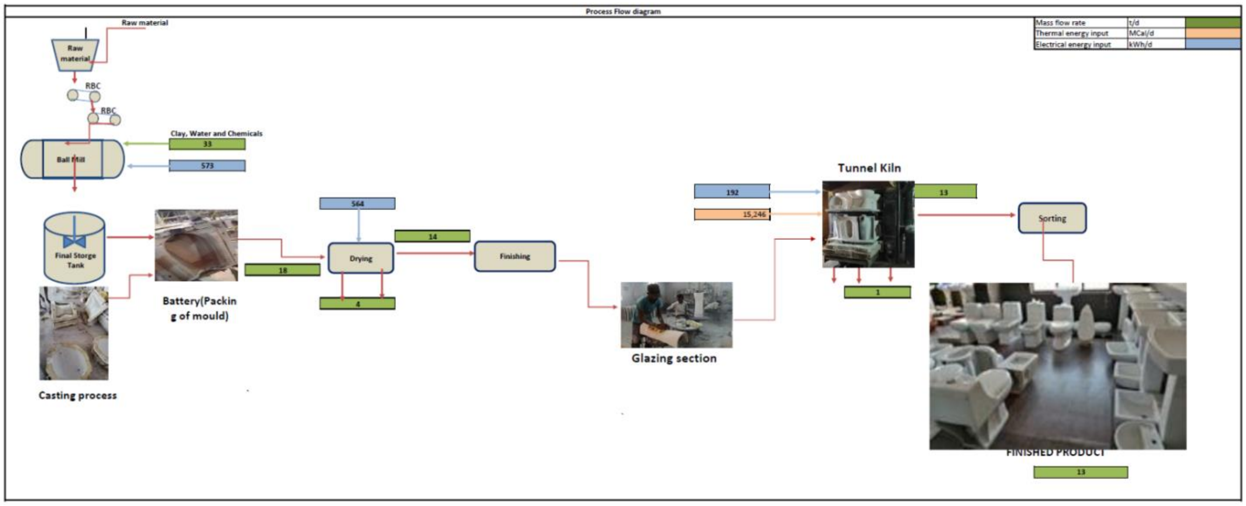


Figure 25: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 50: Detailed Inventory list

Parameters	Units	Value
Kiln	kW	38
Air Compressor	kW	59
Ball mill	kW	60
Agitator tank	kW	22.4
Fans	kW	36
Lighting	kW	33
AC	kW	32
Single phase load	kW	64.5
Total	kW	279.5

