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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE SP-20: HOME DECOR SANITARY COMPLEX

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

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April-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'.

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Disclaimer

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

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. Home Decor Sanitary 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. Bhavin Kalaria, Director
2. Mr. C N Kalaria, Director

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

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

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ABBREVIATIONS

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

UNITS AND MEASURES

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

CONVERSION FACTORS

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

EXECUTIVE SUMMARY

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

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

Home decor sanitary complex 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	Home Decor Sanitary complex
Year of Establishment	1990
Address	Sartanpar Road, NH -27m Morbi - 363643, Gujarat - India
Products Manufactured	One piece closet and other sanitary products
Name(s) of the Promoters / Directors	Mr. Bhavin Kalaria & Mr. C.N. Kalaria

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

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

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio of 2:1:1 respectively along with water to form a plastic mass.
- **Agitator:** The plastic mass after mixing in ball mill is poured in to a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Glaze mill:** For producing glazing material used on the product.
- **Tunnel Kiln:** Moulded sanitary products articles are loaded in kiln car and dried and cured in Tunnel kiln at 1,100-1,150°C.

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 were operational during the field study.

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control at kiln: During the study it was found that excess air levels in the NG fired kiln is 6.1% against the desired level of 3%. It is recommended to install an oxygen sensor and PID controller, so that the air flow can be adjusted or automatically.etc according to fuel firing
- Insulation at kiln: Average surface temperature measured during the study was 87 °C near firing zone, 99 °C in firing zone, 85 °C in cooling zone, resulting surface temperature will be 55°C after recoating of insulation etc
- Waste heat recovery from flue gas: The flue gas measured at kiln exhaust was 175°C. At the same time, inlet temperature of combustion air was 35°C. It is recommended to install a recuperator in flue gas line to recover this waste heat (upto 130°C) and reduce the fuel consumption
- 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 of mass 330 kg
- Replacement of conventional motor with IE3 motor for ball mill: The ball mill constitutes 20% of the total connected load. It is operated with timer controller for 271 minutes per

batch and daily average three batches i.e @ 14 hours a day. It is recommended to replace the existing IE1 or 2 motors with IE3 motor to help reduce the energy consumption

- Timer controller at stirrer motor: At present 3 stirrer motors are operated continuously. A timer controller is recommended to be installed so that operating hours of each motor will reduce upto 12 hour.
- Pressure reduction in air compressor: The pressure at receiver is 7.5 bar (a) and they require maximum pressure up to 4bars in plant (especially in batteries only). It is advisable to reduce operating pressure of compressor from 7.5 bar to 5.5 bar
- Replacement of air compressor with blower: Compressed air is utilized in plant for cleaning purpose only in glaze section, which can be met by installing blower of 1-2 bars only instead of 7.5 bar air compressor. Power consumption for same air flow (149.8 CFM) will reduce from 24 kW to 13.5 kW.
- Replacement of Inefficient Pumps: water pumps used for lifting water from underground tank to overhead tank, having low efficiency (18%). It is recommended to replace these with more efficient pumps
- Installation of energy management system
- V belt replacement with REC belt
- Installation of harmonic filter
- Installation of solar PV system

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

Table 1 Summary of ECMs

Sl. No.	Energy Conservation Measures	Annual Savings				Monetary Savings	Investment	Simple Payback Period	Annual Emission Reduction
		Electricity	NG	Coal	TOE Equivt.				
		KWh	scm/y	t	MTOE/y	Lakh Rs/y	Lakh Rs	Months	tCO_2
1	Excess air control at Kiln	9,739	11,614		11	4.39	6.93	19	30
2	Insulation at kiln		25,187		0	7.95	3.10	5	48
3	Waste heat recovery from flue gas		6,397		6	2.02	2.61	16	12
4	Kiln car with improved design and less weight		17,979		16	5.67	7.00	15	35
5	Replacement of conventional motor with IE3 motor for ball mill	10,455			1	0.77	1.32	20	9
6	Time controller at stirrer motor	5,715			0	0.42	0.55	16	5
7	Pressure reduction in air compressor	13,763			1	1.02	0.30	4	11
8	Replacement of air compressor with blower	50,804			4	3.76	3.96	13	42
9	Replacement of Inefficient Pumps	8,672			1	0.64	0.34	6	7
10	Replacement of T12 tube lights with EE LED lamps	28,728			2	2.13	2.45	14	24
11	Replacement of ordinary fans with EE ceiling fans	55,575			5	4.11	9.04	26	46
12	Installation of harmonic filter	18,579			2	1.37	6.34	55	15
13	Installation of Energy management system	8,569			1	0.63	0.66	12	7
14	V belt replacement with REC belt	7,935			1	0.59	0.79	16	7
	Total	218,533	61,177		51	35	45	15	297

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

- Reduction in energy cost by 18%
- Reduction in electricity consumption by 47.07 %
- Reduction in thermal energy consumption by 11.9%
- Reduction in greenhouse gas emissions by 21.6%

➨ 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 Lakh Rs	Internal Rate of Return %	Discounted Payback Period Months
1	Excess air control at Kiln	6.93	42%	7.13
2	Insulation at kiln	3.10	195%	1.84
3	Waste heat recovery from flue gas	2.61	53%	5.95
4	Kiln car with improved design and less weight	7.00	57%	5.68
5	Replacement of conventional motor with IE3 motor for ball mill	1.32	39%	7.53
6	Time controller at stirrer motor	0.55	53%	5.98
7	Pressure reduction in air compressor	0.30	254%	1.40
8	Replacement of air compressor with blower	3.96	68%	4.88
9	Replacement of Inefficient Pumps	0.34	140%	2.53
10	Replacement of T12 tube lights with EE LED lamps	2.45	64%	5.22
11	Replacement of ordinary fans with EE ceiling fans	9.04	24%	9.77
12	Installation of harmonic filter	6.34	-3%	19.17
13	Installation of Energy management system	0.66	69%	4.83
14	V belt replacement with REC belt	0.79	53%	6.06

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	Home Decor Sanitary complex		
Plant Address	8A National Highway, Shobheshwar Road, Opp. Picnic Centre, Morbi		
Constitution	Partnership		
Name of Promoters	Mr. Bhavin Kalaria & Mr. C.N. Kalaria		
Contact person	Name	Mr. Bhavin Kalaria	
	Designation	Partner	
	Tel	9825231614	
	Fax		
	Email	info@homedecorceramic.com	
Year of commissioning of plant	1990		
List of products manufactured			
Installed Plant Capacity	900 pieces/day or 12.5 tonnes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	Not provided		608

Description	Details		
Net profit	Not provided by the unit		
No of operational days in a year	Days/Year	285	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	80	
	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	5-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.

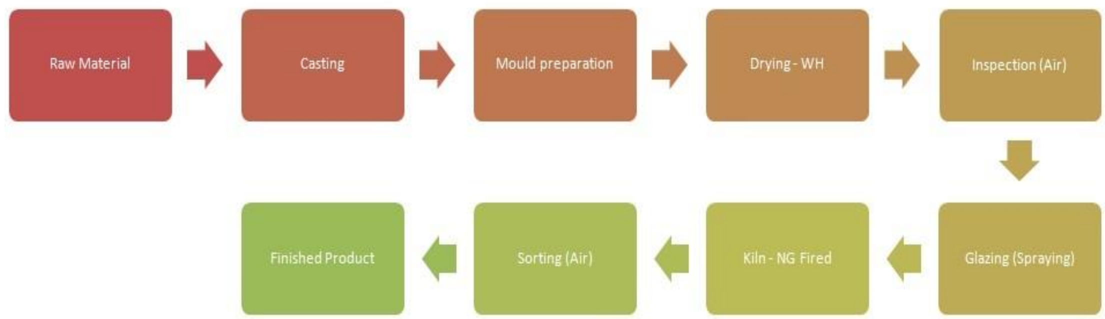


Figure 1 : General methodology

The field work was carried out during 17-21st November 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 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power

Sl. No.	Instruments	Parameters Measured
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

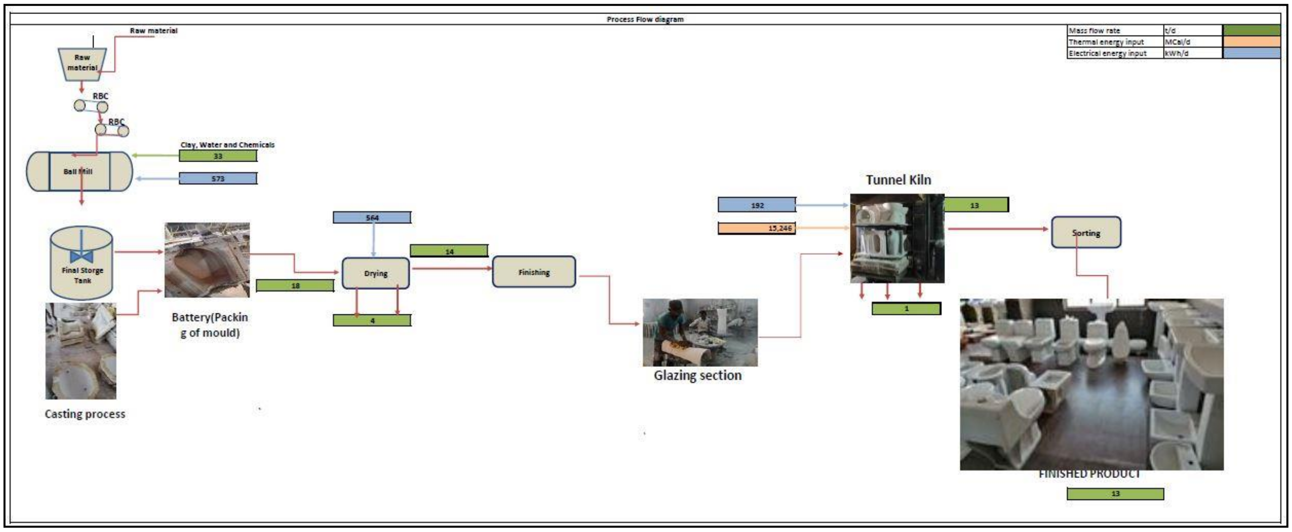


Figure 2: Process Flow Diagram

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 ball mill for a period of 4.5 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 product make a passage through tunnel kiln at 1100- 1,150^{o}C 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:

- **Ball mill:** Here the raw materials like clay, feldspar, potash, talc and quartz are mixed in the ratio of 2:1:1 respectively along with water to form slurry.
- **Glaze mill:** For producing glazing material used for spraying on various Sanitary products.

