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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE SP-11: EAGLE CERAMICS

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DESL

DEVELOPMENT ENVIRONERGY SERVICES LTD

819, Antriksh Bhawan, 22 Kasturba Gandhi Marg, New Delhi -110001

Tel.: +91 11 4079 1100 Fax: +91 11 4079 1101; www.deslenergy.com

April-2019

Bureau of Energy Efficiency, 2019

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'.

For more information

GEF-UNIDO-BEE PMU
Bureau of Energy Efficiency
4th Floor, Sewa Bhawan, Sector-1,
R.K. Puram, New Delhi-110066

Email: gubpmu@beenet.in
Website: www.beeindia.gov.in

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.

ACKNOWLEDGEMENT

DESL places on record its sincere thanks to Bureau of Energy Efficiency (BEE) for vesting confidence in DESL to carry out the assignment "Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India – Morbi Ceramic Cluster". DESL is grateful to the GEF-UNIDO-BEE Project Management Unit (PMU) for their full-fledged support. Special thanks to UNIDO team for co-coordinating with cluster associations and providing support to DESL team in smooth execution of field activities.

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

DESL is indebted to M/s. Eagle ceramics complex 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. Sanjay Jetpariya, Partner

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.

DESL Team

Project Head	R Rajmohan, Chief Executive Officer
Team leader and co-coordinator	Mr. M G Dave, Senior Consultant
Team members	Shridhar Manure, Consultant Rajendra N, Consultant Sunil Senapati, Senior Analyst Ashok Kumar, Analyst Sandeep Sharma, Assistant Analyst Dhruvkumar Lalitbhai Anavadiya, Project Analyst

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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.

Eagle ceramic 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	Eagle Ceramics
Year of Establishment	1999
Address	8A National Highway, At. Nava Jambudia, Morbi - 363642, Gujarat - India
Products Manufactured	One piece closet
Name(s) of the Promoters / Directors	Mr. Sanjay Jetpariya

➨ 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:

- **Clay ball mill:** Here the raw materials like clay, feldspar and quartz are mixed respectively along with water to form slurry.
- **Agitator:** Slurry after mixing in Clay 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 1,150-1200 °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 5.4 % 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 according to fuel firing.
- Kiln car replacement (Kiln car 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 to a mass of 330 kg.
- Waste heat recovery from hot air: 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
- Insulation at kiln: Average surface temperature measured during the study was 86°C in firing zone, resulting surface temperature will be 55°C after recoating of insulation
- Installation of VFD with screw compressor: During unload condition; compressor is consuming 34% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy upto 15% of present consumption
- Leakage arresting for compressor : leakage quantity of air in air compressor was 0.64 m^3/min which can be reduced up to 0.35 m^3/min by arresting leakage
- Pressure reduction in air compressor: The pressure at receiver is 6.5 bar (a) and they require maximum pressure up to 5.5 bars in plant (especially in batteries only). It is advisable to reduce operating pressure of compressor from 6.5 bar to 5.5 bar

- Timer controller at stirrer motor: At present 12 stirrer motors are operated continuously. A timer controller is recommended to be installed so that operating hours of each will reduce upto 12 hour.
- Optimization of resource consumption in clay section: Water quality increases batch timing and resource consumption (water and electricity). Bore well water is having TDS level upto 1,500 ppm which can be improved by installing softener plant which may reduce TDS level upto 400 ppm.
- Replacement of ordinary fans with EE ceiling fans
- Replacement of T12 tube lights with EE LED lamps
- Installation of EMS in plant
- V belt replacement with REC belt
- Installation of solar PV system
- Replacement of horizontal stirrer to vertical stirrer

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	TOE Equivalent				
		kWh	scm/y	MTOE/y	Lakh Rs/y	Lakh Rs	Months	tCO_2
1	Excess air control at Kiln	31,478	8,800	11	5.19	18.48	43	43
2	Waste heat recovery from hot air		74,176	67	23.33	26.40	14	143
3	Kiln car with improved design and less weight		33,657	30	10.59	7.13	8	65
4	Insulation at kiln		5,920	5	1.86	1.58	10	11
5	Optimization of resource consumption in clay section	4,514		0	21.19	10.56	6	4
6	Timer controller at stirrer motors	55,674		5	4.28	1.75	5	46
7	Replacement of horizontal stirrer with vertical stirrer	44,539		4	3.42	2.38	8	37
8	Pressure reduction in air compressors	22,479		2	1.73	0.30	2	18
9	VFD with screw compressor #2	31,015		3	2.38	2.97	15	25
10	Leakage arresting in compressed air network	17,700		2	1.36	0.13	1	15
11	Replacement of T12 tube lights with EE LED lamps	33,359		3	2.56	1.76	8	27
12	Replacement of ordinary fans with EE ceiling fans	205,405		18	15.79	43.56	33	168
13	Installation of Energy management system	16,345		1	1.26	0.48	5	13
14	V belt replacement with REC belt	3,570		0	0.27	0.20	9	3
	Total	**466,078**	**122,553**	**150**	**95**	**118**	**14.8**	**618**

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

- Reduction in energy cost by 40.7%
- Reduction in electricity consumption by 57%
- Reduction in thermal energy consumption by 22.6%
- Reduction in greenhouse gas emissions by 36%

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 at Kiln	18.48	6%	15.00
2	Waste heat recovery from hot air	26.40	63%	5.23
3	Kiln car with improved design and less weight	7.13	113%	3.14
4	Insulation at kiln	1.58	86%	3.97
5	Optimization of resource consumption in clay section	10.56	154%	2.34
6	Timer controller at stirrer motors	1.75	184%	1.94
7	Replacement of horizontal stirrer with vertical stirrer	2.38	107%	3.26
8	Pressure reduction in air compressors	0.30	427%	0.83
9	VFD with screw compressor #2	2.97	59%	5.60
10	Leakage arresting in compressed air network	0.13	761%	0.47
11	Replacement of T12 tube lights with EE LED lamps	1.76	109%	3.22
12	Replacement of ordinary fans with EE ceiling fans	43.56	15%	12.04
13	Installation of Energy management system	0.48	196%	1.82
14	V belt replacement with REC belt	0.20	105%	3.39

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	Eagle Ceramics		
Plant Address	8A National Highway, At. Nava Jambudia, Morbi - 363642, Gujarat - India		
Constitution	Partnership		
Name of Promoters	Mr. Sanjay Jetpariya		
Contact person	Name	Mr. Sanjay Jetpariya	
	Designation		
	Tel	9825312598	
	Fax		
	Email	info@eagleceramics.net	
Year of commissioning of plant	1999		
List of products manufactured	One piece closet		
Installed Plant Capacity			
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover			700

Description	Details		
Net profit	Not provided by the unit		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	150	
	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.

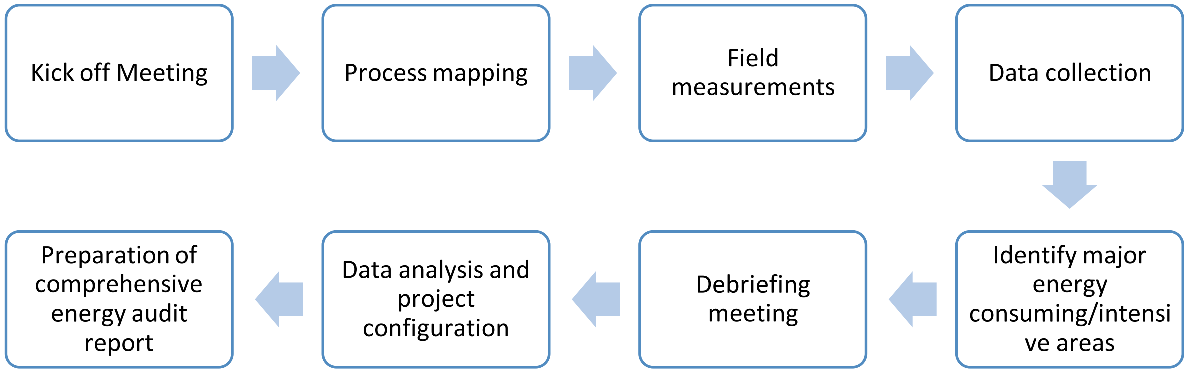

Figure 1 : General methodology

The field work was carried out during 29th -31st October 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
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3	AC Amp, AC-DC Volt, Hz, Power Factor, Power

Sl. No.	Instruments	Parameters Measured
	Phase and 1 Phase	
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:

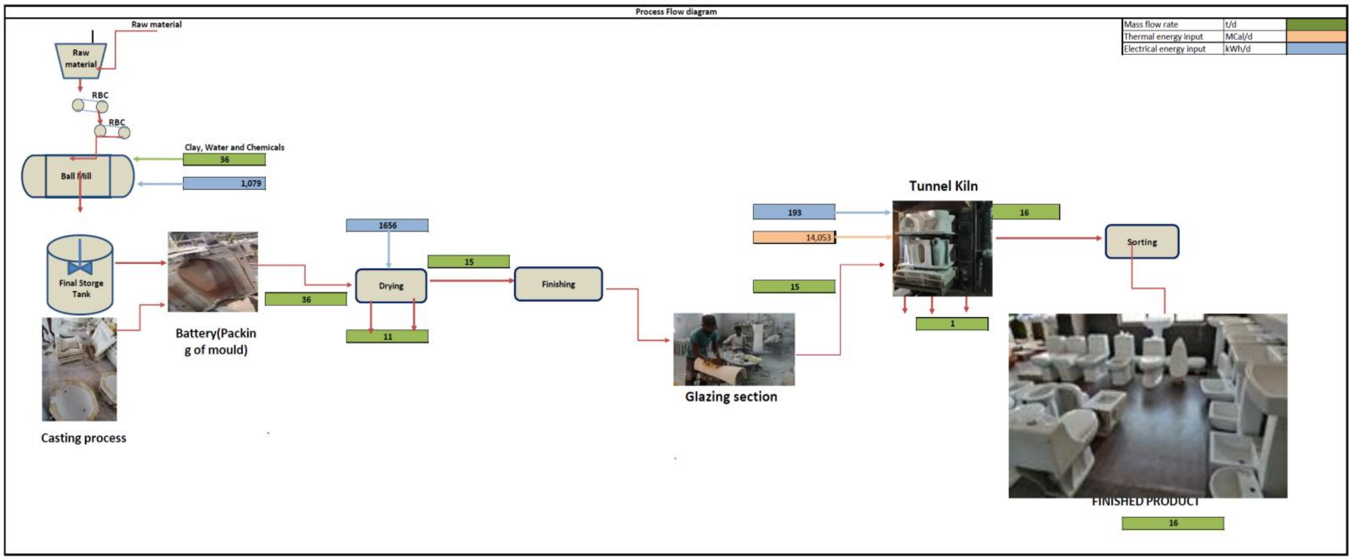

Figure 2: Process Flow Diagram

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.