7.3 Annex-3: Single Line Diagram

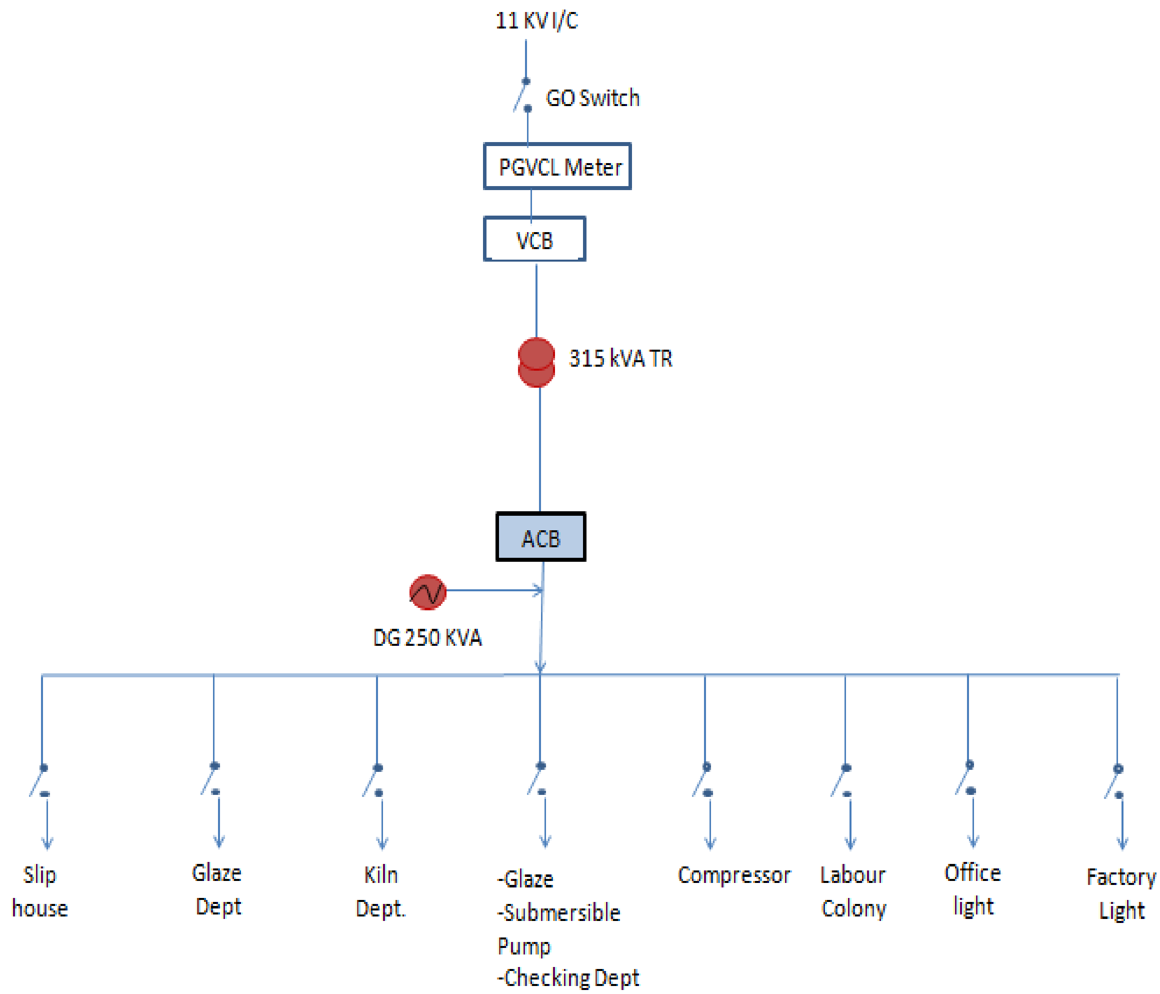
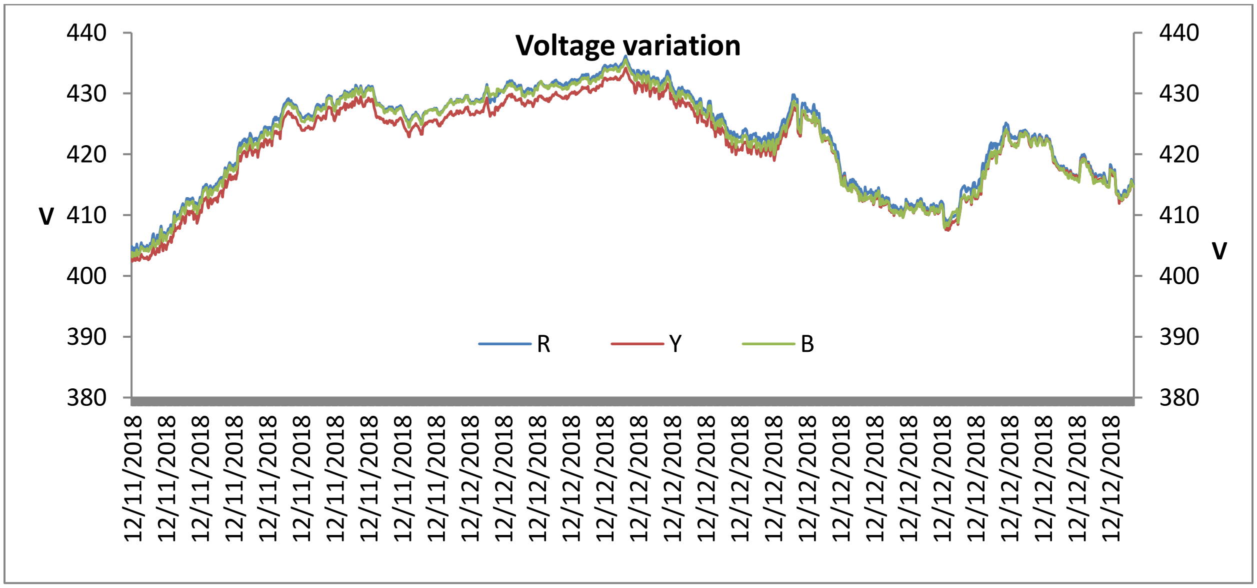