- **Air Compressor:** Pressurized air is used at several locations in a unit viz. cleaning, finishing, glazing etc.
- **Agitator:** The liquid slurry mass after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing settling of solid particles at the bottom.
- **Tunnel Kiln:** The kiln is the main energy consuming equipment where the product is passed after glazing and printing. The kilns are about 70 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^oC to 1,200^oC depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further gone 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	12,500	750-900

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)
Jun-17	15,242	224
July-17	9,411	138
Aug-17		
Sept-17	14,869	218
Oct-17	23,485	345
Nov-17	2,448	360
Dec-17	11,308	166
Jan-18	18,800	276
Feb-18	18,772	276
Mar-18	24,239	356
Apr-18	20,605	303
May-18	21,945	322
Jun-18	18,871	277
Average	17,079	251

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 June-17 to June-18, from different sources was as follows:

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	MTOE	% of total
Grid – Electricity	34.29	17	40	7.9
Thermal – NG	162.80	83	464	92.1
Total	197.08	100	504	100

This is shown graphically in the figures below:

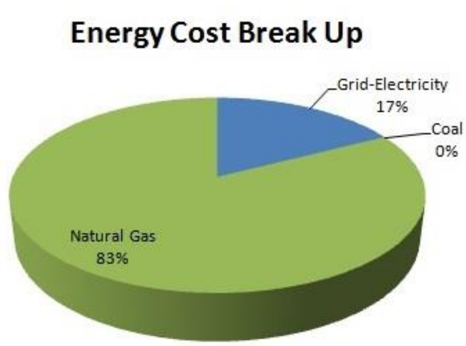


Figure 3: Energy cost share

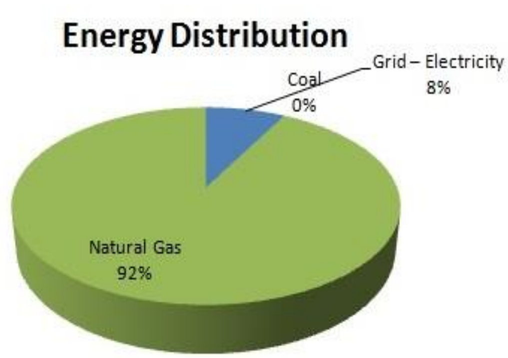


Figure 4: Energy use share

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 17% of the energy cost and 7.9% 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 83% of the total energy cost and 92% 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	8.4302E+10
Tariff Category	LTP-I
Contract Demand, 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	 4.3 0.85 0.4
Fuel Surcharge (Rs./kVAh) (variable)	0.00
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill for Aug-18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units consumed kWh	Total Electricity cost Rs	Average unit Cost Rs/kWh
Jun-17	35,790	268,102	7.58
Jul-17	18,720	146,463	7.70
Aug-17	0		
Sep-17	34,320	262,662	7.65
Oct-17	40,511	298,829	7.23
Nov-17	40,450	298,926	7.39
Dec-17	39,087	289,190	7.40
Jan-18	47,060	337,993	7.15

Month	Units consumed kWh	Total Electricity cost Rs	Average unit Cost Rs/kWh
Feb-18	32,990	244,926	7.52
Mar-18	59,410	427,000	7.20
Apr-18	40,220	289,007	7.16
May-18	43,807	325,951	7.44
Jun-18	31,890	239,576	7.39

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 38,688 kWh/month and cost is Rs. 2.85 Lakhs per month (Jun-17 to Jun-18). The average cost of electricity is Rs. 7.40/kWh, corresponding to the month. Plant was not in operation during Aug 17. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

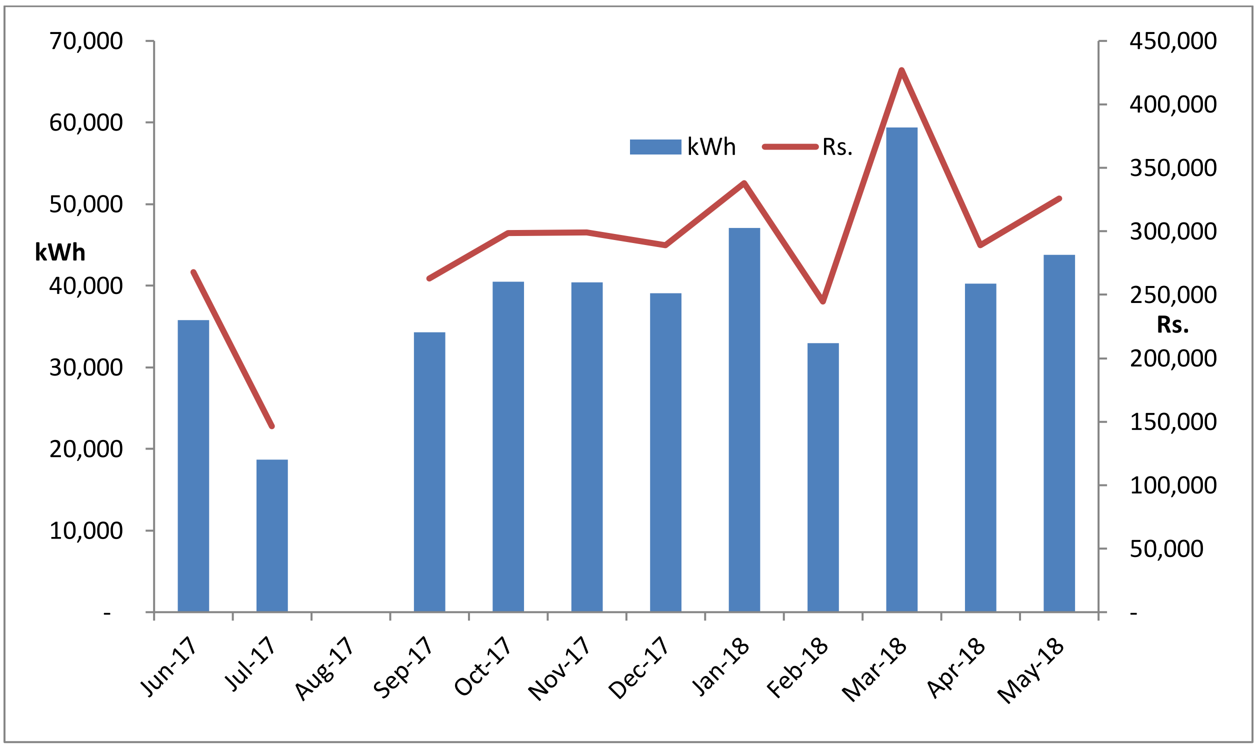


Figure 5: Month wise Variation in Electricity Consumption

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

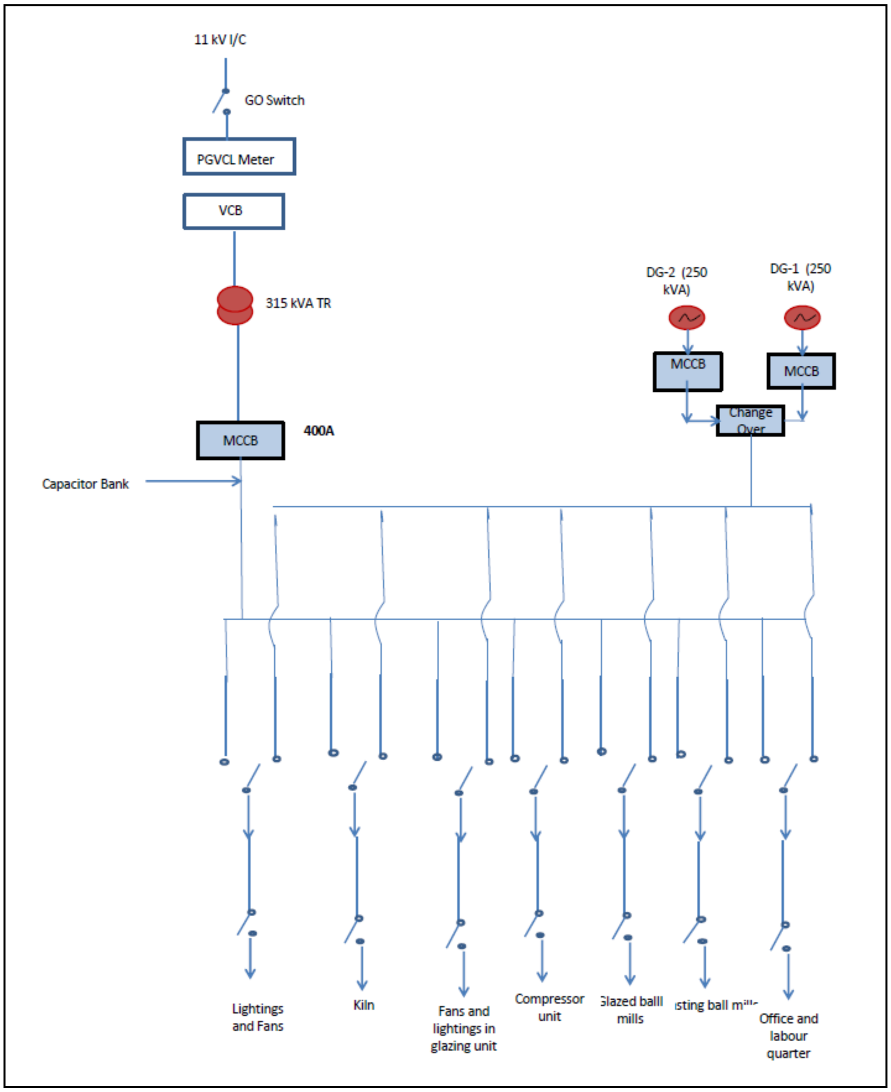


Figure 6: Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 223.7 kW, which includes:

- Plant and machinery load is 162.01 kW.
- Utility load is (lighting, air compressor and fans) about 49 kW including the single phase load.

Table 11: Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Moulding section	5
2	Matti Khata (Clay preparation)	62
3	Glaze Preparation and spray section	23
4	Bharai (Casting)	20
5	Water pump	4
6	Checking section	1
7	Tunnel Kiln	23

Sl. No.	Equipment	Capacity (kW)
8	Air compressors	48
9	Celing Fans	24
10	Lighting	13
11	Single phase load	13
Total Connected Load		223.7

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

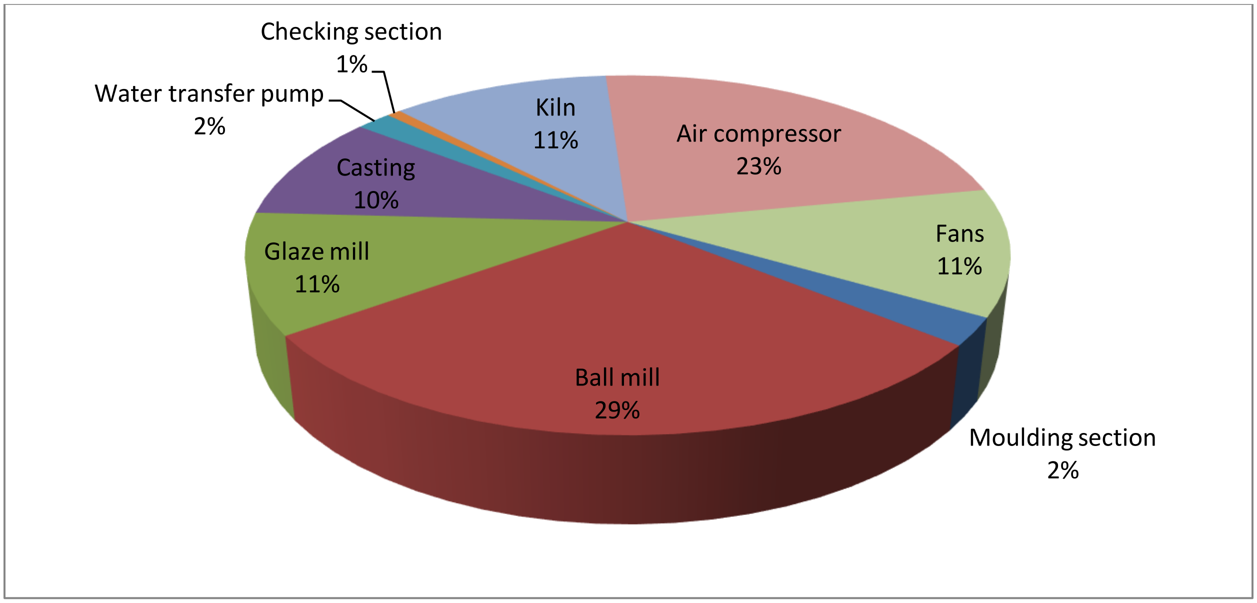


Figure 7: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for ball mill-29%, for the air compressor– 23%, for kiln, fans, glaze mill – 11%, for casting-10% and other loads.

