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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE VT-01: EXCEL CERAMIC PVT. LTD

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DESL

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

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Disclaimer

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

DESL is indebted to M/s. Excel 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. Suresh Patel, Director
2. Mr. Rajesh J. Patel, Technical head

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

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

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ABBREVIATIONS

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

UNITS AND MEASURES

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

CONVERSION FACTORS

TOE Conversion	Value	Unit	Value	Unit
Electricity	1	kWh	0.000086	TOE/kWh
Coal	1	MT	0.45	TOE/MT
Natural Gas	1	scm	0.00089	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.

Excel Ceramic Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Excel 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	Excel Ceramic Pvt. Ltd.
Year of Establishment	2014
Address	8-A, National Highway, Makansar, Morbi, Gujarat-363642
Products Manufactured	Vitrified Tiles
Name(s) of the Promoters / Directors	Mr. Suresh Patel

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

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

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio of 2:1:1 respectively along with water to form a plastic mass.
- **Agitator:** The plastic mass after mixing in ball mill is poured in to a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Dryer:** Biscuits are sent to dryer for pre drying after it is passed through kiln.
- **Glaze mill:** For producing glazing material used on the product.
- **Kiln:** Biscuits are baked in the roller kiln at 1100-1150°C and again baked after glazing
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The main utility equipment installed are:

- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.
- **Coal gasifier:** For producing coal gas, which is used in the kiln, hot air generator and dryer.

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:

- Providing proper insulation on kiln to reduce convection and radiation losses
- Excess air control
- Waste heat recovery
- Installing energy monitoring system
- Cable loss optimization
- Voltage optimization
- Harmonic filter installation
- VFD installation at air compressor
- PID controller at water circulating pump in heat exchanger of presses

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	Estimated Annual Savings				Annual Monetary Savings	Investment	Simple Payback Period	Annual Emission Reduction
		Electricity	PNG	Coal	TOE Equ.				
		kWh	scm	t	MTOE	Lakh Rs/y	Lakh Rs	Months	tCO_2
1	Excess air control in kiln	16,812		235.81	107.37	18.41	7.00	5	514
2	Skin loss reduction in kiln	-		143	64.42	9.57	2.00	3	303
3	Recuperator in smog line of kiln			209	93.92	15.2	10.0	8	442
4	Optimize resources in clay preparation section	37,125		744	337	79.0	30.0	5	1607
5	PID controller at water circulating pump for press	11,101			0.95	0.84	0.28	4	10
6	Time controller for stirrer motor	9,813			0.84	0.74	0.28	5	9
7	VFD installation for smaller air compressor	46,893			4.03	3.53	1.50	5	42
8	Replace Inefficient bore-well pump	30,284			2.60	2.12	3.91	22	27
9	Replace inefficient lighting systems	42,946			4.54	3.24	1.79	7	38
10	Installation of harmonic filter	53,071			4.22	4.00	13.80	41	47
11	Energy monitoring system	16,195		304.33	138.10	22.12	0.75	0.4	658
12	Cable loss minimization	13,567			1.12	1.02	1.11	13	12
13	Voltage optimization	22,514			1.94	1.70	0.50	4	20
14	Replace V belt with REC belt	58,977			5.07	4.44	3.00	8	52
	Total	**359,298**	**0**	**1,636**	**766**	**165.93**	**76**	**5**	**3,783**

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

- Reduction in energy cost by 9.70%
- Reduction in electricity consumption by 5.07%
- Reduction in thermal energy consumption by 12.04%
- Reduction in greenhouse gas emissions by 11.11%

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	7.00	206	1.8
2	Skin loss reduction at kiln	2.00	358	1.0
3	Recuperator in smog line	10.00	113	3.0
4	Optimize resources in clay section	30.00	198	1.8
5	PID controller at water circulating pump for press	0.28	228	1.6
6	Time controller at stirrer motor	0.28	199	1.8
7	VFD installation at air compressor	1.50	177	2.0
8	Inefficient pump replacement with efficient pump	3.91	36	7.8
9	Replacement of inefficient light with EE lights	1.79	140	2.6
10	Installation of Harmonic filter	13.80	6	14.9
11	Energy monitoring system	0.75	2169	0.2
12	Cable loss minimization	1.11	66	5.0
13	Voltage optimization	0.50	254	1.4
14	V belt replacement with REC belt	3.00	110	3.2
	Total	75.92		

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	Excel Ceramics P Ltd			
Plant Address	8-A, National Highway, Ta. Makansar, Dist- Morbi			
Constitution	Private limited			
Name of Promoters	Suresh Patel			
Contact person	Name	Suresh Patel		
	Designation	Director		
	Tel	9879776076		
	Fax			
	Email	info@excelceramics.com		
Year of commissioning of plant	2014			
List of products manufactured	Vitrified tile, 600 x 300 mm (4 tiles/box) Vitrified tile, 300 x 300 mm (5 tiles/box) Vitrified tile, 400 x 400 mm (6 tiles/box)			
Installed Plant Capacity	5,000 boxes/day			
Financial information (Lakh Rs)	2014-15		2015-16	2016-17
Turnover	Not provided			
Net profit				
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	110	
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	Yes	Spray drier, Gasifier
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas (scm)	Yes	Kiln, drier (secondary firing)
	Other (specify)	No	-
Have you conducted any previous energy audit?	Yes		
If Yes	Year of energy audit	2018	
	Conducted by	TERI	
	Recommendations implemented	No	
	Type of ECM		
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.

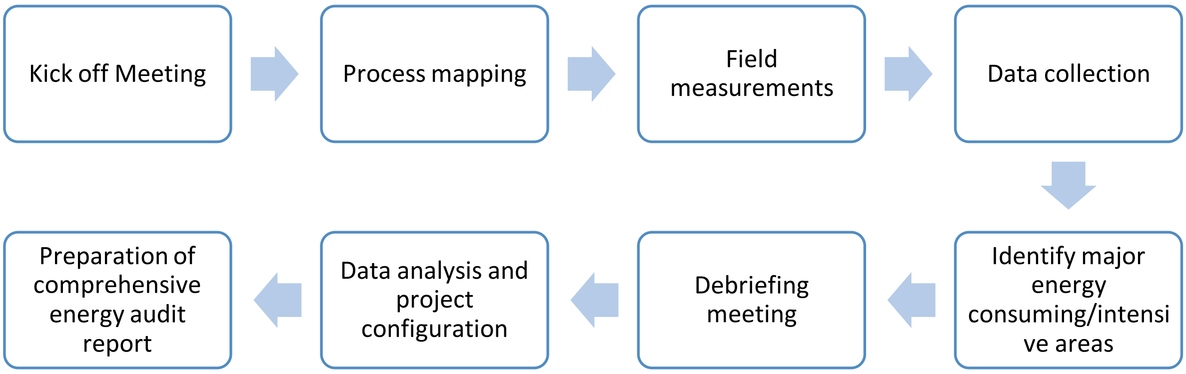


Figure 1: General methodology

The field work was carried out during 23-27th October 2018.

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

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

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit are the following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Parameters Measured
1	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
2	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3 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 Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

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

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

2. CHAPTER -2 PRODUCTION AND ENERGY CONSUMPTION

2.1 MANUFACTURING PROCESS WITH MAJOR EQUIPMENT INSTALLED

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

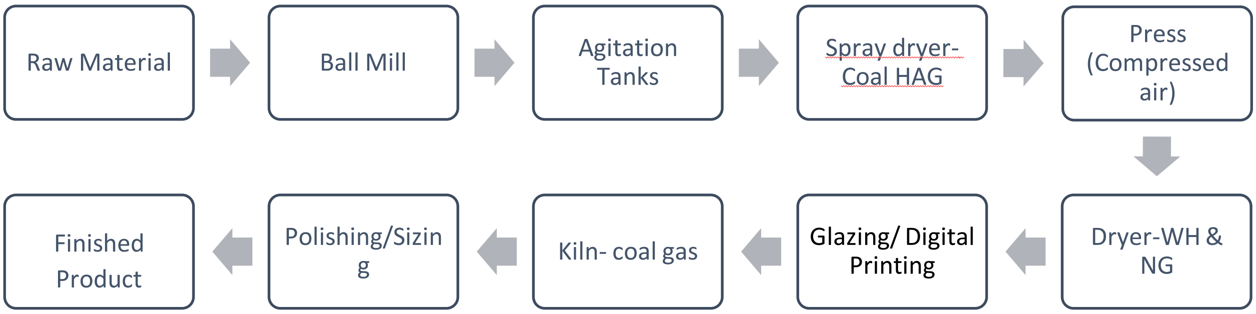


Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is a mixture of china clay, bole clay, Than clay, talc, potash, feldspar and quartz which is mixed along with water to form slurry.
- The raw materials are mixed and ground using pebbles together with water in the ball mill for a period of 7.5-9.0 hours in the new plant and 3.5 hours in the old plant for glaze mill.
- Slurry is then pumped using hydraulic piston into spray dryer where moisture content of slurry 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 is then baked initially in vertical or horizontal dryer at about 140-150°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:

- **Ball mill:** Here the raw materials like clay, feldspar, potash, talc and quartz are mixed in the ratio of 2:1:1 respectively along with water to form slurry.
- **Hot air generator:** Hot air generator is used to generate hot air which is used in spray dryer for evaporation of moisture present in slurry.
- **Glaze mill:** For producing glazing material used on tiles.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. instrument air, air cleaning, glazing etc.

- **Agitator:** The liquid slurry mass after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing 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.
- **Roller 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 150 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150^oC to 1,200^oC depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further gone for 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	5.2	0.72	4
Vitrified Tiles	600 x 300	14	0.45	5
Vitrified Tiles	400 x 400	16	0.96	6

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	600 x 300	400 x 400	300 x 300	600 x 300	400 x 400	300 x 300	600 x 300	400 x 400
Apr-17	103,502	24,397	56,574	74,521	10,979	54,311	538	342	905
May-17	68,381	-	92,161	49,234	-	88,475	356	-	1,475
Jun-17	69,333	80,446	-	49,920	36,201	-	361	1,126	-
Jul-17	41,293	8,930	36,755	29,731	4,019	35,285	215	125	588
Aug-17	77,528	-	-	55,820	-	-	403	-	-
Sep-17	130,740	-	25,902	94,133	-	24,866	680	-	414
Oct-17	193,793	25,417	94,291	139,531	11,438	90,519	1,008	356	1,509
Nov-17	227,482	5,372	83,287	163,787	2,417	79,956	1,183	75	1,333
Dec-17	220,350	-	-	158,652	-	-	1,146	-	-
Jan-18	85,301	-	83,522	61,417	-	80,181	444	-	1,336
Feb-18	111,172	-	-	80,044	-	-	578	-	-
Mar-18	137,841	-	69,834	99,246	-	67,041	717	-	1,117
Apr-18	188,710	20,268	2,392	135,871	13,392	50,239	981	417	837
May-18	199,156	21,390	2,525	143,392	14,133	53,020	1,036	440	884
Jun-18	174,663	18,759	2,214	125,758	12,395	46,500	908	386	775
Jul-18	249,148	26,759	3,159	179,386	17,681	66,329	1,296	550	1,105
Aug-18	235,387	25,281	2,984	169,478	16,704	62,666	1,224	520	1,044
Sep-18	80,588	8,655	1,022	58,024	5,719	21,455	419	178	358
Average	144,132	29,308	61,074	103,775	13,189	58,631	749	410	977
	87,716			65,904			737		

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 Gas for roller kiln
  - Natural Gas (NG) for vertical 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

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	TOE	% of total
Grid – Electricity	532.87	31.1	609	8.5
Thermal-Coal	951.93	55.6	5,843	81.6
Thermal – NG	226.48	13.2	710	9.9
Total	1,711.29	100	7,163	100

This is shown graphically in the figures below:

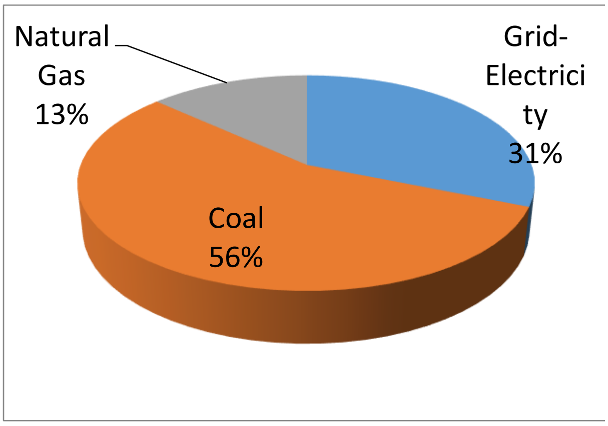


Figure 3: Energy cost share

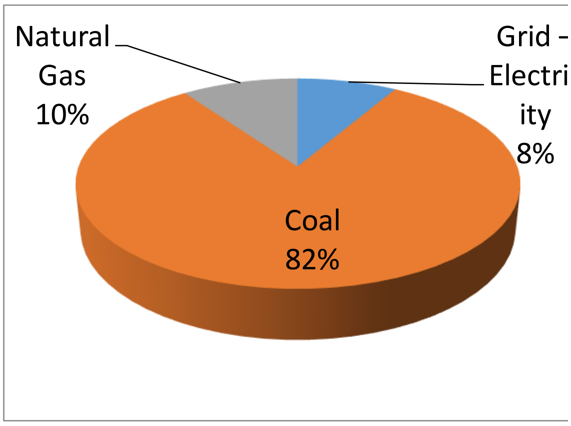


Figure 4: Energy use share

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 31% of the energy cost and 9% 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 56% of the total energy cost and 82% of overall energy consumption. Coal is also used in hot air generator to generate hot air.
- NG used in vertical dryer accounts for 13% of the total energy cost and 10% of overall energy consumption.

2.3.1 Analysis of Electricity Consumption

2.3.1.1 Supply from Utility

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

Table 8: Details of Electricity Connection

Particulars	Description
Consumer Number	26011
Tariff Category	HTP-I
Contract Demand, kVA	1,350
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Electric Tariff structure

Particulars	Tariff structure for Category HTP-1
Demand Charges (Rs./kVA)	
1st 500 kVA	150
2nd 500 kVA	260
Next 297	475
Energy Charges (Rs./kWh)	
Normal Hours	4.2
Peak Hours	0.85
Night Time	0.4
Fuel Surcharge (Rs./kVAh)	1.61
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill for Aug-18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units consumed kWh	Total Electricity cost Rs.	Average unit Cost Rs./kWh
Apr-17	612,046	4,693,320	7.7
May-17	522,407	4,120,740	7.7
Jun-17	511,278	3,990,891	7.9
Jul-17	234,393	2,063,987	7.8
Aug-17	206,925	1,828,012	8.8
Sep-17	546,110	4,179,911	8.8

Month	Units consumed kWh	Total Electricity cost Rs.	Average unit Cost Rs./kWh
Oct-17	779,747	5,800,801	7.7
Nov-17	724,342	5,435,289	7.4
Dec-17	635,040	4,815,792	7.5
Jan-18	598,440	4,561,309	7.6
Feb-18	531,900	4,000,637	7.6
Mar-18	584,860	4,419,769	7.5
Apr-18	537,300	4,066,828	7.6
May-18	596,863	4,462,398	7.6
Jun-18	593,599	4,452,534	7.5
Jul-18	568,754	4,284,581	7.5
Aug-18	656,749	4,814,033	7.5
Sep-18	276,176	2,173,456	7.3

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 590,314 kWh/month and cost is Rs. 44.4 Lakhs per month (Oct-17 to Sep-18). The average cost of electricity is Rs. 7.53/kWh, corresponding to the month Aug-18. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

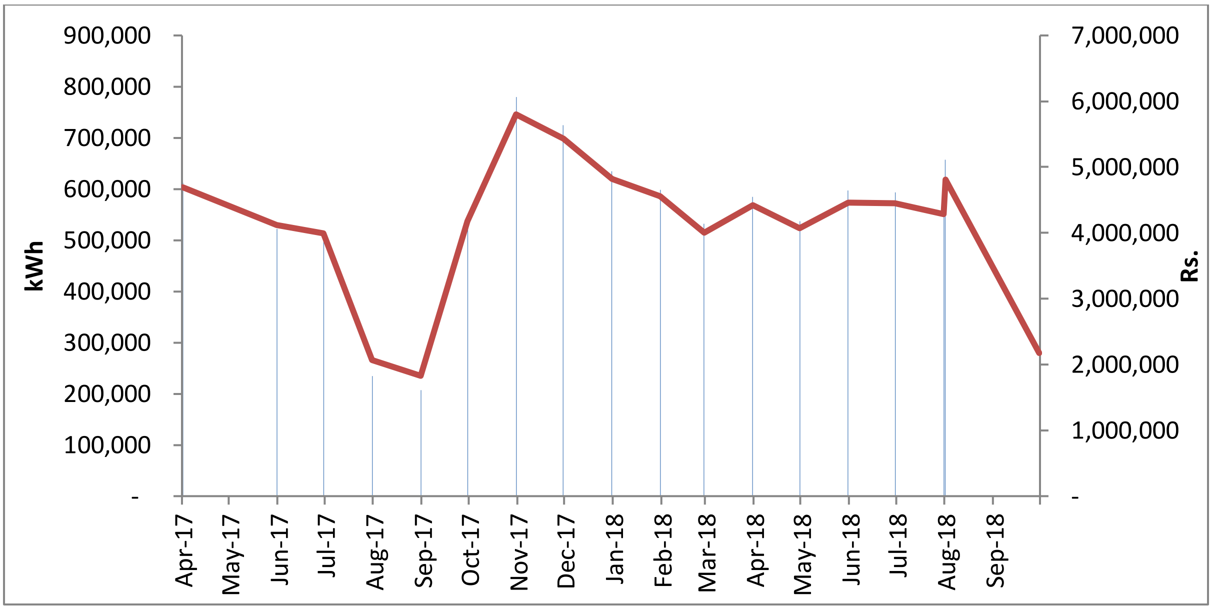


Figure 5: Month wise Variation in Electricity Consumption

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

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

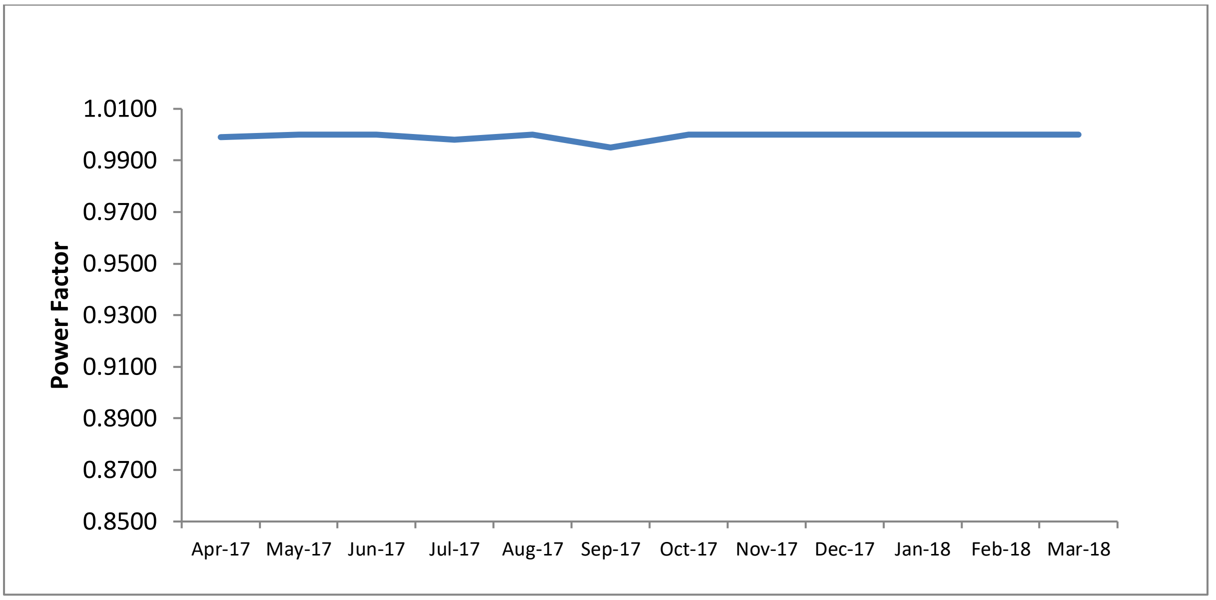


Figure 6: Month wise variation in Power Factor

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 0.99 and the maximum being 1.0.