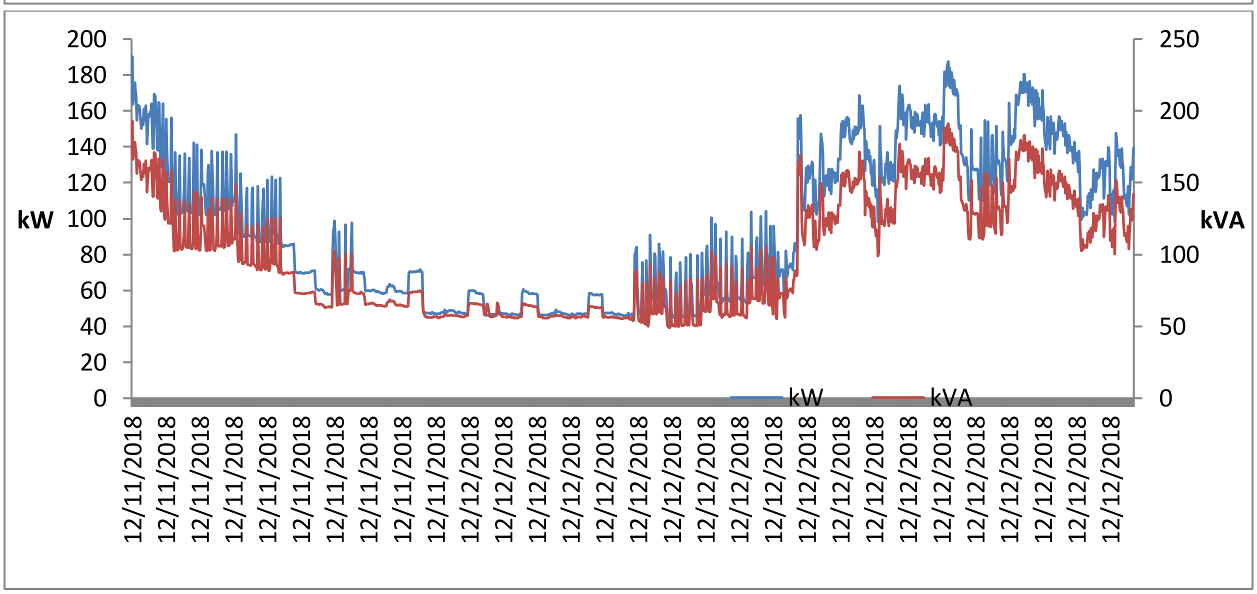
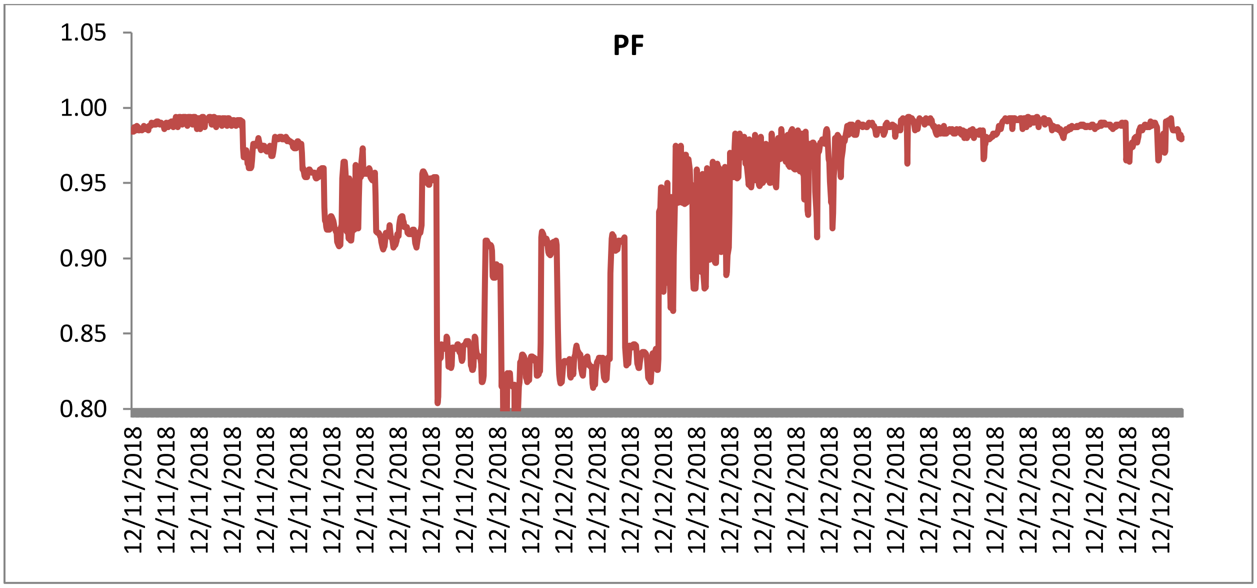