- The raw materials are mixed and ground using pebbles together with water in the Clay ball mill for a period of 4 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

- 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



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


- 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:

- **Clay 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 Clay 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 kiln is about 72 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^{o}C to 1,200^{o}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 vitrified tiles of the following specifications:

Table 5: Product Specifications

Product	Weight	Pieces per day
	kg/d	
One piece closet	15,000	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	Number of pieces	Corresponding Mass (MT)
Sept-17	27,467	412
Oct-17	31,351	470
Nov-17	32,358	485
Dec-17	34,331	515
Jan-18	33,345	500
Feb -18	27,830	417
Mar-17	32,341	485
Apr-17	30,543	458
May-17	22,571	339
Jun-18	30,275	454
July-18	17,495	262
Aug-18	30,099	451
Average	29,167	438

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 Sep-17 to Aug-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	62.83	26.9	70	12.6
Thermal – NG	170.93	73.1	489	87.4
Total	233.76	100	559	100

This is shown graphically in the figures below:

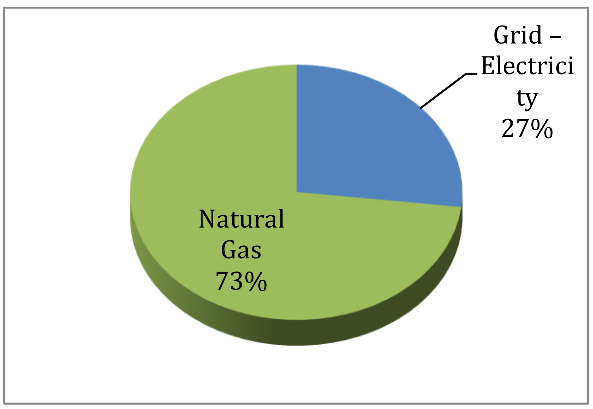

Figure 3 : Energy cost share

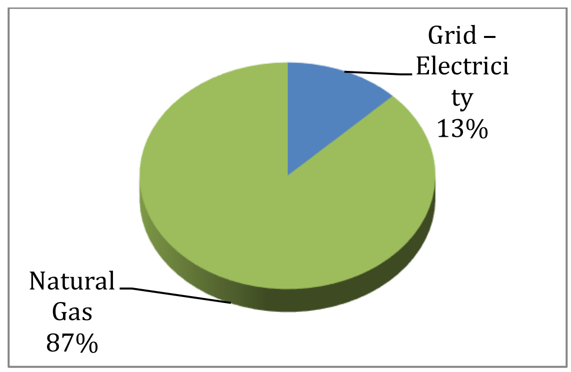

Figure 4: Energy use share

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 27% of the energy cost and 12.6% 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 73% of the total energy cost and 87% 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	
Tariff Category	HTP-I
Contract Demand, kVA	190 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	 4.0 0.45 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 Sep-17 to Mar 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	Total Electricity cost	Average unit Cost
	kWh	Rs.	Rs./kWh
Sep-17	58,955	5,09,777	8.65
Oct-17	75,800	6,19,346	8.17
Nov-17	72,935	6,33,086	8.68
Dec-17	70,817	5,93,998	8.39
Jan-18	74,256	6,40,781	8.63
Feb-18	70,271	5,78,404	8.23
Mar-17	60,702	4,24,488	6.99
Apr-17	67,143	4,66,626	6.95
May-17	60,461	3,78,631	6.26

Month	Units consumed	Total Electricity cost	Average unit Cost
	kWh	Rs.	Rs./kWh
Jun-18	68,625	4,82,607	7.03
July-18	68,831	489,322	7.11
Aug-18	68,472	466,254	6.81

Average electricity consumption is 68,106 kWh/month and cost is Rs. 5.2 Lakhs per month (Sept-17 to Aug-18). The average cost of electricity is 7.7 Rs./kWh, corresponding to the month. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

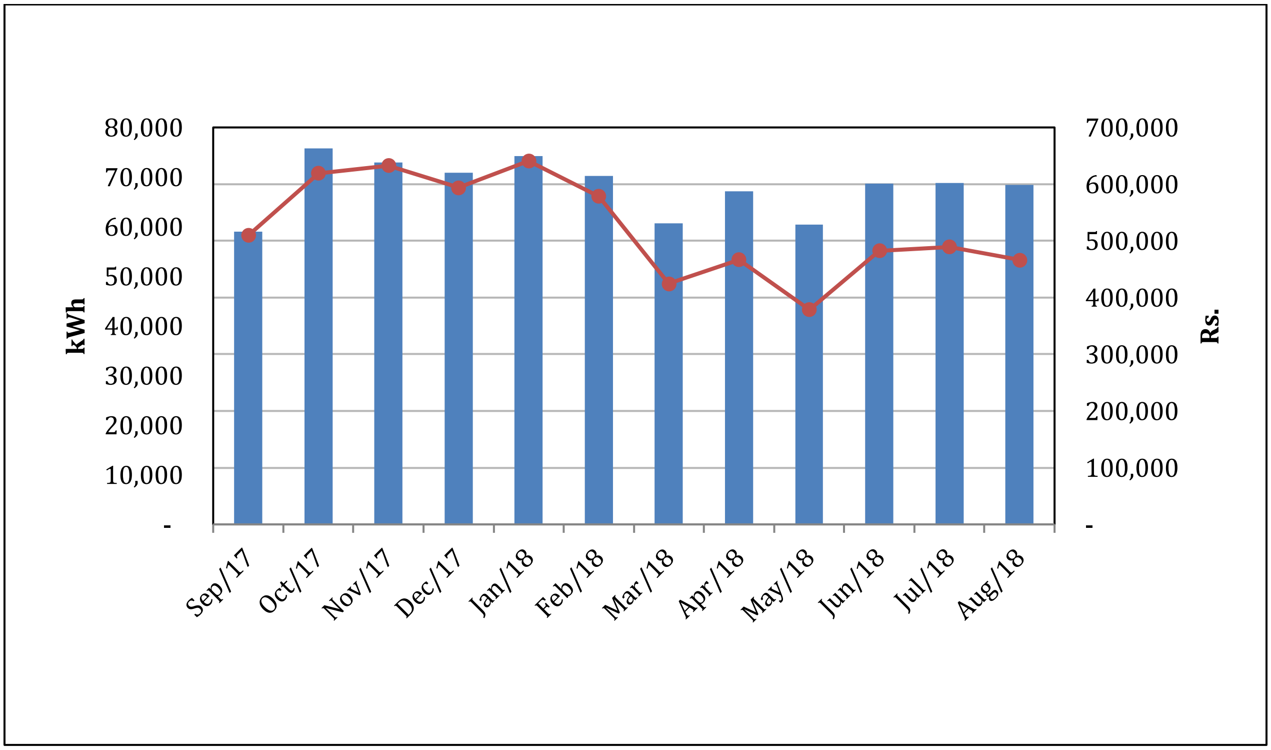

Figure 5: Month wise Variation in Electricity Consumption

2.3.1.3 Single Line Diagram

Single line diagram of plant is shown in figure below:

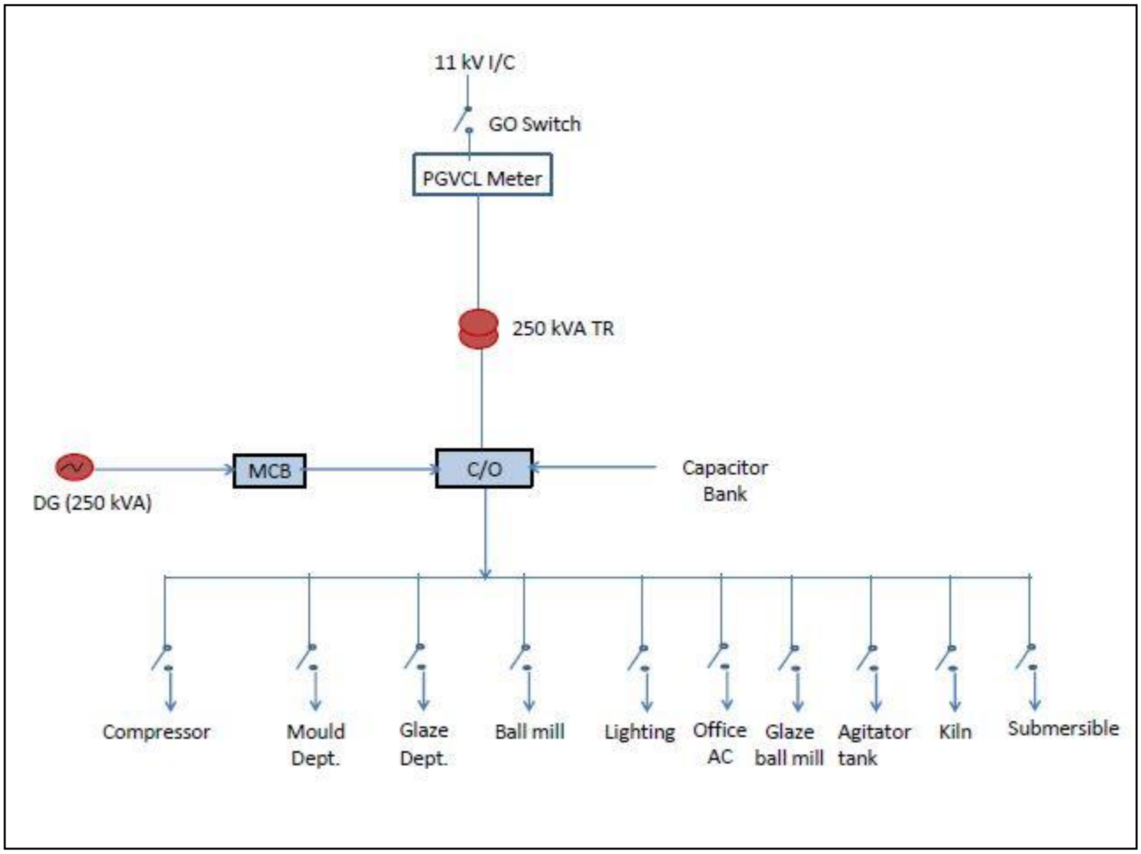

Figure 6: Single Line Diagram (SLD)

2.3.1.4 Electricity consumption areas

The plant's total connected load is 376.3 kW, which includes:

- Plant and machinery load is 155.9kW.
- Utility load is (lighting, air compressor and fans) about 220.4 kW including the single phase load.

Table 11: Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Clay ball mill	78.8
2	Kiln	28.6
3	Agitator Tank	22.4
4	Mud pumps	13.4
5	Glaze Clay ball mill	12.7
6	Submersible pump	18.7
7	Compressor	52.0
8	Ceiling fans	119.7
9	Lighting	22
10	AC and others	8
Total Connected Load		376.3

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

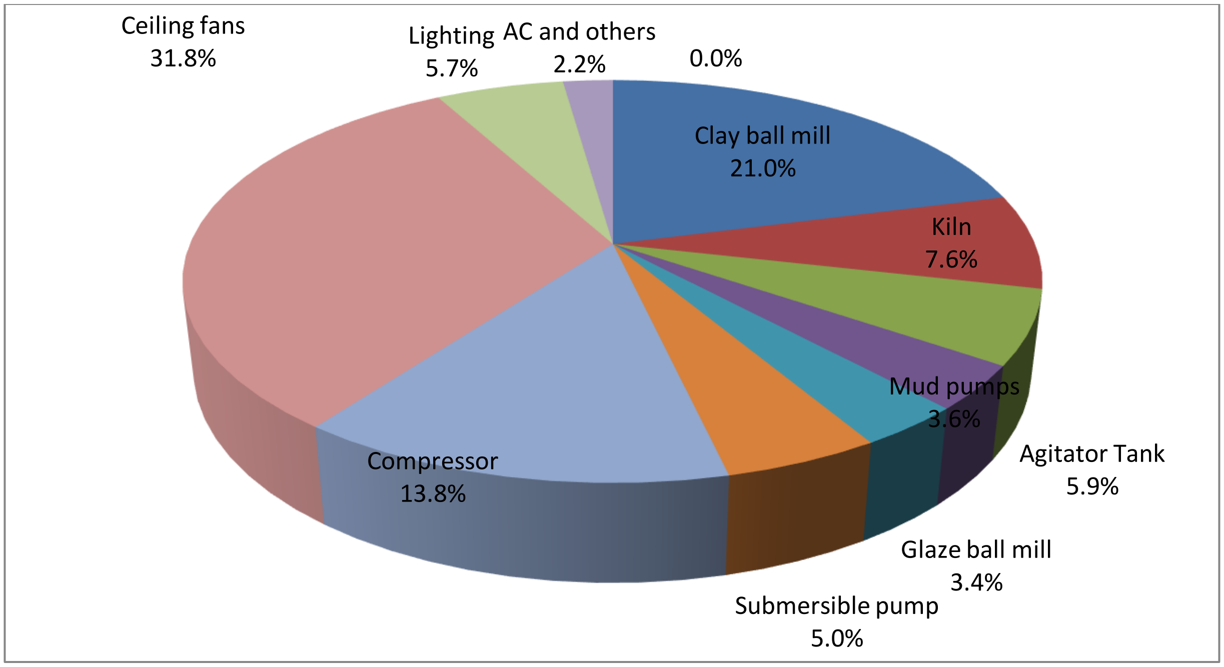

Figure 7: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for ceiling fans-31.8% , for Clay ball mill-21%, for the air compressor– 14 %, for kiln– 8 %, and other loads.

