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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE VT56: KEVIN CERAMIC PVT. LTD

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DEVELOPMENT ENVIRONERGY SERVICES LTD
819, Antriksh Bhawan, 22 Kasturba Gandhi Marg, New Delhi -110001
Tel.: +91 11 4079 1100 Fax: +91 11 4079 1101; www.deslenergy.com

April-2019

Bureau of Energy Efficiency, 2019

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

For more information

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

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

Disclaimer

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. Kevin Ceramic Pvt. Ltd. and their management for showing keen interest in the energy audit and their wholehearted support and cooperation for the preparation of this comprehensive energy audit report, without which the study would not have steered to its successful completion. Special thanks to following members of the unit for their diligent involvement and cooperation.

1. Mr. Vipul Kaneriya, 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.

DESL Team

Project Head	R. Rajmohan, Chief Executive Officer
Team leader and co-coordinator	Rajendra N., Consultant
Team members	Sandeep Sharma, Assistant Analyst Gaurav Gilhotra, Project Analyst Dhruv kumar Lalitbhai Anavadiya, Project Analyst

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

Abbreviations	Expansions
APFC	Automatic Power Factor Controller
BEE	Bureau Of Energy Efficiency
BIS	Bureau Of Indian Standards
BOP	Best Operating Practice
CGCRI	Central Glass And Ceramic Research Institute
CMP	Common Monitorable 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	^oC
Horse Power	hp
Hour(s)	h
Hours Per Year	h/y
Indian Rupee	INR/Rs.
Kilo Calorie	kCal
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	UOM	Value	UOM
Electricity	1	kWh	0.000086	TOE/kWh
Coal	1	MT	0.35	TOE/MT
Natural Gas	1	scm	0.0009	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.

Kevin Ceramic Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Kevin Ceramic is a vitrified tile 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	Kevin Ceramic Pvt. Ltd.
Year of Establishment	2011
Address	8A National Highway, Sartanpar Road, B/h Makansar Vid, At. Village Sartanpar, Tal. Wakaner, Dist. Rajkot, (Gujarat) – India
Products Manufactured	Vitrified Tiles
Name(s) of the Promoters / Directors	Mr. Vipul Kaneriya

➨ 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 coal gas. The temperature maintained in kiln is approximate 1,150 – 1,200^oC (in the heating zone). The other equipment installed includes:

- **Clay ball mill:** Here the raw materials like clay, feldspar and quartz are mixed along with water to form a slip.
- **Agitator:** The slip 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.
- **Spray Dryer:** The slip obtained after agitator is passed into this which removes the moisture content present in slip from 40% to 6% approx.
- **Hydraulic press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit (Green tile).
- **Dryer:** Biscuits (green tiles) are sent to dryer for pre drying after it is passed through kiln.
- **Glaze ball mill:** For producing glazing material which is used on the product.
- **Kiln:** Biscuits (green tiles) are baked in the roller kiln at 1100-1150^oC.
- **Sizing & finishing:** After Kiln, sizing and polishing of the tiles are done and packed in boxes.

The main utility equipment installed are:

- **Air compressor:** Pressurized air is used at several locations in a unit viz. pressing of slip, air cleaning, glazing etc.
- **Coal gasifier:** For producing coal gas which is used in horizontal dryer of kiln.

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 in kiln: Coal gas is used as fuel in kiln and oxygen content in flue gas was found to be 10.30% against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Waste heat recovery from flue gas of kiln: The flue gas temperature at kiln outlet was found to be 250^oC. It is recommended to decrease the smoke temperature from 250^oC to 200^oC at the outlet of recuperator, thereby increasing the heat utilization in kiln and increasing the temperature of combustion air entering in kiln.
- Using soft water in clay ball mill: TDS of water used in clay section was found to be 700ppm against desired level of 400ppm. It is recommended to install water softener plant which will blend RO water with raw water.

- PID Controller at water circulation pump for press: Cooling water pump is running continuously irrespective of the operation of the press. It is recommended to install PID based controller which will ensure that pump will start only when oil temperature is >38^{o}C.
- Timer controller for stirrer motor: All the agitators were operating continuously throughout the day and it is recommended to install timer based control for agitators to reduce the operating hours by 50%.
- Retrofit of VFD in Compressor #1: During unload condition; compressor is consuming 30% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy upto 15% of present consumption.
- Compressed air pressure reduction: The generation pressure of compressor #1 is 6 kg/cm^2 and the pressure requirement at the end utilities were around 4 kg/cm^2. It is recommended to reduce operating pressure of compressor #1 from 6 kg/cm^2 to 5 kg/cm^2.
- Replacement of inefficient pumps: Few pumps such as Press CT pump-1 & 2 (pump 1 - 49.9% & pump 2 - 58.8%), Gasifier CT pump-1 & 2 (pump 1 - 65.2% and pump 2 - 63.3%) and Borewell pump (59.3%) were running at lower efficiency against desired efficiency of 75%. It is recommended to replace the existing pumps with energy efficient pumps.
- Replacement of inefficient lighting systems: Conventional lights like Fluorescent Tube lights and Compact fluorescent light were present in unit which results in higher electrical consumption. It is recommended to replace the conventional lights with energy efficient LED lamps.
- Installation of Harmonic filter: Harmonics levels were found to be higher than the prescribed limits as per IEEE guidelines. It is recommended to install harmonic filter at main incomer.
- Cable loss minimization: In sizing section, power factor was 0.60. It is recommended to install power factor improvement capacitors for sizing section.
- Voltage optimization in lighting circuits: The present voltage for lighting circuit was found to be 416V against desired voltage of 380V. It is recommended to install separate lighting transformer of 60kVA rating for lighting circuit.
- V belt to REC belt replacement: The existing V belts are less efficient compared to REC belts and this will reduce the power consumption by 3.6%.
- Energy Management system: Online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption and there were no proper fuel monitoring system installed at hot air generator, coal gasifier and kiln. It is recommended to install online electrical energy management systems (smart energy meters) on the main incomer and on the various electricity distribution panels and fuel monitoring system.

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

Table 1: Summary of ECM

Sl. No.	Energy Conservation Measures	Annual Energy Savings			Monetary Savings	Investment	Payback Period	Emission reduction
		Electricity kWh/y	Coal t/y	TOE/y	Lakh Rs/y	Lakh Rs	Months	tCO_2/y
1	Excess air control in kiln	3,881	1,208	423	38.96	18.48	6	2,560
2	Waste heat recovery from flue gas of kiln	-	731	256	23.4	99.7	51	1,546
3	Using soft water in clay ball mill	17,710	532	188	56.12	30.00	6	1,140
4	PID controller at water circulating pump for press	71,003	0	6	5.36	0.53	1	58
5	Timer controller for stirrer motor	109,164	0	9	8.24	1.27	1.8	90
6	Retrofit of VFD in compressor#1	35,423	0	3	2.67	1.39	6	29
7	Compressed air pressure reduction	18,058	0	2	1.75	0.00	0	15
8	Replacement of inefficient pumps	103,464	0	9	7.2	3.0	5	85
9	Replacement of inefficient lighting systems	21,132	0	2	1.59	1.24	9	17
10	Installation of harmonic filter	33,998		3	2.57	4.75	22	28
11	Cable loss minimization	2,183		0	0.16	0.15	11	2
12	Voltage optimization in lighting circuits	6,398	0	1	0.48	0.50	12	5
13	V belt to REC replacement	60,794		5	4.59	5.00	13	50
14	Energy Management system	102,571	158	64	12.80	6.63	6	419
	Total	**585,779**	**2,629**	**971**	**165.9**	**172.6**	**12**	**6,044**

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

- Reduction in energy cost by 25.9%
- Reduction in electricity consumption by 11.4%
- Reduction in thermal energy consumption by 33.2%
- Reduction in greenhouse gas emissions by 28.9%

➨ 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 in kiln	18.48	164	2.23
2	Waste heat recovery from flue gas of kiln	99.74	1	17.09
3	Using soft water in clay ball Mill	30.00	140	2.52
4	PID Controller at water circulating pump for press	0.53	746	0.48
5	Timer Controller for stirrer motor	1.27	486	0.74
6	Retrofit of VFD in compressor #1	1.39	146	2.44
7	Compressed air pressure reduction	-	-	-
8	Replacement of inefficient pumps	2.98	182	1.95
9	Replacement of inefficient lighting systems	1.24	99	3.59
10	Installation of harmonic filter	4.75	32	8.36
11	Cable loss minimization	0.15	82	4.17
12	Voltage optimization in lighting circuits	0.50	70	4.75
13	V Belt to REC belt replacement	5.00	68	4.96
14	Energy management system	6.63	148	2.42

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	Kevin Ceramic Pvt. Ltd.		
Plant Address	8-A, National Highway, Sartanpar Road, B/h Makansar Vid, At. Village Sartanpar, Tal. Wakaner, Dist. Rajkot, (Gujarat) - India		
Constitution	Private limited		
Name of Promoters	Vipul Kaneriya		
Contact person	Name	Vipul Kaneriya	
	Designation	Director	
	Tel	9909908735	
	Fax		
	Email	vipul.kcpl@gmail.com	
Year of commissioning of plant	2011		
List of products manufactured	Vitrified tile, 1200 x 1200 mm (9 tiles/box) Vitrified tile, 1200 x 2400 mm (5 tiles/box)		
Installed Plant Capacity	7,000 boxes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	Not provided		
Net profit	Not Provided		
No of operational days in a year	Days/Year	330	

Description	Details		
	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)	Yes	Kiln and HAG
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas (scm)	No	-
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
Interested in DEA	Yes		
	Very 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.

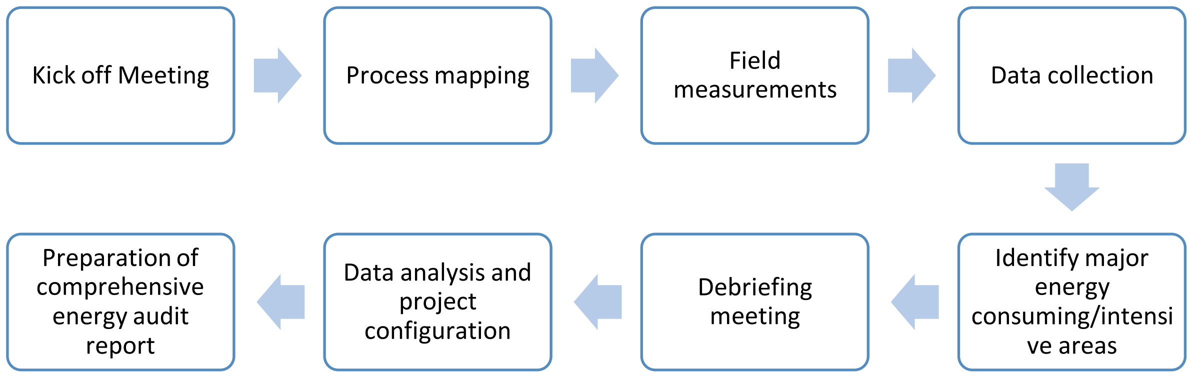


Figure 1: General methodology

The field work was carried out during 10-11th December 2018.

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

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

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit are the following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Parameters Measured
1	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
2	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and flue gas temperature, ambient temperature
6	Digital Temperature and Humidity	Temperature and humidity data logging

Sl. No.	Instruments	Parameters Measured
	Logger	
7	Digital Temperature & Humidity Meter	Temperature & humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant surface temperature
11	Contact Type Temperature Meter	Liquid and surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

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

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

2. CHAPTER - 2 PRODUCTION AND ENERGY CONSUMPTION

2.1 Manufacturing process with major equipment installed

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

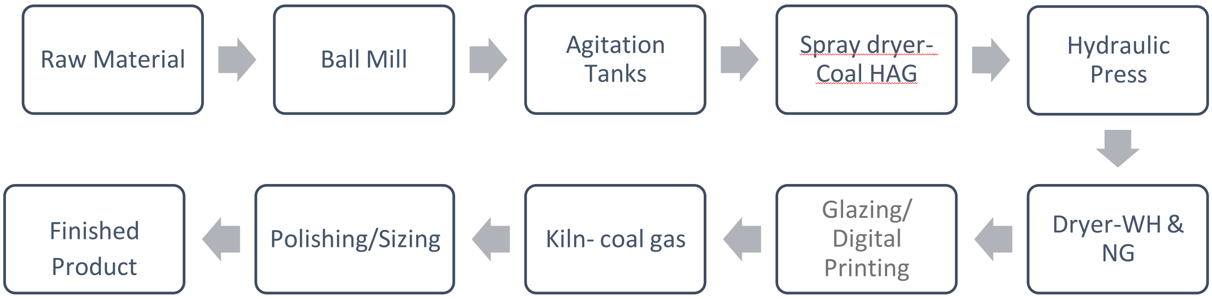


Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is a mixture of clay, feldspar and quartz which is mixed along with water to form slip.
- The raw materials are mixed and ground using pebbles together with water in the clay ball mill for a period of 3-6 hours.
- Slip is then pumped using hydraulic piston into spray dryer where moisture content of slip is reduced from 35-40% to about 5-6% and output of spray dryer is in powder form.
- Clay in powdered form is stored in silos for 24 hours and then conveyed to hydraulic press machine where it is pressed and tiles is formed of required size, output of press is called biscuit.
- Biscuit (green tile) is preheated initially in horizontal dryer at about 130-150°C.
- This is followed by the glazing process and digital printing.
- After this, the glazed product make a passage through kiln at 1,150-1,200°C for final drying and hardening.
- Output of kiln is called tiles; these tiles are then passed through cutting, sizing and polishing machines to match exact dimensions required.
- After sizing tiles are packed in boxes and then dispatched.

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

- **Clay ball mill:** Here the raw materials like clay, feldspar, potash, talc and quartz are respectively along with water to form slip.
- **Hot air generator:** Hot air generator is used to generate hot air which is used in spray dryer for evaporation of moisture present in slip.
- **Glaze ball mill:** For producing glazing material used on tiles.
- **Air compressor:** Pressurized air is used at several locations in a unit viz. instrument air, service air, etc.

- **Agitator:** The liquid slip mass after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.
- **Kiln:** The kiln is the main energy consuming equipment where the product is passed twice, once in biscuit form and second time after glazing and printing. The kilns are about 147 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150^{o}C to 1,200^{o}C depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further gone for sizing, finishing and quality tested and 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	Size /Piece	Weight/box	Area per box	Pieces per box
	mm × mm	kg	m^2	#
Vitrified Tiles	300 x 300	17.37	0.81	9
Vitrified Tiles	300 x 600	25	0.925	5

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 boxes		Corresponding area (m^2)		Corresponding mass (MT)	
	300 x 300	300 x 600	300 x 300	300 x 600	300 x 300	300 x 600
Oct-17	172,000	-	139,320	-	2,988	-
Nov-17	190,000	7,000	153,900	6,475	3,300	175
Dec-17	200,000	-	162,000	-	3,474	-
Jan-18	185,000	-	149,850	-	3,213	-
Feb-18	188,000	12,000	152,280	11,100	3,266	300
Mar-18	189,000	-	153,090	-	3,283	-
Apr-18	197,748	-	160,176	-	3,435	-
May-18	217,144	-	175,887	-	3,772	-
Jun-18	193,299	-	156,572	-	3,358	-
Jul-18	163,472	-	132,412	-	2,840	-
Aug-18	189,764	-	153,709	-	3,296	-
Sep-18	144,447	-	117,002	-	2,509	-
Total	2,229,874	19,000	1,806,198	17,575	38,733	475

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 :
  - Coal for HAG; Coal gas for Kiln and horizontal dryer

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

Table 7: Energy use and cost distribution

Parameters	Energy cost		Energy use	
	Rs Lakhs	% of total	TOE	% of total
Grid – Electricity	387.06	60	441.1	14
Thermal-Coal	253.06	40	2,767.8	86
Thermal – NG	-	0	0	0
Total	640.12	100	3,208.9	100

This is shown graphically in the figures below:

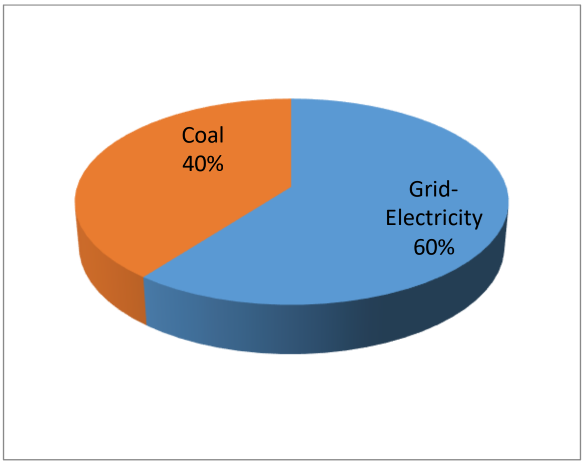


Figure 3: Energy cost share

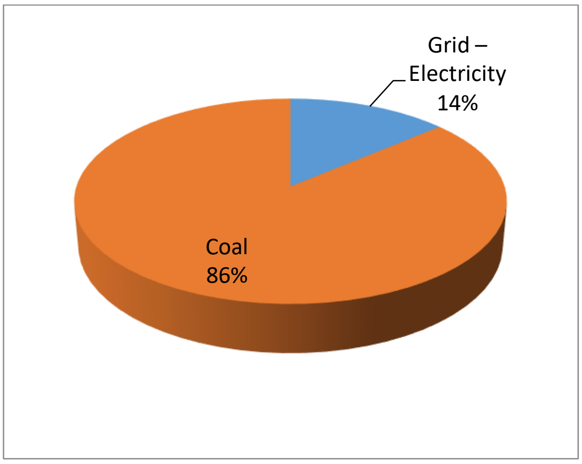


Figure 4: Energy use share

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 60% of the energy cost and 14% of the overall energy consumption.
- Source of thermal energy is from combustion of coal gas, which is used for firing in the kiln.

- Coal used (in form of coal gas) in kiln and as coal in hot air generator account for 40% of the total energy cost and 86% of overall energy consumption. Coal is also used in hot air generator to generate hot air.