Maximum Demand: Maximum demand as reflected in the utility bill is 1,271 kVA from the bill analysis[1].

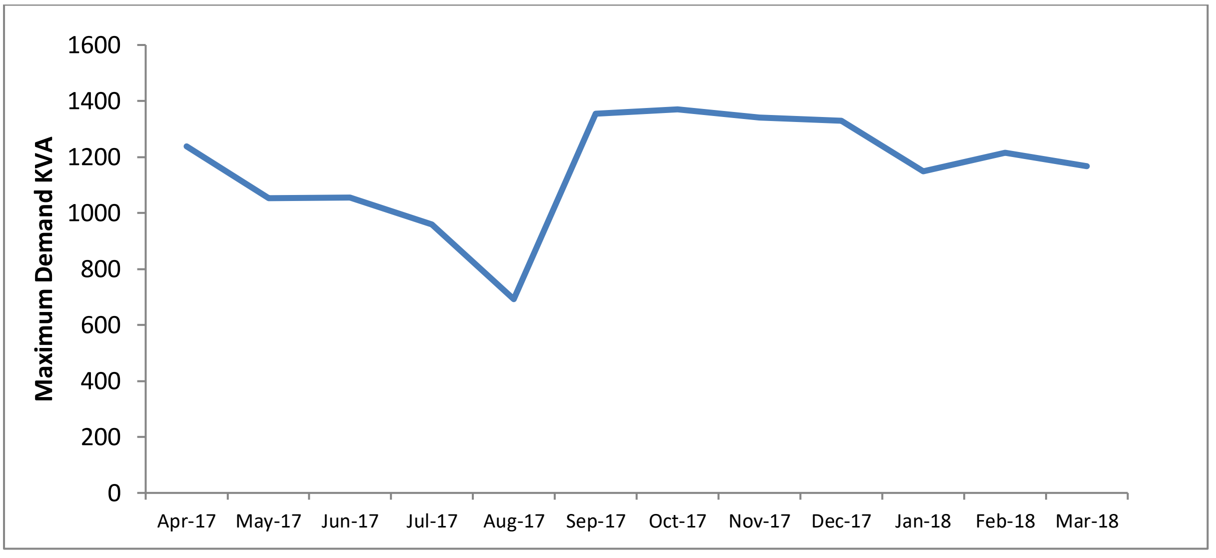


Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

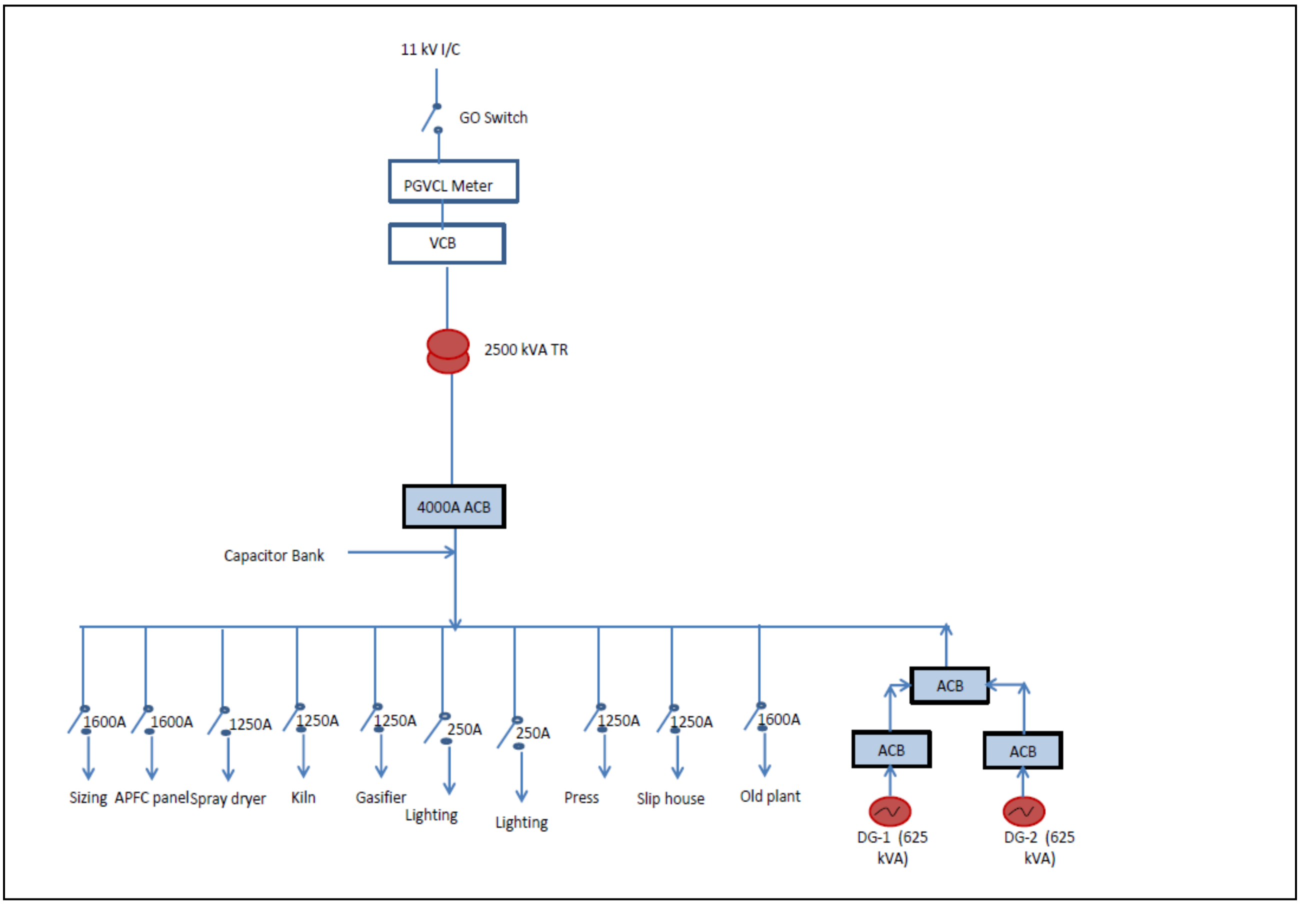


Figure 8 Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 2,000.8 kW, which includes:

- Plant and machinery load is 1,919.6 kW.
- Utility load is (lighting, air compressor and fans) about 61 kW including the single phase load.

Table 11 : Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Old Plant Clay Section	118
2	Old Plant Glaze Section	72
3	Old Plant Spray Dryer	120
4	New Line	83
5	New Spray Dryer	231
6	New Press - HLT-5000	152
7	New Plant – Vertical Dryer	96
8	Old Press 980-1	70
9	Old Press 980-2	63
10	Old Dryer	27
11	Old Plant Kiln Section (Horizontal Dryer)	153
12	Old Line to kiln	20
13	Old Sizing	129
14	Old plant coal conveyor	11
15	New Plant Kiln	264
16	New Plant Sizing Machine	272
17	New plant coal conveyor	38

Sl. No.	Equipment	Capacity (kW)
18	Coal Gasifier	61
19	Single phase load	20
Total Connected Load		2,001

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

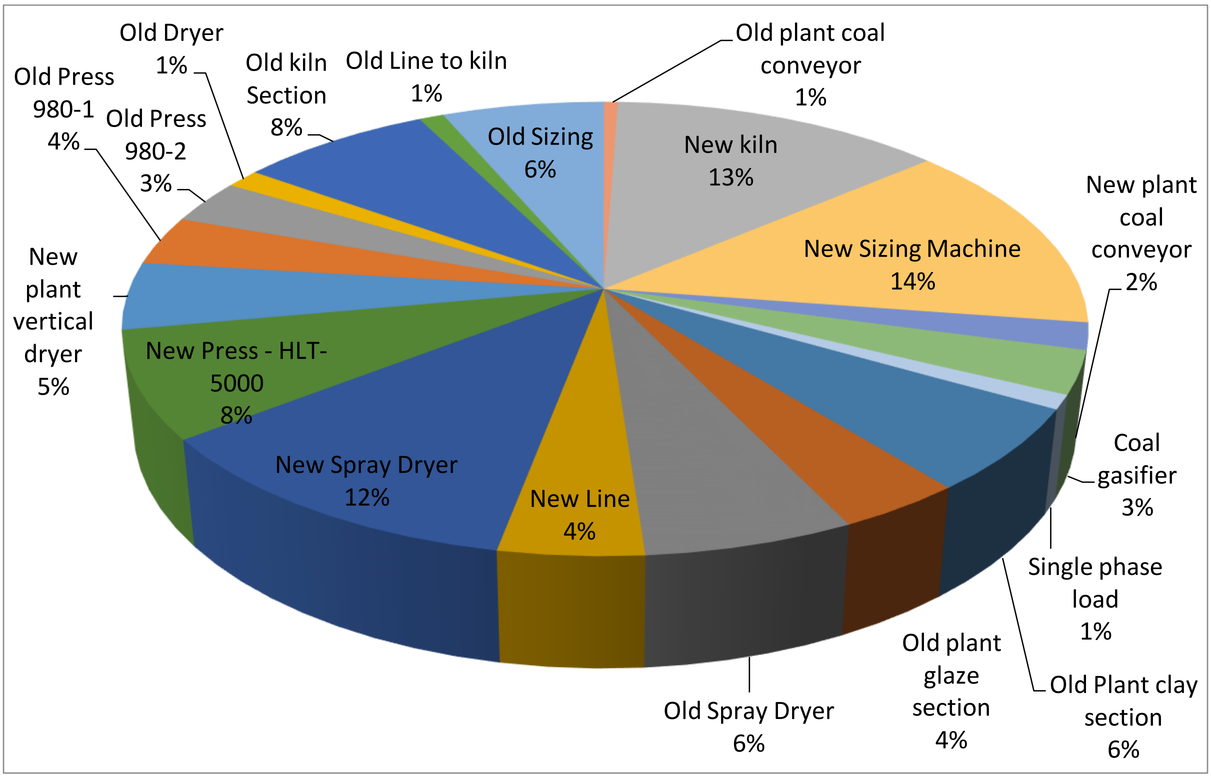


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for new sizing machine-14%, for the new kiln – 13%, for New Spray dryer – 12%, for old kiln section- 8%, for New Press-HT-5000 - 8% , for old spray dryer – 6%, for Big Mill- 6% 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:

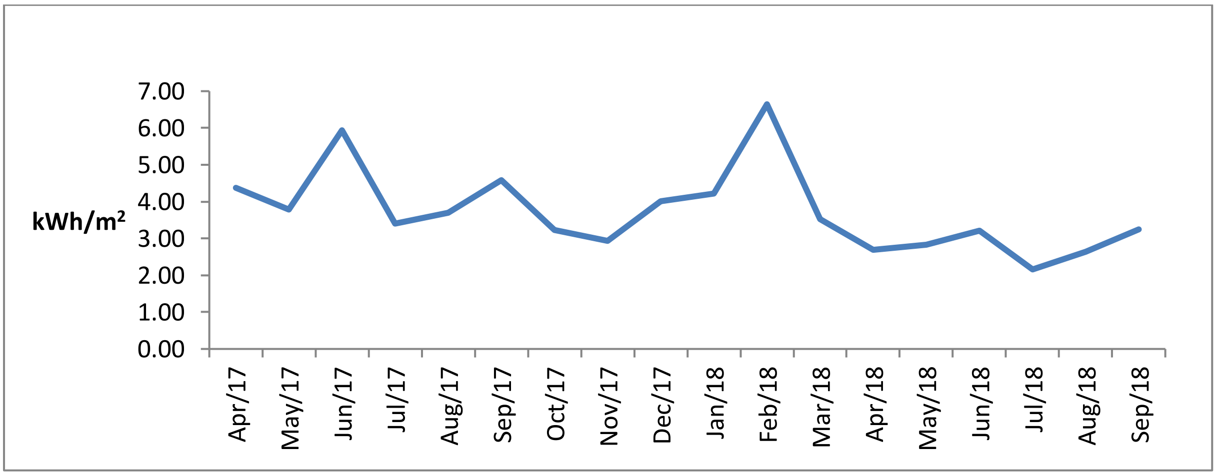


Figure 10: Month wise variation in Specific Electricity Consumption

Three months, Jun-17, Feb-18 and Jul-18 are outliers. Excluding these months, the maximum and minimum values are within ±25% of the average SEC of 3.73 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 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, secondary dryers and the kilns. Coal is used as the fuel for 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. Natural Gas is purchased from GSPC (Gujarat State Petroleum Corporation) and used in the vertical dryer only. Based on the gas bill shared for the month of April-17 to Sept-18 annual fuel cost has been derived as under. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	NG Used in Drier			Coal Gasifier		
	NG Use	NG Cost	NG Cost	Coal Used	Coal Cost	Coal cost
	scm	Rs	Rs./scm	MT	Rs	Rs./MT
Apr-17	110,669	2,734,130	25	416	2,881,721	6,923
May-17	23,354	570,236	24	347	2,255,383	6,492
Jun-17	20,458	500,733	24	448	3,393,944	7,570
Jul-17	27,605	672,575	24	197	1,414,860	7,169
Aug-17	98,154	2,384,463	24	163	860,062	5,274
Sep-17	158,201	3,942,463	25	636	4,625,652	7,270
Oct-17	165,892	4,146,397	25	891	6,215,945	6,976
Nov-17	165,824	4,176,141	25	1,125	7,994,054	7,104
Dec-17	52,655	1,312,528	25	1,297	10,300,598	7,941
Jan-18	181,474	5,328,848	29	814	6,238,642	7,661
Feb-18	21,451	577,325	27	963	7,577,191	7,865
Mar-18	25,464	693,608	27	1,236	9,169,597	7,422
Apr-18	22,672	740,630	33	1,173	8,370,653	7,139
May-18	35,474	1,198,819	34	1,122	8,008,139	7,139
Jun-18	39,585	1,405,364	36	1,100	7,852,868	7,139
Jul-18	39,488	1,343,285	34	1,104	7,883,922	7,139
Aug-18	36,368	1,305,934	36	1,667	11,900,342	7,139
Sep-18	11,386	419,612	37	516	3,681,177	7,139

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

- Average monthly coal consumption is 1,084 tons and average cost Rs. 79 Lakhs/month

- Average monthly gas consumption is about 66,478 scm and average cost is Rs. 19 Lakhs/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:

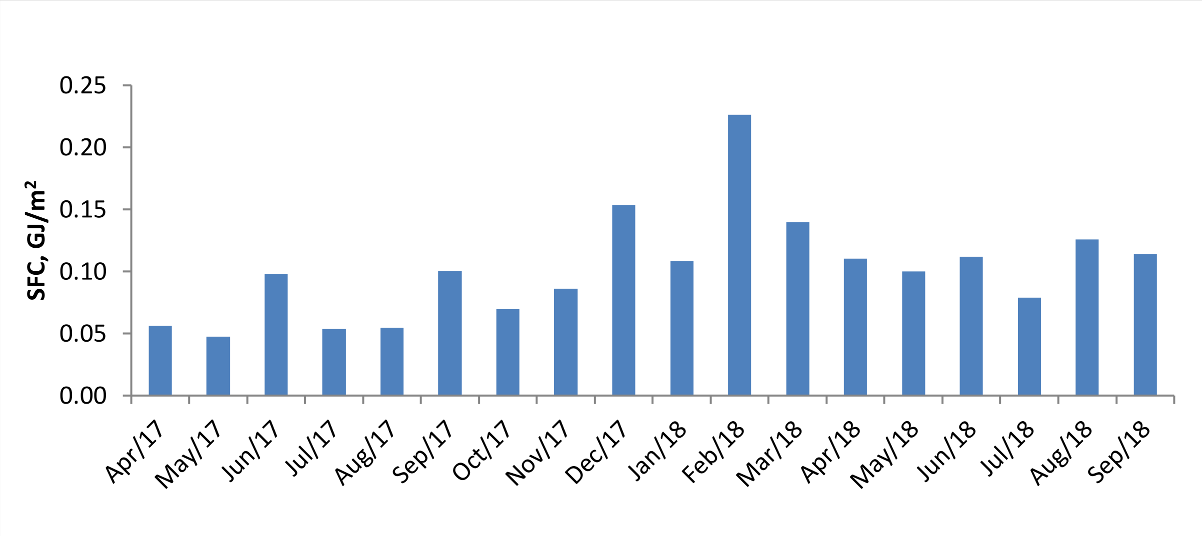


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.19 GJ/m^2. SFC is high in the month of Feb-18 (production was 80,044 m^2 and thermal consumption was 18,915 GJ) and low in the month of May-17 (production was 210,545 m^2 and thermal consumption was 22,415 GJ). While metering for NG is recorded, 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

Particulars	Units	Value
Average production	m^2/h	211
Power consumption	kW	1,080
Coal consumption	kg/h	22,98
NG consumption	scm/h	41.5
Energy consumption	TOE/h	1.162
SEC of plant	TOE/m^2	0.0055

2.3.3.2 *Section wise specific energy consumption*

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

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

Particulars	NG	Coal	Electricity
	scm/t	kg/t	kW/t
Ball Mill #1			24.0
Agitator			0.17
HAG (Chain Stoker)		0.25	17.0
HAG (Bubbling bed)		0.40	28.0
Spray Dryer (New)			1.06
Spray Dryer (Old)			0.89
Vertical Dryer	15		5.96
Horizontal Dryer		115	2.50
Hydraulic Press- New			14.5
Hydraulic Press-Old			23.6
Kiln		134	40.4
New sizing unit			52.8
Old sizing unit			93.9

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

2.3.3.3 Based on yearly data furnished by unit

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

Table 15: Overall: specific energy consumption

Parameters	Units	Value
Annual Grid Electricity Consumption	kWh/y	7,083,770
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	7,083,770
Annual Thermal Energy Consumption (Imported Coal)	t/y	13,008
Annual Thermal Energy Consumption (NG)	scm/y	797,733
Annual Energy Consumption	TOE	7,163
Annual Energy Cost	Rs. Lakh	1,711
Annual production	m^2	2,226,368
	t	24,158
SEC; Electrical	kWh/m^2	3.73
	kWh/t	293
SEC; Thermal	GJ/m^2	0.19
	GJ/t	10
SEC; Overall	$MTOE/ m^2$	0.0032
	MTOE/t	0.29
SEC; Cost Based	$Rs./m^2$	81.6
	Rs./t	7,084

(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 NG : 8,902 kCal/scm
- GCV of Imported Coal : 4,492 kCal/kg
- CO_2 Conversion factor
  - Grid : 0.82 kg/kWh
  - Imported Coal : 2.116 t/t of coal
  - NG : 0.001923 tCO_2/scm

2.3.3.4 Baseline parameters

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

Table 16: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs./ kWh for Aug-2018	7.53
Cost of NG	Rs/scm	25.7
Cost of Coal	Rs/MT	7,270
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	2,226,368

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using submersible pumps (2 numbers). These pumps lift water from ground and which is collected in raw water tank. From this raw water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 150-200 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.