2.3.1.6 Specific electricity consumption

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

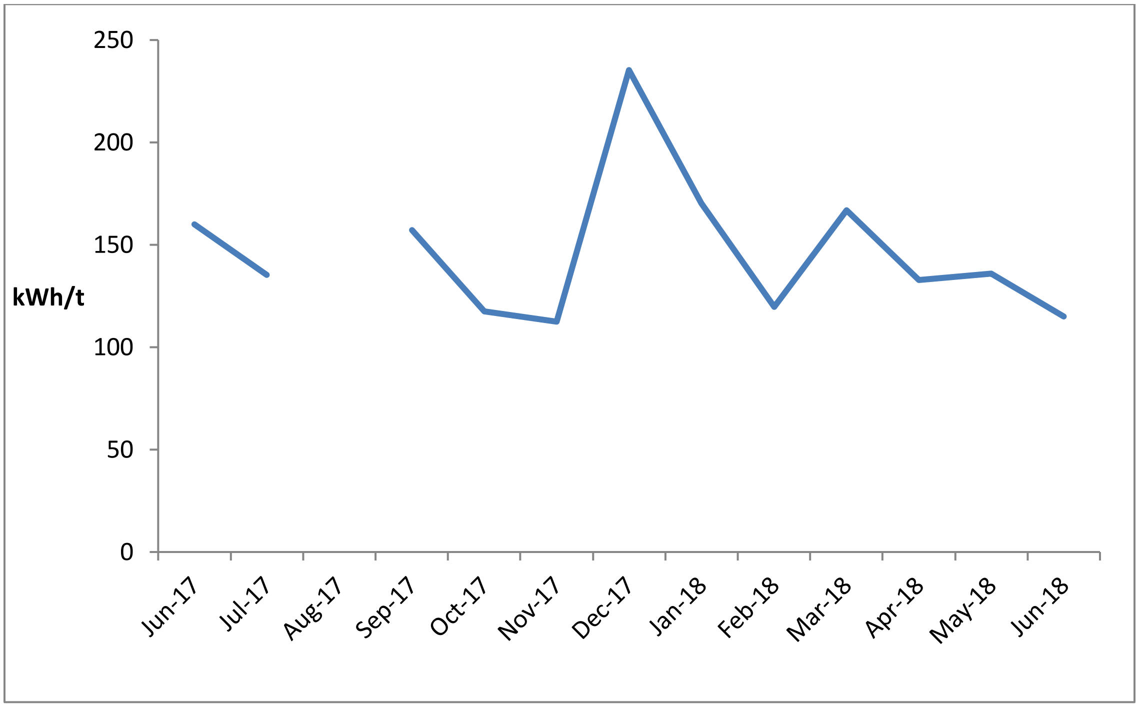


Figure 8: Month wise variation in Specific Electricity Consumption

The maximum and minimum values are within ±25% of the average SEC of 147 kWh/t indicating that electricity consumption follows the production. Plant was not in operation during august months for holidays. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in ball mill section, glaze mill, utility like compressor, pumps etc.

2.3.2 Analysis of Thermal Consumption

2.3.2.1 Month wise Fuel Consumption and Cost

The thermal consumption area is kiln. Natural gas is used as the fuel for firing in the kiln .Based on the gas bill shared for the month of June-17 to June-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
June-17	39,192	1,196,737	30.54
Jul-17	23,574	1,109,408	47.06
Aug-17			
Sep-17	35,307	1,093,263	30.96
Oct-17	52,637	1,501,670	28.53
Nov-17	53,231	1,546,379	29.05
Dec-17	37,078	1,157,380	31.21
Jan-18	51,629	1,573,049	30.47

Month	Kiln		
	NG Used	NG Cost	NG cost
Feb-18	45,216	1,401,097	30.99
Mar-18	51,685	1,600,933	30.97
Apr-18	49,287	1,552,479	31.50
May-18	51,258	1,671,883	32.62
June-18	25,823	875,360	33.90

Observation (for the period June-17 to June-18)

- Average monthly NG consumption is 42993 scm and average cost Rs 13.6 Lakhs/month

2.3.2.2 Specific Fuel Consumption.

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

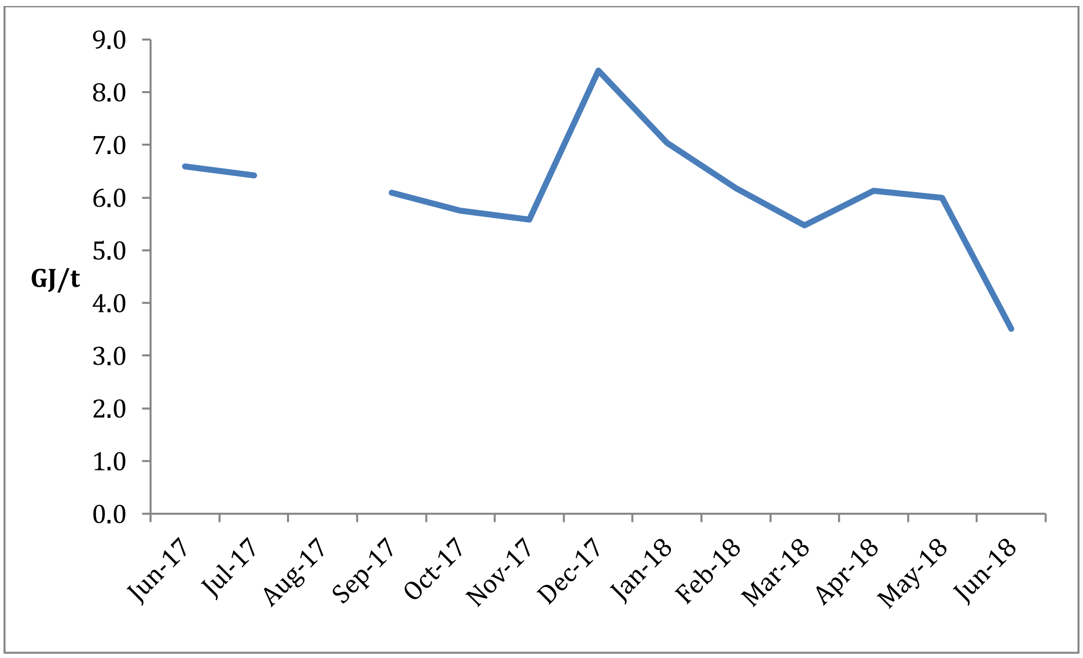


Figure 9: Month wise variation in Specific Fuel Consumption

The average SFC is 6.1 GJ/t. SFC is high in the months of Dec-17 (production was 166.1 MT and thermal consumption was 1,397 GJ) and low in the month of Sept-17 (production was 277 MT and thermal consumption was 973 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	515
Power consumption	kW	70.6
Coal consumption	kg/h	nil
NG consumption	scm/h	71
Energy consumption	kg TOE/h	63.9
SEC of plant	kg TOE/kg	0.124

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	Coal	Electricity
	scm/t	kg/t	kWh/t
Ball Mills			30.52
Agitator			0.7
Kiln	131		14.9

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	464,255
Annual Total Electricity Consumption	kWh/y	464,255
Annual Thermal Energy Consumption (NG)	scm/y	515,915
Annual Energy Consumption	TOE	504
Annual Energy Cost	Rs Lakh	197
Annual production	MT	3,261
SEC; Electrical	kWh/t	142.36
SEC; Thermal	GJ/t	5.96
SEC; Overall	TOE/t	0.1546
SEC; Cost Based	Rs./t	6,043.5

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

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

- Conversion Factors
  - Electricity from the Grid : 860 kCal/kWh
- GCV of NG : 9,000 kCal/scm

- CO_2 Conversion factor
    - Grid : 0.82 kg/kWh
    - NG : 0.001923 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 Jun-17 to Jun-18	7.40
Cost of NG	Rs./SCM	31.55
Annual operating days	d/y	285
Operating hours per day	h/d	24
Annual production	MT	3,261

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 outsourcing water tankers 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 131 m^3/day based on measurement.

Water distribution diagram is shown below.

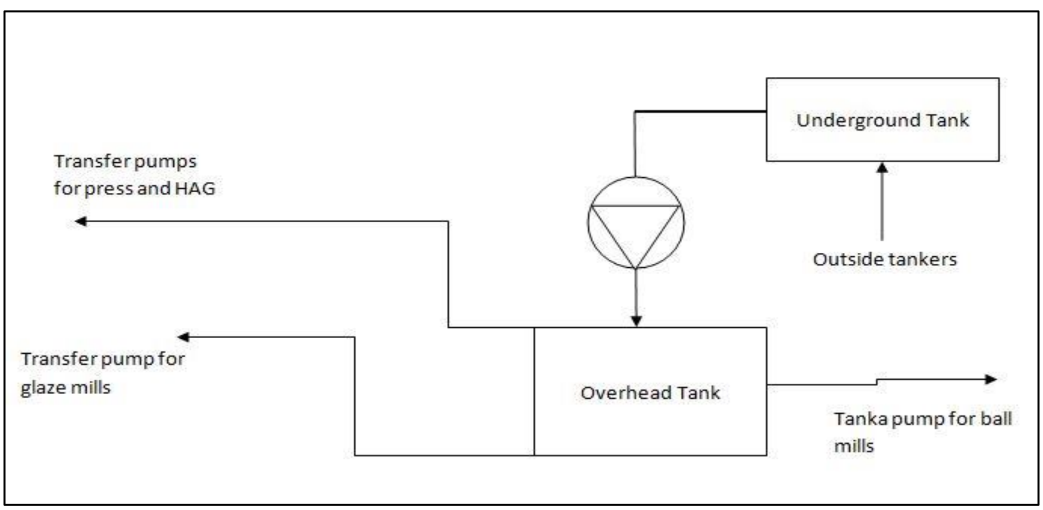


Figure 10: Water Distribution Diagram

Outsourced water with low TDS is used in plant to meet the water requirements of process (casting, ball mills and glazing). Only one pump installed to transfer water from underground tank to overhead tank. Installation details of submersible pumps are tabulated hereunder.

Table 17: Submersible pump details

Parameters	Unit	Submersible Pump
Make	-	-
Motor rating	HP	5
RPM	rpm	2,900
Quantity	Number	1

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 31 HP electrical load of which 7.5 HP is for chimney motor blower, 3 HP for preheating blower, 5 HP for combustion blower, 7.5 HP for cooling blower and others load.