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

Parameters	Description
Consumer number	26,895
Tariff category	HTP-I
Contract demand, kVA	1,065
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Electric tariff structure

Parameters	Tariff structure for Category HTP-1
Demand charges (Rs./kVA) 1st 500 kVA 2nd 500 kVA Next	 150 260 475
Energy charges (Rs./kWh) Normal hours Peak hours (extra cost) Night time (rebate)	 4.20 (+) 0.85 (-) 0.40
Fuel Surcharge (Rs./kVAh)	1.63
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill for Sep-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
Oct-17	435,923	4,209,318	9.66
Nov-17	452,813	3,473,845	7.67
Dec-17	423,720	3,144,333	7.42
Jan-18	430,395	3,186,222	7.40
Feb-18	428,453	3,101,794	7.24
Mar-18	413,595	3,053,131	7.38
Apr-18	475,058	3,463,538	7.29
May-18	415,988	3,027,451	7.28
Jun-18	433,643	3,143,451	7.25
Jul-18	402,023	2,939,477	7.31

Month	Units consumed kWh	Total electricity cost Rs.	Average unit Cost Rs./kWh
Aug-18	398,918	2,920,888	7.32
Sep-18	418,020	3,042,525	6.36

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 427,379kWh/month and cost is Rs 32 Lakhs per month (Oct-17 to Sep-18). The average cost of electricity is Rs 7.5/kWh, from duration of Oct-17 to Sep-18. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

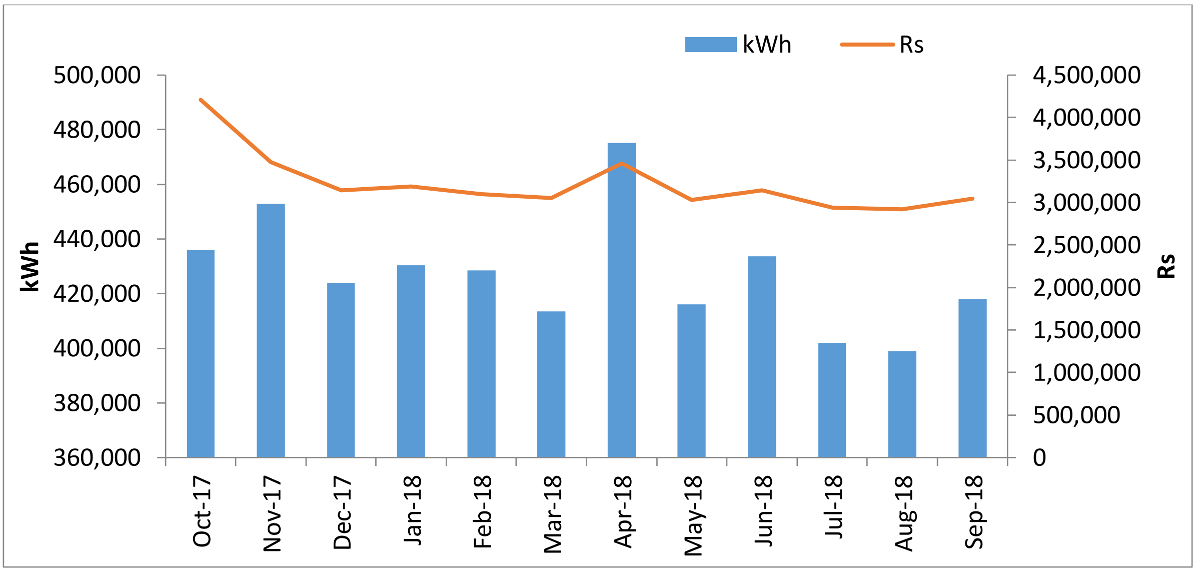


Figure 5: Month wise variation in Electricity Consumption

Power Factor: Power factor as per electricity bills is shown below[1]:

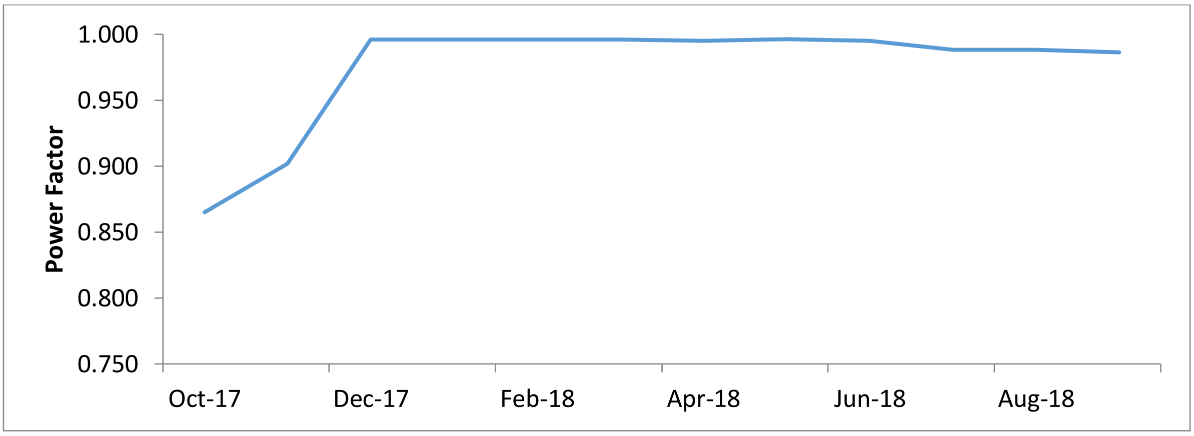


Figure 6: Month wise variation in Power Factor

The utility bills of the unit reflect the power factor. A study was conducted by logging the electrical parameters of the main incomer using a power analyzer. The average power factor was found to be 0.96 and the maximum being 0.99.

[1] PF and kVA details are available in duration of Apr-17 to Oct-18

Maximum Demand: Maximum demand as reflected in the utility bill is 1,119 kVA from the bill analysis.

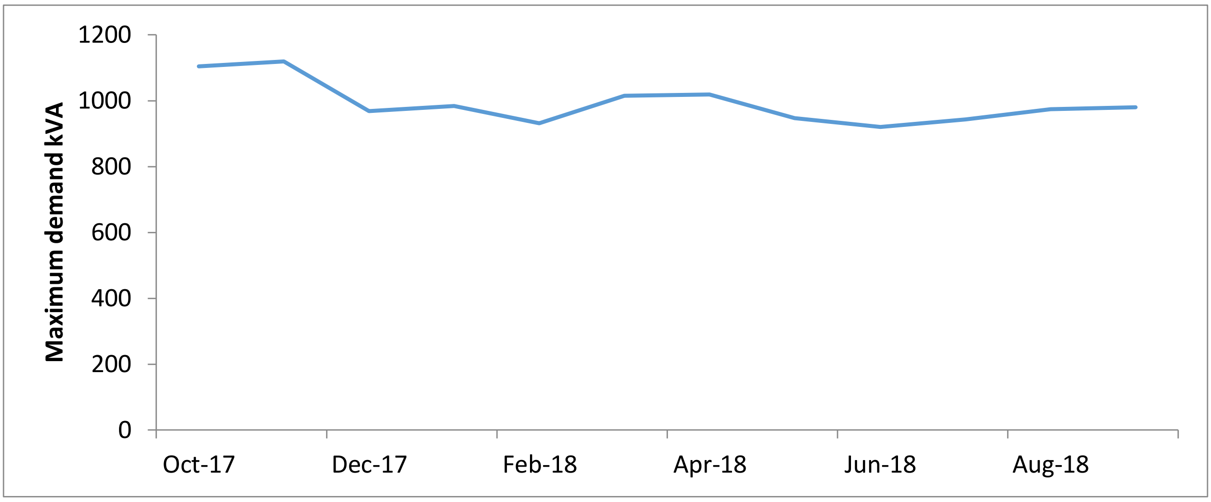


Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single line diagram

Single line diagram of plant is shown in figure below:

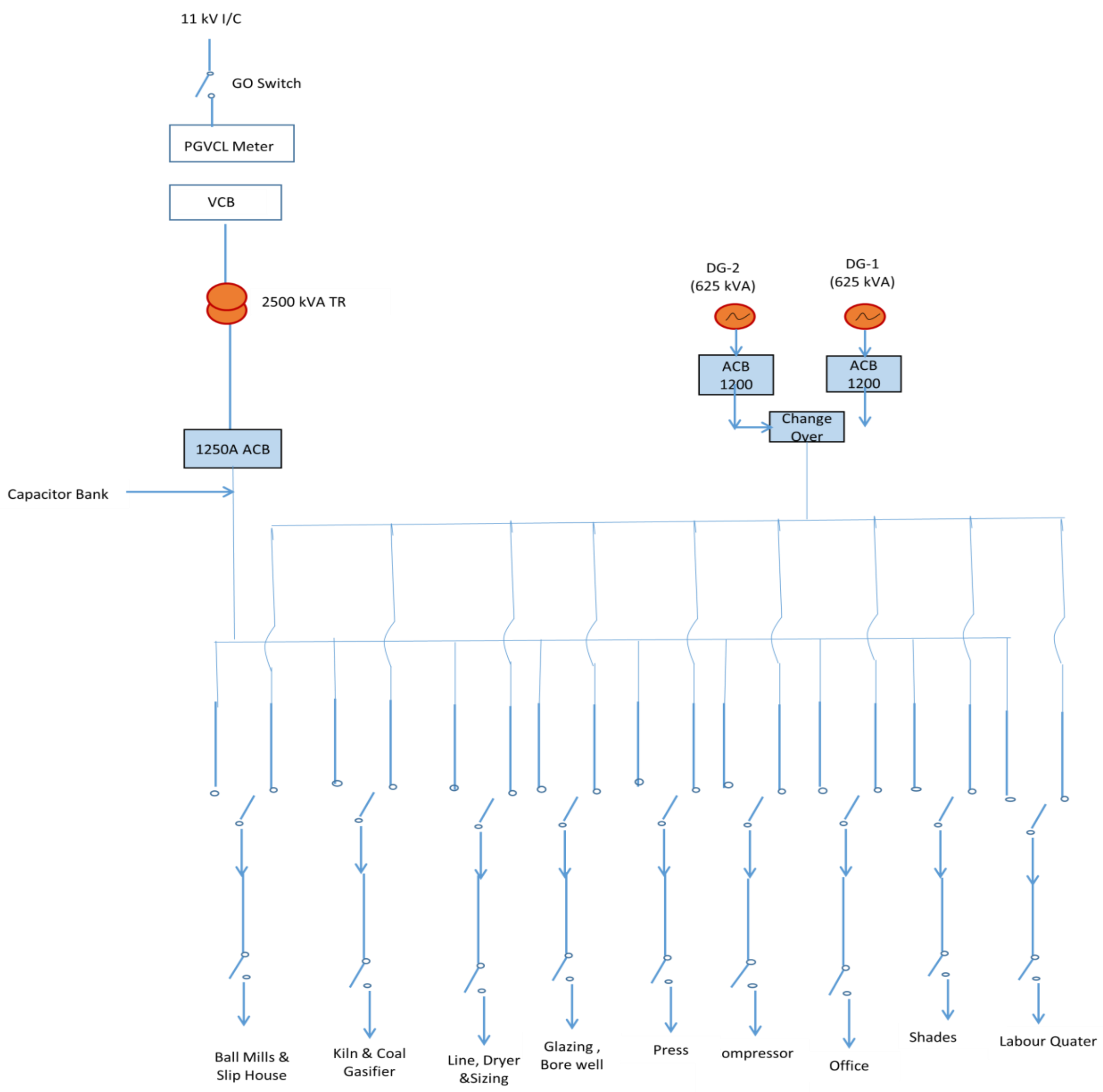


Figure 8: Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 1,424 kW, which includes:

- Plant and machinery load is 1,309 kW.
- Utility load is (lighting, air compressor and fans) about 115 kW including the single phase loads.

Table 11: Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Compressor	59
2	Press-2000	77
3	Press-2590	82
4	Press cooling towers	11
5	Horizontal dryer	85
6	Kiln	189
7	Sizing machine-1	58
8	Sizing machine-2	58

Sl. No.	Equipment	Capacity (kW)
9	Coal gasifier	88
10	Glaze ball mills	49
11	Agitators	33
12	Final tanks	11
13	Slip piston pumps	37
14	HAG & Spray dryer	257
15	Lights	9
16	Clay ball mill	320
	Total	1,424

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

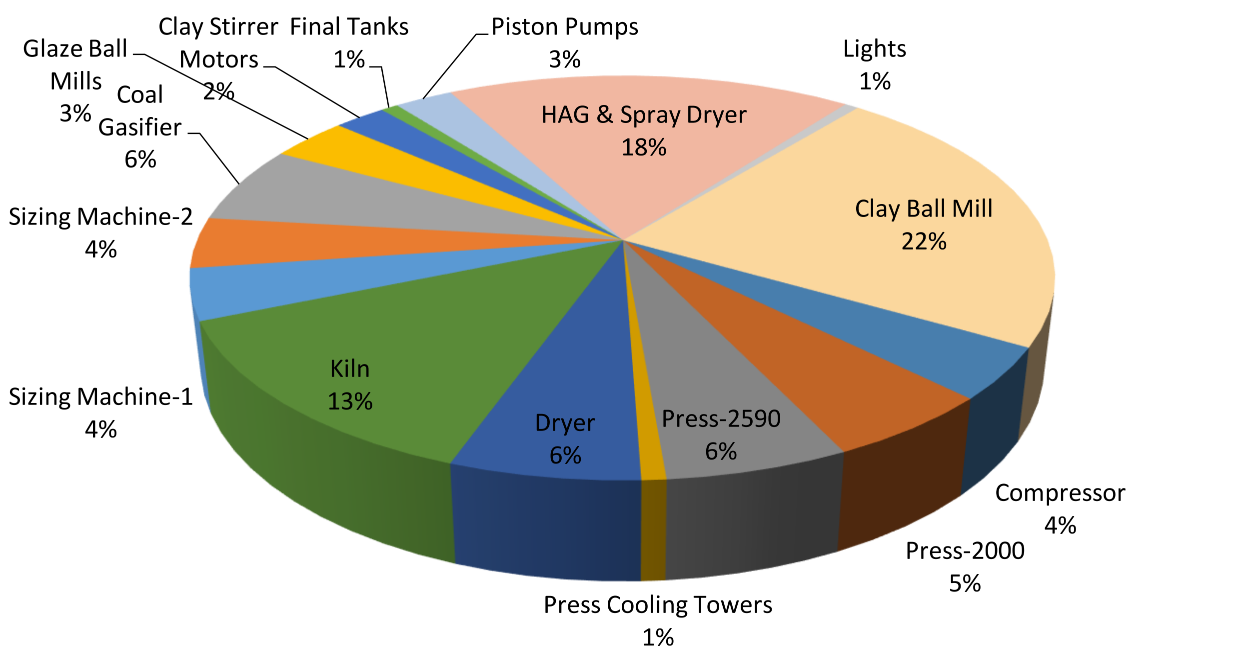


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Clay Ball mill-23%, for HAG & Spray dryer- 18%, for Kiln-13%, for Dryer and Press-2590 and Coal Gasifier-6%, for Press-2000-5% and other loads.

2.3.1.6 Specific electricity consumption

The month wise variation of specific electricity consumption (kWh/m^2 of production) is shown in the figure below:

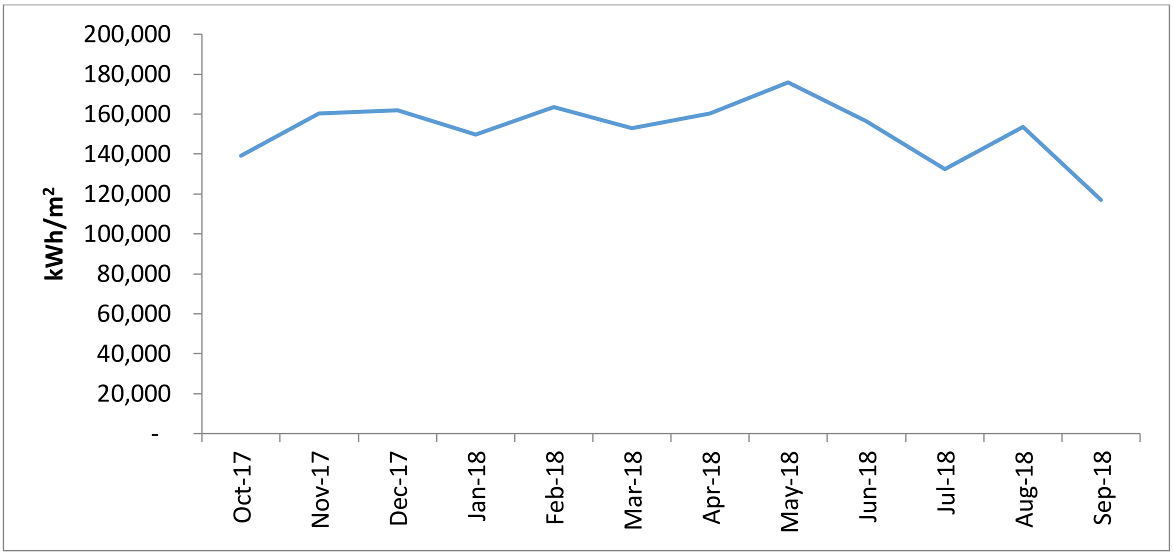


Figure 10: Month wise variation in Specific Electricity Consumption

For duration of Oct-17 to Sep-18, the maximum and minimum values of SEC for all months are within ±25% of the average SEC of 2.839 kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in ball mill section, spray dryer section, press section, Biscuits (green tiles) kiln, glaze kiln, 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 areas are the hot air generator and the kiln. Coal is used as the fuel to produce coal gas for firing in the kiln and to generate hot air from hot air generator. Coal gas is produced at plant level by a coal gasifier. Coal imported from Indonesia is being used. Coal consumption and Coal cost for the month of Oct-17 to Sept-18 are mentioned below:

Table 12: Month wise fuel consumption and Cost

Month	Coal used MT	Coal cost Rs	Coal cost Rs/MT
Oct-17	710	2,272,000	3,200
Nov-17	610	1,952,000	3,200
Dec-17	690	2,208,000	3,200
Jan-18	680	2,176,000	3,200
Feb-18	510	1,632,000	3,200
Mar-18	595	1,904,000	3,200
Apr-18	750	2,400,000	3,200
May-18	810	2,592,000	3,200
Jun-18	730	2,336,000	3,200
Jul-18	604	1,932,800	3,200
Aug-18	765	2,448,000	3,200
Sep-18	454	1,452,800	3,200

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

- Average monthly coal consumption is 659 tons and average cost is Rs 21 Lakh /month

2.3.2.2 Specific fuel consumption.

The month wise variation of specific fuel consumption (SFC- GJ/m^2 of production) is shown in figure below:

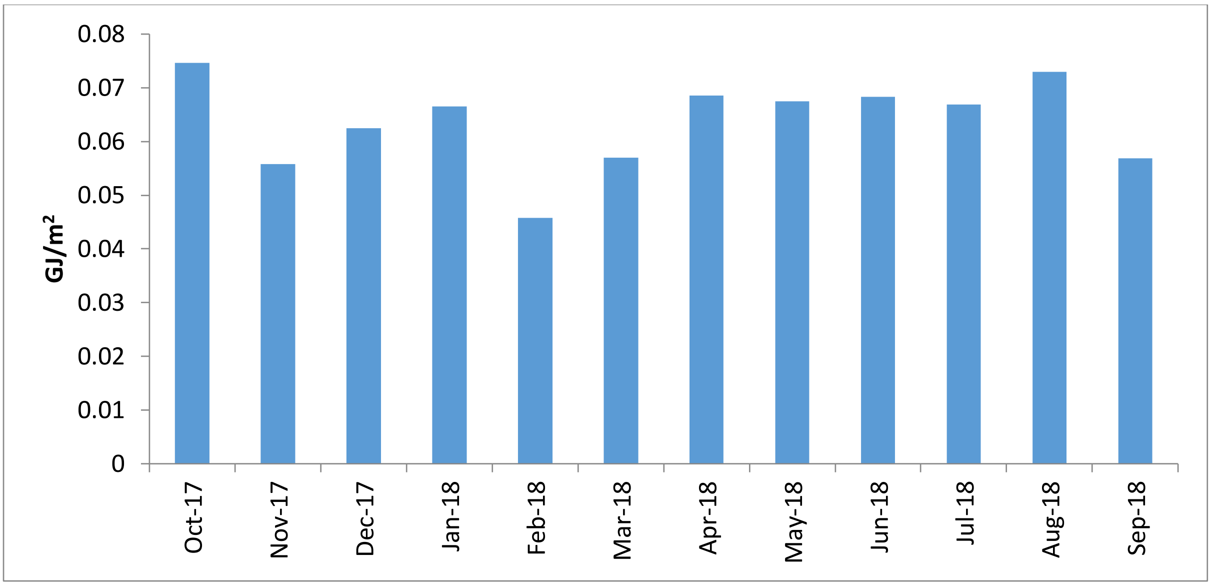


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.06 GJ/m^2. SFC is high in the month of May-18 (production was 175,887 m^2 and thermal consumption was 11,870 GJ) and low in the month of Sep-18(production was 117,002 m^2 and thermal consumption was 6,653 GJ). The coal data is based on purchase. Actual information on coal consumption is not being maintained, and hence the SFC does not follow the production. For better quality information, sub-metering/data logging is required at kiln, hot air generator and dryers are required.