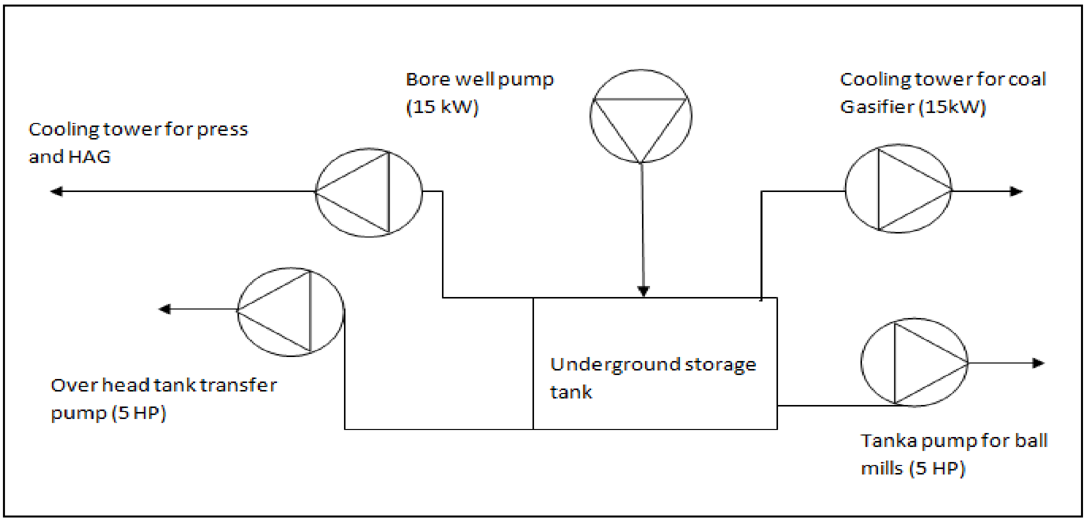


Figure 12: Water Distribution Diagram

Two submersible pumps (only one is in working condition) are installed to meet the water requirements of process (cooling towers for press and coal gasifier, ball mills, sizing and cutting section, chain stoker HAG and domestic use). Installation details of submersible pumps are tabulated hereunder.

Table 17: Submersible pump details

Parameters	Unit	Submersible Pump
Make	-	-
Motor rating	kW	15
RPM	rpm	2,900
Quantity	Number	2

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 354 HP electrical load of which 75 HP is for smoke blower, 75 HP for combustion blowers, 40 HP for rapid cooling, 40 HP for Hot air blower, 40 HP for cooling section, 60 HP for final cooling blowers & remaining electrical load of kiln roller motors.

Table 18: Kiln Details

Sl. No.	Parameter	Unit	Value
	Make		Modema
1	Kiln operating time	H	24
2	Fuel consumption	kg/h	1,278.5
3	Number of burner to left	-	90
4	Number of burner to right	-	90
5	Cycle Time	Minutes	49
6	Pressure in firing zone	mmWC	50
7	Maximum temperature	°C	1,200
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	M	50.4 x 0.8 x 3.6
	Firing Zone	M	33.6 x 1.87 x 3.6
	Rapid Cooling Zone	M	8.4 x 0.8 x 3.6
	Indirect cooling Zone	M	23.1 x 0.8 x 3.6
	Final cooling zone	M	21x 0.8 x 3.6

3.1.2 Field measurement and analysis

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

Table 19: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	8.3%
Ambient Air Temperature	40.2 °C
Exhaust Temperature of Flue Gas	250 °C

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

Table 20: Surface temperature of kiln

Zone	Temperature (°C)
Ambient Temperature	40.2
Pre-heating zone Average Surface Temperature	54.9
Heating zone Average Surface Temperature	77.2
Rapid cooling zone Average Surface Temperature	99.4
Indirect cooling zone Average Surface Temperature	67.2
Final cooling zone Average Surface Temperature	55.1

The temperature profile of the kiln is shown below:

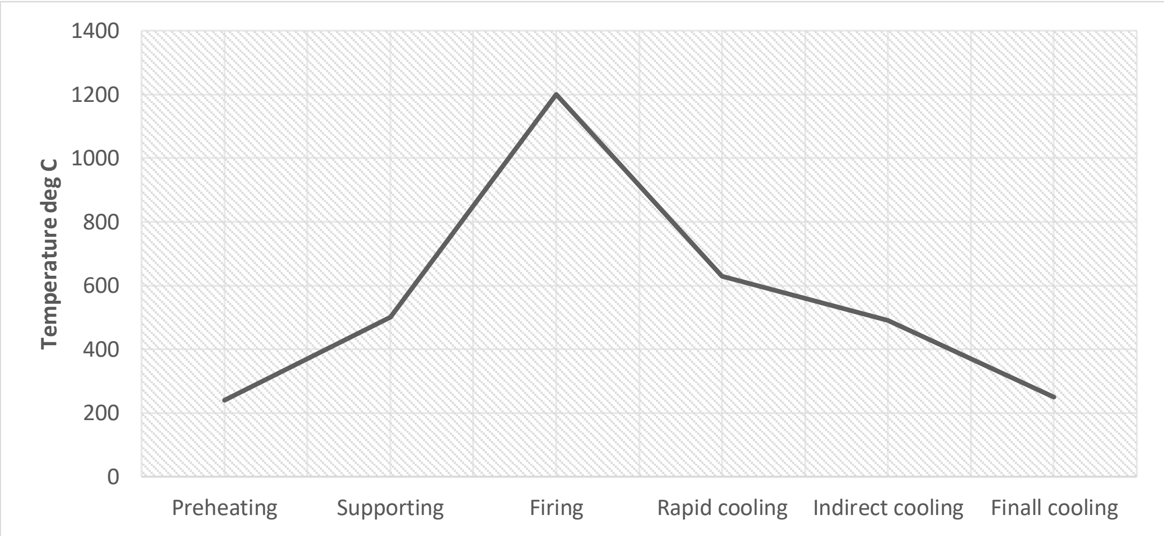


Figure 13 : Temperature Profile of Kiln

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

Table 21 Power measurements of all blowers

Equipment	Average Power (kW)	Power factor
Final Cooling Blower	36	0.86
Suction Blower	9.5	0.99
Heat Recovery Kiln Blower	11.05	0.99
Rapid Cooling Blower	12.0	0.99
Smoke Blower	10.9	0.99
Combustion Blower	10.8	0.99

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln is 33.2%. Summary of all losses is shown in below figure:

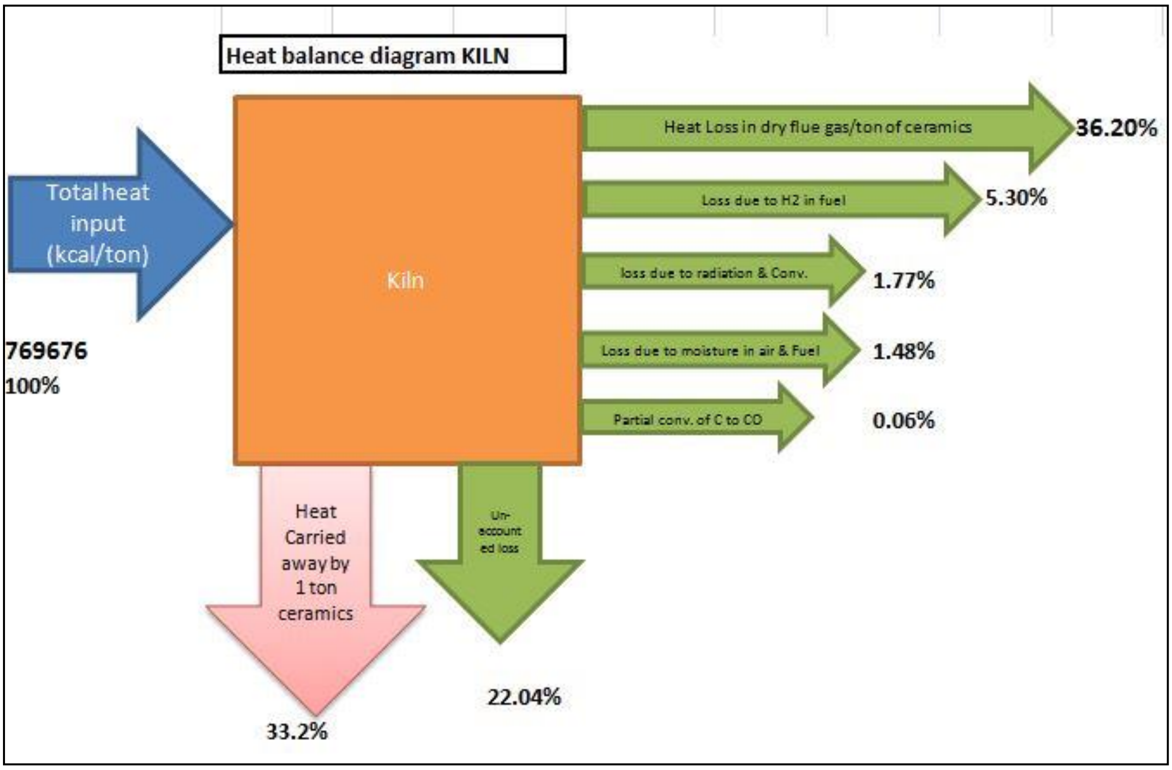


Figure 14 Heat balance diagram of Kiln

Detailed calculation is included in Annexure-5.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln -Excess Air Control

Technology description

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

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

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

Study and investigation

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

Flue gas analysis of kiln is given in below table:

Table 22: Flue gas analysis

Parameters	Units	Value
O_2 in flue gas	%	8.3
CO_2 in flue gas	%	7.3
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: Kiln Excess Air Control (ECM-1)

Parameters	UOM	Present	Proposed
A. Fuel Saving			
Oxygen level in flue gas	%	8.30	5.00
Excess air control	%	65.35	31.25
Dry flue gas loss	%	35%	
Saving in fuel	Every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%		
Specific fuel consumption	kg/t	625.02	603.71
Reduction in specific fuel consumption	kg/h		43.60
Operating hours per day	h/d		330.00
Operating days per year	d/y		24.00
Annual fuel savings	kg/y		235 ,813
Corresponding monetary savings	Lakh Rs/y		17.14
B. Power saving at combustion blower			
Mass flow rate of air	t/h	12.35	9.81
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	2.8	2.2
Total pressure rise	Pa	2,412.44	2,412.44
Fan power	kW	6.76	5.36
Motor power	kW	10.3	8.2
Motor efficiency	%	90	90
Fan efficiency	%	66%	66%
Power saving	kW	2.12	
Operating hours per day	h/d	330.00	
Operating days per year	d/y	24.00	

Parameters	UOM	Present	Proposed
Savings in electrical energy	kWh/y	16,812	
Cost of electricity	Rs/kWh	7.53	
Savings in terms of energy cost	Lakh Rs/y	1.27	
C. Summary of Savings			
Coal saving	kg/y	345,329	
Electricity saving	kWh/y	16,812	
Monetary savings	Lakh Rs/y	18.41	
Estimated investment	Lakh Rs	7.00	
Payback Period	Months	5	

3.1.4.2 ECM #2: Skin loss reduction at kiln

Technology description

A significant portion of the losses in a kiln occurs as radiation and convection loss from the kiln walls and roof. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of refractory and insulation should be provided on the kiln walls and roof to maintain the skin temperature of the furnace at around 45-50°C, so as to avoid heat loss due to radiation and convection. Refractories are heat-resistant materials that constitute the linings for high-temperature kilns. In addition to being resistant to thermal stress and other physical phenomena induced by heat, refractory must also withstand physical wear and corrosion by chemical agents.

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

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

Study and investigation

There are mainly five different zones in kiln, i.e. pre- heating, firing, rapid cooling, indirect cooling and final cooling zones. The surface temperature of each zones were measured. The average surface temperature of kiln body in the firing zone must be in the range of 45-50°C and it was measured as high as 99.4°C; hence the kiln surface has to be properly insulated to keep the surface temperature within the specified range. Some photographs of kiln surface are shown below:

Figure 15: Kiln surface

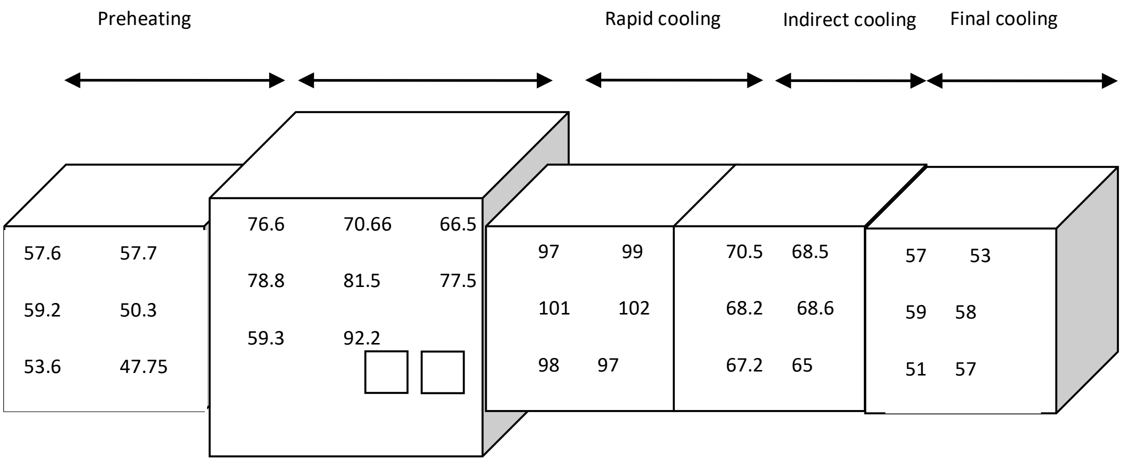


Figure 16: Kiln surface temperature schematic diagram

Recommended action

Recommended surface temperature of the firing zone has to be brought to within 50°C to reduce the heat loss due to radiation and convection and utilize the useful heat. The amount of heat lost through radiation and convection in each zone is given in the table below.

Table 24: Radiation & Convection losses

Particulars	Units	Value
Pre-Heating Zone	kCal/h	5,428
Heating Zone	kCal/h	22,298
Rapid cooling Zone	kCal/h	7,315
Indirect cooling zone	kCal/h	6,141
Final cooling zone	kCal/h	3,554
Total Radiation & Convection loss	kCal/h	44,736

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

Table 25: Cost benefit analysis (ECM 2)

Particulars	Unit	Value
Total reduction in heat loss due to Radiation & convection	kCal / h	32,655
Calorific value of Fuel	kCal / kg	1,231
Equivalent savings in Fuel	kg / h	26.52

Particulars	Unit	Value
Plant running time	d / y	330
	h / d	24
Annual savings in Fuel	kg/y	143,415
Cost of coal	Rs. / kg	7.27
Annual Monetary savings	Rs / y	1,042,616
	Lakhs Rs/ y	10
Estimated investment	Lakh Rs.	2
Payback Period	months	2

3.1.4.3 ECM #3: Recuperator in Smog Line

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 marginally increase the temperature of air at the FD blower of hot air generator (HAG), thereby also bringing down the flue gas temperatures at stack by further 50°C.

Recommended action

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

Table 26: Recuperator in Smog Line [ECM-3]

Particulars	Units	Value
Temperature at smog blower	°C	250.0
Smog flow rate	t/h	12.35
Waste gas flow	kg/h	12.4
Specific heat of waste gas	kCal/kg°C	0.24
Smog temperature after recuperator	°C	200.0
Heat available in smog	kCal/h	148,237
Heat utilization	%	80%
Specific heat of FD blower air	kCal/kgK	0.24
Thermic fluid temperature at ambient	°C	35.0
Combustion air flow	m^3/h	25,038
Density of combustion air	kg/m^3	1.2
Mass flow rate of FD blower air	kg/h	6,283
Effectiveness of HE-1	%	90.0
FD blower air temperature after recuperator	°C	105.8
Heat saving	kCal/h	118,590
GCV of coal	kCal/kg	4,492
Fuel savings	kg/h	26.4

Particulars	Units	Value
Operating hours per day	d/y	330
Operating gays per year	h/d	24
Unit Cost of Coal	Rs./kg	7.27
Annual running hours	h/y	7,920
Annual coal saving	kg/y	209,090
Annual Monetary saving	Lakh Rs/y	15.2
Estimated Investment	Lakhs Rs	10.0
Payback Period	months	8

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 27: Specifications of coal gasifier

Particular	Units	Value
Make		Radhey
Coal consumption	t/d	27
Water consumption	l/d	2,000
Tar generation	kg/d	400
FD Blower	hp	2 x 7.5
Cooling water pump	hp	2 x 10

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Recording of coal consumption data
- Measurement of power consumption of cooling water pumps and FD blower
- Air flow measurement of FD blower

Coal consumption is recorded by the plant in terms of lifts as per kiln cycle time. Kiln cycle time varies between 45-60 minute depending on the production. During the DEA, the kiln cycle time was 49 minutes. The log book data for coal consumption recorded during DEA is as follows:

Table 28: Log book data on coal consumption

Date	Coal consumption (kg/d)
10/10/2018	393
11/10/2018	403
12/10/2018	660
13/10/2018	704
14/10/2018	660
15/10/2018	460
16/10/2018	660
17/10/2018	700
18/10/2018	692

19/10/2018	560
20/10/2018	704
21/10/2018	692
22/10/2018	704

FD blower and cooling water pumps was operating with VFDs. Average power consumption of FD blower is 3.23kW (PF 0.99), CWP-1 is 3.86kW (PF 0.99) and CWP-2 is 3.36kW (PF 0.99). Air flow is 1689 m^3/h at FD fan suction.

There is no monitoring system for coal gas generation quantity or quality.

