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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE FT-28: LANDGRACE CERAMIC PVT. LTD.

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

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Disclaimer

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3. Kaushik Bhai, Technician

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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

Parameters	Unit of Measurement (UOM)
Kilo watt hour	kWh
Kilogram	kg
Litre	L
Meter	m
Meter Square	m^2
Metric Ton	MT
Oil Equivalent	OE
Standard Cubic Meter	scm
Ton	t
Tons of Oil Equivalent	TOE
Ton of CO_2	tCO_2
Ton per Hour	t/h
Ton per Year	t/y
Voltage	V
Watt	W
Year(s)	Y

CONVERSION FACTORS

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

EXECUTIVE SUMMARY

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

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

Landgrace Ceramic Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Landgrace Ceramic is a floor 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	Landgrace Ceramic Pvt. Ltd.
Year of Establishment	2010
Address	Sartanpar Road, NH -27m Morbi - 363643, Gujarat - India
Products Manufactured	Floor Tiles
Name(s) of the Promoters / Directors	Mr. Kishorbhai Bhalodiya and Mr. Mahesh 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 includes:

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed 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, this is used in the kiln, hot air generator and dryer.

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control at kiln: During the study it was found that excess air levels in the NG fired kiln is 8.5% against the desired level of 5%. It is recommended to install an oxygen sensor and PID controller, so that the air flow can be adjusted or automatically according to fuel firing
- Insulation at kiln: Average surface temperature measured during the study was 170 °C in rapid cooling zone and firing zone, resulting surface temperature will be 55°C after recoating of insulation
- Waste heat recovery from flue gas: The flue gas measured at kiln exhaust was 250°C. At the same time, inlet temperature of combustion air was 35°C. It is recommended to install a recuperator in flue gas line to recover this waste heat (increase combustion air temperature upto 130°C) and reduce the fuel consumption
- Replacement of Inefficient Pumps: Water pumps were used for circulating water in primary condenser and secondary condenser of coal gasifier, having low efficiency (for pump-1 is 45 % and for pump-2 is 48 %). It is recommended to replace these with more efficient pumps
- Insulation at horizontal dryer: Average surface temperature of hot air pipes measured during the study was 107 °C, resulting surface temperature will be 55°C after recoating of insulation

- Insulation at hot air generator (HAG): Average surface temperature of cyclone separator measured during the study was 138°C and of duct connecting HAG to cyclone separator was 120°C, resulting surface temperature will be 55°C after recoating of insulation
- Optimization of resource consumption in clay section: Water quality increases batch timing and resource consumption (water, electricity and coal in HAG). Bore well water is having TDS level upto 1,500 ppm which can be improved by installing softener plant which may reduce TDS level upto 400 ppm.
- Timer controller at CT fan: Timer controller is recommended to be installed at CT fan of cooling tower of press (CT fan working will control be sensing return temperature of hydraulic oil in press) so that operating hours of fan will reduce upto 15 hours.
- Timer controller at stirrer motor: At present 7 stirrer motors are operated continuously. A timer controller is recommended to be installed so that operating hours of each will reduce.
- Installation of VFD with screw compressor: During unload condition; compressor is consuming 30% without doing work. A VFD can manage variable air demand by changing RPM of compressor and will help to save energy upto 15% of present consumption.
- Pressure reduction in air compressor: The pressure at receiver is 7 bar (a) and they require maximum pressure up to 5 bar (a) in plant (maximum pressure requirement at sizing unit). It is advisable to reduce operating pressure of compressor from 7 bar to 5 bar
- Voltage optimization in lighting MDB
- Installation of energy management system
- V belt replacement with REC belt
- Installation of harmonic filter
- Installation of solar PV system

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

Table 1: Summary of ECMs

Sl. No.	Energy Conservation Measures	Annual Energy Savings				Monetary Savings	Investment	Simple Payback Period	Annual Emission Reduction
		Electricity	NG	Coal	TOE Equiv.				
		kWh	scm	t	MTOE	Lakh Rs/y	Lakh Rs	Months	tCO_2
1	Excess air control	19,766		764	421	15.60	18.48	14	1633
2	Skin loss reduction at kiln			86	47	6.18	1.68	3	182
3	Waste heat recovery from flue gas			544	299	39.01	66.00	20	1,151
4	Replacement existing cooling water pump with energy efficient pump	66,358		0	6	4.83	2.77	7	54
5	Insulation of hot air pipe for horizontal dryer			8	5	0.60	0.44	9	18
6	Insulation of HAG duct			65	36	4.69	3.84	10	138
7	Optimization of resource consumption in clay section	14,218		587	324	65.12	39.60	7	1,253
8	Temperature controller for CT fan of press	68,072		0	6	4.95	0.53	1	56
9	Time controller with stirrer motors	56,140		0	5	4.09	0.55	2	46
10	VFD installation with compressor	24,248		0	2	1.76	1.98	13	20
11	Pressure reduction for compressor	19,399		0	2	1.41	0.40	3	16
12	Voltage optimization in lighting MDB	16,218		0	1	1.18	1.32	13	13
13	Installation of Harmonic filter	25,078		0	2	1.82	9.50	62	21
14	Installation of energy monitoring system	63,527		223	128	20.00	25.56	15	523
15	V belt replacement with REC belt	57,374			5	4.18	1.85	5	47
	Total	430,397		2,277	1,288	175	174	12	5,172

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

- Reduction in energy cost by 15.6%
- Reduction in electricity consumption by 9.56%
- Reduction in thermal energy consumption by 20.4%
- Reduction in greenhouse gas emissions by 18.9%