Table 18: Kiln Details

Sl. No	Parameter	Unit	Value
	Make		Modema
1	Kiln operating time	H	24
2	Fuel consumption	scm/h	71
3	Number of burner to left	-	16
4	Number of burner to right	-	16
5	Cycle Time	h	27
6	Pressure in firing zone	mmWC	50
7	Maximum temperature	°C	1,137
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	M	40 x 2.1 x 1
	Firing Zone	M	9 x 2.1 x 1
	Final cooling zone	M	22x 2.1 x 1

3.1.2 Field measurement and analysis

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

Table 19: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	6.1%
Ambient Air Temperature	40.2 °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 – 42ºC which was the ambient air temperature. Surface temperature was high, throughout the surface of the kiln as shown in the table below:

Table 20: Surface temperature of kiln

Zone	Temperature (°C)
Ambient Temperature	40.2
Pre-heating zone Average Surface Temperature	51.0
Firing zone Average Surface Temperature	92.81
Cooling zone Average Surface Temperature	72.64

The temperature profile of the kiln is shown below:

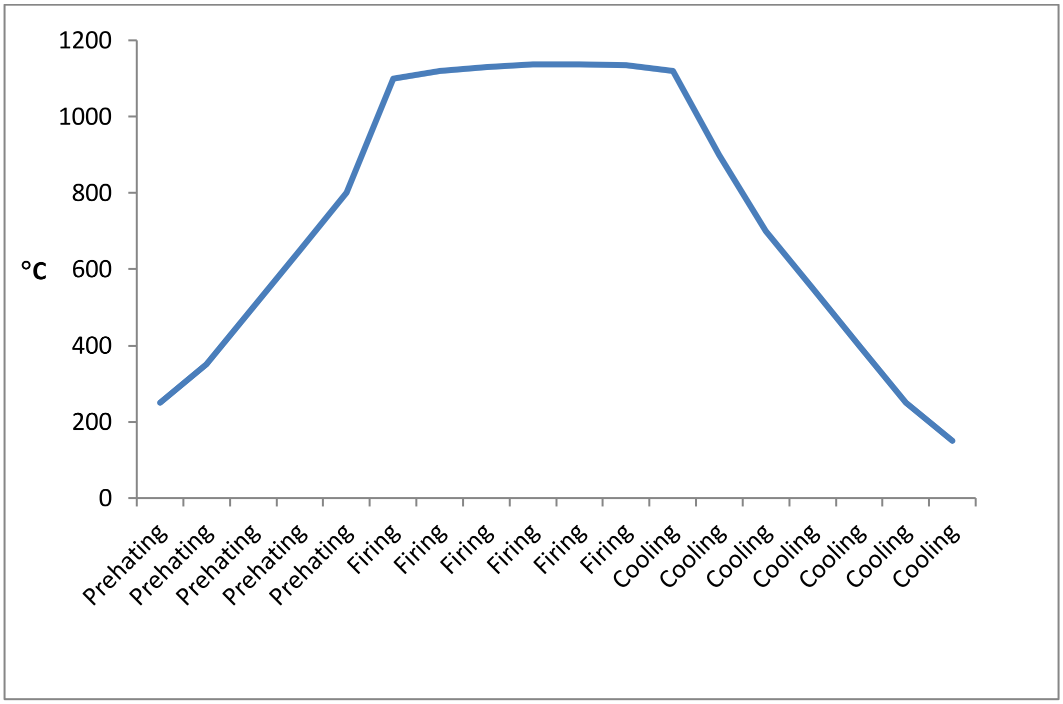


Figure 11 : Temperature Profile of Kiln

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
Chimney motor Blower	1.54	0.97
Preheating Blower	1.004	0.94
Cooling Blower	2.26	0.93
Combustion Blower	3.186	0.96

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln is 36.74%. Summary of all losses is shown in below figure:

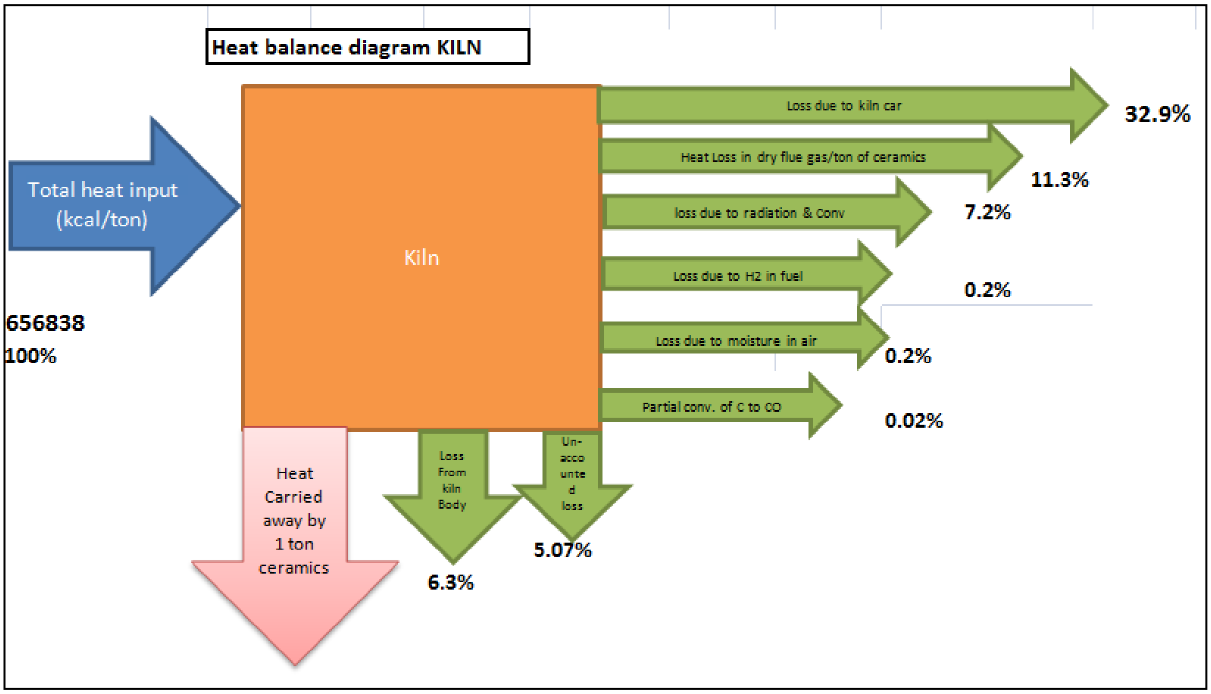


Figure 12: Heat balance diagram of Kiln

Detailed calculation is included in Annexure-5.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln -Excess Air Control at kin

Technology description

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

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

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

Study and investigation

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

Flue gas analysis of kiln is given in below table:

Table 22: Flue gas analysis

Parameters	Units	Value
O_2 in flue gas	%	6.1
CO_2 in flue gas	%	8.9
CO in flue gas	ppm	30

Recommended action

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

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

Parameters	UOM	Present	Proposed
Fuel Saving			
Oxygen level in flue gas before firing zone	%	6.1	3.00
Excess air percentage in flue gas	%	40.7	16.7
Dry flue gas loss	%	11%	
Saving in fuel (Every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%)	Scm/t	137	134
Saving in specific fuel consumption	scm/h		1.70
Operating hours per day	h/d		285
Operating days per year	d/y		24.00
Annual fuel savings	Scm/y		11,614
Fuel cost	Rs/scm		32
Corresponding monetary savings	Lakh Rs/y		3.7
B. Power saving at combustion blower			
Mass flow rate of air	t/h	1.25	1.04
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	0.3	0.2
Total pressure rise	Pa	5000	5000
Measured power of blower	kW	3.31	1.89
Motor power	kW	10.3	8.2

Parameters	UOM	Present	Proposed
Motor efficiency	%		
Fan efficiency	%		
Power saving	kW	1.42	
Operating hours per day	h/d	285.00	
Operating days per year	d/y	24.00	
Savings in electrical energy	kWh/y	9,739	
Cost of electricity	Rs/kWh	7.40	
Savings in terms of energy cost	Lakh Rs/y	0.72	
C. Summary of Savings			
Coal saving	kg/y		
Electricity saving	kWh/y	9739	
Monetary savings	Lakh Rs/y	4.39	
Estimated investment	Lakh Rs	6.93	
Payback Period	Months	19	
IRR	%	42	
Discounted payback period	Months	7.1	

3.1.4.2 ECM #2: Insulation 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 as 99.4°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

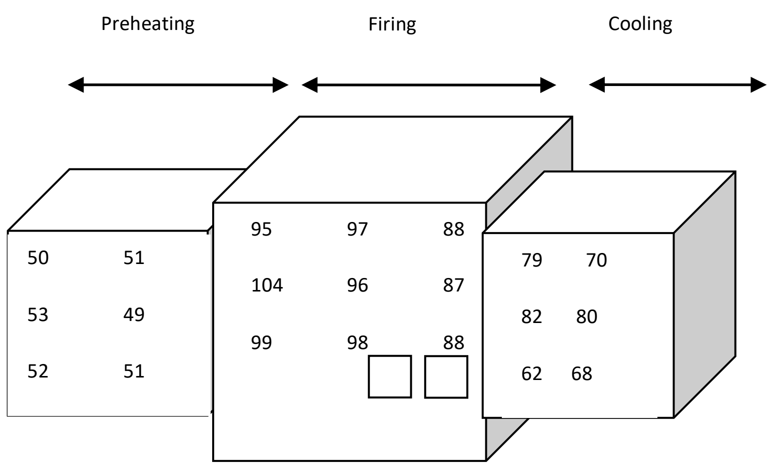


Figure 14: Kiln surface temperature schematic diagram

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.

The cost benefit analysis of the energy conservation measure is given below:

Table 24: Cost benefit analysis (ECM 2)

Parameter	Units	Preheating zone		Firing zone		Cooling zone	
		As IS	To Be	As IS	To Be	As IS	To Be
Kiln height	m	2.04	2.04	2.10	2.10	2.00	2.00
Kiln length	m	1.96	1.96	9.00	9.00	3.90	3.90
Rapid zone surface area	m^2	8.00	8.00	37.80	37.80	15.60	15.60
Average surface temperature of pipes in rapid zone	°C	87	55	99	55	85	55
Ambient air temperature	°C	35	35	35	35	35	35
Heat loss in rapid zone	$kcal/h/m^2$	657	220	837	220	626	220
Heat loss in rapid zone	kcal/h	5,252	1,759	31,633	8,316	9,764	3,432
GCV of fuel	kcal/scm	9,000	9,000	9,000	9,000	9,000	9,000
Heat loss in terms of fuel	scm/h	0.6	0.2	3.5	0.9	1.1	0.4
Fuel saving	scm/h		0.4		2.6		0.7
Operating hours per day	h/d	24	24	24	24	24	24
Annual operating days	d/y	285	285	285	285	285	285
Annual fuel saving	SCM/y		2,654			17,721	4,812
Fuel cost	Rs/scm		32		32		32
Annual fuel cost saving	Rs Lakh/y	7.95					
Estimated investment	Rs Lakh	3.1					
Simple payback period	Months	5					
IRR	%	195%					
Discounted payback period	Months	1.8					

3.1.4.3 ECM #3: Waste heat recovery from flue gas

Technology description

Utilization of additional heat content available in smoke (flue gas and vapors).

Study and investigation

It was observed during the field visit that the flue gas (smoke) temperature at kiln outlet was 175°C. So, to improve efficiency levels of kiln and to save fuel, it is suggested to utilize this additional heat content in the flue gases (that is presently being wasted) to marginally increase the temperature of combustion air used in firing zone , thereby also bringing down the flue gas temperatures at stack by further 45°C.

Recommended action

It is recommended to decrease the smoke temperature at kiln so that the outlet temperature could be decreased from 250°C to 200°C, thereby increasing the more heat utilization in kiln and increasing the temperature of fresh air entering in kiln. This would help to reduce amount of fuel consumption.

Table 25: Waste heat recovery from flue gas [ECM-3]

Particulars	Units	Value
Temperature at smog blower	°C	175.0
Smog flow rate	t/h	1.30
Waste gas flow	kg/h	1300.2
Specific heat of waste gas	kCal/kgK	0.24
Smog temperature after recuperator	°C	130
Heat available at recuperator inlet	kCal/h	54,556
Heat recovered	%	26%
Specific heat of combustion blower air	kCal/kgK	0.24
Ambient temperature of air	°C	35.0
Density of combustion air	kg/m^3	1.2
Mass flow rate of combustion blower air	kg/h	1,249
Effectiveness of HE-1	%	60.0

Particulars	Units	Value
FD blower air temperature after recuperator	°C	63.1
Heat saving	kCal/h	8,417
GCV of fuel	kCal/scm	9,000
Fuel savings	scm/h	0.9
Operating hours per day	d/y	285
Operating days per year	h/d	24
NG price	Rs/kg	31.6
Annual running hours	h/y	6,840
Annual coal saving	scm/y	6,397
Annual Monetary saving	Lakh Rs/y	2.0
Estimated Investment	Lakhs Rs	3.0
Payback Period	months	16
IRR	%	53
Discounted payback period	Months	5.9

3.1.4.4 ECM #4: Replacement of Kiln car 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.

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

Recommended action

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

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

Table 26: Kiln car replacement [ECM-4]

Particulars	Units	As is	To be
Production of the material	t/h	0.52	0.52
Weight of existing kiln car	Kg	500	330
Total number of kiln car inside kiln	Nos.	36	36
Initial temperature of kiln car	°C	40.2	40.2
Final temperature of kiln car	°C	1137	1137
Estimated percentage saving by new kiln car material	%	30	
Heat carried away by the kiln material	kcal/h	111,325	77,928
Reduction in the heat carried by the kiln	kcal/h		33,398
Operating hrs of kiln	h	4845	4,845
Savings in terms of fuel consumption	scm/y		17,979
NG price	Rs/scm	31.6	32
Savings in terms of cost	Rs Lakh/y		5.7
Estimated investment of kiln material	Rs Lakh/y		7.00
Payback period	months		14.8
IRR	%		57
Discounted payback period	Months		5.7

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 BALL MILLS

4.1.1 Specifications

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

Table 27: Specifications of ball mills

Particular	Units	Value
Numbers of ball mills	#	1
Capacity of each ball mill	t/batch	8
Water consumption in each ball mill	t/batch	3
Water TDS	ppm	400
Nos. of batch per day		3

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all ball mills

FD blower and cooling water pumps was operating with VFDs. 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 ball mills

Equipment	Average Power (kW)	PF
Mota Ball Mill	23.9	0.94

Average power of mota ball mill is 23.9kW (PF0.94) .