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, the specific energy consumption of coal gasifier was 0.4 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm coal in plant which is 0.015 kWh/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed

3.3 DRYERS

3.3.1 Specifications

There are two dryers a vertical dryer installed for the new ball mills, and a horizontal dryer for the old ball mills. These are used for pre drying of tiles before entering into kiln. The specifications of dryers are given below table:

Table 29: Specifications of vertical and horizontal dryer

Particular	Units	Vertical dryer	Horizontal dryer
Capacity	Nos. of tiles/h	3,000	1,100
Fuel type		NG	Coal Gas
Rated fuel consumption	scm/h	42	636
Exit temperature of tiles	°C	135	135
FD Blower	hp	2 x 50	1 x 25
Combustion Blower	hp	-	1 x 5

3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

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

Data measured during study is tabulated below:

Table 30: Field measurement at site

Particular	Units	Vertical dryer	Horizontal dryer
Tiles counter reading at start		2,100	4,022
Tiles counter reading at end		8,100	6,260

Particular	Units	Vertical dryer	Horizontal dryer
Mass of each tile at entry	g	2,003	1,980
Mass of each tile at exit	g	1,828	1,855
Temperature of tile at exit	° C	135	135
Gas consumption	scm/h	41.5 (NG)	636 (coal gas)

Hot air blower discharge duct from kiln is utilized in only in vertical dryer which helps in fuel savings. All blowers are operating with VFDs. The power profile and PF profile of blowers installed in vertical dryer are given below:

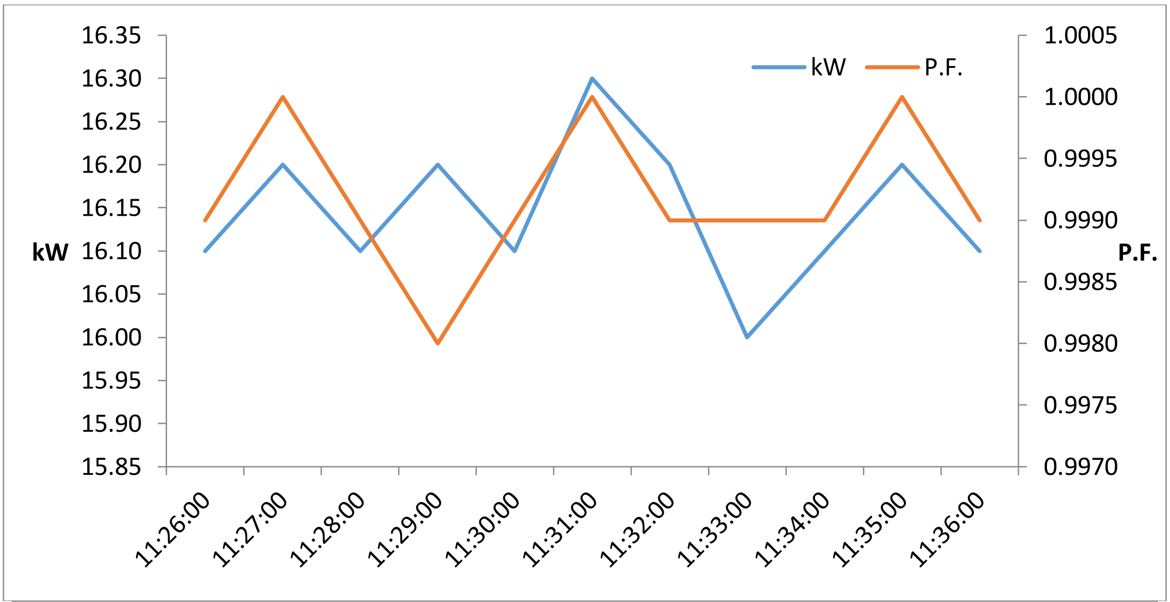


Figure 17 Power and PF profile of FD blowers of Vertical Dryer

Average power consumption of blower 1 is 16.1 kW (PF 0.99) and for blower 2 is 16.5 kW (PF 0.97).

The power profile and PF profile of blowers of the horizontal dryer is given below:

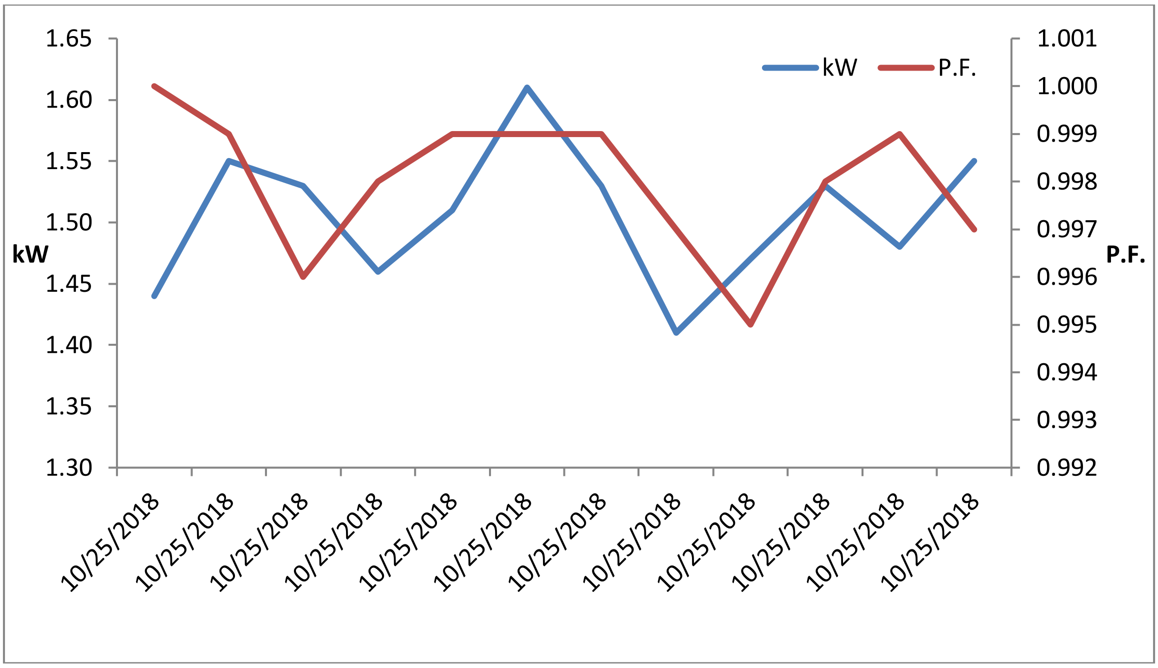


Figure 18 Power and PF profile of smoke (FD) blowers

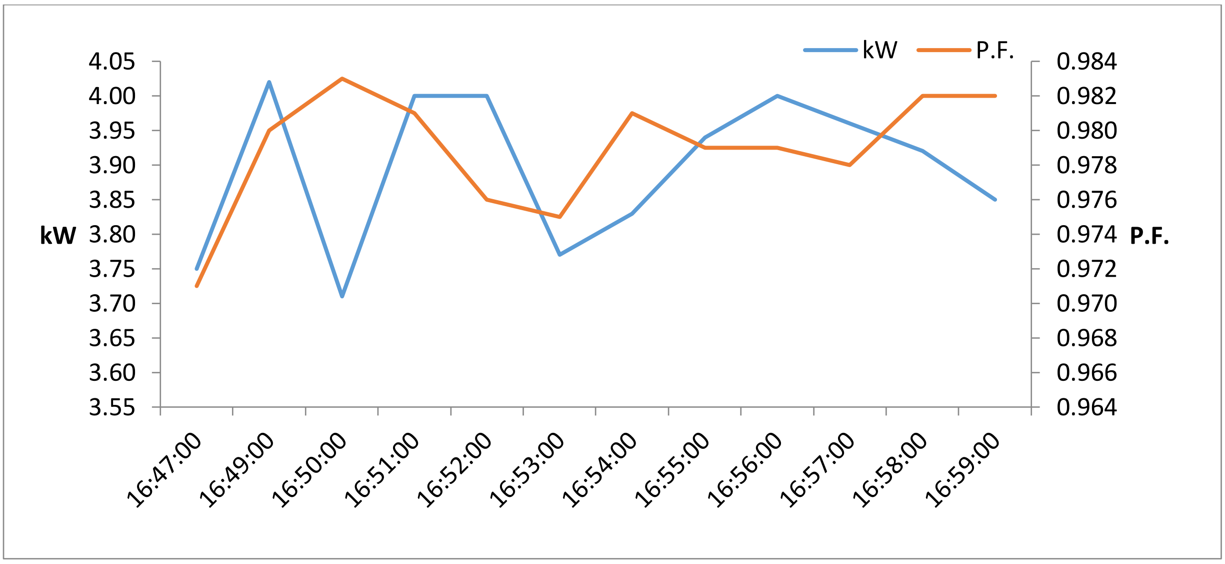


Figure 19 Power and PF profile of combustion blowers

Average power consumption of smoke blower is 1.521 kW (PF 0.99) and for combustion blower is 3.9 kW (PF 0.98).

3.3.3 Observation and Performance assessment

Mass and energy balance of vertical dryer determined based on DEA is as follows:

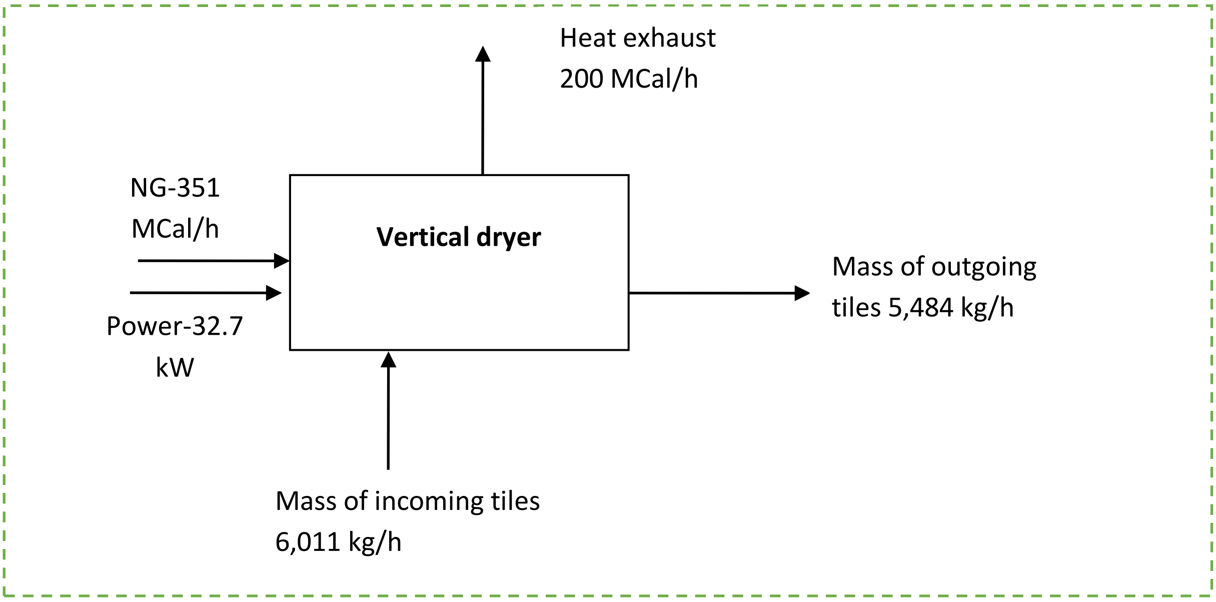


Figure 20 Mass and energy balance of vertical dryer

As mentioned in the preceding section, for the horizontal dryer, there is no metering for coal gas. Therefore energy balance has been determined by energy balance.

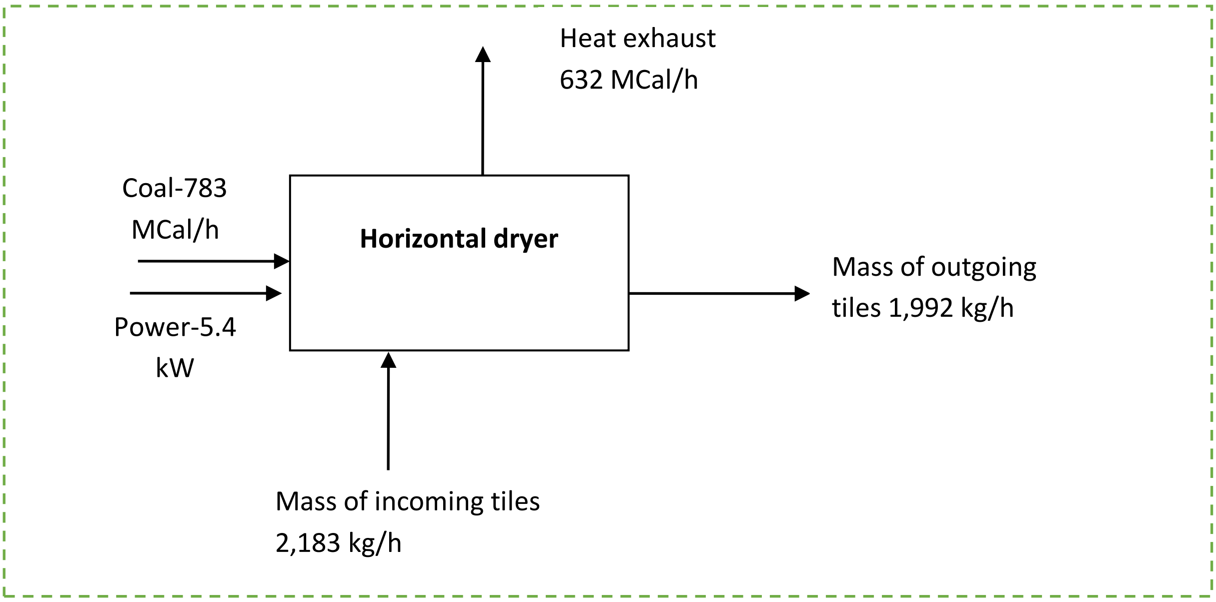


Figure 21: Mass and energy balance of horizontal dryer

Based on observations during DEA, the specific electricity consumption of vertical dryer is 5.96 kW/ton of tile and specific thermal energy is 15 scm/ton of tile. For the horizontal dryer, the corresponding values are 2.5 kW/ton of tile and 115 kg of coal/ton of tile respectively.

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

3.4 Hot Air Generators & Spray Dryers

3.4.1 Specifications

There are two hot air generators (HAG), a chain stoker type and a bubbling bed type are used for evaporating water from slurry which is coming from ball mill. There are two spray dryers installed, the new spray dryer, which is taking heat from chain stoker HAG and the old spray dryer which is taking heat from the bubbling bed HAG. Spray dryer is the heat exchanging unit for powder generation from slurry. Specifications of HAG are given below:

Table 31: Specifications of Hot air generator (HAG)

Particular	Units	Chain stoker	Bubbling bed
Air handling capacity	m^3/h	9,000	9,500
Fuel type		Coal	Coal
Rated fuel consumption	scm/h	1,173	1,200
Exhaust air temperature	^oC	750	750
FD Blower	hp	1 x 50	1 x 30
Combustion blower	hp	1 x 150	1 x 75

The specifications of spray dryers is given below:

Table 32: Specifications of spray dryer

Particular	Units	New	Old
Powder generation capacity		12,500	6,250
Inlet slurry moisture	%	40	40
Outlet powder moisture	%	6	6
Slip house pump	hp	30	20

3.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Hot air generators
  - Power consumption of FD and ID fan
  - Air flow measurement of FD fan
  - Exhaust air temperature
  - Surface temperature
- Spray drier
  - Inlet and outlet moisture data
  - Power consumption of slip house pump
  - Powder generation data (monthly basis)

Details of measurements on HAG are given below:

Table 33: Field measurement at site

Particular	Units	Chain stoker	Bubbling bed
Air velocity at FD fan suction	m/s	12.6	17.8
Suction area	M^2	0.196	0.126
Exit temperature of air	° C	750	750
Surface temperature	° C	70	70
Average power consumption-FD Blower	kW	4.88 (PF=1)	12 (PF=1)
Average power consumption-ID Fan	kW	77 (PF =0.99)	47.32 (PF=0.99)

All blowers are operating with VFDs.

During DEA, the following measurements/ data were collected on spray dryers:

Table 34: Field measurement at site

Particular	Units	New Spray Dryer	Old Spray Dryer
A. Powder generation data			
Jan 18	MT	4,965	730
Feb 18	MT	3,680	620
Mar 18	MT	4,415	975
Apr 18	MT	4,170	
May 18	MT	4,495	260
Jun 18	MT	4,310	300
July 18	MT	4,585	400
Aug 18	MT	5,040	2,215
B. Moisture data			
Inlet moisture	%	40	40
Outlet moisture	%	6.2	6

In both spray dryers the slip house pumps are operated with VFD. Average power consumption 13.8 kW (PF 1.00) in new spray dryer and 5.6kW (PF 0.99) for old spray dryer.

3.4.3 Observations and performance assessment

Mass and energy balance of chain stoker HAG and spray dryer determined based on data collected is as follows:

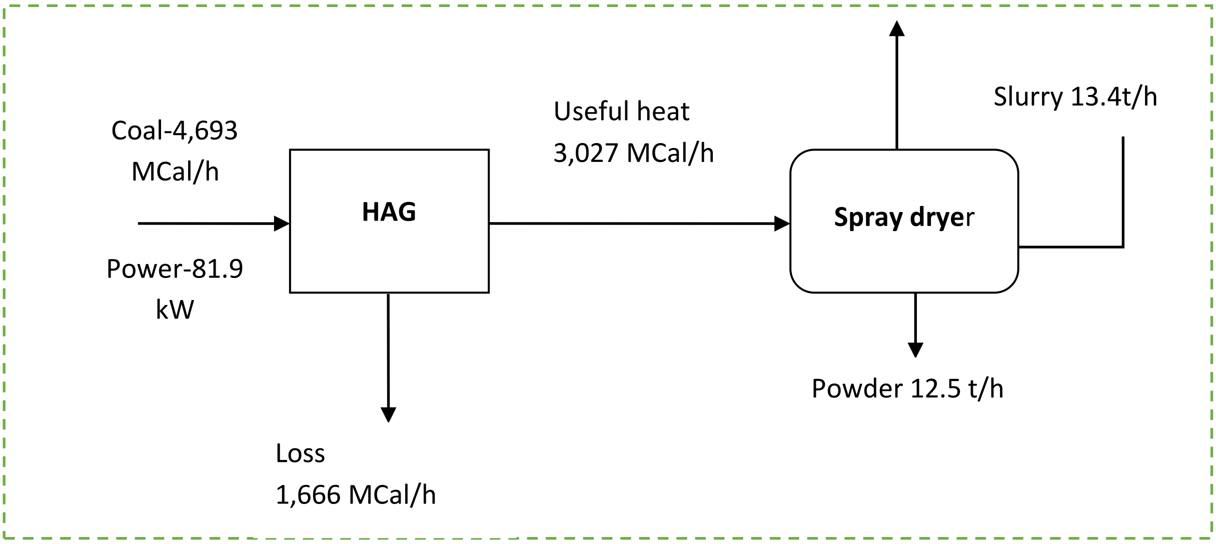


Figure 22 Energy and mass balance of Chain Stoker HAG and New Spray dryer

The old spray dryer was not in stable operation during the DEA. Based on log book data (intermittently maintained), the energy and mass balance has been determined as follows:

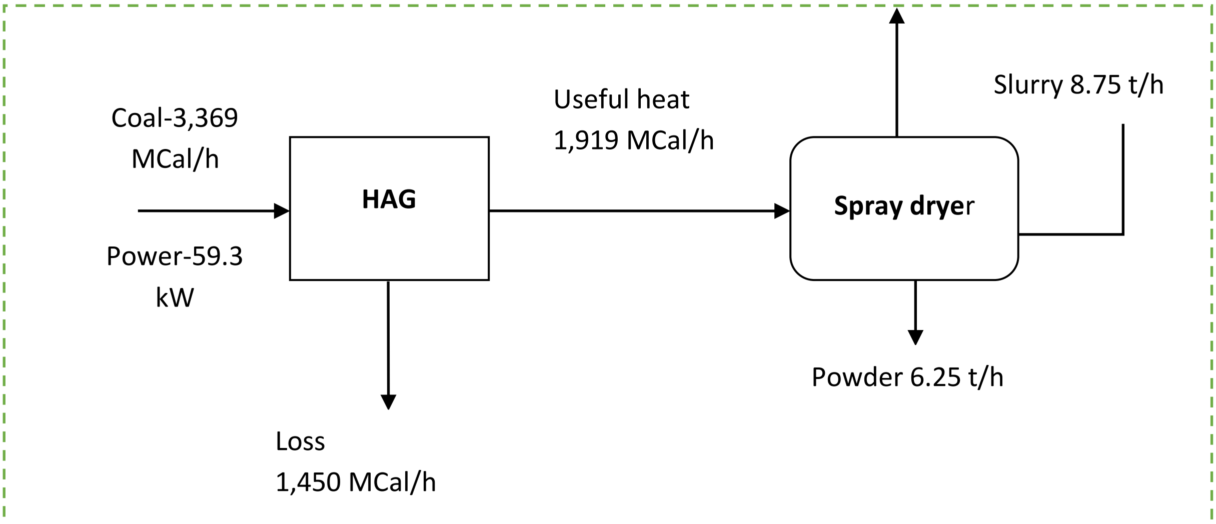


Figure 23: Energy and mass balance of Bubbling HAG and Old Spray dryer

Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for evaporating one kg water from slurry) and specific thermal energy measure (fuel used for evaporating 1 kg of water in slurry). Based on observations during DEA, for the chain stoker HAG the specific electricity consumption of HAG is 17 kW/ton and specific thermal energy is 0.25 kg of coal/kg. For the bubbling bed HAG corresponding values are 28 kW/ton and 0.40 kg of coal/kg.