2.3.1.5 Specific electricity consumption

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

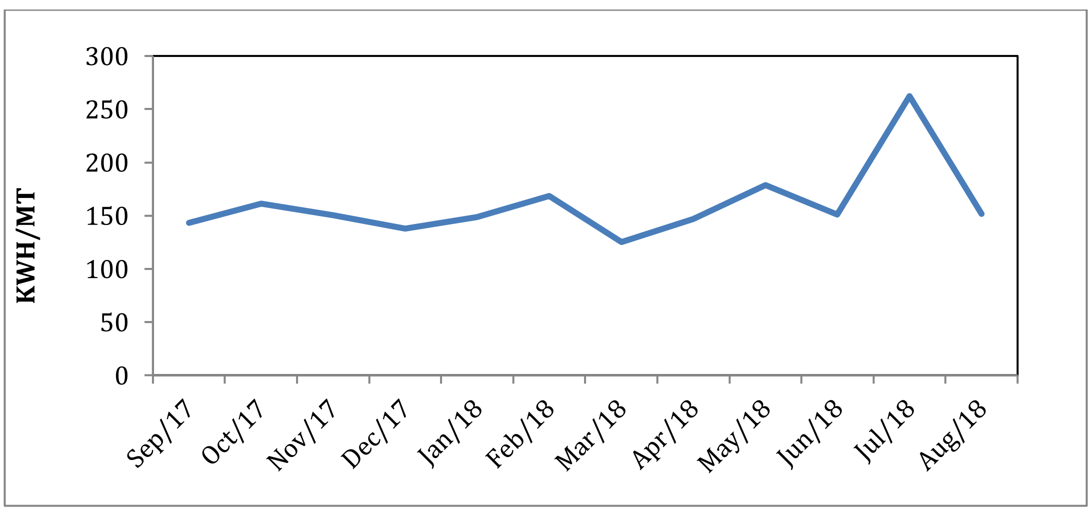

Figure 8: Month wise variation in Specific Electricity Consumption

The maximum and minimum values are within ±25% of the average SEC of 160 kWh/t indicating that electricity consumption follows the production. 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 Clay 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 Sept-17 to Aug-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
Sep-17	40,765	11,66,034	29
Oct-17	48,178	13,79,161	29
Nov-17	47,393	13,78,684	29
Dec-17	49,872	14,56,618	29
Jan-18	50,641	15,51,872	31
Feb-18	44,770	14,01,882	31
Mar-17	50,155	15,61,945	31
Apr-17	48,051	15,21,634	32
May-17	37,886	12,35,167	33
Jun-18	48,038	16,58,766	35
July-18	29,571	10,39,846	35
Aug-18	48,187	17,41,327	36

Observation (for the period Sep-17 to Aug-18)

- Average monthly natural gas consumption is 45,292 scm and average cost is around Rs. 14 Lakhs/month

2.3.2.2 Specific Fuel Consumption.

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

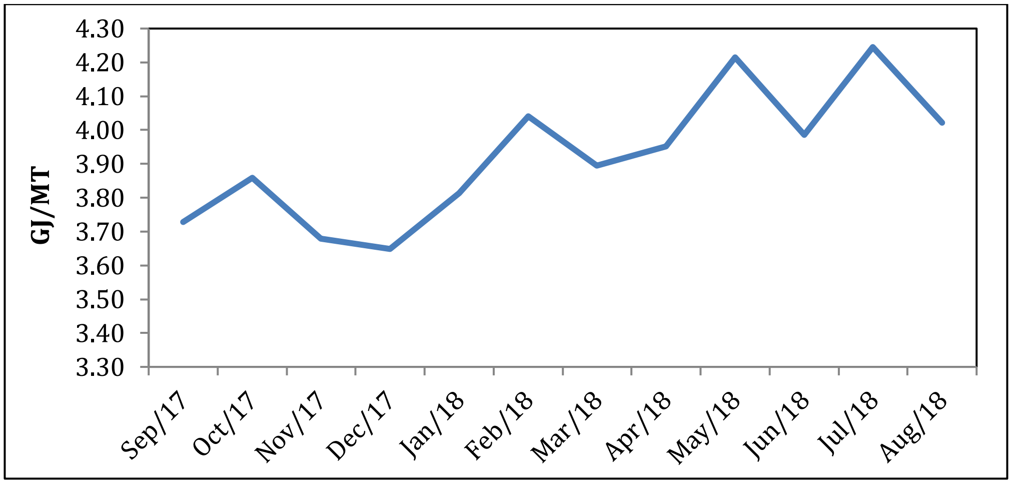

Figure 9 : Month wise variation in Specific Fuel Consumption

The average SFC is 3.92 GJ/MT. SFC is high in the months of Jul-18 (production was 262 MT and thermal consumption was 1,113 GJ) and low in the month of Dec-17 (production was 515 MT and thermal consumption was 1,880 GJ). While metering for NG is recorded, the coal consumption is not there.

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 during energy audit is shown in below table:

Table 13: Specific energy consumption

Particulars	Units	Value
Average production	kg/h	651
Power consumption	kW	89
NG consumption	scm/h	65.1
Energy consumption	kgOE/h	58.6
SEC of plant	kgOE/MT	90

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
Clay ball mills		30
Agitator		14.6
Kiln	100	12.4

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	8,17,268
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	8,17,268
Annual Thermal Energy Consumption (NG)	scm/y	5,43,507
Annual Energy Consumption	TOE	559
Annual Energy Cost	Rs Lakh	234
Annual production	MT	5,250
SEC; Electrical	kWh/t	155.7
SEC; Thermal	GJ/MT	3.9
SEC; Overall	TOE/MT	0.11
SEC; Cost Based	Rs/t	4453

(Annual data based on the period Sept-17 to Aug-18)

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

- Conversion factors
  - Electricity from grid : 860 kCal/kWh
  - GCV of NG :9000 kCal/scm
- CO_2 Conversion factors
  - Electricity : 0.82 tCO_2/MWh
    NG : 0.001923 tCO_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 Sept-17 to Aug-18	7.69
Cost of NG	Rs/SCM	31.4
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	MT	5,250

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 50 to 70 m^3/day based on measurement.

Water distribution diagram is shown below.

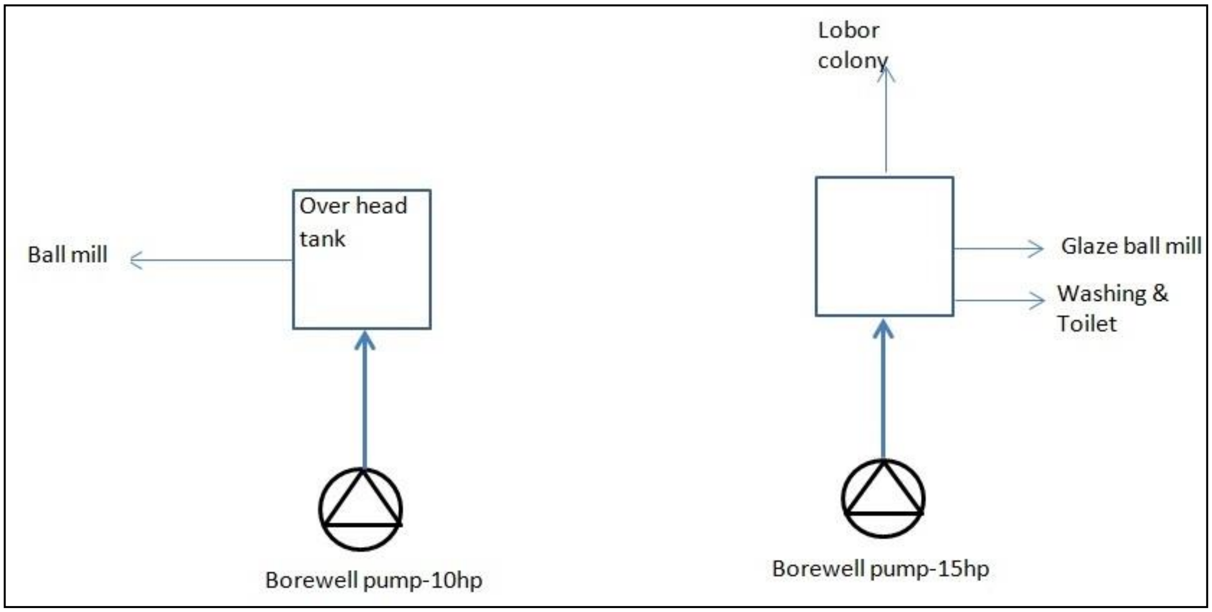

Figure 10: Water Distribution Diagram

Two submersible pumps are installed to meet the water requirements where pump 1 is used for process requirements of Clay ball mills and pump 2 is used for glaze Clay ball mills 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	10	15
RPM	rpm	2,900	2,900

Factory does not have any water treatment plant. 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 26.4 kW electrical load of which 5.5 is for cooling blower, 5.5 kW for combustion blowers, 2.2 kW for preheating blowers 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	65.1
3	Number of burner to left	-	20
4	Number of burner to right	-	20
5	Cycle Time	h	32
6	Pressure in firing zone	mmWC	50
7	Maximum temperature	°C	1,198
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	M	28 x 2.1 x 1
	Firing Zone	M	10 x 2.1 x 1
	Final cooling zone	M	33.5 x 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	5.38 %
Ambient Air Temperature	45 °C
Exhaust Temperature of Flue Gas	175 °C

From the above table, it is clear that the oxygen level measured in flue gas was high. The inlet temperature of raw material 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	45
Pre-heating zone Average Surface Temperature	59
Firing zone Average Surface Temperature	86
Cooling zone Average Surface Temperature	64

The temperature profile of the kiln is shown below:

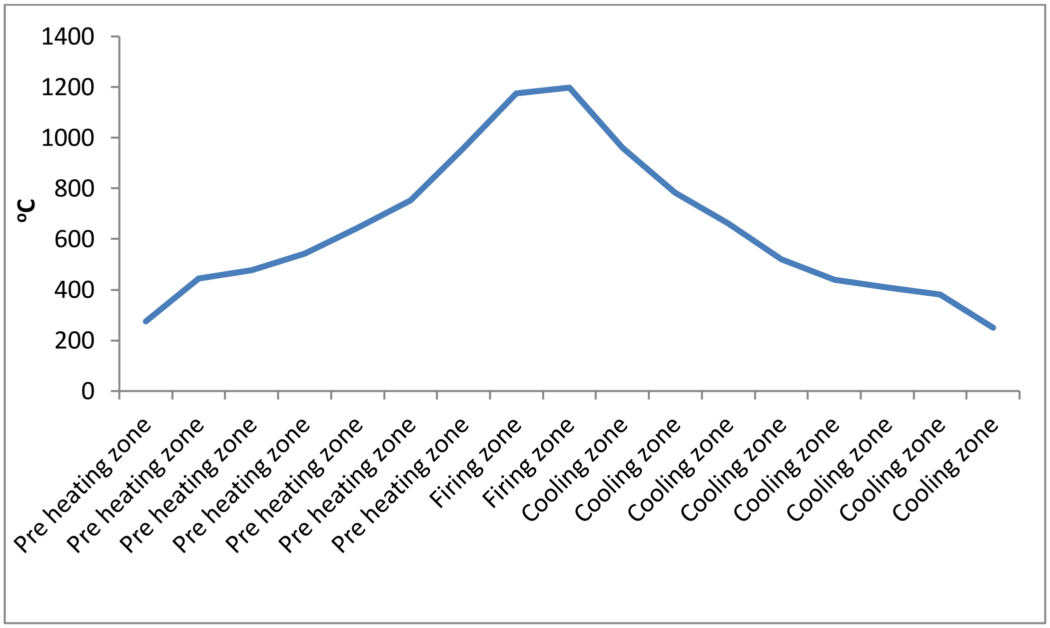

Figure 11 : Temperature Profile of Kiln

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)	Power factor
Preheating Blower	1.62	0.97
Combustion Blower	4.13	0.98
Cooling Blower	6.77	0.98