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

Parameters	UOM	Value
Average production	m^2/h	211
Power consumption	kW	594
Coal consumption	kg/h	915
Energy consumption	TOE/h	0.32
SEC of plant	TOE/m^2	0.0015

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)

Parameters	Coal kg/t	Electricity kWh/t
Clay ball mill		2.1
Agitator motors		1.12
HAG & spray dryer	1597.5	15.4
Hydraulic presses		16.98
Slip Piston pumps		2.1
Horizontal dryer	5.7	7.1
Kiln	234	12.6
Glaze ball mill		2.86
Sizing machines		13.4

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

2.3.3.3 Based on yearly data furnished by unit

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

Table 15: Overall specific energy consumption

Parameters	UOM	Value
Annual Grid Electricity Consumption	kWh/y	5,128,548
Self-Generation from DG set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	5,128,548
Annual Thermal Energy Consumption (Coal)	t/y	7,908
Annual Energy Consumption	TOE/y	3,209
Annual water Consumption	kL/y	28,800
Annual Energy Cost	Lakh Rs/y	640
Annual Production	m^2/y	1,823,773
	t/y	39,208
SEC; Electrical	kWh/m^2	2.812
	kWh/t	130.80
SEC; Thermal	TOE/m^2	0.0015
	TOE/t	0.070
SEC; Overall	TOE/m^2	0.0018
	TOE/t	0.08
SEC; Cost Based	Rs/m^2	35.0984
	Rs/t	1,633

(Annual data based on the period Oct-17 to Sep-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 Imported Coal : 3,500 kCal/kg
- CO_2 Conversion factor

- Grid : 0.82 kg/kWh
- Imported Coal : 2.116 t/t of coal

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	UOM	Value
Cost of electricity	Rs/ kWh	7.55
Cost of coal	Rs/MT	3,200
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	1,823,773

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using one bore well pump. These pump lifts water from ground and which is collected in underground storage tank. From this tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 400-500 m^3/day as reported by the unit and verified during DEA. There is no metering available to monitor the exact water consumption.

Water distribution diagram is shown below.

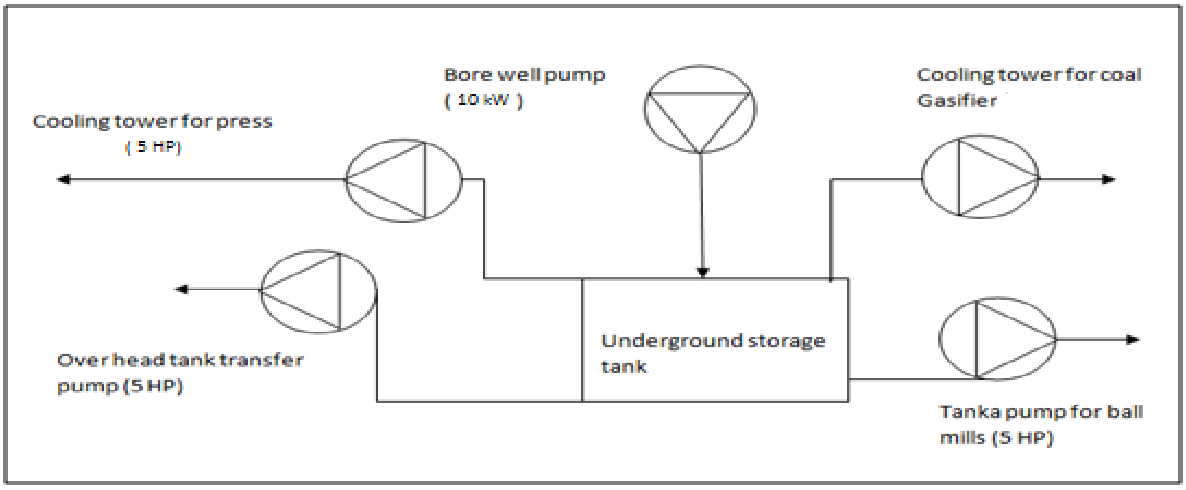


Figure 12: Water Distribution Diagram

One borewell pump is installed to meet the water requirements of process (cooling towers for press and coal gasifier, ball mills, sizing and cutting section and domestic use). Installation details of submersible pumps are tabulated here under.

Table 17: Bore-well pump details

Parameters	UOM	Value
Make	-	-
Motor rating	kW	10
RPM	rpm	-
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

Coal gas is used as a fuel in the kiln to heat the ceramic tiles to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan). Cooling blower and rapid cooling blowers are used for cooling the tiles after combustion zone to get required tile quality and at the starting point, a smoke blower is installed which preheats the tiles before combustion zone of kiln. Kiln consists 253 HP electrical load of which 50 HP is for smoke blower, 60 HP for combustion blowers, 20 HP for rapid cooling, 50 HP for Hot air blower, 50 HP for final cooling blowers & remaining electrical load of kiln roller motors.

Table 18: Kiln details

Parameters	UOM	Value
Make		-
Kiln operating time per day	h/d	24
Fuel consumption	kg/h	1,302.5
Number of burner to left	-	80
Number of burner to right	-	80
Cycle time	Minutes	30
Pressure in firing zone	mmWC	35
Maximum temperature	°C	1,200
Waste heat recovery option		Yes
Kiln dimensions (Length X Width X Height)		
Preheating zone	m	73.5 x 4 x 1
Firing zone	m	56.7 x 4 x 1
Rapid cooling zone	m	16.8 x 4 x 1
Indirect cooling zone	m	16.8 x 4 x 1
Final cooling zone	m	23.1 x 4 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 dryer; 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	10.3%
Ambient air temperature	38°C
Exhaust temperature of flue gas	230°C

From the above table, it is clear that the oxygen level measured in flue gas was high. The inlet temperature of raw material in kiln was in the range of 35 – 42°C which was the ambient air temperature. Surface temperature was high, throughout the surface of the kiln is 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	50.0
Heating zone average surface temperature	50.0
Rapid cooling zone average surface temperature	50.0
Indirect cooling zone average surface temperature	50.0
Final cooling zone average surface temperature	50.0

The temperature profile inside the kiln is shown below:

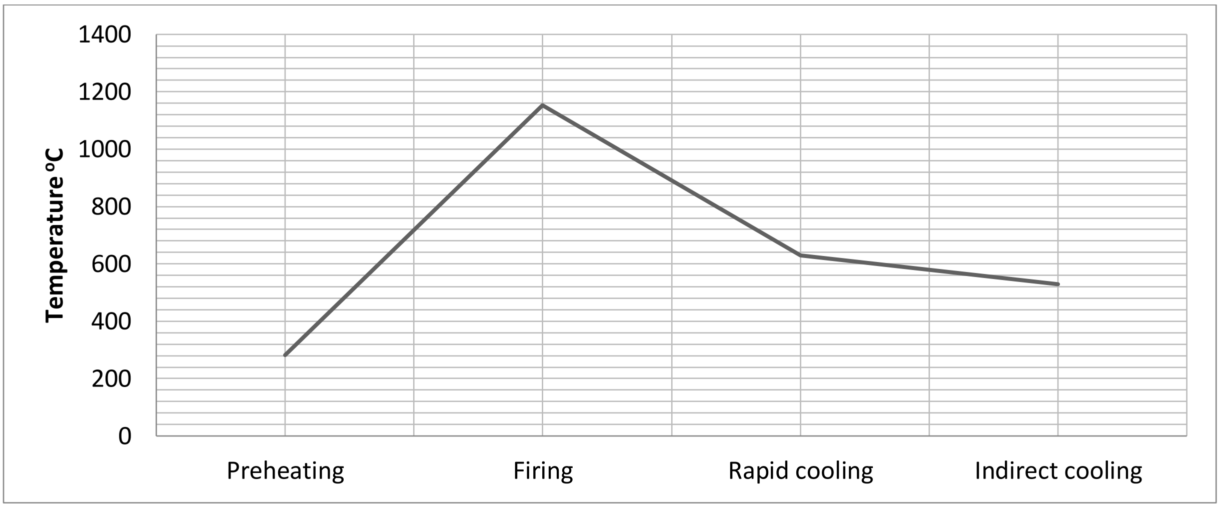


Figure 13: Temperature profile inside the kiln

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
Final cooling blower	4.36	0.98
Hot air blower	6.97	0.99
Rapid cooling blower	1.67	0.98
Smoke blower	13.10	0.99
Combustion blower	4.20	0.99

3.1.3 Observations and performance assessment

Kiln heat utilization has been calculated based on the flue gas analysis study conducted during visit. Overall heat utilization of the kiln is 25.2%. Summary of all losses is shown in below figure:

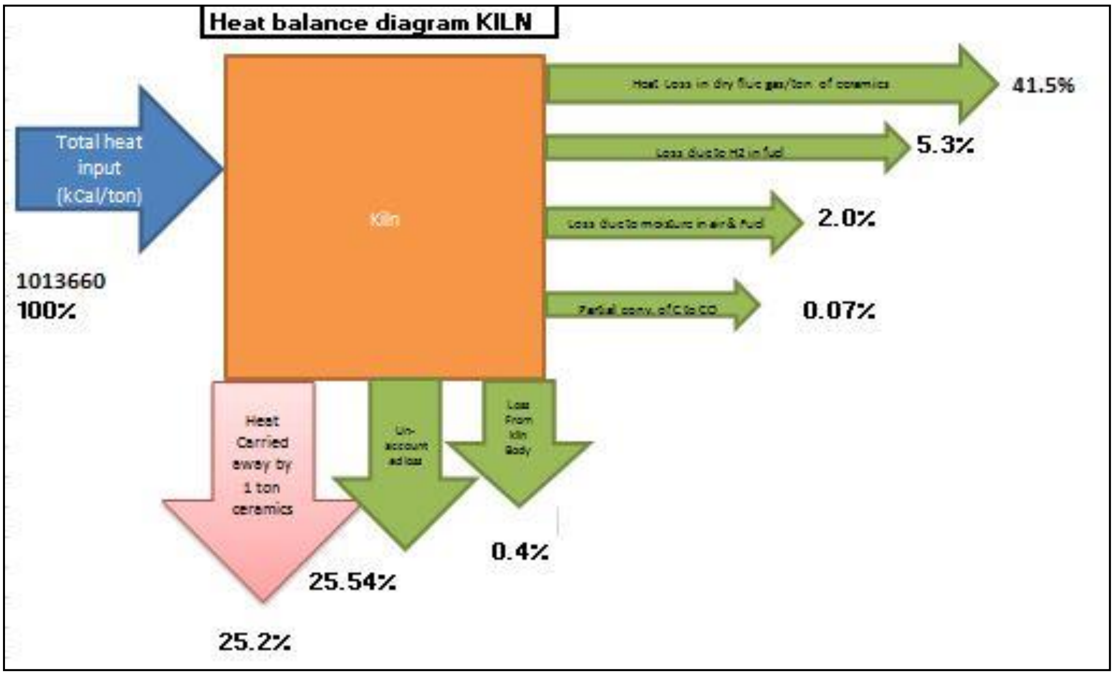


Figure 14: Heat balance diagram of Kiln

Causes of unaccounted losses arising due to following reasons:

1. Kiln leakage observed in kiln.
2. Rollers are getting heated itself by kiln heat.
3. Inspection holes are closed by aluminum dart which increases radiation loss.
4. Hot air fans body are un-insulated.
5. Atmospheric air dilution in kiln.

Detailed calculation is included in **Annexure-5**.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln - Excess Air Control

Technology description

It is necessary to maintain optimum excess air levels 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 along with O_2 sensor, 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	UOM	Value
O_2 in flue gas	%	10.30
CO_2 in flue gas	%	6.2
CO in flue gas	ppm	76

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: Savings and Cost benefit analysis for excess air control in kiln [ECM-1]

Parameters	UOM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	10.30	5.0
Excess air percentage in flue gas	%	96.3	31.3
Dry flue gas loss	%	42%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	kg/t	823.44	770
Average production in Kiln	t/h	2.9	2.9
Saving in specific fuel consumption	kg/h		152.57
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual fuel saving	t/y		1208
Fuel cost	Rs/t		3,200
Annual fuel cost saving	Lakh Rs/y		38.7
Power saving in combustion blower			
Mass flow rate of air	t/h	26.91	17.99
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	6.1	4.1
Total pressure rise	Pa	337.29	337.29
Measured power of blower	kW	2.058	1.38

Parameters	UOM	Present	Proposed
Motor power	kW	4.2	2.8
Motor efficiency	%	90	90
Shaft power	kW	0.0	2.809
Fan efficiency	%	49%	49%
Operating days per year	d/y		330
Operating hours per day	h/d		24
Annual energy saving	kWh/y	3,881	
Weighted electricity cost	Rs/kWh	7.55	7.55
Annual energy cost saving	Lakh Rs/y		0.29
Overall energy cost saving	Lakh Rs/y		38.96
Estimated investment	Lakh Rs		18.48
Payback period	Months		5.69
Project IRR	%		164
Discounted payback period	Months		2.23

3.1.4.2 ECM #2: Waste heat recovery from flue gas of kiln

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 250°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 increase the temperature of combustion air entering the Kiln.

Recommended action

It is recommended to decrease the smoke temperature from 250°C to 200°C at the outlet of recuperator, thereby increasing the heat utilization in kiln and increasing the temperature of combustion air entering in kiln. This would help to reduce amount of fuel consumption.

Table 24: Savings and cost benefit analysis for waste heat recovery from flue gas of kiln [ECM-2]

Parameters	UOM	Value
Smoke temperature at smoke blower	°C	250
Smoke flow rate	t/h	14.94
Waste gas flow	kg/h	14.90
Specific heat of waste gas	kCal/kg °C	0.24
Smoke temperature after recuperator	°C	200
Heat available in smoke	kCal/h	179,247
Heat utilization	%	100
Specific heat of FD blower air	kCal/kg °C	0.24
Thermic fluid temperature at ambient	°C	35
Combustion air flow	m^3/h	25,038
Density of combustion air	kg/m^3	1.20
Mass flow rate of Combustion blower air	kg/h	14,937
Effectiveness of HE	%	90.0

Parameters	UOM	Value
FD blower air temperature after recuperator	°C	**80.0**
Heat saving	kCal/h	179,247
GCV of coal	kCal/kg	3500
Fuel savings	kg/h	51.2
Operating hours per day	h/d	24
Operating days per year	d/y	330
Coal gas price	Rs/kg	3.2
Annual running hours per year	h/y	7,920
Annual coal saving	kg/y	405,611
Net monetary saving	Rs Lakh/y	13.0
Estimated Investment	Lakh Rs	55
Payback period	Months	51
Project IRR	%	1
Discounted payback period	Months	17.09

3.2 Coal Gasifier

3.2.1 Specifications

Coal gasifier produces coal gas from coal at controlled combustion by partial combustion using coal and water vapor. Coal gas is used in kiln and horizontal dryer. The specification of coal gasifier is given below:

Table 25: Specifications of coal gasifier

Parameters	UOM	Value
Make		Radhey Renewable Energy Development Ltd.
Coal consumption	t/d	16
Water consumption	l/d	4,008
FD Blower	kW	2 x 15
Cooling water pump	kW	2 x 15

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Measurement of power consumption of FD blower
- Air flow measurement of FD blower
- Coal consumption in gasifier
- Volume of coal gas produced by gasifier

During the DEA, the kiln cycle time was 50 minutes. The coal consumption of gasifier was 13.6 t/d. FD blower was operating with VFD. Average power consumption of FD blower is 4.15 kW (PF 0.99) and air flow is 1,905 m^3/h at FD fan suction. The volume of coal gas generated by gasifier is 2,767 sm^3/h.

3.2.3 Observations and performance assessment

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, Specific thermal consumption will be considered as how much coal consumed for 1 scm coal gas produced in plant which is 0.24 kg/scm. Since blowers are operating with VFDs, no energy conservation measure is proposed for the same.

3.3 Dryer

3.3.1 Specifications

There is one horizontal dryer for the clay ball mill. These are used for pre-heating of tiles before entering into kiln. The specifications of dryers are given below table:

Table 26: Specifications of horizontal dryer

Parameters	UOM	Value
Capacity	Nos. of tiles/h	1,500
Fuel type		Coal Gas
Rated fuel consumption	scm/h	-
Exit temperature of tiles	°C	130
Combustion blower	hp	1 x 30

3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

a) Mass flow study
b) Temperature of each tile at exit
c) Power consumption of blowers
d) Gas consumption data

Data measured during study is tabulated below:

Table 27: Field measurement at site

Parameters	UOM	Horizontal dryer
Tiles passed through dryer	Nos/h	1,500
Mass of each tile at entry	g	2,303
Mass of each tile at exit	g	1,928
Temperature of tile at exit	° C	130
Gas consumption	scm/h	335

Hot air blower discharge duct from kiln is utilized in horizontal dryer which helps in fuel savings. All blowers are operating with VFDs.