Performance of spray dryer measures in terms of specific electricity consumption (electrical energy used for delivering one kg of slurry). Based on observations during DEA, the specific electricity consumption of new spray dryer was 1.06 kW/ton and old spray dryer is 0.89 kW/ton. Since blowers are VFD controlled and operation is optimized no energy conservation measure is proposed.

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 BALL MILLS

4.1.1 Specifications

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

Table 35: Specifications of ball mills

Particular	Units	Value
Numbers of ball mills	#	2
Capacity of each ball mill	t/batch	40
Water consumption in each ball mill	t/batch	18
SMS (chemical consumption)	Kg/batch	150
STPP (chemical consumption)	Kg/batch	25
Water TDS	ppm	1,500
Nos. of batch per day		5

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all ball mills

FD blower and cooling water pumps was operating with VFDs. All power profile are included in Annexure-4. Average power consumption and power factor are given in below table:

Table 36: Average power consumption and PF of ball mills

Equipment	Average Power (kW)	PF
Ball Mill#1 Old	25.5	0.99
Ball Mill#2 Old	29.9	0.99
Ball Mill#1 New	97.4	0.99
Ball Mill#2 New	154.8	0.99

Average #1 new is 97.4kW (PF0.99) and Ball Mill#2 new is 154.8 kW (PF0.99).

4.1.3 Observations and performance assessment

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

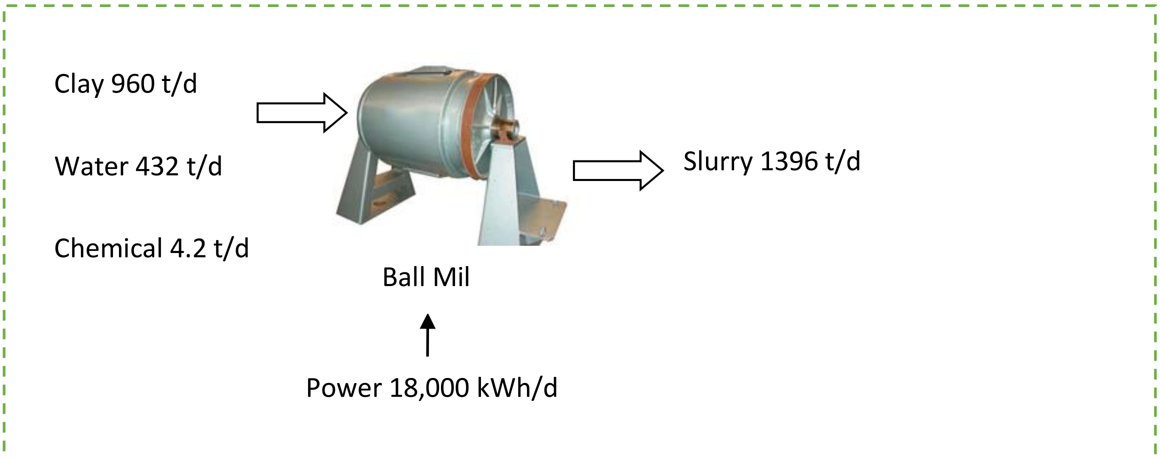


Figure 24: Energy and mass balance of Ball Mill

Performance of ball mills measure in terms of specific energy consumption (power consumed for preparation of 1 ton of slurry). Based on observations during DEA, the specific energy consumption of coal was 24kW/ton. 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) – ECM # 4 –Optimized Resource Consumption in Clay Section

Technology description

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

Study and investigation

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

Recommended action

It is recommended to install brackish water plant which will blend RO water with raw water to get desired TDS of water(less than 300 ppm) to be used in 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 37: Saving and cost benefit by using improved water quality [ECM-4]

Particulars	Unit	As Is	To Be	Remarks
Existing TDS of Water	ppm	1,500	400	
Water consumption per batch	m^3	18	15	40 ton batch
Power consumption per batch	kWh	750	728	3% saving

Particulars	Unit	As Is	To Be	Remarks
Electricity saving per batch	kWh	23		
Water saving per batch	m^3	3		
Coal saving per batch	kg/batch	451		
Water Cost	Rs /m^3	5		Assumption
Cost of Electricity	Rs/kWh	7.53		
Chemical Cost	Rs /batch	5,425	3,798	
Chemical cost saving per batch	Rs/ batch	1,628		
Electricity cost saving per batch	Rs/batch	169		
Water cost saving per batch	Rs/batch	15		
Coal saving per batch	Rs/batch	3,277		
Total cost saving per batch	Rs/batch	5,089		
Total batches per day	batches/d	5		As per discussion
Cost saving per day	Rs/d	25,447		
Operating days	d/y	330		
Cost saving per annum	Lakh Rs/y	84.0		
RO Operating cost per m^3	Rs/m^3	15.0		
Annual operating cost for RO	Lakh Rs/y	5.0		
Annual monetary savings (net)	Lakh Rs/y	79.0		
Estimated Investment	Lakh Rs	30.0		As per quotation
Payback Period	months	5		

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 (15.5MPa). 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 38: Specifications of hydraulic press

Particular	Units	Old	New
Cycle (stock) per min	N/m	6	6.8
Nos. of tiles per stock		3	8
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 4.23kW (PF 0.78), water circulation pump 2 is 4.18kW (PF 0.64).

Tiles are producing from new press were 3,000 per hour and old press is producing 1,120 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 new press was 14.5kW/ton and that off the old press was 23.6 kW/ton.

4.2.3.1 Energy conservation measures (ECM) - ECM #5: PID Controller for Press 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 this pump is drawing 8.4kW. It was also observed that even when press is not in operation pump is running.

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 39: PID Controller for Press Water Circulating Pump [ECM-5]

Particulars	UoM	AS IS	TO BE
Nos. of heat water circulating pumps	Nos.	2	2
Nos. of pumps running	Nos.	2	2
Rated power of agitator stirrer motor	kW	5	5
Running hour of pumps	h/d	24	20
Average power of motor	kW	8.4	8.4
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	66,607	55,506
Annual energy saving	kWh/y	11,101	
Cost of Electricity	Rs./kWh	7.53	
Annual energy cost saving	Lakh Rs/y	0.84	
Estimated investment	Lakh Rs.	0.28	
Payback period	months	4	

4.3 AGITATOR

4.3.1 Specifications

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

Table 40: Specifications of agitators

Particular	Units	Value
Numbers of agitators in tank	#	20
Capacity of each agitator motor	kW	2.5
Number of motors	#	15

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

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

Table 41: Power consumption and P.F. of agitator motors

Equipment	kW	PF
Agitator#1	1.39	0.34
Agitator#2	1.76	0.99
Agitator#3	1.68	0.99
Agitator#5	1.51	1.00
Agitator#6	1.54	1.00
Agitator#7	1.51	0.99
Agitator#8	1.72	0.99
Agitator#9	5.36	0.80
Agitator#9	1.62	0.40
Agitator#13	4.47	1.00
Agitator#11	1.56	0.99
Agitator#12	4.00	1.00
Agitator#13	4.56	1.00
Agitator#13	3.09	1.00
Agitator#15	3.03	1.00

4.3.3 Observations and performance assessment

Excluding two agitator motors (#1 and #9), all are running at good power factor. During DEA it is observed that all motors operate same time. It is suggested that all motor should operate by timer control.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry). Based on observations during DEA, the specific energy consumption of agitator motors were 0.17kW/ton.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 ECM #6: Timer Controller for stirrer motor

Technology description

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

Study and investigation

It was observed that all the agitators are equipped with VFD and all agitators are in continuous operation throughout the day.

Recommended action

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

Table 42: Stirrer Time Controller [ECM-6]

Particulars	Unit	AS IS	TO BE
No of agitator stirrer	Nos.	20	20
No of agitator stirrer running	Nos.	16	16
Rated power of agitator stirrer motor	kW	5	5
Running of each stirrer motor	h/d	24	12
Average power of stirrer motor	kW	2.5	2.5
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	19,626	9,813
Annual energy saving	kWh/y	0	9,813
Cost of Electricity	Rs./kWh	7.53	7.53
Annual energy cost saving	Lakh Rs./y	0.74	
Estimated investment	Lakh Rs.	0.28	
Payback Period	Months	5	

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 43: Specifications of glazing machine

Particular	Units	New sizing
Numbers of glazing mills	Nos.	4
Capacity of glazing mills	HP	20

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

4.5 Sizing

4.5.1 Specifications

There were two sizing unit as old and new sizing which comprising many grinders along dust collector blower. The specifications of sizing machines are given below:

Table 44: Specifications of sizing machine

Particular	Units	New sizing	Old sizing
Numbers of grinders	Nos.	56	34
Capacity of grinders	hp	5.5	4
Capacity of dust collectors blower	hp	30	20

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of new sizing and old sizing machines
- Daily tiles production of each sizing machine

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

Table 45: Measured Parameters of sizing machine

Equipment	Average Power (kW)	Average boxes production (boxes/d)
New sizing machine	104	6,000
Old sizing machine	49.5	1,977

4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were 29.7 kW/t for new sizing machine and 42.9 kW/t for old machine

4.6 Air Compressors

4.6.1 Specifications

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

Table 46: Specifications of compressors

Particular	Units	Air compressor 1	Air compressor 2	Air compressor 3
Power rating	HP	30	30	45
Maximum pressure	Bar (a)	8	8	8
Air handling capacity	m^3/m	3.96	3.96	7.14

4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

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

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

Table 47: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)	% of time on load
Compressor-1	18.2	0.72	2	65
Compressor-2	20.5	0.77	1.7	100
Compressor-3	32.8	0.83	2.9	100

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

4.6.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption are 0.29 kW/CFM, 0.31 kW/CFM and 0.33 kW/CFM for the three compressors, respectively.

4.6.4 Energy conservation measures (ECM) - ECM #7: VFD installation for 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 three compressors were captured to understand unload/load pattern of air compressor it was found that two of compressor 1 is getting unloaded for 35% of the time. There was only one receiver and it was not possible to conduct FAD test for compressor.

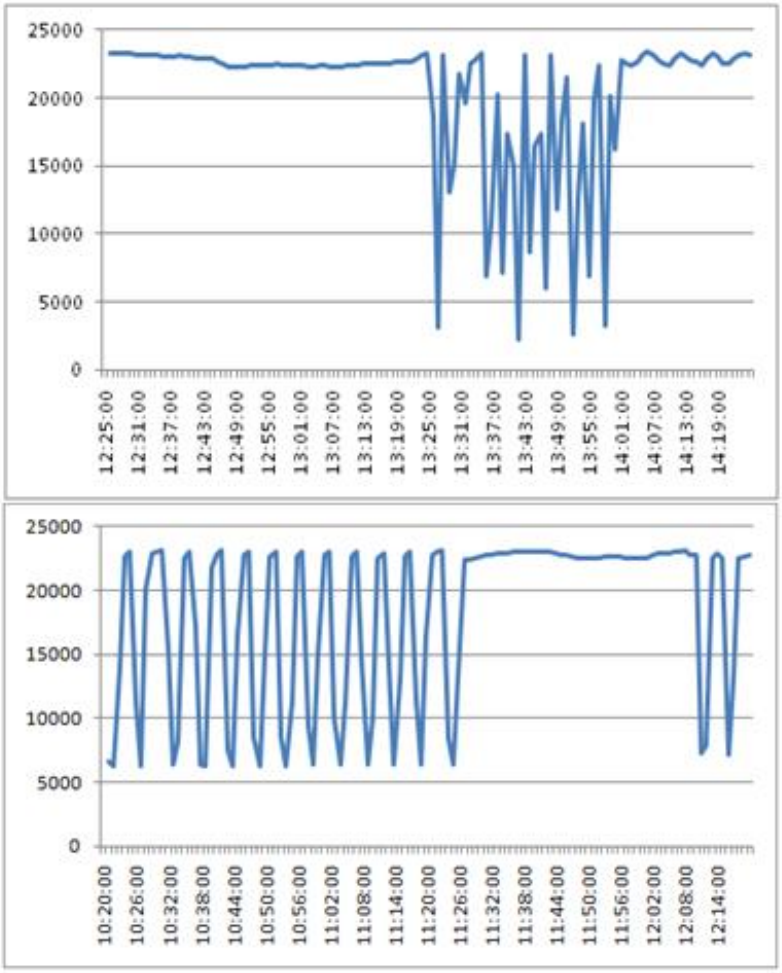


Figure 25: Load/Unload pattern of Compressor#1 and Compressor#2

Recommended action

It is recommended to install VFD on compressor 1 which will cater to the variable air demand of the plant whereas other two compressors will run to meet the base load. The cost benefit analysis for this project is given below:

Table 48: VFD for compressor 1 [ECM-7]

Particulars	Unit	Values
Present Power Consumption of smaller compressors	kWh/d	406
Unload Power of Compressor	kW	9.79
Percentage Unload	%	35
Saving Potential	kWh/d	142
Operating days	d	330
Saving Potential	kWh/y	46,893
Cost of Electricity	Rs/kWh	7.5
Saving Potential	Rs/y	353,258
Estimated Investment	Rs	150,000
Payback Period	months	5

4.7 WATER PUMPING SYSTEM

4.7.1 Specifications

Pumping system comprises one bore well pumps and five transfer pumps.

4.7.2 Field measurement and analysis

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

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

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

Table 49: Operating details of pump

Particulars	Unit	Value
Measured flow	m^3/h	13.9
Total head	M	96
Actual power consumption	kW	14.9

4.7.3 Observation and performance assessment

Based on observations during DEA, the pump efficiency is determined as 29%.

4.7.4 Energy conservation measures (ECM) - ECM #8: Replacement of inefficient bore well pump with efficient pump

Technology description

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

Study and investigation

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

Recommended action

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

Table 50: Replace bore-well pump by energy efficient pump [ECM-8]

Particulars	Unit	Present	Proposed
Measured Data			
Flow rate Q	m^3/h	13.9	13.9
Suction Pressure	kgf/cm^2 (a)	-7.6	-7.6
Discharge Pressure	kgf/cm^2 (a)	2.00	2.00
Motor Input Power	kW	14.9	5.1
Calculated Data			
Flow rate Q	m^3/s	0.00387	0.00387

Particulars	Unit	Present	Proposed
Pressure Difference	kgf/cm^2 (a)	9.6	9.6
Total Head/head developed	M	96.0	96.0
Liquid Horse Power	kW	3.6	3.6
Motor Input Power	kW	14.9	5.1
Motor Efficiency	%	95.00	95.00
Motor Loading	%		
Pump Efficiency	%	25.8	75.0
Potential saving	kW	9.2	
Operating hour per day	h/d	10	
Annual operating days	d/y	330	
Annual power savings	kWh/y	30,284	
Cost of Electricity	Rs./kWh	7	
Annual Monetary savings	Lakh Rs/y	2.1	
Estimated investment	Lakh Rs	3.9	
Payback Period	Months	22	

4.8 Lighting System

4.8.1 Specifications

The plant lighting system includes:

Table 51: Specifications of lighting load

Particular	Units	CFL	Fluorescent tube light
Power consumption of each fixture	W	85	36
Numbers of fixtures	#	205	50

4.8.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 52: Lux measurement at site

Particular	Units	Value
Office	$Lumen/m^2$	160
Kiln control room	$Lumen/m^2$	110
Kiln area	$Lumen/m^2$	60
New Press	$Lumen/m^2$	70
Old press	$Lumen/m^2$	65
Ball mill and agitators	$Lumen/m^2$	70
HAG and spray dryer new	$Lumen/m^2$	75
HAG and spray dryer old	$Lumen/m^2$	70
Vertical dryer	$Lumen/m^2$	65
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 luminares with more energy efficient types which are currently available.

4.8.4 Energy conservation measures (ECM) - ECM #9: Replacement of inefficient light

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 205 CFL and 50 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 53: Replacement of CFL 85 watt to retrofit 36 watt flood light [ECM-9]

Particulars	Units	Present	Proposed
Fixture		CFL	36 watt flood light
Power consumed by CFL	W	85	36
Operating hours	h/d	12	12
Operating days	d/y	330	330
Energy Used	kWh/y	337	143
Cost of Electricity	Rs./kWh	7.53	7.53
No. of Fixture	Unit	205	205
Power consumption	kWh/y	69,003	29,225
Operating cost	Rs. Lakh/y	5.20	2.20
Electrical saving	kWh/y	39,778	
Annual Monetary saving	Rs Lakh/y	3.00	
Investment per fixture of LED	Rs Lakh	0.0075	
Estimated Investment	Rs Lakh	1.54	
Payback Period	months	6	

Table 54: Replacement of tube light 36 watt to retrofit 20 watt LED Tube light [ECM-9]

Particulars	Units	Present	Proposed
Fixture		36 W FTL	20 W LED
Power consumed by Tube light	W	36	20
Operating hours	h/d	12	12
Operating days	d/y	330	330
Energy Used	kWh/y	143	79
Cost of Electricity	Rs./kWh	7.53	7.53
No. of Fixture	Unit	50	50
Power consumption	kWh/y	7,128	3,960
Operating cost	Rs. Lakh/y	0.54	0.30
Electrical savings	kWh/y	3,168	

Particulars	Units	Present	Proposed
Annual Monetary saving	Rs. Lakh/y	0.25	
Investment per fixture of LED	Rs	500	
Estimated Investment	Rs. Lakh	0.25	
Payback Period	months	13	

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 are 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 new and old plant main incomer feeder

4.9.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **380 kVA** at old plant feeder and **1370 kVA** at new plant feeder.