4.1.3 Observations and performance assessment

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

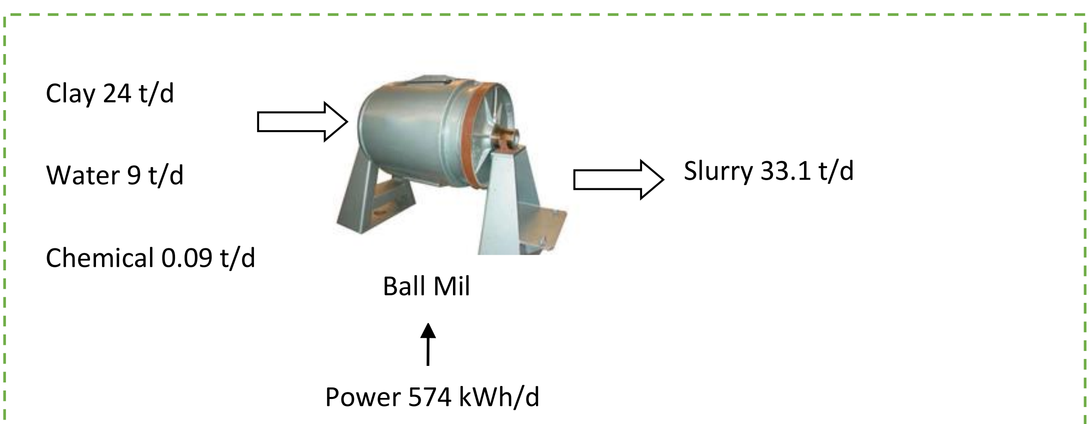


Figure 15: Energy and mass balance of Ball Mill

Performance of 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 17.4 kW/ton. TDS of water is not too high since they purchase tankers from outside.

4.1.4 Energy conservation measures (ECM) – ECM # 5 –Replacement of conventional motor with IE3 motor in ball mill

Technology description

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

Study and investigation

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

Recommended action

It is recommended to replace existing conventional motor with EE motor (IE#3 motor).
Estimated cost benefit is given in the table below:

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

Particular	Unit	AS IS	To Be
Rated power of motor	kW	30	30
Existing efficiency of motor	%	90.7	93.6
Existing power consumption	kW	23.88	22.35
Energy loss in motor	kW	2.2	0.7
Estimated energy saving	kW		1.5
Operating hours/day	d/y	285	285
Operating days/year	h/d	24	24
Annual energy consumption	kWh/y	163,360	152,905
Annual energy savings	kWh/y		10,455
Unit cost of electricity	Rs/kWh		7.40
Annual monetary savings	Lakh Rs/y		0.77
Estimated Investment	Lakh Rs		1.32
Payback Period	Months		20.47
IRR	%		39
Discounted payback period	Months		7.5

4.2 Agitator Motor

Figure 16: Agitator motor

4.2.1 Specifications

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

Table 30: Specifications of agitators

Particular	Units	Value
Numbers of agitators in tank	#	2
Capacity of each agitator motor	kW	2.5
Number of motors	#	6

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

Power consumption 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
Agitator#1	1.3	0.56

4.2.3 Observations and performance assessment

During DEA it was observed that all motors operate same time. It is suggested that all motor should operate by timer control.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry).

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.	6	6
No of agitator stirrer running	Nos.	3	3
Rated power of agitator stirrer motor	kW	13,428	13,428
Running of each stirrer motor	h/d	24	12
Operating power of stirrer motor	kW	0.6	0.6
Annual operating days	d/y	285	285
Annual power consumption	kWh/y	11,430	5,715
Annual energy saving	kWh/y	0	5,715
Cost of Electricity	Rs./kWh		7.40
Annual energy cost saving	Lakh R./y	0.42	
Estimated investment	Lakh Rs	0.55	
Payback Period	Months	15.73	
IRR	%	53	
Discounted payback period	Months	6	

4.3 GLAZING

4.3.1 Specifications

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

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



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 33: Specifications of glazing machine

Particular	Units	New sizing
Numbers of glazing mills	Nos.	4
Capacity of glazing mills	HP	5

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

4.4 Air Compressors

4.4.1 Specifications

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

Table 34: Specifications of compressors

Particular	Units	ELGI Air compressor1	ELGI compressor 2	INGERSOLL Air compressor 3
Power rating	HP	22	22	20
Maximum pressure	Bar (a)	8	8	8
Air handling capacity	m^3/m	3.96	3.96	

Note: Ingersoll is a stand by Vertical reciprocating air compressor (Details missing) and came in operation when ELGI screw compressor went in maintenance.

Figure 17: Compressors and recievers

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

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

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

Table 35 Measured Parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)	% of time on load
ELGI Compressor-1	23.7	0.88	2.93	
Ingersoll Compressor-3	8.25	0.56		

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

4.4.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption of ELGI compressor was 0.23 kW/CFM. It is recommended to provide cool air suction to compressor by shifting to open air.

4.4.4 Energy conservation measures (ECM) - ECM #7: Pressure Reduction at air compressor

Technology description

When the generation pressure of compressed air is reduced by 2 kg/cm^2, there is reduction in energy consumption of compressor by 12% as per BEE.

Study and investigation

During DEA, it was found that the compressed air was generating compressed air at 7.5 kg/cm^2 and the pressure requirement at the end utilities were around 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 36 pressure reduction of compressor [ECM7]

Parameter	Units	As is	To Be
Operating pressure required	kg/cm^2	7.5	5.5
Cut off pressure	kg/cm^2	8	8
Reduction in pressure	kg/cm^2	-	2
% of energy saving	%	-	12%
Average load	kW	23.7	20.83
Operating hours/day	h/d	17	17
Operating days/year	d/y	285	285
Annual energy consumption	kWh/y	114,689	100,927
Annual energy savings	kWh/y		13,763
Unit cost of electricity	Rs/kWh		7.40
Annual monetary saving	Lakh Rs/y		1.02
Estimated Investment	Lakh Rs		0.30
Payback period	Months		3.53
IRR	%		254
Discounted payback period	Months		1.4

4.4.5 Energy conservation measures (ECM) - ECM #8: Replacement of air compressor with blower for cleaning purpose in glazing section

Technology description

In sanitary unit, compressed air utilizes in cleaning purpose which can be replaced with blower of 1- bar (a) air pressure.

Study and investigation

During DEA, it was found that there were 30 air cleaning points in plants where high pressure compressed air was not necessary

Recommended action

It is recommended to replace compressor with low pressure high volume air blower. The cost benefit analysis for this project is given below

Table 37: Replacement of compressor with blower [ECM 8]

Parameters	Unit	Value
Compressor Flow	CFM	149.80
Compressor SPC	kW/CFM	0.16
Operating hours	h/y	4,845
Present Consumption	kWh/y	116,123
Blower Flow	CFM	149.80
Blower SPC	kW/CFM	0.09
Operating Hours	h	4,845
Proposed Consumption	kWh/y	65,319
Energy savings	kWh/y	50,804
Unit cost of electricity	Rs/kWh	7.40
Monetary savings	Rs Lakh/y	3.8
Investment	INR	3.96
Payback period	months	13
IRR	%	68
Discounted payback period	Months	4.9

4.5 Water Pumping System

4.5.1 Specifications

Pumping system comprises.

4.5.2 Field measurement and analysis

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

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

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

Table 38: Operating details of pump

Particulars	Unit	Value
Measured flow	m^3/h	13.1

Total head	M	17.2
Actual power consumption	kW	4.1

4.5.3 Observation and performance assessment

Based on observations during DEA, the pump efficiency is determined as 18%.

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

Technology description

The bore-well pump is running at lower efficiency and is recommended to be replaced with new high efficiency pumps.

Study and investigation

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

Recommended action

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

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

Particulars	Unit	Present	Proposed
Measured Data			
Flow rate Q	m^3/h	13.1	13.1
Suction Pressure	kgf/cm^2 (a)	-0.5	-0.5
Discharge Pressure	kgf/cm^2 (a)	1.2	1.2
Motor Input Power	kW	4.1	1.03
Calculated Data			
Flow rate Q	m^3/s	0.00363	0.00363
Pressure Difference	kgf/cm^2 (a)	9.6	9.6
Total Head/head developed	M	17.2	17.2
Liquid Horse Power	kW	0.61	0.61
Motor Input Power	kW	4.07	1.03
System Efficiency	%	15	60
Motor Loading	%	109	28
Pump Efficiency	%	18	70
Operating hour per day	h/d	10	
Annual operating days	d/y	285	
Annual power savings	kWh/y	20,813	
Cost of Electricity	Rs./kWh	7.40	
Annual Monetary savings	Lakh Rs/y	1.5	
Estimated investment	Lakh Rs	0.345	

Particulars	Unit	Present	Proposed
Payback Period	Months	3	
IRR	%	140	
Discounted payback period	Months	2.5	

4.6 Lighting System

4.6.1 Specifications

The plant lighting system includes:

Table 40: Specifications of lighting load

Particular	Units	Fluorescent tube light
Power consumption of each fixture	W	36
Numbers of fixtures	#	350

4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 41: Lux measurement at site

Particular	Units	Value
Office	Lumen/m^2	160
Kiln control room	Lumen/m^2	110
Kiln area	Lumen/m^2	60
Ball mill and agitators	Lumen/m^2	70
Vertical dryer	Lumen/m^2	65
Horizontal dryer	Lumen/m^2	65

4.6.3 Observations and performance assessment

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

4.6.4 Energy conservation measures (ECM) - ECM #10: Replacement of inefficient light

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 350 tube lights.

Recommended action

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

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

Particulars	Units	Present	Proposed
Fixture		T12	EE LED tubes
Power consumed by T12 Tube lights	W	52	28
Operating hours	h/d	12	12
Operating days	d/y	285	285
Energy Used per fixture	kWh/y	178	96
Cost of Electricity	Rs./kWh	7.40	7.40
No. of Fixture	Unit	350	350
Power consumption	kWh/y	62,224	33,516
Operating cost	Rs. Lakh/y	4.61	2.48
Electrical savings	kWh/y		28,728
Annual Monetary saving	Rs. Lakh/y		2.13
Investment per fixture of LED	Rs		0.0075
Estimated Investment	Rs. Lakh		3.00
Payback Period	months		16.93
IRR	%		64
Discounted payback period	Months		5.2

4.7 Electrical Distribution System

4.7.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (442V) by step down transformer (2.5 MVA). Automatic power factor correction system is installed in parallel to main supply. There were one DG (capacity of 225 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.

4.7.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.7.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **134.67 kVA** at new plant feeder.