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit heat utilization of kiln is 40.3%. Summary of all losses is shown in below figure:

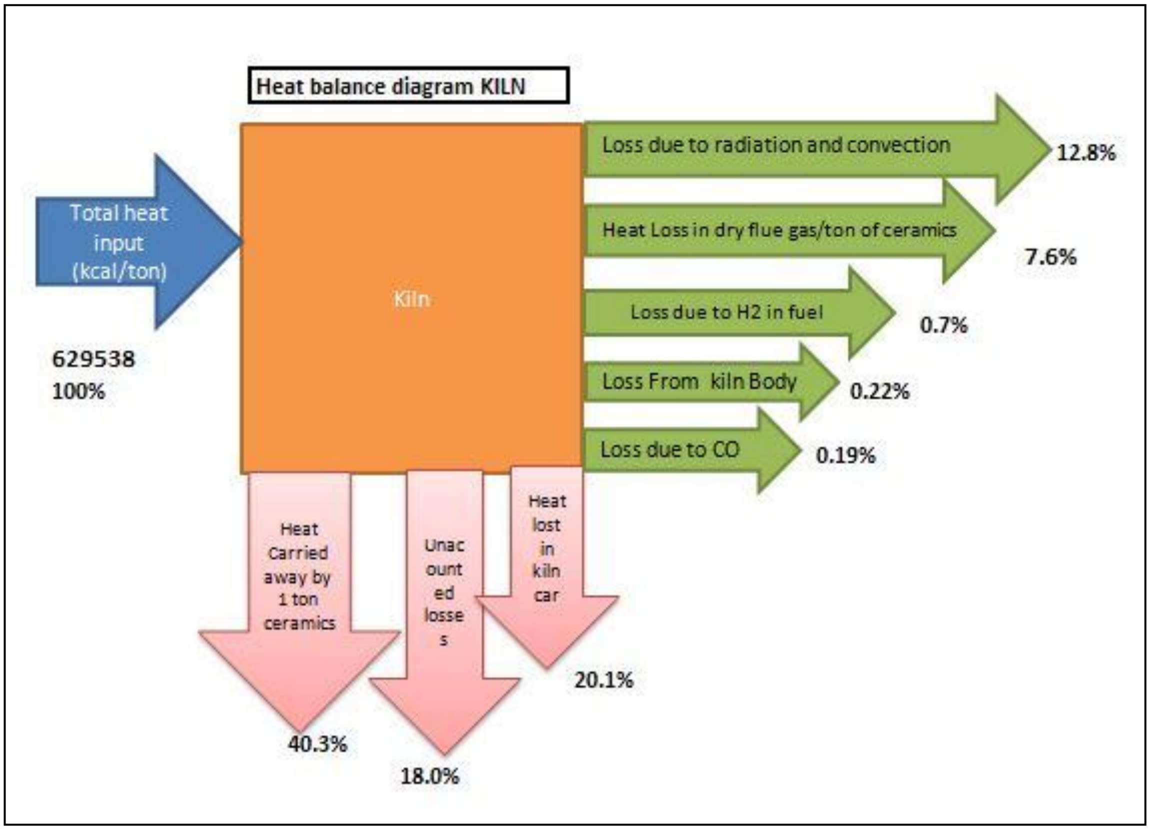

Figure 12 Heat balance diagram of Kiln

Causes of unaccounted losses arising due to following reasons:

1. Kiln leakage observed in VT old kiln
2. Rollers are gettinng heated itself by kiln heat
3. Inspection holes are closed by aluminnum dart which increases radiation loss
4. Hot air fans body are uninsulated
5. Atmopsheric air dilution in 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	%	5.38
CO_2 in flue gas	%	8.75
CO in flue gas	ppm	362

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	%	5.4	3.0
Excess air percentage in flue gas	%	34.5	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	96	94

Parameters	Units	Present	Proposed
Saving in specific fuel consumption	scm/h		1.11
Operating hours per day	h/d		24
Operating days per year	d/y		330
Annual fuel savings	Scm/y		8,800
Fuel cost	Rs/scm		31
Corresponding monetary savings	Lakh Rs/y		2.8
B. Power saving at combustion blower			
Mass flow rate of air	t/h	3.32	1.11
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	0.8	0.3
Total pressure rise	Pa	4,000	4,000
Measured power of blower	kW	4.13	0.16
Motor power	kW		
Power saving	kW	3.97	
Operating hours per day	h/d	24	
Operating days per year	d/y	330	
Savings in electrical energy	kWh/y	31,478	
Cost of electricity	Rs/kWh	7.69	
Savings in terms of energy cost	Lakh Rs/y	2.42	
C. Summary of Savings			
NG saving	scm/y	8,800	
Electricity saving	kWh/y	31,478	
Monetary savings	Lakh Rs/y	5.19	
Estimated investment	Lakh Rs	18.5	
Payback Period	Months	42.7	
IRR	%	6	
Discounted payback period	Months	15	

3.1.4.2 ECM #2: Waste Heat recovery from hot air

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.

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: waste heat recovery from hot air [ECM-2]

Particulars	Units	Value
Combustion air flow	m^3/h	1,042.6
Density of air	kg/m^3	1.225
Combustion air flow	kg/h	1,277
Combustion air temperature in present scenario	°C	35.0
Combustion air temperature after recuperator	°C	200
Heat required	kcal/h	50,575
Effectiveness of recuperator	%	60%
Heat supply at recuperator inlet	kcal/h	84,291
GCV of NG	kcal/scm	9,000
NG savings	scm/h	9.4
Operating hours per day	d/y	330
Operating gays per year	h/d	24
Annual running hours	h/y	7,920
Annual NG savings	scm/y	74,176
NG price	Rs/scm	31.4
Monetary saving	Rs Lakh/y	23.3
Investment	Lakhs	26
Simple payback Period	months	14
IRR	%	86
Discounted payback period	Months	4

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

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

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.

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) is given in the table:

Table 25: Replacement of kiln car with improved design and less weight [ECM-3]

Particulars	Units	As is	To be
Production of the material	t/h	0.65	0.65
Weight of existing kiln car	kg	500	330

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

Total number of kiln car inside kiln	Nos.	36	36
Initial temperature of kiln car	°C	39	39
Final temperature of kiln car	°C	1,198	1,198
Estimated percentage saving by new kiln car material	%	30	
Heat carried away by the kiln material	kcal/h		89,243
Reduction in the heat carried by the kiln	kcal/h		38,247
Operating hoursof kiln	hours	7,920	7,920
Savings in terms of fuel consumption	scm/y		33,657
NG price	Rs/scm	31	31
Savings in terms of cost	Rs Lakh/y		10.6
Estimated investment of kiln material	Rs Lakh/y		7.13
Payback period	months		8.1
IRR	%		113
Discounted payback period	Months		3.1

3.1.4.4 ECM #4: Skin loss reduction at kiln

Technology description

A significant portion of the losses in a kiln occurs as radiation and convection loss from the kiln walls and roof. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of insulation should be provided on the kiln walls and roof to maintain the skin temperature of the furnace at around 45-50°C, so as to avoid heat loss due to radiation and convection.

Thermal insulation are used for reduction in heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact or in range of radiative influence.

Kiln wall is designed in combinations of insulation layers, with the objective of retaining maximum heat inside the kiln and avoid losses from kiln walls.

Study and investigation

There are mainly three different zones in kiln, i.e. pre- heating, firing, and cooling zones. The surface temperature of each zones were measured. The average surface temperature of kiln body in the firing zone must be in the range of 45-50°C and it was measured as high as86°C; hence the kiln surface has to be properly insulated to keep the surface temperature within the specified range. Some photographs of kiln surface are shown below:

Figure 13: Kiln surfaces

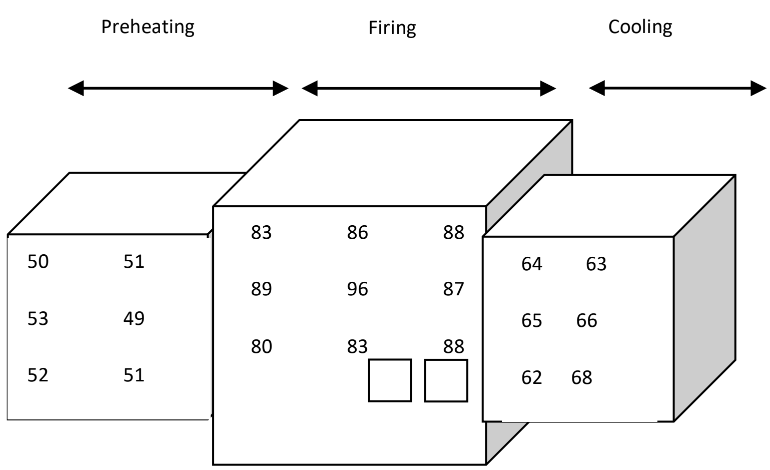

Figure 14: Kiln surface temperature schematic diagram

Recommended action

Recommended surface temperature of the firing zone has to be brought to within 70°C to reduce the heat loss due to radiation and convection and utilize the useful heat.

Table 26: Skin loss reduction at kiln [ECM-4]

Parameter	Units	Firing zone	
		As IS	To Be
Kiln height	m	0.80	0.80
Kiln length	m	10.00	10.00
Firing zone surface area	m^2	16.00	16.00
Average surface temperature of pipes in firing zone	°C	86	55
Ambient air temperature	°C	35	35
Heat loss in firing zone	$kCal/h/m^2$	640	220
Heat loss in firing zone	kCal/h	10,247	3,520
GCV of fuel	kCal/scm	9,000	9,000
Heat loss in terms of fuel	scm/h	1.1	0.4
Fuel saving	scm/h		0.7
Annual operating hours	h/y	7920	7920
Annual fuel saving	scm/y		5,920
Fuel cost	Rs/scm		31
Annual fuel cost saving	Rs Lakh/y		1.86
Estimated investment	Rs Lakh		1.6
Simple payback period	Months		10.2
IRR	%		86
Discounted payback period	Months		3.97

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 CLAY BALL MILLS

4.1.1 Specifications

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

Table 27: Specifications of Clay ball mills

Particular	Units	Value
Numbers of Clay ball mills	#	2
Capacity of each Clay ball mill	t/batch	6
Water consumption in each Clay ball mill	t/batch	3
Water TDS	ppm	1500
Nos. of batch per day		4

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all Clay ball mills

All power profile are included in Annexure-4. Average power consumption and power factor are given in below table:

Table 28: Average power consumption and PF of Clay ball mills

Equipment	Average Power (kW)	PF
Clay ball mill 1	23.2	0.9
Clay ball mill 2	21.8	0.9

4.1.3 Observations and performance assessment

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

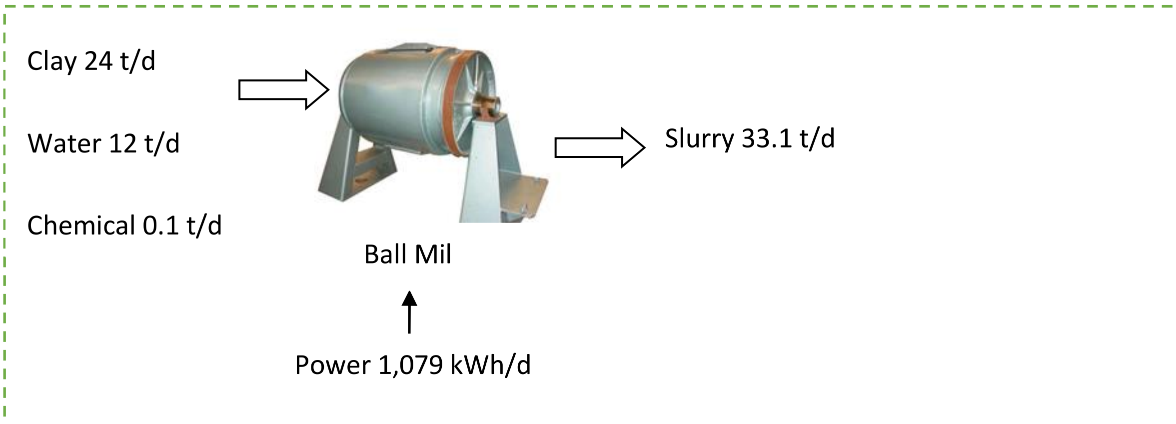

Figure 15: Energy and mass balance of Clay ball mill

Slurry mass calculated based on the full capacity of clay ball as data received. Performance of Clay ball mills measure 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 30 kW/ton. TDS of water is not too high since they purchase tankers from outside.