The voltage profile of the unit is satisfactory and average voltage measured was **428.5 V.** Maximum voltage was **438.9 V** and minimum was **419.5 V**.

Average total voltage and current Harmonics distortion found **9.8%** & **19.9%** 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: Install active harmonics Filter

Technology description

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

- Increased line losses.
- Reduced efficiency and increased losses in rotating machines.
- Overstressing of capacitors.
- Cable insulation failure.

- Increased losses and stress on insulation of transformers.
- Mal operation of relays.
- Errors in metering equipment.
- Telephone interference.

Study and investigation

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 6.7 kW.

Table 55: Measured Harmonics Level at Main Incomer

Name & Sr. No.	Phase		Voltage	Amp.	THD V (%)	THD I (%)	Individual Current Harmonics				
							A3%	A5%	A7%	A9%	A11%
Main Incomer	R	Average	433	1394	9.74	20.6	2.40	17.9	9.75	0.97	0.62
		Maximum	443	1652	11.6	31.0	3.50	26.8	15.2	1.4	1.4
		Minimum	363	902	7.20	12.8	1.20	12.4	2.50	0.60	0.00
	Y	Average	437	1500	9.45	19.4	3.98	16.5	9.22	0.62	0.64
		Maximum	447	1782	11.2	30.3	5.80	26.1	14.2	1.2	1.6
		Minimum	428	963	7.00	11.6	2.80	10.7	3.10	0.00	0.00
	B	Average	431	1404	10.1	19.8	0.76	18.1	7.81	0.28	0.54
		Maximum	442	1646	12.1	29.5	1.70	26.9	11.9	0.7	1.4
		Minimum	365	926	7.50	12.7	0.00	16.7	7.00	0.40	0.30

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

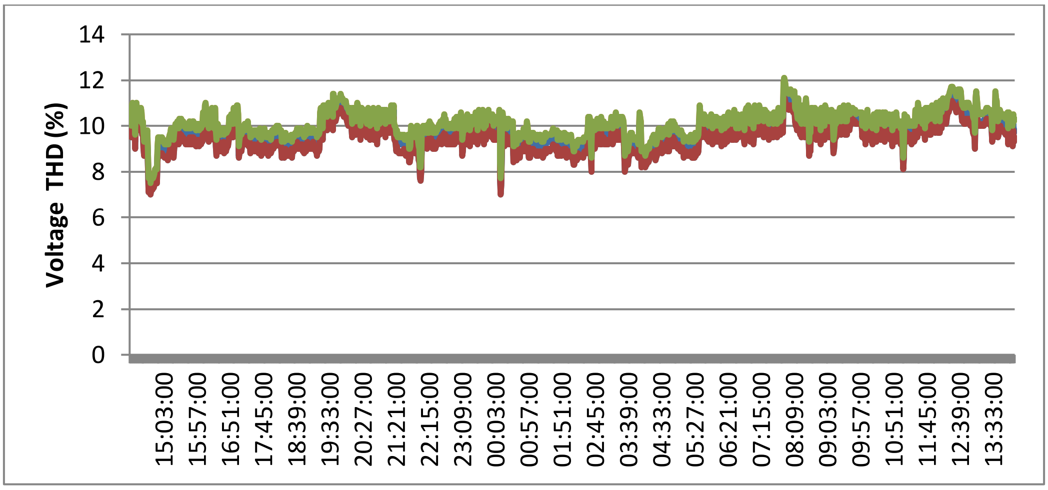


Figure 26: Voltage THD profile

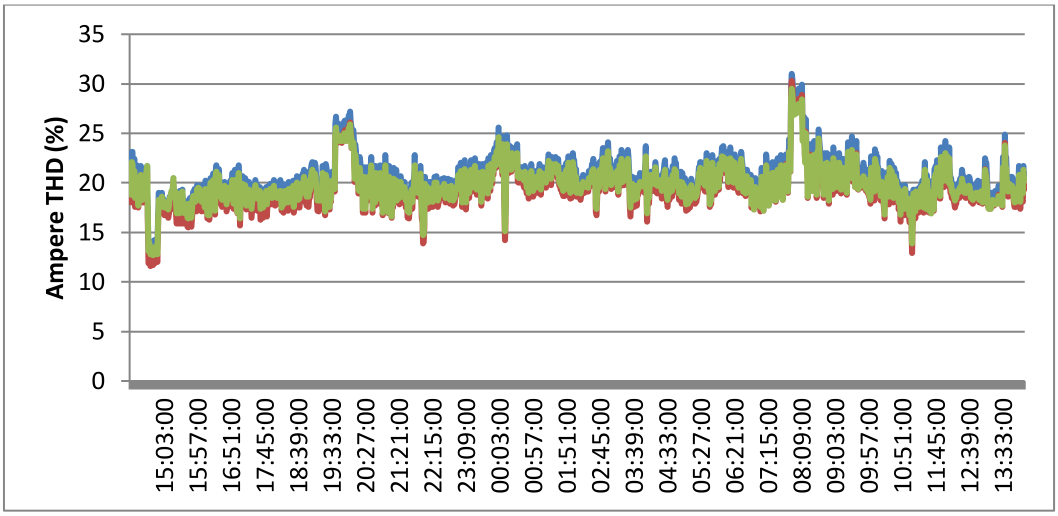


Figure 27: Ampere THD profile

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 230 A**. Estimation of ratings for AHF is done on the basis of power cycles captured during field visit.

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

The cost benefit analysis for this project is given below:

Table 56: Install active harmonics Filter [ECM-10]

Particulars	Unit	As Is	To be
Estimated losses due to Harmonics	kW	6.70	0
Saving potential by installation of active harmonics filter	kW	6.7	
Operating days	d	330	
Operating hours	h	24	
Saving potential	kWh/y	53,071	
Cost of Electricity	Rs./kWh	7.53	
Annual Saving	Rs./y	399,798	
Estimated rating of active harmonics filter	Ampere	230	
Estimated Investment	Rs	1,380,000	
Payback Period	months	41	

4.9.4.2 ECM #11: Energy monitoring system

Technology description

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

Study and investigation

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

Recommended action

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

- Kiln
- Horizontal dryer

The cost benefit analysis for this project is given below:

Table 57: Cost benefit analysis [ECM-11]

Parameters	Unit	As Is	To Be
Energy monitoring saving for electrical system	%		3.00
Energy consumption of major machines per year	kWh/y	539,829	523,635
Annual electricity saving per year	kWh/y		16,195
Unit Cost	Rs/kWh		7.53
Annual monetary savings	Lakh Rs./y		1.22
Number of equipments	Nos.	-	7.00
Estimate of Investment	Lakh Rs.	0.35	
Simple Payback	months	3	
Energy monitoring saving	%	3.00	
Current fuel consumption for kiln	kg/y	10,144,483	9,840,149
Annual fuel saving per year	kg/y	304,335	
Unit Cost	Rs./kg	7.27	
Annual monetary savings	Lakhs Rs./y	22.12	
Number of equipments	Nos.	2.00	
Estimate of Investment	Lakhs Rs.	0.40	
Payback Period	months	<1	

4.9.5 ECM #12: Cable loss minimization

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted in sizing section power factor was between 0.59-0.70, whereas in press section the power factor was 0.69-0.87 and keeps on varying as per the operation of the press.

Recommended action

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

Table 58: Cable Loss minimization [ECM-12]

Location/Parameter	Unit	Sizing Old Plant	Press Old Plant	Sizing New Plant	Press New Plant
Existing Power Factor	pf	0.70	0.68	0.59	0.87
Proposed Power Factor	pf	0.98	0.98	0.98	0.98
Existing load	kW	54.9	71.9	104	257
Cable Losses	Watts	143	1,058	1,222	1,672
Capacitor Required	kVAr	45	63	121	93
Savings Estimated	Rs/y	3,847	30,916	46,306	21,135
Total Savings	Rs/y	102,204			
Estimated Investment	Rs	111,037			
Payback Period	months	13			

4.9.6 ECM #13: Voltage Optimization

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.

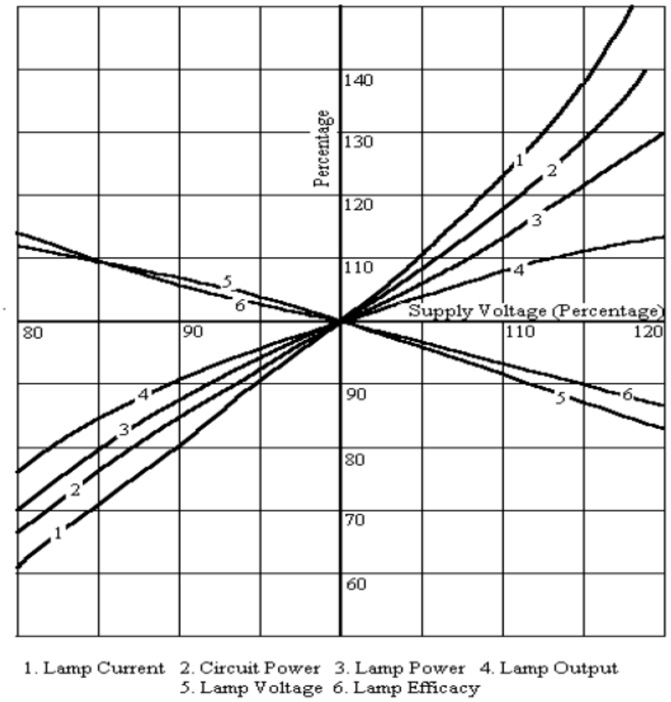


Figure 28: Effect of supply voltage on lamp parameters

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 including old and new plant is 12 kW and measured voltage level is 435 V.

Recommended action

It is recommended to install separate lighting transformer of 20 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 59: Voltage Optimization in lighting circuit [ECM-13]

Particulars	Unit	Values
Present Power Consumption in Lighting	kWh/d	288
Present Voltage Level in Lighting Circuit	V	435
Proposed Voltage Level in Lighting Circuit	V	380
Saving Potential	%	23.69
Saving Potential	kWh/d	68
Saving Potential	kWh/y	22514
Saving Potential	Rs/y	169,602
Investment Required	Rs	50,000
Payback Period	months	4

4.10 Belt Operated Drives

4.10.1 Specifications

There are 13 drives operated with V Belt of total capacity of 207 kW. Locations include

- Kiln (5
- HAG (2)
- Vertical and horizontal dryer (6)

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 #14: V Belt replacement with REC belt

Technology description

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

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

Study and investigation

The unit is having about 15 belt driven blowers in plant

Recommended action

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

Table 60: Replacement of conventional belt with REC belt [ECM-14]

Particulars	UoM	AS IS	TO BE
Measured power of all belt driven blowers	kW	207	199[2]
Running hours of blowers	h/d	24	24
Average power of blowers	kWh/d	4,964	4,786
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	1,638,249	1,579,272
Annual energy saving	kWh/y	58,977	
Electricity cost	Rs./kWh	7.53	
Annual energy cost saving	Rs. Lakh	4.44	
Estimated investment	Rs. Lakh	3	
Payback Period	Months	8	

[2] 3.6% energy saving is claimed as per latest suppliers

5. Chapter -5 Energy consumption monitoring

5.1 ENERGY CONSUMPTION MONITORING

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

5.2 BEST OPERATING PRACTICES

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

Table 61: Unique operating practices in the unit

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Ball mill	VFD for energy saving.
3	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing pollution
3	Press	PRV installed for regulating usage of compressed air
5	VT Dryer	Waste heat from kiln is used in VT dryer. Out of three VT dryer, one VT dryer runs without supplementary fuel.
6	Glaze ball mill	Timer control in each ball mill.
7	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
8	Sizing	Fully automatic system. Dust collected system installed.
9	Printing	Automated digital printing with fully auto control system
10	Lighting	LED lights installed in some areas

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[3].

The main technical specifications are as follows:

Table 62: 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

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

Parameter	UOM	Scenario-1	Scenario-2	Scenario-3
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[4]:

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%
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:

[4] 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

Cooling air may have temperature ranging from 120°C to 250 °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°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 °C depending upon the product and kiln temperature.

Figure 29: Heat recovery system for combustion air

The estimated benefits of double heat recovery include[5]:

- Fuel savings upto 10%
- Combustion air temperature up to 250 °C at burner
- Easy installation

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

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[6]:

1. **Upgrading burners** with better technology and higher combustion efficiency with several benefits like:

[5] SACMI Kiln Revamping catalogue for roller kilns

[6] SACMI Kiln Revamping catalogue for roller kilns

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** – Sin**gle 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 30: 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.

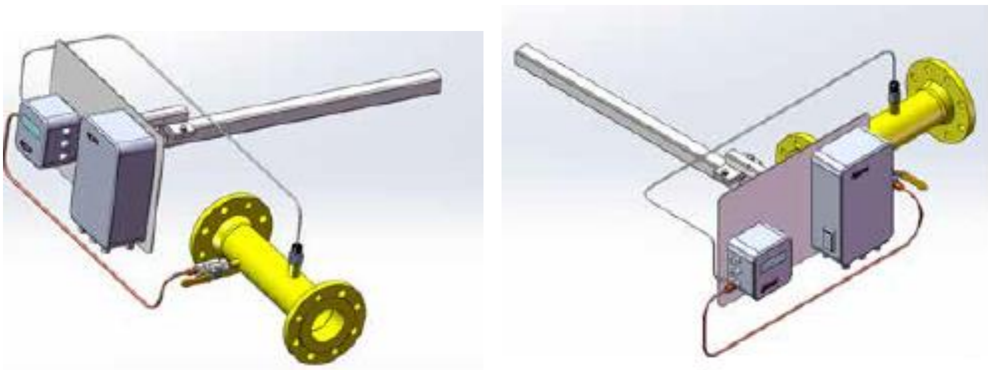


Figure 31: Combustion air control for burner

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 set 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 32: 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

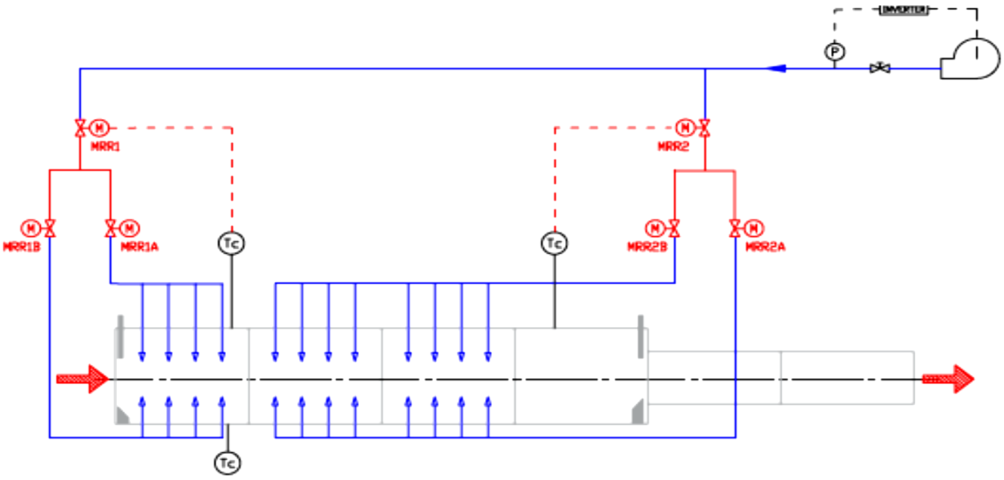


Figure 33: Fast cooling air management

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
    - Complete consumption and production database available to corporate network and to management software using internet or database SQL protocols.

Figure 34: 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 35: - 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. These 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 is 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[7]) 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 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[8] 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:

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

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

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

Advantages of using Binder for Vitrified tiles include:

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

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

5.3.7 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 36: Direct drive blower fan

6. Chapter -6 Renewable energy applications

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

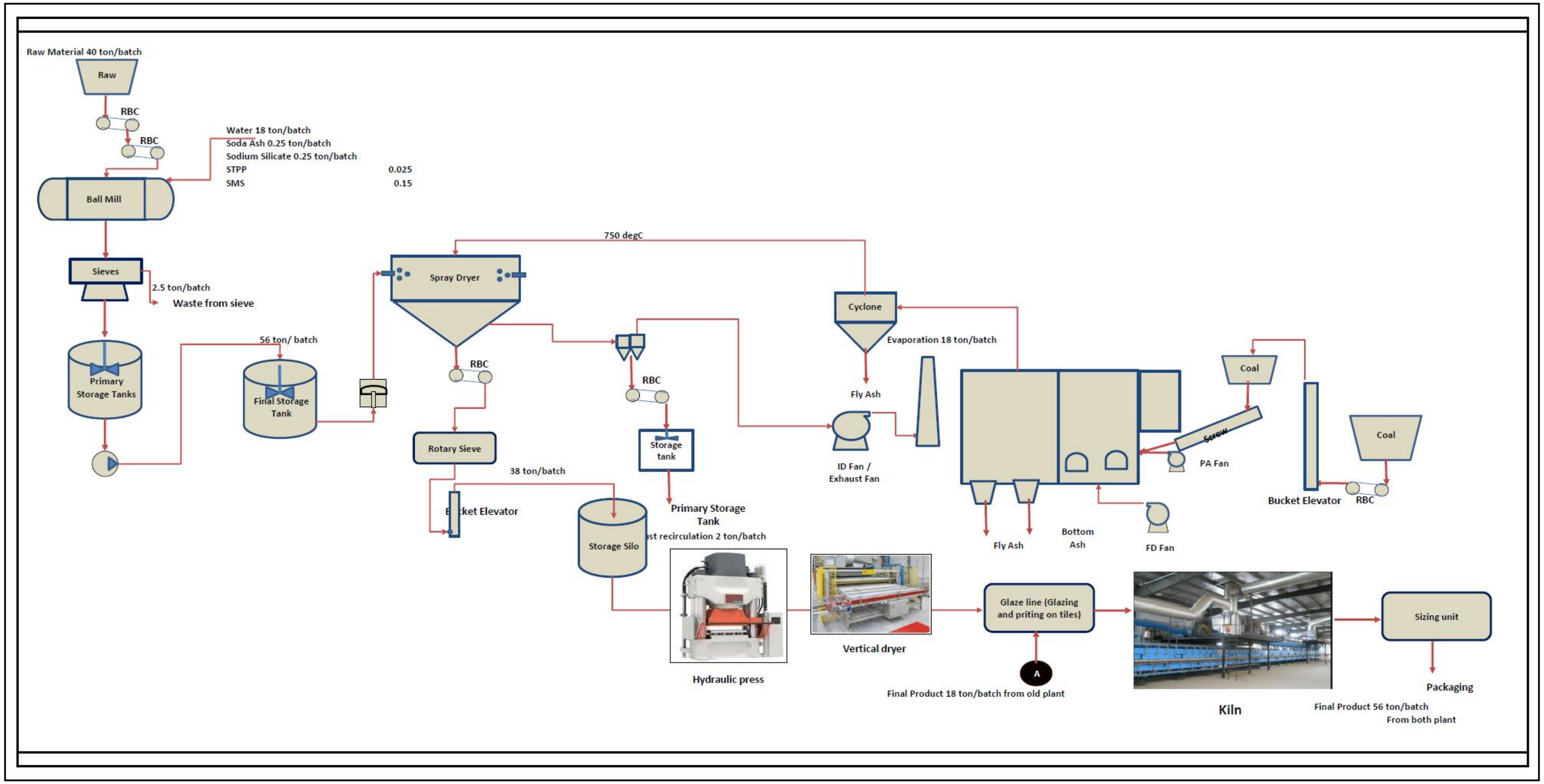
The RCC roof top space available is 1,000m2 and corresponding solar power potential will be 100kW. Other roof areas are sloping structures, where structural enhancement is required for solar PV installation. There is no ground space available for solar PV installation.