The power profile and PF profile of horizontal dryer is attached in annexure-4.

Average power consumption of Horizontal dryer is 19.93 kW (PF 0.99).

3.3.3 Observation and Performance assessment

There is no metering for coal gas present in horizontal dryer. The energy balance for the horizontal dryer is mentioned below.

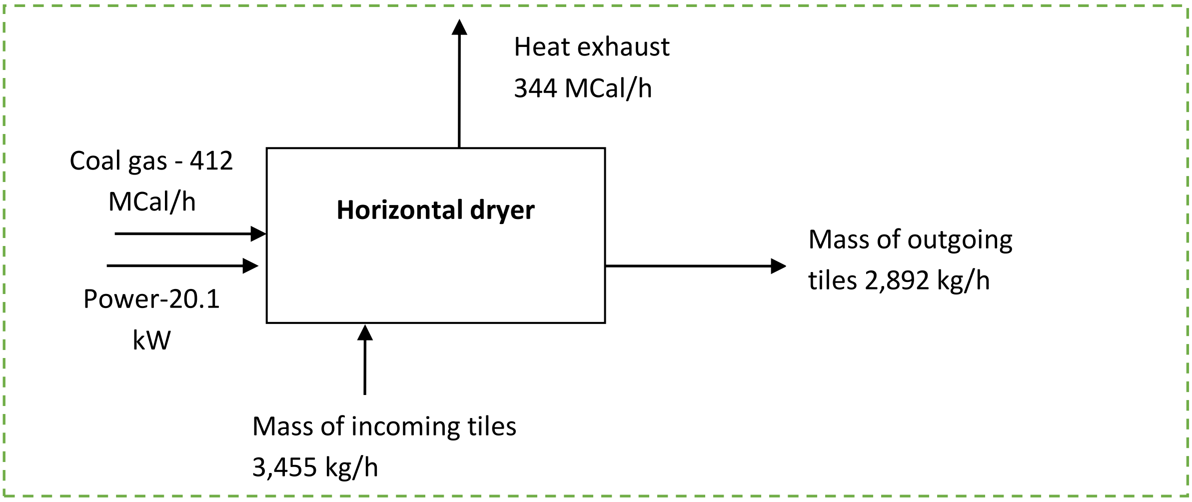


Figure 15: Mass and energy balance of horizontal dryer

Based on observations during DEA, the specific electricity consumption of horizontal dryer is 7.17 kW/ton of tile and specific thermal energy is 5.7 kg/ton of tile.

Since blowers are VFD controlled, hot air is utilization and operation is optimized. No energy conservation measure is proposed.

3.4 Hot Air Generators & Spray Dryers

3.4.1 Specifications

There is one hot air generator (HAG) of bubbling bed type, used for evaporating water from slip which is coming from ball mill. There is one spray dryer installed, which is taking heat from the bubbling bed HAG. Spray dryer is the heat exchanging unit for removing moisture from slip. Specifications of HAG are given below:

Table 28: Specifications of hot air generator (HAG)

Parameters	UOM	
Type		Bubbling bed
Air handling capacity	m^3/h	-
Fuel type		Coal
Rated fuel consumption	scm/h	-
Exhaust air temperature	°C	-
FD Blower	kW	2 x 55
Combustion blower	kW	1 x 112

The specifications of spray dryer are given below:

Table 29: Specifications of spray dryer

Parameters	UOM	Value
Powder generation capacity		-
Inlet slip moisture	%	40
Outlet powder moisture	%	6
Slip piston pump	kW	2 x 18.5

3.4.2 Field measurement and analysis

During field study, the HAG was not in operation, so measurements could not be done for the same.

4. CHAPTER - 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 CLAY BALL MILLS

4.1.1 Specifications

Clay ball mills produce slip by mixing clay, water and chemicals SMS and STPP. Clay ball mills take 3 to 6 hours for slip preparation. The specifications of ball mills and its accessories are given below:

Table 30: Specifications of ball mills

Parameters	UOM	Value
Numbers of clay ball mills	#	2
Capacity of each clay ball mill	t/batch	40
Water consumption in each clay ball mill	t/batch	13
SMS (chemical consumption)	Kg/batch	350
STPP (chemical consumption)	Kg/batch	30-35
Water TDS	ppm	700
Nos. of batch per day		4

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of clay ball mill #1
- Mass of raw material fed in clay ball mill

FD blower and cooling water pumps was operating with VFDs. All power profile is included in Annexure-4.

Average power consumption and power factor are given in below table:

Table 31: Average power consumption and PF of Big ball mill

Equipment	Average Power (kW)	PF
Ball Mill #1	149	0.94

Average power consumption of Ball Mill #1 is 149 kW (PF 0.94).

4.1.3 Observations and performance assessment

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

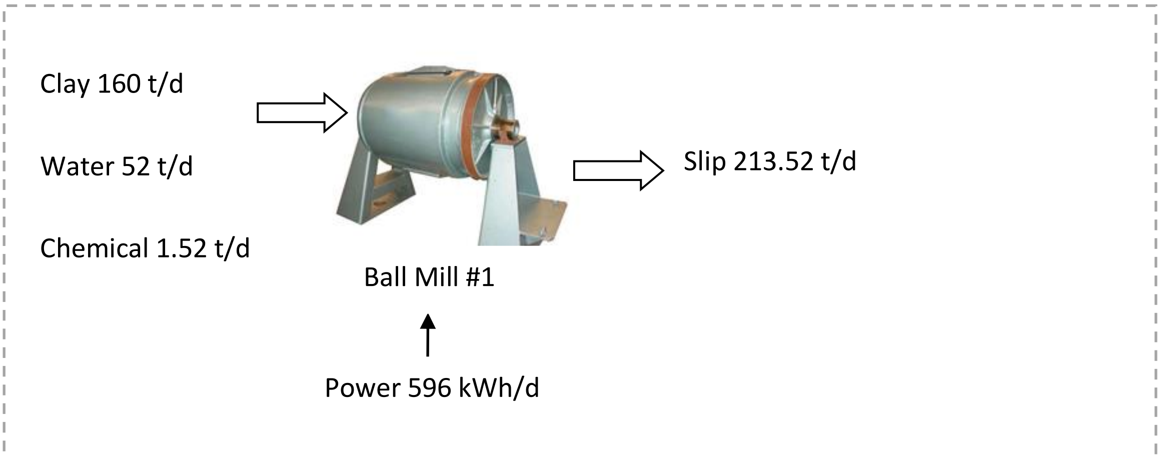


Figure 16: Energy and mass balance of Ball Mill

Performance of ball mills is measured in terms of specific energy consumption (power consumed for preparation of 1 ton of slip). Based on observations during DEA, the specific energy consumption of coal was 2.1 kW/t.TDS of bore well water is very high; this should be controlled by installing softener plant, which will enable resource savings.

4.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.1.4.1 ECM #3: Using soft water in clay ball mill

Technology description

It was observed that the TDS of water used in clay section is 700 ppm, which results in higher consumption of water, chemicals and electricity per batch of slip preparation and later higher coal consumption for spray dryer.

Study and investigation

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

Recommended action

It is recommended to install water softener plant which will blend RO water with raw water to get desired TDS of water(less than 400 ppm) to be used in ball mill. Resource saving has been considered for water, chemicals, coal and power consumption to arrive at techno economics of the proposed energy conservation measure. Coal consumption will be reduced due to reduced quantity of water to be evaporated in spray dryer.

Estimated cost benefit is given in the table below:

Table 32: Savings and cost benefit analysis for using soft water in clay ball mill [ECM-3]

Parameters	UOM	Present	Proposed
Existing TDS of raw water	ppm	700	400
Assumption : Water saving			15%
Assumption : Electricity saving			3%

Parameters	UOM	Present	Proposed
Assumption : Fuel saving			30%
Assumption : Chemical saving			30%
Water used per batch	m^3	13.00	11.05
Water saving	m^3		1.95
Electricity used per batch	kWh	149	145
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kCal/kg	3,500	3,500
Eff. Of HAG	%	85	85
Coal saving per batch	kg		403
Chemical saving per batch			
SMS	kg	350	245
STPP		30	21
Per Unit Cost			
Water	Rs/m^3	3.14	3.14
Electricity	Rs/kWh	7.55	7.55
Coal	Rs/kg	3.20	3.20
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost savings per batch	Rs		4,405
Total batches per day	#	4	4
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		2,574
Electricity	kWh/y		5,903
Coal	t/y		532.1
Chemical	kg/y		150,480
Annual cost savings	Lakh Rs/y		58.14
Operating cost- Water treatment	Rs/m^3		20
	Lakh Rs/y		2.92
Net monetary savings	Lakh Rs/y		55.23
Estimated investment	Lakh Rs		30
Payback period	Months		6.52
Project IRR	%		140
Discounted payback period	Months		2.52

4.2 HYDRAULIC PRESSES

4.2.1 Specifications

Hydraulic presses give shape for powder that is coming from spray dryer in tiles form by pressing powder with high pressure. Hydraulic oil gets heated when pressed so that it is required to be cooled in heat exchanger where water circulates as cold media. The specifications of presses and its accessories are given below:

Table 33: Specifications of hydraulic press

Parameters	UOM	Press-2560	Press-2000
Cycle (stroke) per min	N/m	11	10

Parameters	UOM	Press-2560	Press-2000
Nos. of tiles per stroke		2	2
Water circulation pump	#s	1	1

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all water circulation pumps
- Count of tiles processed

Average power consumption of water circulation pump 1 is 5.93kW (PF 0.8), water circulation pump 2 is 7.11kW (PF 0.75).

Tiles are being produced from press-2560 were 2.7 tonnes per hour and press-2000 is producing 2.52 tonnes per hour.

4.2.3 Observation and performance assessment

Both circulation pumps operates 24 hours in a day while press has frequent shut down. So it is suggested that pump operation must be controlled by sensing return oil temperature from press.

Performance of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press-2560 was 16.9kW/ton and that off the press-2000 was 17.2kW/ton.

4.2.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.2.4.1 ECM #4: PID Controller at water circulating pump for press

Technology description

Cooling water is circulated in heat exchanger of press machine for oil cooling. A PID controller for cooling water pump will ensure operation of pump only when it is required based on temperature set point.

Study and investigation

It was observed that cooling water pump is running continuously irrespective of the operation of the press and this pump is consuming 6.5kW.

Recommended action

It is recommended to install PID based controller which will ensure that pump will start only when oil temperature is >38°C; and once this temperature is maintained, pump will stop automatically. The cost benefit analysis for this project is given below:

Table 34: Savings and cost benefit analysis for PID Controller at water circulating pump for press [ECM-4]

Parameters	UOM	Present	Proposed
No. of cooling tower	#	2	2
No. of cooling tower Pump	#	2	2
Rated power of pump	kW	5.5	5.5

Parameters	UOM	Present	Proposed
Operating power	kW	6.5	6.5
Operating hours per day	h/d	24	15
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	103,277	32,274
Annual electricity saving	kWh/y		71,003
Unit cost of electricity	Rs/kWh		7.55
Annual monetary savings	Lakh Rs/y		5.36
Estimated Investment	Lakh Rs		0.53
payback period	Months		1.19
Project IRR	%		746
Discounted payback period	Months		0.48

4.3 Agitator

4.3.1 Specifications

Slip stored in agitation tank after preparation in ball mils where agitator motors (stirrer) were rotating continuously. Stirrer avoids settling of slip. The specifications of agitator motors are given below:

Table 35: Specifications of agitators

Parameters	UOM	Value
Numbers of agitators in tank	#	15
Capacity of each agitator motor	kW	2.2
Number of motors	#	15

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors
- Mass of slip fed to agitators

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

Table 36: Power consumption and P.F. of agitator motors

Equipment	kW	PF
Agitator#1 (Tank 3)	3.13	0.59
Agitator#2(Tank 3)	1.19	0.29
Agitator#3(Tank 3)	2.48	0.45
Agitator#1(Tank 4)	2.21	0.51
Agitator#2(Tank 4)	1.23	0.51
Agitator#3(Tank 4)	1.39	0.41
Agitator#1(Tank 5)	1.55	0.38
Agitator#2(Tank 5)	1.62	0.44
Agitator#3(Tank 5)	1.74	0.40

4.3.3 Observations and performance assessment

All agitator motors were running at poor power factor. During DEA, it is observed that out of 15 agitators, 9 motors were in operation and the total mass of slip fed to the agitators was 19 t/h. It is suggested that all motor should operated by timer control.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slip). Based on observations during DEA, the specific energy consumption of agitator motors were 1.12kW/ton.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 ECM #5: Timer Controller for stirrer motor

Technology description

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

Study and investigation

It was observed that all the 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 37: Savings and cost benefit analysis for time controller in stirrer motor [ECM-5]

Parameters	UOM	Present	Proposed
No of agitator stirrer	#	15	15
No of agitator stirrer running	#	15	15
Rated power of agitator stirrer motor	kW	2.2	2.2
Daily running of each stirrer motor	h/d	24	12
Operating days per year	d/y	330	330
Rated power of agitator stirrer motor	kW	1.84	1.8
Annual energy consumption	kWh/y	218,328	109,164
Annual energy saving	kWh/y		109,164
Unit cost of electricity	Rs/kWh		7.55
Annual monetary savings	Lakh Rs/y		8.24
Estimated investment	Lakh Rs		1.27
Payback period	Months		1.85
Project IRR	%		486
Discounted payback period	Months		0.74

4.4 GLAZING

4.4.1 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 38: Specifications of glazing machine

Parameters	UOM	Value
Numbers of glaze ball mill	Nos.	3
Capacity of glaze ball mill	kW	1 x 18.6, 1 x 15, 1 x 3.7

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of Glaze ball mill (15 kW)
- Mass of glazing material entering Glaze ball mill

Power consumption and P.F. of Glaze ball mill (15 kW) are given in below table:

Table 39: Power consumption and P.F. of glaze ball mill

Equipment	kW	PF
Glaze Ball Mill (15 kW)	8.57	0.56

The mass of glazing material entering the Glaze ball mill is 3.45 t/h.

4.4.3 Observations and performance assessment

During DEA, it was found that the Glaze Ball Mill (15 kW) was operating at poor power factor. Performance of glaze ball mill is measured in terms of specific energy consumption (power consumed for holding 1 ton of slip). Based on observations during DEA, the specific energy consumption of agitator motors were 2.86 kW/t.

4.5 SIZING

4.5.1 Specifications

There were two sizing machines present and the specifications of sizing machines are given below:

Table 40: Specifications of sizing machine

Parameters	UOM	Sizing machine -1	Sizing machine -2
Capacity of head motors	kW	20 x 2.2	20 x 2.2
Capacity of main belt servo motor	kW	2 x 5	2 x 5
Capacity of belt servo motor	kW	4 x 1	4 x 1

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of Sizing machine-1 & 2
- Daily tiles production of each sizing machine

Average power consumption and boxes production from sizing machines are tabulated below:

Table 41: Measured Parameters of sizing machine

Equipment	Average Power (kW)	Average boxes production (boxes/d)
Sizing machine-1 & 2	38.2	6,200

4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption was 13.4kW/ton for Sizing machine-1 & 2.

4.6 AIR COMPRESSORS

4.6.1 Specifications

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

Table 42: Specifications of compressors

Parameters	UOM	Air compressor 1	Air compressor 2
Power rating	kW	37	22
Maximum pressure	Bar (a)	8	7
Air handling capacity	m^3/m	6.35	3.85

4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all compressor

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

Table 43: Measured parameters of compressors

Equipment	Average power (kW)	PF	% of time on load
Compressor-1	30.1	0.90	48
Compressor-2	20.5	0.77	56

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

4.6.3 Observation and performance assessment

The specific energy consumption of compressors cannot be determined as there were no compressed air flow meters and FAD test could not be conducted.

4.6.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.6.4.1 ECM #6: Retrofit of VFD in compressor #1

Technology description

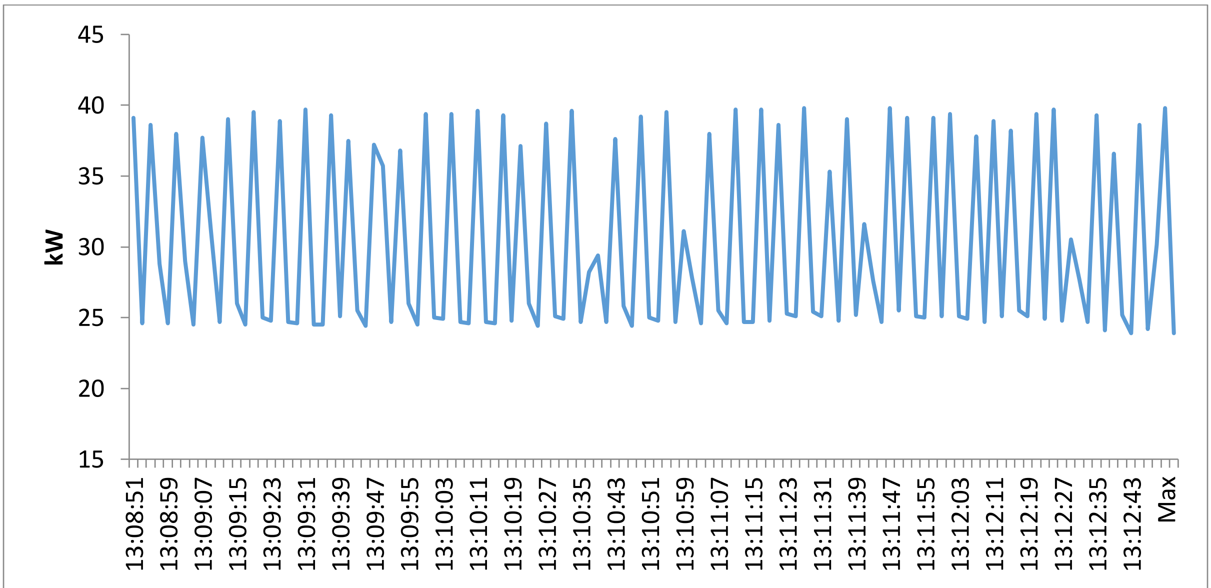
In any industry, compressor requirement keeps on varying based on the production demand and hence air compressor will run in load/unload sequence as per demand. During the unload condition air compressor will consume about 30% power without doing any work. A VFD can take care of this variable air demand by changing the RPM of compressor motor based on pressure feedback received from pressure sensor.

As the demand reduces, pressure will increase, hence compressor RPM will reduce. Similarly, when there is high demand pressure will reduce during this period VFD will raise the RPM of motor to meet the demand.

Study and investigation

Power cycles of all two compressors were captured to understand unload/load pattern of air compressor. There was only one receiver and it was not possible to conduct FAD test for compressor.