4.1.3.1 Energy conservation measures (ECM#5) –Optimization of Resource Consumption in Clay Section

Technology description

It was observed that the TDS of water used in clay section is 1,500 ppm, which results in higher consumption of water, chemicals and electricity per batch of slurry preparation and later higher coal consumption for spray dryer.

Study and investigation

All the details of the composition of raw materials per batch, water consumption per batch and electricity consumption per batch were collected for analysis and proposed solution for resource conservation.

Recommended action

It is recommended to install brackish water plant which will blend RO water with raw water to get desired TDS of water(less than 300 ppm) to be used in Clay ball mill. Resource saving has been considered for water, chemicals, coal and power consumption to arrive at techno economics of the proposed energy conservation measure. Coal consumption will be reduced due to reduced quantity of water to be evaporated in spray dryer.

Estimated cost benefit is given in the table below:

Table 29: Saving and cost benefit by using improved water quality [ECM-5]

Parameters	Unit	AS IS	TO BE
TDS of Water	ppm	1500	400
Assumption : Water Saving			15%
Assumption : Electricity Saving			3%
Assumption : Chemical Saving			30%
Water used per batch	m^3	3.00	2.55
Water saving	m^3		0.45
Electricity used per batch	kWh	114.0	111
Chemical saving per batch			
SMS	kg	150	105
STPP		25	17.5
Per Unit Cost			
Water	Rs./m^3	5.00	5.00
Electricity	Rs/kWh	7.69	7.69
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		1,656
Total batches per day	#	4	4
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		594.0
Electricity	kWh/y		4,514
Chemical	kg/y		69,300
Annual cost savings	Lakh Rs/y		21.86
Operating cost- Water Treatment	Rs/m^3		20.00
Water savings	Lakh Rs/y		0.67
Net monetary savings	Lakh Rs/y		21.19
Estimated investment	Lakh Rs		10.56
Payback period	Months		5.98
IRR	%		151
Discounted payback period	Months		2.36

4.2 AGITATOR MOTOR

4.2.1 Specifications

Slurry stored in agitation tank after preparation in Clay 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 in tank	#	2
Rating of each agitator motor	kW	1.5/2.2
Number of motors	#	12

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

Power consumption and P.F. of all agitator motors (stirrer) are given in below table:

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

	Equipment	kW	PF
Old shed	Stirring motor-1	2.23	0.87
	Stirring motor-2	2.23	0.87
	Stirring motor-3	2.17	0.87
	Stirring motor-4	2.29	0.85
	Stirring motor-5	2.26	0.88
	Stirring motor-6	2.14	0.84
	Primary agitator stir motor	0.878	0.77
New shed	Stirring motor-1	2.35	0.93
	Stirring motor-2	0.49	0.43
	Stirring motor-3	2.3	0.78
	Stirring motor-4	2.33	0.79
	Stirring motor-5	0.638	0.54
	Stirring motor-6	0.54	0.48
	Final tank stirring motor	1.19	0.32

4.2.3 Observations and performance assessment

During DEA, it was observed that all motors operate for same time. It is suggested that all motor should operate by timer control. Mass of slurry is considered as same as slurry prepared in clay ball mill

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 was 14.6 kW/t

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 VFD 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.	12	12
No of agitator stirrer running	Nos.	12	12
Rated power of agitator stirrer motor	kW	1.76	1.76
Running of each stirrer motor	h/d	24	16
Operating power of stirrer motor	kW	1.8	1.8
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	1,67,022	1,11,348
Annual energy saving	kWh/y		55,674
Cost of Electricity	Rs/kWh	7.69	
Annual energy cost saving	Lakh Rs/y	4.28	
Estimated investment	Lakh Rs	1.75	
Payback Period	Months	4.9	
IRR	%	184	
Discounted payback period	Months	2	

4.2.4.2 ECM #7: Replacement of horizontal stirrer wit vertical stirrer

Technology description

Replacement of horizontal stirrer with energy efficient vertical stirrer.

Study and investigation

It was observed that all the agitators are horizontal in tank and were consuming more power than energy efficient vertical stirrer

Recommended action

It is recommended to change all horizontal stirrers with energy efficient vertical stirrer. Cost benefit analysis of same is given in below table:

Table 33: Cost benefit analysis [ECM-7]

Parameters	Units	AS IS	TO BE
No of agitator stirrer	#	12	12
No of agitator stirrer running	#	12	12
Rated power of agitator stirrer motor	kW	1.76	1.1[2]
Daily running of each stirrer motor	h/d	16	16
Operating days per year	d/y	330	330
Operating power of agitator stirrer motor	kW	1.8	1.1
Annual energy consumption	kWh/y	111,348	66,809
Annual energy saving	kWh/y		44,539
Unit cost of electricity	Rs/kWh		7.69
Annual monetary savings	Lakh Rs/y		3.42
Estimated Investment	Lakh Rs		2.38
Payback Period	Months		8.33
IRR	%		107%
Discounted payback period	Months		3.26

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

[2] http://www.dcmsme.gov.in/reports/ahmedabadchemical/09energyefficientverticalagitator6000liter.pdf

sometimes boron trioxide. These glass formers may be included in the glaze materials, or may be drawn from the clay beneath.



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
Rating of glazing mill 1	HP	3
Rating of glazing mill 2	HP	5
Rating of glazing mill 3	HP	5
Stirrer motor	HP	4

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

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

Table 35: Specifications of compressors

Particular	Units	ELGI compressor 1	ELGI compressor 2
Power rating	kW	22	30
Maximum pressure	Bar (a)	6.9	7
Air handling capacity	m^3/min	3.57	5.41

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
- FAD test of compressor 2

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)	% of time on load
ELGI Compressor 1	21.2	0.8		
ELGI Compressor 2	26.11	0.95	3.47	47

FAD test conducted for compressor 2 only that is tabulated below:

Table 37: FAD test of compressor 2

Parameter	Unit	Value
Air Dryer Design Load	kW	
Air Dryer Operating Load	kW	
Final Pressure (P2)	kg/cm²	6.9
Initial Pressure (P1)	kg/cm²	1.3
Atmospheric Pressure (P0)	kg/cm²	1.026
Storage Volume (V)	m³	1.00
Time Taken (T)	Min	1.57
Rated Free Air Discharge	m³/Min	5.41
	CFM	191.05
Actual Free Air Discharge	m³/Min	3.47
Actual Free Air Discharge	CFM	122.66
Power consumption during normal operating condition	kW	26.11
Specific Power Consumption	cfm/kW	4.70
	kW/cfm	0.21

4.4.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption of ELGI compressor 2 is 0.21 kW/CFM. It is recommended to arrest leakage for compressor 2 line and installation of VFD with compressor 2. It is recommended to reduce operating pressure of both compressors.

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

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 guidebooks.

Study and investigation

During DEA, it was found that the compressed air was generating compressed air at 6.5 kg/cm^2 and the pressure requirement at the end utilities were around 5.5 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 38: Pressure reduction of compressor [ECM-8]

Parameter	Units	As is	To Be
Operating pressure required	kg/cm²	6.5	7.5
Cut off pressure	kg/cm²	7.3	7.3
Reduction in pressure	kg/cm²		1
% of energy saving	%		6
Average load	kW	47.3	44.47
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	3,74,643	3,52,165
Annual energy savings	kWh/y		22,479
Unit cost of electricity	Rs/kWh		7.69
Annual monetary saving	Lakh Rs/y		1.73
Estimated Investment	Lakh Rs		0.30
Payback period	Months		2.08
IRR	%		427
Discounted payback period	Months		0.8

4.4.5 Energy conservation measures (ECM#9) - VFD installation for screw compressor#2

Technology description

In any industry, compressor requirement keeps on varying based on the production demand and hence air compressor will run in load/unload sequence as per demand. During the unload condition air compressor will consume about 30% power without doing any work. A VFD can take care of this variable air demand by changing the RPM of compressor motor based on pressure feedback received from pressure sensor. As the demand reduces, pressure will increase, hence compressor RPM will reduce. Similarly, when there is high demand pressure will reduce during this period VFD will raise the RPM of motor to meet the demand.

Study and investigation

Power cycles of both the compressors were captured to understand unload/load pattern of air compressor it was found that the compressor#2 is getting unloaded for 53% of the time. There was only one receiver and it was not possible to conduct FAD test for compressor.

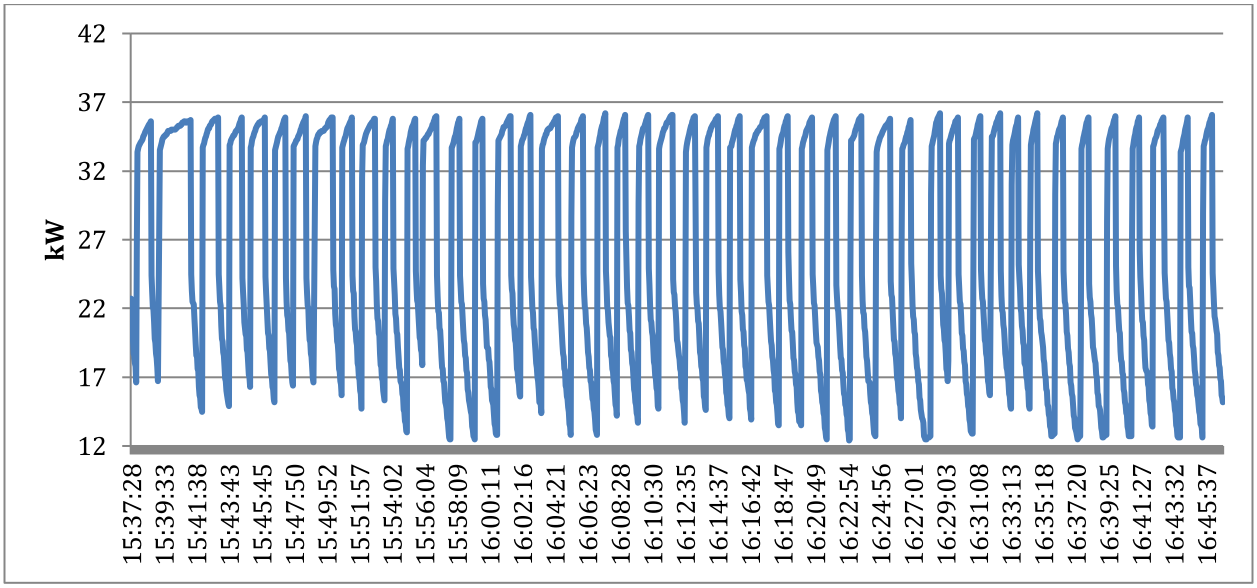

Figure 16: Load/Unload pattern of Compressor

Recommended action

It is recommended to install VFD on ELGI compressor 2 which will cater to the variable air demand of the plant whereas other two compressors will run to meet the base load. The cost benefit analysis for this project is given below:

Table 39: VFD for compressor 2 [ECM-9]

Parameter	Units	As is	To Be
Compressor motor rating	kW	30	30
Average power consumption during loading	kW	34.95	
Average power consumption during unloading	kW	18.37	
On load time in percentage	%	46.65%	
Off load time in percentage	%	53.35%	
Average power consumption	kW	26.11	22.19
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	2,06,766	1,75,751
Annual energy saving	kWh/y	31,015	
Unit cost of electricity	Rs/kWh	7.69	
Annual monetary savings	Lakh Rs/y	2.38	
Estimated Investment	Lakh Rs	2.97	
Payback period	Months	14.9	
IRR	%	59	
Discounted payback period	Months	5.6	

4.4.6 Energy conservation measures (ECM) - ECM #10: Leakage arresting in compressed air network

Project

Leakage arresting in the compressed air line.