As per discussion with vendors, due to high dust content in the region, installation of solar PV is not feasible. The extent of degradation on account of dust is upto 40% (for 6g of dust per panel).

Therefore Solar PV installation is not recommended.

7. ANNEXES

7.1 ANNEX-1: PROCESS FLOW DIAGRAM



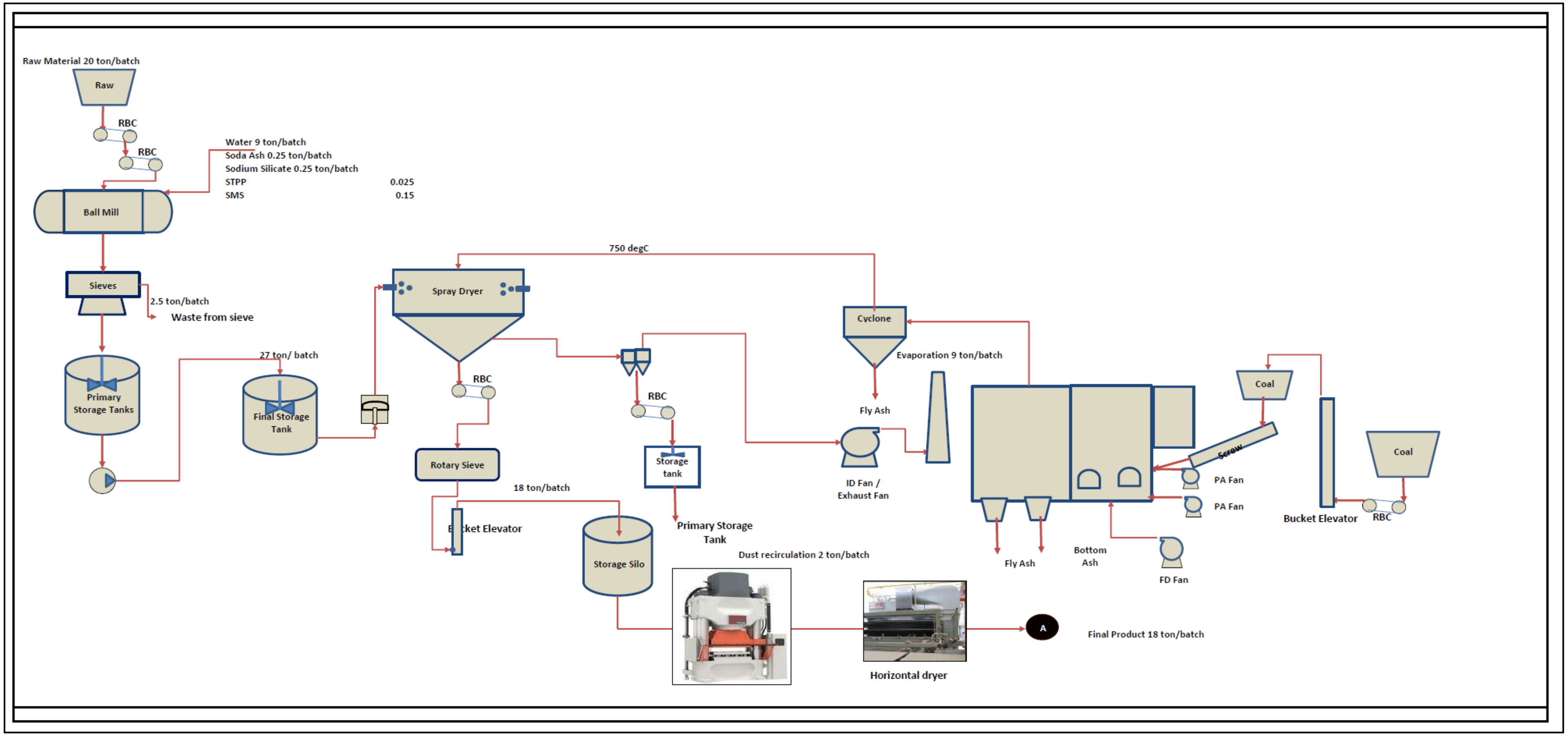


Figure 37: Process Flow Diagram of Plant

7.2 ANNEX-2: DETAILED INVENTORY

Table 63: Detailed Inventory list

Parameters	UOM	Value
Old Plant clay section	kW	117.8
Old plant glaze section	kW	72.4
Old Spray Dryer	kW	120.1
New Line	kW	82.8
New Spray Dryer	kW	230.5
New Press - HLT-5000	kW	152.2
New plant vertical dryer	kW	96.2
Old Press 980-1	kW	70.1
Old Press 980-2	kW	63
Old Dryer	kW	27.2
Old kiln Section	kW	152.7
Old Line to kiln	kW	19.8
Old Sizing	kW	129.1
Old plant coal conveyor	kW	11.2
New kiln	kW	264.1
New Sizing Machine	kW	272.3
New plant coal conveyor	kW	38.
Coal Gasifier	kW	61.2
Single phase load	kW	20
Total	kW	2,001

7.3 ANNEX-3: SINGLE LINE DIAGRAM

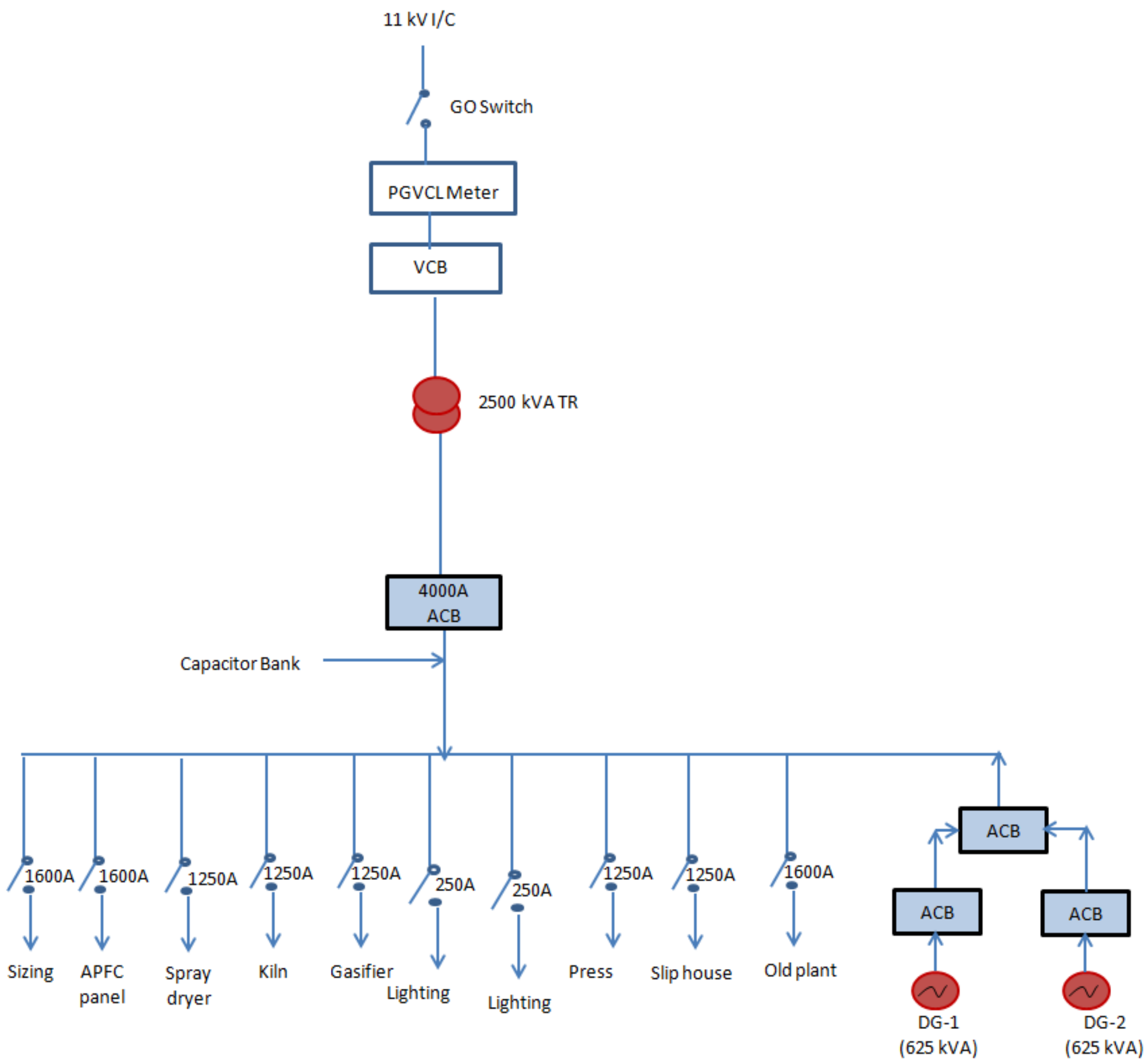


Figure 38: Single Line Diagram (SLD)

7.4 ANNEX-4: ELECTRICAL MEASUREMENTS

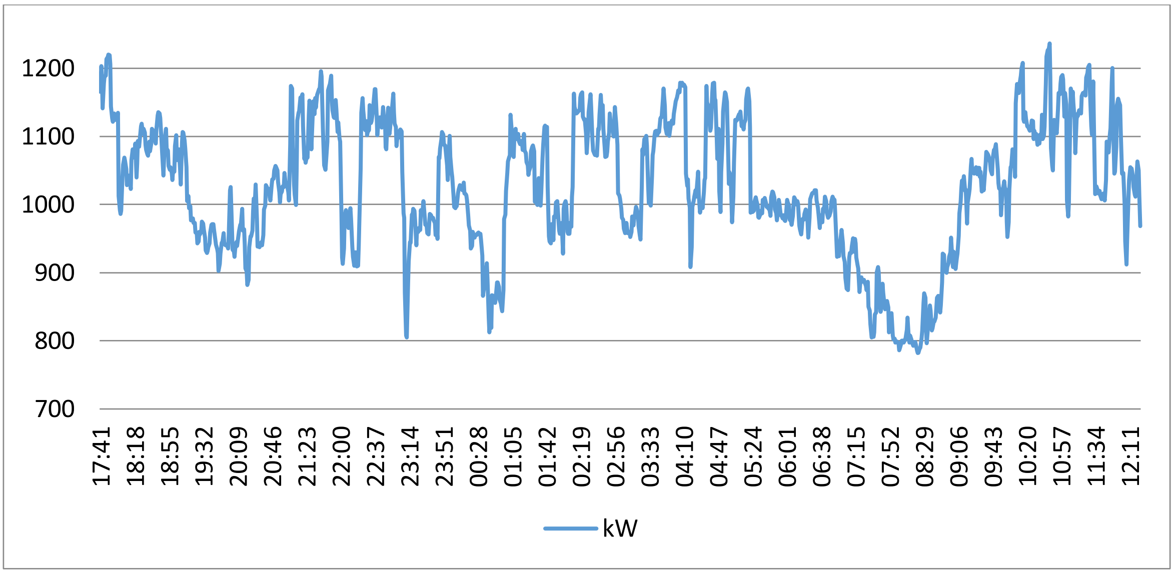
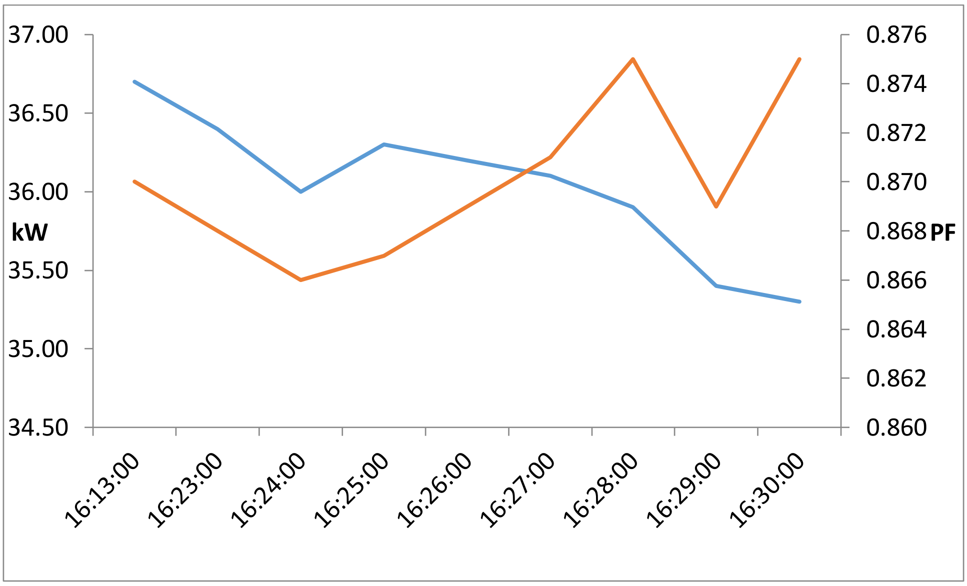
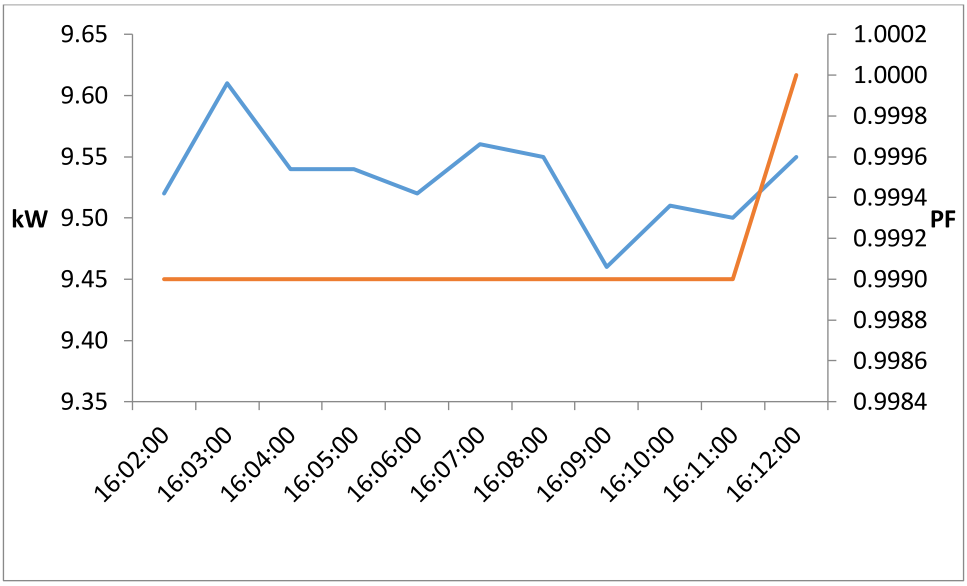