The power recording of both the compressors are mentioned below.



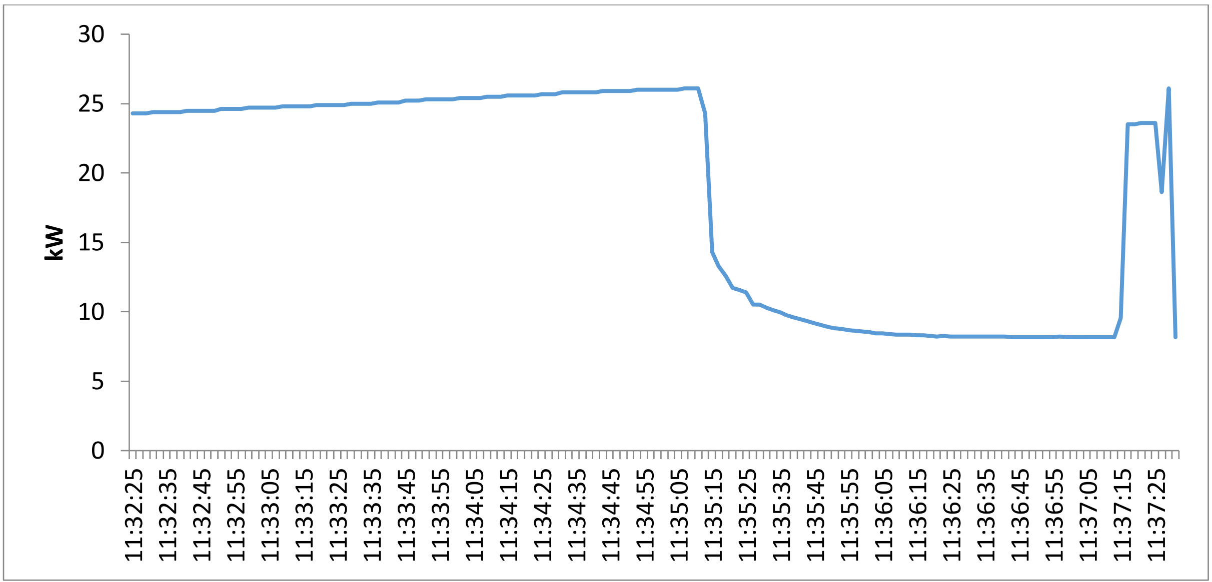


Figure 17: Load/Unload pattern of Compressor#1 and Compressor#2

Recommended action

It is recommended to install VFD on compressor #1. The cost benefit analysis for this project is given below:

Table 44:Saving and cost benefit analysis for retrofit of VFD in compressor #1 [ECM-6]

Parameters	UOM	Present	Proposed
Compressor motor rating	kW	37	37
Average power consumption during loading	kW	35	-
Average power consumption during unloading	kW	25	-
On load time in percentage	%	48.18	-
Off load time in percentage	%	51.82	-
Average power consumption	kW	29.82	25.34
Operating hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	236,155	200,732
Annual energy saving	kWh/y		35,423
Unit cost of electricity	Rs/kWh		7.55
Annual monetary savings	Lakh Rs/y		2.67
Estimated Investment	Lakh Rs		1.39
payback period	Months		6.22
Project IRR	%		146
Discounted payback period	Months		2.44

4.6.4.2 ECM #7: Reduction of pressure of compressed air

Technology description

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

Study and investigation

During DEA, it was found that the compressor #1 was generating compressed air at 6 kg/cm^2 and the pressure requirement at the end utilities were around 4 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 45: Saving and cost benefit analysis for reduction of pressure of compressed air [ECM-7]

Parameter	UOM	Present	Proposed
Operating pressure required	kg/cm²	6	5
Cut off pressure	kg/cm²	7	6
Reduction in pressure	kg/cm²	-	1
% of energy saving	%	-	6
Average load	kW	38	35.72
Operating hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	300,960	282,902
Annual energy savings	kWh/y		18,058
Unit cost of electricity	Rs/kWh		9.70
Annual monetary saving	Lakh Rs/y		1.75
Estimated Investment	Lakh Rs		-
Payback period	Months		Immediate
Project IRR	%		-
Discounted payback period	Months		-

4.7 WATER PUMPING SYSTEM

4.7.1 Specifications

Pumping system comprises one bore well pump, two Press CT pumps and two gasifier CT pumps.

4.7.2 Field measurement and analysis

During DEA, the following measurements were done for the above mentioned pumps:

- Power consumption of Bore-well, Press CT and Gasifier CT pumps
- Water flow of Bore-well, Press CT and Gasifier CT pumps

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

Table 46: Operating details of pumps

Parameters	UOM	Press CT pump-1	Press CT pump-2	Bore well pump	Gasifier CT pump-1	Gasifier CT pump-2
Flow rate	m³/h	19.5	25.2	19.4	98.0	69.0
Total head	m	40	44	77	18	18
Motor Input Power	kW	5.9	7.1	9.5	10.2	7.4

4.7.3 Observation and performance assessment

Based on observations during DEA, the pump efficiency for above mentioned pumps ranges from 42-55%.

4.7.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.7.4.1 ECM #8: Replacement of inefficient pumps

Technology description

The above mentioned pumps are running at lower efficiency and are recommended to be replaced with new high efficiency pumps.

Study and investigation

All the pumps are running for about 20 hours/day.

Recommended action

Recommendations have been given to replace above pumps with energy efficient pumps. Measured parameters and the derived efficiency of the pumps are mentioned here under.

Table 47: Savings and cost benefit analysis by replacing inefficient pumps [ECM-8]

Design Parameters		Press CT Pump-1		Press CT Pump-2		Borewell		Gasifier CT Pump-1		Gasifier CT Pump-2	
	UOM	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Flow	m^3/h	-	-	-	-	-	-	-	-	-	-
Head	m	-	-	-	-	-	-	-	-	-	-
Pump I/P power	kW	6	3.0	7.5	4.2	10.0	5.7	10.0	6.7	7.0	4.8
Pump efficiency	%	49.86	75.00	58.82	75.00	59.31	75.00	65.23	75.00	63.30	75.00
Motor rated power	kW	6	3.0	7.5	4.2	10	5.7	10	6.7	7	4.8
Motor efficiency	%	85.00	95.00	85.00	95.00	85.00	95.00	85.00	95.00	85.00	95.00
Overall efficiency	%	42.38	71.25	50.00	71.25	50.41	71.25	55.44	71.25	53.81	71.25
VFD	Y/N	N		N		N		N		N	
VFD frequency	Hz	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Measured Parameters											
Flow rate	m^3/h	19.5	19.5	25.2	25.2	19.4	19.4	98.0	98.0	69.0	69.0
Suction pressure	kg/cm^2	-1.8	-1.8	-1.8	-1.8	-4.2	-4.2	-0.2	-0.2	-0.2	-0.2
Discharge pressure	kg/cm^2	2.20	2.20	2.60	2.60	3.50	3.50	1.60	1.60	1.60	1.60
Motor Input power	kW	5.9	3.0	7.1	4.2	9.5	5.7	10.2	6.7	7.4	4.8
Calculation											
Flow rate	m^3/s	0.00542	0.00542	0.00700	0.00700	0.00539	0.00539	0.02722	0.02722	0.01917	0.01917
Total head/head developed	m	40.0	40.0	44.0	44.0	77.0	77.0	18.0	18.0	18.0	18.0
Liquid horse power	kW	2.1	2.1	3.0	3.0	4.1	4.1	4.8	4.8	3.4	3.4
Motor shaft power	kW	5.0	2.8	6.0	4.0	8.1	5.4	8.7	6.4	6.3	4.5
Motor loading	%	83.6	95	80.6	95	80.8	95	86.7	95	89.9	95
Overall system efficiency	%	42	75	50	75	50	75	55	75	54	75
Pump efficiency	%	**49.9**	**75.0**	**58.8**	**75.0**	**59.3**	**75.0**	**65.2**	**75.0**	**63.3**	**75.0**
Operating hour per day	h/d		20		20		20		20		20
Annual operating days per year	d/y		330		330		330		330		330
Annual power savings	kWh/y		19251.2		18937.6		24993.3		22792.9		17489.3
Electricity tariff	Rs/kWh		7		7		7		7		7
Monetary savings	Lakh Rs /y		1.3		1.3		1.7		1.6		1.2
Estimated investment	Lakh Rs		0.6		0.6		0.6		0.6		0.6
payback period	months		5.3		5.3		5.3		5.3		5.3
Total monetary savings	Lakh Rs /y		**7.2**								
Total Estimated investment	Lakh Rs		**2.98**								
Payback period	Months		**5**								

Design Parameters		Press CT Pump-1		Press CT Pump-2		Borewell		Gasifier CT Pump-1		Gasifier CT Pump-2	
	UOM	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Project IRR	%		**182**								
Discounted payback period	Months		**1.95**								

4.8 Lighting System

4.8.1 Specifications

The plant lighting system includes:

Table 48: Specifications of lighting load

Parameters	UOM	CFL	CFL	Fluorescent tube light-T8	Fluorescent tube light-T5
Power consumption of each fixture	W	36	65	36	28
Numbers of fixtures	#	16	39	153	9

4.8.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 49: Lux measurement at site

Parameters	UOM	Value
Office	Lumen/m^2	160
Kiln control room	Lumen/m^2	120
Kiln area	Lumen/m^2	70
Press	Lumen/m^2	55
Old press	Lumen/m^2	60
Ball mill and agitators	Lumen/m^2	50
HAG and spray dryer	Lumen/m^2	55
Horizontal dryer	Lumen/m^2	65

4.8.3 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.

4.8.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.8.4.1 ECM #9: Replacement of inefficient lighting systems

Technology description

Replacing conventional lights like CFL and 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 55 CFL and 162 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 50: Savings and cost benefit analysis by replacement of inefficient lighting systems [ECM-9]

Parameter	UOM	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Type of fixture		CFL	LED	CFL	LED	FTL-T8	LED Tube Light	FTL-T5	LED Tube Light
Type of controller		Electronic	Driver	Electronic	Driver	Electronic choke	Driver	Electronic choke	Driver
Number of fixtures	#	16	16	39	39	153	153	9	9
Rated power of fixture	W/Unit	36	20	65	36	36	20	28	20
Consumption of choke	W	0	0	0	0	3	0	3	0
Operating power	W/fixture	36	18	65	40	39	20	31	20
Operating hours per day	h/d	15	15	15	15	15	15	15	15
Operating days per year	d/y	330	330	330	330	330	330	330	330
Annual energy consumption	kWh/y	2,851	1,426	12,548	7,722	29536.65	15147	1,381	891
Annual energy saving	kWh/y		1,426		4,826		14,390		490
Unit cost of electricity	Rs/kWh		7.55		7.55		8		7.55
Annual monetary savings	Lakh Rs/y		0.11		0.36		1.09		0.04
Estimated Investment	Lakh Rs		0.06		0.36		0.78		0.05
Payback Period	Months		7		12		8.59		15
Total Project IRR	%	99							
Total Discounted payback period	Months	3.59							

4.9 ELECTRICAL DISTRIBUTION SYSTEM

4.9.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (433V) by step down transformer (2.5 MVA). Automatic power factor correction system is installed in parallel to main supply. There were two DGs (capacity of 0.625 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeder which is shown in Figure 8.

4.9.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.9.3 Observations and performance assessment

After analyzing feeder power profiling, it is observed that the maximum kVA recorded during study period was **710 kVA**.

The voltage profile of the unit is satisfactory and average voltage measured was **415 V.** Maximum voltage was **424 V** and minimum was **404 V**.

Average total voltage and current Harmonics distortion found **8.2%** & **15.7%** 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.

4.9.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.9.4.1 ECM #10: Installation of 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 6.7kW.

Table 51: 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	415	646	8.03	15.7	0.68	14.5	3.76	0.19	3.14
		Maximum	424	974	9.30	19.1	1.50	17.6	6.60	0.50	4.00
		Minimum	404	401	6.80	11.2	0.10	9.7	0.40	0.00	2.40
	Y	Average	416	630	8.16	14.1	0.46	12.9	3.34	0.33	2.79
		Maximum	425	971	9.40	17.4	1.10	15.9	6.00	0.70	4.40
		Minimum	405	386	6.80	9.1	0.10	8.3	0.00	0.10	2.00
	B	Average	417	676	7.8	13.1	0.85	11.9	3.64	0.07	2.73
		Maximum	425	1011	9.0	15.7	1.40	14.2	6.10	0.30	3.90
		Minimum	406	429	6.6	9.5	0.10	8.6	0.70	0.00	1.90

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

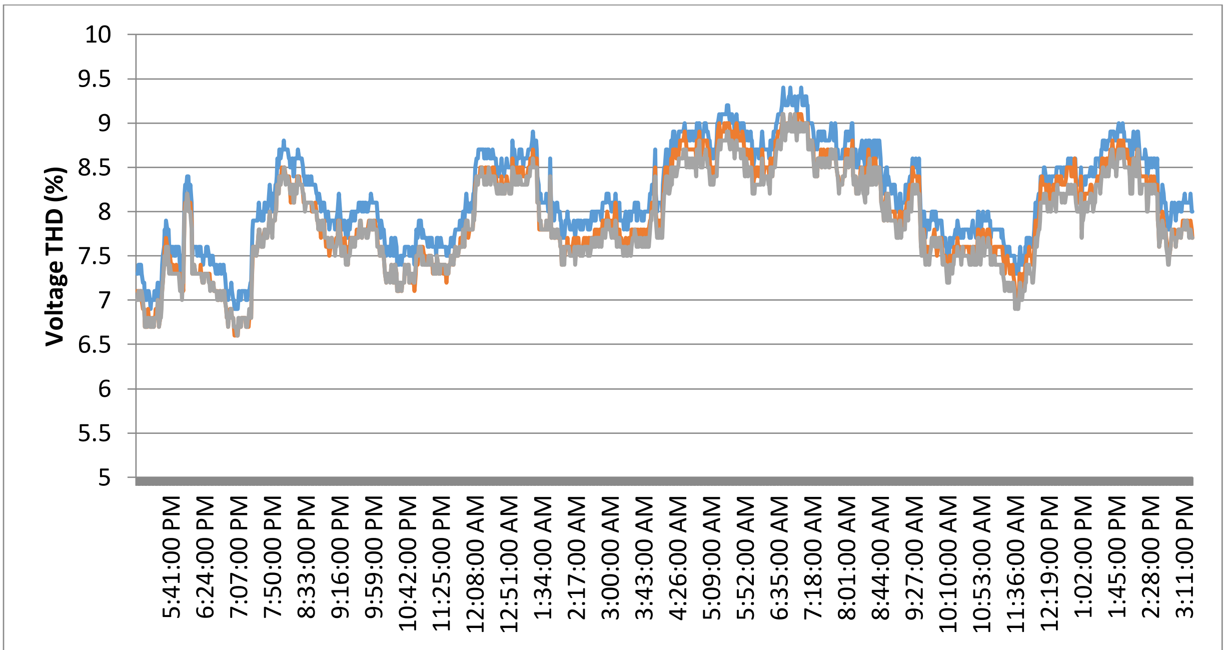


Figure 18: Voltage THD profile

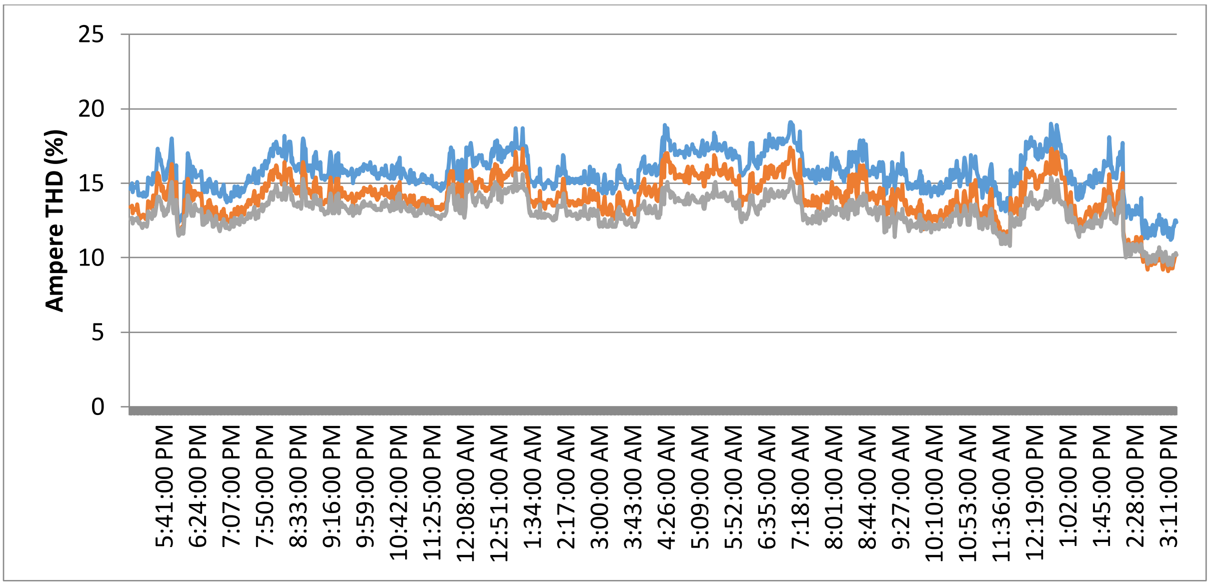


Figure 19: Ampere THD profile

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 60A**. 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 recommended 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 52: Savings and cost benefit analysis by installing harmonic filter [ECM-10]

Parameters	UOM	Present	Proposed
Estimated losses due to harmonics	kW	4.29	0
Saving potential by installation of active harmonics filter	kW	4.3	
Operating days	days	330	
Operating hours	hours	24	
Saving potential	kWh/y	33,998	
Unit cost of electricity	Rs/kWh	7.55	
Saving potential	Rs/y	256,590	
Estimated rating of active harmonics filter	Ampere	60	
Estimated cost of active harmonics filter	Lakh Rs	5	

Parameters	UOM	Present	Proposed
payback period	Months	22	
Project IRR	%	32	
Discounted payback period	Months	8.36	

4.9.4.2 ECM #11: Cable loss minimization

Technology description

It was observed that some of the outgoing feeders to sizing section has very poor factor.

Study and investigation

Electrical parameters were logged in these feeders and it was found that power factor was 0.60 in sizing section.