The voltage profile of the unit is satisfactory and average voltage measured was **442.28 V.** Maximum voltage was **455.47 V** and minimum was **427.467 V**.

Average total voltage and current Harmonics distortion found **5%** & **8%** respectively during power profile recording.

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

It is observed that some of the outgoing feeders to sizing and press section has very poor power factor. Poor power factor leads to cable losses (I^2R) in the electrical distribution system.

4.7.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

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

Technology description

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

Study and investigation

During DEA, it was found that each fan was consuming 62 watt as compared to . 30 watt (EE ceiling fan)

Recommended action

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

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

Particulars	Units	AS IS	TO BE
Number of fans in the facility	Nos	400	400
Run hours per day	H/d	15	15
Power consumption at Maximum speed	kW	0.0625	0.03
Number of working days/year	d/y	285	285
Tariff for Unit of electricity	Rs/kWh	7.40	7.40
Fan unit price* (use '0' for ordinary fan if replaced)	Rs/piece	2,000	2,261

Particulars	Units	AS IS	TO BE
Electricity consumption:			
Electricity demand	kW	25.00	12.00
Power consumption by fans in a year	kWh/y	106,875	51,300
Savings in terms of power consumption	kWh/y	55,575	
Savings in terms of cost	Rs Lakh/y		4.11
Estimated investment	Rs Lakh/y		9.04
Payback period	months		26.38
IRR	%		24
Discounted payback period	Months		9.8

4.7.4.2 ECM #12: Install active harmonics Filter

Technology description

During the field visit, it was found that harmonics levels are higher than the prescribed limits as per IEEE guidelines.

Some of the effects of harmonics are mentioned hereunder.

- Increased line losses.
- Reduced efficiency and increased losses in rotating machines.
- Overstressing of capacitors.
- Cable insulation failure.
- Increased losses and stress on insulation of transformers.
- Mal operation of relays.
- Errors in metering equipment.
- Telephone interference.

Study and investigation

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 2.72 kW.

Table 44: Measured Harmonics Level at Main Incomer

Name & Sl. No.	Phase		Voltage	Amp.	THD V (%)	THD I (%)	Individual Current Harmonics				
							A3%	A5%	A7%	A9%	A11%
Main Incomer	R	Average	444	97	4.7	12.2	3.46	8.9	3.66	1.00	3.10
		Minimum	428	41	4.2	5.5	1.00	2.6	0.70	0.10	0.00
		Maximum	457	173	5.3	20.1	7.00	16.3	9.60	3.10	7.00
	Y	Average	441	102	4.6	13.6	1.79	10.7	4.53	0.69	3.41
		Minimum	425	39	4.1	7.3	0.20	6.3	0.30	0.00	0.10
		Maximum	454	186	5.3	24.5	4.40	18.2	14.30	2.10	6.90
	B	Average	442	102	4.9	13.0	5.52	9.1	3.02	1.07	3.26
		Minimum	430	43	4.3	7.4	2.40	5.1	0.30	0.00	0.00
		Maximum	455	176	5.6	19.6	10.40	14.1	8.60	3.60	7.00

Voltage and Ampere THD profile for main incomer is shown in below figure:

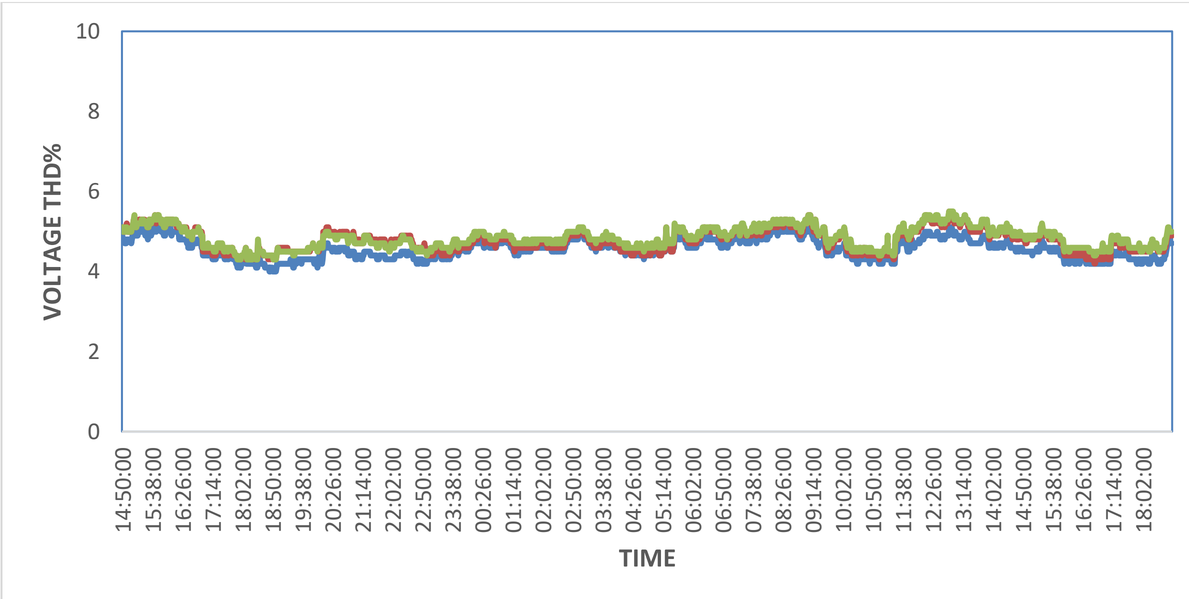


Figure 18: Voltage THD profile

Figure 19: Ampere THD profile

Recommended action

It is recommended to install active harmonics filters (AHF) at main incomer; further study can be conducted to find out exact source of harmonics generation. **Ampere ratings of harmonics filters to be installed are 15.6 A**. Estimation of ratings for AHF is done on the basis of power cycles captured during field visit.

- It is a known fact that if harmonics are present in any system, then power factor improvement capacitors will further amplify the existing harmonics.
- It is strongly recommend to install active harmonic filter at locations where THD is exceeding the prescribed limits.
- The active harmonic filter will take care of harmonics in the system and maintain the desired power factor as per requirement.
- Active harmonic filters can also take care of unbalanced load problems
- It is further recommended that all VFDs, UPS should be procured only with 12-pulse or 18-pulse rectifier circuit.
- All electronic ballasts to be procured in future shall be specified for less than 10% THD (Current).

The cost benefit analysis for this project is given below:

Table 45: Install active harmonics Filter [ECM-12]

Particulars	Unit	As Is	To be
Estimated losses due to Harmonics	kW	2.70	0
Saving potential by installation of active harmonics filter	kW	2.7	
Operating days	d	285	
Operating hours	h	24	
Saving potential	kWh/y	18,579	
Cost of Electricity	Rs/kWh	7.40	
Annual Saving	Rs./y	137,497	
Estimated rating of active harmonics filter	Ampere	10	
Estimated Investment	Rs	633,600	
Payback Period	months	55	
IRR	%	-3	
Discounted payback period	Months	19.2	

4.7.4.3 ECM #13: 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 coal Gasifier and hot air generator and 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:

- Kiln
- Ball mills
- Casting section for lights and fans

The cost benefit analysis for this project is given below:

Table 46: 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	428,465	419,896
Annual electricity saving per year	kWh/y		8,569
Unit Cost	Rs/kWh		7.40
Annual monetary savings	Lakh Rs./y		0.63
Number of equipments	Nos.	-	4.00
Estimate of Investment	Lakh Rs.	1.84	
Annual monetary savings	Lakhs Rs./y	0.63	
Number of energy meters	Nos.	4.00	
Estimated	Lakhs Rs.	0.66	
Payback Period	months	12	
IRR	%	69	
Discounted payback period	Months	4.8	

4.8 Belt Operated Drives

4.8.1 Specifications

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

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

4.8.2 Field measurement and analysis

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

4.8.3 Observations and performance assessment

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

4.8.4 Energy conservation measures (ECM) - ECM #14 V Belt replacement with REC belt

Technology description

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

Benefits of Cogged belts & Pulley over V belts:

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

Study and investigation

The unit is having about belt driven blowers in plant

Recommended action

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

Table 47: Replacement of conventional belt with REC belt [ECM-14]

Particulars	UoM	AS IS	TO BE
Measured power of all belt driven blowers	kW		
Running hours of blowers	h/d	24	24
Average power of blowers	kWh/d		
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	220,406	212,471
Annual energy saving	kWh/y	7,935	
Electricity cost	Rs./kWh	7.40	
Annual energy cost saving	Rs. Lakh	0.59	
Estimated investment	Rs. Lakh	0.79	
Payback Period	Months	16.18	
IRR	%	53	
Discounted payback period	Months	6	

5. Chapter -5 Energy consumption monitoring

5.1 Energy Consumption Monitoring

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

5.2 Best operating practices

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

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

5.3 New & Emerging Technologies for consideration:

5.3.1 HIGH ALUMINA Pebbles for Ball Mills

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

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

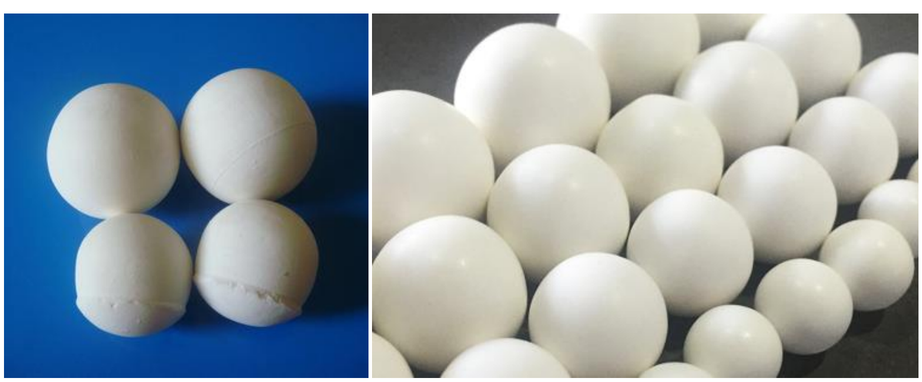


Figure 20: High Alumina pebbles for Ball mill

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.

5.3.2 Use of Organic deflocculant in Ball Mill grinding Process

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

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

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

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

- STPP dosage is reduced by more than 50%
- 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.

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

5.3.3 Use of Organic Binder in Porcelain Manufacture

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

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

Advantages of using Binder for Vitrified tiles include:

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

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.
- 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

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

Figure 21: 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 150 m^2 and corresponding solar power potential will be 15kW. 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). Therefore Solar PV installation is not recommended.

6.1.1 Energy conservation measures (ECM) - ECM #16: Installation of solar PV system

Technology description

The RCC roof top space available in plant is 150m^2 under office admin and administrative building.

Study and investigation

During DEA, it was found that plant is having solar power potential but due to constraints mentioned below, it is not recommended.