Figure 39: Power profile (kW) of Main Incomer

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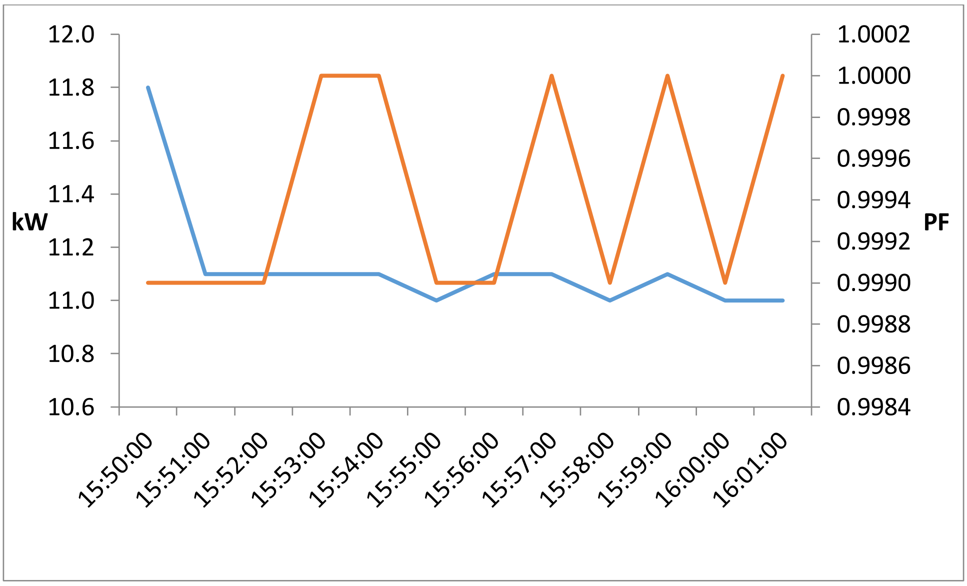
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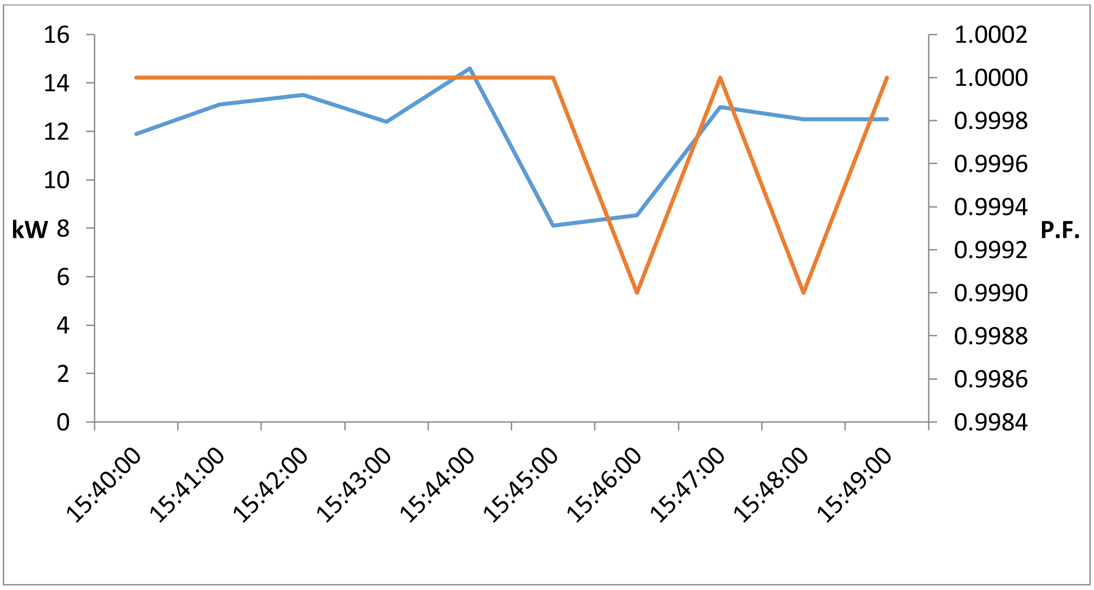
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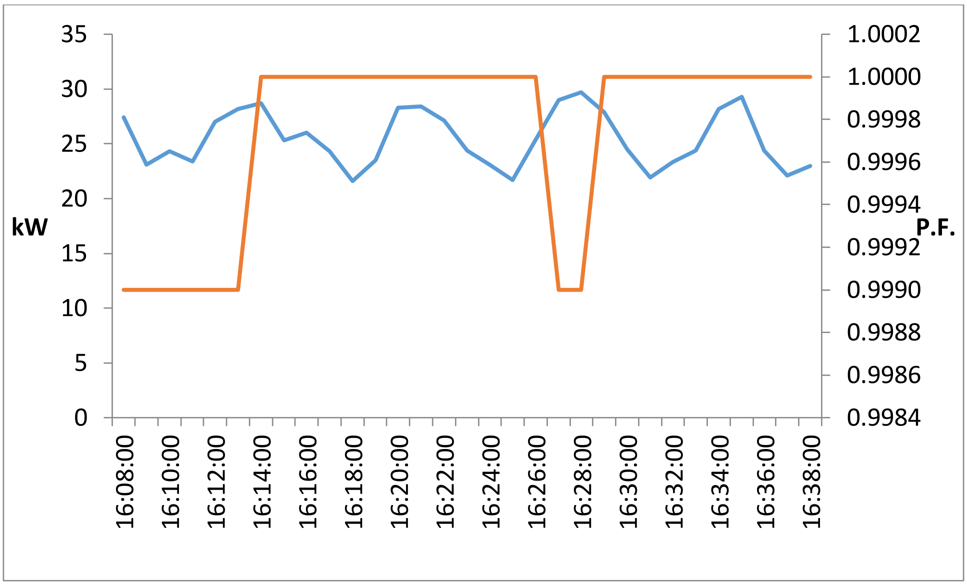
Figure 40: Power and PF profile of blowers of kiln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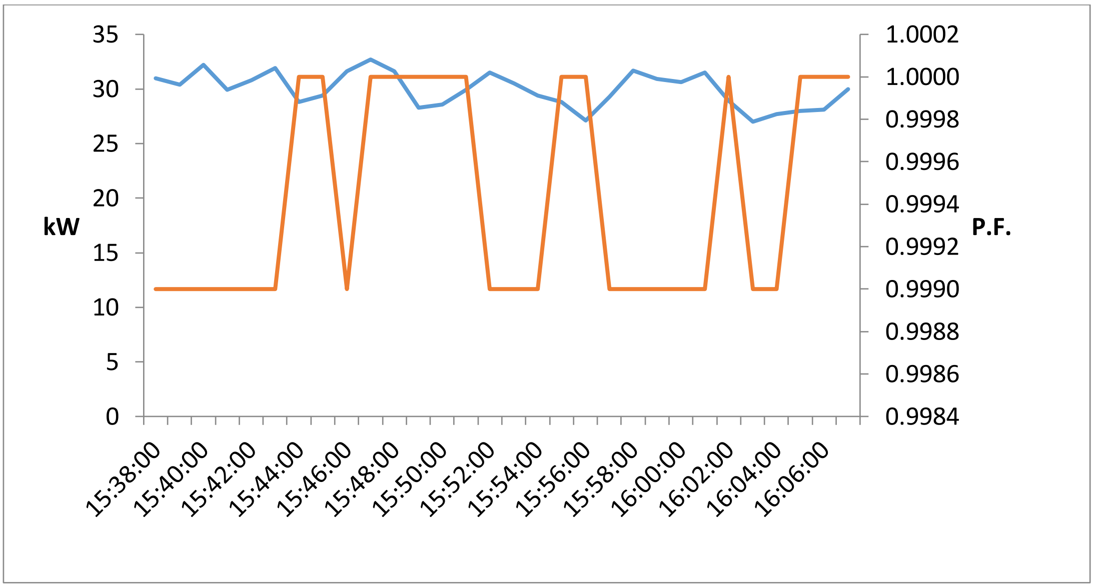
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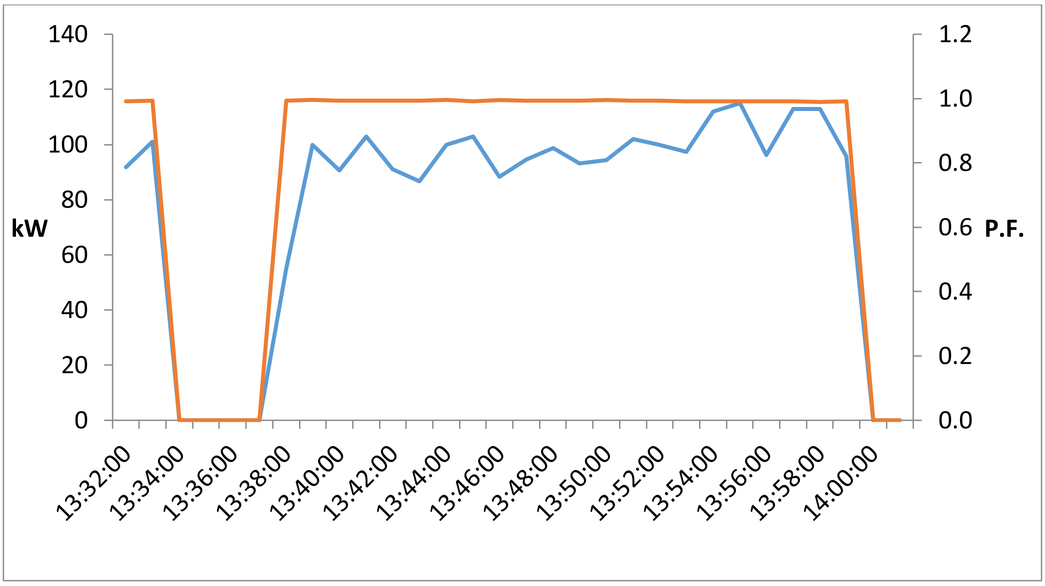
16:06:00



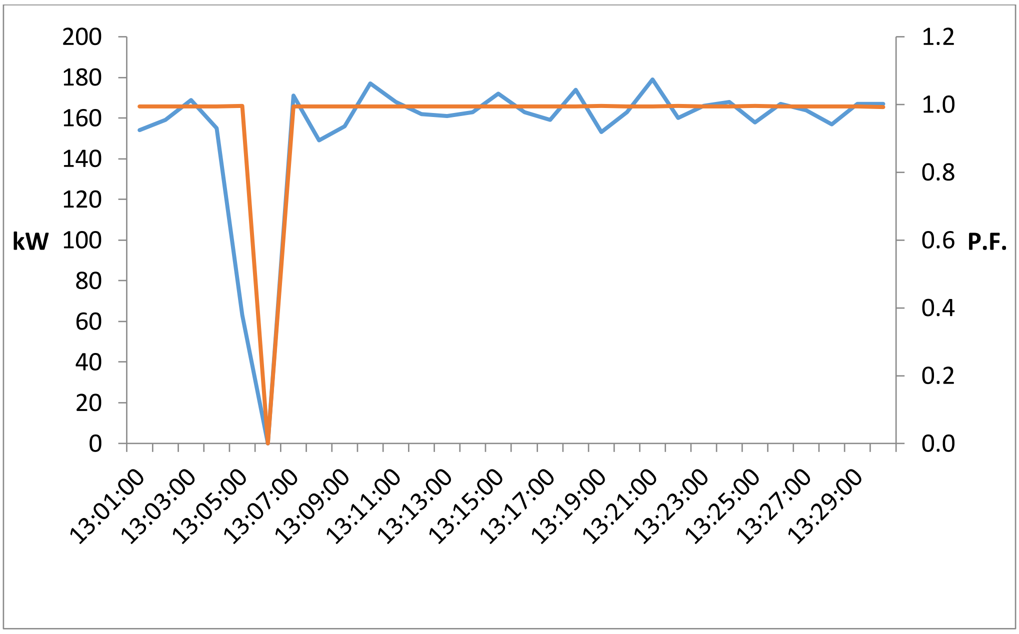


Figure 41: Power and PF profile of blowers of Ball Mills

7.5 ANNEX-5: THERMAL MEASUREMENTS, KILN EFFICIENCY, HAG EFFICIENCY, GASIFIER PERFORMANCE

1. Kiln efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1200	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	1278.49	*kg/h*
Flue Gas Details		
Flue gas temp at smog blower	240	*°C*
Preheated air temp./Ambient	110	*°C*
O2 in flue gas	8.3	*%*
CO2 in flue gas	7.3	*%*
CO in flue gas	76	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*12.78*	%
H	*14.90*	%
N	*50.17*	%
O	*19.31*	%
S	*0.33*	%
Moisture	*2.50*	%
Ash	*0.00*	%
GCV of fuel	1178	*kCal/kg*
Ash Analysis		

Input Data Sheet		
Un-burnt in bottom ash	*0.00*	%
Un=burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kCal/kg
GCV of fly ash	*0*	kCal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	2046	*Kg/h*
Weight of Stock	2046	*kg/h*
Specific heat of clay material	0.22	*KCal/kg°C*
Avg. specific heat of fuel	0.51	*KCal/kg°C*
fuel temp	40.2	*°C*
Specific heat of flue gas	0.24	*KCal/kg°C*
Specific heat of superheated vapor	0.45	*KCal/kg°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	5428	*kCal/h*
Radiation and convection from heating zone surface	22,298	*kCal/h*
Heat loss from all zones	27,726	*kCal/h*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.82	*h*
Area of entry opening	1.2	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temperature of kiln	343	*deg K*

Efficiency calculations

Parameters	Value	Unit
Theoretical Air Required	5.84	*kg/kg of fuel*
Excess Air supplied	65.35	*%*
Actual Mass of Supplied Air	9.66	*kg/kg of fuel*
Mass of dry flue gas	9.32	*kg/kg of fuel*
Amount of Wet flue gas	10.66	*kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.65	*kg of H_2O/kg of fuel*
Amount of dry flue gas	9.01	*kg/kg of fuel*
Specific Fuel consumption	625.02	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	769,676	*kCal/ton of tiles*
Sensible heat of fuel		*kCal /ton of tile*
Total heat input	769,676	*kCal /ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	255,156	*kCal /ton of tile*
Heat loss in dry flue gas	278,611	*kCal /ton of tile*
Loss due to H2 in fuel	40,770	*kCal /ton of tile*
Loss due to moisture in combustion air	869	*kCal /ton of tile*

Parameters	Value	Unit
Loss due to partial conversion of C to CO	470	*kCal /ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	13,624	*kCal /ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	10,530	*kCal /ton of tile*
Total heat loss from kiln (surface) body	-	*kCal /ton of tile*
Heat loss due to un-burnt in Fly ash	-	*kCal /ton of tile*
Heat loss due to un-burnt in bottom ash	-	*kCal /ton of tile*
Heat loss due to kiln car	169,646	*kCal /ton of tile*
Unaccounted heat losses	255,156	*kCal /ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	13555	*kCal /tons*
Kiln Efficiency	33.2	*%*

2. *Heat Balance Diagram*

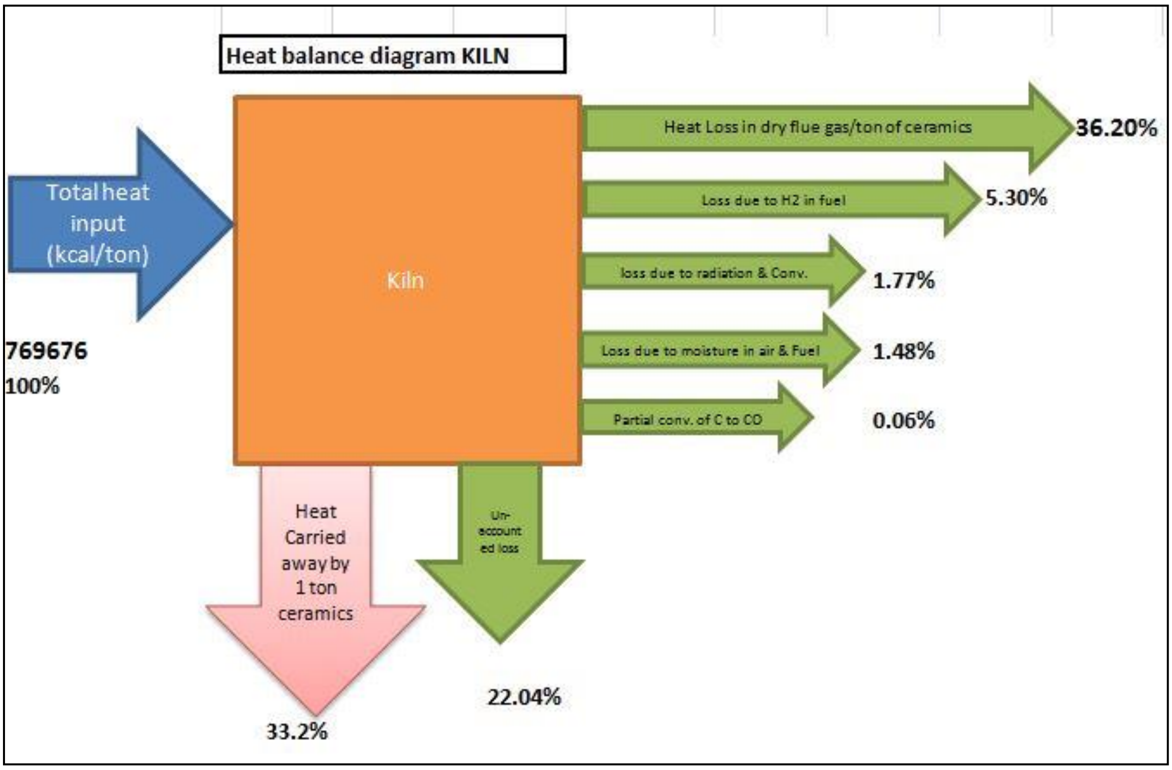


Figure 42: Heat Balance diagram of kiln

7.6 ANNEX-6: LIST OF VENDORS

ECM – 1: Excess air control in kiln

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

ECM 2: Radiation and convection loss reduction from surface of kiln

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

ECM 3: WHR from kiln using recuperator

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Knackwell Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445,	9824037124, 9624042423	http://www.knackwellengineers.com/ darshan@kanckwell.com ravi@kanckwell.com
2	Aerotherm Products	No. 2406, Phase 4, G. I. D. C. Estate Vatva,	+91-9879104476,	http://www.aerotherm.in

Sl. No.	Name of Company	Address	Phone No.	E-mail
		Ahmedabad - 382445,	9898817846	
3	Aerotherm Systems Pvt Ltd	Plot No 1517, Phase III, GIDC, Vatwa Ahmedabad-382445	079 -25890158, 25895243	AeroThermSystems.com contact@aerothermsystems.com

ECM: 4- Using soft water in Clay ball mill

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

ECM 5: PID controllers

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	SHIWKON controls	33-34-35, First Floor, Shakti Chamber - 1, N. H. 8A, Opposite Adarsh Hotel, Morbi-363642	93750 50704	morbi@shiwkon.com
2	Happy Instruments	20, Prafullit Society, Near Navo Vas Rakhial Gam Ahmedabad- 380021,	8048707581	https://www.happyinstrument.co.in/
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 –6 : Installation of Electronic timer controller fro stirrer

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

ECM 7: VFD installation

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

ECM - 8: Pumps replacement with Efficient pumps

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Varuna Pumps Pvt Ltd.	La-Gajjar Machineries Pvt.Ltd. Acidwala estate, Nagarwel Hanuman Road, Amraiwadi, Ahmedabad – 380 026	79- 22777485 / 487	www.varunapumps.com crm@lgmindia.com
2	Kirloskar Brothers Ltd	1st floor, Kalapi Avenue, Opp. Vaccine Institute, Old Padra Road, Vadodara	Mr. Sanjeev Jadhav 0265-2338723/2338735	aksur@bdq.kbl.co.in

3	KSB Pumps Ltd	Neel Kamal, Ashram Road, Opposite Sales India, Ashram Road, Ahmedabad, Gujarat 382410	Mr. Jayesh Shah 098794 83210	https://www.ksb.com/ksb-in/ksb-in-india/

ECM 9: Energy efficient light

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Osram Electricals Contact Person: Mr. Vinay Bharti	OSRAM India Private Limited, Signature Towers, 11th Floor, Tower B, South City - 1,122001 Gurgaon, Haryana	Phone: 011-30416390 Mob: 9560215888	vinay.bharti@osram.com
2	Philips Electronics Contact Person: Mr. R. Nandakishore	1st Floor Watika Atrium, DLF Golf Course Road, Sector 53, Sector 53 Gurgaon, Haryana 122002	9810997486, 9818712322 (Yogesh-Area Manager), 9810495473 (Sandeep-Faridabad)	r.nandakishore@phillips.com, sandeep.raina@phillips.com
3	Bajaj Electricals Contact Person: Mr. Kushgra Kishore	Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002	9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341 (Mr. Rahul Khare),	kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com; sanjay.adlakha@bajajelectricals.com

ECM - 10: Installation of Harmonics filter

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Infinity Enterprise Private Limited	13, Crystal Avenue & Industrial Park, near Odhav Ring road circle, Odhav, Ahmedabad – 382415, Gujarat, India.	Mob: +91 8048412433	info@infinityenterprise.net
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com
3	Hitachi Hi-Rel Power Electronics Pvt. Ltd	B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044	Mr. V.Jaikumar 079 2328 7180 - 81	v_jaikumar@hitachi-hirel.com

ECM 11: Energy Monitoring System

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Iadept Marketing Contact Person: Mr. Brijesh Kumar Director	S- 7, 2nd Floor, Manish Global Mall, Sector 22 Dwarka, Shahabad Mohammadpur, New	Tel.: 011-65151223	iadept@vsnl.net, info@iadeptmarketing.com

		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

ECM 12: cable loss minimization

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

ECM - 13: Voltage optimization using Servo-stabilizers

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Protek Enterprises	Protek House, Opp Swaminarayan mandir, On I.O.C. road, Chandkela, Ahmedabad-382424, Gujarat, India.	Mob: +91 7965216521	info@protekg.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	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee	+91 9111234567	customercare@servomax.in

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
	(Manufacturer)	Hills, Hyderabad, Telangana - 500033		www.wervomax.in

ECM-14: V Belt with REC belt replacement

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

7.7 ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 64: Assumptions for Financial Analysis

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