Recommended action

It is recommended to install power factor improvement capacitors for sizing section.
The cost benefit analysis for this project is given below:

Table 53: Savings and cost benefit analysis for cable loss minimization [ECM-11]

Parameters	UOM	Value
Existing power factor	pf	0.60
Proposed power factor	pf	0.98
Existing load	kW	38.2
Cable losses	W	446
Capacitor required	kVAr	42
Savings estimated	Lakh Rs/y	0.16
Total savings	Lakh Rs/y	0.16
Estimated investment	Lakh Rs	0.19
Payback period	Months	14
Project IRR	%	82
Discounted payback period	Months	4.17

4.9.4.3 ECM #12: Voltage optimization in lighting circuits

Technology description

In most of the industries, lighting load varies between 2-10%. Most of the problems faced by lighting equipment and the gears are due to the voltage fluctuations. Hence, the lighting circuit should be isolated from the power feeders. This provided a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lighting system. In many industries, night time grid voltages are higher than normal; hence reduction in voltage can save energy and also provide the rated light output.

A large number of industries have used these devices and have saved to the tune of 5-15%. Industries having a problem of higher night time voltage can get an additional benefit of reduced premature failure of lamps.

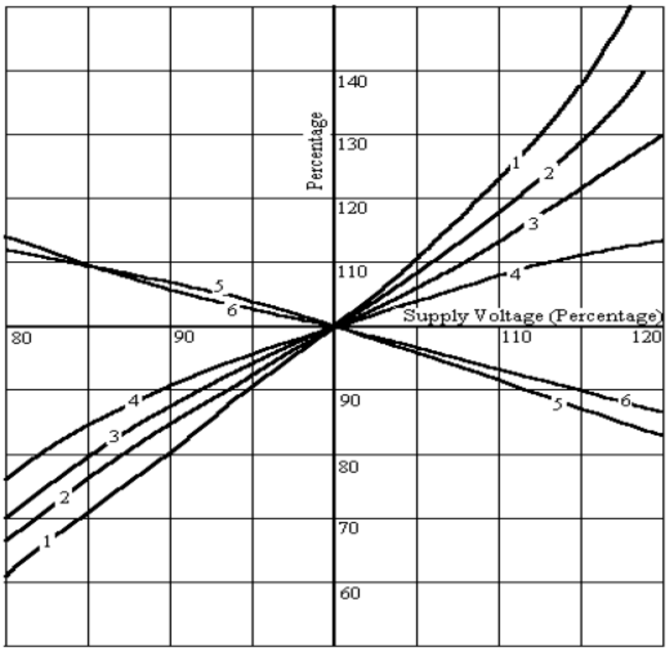


Figure 20: Effect of supply voltage on lamp parameters

Study and investigation

Lighting feeder measurements were carried out to estimate existing lighting load and the voltage level in the lighting circuit. Present lighting load in plant is 9kW and measured voltage level is 424V.

Recommended action

It is recommended to install separate lighting transformer of 15 kVA rating for lighting circuit to save energy, optimize voltage and also reduce premature failure of lamps. The cost benefit analysis for this project is given below:

Table 54: Savings and cost benefit analysis for Voltage Optimization in lighting circuit [ECM-12]

Parameter	UOM	Present	Proposed
Maximum load	kW	9	9
Maximum load	KVA	9.20	9.20
Maximum line voltage	V	424	380
Maximum phase voltage	V	246	219
Average line voltage	V	415	380
Average phase voltage	V	240	220
% reduction in voltage	%	8.4	
% reduction in energy consumption	%	16.06	
Average power factor		0.90	0.9
Annual lighting energy consumption	kWh/y	63,072	
Savings estimate from lighting EPIAs	kWh/y		21132
Actual energy considered for voltage regulation	kWh/y		41,940
Actual energy consumption after voltage regulation	kWh/y		35,206
Efficiency of servo Stabilizer	%		95
Assumption : Period for which voltage regulation is required	Months/y		12

Parameter	UOM	Present	Proposed
Net saving from voltage regulation	kWh/y		6,398
Electricity tariff from grid only	Rs/kWh	7.55	
Annual monetary saving	Lakh Rs	0.5	
Sizing of servo stabilizer	kVA	11	
Rating of servo stabilizer	kVA	15	
Estimate investment	Lakh Rs	0.50	
Payback period	Months	12	
Project IRR	%	70	
Discounted payback	Months	5	

4.10 Belt Operated Drives

4.10.1 Specifications

There are 13 drives operated with V-Belts of total capacity of 890 kW. Locations include

- Kiln (5)
- HAG & Spray dryer (3)
- Clay ball mill (2)
- Glaze ball mill (3)

4.10.2 Field measurement and analysis

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

4.10.3 Observations and performance assessment

Maximum belts in plant are V-belt which are not energy efficient.

4.10.4 Energy conservation measures (ECM) - ECM #13: V-belt replacement with REC belt

Technology description

Replacing 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% more 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 at 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 13 belt drives 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 55: Replacement of conventional belt with REC belt [ECM-13]

Parameters	UOM	Present	Proposed
Total rated power of belt drives	kW	890	890
Energy saving	%		3.60%
Measured total power of belt drives	kW	213	206
Operating hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	1,688,728	1,627,934
Annual energy saving	kWh/y		60,794
Unit cost of electricity	Rs/kWh		7.55
Annual monetary savings	Lakh Rs/y		4.59
Estimated Investment	Lakh Rs		5.00
Payback period	Months		13
Project IRR	%		68
Discounted payback	Months		4.96

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 management system has been proposed for the unit and is mentioned below.

5.1.1 ECM #14: Energy management system

Technology description

Installation of energy management 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 2% from its present levels.

The recommended locations for the energy meter are:

- Clay ball mills
- Agitator motors
- Glaze ball mills
- Sizing machines
- Compressors
- Sprayer dryer (ID fan & Pump)
- HAG (FD & PA fan)
- CT pumps
- Glaze line and kiln
- Horizontal dryer

The cost benefit analysis for this project is given below:

Table 56: Savings and cost benefit analysis for energy management system [ECM-14]

Parameters	UOM	Present	Proposed
Energy management system for electrical system savings	%		2.00
Energy consumption of major machines per year	kWh/y	5,128,548	5,025,977
Annual electricity saving per year	kWh/y	0	102,571

Parameters	UOM	Present	Proposed
Average electricity tariff	Rs/kWh	7.55	7.55
Annual monetary savings	lakh Rs/y	0	7.74
Number of electrical equipments	#	40	40
No. of energy meters	#	0	40
Estimate of investment	Lakh Rs		3.99
Thermal energy monitoring system savings	%		2.00
Current coal consumption in kiln & HAG	kg/y	7,908,000	7,749,840
Annual coal saving per year	kg/y		158,160
Cost of coal	Rs/kg		3.20
Annual NG consumption	scm/y	-	-
Annual fuel saving	scm/y		-
Average NG cost	Rs/scm		-
Total annual monetary savings	Lakh Rs/y		5.06
Number of equipments or system	#	2	2
Number of coal weighing machines			2
Estimated Investment	Lakh Rs		2.64
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		12.80
Total estimated investment (Electrical + Thermal)	Lakh Rs		6.63
payback period	Months		6.21
Project IRR	%		148
Discounted payback period	Months		2.42

5.2 Best Operating Practices

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

Table 57: Unique operating practices at the unit

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installation to maintain power factor
2	Ball mill	VFD and timer control system for motors.
3	Agitation tank	None
4	Spray dryer and HAG	Cyclone separator and wet scrubber for reducing emission
5	Press	None
6	Vertical dryer and horizontal dryer	Waste heat from kiln is used in VD with supplementary firing but horizontal dryer is still running on fresh air with coal gas
7	Glaze ball mill	Timer controller for motors in each ball mill.
8	Glaze line	None
9	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
10	Sizing	Fully automatic system. Dust collected system to remove the dust from operating area.
11	Printing	Automated digital printing with fully auto control system
12	Lighting	LED lights

5.3 New/Emerging Technologies

Evaluation of the techno-economic viability of the following emerging and new technology options, are suggested here:

5.3.1 Dry Clay Grinding Technology: "Magical Grinding System "Technology description

"Magical Grinding System", a technology offered by Boffin - China, is a high-efficiency energy-saving ceramic raw material grinding process, which overcomes the drawbacks of traditional milling process in ceramic production, viz. high energy consumption and high cost of mill materials and consumables[2]. The main technical specifications are as follows:

Table 58 : Specifications of dry clay grinding technology

Parameter	UOM	Scenario-1	Scenario-2	Scenario-3
Moisture content of input material	%	5-7%	7-8%	8-10%
Production output	t/h	≥60	≤50	≤15
Power consumption	kWh/t	~7.5	~8.5	~11
Remarks		Low dust emission, steady output		When the moisture is higher than 8%, the output drops. The cost increases accordingly.

When water content of input materials ≤8% and size of materials <60mm, the overall equipment has a capacity up to 50 t/h, and unit energy consumption is lower than 8.5 kWh/t. Savings include reduction in power consumption by over 25% and reduction in consumables by over 25%.

The working principle is as follows:

- Grinding equipment are used to crush large pieces of different sizes into even, small-size materials (≤10-mesh sieve) – equivalent to rough grinding stage in ball mill. As against the conventional method of grinding by impact, in the dry grinding process, the size reduction is achieved by "squeezing method", where in the squeezing of the two working faces – grinding roller and grinding plate results in the force being fully applied on the materials with lower energy loss (and hence lower power consumption).
- Further, the grinding process optimizes the ball media grading of the ball mill, so as to increase contact of ball media and materials and increase grinding efficiency. Since this process features very small grain sizes of materials, it can directly enter fine grinding stage, without the need of rough grinding of large-size ball media.

Case Study New Pearl Ceramics and Beisite Ceramics Co., Ltd[3]:

After the implementation of dry grinding, the benefits accrued are:

a) Reduction in thermal energy consumption -70%
b) Reduction in water consumption- 75.4%
c) Reduction in power consumption -1%
d) Reduction in use of chemical additives – 100%

---

[2] The information in this section has been obtained from : http://www.guangdong-boffin.com/en/

[3] Case Study presented by Mr. Chaitanya Patel – Regional Manager-Guangdong Boffin at the Knowledge Dissemination Workshop for WT & FT units on 8th Feb- 19, under this project

e) Overall reduction in manufacturing costs – 44%
f) Reduction in abrasion
g) Reduction in ball milling time
h) Reduction in floor area required

5.3.2 Waste Heat Recovery from Kiln: SACMI Double heat recovery technology description

Heat recovery from roller kiln is most important feature to operate the kiln at optimum efficiency and reduce fuel consumption. The working principle of the heat recovery system with double heat recovery is as follows:

Cooling air may have temperature ranging from 120^{o}C to 250^{o}C (depending on whether cooling is with a single chimney or with double cooling circuit). Air is drawn from the fan and sent to a filter before being made available to the combustion air fan passing through heat recovery system to raise the combustion air temperature up to 250^{o}C. Final cooling air is also retrieved for use as combustion air, where the air is filtered and sent to combustion air fan before being heated via a heat exchanger in the fast cooling zone reaching temperature up to 250^{o}C depending upon the product and kiln temperature.

Figure 21: Heat recovery system for combustion air

The estimated benefits of double heat recovery include[4]:

- Fuel savings upto 10%
- Combustion air temperature up to 250^{o}C at burner
- Easy installation

A working installation of double heat recovery system is available at a vitrified tile unit in Morbi cluster.

[4] SACMI Kiln Revamping catalogue for roller kilns

5.3.3 Roller Kiln Performance Improvement by Total Kiln Revamping

The roller kiln is major energy consuming system in ceramic tile unit. Over a period of time, the losses from kiln increases for various reasons like operating practices, insulation deterioration, poor maintenance, high breakdown level etc. It is beneficial to upgrade the kiln performance by total kiln revamping including following systems[5]:

1. **Upgrading burners** with better technology and higher combustion efficiency with several benefits like:
    a. Broad working range
    b. Most stable flame detection
    c. Better flame speed
    d. Compatibility with burner block types
    e. Easy head cleaning procedure

2. **Heat recovery systems** – **Single and double heat r**ecovery for combustion air.
3. **NG fuel consumption monitoring kit** : Real time monitoring of gas consumption on operator panel and on kiln.
    a. Retrofittable and can be installed on dryers and kilns
    b. Real-time gas consumption monitoring on operator panel
    c. Instantaneous pressure and temperature readings
    d. Easy calibration

Figure 22: NG consumption monitoring kit

4. **Combustion air control:** The combustion system is divided in to 3 macro zones, each of which supplies a specific kiln zone namely: Pre-heating, Pre-firing and Firing zone. The operator panel can be used to adjust the air flow to burners in specific zones according to raw material recipe used in body clay, product and kiln conditions. Maximum efficiency is obtained by combining this modification with Oxygen Analyzer to optimize the amount of combustion air under all conditions and consequently, optimize product quality and fuel consumption both.

[5] SACMI Kiln Revamping catalogue for roller kilns

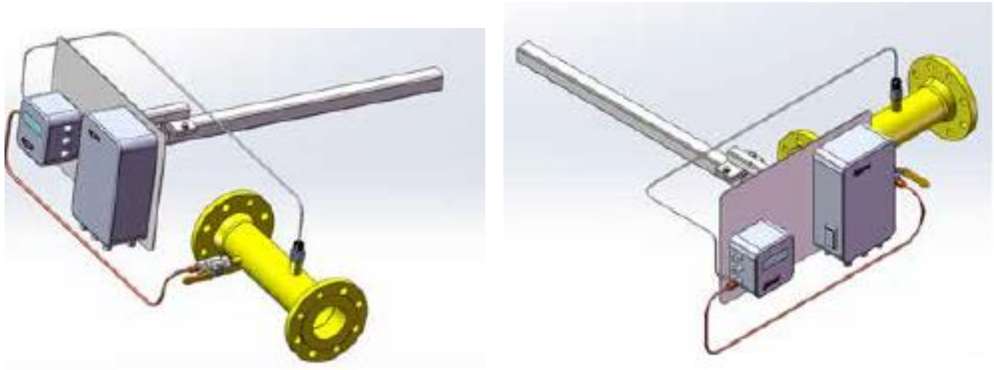


Figure 23: Combustion air control for burner

The combustion air circuit is modified to create three fuel feed macro-zones. Each macro-zone is, in turn, sub-divided into an upper branch and a lower one and each branch has a motorized valve connected to a pressure transducer. The system is completed by installation of an inverter on the fan and a pressure transducer on the main duct to keep circuit pressure stable under all operating conditions. The system is managed via a control panel, ensuring repeatability of settings and letting the user differentiate opening in the different zones according to production requirements. In the event of a gap in production valve aperture can be adjusted to a pre-defined setting. The advantages include:

- Flexibility – Air volume can be ser according to the product
- Fuel consumption optimisation
- Reduced consumption if there is gap in production
- 3 independent macro zones can be controlled separately

5. **Heat recovery from kiln to dryer:** The air is drawn from the final cooling chimney by a fan and sent via an insulated duct to the dryers. The booster fan is equipped with an inverter getting feedback from the pressure transducer mounted on the duct downstream from the fan helps to control the air transfer flow. The control panel is independent and can be installed /retrofitted on any machine. System parameters are constantly monitored by software to maximize the saving without changing the production cycle. The advantages of the system include:
    - Immediate savings
    - Control system to optimize the economic advantages
    - Complete integration with existing plant
    - Suitable for all kilns and dryers – horizontal and vertical
    - Quick return on investment

Figure 24: Heat recovery from kiln to dryer

6. **Fast cooling management:** This retrofit intervention involves modification of the fast cooling duct by separating the upper and lower circuit with motorized control valve which can be controlled from operator panel. Further modification to the duct can allow the creation of two separate fast cooling zones. Each zone has a general motorized valve which is controlled by a thermocouple; it also has a motorized valve with position control for both upper and lower channel separately. To complete the system, an inverter is fitted on fan drive motor and a pressure transducer is fitted on the main duct. All regulators and valves are controlled via operator panel. The advantages of the system include:
    - Complete control
    - Parameters can be changed / set as per RM recipe
    - Volume control in case of gap in production
    - Flow control via fan inverter
    - Adjustment flexibility in upper and lower roller bed

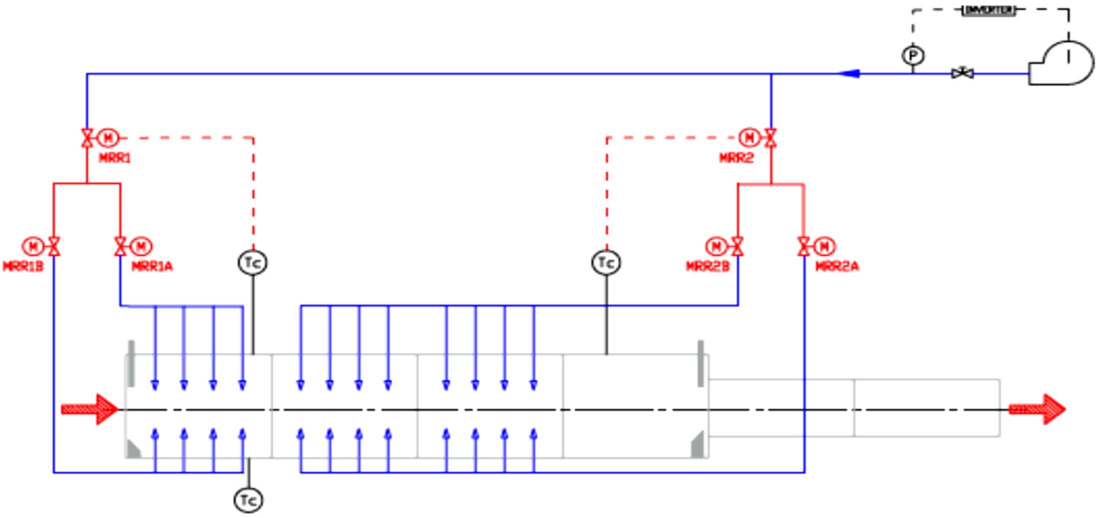


Figure 25: Fast cooling air management

7. **Industry 4.0 system for easiness in operation and real-time information:** Industry 4.0 system provides opportunity to make full use of data control and management system. These systems are modern, compatible with the most widely used data platforms and ensure machines can be

used flexibly with excellent usability of collected data. The technical features of such a system includes:

- Network connected PLC system for automation and operator/machine safety
- Simple user-friendly man-machine interface that can be used by operators in any situation
- Continuous monitoring of process parameters and working conditions using suitable sensors
- Adaptive - behavior system control in the event of any process drift
- Remote tele-assistance service allows modification of process parameters and updating the software
- PC/SCADA system allows monitoring, control and supervision of the machine using connection network
- Compete consumption and production database available to corporate network and to management software using internet or database SQL protocols.

Figure 26: Real time information system 4.0

The advantages of the system are:

- Production and consumption data can be shared with company management system
- Coordinated automation to plan production
- Remote/Tele-assistance system
- Productivity and plant problem analysis

5.3.4 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 27: - High Alumina pebbles for Ball mill

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

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

5.3.5 Use of Organic deflocculant in Ball Mill grinding process of Ceramic tiles

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[6]) to save fuel cost during spray drying. Slip is stored in tanks which will be sieved for sending to spray drying.