Study & Investigation

While the Compressor study it is found that the percentage of leakage in the compressed air line is very high i.e. 19. To reduce the leakage percentage which automatically reduce the power consumption.

Recommendation Action

It is recommended to install arrester in the compressed air line

Saving Assessment

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

Table 40: Cost Benefit [ECM-10]

Parameter	Unit	AS IS	TO BE
Cut in pressure	kg/cm²	6.5	6.5
Cut out pressure	kg/cm²	7.3	7.3
Free air discharge	Nm³/Min	3.47	3.47
Average load time (T)	min	0.41	-
Average unload time (t)	min	1.79	-
Leakage quantity	Nm3/min	0.645	0.347
Average operating power	kW	26	26
Specific energy consumption	kW/Nm3	0.13	0.13
Operating hours per day	h/d	24	24
Annual operating days per year	d/y	330	330
Annual energy consumption	kWh/Year	38,377	20,677
Energy savings	kWh/Year	-	17,700
Weighted average cost of electricity	Rs/kWh	7.69	7.69
Annual monetary savings	Lakh Rs./y		1.36
Estimated investment	Lakh Rs.		0.13
Simple payback period	Months		1.16
IRR	%		761
Discounted payback period	Months		0.5

4.5 LIGHTING SYSTEM

4.5.1 Specifications

The plant lighting system includes:

Table 41: Specifications of lighting load

Fixture	Rated power	Quantity	Total power (KW)
Tube light 1	52	187	9.7
Tube light 2	48	164	7.9
LED	26	23	0.6
	30	3	0.1
	50	4	0.2
	10	43	0.4
CFL	36	19	0.7
	18	112	2.0
Total			21.6

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 42: Lux measurement at site

Particular	Units	Value
Office	$Lumen/m^2$	165
Kiln control room	$Lumen/m^2$	105
Kiln area	$Lumen/m^2$	65
Clay ball mill and agitators	$Lumen/m^2$	70

4.5.3 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.

4.5.4 Energy conservation measures (ECM#11) - Replacement of T12 tube lights with EE LED lamps

Technology description

Replacing conventional lights like T12 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 52 T12 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 43: Replacement of T12 tube light with EE LED lamps [ECM-11]

Particulars	Units	Present	Proposed
Fixture		T12	EE LED tubes
Power consumed by T12 Tube lights	W	52	28
Operating hours	h/d	12	12
Operating days	d/y	330	330
Energy Used per fixture	kWh/y	206	111
Cost of Electricity	Rs./kWh	7.69	7.69
No. of Fixture	Unit	351	351
Power consumption	kWh/y	72,278	38,919
Operating cost	Rs Lakh/y	5.56	2.99
Electrical savings	kWh/y		33,359
Annual Monetary saving	Rs. Lakh/y		2.56
Investment per fixture of LED	Rs		4.712
Estimated Investment	Rs Lakh		1.76
Payback Period	months		8.24
IRR	%		109
Discounted payback period	Months		3.22

4.6 Electrical Distribution System

4.6.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415 KV) by step down transformer (0.25 MVA). Automatic power factor correction system is installed in parallel to main supply. There was one DG (capacity of 250 KVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeder which are shown in Figure 8.

4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.6.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **137.93 kVA** at the plant feeder.

The voltage profile of the unit is satisfactory and average voltage measured was **439 V.** Maximum voltage was **451 V** and minimum was **425 V**.

Average total voltage and current Harmonics distortion found to 5% & 15% about respectively during power profile recording.

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

It is recommended to maintain power factor in distribution feeders above 0.95. Poor power factor leads to cable losses (I^2R) in the electrical distribution system.

4.6.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.6.4.1 ECM #12: 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 69 watt as compared to 30 watt (EE ceiling fan)

Figure 17: Ceiling fans in production area

Recommended action

It is recommended to replace conventional fans with EE ceiling fans.

The cost benefit analysis for the ECM is given below:

Table 44 Cost benefit analysis of EE ceiling fans [ECM 12]

Parameter	Units	AS IS	TO BE
Number of ceiling fans	#	1596	1596
Rated power of ceiling fans	W	0.075	0.030
Operating power	kW	0.069	0.030
Operating hour per day	h/d	10	10
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	363,409	158,004

Parameter	Units	AS IS	TO BE
Annual energy saving	kWh/y		205,405
Unit cost of electricity	Rs/kWh		7.69
Annual monetary savings	Lakh Rs/y		15.79
Estimated Investment	Lakh Rs		43.6
Payback Period	Months		33
IRR	%		16
Discounted payback period	Months		11.7

4.6.4.2 ECM #13: installation of 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
- Clay ball mills
- Agitator motors
- Compressor
- Glaze line and kiln line

The cost benefit analysis for this project is given below:

Table 45: Cost benefit analysis [ECM-13]

Parameters	Unit	As Is	To Be
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	8,17,268	8,00,923
Annual electricity saving per year	kWh/y		16,345
Unit Cost	Rs/kWh		7.69
Annual monetary savings	Lakh Rs/y		1.26
Number of equipments	Nos.	5	5
Annual monetary savings	Lakhs Rs/y	1.26	

Parameters	Unit	As Is	To Be
Number of energy meters	Nos.	5	
Estimated	Lakhs Rs	0.5	
Payback Period	months	5	
IRR	%	196	
Discounted payback period	Months	1.8	

4.7 Belt Operated Drives

4.7.1 Specifications

There are 5 drives operated with V Belt of total capacity of Locations include

- Kiln blowers (4)
- Clay ball mill (1)

4.7.2 Field measurement and analysis

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

4.7.3 Observations and performance assessment

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

4.7.4 Energy conservation measures (ECM) - ECM #14 Replacement of V belt by 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 3 belt driven blowers in kiln

Recommended action

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

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

Particulars	Units	AS IS	TO BE
Rated power of motor/blower	kW	13	13
Existing power consumption	kW	13	12
Assumed: Energy loss in transmission	%		3.60
Power loss in transmission	kW		

Particulars	Units	AS IS	TO BE
Annual operating days	d/y	24	24
Operating hours per day	h/d	330	330
Annual energy consumption	kWh/y	99,158	95,589
Annual energy saving	kWh/y	3,570	
Electricity cost	Rs./kWh	7.69	
Annual energy cost saving	Rs. Lakh	0.27	
Estimated investment	Rs. Lakh	0.20	
Payback Period	Months	8.77	

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 #14).

5.2 Best Operating Practices

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

Table 47: Unique operating practices in the unit

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Clay ball mill	VFD for energy saving. Timer control system.
3	Glaze Clay ball mill	Testing residue percentage for each batch. In house RO system for glaze ball bill.
4	Glazing (spraying)	Pressure reducing valve for compressed air line.
5	Kiln	Re use of hot air in pre heating zone. Daily specific energy consumption (SCM/Piece). Wet product kept near kiln wall for pre heating. Temperature is controlled by PID sensor.
6	Lighting	LED lights

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

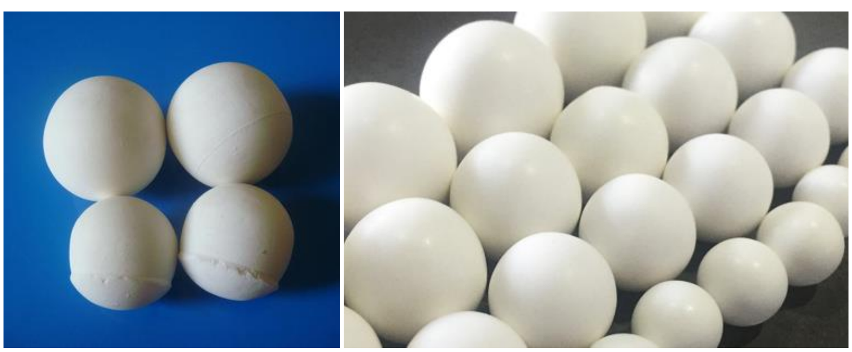

Figure 18: - High Alumina pebbles for Ball mill

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[3]) 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%

[3] Product brochure of M/s SNF (India) Pvt. Ltd. Vizag–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[4] 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.

---

[4] Source: Product brochure of M/s SNF (India(Pvt. Ltd., Vizag, 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 19: Direct drive blower fan

6. Chapter -6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA (details below). The RCC roof top space available is 90 m^2 and corresponding solar power potential will be 9kW. 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. As per discussion with vendors, due to high dust content in the region, installation of solar PV is not feasible. The extent of degradation on account of dust is upto 40% (for 6g of dust per panel).

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 90 m^2 under office admin and administrative building.

Study and investigation

During DEA, it was found that plant is having solar potential but due to poor IRR, it is not recommended.

Recommended action

The cost benefit analysis for this project is given below:

Table 48: Installation of solar PV system [ECM-15]

Parameters	Units	Value
Available area on roof	m^2	90
Capacity of solar panel	kW	9
Energy generation from solar panel	kWh/d	43
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	15,768
Electricity Cost	Rs/kWh	7.69
Annual monetary savings	Rs Lakh/y	1.2
Estimate of Investment	Rs Lakh	4.7
Payback period	Months	47
IRR	%	2
Discounted payback period	Months	16.5

The project IRR is poor and hence the project is not considered feasible. The reasons are as follows:

a) Increase in capital expenditure on account of
   a. Requirement for strengthening the structure for accommodating the solar panels.
   b. Requirement for construction of walkways for cleaning of solar panels.
b) Degradation of generation considered on account of heavy dust accumulation on the panels.
c) Increase in operating costs on account of
   a. Increased cleaning frequency.
   b. Requirement of DM water for cleaning the panels twice a day.