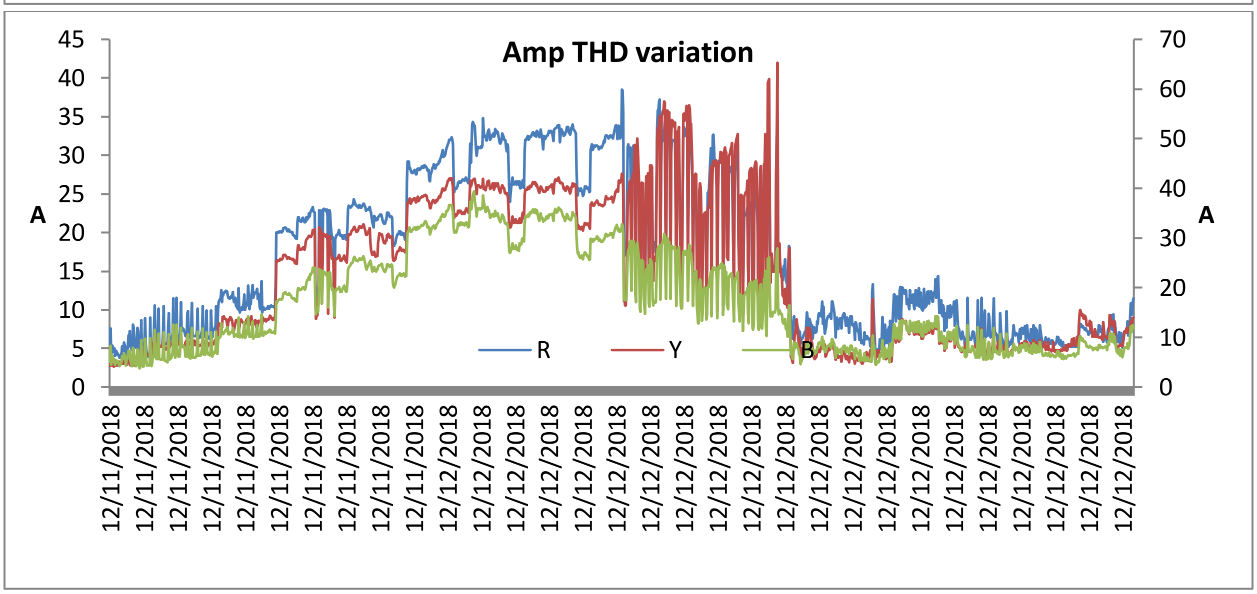
Figure 26: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements