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 & spray drier nozzles, thus ensuring

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

proper granulometry of spray dried dust/clay, which is essential for achieving green tile strength. Deflocculants allows for achieving higher slurry density (more solids loading per litre of slurry) without increasing viscosity. For spray drying operation, achieving higher slurry density is important since more solids in slurry, less water to be evaporated in spray drier and less fuel consumption , making the operation viable commercially.

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 in terms of fuel cost in spray dryer

Since this is a new product, a small scale pilot is recommended to ascertain the cost and benefits.

5.3.6 Use of Organic Binder in Porcelain/Granite Tiles 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 vitrified/granite tiles, almost 75 % of raw materials are non-plastic in nature which contribute very less to green and dry strength. Special white firing clays which are not highly plastic are used in small quantity and do not impart sufficient strength. Organic binders like FLOBIND[7] 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

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

two parameters, yield stress, τ0, and plastic viscosity, μ, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.

- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost

Since this is a new product, a small scale pilot is recommended to ascertain the cost and benefits.

5.3.7 Use of Direct Blower Fans Instead of Belt Drive

There are a numbers of fans used in tile manufacturing, most of which are using belt drive system. The major application of blower fans in kiln is for combustion heating, cooling, recovery of hot air, exhaust / flue air etc. There are also other applications viz. 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. In order 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.
A few units in Morbi cluster are using direct drive fans.

Figure 28: Direct drive blower fan

6. Renewable Energy Applications

The possibility of adopting renewable energy measures was evaluated during the DEA. A rooftop area of 2,400 m^2 is available in the unit. The feasibility of installing solar PV in this area was evaluated. The corresponding solar energy generation potential is shown below.

Table 59: Solar PV installation

Particulars	UOM	Value
Available area on roof	m^2	4,000
Estimated total solar PV panel area	m^2	2,400
Number of panels (1m x 2m) of 320 Wp	#	1,200
Estimated installed capacity of solar panel	kW	384
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	1,613
Solar radiation days per year	d/y	365
Average electricity generation per year	kWh/y	588,672
Cost of Electricity	Rs/kWh	7.5
Annual monetary savings	Lakh Rs/y	44.43
Estimated Investment	Lakh Rs	211
Payback Period	Months	57
Project IRR	%	-4
Discounted payback period	Months	20

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

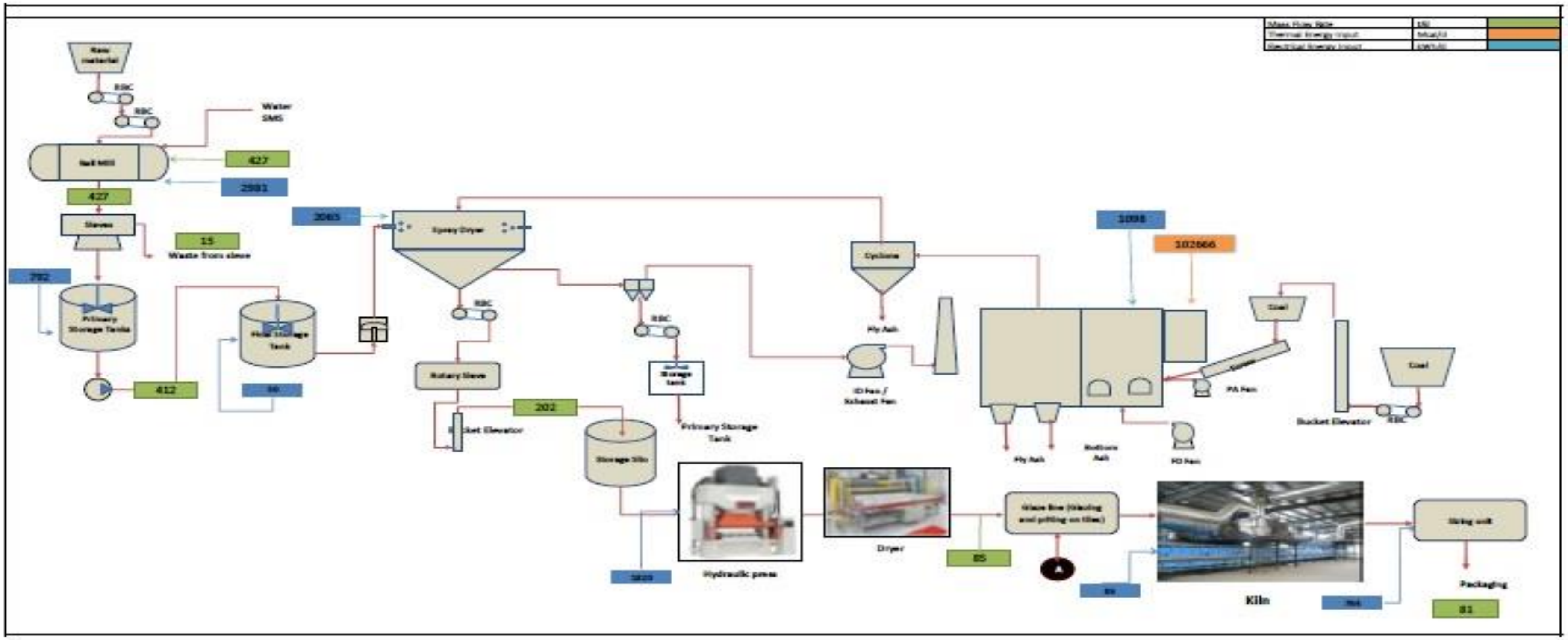


Figure 29: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 60: Detailed inventory list

Equipment name	Electrical load (kW)
Compressor	59
Press-2000	77.2
Press-2590	82.2
Press cooling towers	11
Dryer	85.25
Kiln	188.761
Sizing machine-1	58
Sizing machine-2	58
Coal gasifier	88
Glaze ball mills	49.3
Clay stirrer motors	33
Final tanks	11
Slip piston pumps	37
HAG & Spray dryer	257.245
Lights	8.799
Clay ball mill	320

7.3 Annex-3: Single Line Diagram

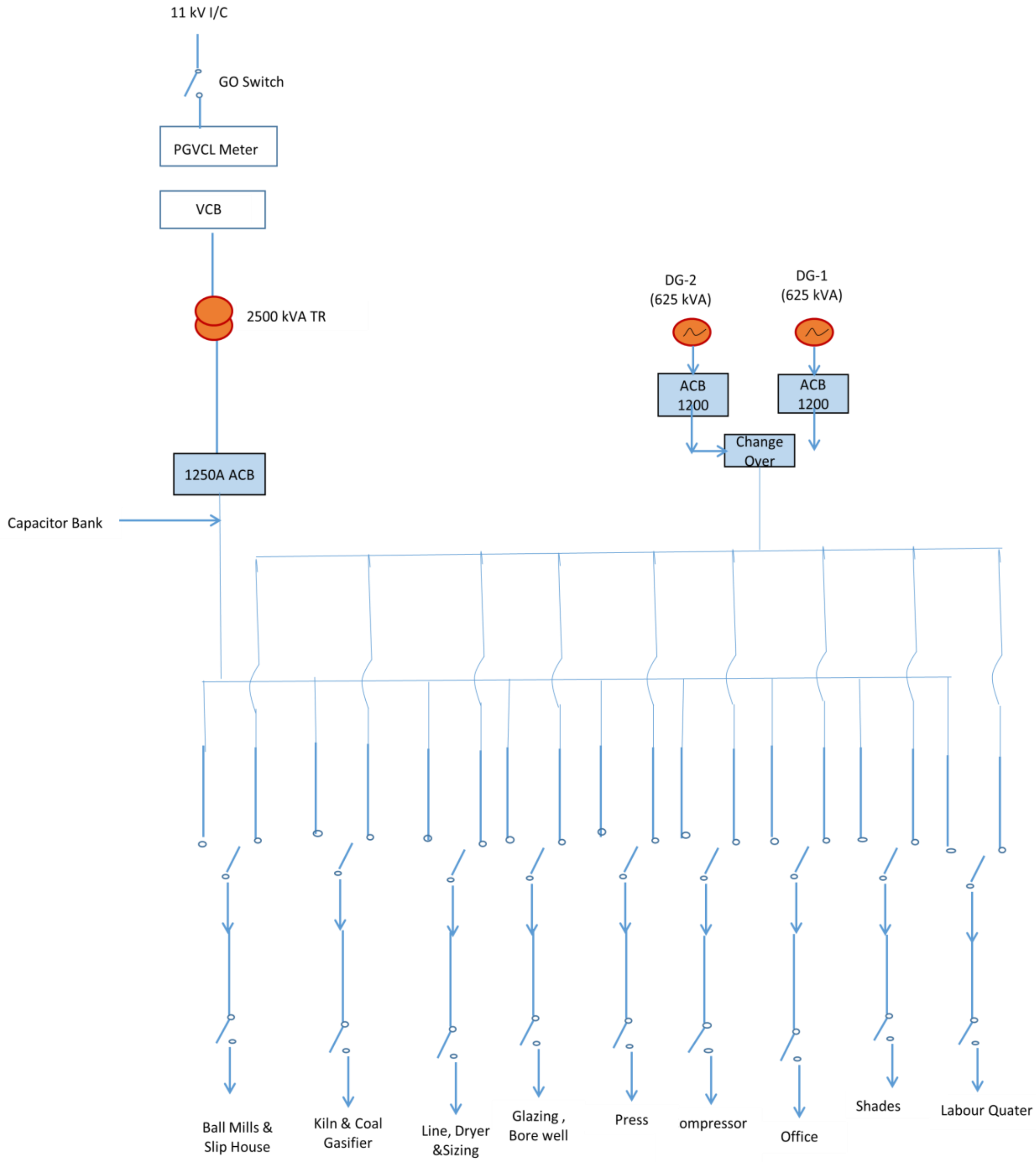


Figure 30: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

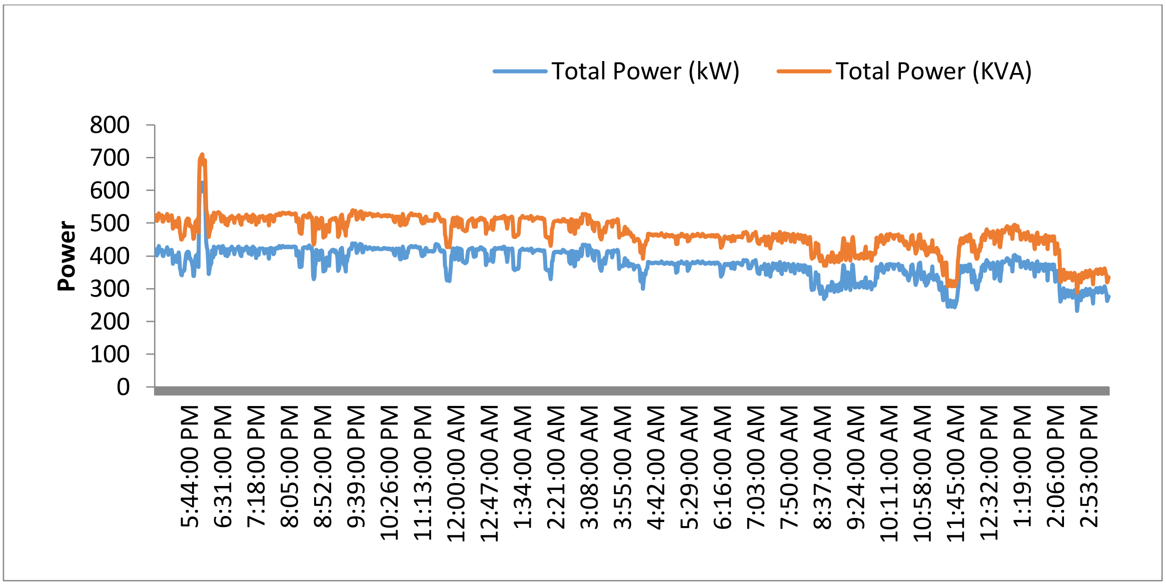
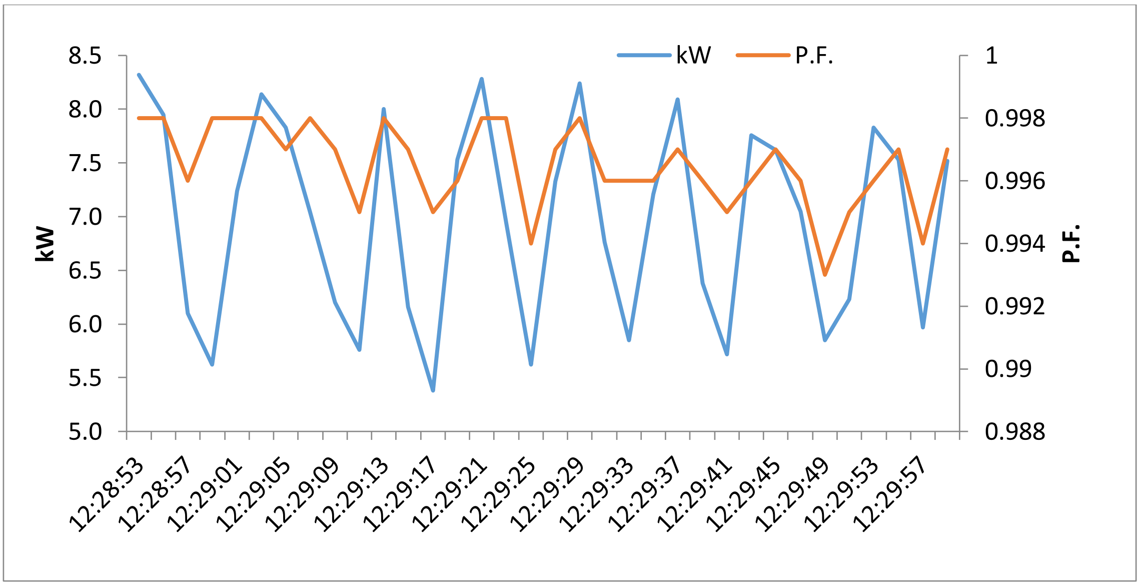
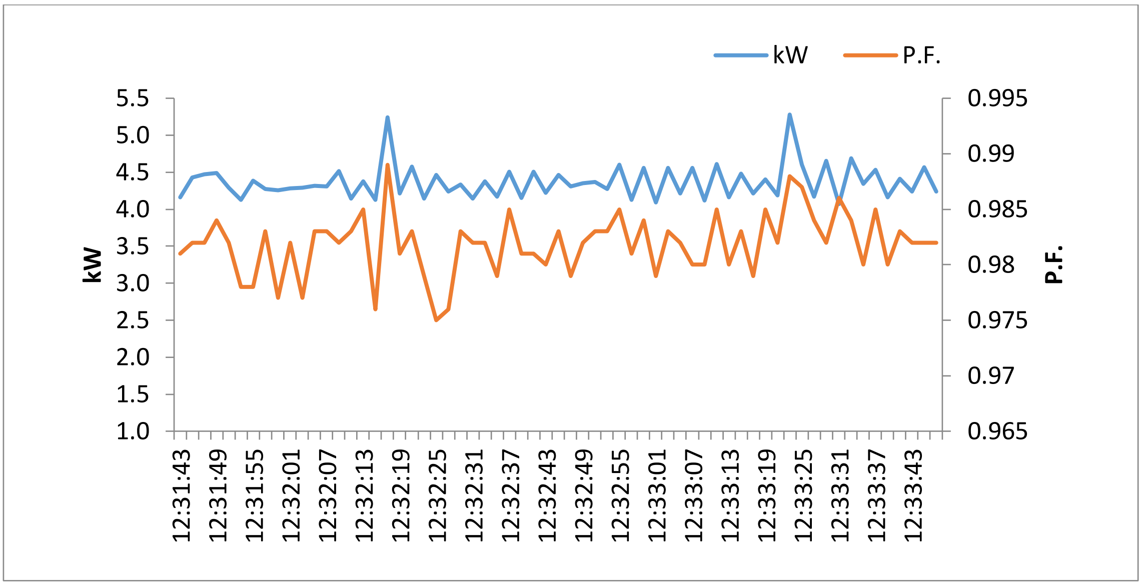