7. ANNEXES

7.1 Annex-1: Process Flow Diagram

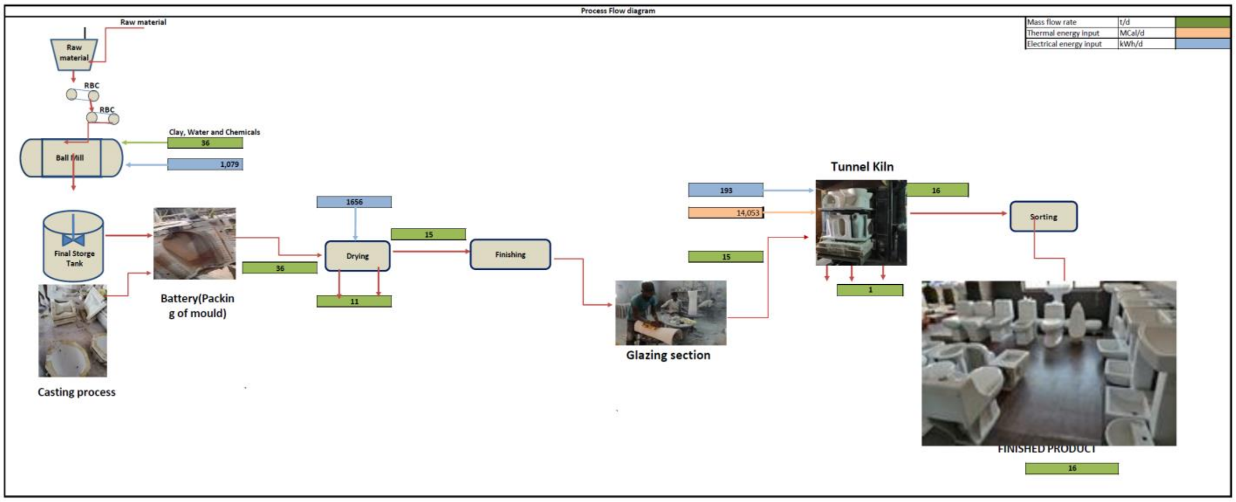

Figure 20: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 49: Detailed Inventory list

Parameters	Units	Value
Clay ball mill	kW	79
Kiln	kW	29
Agitator Tank	kW	22
Mud pumps	kW	13
Glaze Clay ball mill	kW	13
Submersible pump	kW	19
Compressor	kW	52
Ceiling fans	kW	120
Lighting	kW	22
AC and others	kW	8
Total	kW	**376.3**