PF
1.05
1.00
0.95
0.90
0.85
0.80
12/11/2018
12/12/2018


Amp THD variation
A
A
45
40
35
30
25
20
15
10
5
0
70
60
50
40
30
20
10
0
R
Y
B
12/11/2018
12/12/2018

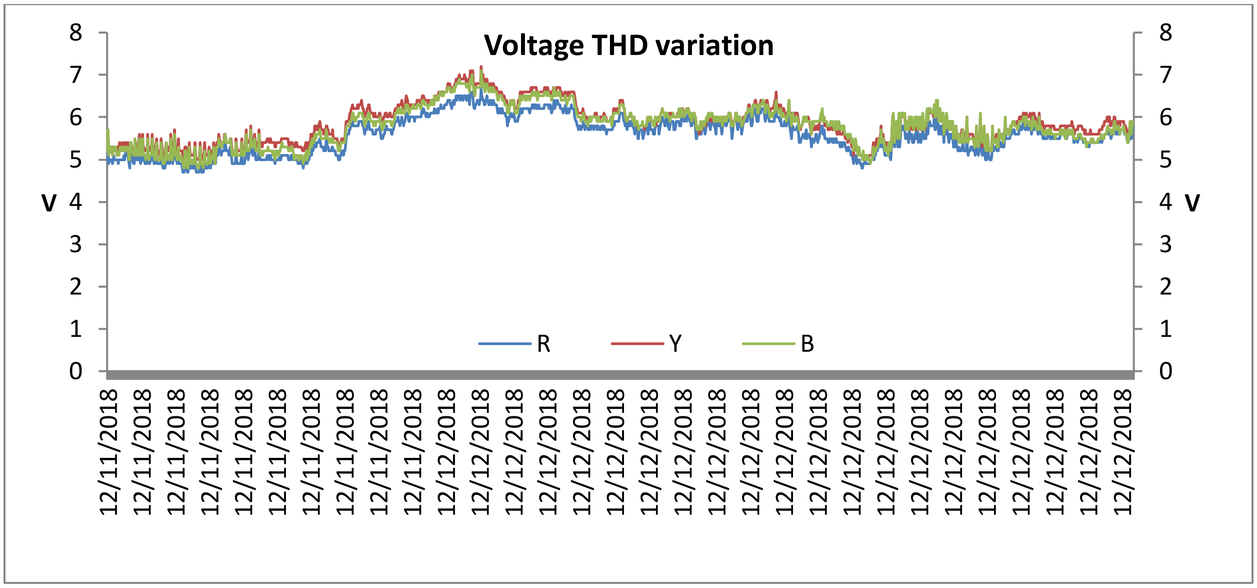


Figure 27: **Power profile (kW) of Main Incomer**

7.5 Annex-5: Thermal Measurements, Kiln Efficiency

Kiln efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	Natural Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1170	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	77	*scm/hr*
Flue Gas Details		
Flue gas temp at smog blower	130	*°C*
Preheated air temp./Ambient	35	*°C*
O2 in flue gas	6.7	*%*
CO2 in flue gas	8.9	*%*
CO in flue gas	30	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
Fuel Analysis		
C	*73.80*	%
H	*24.90*	%
N	*1.30*	%
O	*0.00*	%
S	*0.00*	%
Moisture	*0.00*	%
Ash	*0.00*	%
GCV of fuel	9000	*kCal/kg*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un=burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kCal/kg
GCV of fly ash	*0*	kCal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	498	*Kg/h*
Weight of Kiln car material	500	*Kg/h*
Weight of Stock	998	*kg/h*

Specific heat of clay material	0.22	*kCal/kg°C*
Specific heat of kiln car	0.203	*kCal/kg°C*
Avg. specific heat of fuel	0.51	*kCal/kg°C*
fuel temp	40.2	*°C*
Specific heat of flue gas	0.24	*kCal/kg°C*
Specific heat of superheated vapor	0.45	*kCal/kg°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface		*kCal/h*
Radiation and convection from heating zone surface		*kCal/h*
Radiation and convection from cooling zone surface	7,310	*kCal/h*
Heat loss from all zones		*kCal/h*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.75	*h*
Area of entry opening	8.4	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temperature of kiln	398	*deg K*

Efficiency calculations

Parameters	Value	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	46.44	*%*
Actual Mass of Supplied Air	25.23	*kg/kg of fuel*
Mass of dry flue gas	23.98	*kg/kg of fuel*
Amount of Wet flue gas	26.23	*kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*kg of H_2O/kg of fuel*
Amount of dry flue gas	23.99	*kg/kg of fuel*
Specific Fuel consumption	113.56	*kg of fuel/ton of water closet*
Heat Input Calculations		
Combustion heat of fuel	745,855	*kCal/ton of water closet*
Sensible heat of fuel		*kCal /ton of water closet*
Total heat input	745,855	*kCal /ton of water closet*
Heat Output Calculation		
Heat carried away by 1 ton of water closet	2,48,556	*kCal /ton of water closet*
Heat loss in dry flue gas	58,700	*kCal /ton of water closet*
Loss due to H2 in fuel	1,588	*kCal /ton of water closet*
Loss due to moisture in combustion air	1,019.40	*kCal /ton of water closet*
Loss due to partial conversion of C to CO	159.25	*kCal /ton of water closet*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	3,336.97	*kCal /ton of water closet*

Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln car)	6,690	*kCal /ton of water closet*
Loss Due to Evaporation of Moisture Present in Fuel	-	*kCal /ton of water closet*
Total heat loss from kiln (surface) body	-	*kCal /ton of water closet*
Heat loss due to un-burnt in Fly ash	-	*kCal /ton of water closet*
Heat loss due to un-burnt in bottom ash	-	*kCal /ton of water closet*
Heat loss due to kiln car	230,432	*kCal /ton of water closet*
Unaccounted heat losses	195,373	*kCal /ton of water closet*
Heat loss from kiln body and other sections		
Total heat loss from kiln		*kCal /tons*
Kiln Efficiency	33.32	*%*