Recommended action

The cost benefit analysis for this project is given below:

Table 48: Installation of solar PV system [ECM-16]

Parameters	Units	Value
Available area on roof	m^2	150
Capacity of solar panel	kW	15
Energy generation from solar panel	kWh/d	72
Solar radiation day per year	d/y	285
Average electricity generation per year	kWh/y	20,520
W. Average Electricity Tariff	Rs/kWh	7.28
Annual monetary savings	Rs Lakh/y	1.5
Estimate of Investment	Rs Lakh	7.8
Simple Payback	Months	63
IRR	%	-6
Discounted payback period	Months	21.4

The project IRR is negative 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

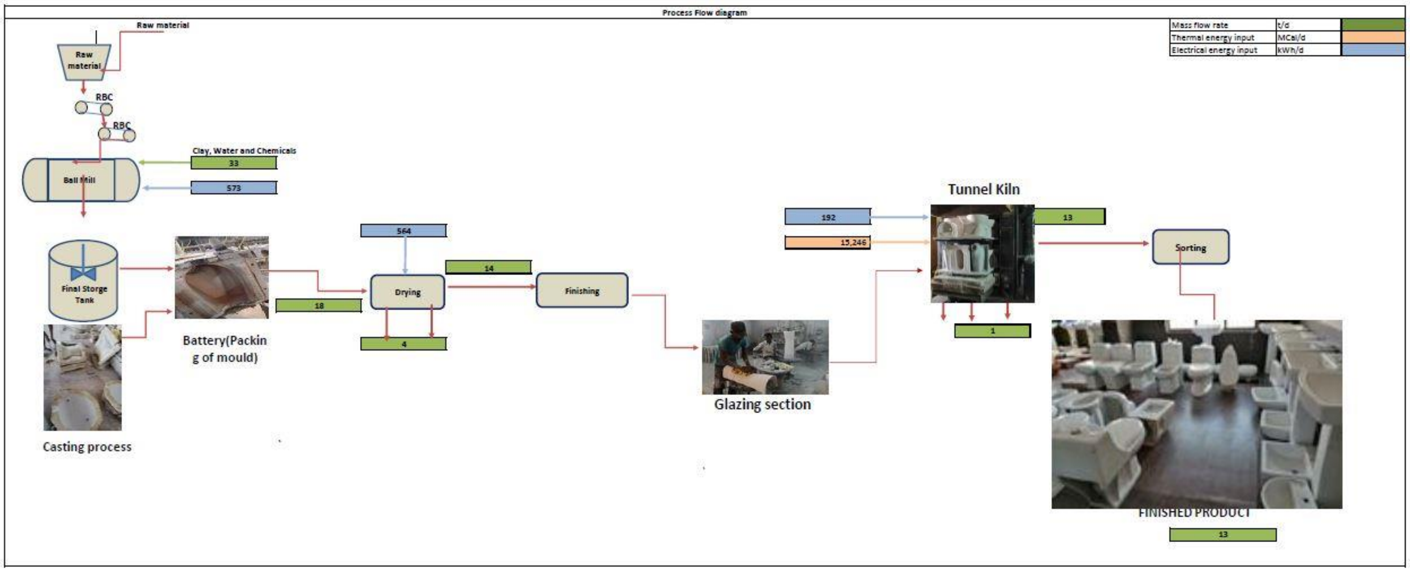


Figure 22: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 49: Detailed Inventory list

Parameters	UOM	Value
Molding section	kW	5
Ball mill section	kW	62
Glaze mill section	kW	23
Casting section	kW	20
Water transfer pump	kW	4
Checking section	kW	1
Tunnel Kiln	kW	23
Air Compressor	kW	48
Fans	kW	24
Lighting	kW	13
Single phase load	kW	13.20
Total	kW	223.7

7.3 Annex-3: Single Line Diagram

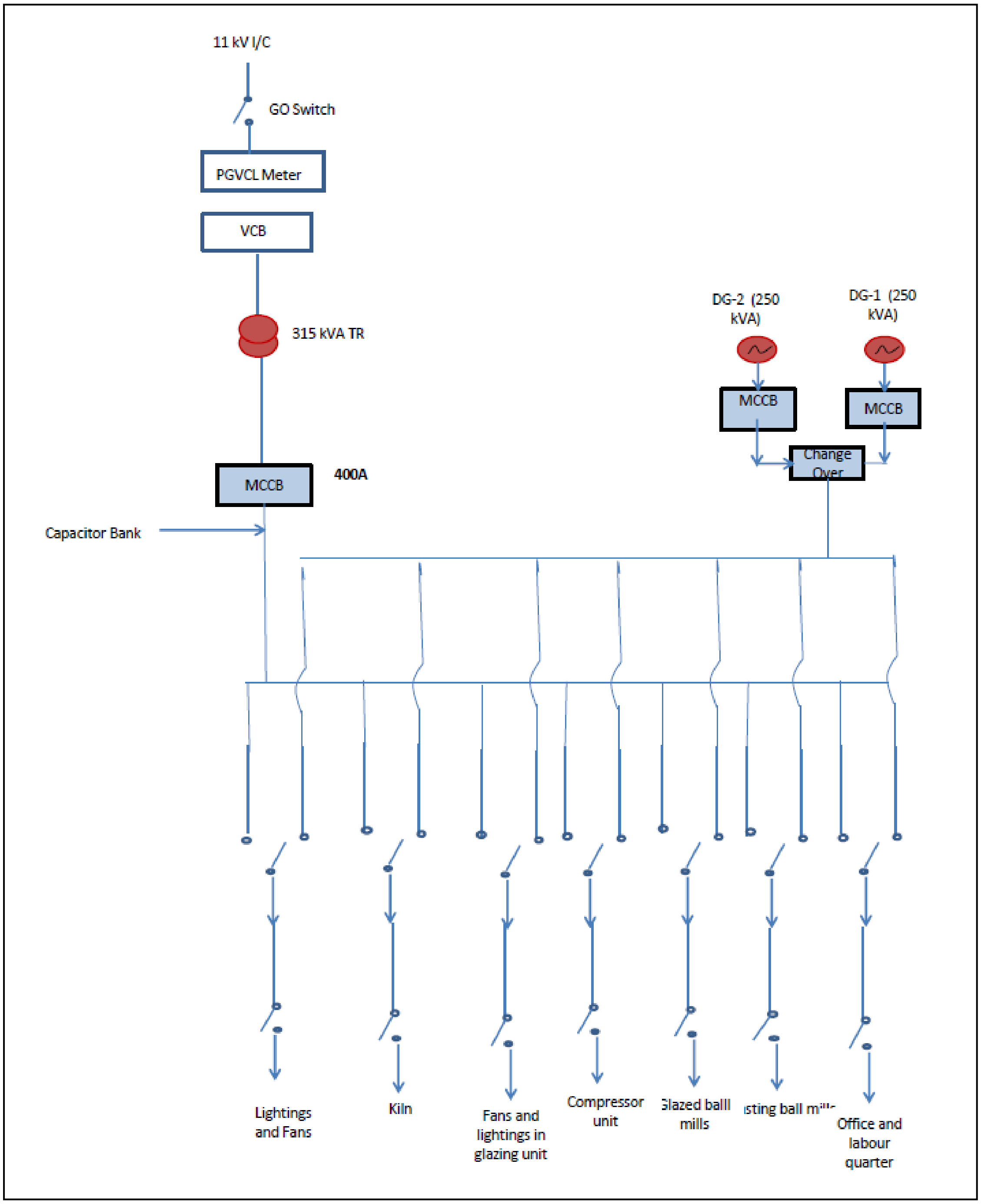


Figure 23: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

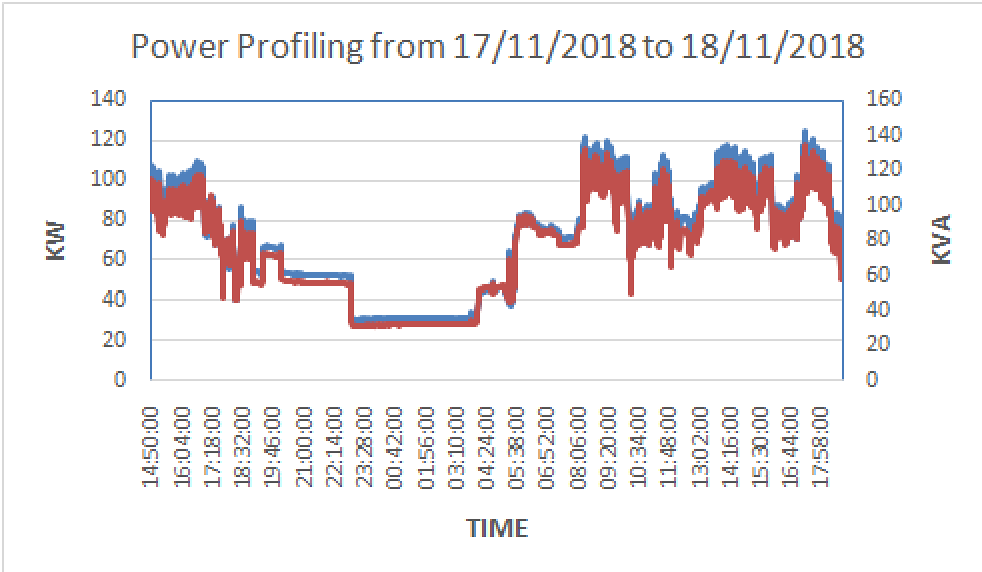


Figure 24: Power profile (kW) of Main Incomer

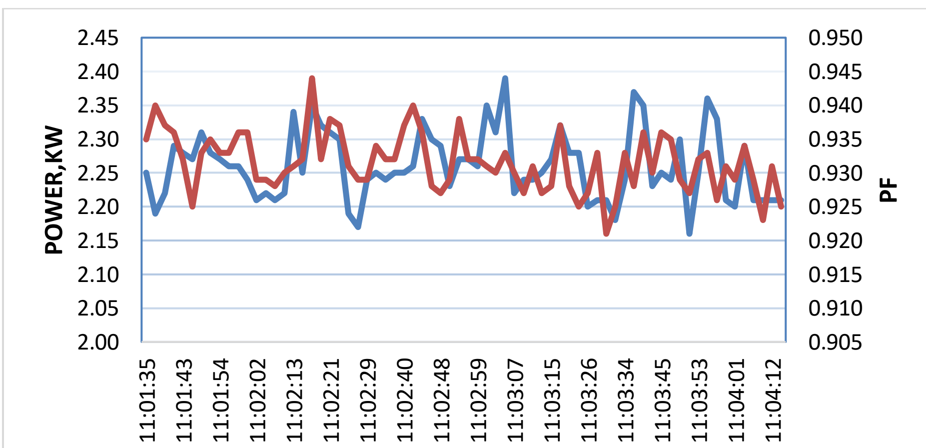
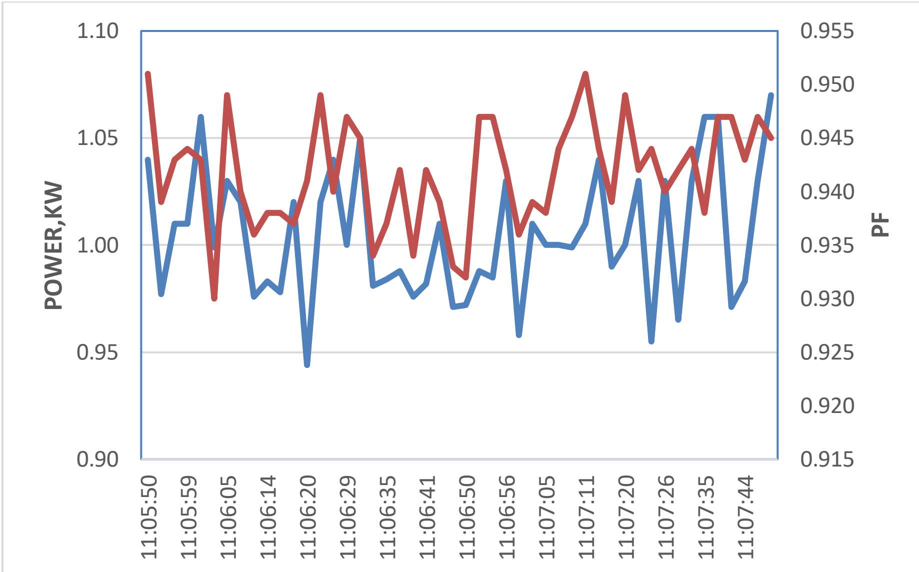