Figure 31: Power profile (kW & kVA) of Main Incomer





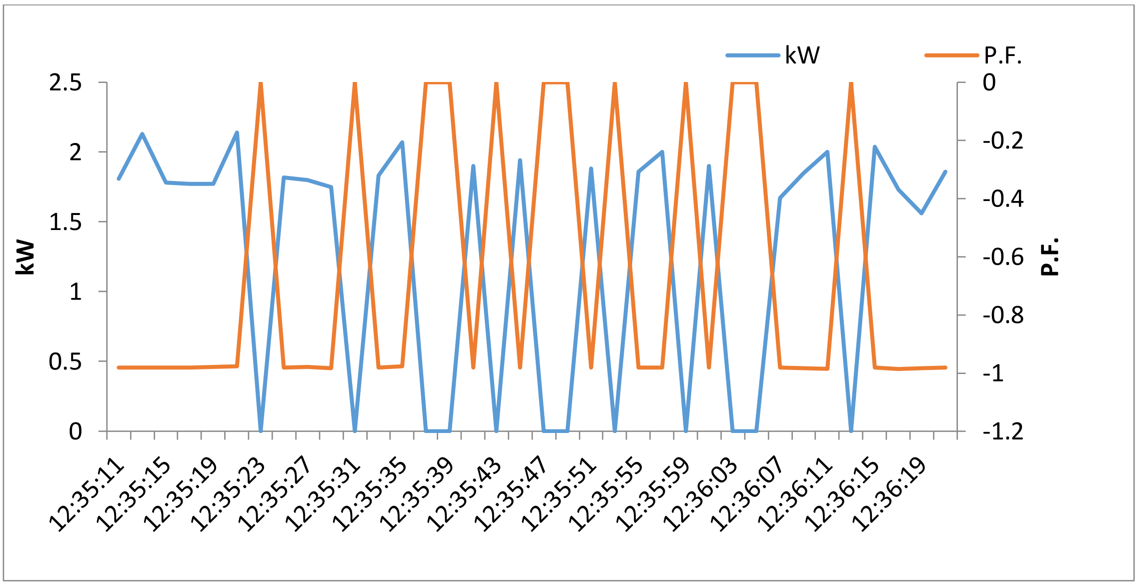


Figure 32: Power and PF profile of Blowers of kiln

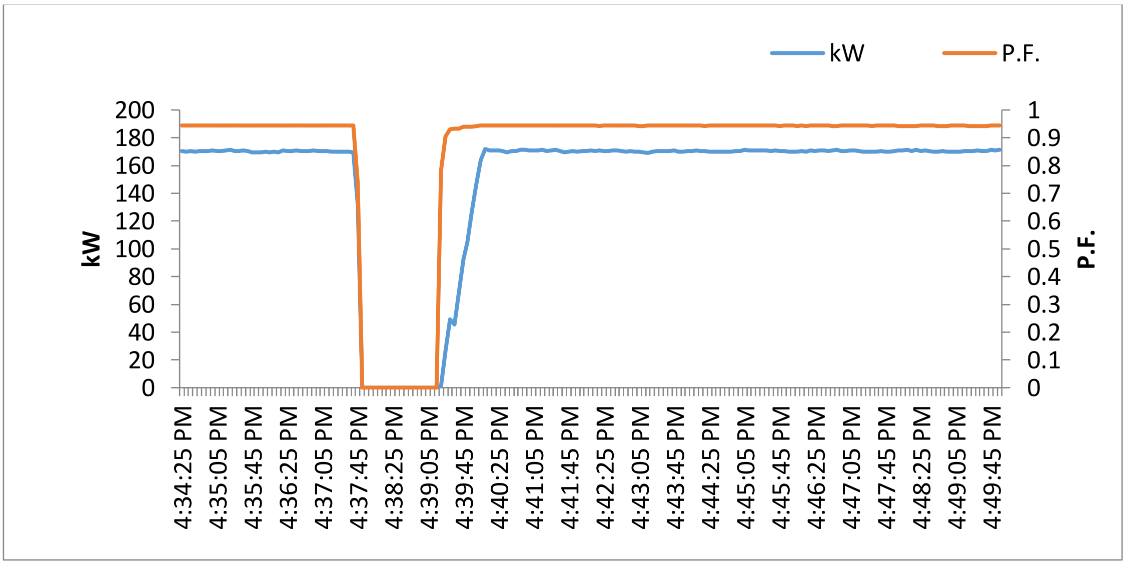


Figure 33: Power and PF profile of Ball Mill #1

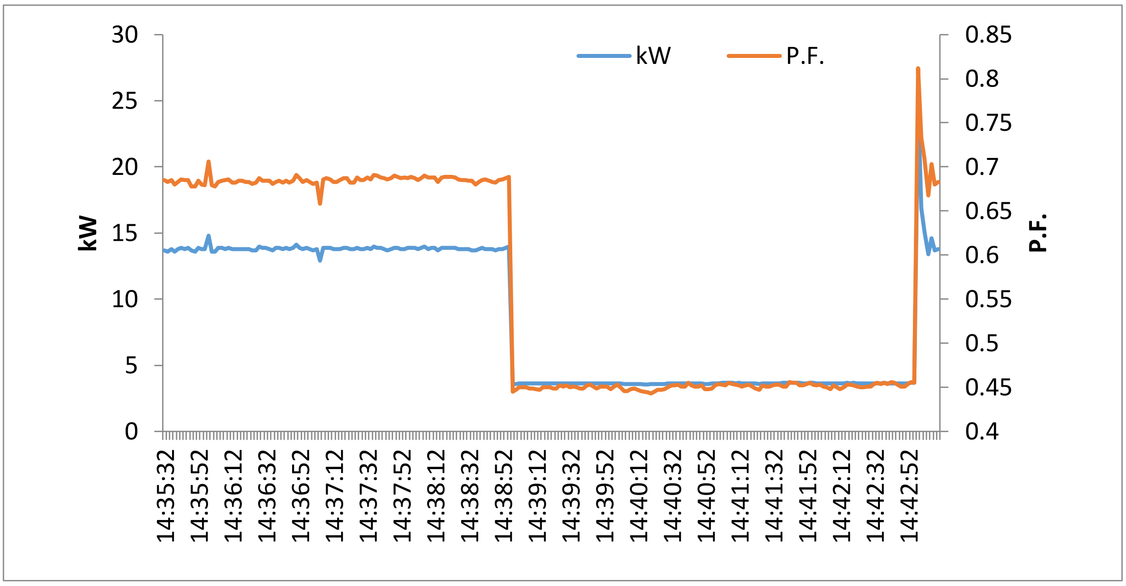


Figure 34: Power and PF profile of Glaze Ball Mill

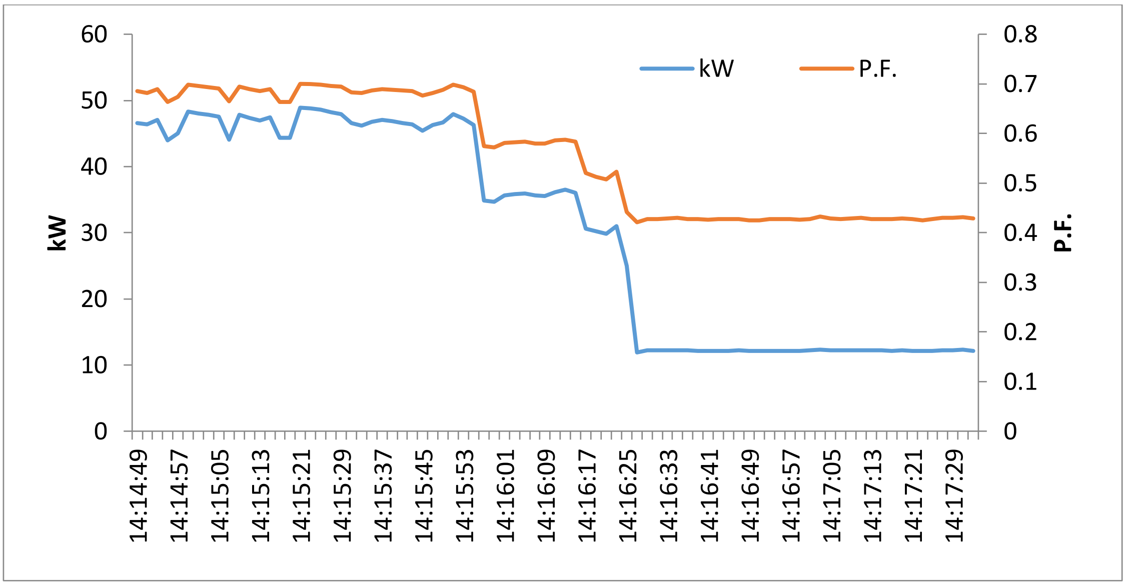


Figure 35: Power and PF profile of Sizing Machine

7.5 Annex-5: Thermal Measurements

1. Kiln heat utilization calculations

Input parameters

Input Data Sheet		
Type of fuel	Coal Gas	
Source of fuel	Gasifier	
Roller kiln operating temperature (Heating Zone)	1200	*Deg C*
Initial temperature of kiln tiles	40.2	*Deg C*
Avg. fuel consumption	2,246	*sm^3/h*
Flue gas temp at smog blower	230	*deg C*
O2 in flue gas	10.3	*%*
CO2 in flue gas	6.2	*%*
CO in flue gas	76	*ppm*
Ambient temp.	38	*Deg C*
Relative humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
C	*12.78*	%
H	*14.90*	%
N	*52.97*	%
O	*19.31*	%
S	*0.33*	%
Moisture	*3.50*	%
Ash	*0.00*	%
GCV of fuel	1231	*kcal/kg*
Weight of ceramic material being heated in Kiln	2850	*Kg/h*
Specific heat of clay material	0.22	*Kcal/kg degC*
Avg. specific heat of fuel	0.51	*Kcal/kg degC*
fuel temp	40.2	*deg C*
Specific heat of flue gas	0.24	*Kcal/kg degC*
Specific heat of superheated vapour	0.45	*Kcal/kg degC*
Radiation and convection from preheating zone surface	6712	*kcal/h*
Radiation and convection from heating zone surface	5178	*kcal/h*
Heat loss from all zones	**11889**	*kcal/h*
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.50	*h*
Area of entry opening	1.2	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*K*

Heat utilization calculations

Calculations	Kiln	UOM
Theoretical air required	5.84	*kg/kg of fuel*
Excess air supplied	96.26	*%*
Actual mass of supplied air	11.47	*kg/kg of fuel*
Mass of dry flue gas	11.13	*kg/kg of fuel*
Amount of wet flue gas	12.47	*kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.38	*kg of H2O/kg of fuel*
Amount of dry flue gas	11.09	*kg/kg of fuel*
Specific fuel consumption	823.44	*kg of fuel/ton of tile*
Heatinput calculations		
Combustion heat of fuel	1,013,660	*kCal/ton of tiles*
Sensible heat of fuel	0	*kCal /ton of tile*
Total heat input	1013660	*kCal /ton of tile*
Heat output calculation		
Heat carried away by 1 ton of tile	255156	*kCal /ton of tile*
Heat loss in dry flue gas	420791	*kCal /ton of tile*
Loss due to H_2 in fuel	53556	*kCal /ton of tile*
Loss due to moisture in combustion air	991	*kCal /ton of tile*
Loss due to partial conversion of C to CO	728	*kCal /ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	30	*kCal /ton of tile*
Loss due to evaporation of moisture present in fuel	19321	*kCal /ton of tile*
Total heat loss from kiln (surface) body	4172	*kCal /ton of tile*
Heat loss due to un-burnt in fly ash	0	*kCal /ton of tile*
Heat loss due to un-burnt in bottom ash	0	*kCal /ton of tile*
Heat loss due to kiln car	0	*kCal /ton of tile*
Unaccounted heat losses	258915	*kCal /ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	4172	*kCal /tons*
Kiln efficiency	25.2	*%*

2. Heat balance diagram

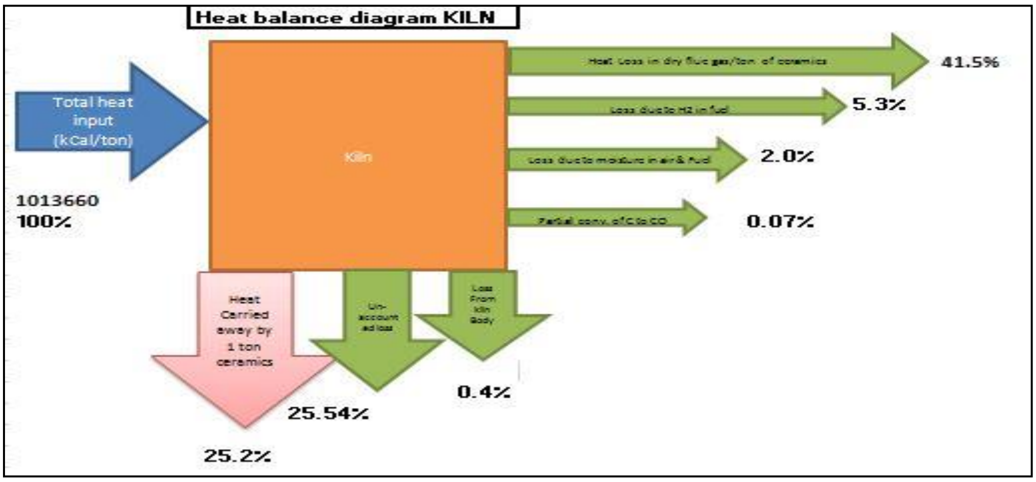


Figure 36: Heat balance diagram of kiln

3. Gasifier performance

Performance analysis	UOM	Value
Fuel fired		Coal
Fuel through put	kg/h	666.67
Fuel composition		
Carbon	%	0.70
Hydrogen	%	0.04
Oxygen	%	0.13
Nitrogen	%	0.01
Moisture	%	0.04
Ash	%	0.07
GCV of fuel fired	kcal/kg	3,500.00
Atmospheric conditions		
Nitrogen	%	77
Oxygen	%	20
Water vapour	%	3
Coal Gas analysis		
Carbon dioxide	%	7
Carbon monoxide	%	21
Methane	%	3
Hydrogen	%	14
Nitrogen	%	53
Water vapour	%	3
Ashes generated	%	9
Calculations		
Amount of gas produced	kg mole	125.00
Volume of the gas produced	sm^3/h	2,767.65
Density of coal gas	kg/m^3	1.05
Mass flow of coal gas	kg/h	2,892.31
Coal gas fed to horizontal dryer	kg/h	545.49
Coal gas fed to kiln	kg/h	2,346.82
Volume of air required	kg mole	85.87
Volume of air required	sm^3/h	1,924.70
Density of air	kg/sm^3	1.29
Amount of air required	kg/h	2,488.64
HHV of gas produced	$kcal/sm^3$	1,231
HHV of gas produced	kcal/kg	1,178

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	Nevcodelhi@yahoo.co.in
2	High-tech controls for ABB Oxygen Analysers	A 5, Vrindavan Tenament, Gorwa Behind SBI Bank, Near Sahyog Garden, Vadodara - 390016, Gujarat, India	Mr. Bhavik Parikh M: 8071640984	NA
3	Knack well Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	Darshan Thanawala, Ravi Thanawala (Proprietor) 8079452278, 9428597582, 9327013773	www.knackwellengineers.com darshan@kanckwell.com, ravi@kanckwell.com

ECM-2: Waste heat recovery from flue gas of kiln

Sl. No.	Name of company	Address	Phone no.	E-mail
1	Encon Thermal Engineers Pvt Ltd	Faridabad	Mob: 9971499075	
2	Knack well Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	9824037124, 9624042423	http://www.knackwellengineers.com/ darshan@kanckwell.com ravi@kanckwell.com
3	Aerotherm Products	No. 2406, Phase 4, G. I. D. C. Estate Vatva, Ahmedabad - 382445,	+91-9879104476, 9898817846	http://www.aerotherm.in

ECM-3: Using soft water in clay ball mill

Sl. No.	Name of Company	Address	Phone no.	E-mail
1	Aqualux Water India	A/2, Pawan Apartment, Nr. Ahmedabad Homiopathic Medical College, Bopal - Ghuma Road, Ghuma, Ahmedabad, Gujarat 380058	Mob: 9924312411	sales@aqualuxwater.com
2	Aquatechplus Pvt. Ltd.	Shree Khodiyar Park, behind Ruda	Mr. Bhavesh Dabhi 9512301122	www.aquatechro.com bhavesh@aquatechro.c

Sl. No.	Name of Company	Address	Phone no.	E-mail
		Transportnagar,Rajkot-Amdavad Highway, Rajkot-363670		om
3	Raj Water Technology (Gujarat) Pvt Ltd	Plot-27, Survey-47, Jivraj Industrial Area Near Falcon Pump, Gondal Rd, Vavdi, Rajkot, Gujarat 360004	70439 55777	marketing@rajwater.com www.rajwater.com

ECM-4: PID controller at water circulating pump for press

Sl. No.	Name of company	Address	Phone no.	E-mail
1	Cogent Controls	205, Vinay Industrial Estate, Chincholi Bunder Link Road, Malad – West, Mumbai - 400064	Tel: 022-28750421 Mob: 9820032946	COGENT CONTROLS [enquiry@cogentcontrols.com]
2	SHIWKON controls	33-34-35, First Floor, Shakti Chamber - 1, N. H. 8A, Opposite Adarsh Hotel, Morbi-363642	93750 50704	morbi@shiwkon.com
3	Shivson Instruments & Sensors	No-27, Shakti Chamber, 1st Floor, 8-A N.H., Morbi- 363642	Mr. Pragnesh Bhai Ramavat	https://www.tradeindia.com/Seller-2748902-Shivson-Instrument-Sensor/

ECM-5: Timer controller for stirrer motor

Sl. No.	Name of company	Address	Phone no.	E-mail
1	Swastik Automation & Control	D-60, Vivekanand Estate, Vivekanand Mill Compound, Near Rakhial Cross Road, Rakhial, Ahmedabad – 380023	Mob: 8048763940	
2	Jagdish Electro Automation	41,Sreenath complex, National Highway 8-A, Trajpar, Morbi-363641	Mr. Paresh Patel 9909458699	www.jagdishautomation.com
3	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com

ECM-6: Retrofit of VFD in compressor #1

Sl. No.	Name of company	Address	Phone no.	E-mail
1	Samhita Technologies Pvt. Ltd	309, Vardhman Grand Plaza, Distt Center, Mangalam Place, Plot No. 7, Outer ring road, Sec 3, Rohini, Delhi – 110085	Mob: +91 9711320759 Tel: +91 11 45565088	sales@samhitatech.com
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com
3	Hitachi Hi-Rel Power Electronics Pvt. Ltd	B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044	Mr. V.Jaikumar 079 2328 7180 - 81	v_jaikumar@hitachi-hirel. com

ECM-8: Replacement of inefficient pumps

Sl. No.	Name of company	Address	Phone no.	E-mail
1	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/
2	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
3	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

ECM-9: Replacement of inefficient lighting systems

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.	1st Floor Watika Atrium, DLF Golf Course Road, Sector 53, Sector 53	9810997486, 9818712322(Yogesh-Area Manager),	r.nandakishore@phillips.com

Sl. No.	Name of company	Address	Phone no.	E-mail
	Nandakishore	Gurgaon, Haryana 122002	9810495473(Sandeep-Faridabad)	sandeep.raina@phillips.com
3	Bajaj Electricals Contact Person: Mr. Kushgra Kishore	Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002	9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341 (Mr. Rahul Khare),	kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com;sanjay.adlakha@bajajelectricals.com

ECM-10: Installation of harmonics filter

Sl. No.	Name of company	Address	Phone no.	E-mail
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-11: Cable loss minimization

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

ECM-12: Voltage optimization in lighting circuits

Sl. No.	Name of company	Address	Phone no.	E-mail
1	Beblec (India) Private Limited	N-3, Phase-3, SIDCO Industrial Estate, Hosur-635126	04344-276358/278658/ 276958/59/ 400687	info@beblec.com nirmala@beblec.com
2	SERVOKON System ltd. (Manufacturer/Exporter)	Servokon House,C-13,Radhu palace road, opp.scope minar,Laxmi Nagar, Delhi-110092	75330088 Toll free:18002001786	http://www.servokonstabilizer.com/contact-us.html
3	SERVOMAX INDUSTRIES LIMITED (Manufacturer)	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033 BRANCH: #166A, 2nd Floor,Pratap Nagar, Mayur Vihar,Phase-I, New Delhi- 110092	+91 9111234567	customercare@servomax.in www.wervomax.in

ECM-13: 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	
2.	Mangal singh Bros. Pvt Ltd	24-B, Raju Gardens, Near Krishnasamy nagar, Sowripalayamp Post, Coimbatore-641028	Ramiz Parker +91 77381 86851	mangalsinghcbe@gmail.com
3	Shreeji Traders	Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001	+91 94281 01565	NA

ECM-14: Energy Management 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	Tel.: 011-65151223	iadept@vsnl.net, info@iadeptmarketing.com

Sl. No.	Name of company	Address	Phone no.	E-mail
		Delhi, DL 110075		
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

7.7 Annex-7: Financial analysis of project

Table 61: Assumptions for Financial Analysis

Parameters	UOM	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	%	26.75%
Effective MAT rate	%	21.64%
Discount factor	%	15.00%