1. *Heat Balance Diagram*

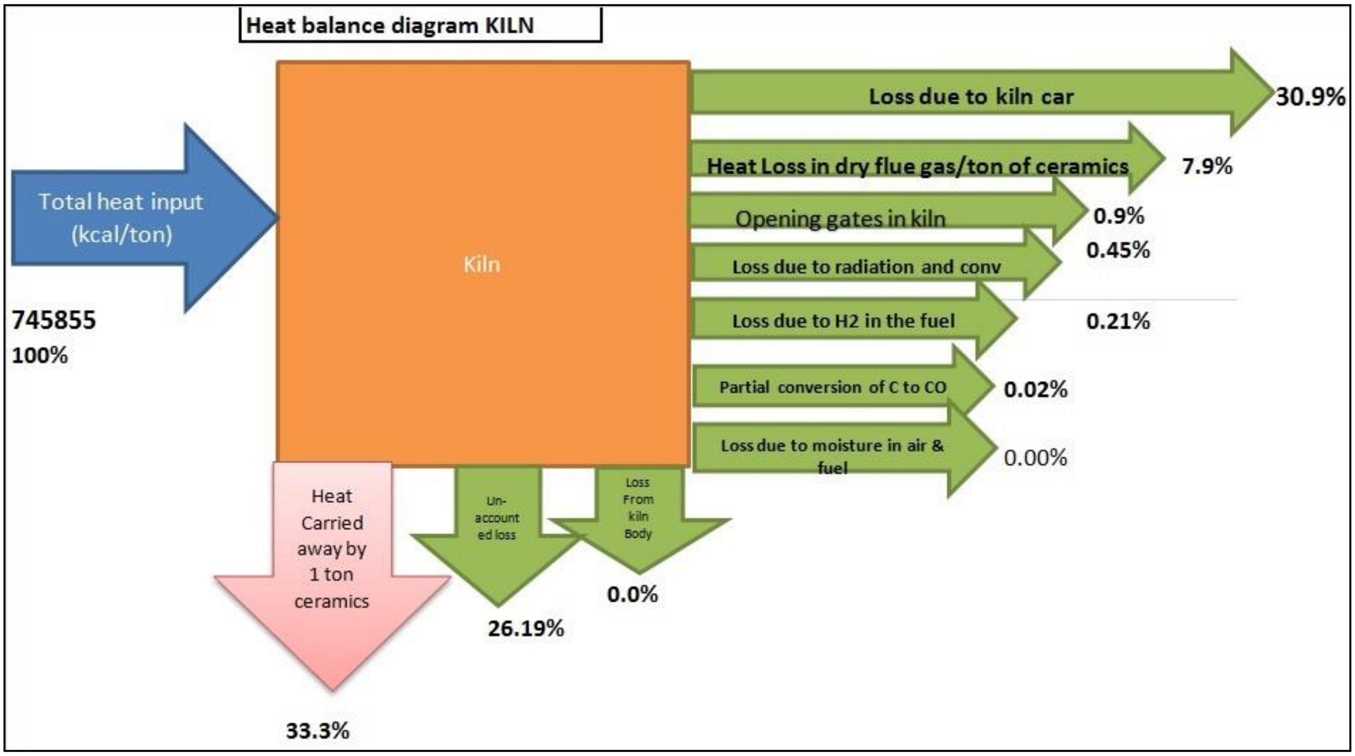


Figure 28: Heat Mass Balance diagram

7.6 Annex-6: List of Vendors

ECM – 1: Excess air control in kiln

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Nevco Engineers	90-A (2nd floor), Amrit Puri B, Main Road, East of Kailash, New Delhi – 110065	Tel : 011 – 26285196/197 Fax: 011 – 26285202	Nevco_delhi@yahoo.co.in
2	High-tech controls for ABB Oxygen Analysers	A 5, Vrindavan Tenament, Gorwa Behind SBI Bank, Near Sahyog Garden, Vadodara - 390016, Gujarat, India	Mr. Bhavik Parikh M: 8071640984	NA
3	Knack well Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	Darshan Thanawala, Ravi Thanawala (Proprietor) 8079452278, 9428597582, 9327013773	www.knackwellengineers.com darshan@kanckwell.com, ravi@kanckwell.com

ECM 2: WHR from kiln using HE

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Knack well Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	9824037124, 9624042423	http://www.knackwellengineers.com/ darshan@kanckwell.com ravi@kanckwell.com
2	Aerotherm Products	No. 2406, Phase 4, G. I. D. C. Estate Vatva, Ahmedabad - 382445,	+91-9879104476, 9898817846	http://www.aerotherm.in
3	Aerotherm Systems Pvt Ltd	Plot No 1517, Phase III, GIDC, Vatwa Ahmedabad-382445	079 -25890158, 25895243	AeroThermSystems.com contact@aerothermsystems.com