7.3 Annex-3: Single Line Diagram

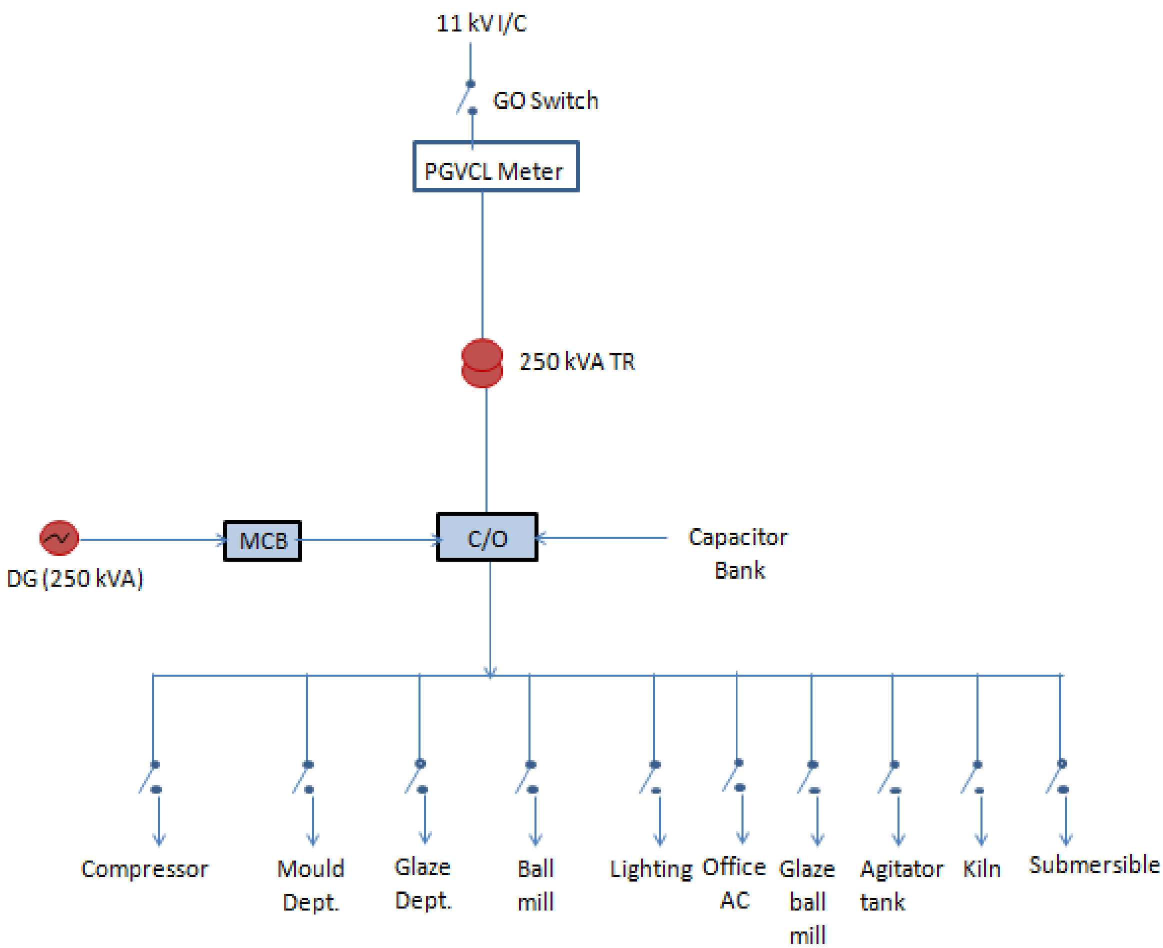

Figure 21: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

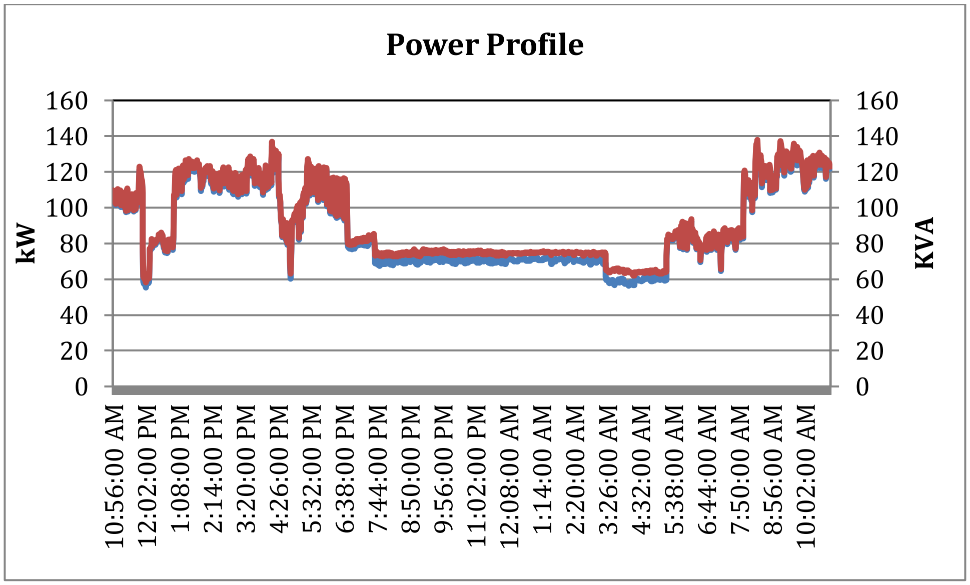

Figure 22: Power profile (kW) of Main Incomer

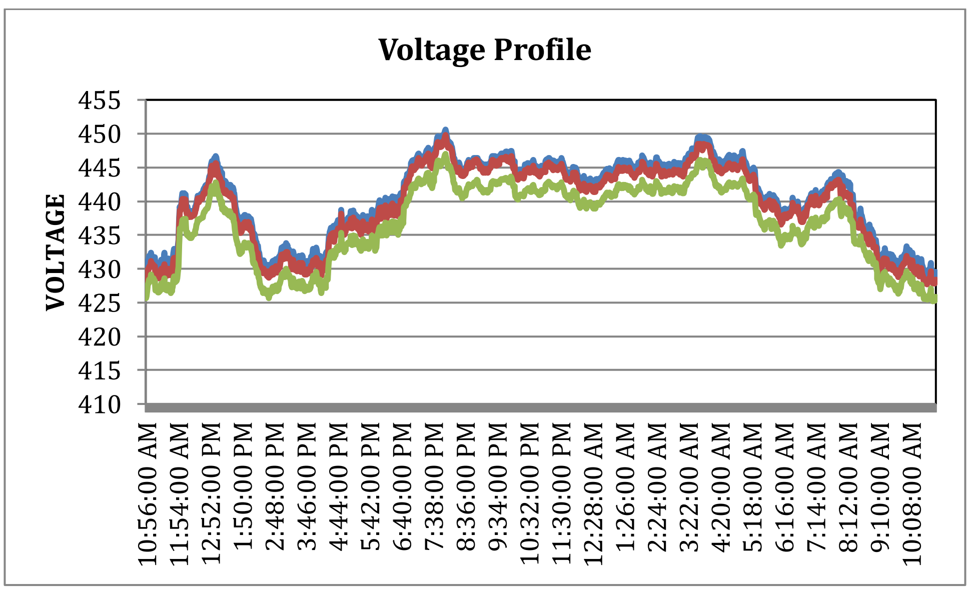

Figure 23: Voltage profile of Main Incomer

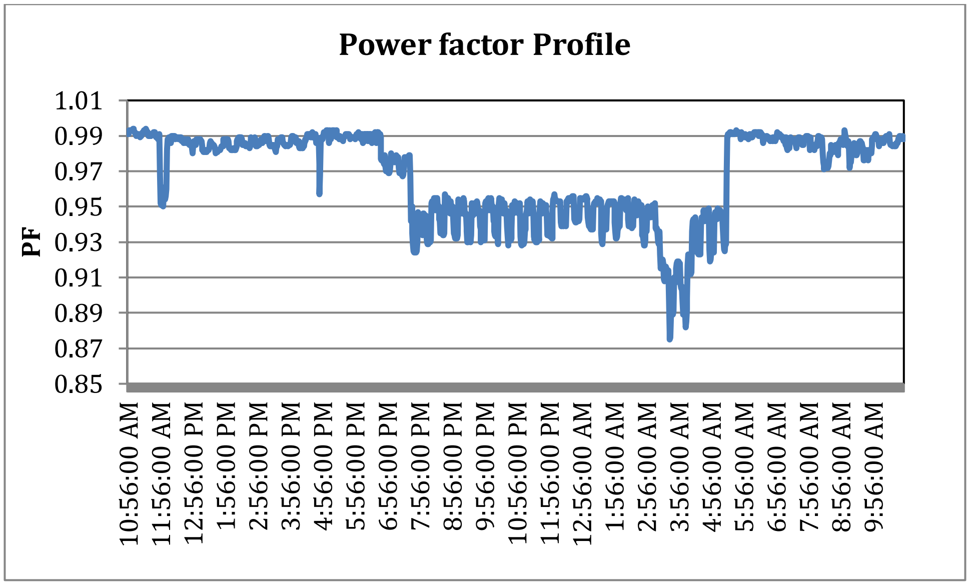

Figure 24: PF profile of Main Incomer

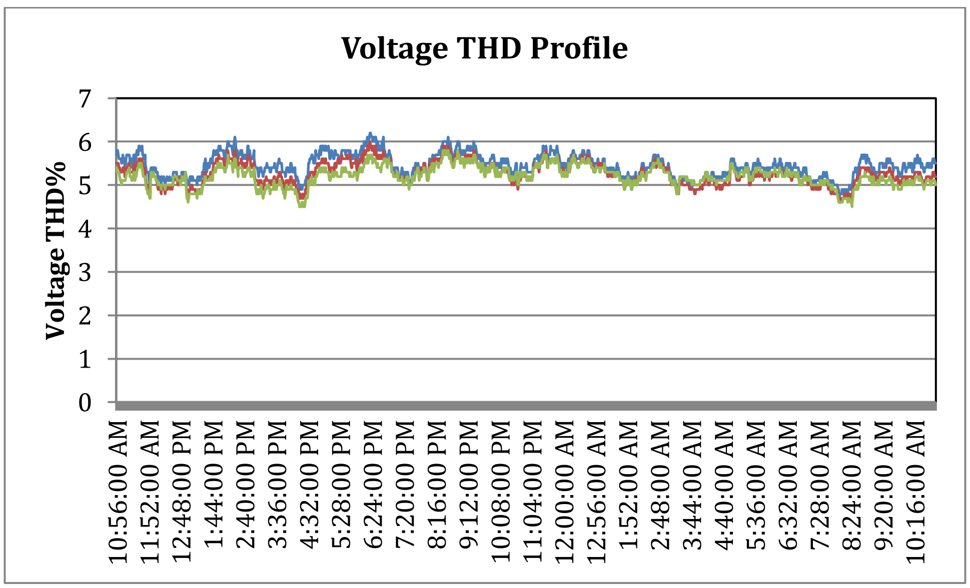

Figure 25: Voltage THD profile of Main Incomer

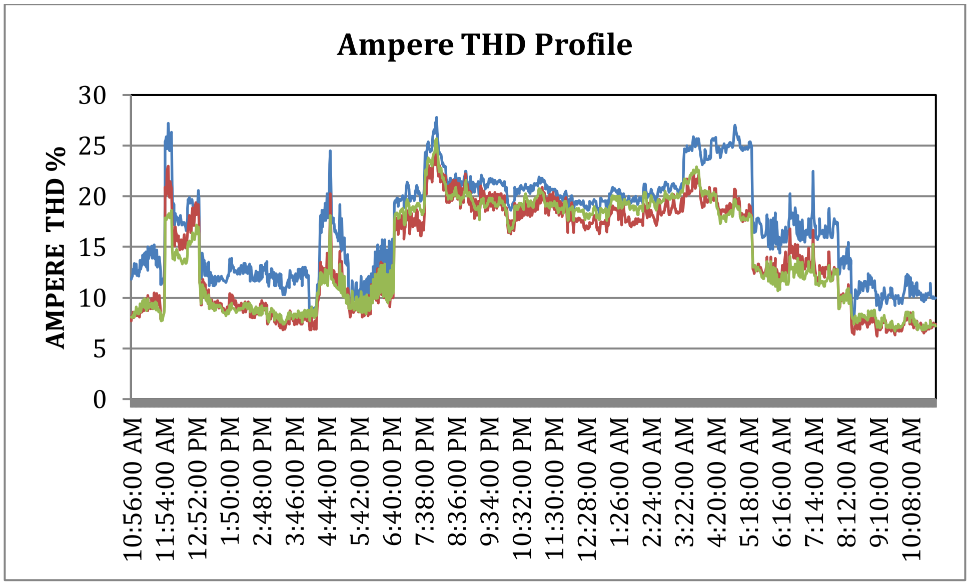

Figure 26: Ampere THD profile of Main Incomer

7.5 Annex-5: Thermal Measurements, heat utilization of kiln

1. *Heat utilization at kiln - Calculations*

Input parameters

Input Data Sheet		
Type of Fuel	Natural Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1198	*°C*
Initial temperature of kiln tiles	45	*°C*
Avg. fuel Consumption	65.1	*scm/hr*
Flue Gas Details		
Flue gas temp at smog blower	175	*°C*
Preheated air temp./Ambient	39	*°C*
O_2 in flue gas	5.38	*%*
CO_2 in flue gas	8.75	*%*
CO in flue gas	362	*ppm*
Atmospheric Air		
Ambient Temp.	45	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry 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/scm*
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	500	*Kg/h*
Weight of Kiln car material	651	*Kg/h*

Input Data Sheet		
Weight of Stock	1151	*kg/h*
Specific heat of clay material	0.22	*KCal/kg°C*
Specific heat of kiln car		*KCal/kg°C*
Avg. specific heat of fuel		*KCal/kg°C*
fuel temp		*°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	80,867	*kCal/h*
Radiation and convection from heating zone surface		*kCal/h*
Radiation and convection from cooling zone surface		*kCal/h*
Heat loss from all zones	80,867	*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		
Average operating temperature of kiln		*deg K*

Efficiency calculations

Parameters	Value	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	34.47	*%*
Actual Mass of Supplied Air	23.16	*kg/kg of fuel*
Mass of dry flue gas	21.92	*kg/kg of fuel*
Amount of Wet flue gas	24.16	*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	21.92	*kg/kg of fuel*
Specific Fuel consumption	69.95	*kg of fuel/ton of water closet*
Combustion heat of fuel	629,538	*kCal/ton of water closet*
Sensible heat of fuel		*kCal /ton of water closet*
Total heat input	629,538	*kCal /ton of water closet*
Heat carried away by 1 ton of water closet	253,660	*kCal /ton of water closet*
Heat loss in dry flue gas	47,845	*kCal /ton of water closet*
Loss due to H2 in fuel	4,563	*kCal /ton of water closet*
Loss due to moisture in combustion air	1,355	*kCal /ton of water closet*
Loss due to partial conversion of C to CO	1,203	*kCal /ton of water closet*

Parameters	Value	Unit
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)		*kCal /ton of water closet*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln car)		*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	70,252	*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	126,830	*kCal /ton of water closet*
Unaccounted heat losses	126,830	*kCal /ton of water closet*
Total heat loss from kiln	70,252	*kCal /tons*
Heat utilization in kiln	40.3	*%*

2. *Heat Balance Diagram*

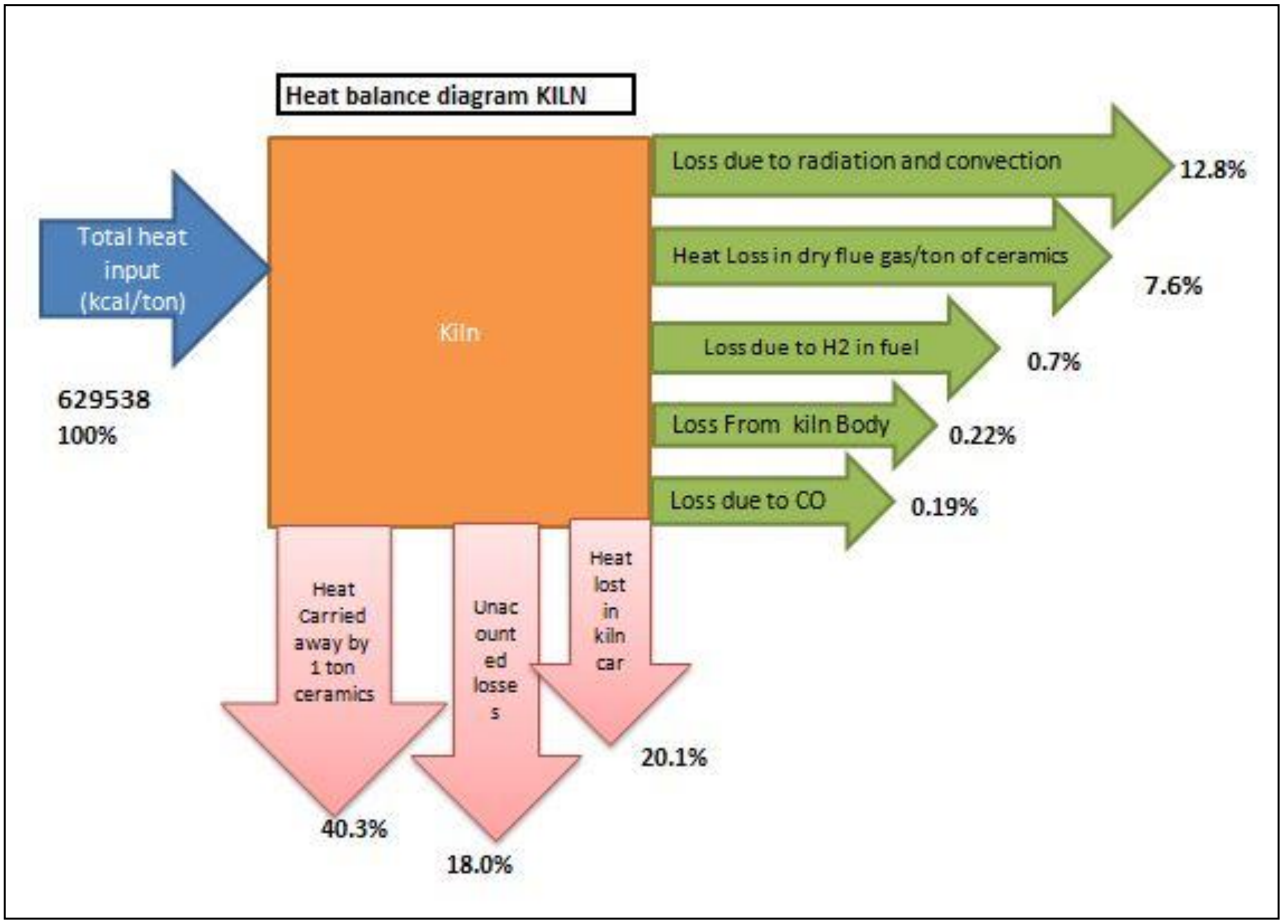

Figure 27: Heat Balance Diagram of Tunnel Kiln

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 INDUSTRIES LTD.	Sanghavi Chambers, Beside Canara Bank, Navrangpura, Ahmedabad	+91-79-30911069 079-6438180	ik@interkiln.com
2	Shivang Furnaces And Ovens	No. 483, Jalaram Estate, Narol Vatva Road Narol	08048763653	

	Industries	Ahmedabad - 382405 Gujarat, India		
3	Mahek Enterprises	No. 607, Corporate Avenue, Sonawala Road, Goregaon East, Morbi-400063, Gujarat, India	08048719133	

ECM 4: Radiation and convection loss reduction from surface of kiln

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA	T 91 44 2530 6888 F 91 44 2534 5985 M 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com ramaswamy.pondian@morganplc.com
2	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 Mr. Rajneesh Phone : 0161-2819388 Mobile : 9417004025	Email: kk.mitra@lloydinsulation.com
3	Shivay Insulation	20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009	Mobile- 9712030444	shivayinsulation@gmail.com

ECM: 5 Optimisation of resources using soft water in Clay ball mill

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Aqualux Water India	A/2, Pawan Apartment, Nr. Ahmedabad Homiopathic Medical College, Bopal - Ghuma Road, Ghuma, Ahmedabad, Gujarat 380058	Mob: 9924312411	sales@aqualuxwater.com
2	Aquatechplus Pvt. Ltd.	Shree Khodiyar Park, behind Ruda Transportnagar,Rajkot-Amdavad Highway, Rajkot-363670	Mr. Bhavesh Dabhi 9512301122	www.aquatechro.com bhavesh@aquatechro.com
3	Raj Water Technology (Gujarat) Pvt Ltd	Plot-27, Survey-47, Jivraj Industrial Area Near Falcon Pump, Gondal Rd, Vavdi, Rajkot, Gujarat 360004	70439 55777	marketing@rajwater.com www.rajwater.com

ECM – 6 : 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,	Mr. Paresh Patel 9909458699	www.jagdishautomation.com

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
		Trajpar, Morbi-363641		
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 – 7: Vertical Stirrer/Agitator

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Nurshi Machine Tools	National Highway 8, Varmura Siram, Morbi-363641, Gujarat	8048830850	https://www.indiamart.com/nurshi-machine-tool/#home
2	Mixsep Mixing & Separation Technologies	04 AB, Government Industrial Estate, Charkop, Kandivali (W),Mumbai-400067	8061855557	http://www.mixsepmixing.com/
3	Hi-Tech Applicator	1102/B, Phase-III, GIDC, Vatva, Ahmedabad-382445	8068214408	https://ptfeindia.tradeindia.com/

ECM 8: VFD installation

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Samhita Technologies Pvt. Ltd	309, Vardhman Grand Plaza, Distt Center, Mangalam Place, Plot No. 7, Outer ring road, Sec 3, Rohini, Delhi – 110085	Mob: +91 9711320759 Tel: +91 11 45565088	sales@samhitatech.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 11: 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 City - 1,122001 Gurgaon, Haryana	Phone: 011-30416390 Mob: 9560215888	vinay.bharti@osram.com
2	Philips Electronics Contact Person:	1st Floor Watika Atrium, DLF Golf Course Road, Sector 53,	9810997486, 9818712322 (Yogesh-Area Manager),	r.nandakishore@phillips.com,

Sl. No.	Name of Company	Address	Phone No.	E-mail
	Mr. R. Nandakishore	Sector 53 Gurgaon, Haryana 122002	9810495473 (Sandeep-Faridabad)	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 12: 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)r	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 13: 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-14: 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 15 : 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	Sun gold 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 50: 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%