Figure 25: Power (kW) & PF profile of Main Incomer



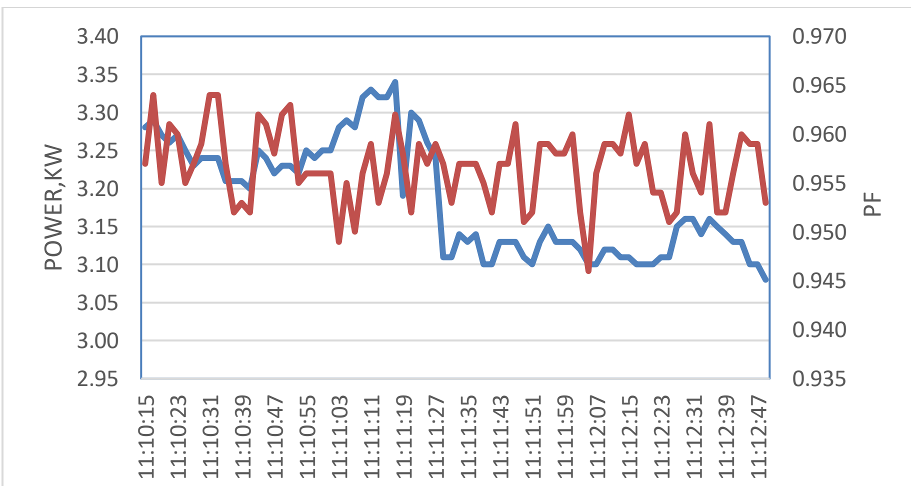


Figure 26: Power and PF profile of blowers of kiln

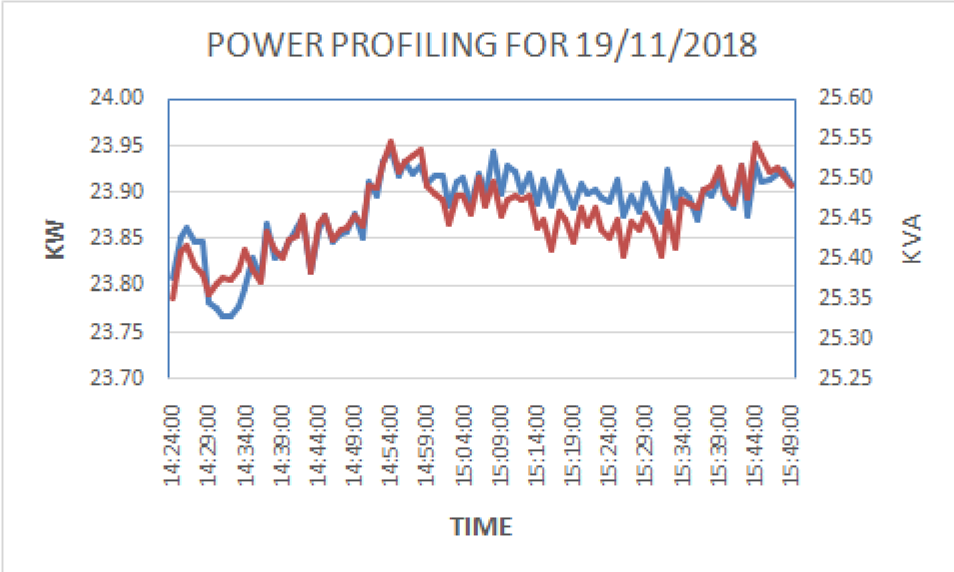


Figure 27: Power and PF profile of blowers of Ball Mills

7.5 Annex-5: Thermal Measurements, Kiln Efficiency

1. *Kiln efficiency calculations*

Input parameters

Input Data Sheet		
Type of Fuel	Natural Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1137	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	71	*scm/hr*
Flue Gas Details		
Flue gas temp at smog blower	175	*°C*
Preheated air temp./Ambient	35	*°C*
O2 in flue gas	6.1	*%*
CO2 in flue gas	8.9	*%*
CO in flue gas	30	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
Fuel Analysis		
C	*73.80*	%
H	*24.90*	%
N	*1.30*	%
O	*0.00*	%
S	*0.00*	%
Moisture	*0.00*	%
Ash	*0.00*	%
GCV of fuel	9000	*kCal/kg*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un=burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kCal/kg
GCV of fly ash	*0*	kCal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	515	*Kg/h*
Weight of Kiln car material	500	*Kg/h*

Input Data Sheet		
Weight of Stock	1015	*kg/h*
Specific heat of clay material	0.22	*KCal/kg°C*
Avg. specific heat of fuel	0.51	*KCal/kg°C*
fuel temp	40.2	*°C*
Specific heat of flue gas	0.24	*KCal/kg°C*
Specific heat of superheated vapor	0.45	*KCal/kg°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	8661	*kCal/h*
Radiation and convection from heating zone surface	14,181	*kCal/h*
Radiation and convection from cooling zone surface	18,880	*kCal/h*
Heat loss from all zones	41,722	*kCal/h*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.75	*h*
Area of entry opening	8.4	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temperature of kiln	398	*deg K*

Efficiency calculations

Parameters	Value	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	40.72	*%*
Actual Mass of Supplied Air	24.24	*kg/kg of fuel*
Mass of dry flue gas	23.00	*kg/kg of fuel*
Amount of Wet flue gas	25.24	*kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*kg of H_2O/kg of fuel*
Amount of dry flue gas	23.00	*kg/kg of fuel*
Specific Fuel consumption	100.00	*kg of fuel/ton of water closet*
Heat Input Calculations		
Combustion heat of fuel	656,838	*kCal/ton of water closet*
Sensible heat of fuel		*kCal /ton of water closet*
Total heat input	656,838	*kCal /ton of water closet*
Heat Output Calculation		
Heat carried away by 1 ton of tile	241,296	*kCal /ton of water closet*
Heat loss in dry flue gas	74,411	*kCal /ton of water closet*
Loss due to H2 in fuel	1,425	*kCal /ton of water closet*
Loss due to moisture in combustion air	1,470.45	*kCal /ton of water closet*
Loss due to partial conversion of C to CO	140.25	*kCal /ton of water closet*

Parameters	Value	Unit
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	3,279.60	*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	41,101	*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	216,122	*kCal /ton of water closet*
Unaccounted heat losses	71,129	*kCal /ton of water closet*
Heat loss from kiln body and other sections		
Total heat loss from kiln	41,101	*kCal /tons*
Kiln Efficiency	36.74	*%*

2. *Heat Balance Diagram*

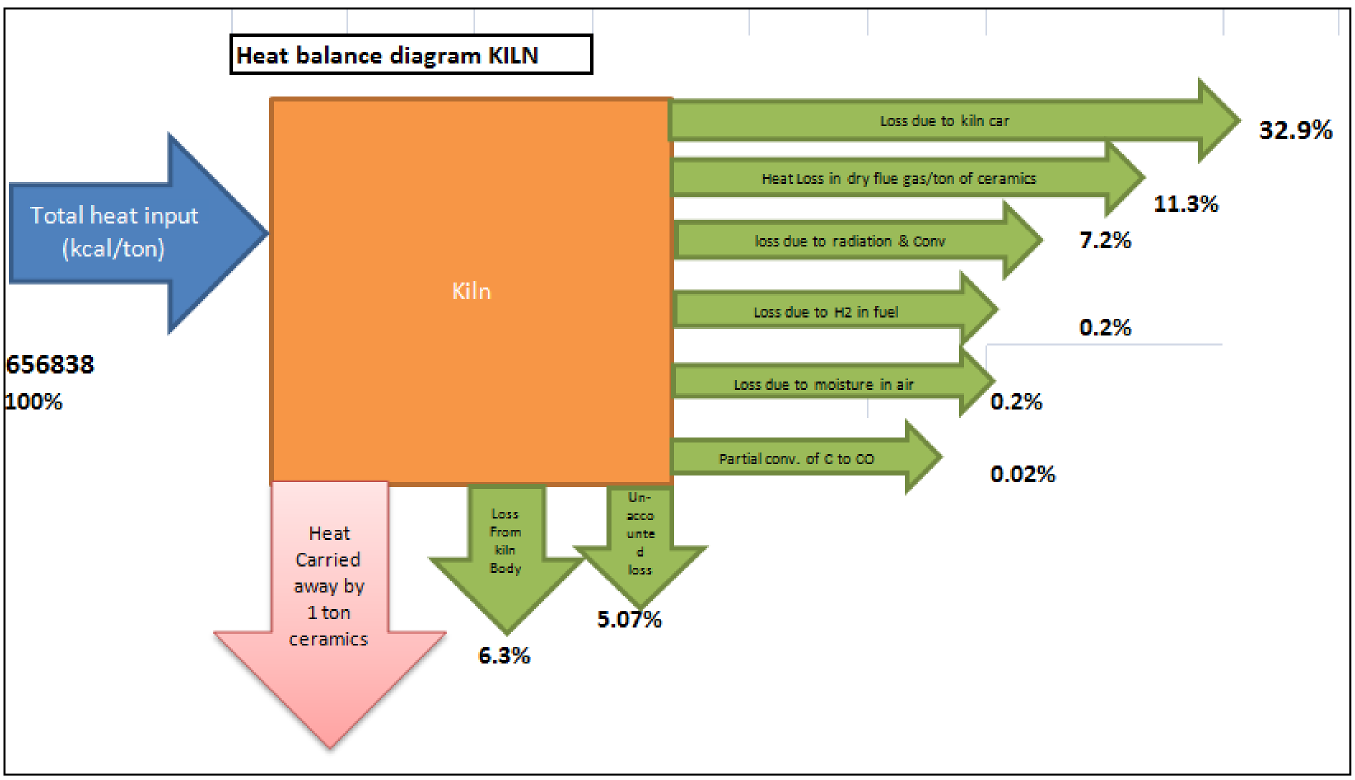


Figure 28: Heat Balance diagram of Tunnel Kiln

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	Knackwell 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: Radiation and convection loss reduction from surface of kiln by insulation

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 Fax: +91-11-44-30882894 /95 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 3: WHR from kiln using HE

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Knackwell 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 4: 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 Industries	No. 483, Jalaram Estate, Narol Vatva Road Narol Ahmedabad - 382405 Gujarat, India	08048763653	
3	Mahek Enterprises	No. 607, Corporate Avenue, Sonawala Road, Goregaon East, Morbi-400063, Gujarat, India	08048719133	

ECM 5: Replacement of motors by EE motor

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

ECM – 6 : Installation of Electronic timer control for stirrer

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

ECM 7: Air blowers

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

ECM - 9: Pumps replacement with Efficient pumps

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Varuna Pumps Pvt Ltd.	La-Gajjar Machineries Pvt.Ltd. Acidwala estate, Nagarwel Hanuman Road, Amraiwadi, Ahmedabad – 380 026	79- 22777485 / 487	www.varunapumps.com crm@lgmindia.com

Sl.No.	Name of Company	Address	Phone No.	E-mail
2	Kirloskar Brothers Ltd	1st floor, Kalapi Avenue, Opp. Vaccine Institute, Old Padra Road, Vadodara	Mr. Sanjeev Jadhav 0265-2338723/2338735	aksur@bdq.kbl.co.in
3	KSB Pumps Ltd	Neel Kamal, Ashram Road, Opposite Sales India, Ashram Road, Ahmedabad, Gujarat 382410	Mr. Jayesh Shah 098794 83210	https://www.ksb.com/ksb-in/ksb-in-india/

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

ECM 11: Replacing conventional ceiling fans with energy efficient fans

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

ECM - 12: Installation of Harmonics filter

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Infinity Enterprise Private Limited	13, Crystal Avenue & Industrial Park, near Odhav Ring road circle, Odhav, Ahmedabad – 382415, Gujarat, India.	Mob: +91 8048412433	info@infinityenterprise.net
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 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-15: V Belt with REC belt replacement

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

Sl. No.	Name of Company	Address	Phone No.	E-mail
		B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001		

ECM 16 : Solar PV system

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

7.7 Annex-7: Financial analysis of project

Table 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%