ECM 3: Replacement of kiln car material

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	INTERKILN	Sanghavi Chambers,	+91-79-30911069	ik@interkiln.com

	INDUSTRIES LTD.	Beside Canara Bank, Navrangpura, Ahmedabad	079-6438180	
2	Shivang Furnaces And Ovens Industries	No. 483, Jalaram Estate, Narol Vatva Road Narol Ahmedabad - 382405 Gujarat, India	08048763653	
3	Mahek Enterprises	No. 607, Corporate Avenue, Sonawala Road, Goregaon East, Morbi-400063, Gujarat, India	08048719133	

ECM 6: Replacement of motors by EE motor

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	The General Electric Agency	Crompton House, Ganesh Shopping Centre, Opp. Dr. Beck & Co. GIDC, Ankleshwar	Mr. Nimesh Patel 9925152416	generalagenc@sify.com
2	Siemens Limited	3rd floor, Prerna Arbour, Girish Cold Drinks Cross Road, Off. C.G.Road, Ahmedabad	Mr. Paresh Prajapati 079-40207600	paresh.prajapati@siemens.com
3	Crompton Greaves	909-916, Sakar-II, Near Ellisbridge, Ahmedabad	079-40012000 079-40012201 079-40012222	sagar.mohbe@cgglobal.com

ECM – 7 : Installation of Electronic timer control

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Jagdish Electro Automation	41,Sreenath complex, National Highway 8-A, Trajpar, Morbi-363641	Mr. Paresh Patel 9909458699	www.jagdishautomation.com
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com
3	Hitachi Hi-Rel Power Electronics Pvt. Ltd	B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044	Mr. V.Jaikumar 079 2328 7180 - 81	v_jaikumar@hitachi-hirel.com

ECM 9: Energy efficient light

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Osram Electricals Contact Person: Mr. Vinay Bharti	OSRAM India Private Limited, Signature Towers, 11th Floor, Tower B, South	Phone: 011-30416390 Mob: 9560215888	vinay.bharti@osram.com

		City - 1,122001 Gurgaon, Haryana		
2	Philips Electronics Contact Person: Mr. R. Nandakishore	1st Floor Watika Atrium, DLF Golf Course Road, Sector 53, Sector 53 Gurgaon, Haryana 122002	9810997486, 9818712322 (Yogesh-Area Manager), 9810495473 (Sandeep-Faridabad)	r.nandakishore@phillips.com, sandeep.raina@phillips.com
3	Bajaj Electricals Contact Person: Mr. Kushgra Kishore	Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002	9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341(Mr. Rahul Khare),	kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com; sanjay.adlakha@bajajelectricals.com

ECM 10: Replacing conventional ceiling fans with energy efficient fans

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Super fans	351B/2A, Uzhaipalar street, GN Mills PO, Coimbatore. INDIA 641029.	Mob: 9489078737	Email: superfan@versadrives.com
2	Usha pumps Contact Person: Mr. KB Singh	J-1/162, Rajouri Garden, Rajouri Garden New Delhi, DL 110005	011(23318114),011 2510 4999,01123235861 (Mr.Manish)	Email: kb_singh@ushainternational.com
3	Atomberg Technology Pvt. Ltd.	Electronics zone, EL 111, MIDC, Mahpe, Navi Mumbai-400710	022-65352777	contact@atomberg.com Local representative in Morbi is also available

ECM - 11: Pumps replacement with Efficient pumps

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Varuna Pumps Pvt Ltd.	La-Gajjar Machineries Pvt.Ltd. Acidwala estate, Nagarwel Hanuman Road, Amraiwadi, Ahmedabad – 380 026	79- 22777485 / 487	www.varunapumps.com crm@lgmindia.com
2	Kirloskar Brothers Ltd	1st floor, Kalapi Avenue, Opp. Vaccine Institute, Old Padra Road, Vadodara	Mr. Sanjeev Jadhav 0265-2338723/2338735	aksur@bdq.kbl.co.in
3	KSB Pumps Ltd	Neel Kamal, Ashram Road, Opposite Sales India, Ashram Road, Ahmedabad, Gujarat 382410	Mr. Jayesh Shah 098794 83210	https://www.ksb.com/ksb-in/ksb-in-india/

ECM 12: Energy Monitoring System

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Iadept Marketing Contact Person: Mr. Brijesh Kumar Director	S- 7, 2nd Floor, Manish Global Mall, Sector 22 Dwarka, Shahabad Mohammadpur, New Delhi, DL 110075	Tel.: 011-65151223	iadept@vsnl.net, info@iadeptmarketing.com
2	Aimil Limited Contact Person: Mr. Manjul Pandey	Naimex House A-8, Mohan Cooperative Industrial Estate, Mathura Road, New Delhi - 110 044	Office: 011-30810229, Mobile: +91-981817181	manjulpandey@aimil.com
3	Panasonic India Contact Person: Neeraj Vashisht	Panasonic India Pvt Ltd Industrial Device Division (INDD) ABW Tower,7th Floor, Sector 25, IFFCO Chowk, MG Road,Gurgaon - 122001, Haryana,	9650015288	neeraj.vashisht@in.panasonic.com

ECM 13: Power factor improvement

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Cummins Power Generation Contact Person: Rishi Gulati Senior Manager-Power Electronics	Cummins India Limited Power Generation Business Unit 35/A/1/2, Erandawana, Pune 411 038, India	Phone: (91) 020-3024 8600 , +91 124 3910908	cpgindia@cummins.com rishi.s.gulati@cummins.com
2	Krishna Automation System Contact Person: Vikram Singh Bhati	ESTERN CHAWLA COLONY, NEAR KAUSHIK VATIKA, GURGAON CANAL BALLBGARH FARIDABAD 121004	Mob: 9015877030, 9582325232	krishnaautomationsystems@gmail.com
3	Next Gen Power controls	8, Rashmi Growth Hub Estate, Near Shree Sai Palace Hotel Odhav, Ahmedabad- 382415, Gujarat, India	08048110759	NA

ECM 14: Direct drive air blowers

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Chicago Blower India Pvt. Ltd.	No.3702, Phase-4, Gidc Industrial Are, Vatva, Behind-New Nirma, Near-Sabar Pump, Ahmedabad, Gujarat, 382445, India	079-25842499	http://www.chicagoblower.in info@chicagoblower.in
2	Jaldhara Industries	Plot No.: 244, Pushpam(Pushpak) Estate, Nica Tube Compound, Phase-I, Gidc, Vatva,Ahmedabad, Gujarat, 382445, India	8068216807	https://airblower.tradeindia.com/
3	Hexagon Engineering	1&2, Anupam Ind Estate, Near Zaveri Estate, Kathwada GIDC estate,, Ahmedabad-382430	8042972891	https://www.hexagonblower.in

ECM-15: V Belt with REC belt replacement

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Shree Ram Marketing Co.	67, Sharhanand Marg, G.B. Road, Shardanand Marg, Delhi – 110006	08048022651	NA
2.	Mangal singh Bros. Pvt Ltd	24-B, Raju Gardens, Near Krishnasamy nagar, Sowripalayamp Post, Coimbatore-641028	Ramiz Parker +91 77381 86851	mangalsinghcbe@gmail.com
3	Shreeji Traders	Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001	+91 94281 01565	NA

ECM 16 : Solar PV system

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	GREEN EARTH INFRACON & SOLAR	348, Avadh Viceroy, Sarthana Jakatnaka, Varachha Road, Surat, Gujarat, 395006, India	Mr. Dhaval Patel 7210113608	NA
2	CITIZEN Solar Pvt. Ltd	711, Sakar-2 Ellisbridge corner, Ahmedabad-380006	Girishsinh Rav Jadeja 9376760033	www.citizensolar.com sales@citizensolar.com
3	Sungold Enterprise	D-134, Udhna Sangh Commercial Complex, Near Divya Bhaskar press, Central Road, Udhna Udhyog nagar, Surat-394010	Mr. Pravin Patel 98251 94488	sungoldindia@gmail.com

7.7 Annex-7: Financial analysis of project

Table 51: Assumptions for Financial Analysis

Particulars	Units	Value
Debt Equity Ratio for Bank Loan		2.00: : 1.00
Interest Rate on Bank Loan	%	13.50%
Project Implementation Period	y	0.50
Moratorium Period	y	0.50
Loan Repayment Period	y	5.00
Depreciation Rate (IT Act)	%	80.00%
Depreciation Rate (Co's Act)	%	15.00%
Effective Income Tax Rate	%	26.750%
Effective MAT Rate	%	21.644%
Discount factor	%	15.000%