➨ FINANCIAL ANALYSIS

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

Table 2 Financial indicators

#	Energy Conservation Measure	Investment Lakh Rs	Internal Rate of Return %	Discounted Payback Period Months
1	Excess air control	18.48	61%	5.43
2	Skin loss reduction at kiln	1.68	278%	1.29
3	Installation of recuperator in smog line	66.00	37%	7.67
4	Replacement existing cooling water pump with energy efficient pump	2.77	131%	2.71
5	Insulation of hot air pipe for horizontal dryer	0.44	105%	3.37
6	Insulation of HAG duct	3.84	91%	3.81
7	Optimize resource consumption in clay section	39.60	123%	2.86
8	Temperature controller for CT fan of press	0.53	690%	0.52
9	Time controller with stirrer motors	0.55	550%	0.65
10	VFD installation with compressor	1.98	63%	5.19
11	Pressure reduction for compressor	0.40	270%	1.33
12	Voltage optimization in lighting MDB	1.32	64%	5.16
13	Installation of Harmonic filter	9.50	-6%	21.32
14	Installation of energy monitoring system	25.56	54%	5.88
15	V belt replacement with REC belt	1.85	173%	2.08

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	Land Grace Tiles LLP		
Plant Address	Sartanpar Road, NH -27m Morbi - 363643, Gujarat - India		
Constitution	Partnership		
Name of Promoters	Mahesh Patel		
Contact person	Mahesh Patel		
	Director		
	9909991745		
	info@granoland.com		
Year of commissioning of plant	2010		
List of products manufactured	Floor tile, 400 x 400 mm (6 tiles/box) Floor tile, 300 x 600 mm (4 tiles/box)		
Installed Plant Capacity	6,500 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	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	50	

Description	Details		
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	Yes	Hot air generator, Gasifier
	Diesel (liters)	Yes	DG set; rarely used
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
If Yes	Year of energy audit		
	Conducted by		
	Recommendations implemented		
	Type of ECM		
Interested in DEA	Yes		
	Interested		

1.3 METHODOLOGY AND APPROACH

The study was conducted in 3 stages:

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

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

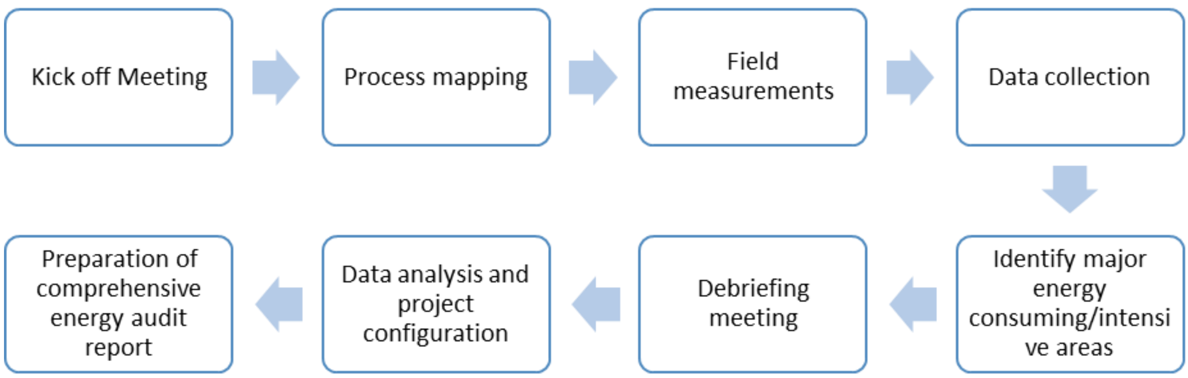


Figure 1: General methodology

The field work was carried out during 28-30th 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 Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°*C*
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

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

- Executive Summary of the report covers the summary list of projects along with estimated investment & energy and financial saving figures for individual projects.
- Chapter 1 (this chapter) of the report provides a brief background of the project, the scope of work and unit details and the methodology and approach for detailed energy audit.

- Chapter 2 of the report provides a description of the manufacturing process, analysis of historical energy consumption and establishment of baseline.
- Chapter 3 and 4 covers the performance evaluation of major energy consuming equipment and sections, thermal and electrical.
- Chapter 5 covers information on energy monitoring practices and best monitoring practices.
- Chapter 6 covers information on renewable energy assessment in the unit.

2. CHAPTER -2 PRODUCTION AND ENERGY CONSUMPTION

2.1 Manufacturing process with major equipment installed

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

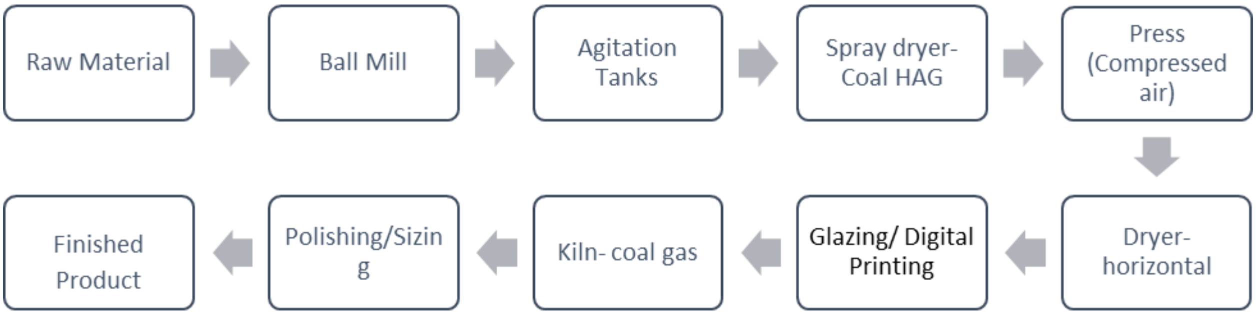


Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is a mixture of china clay, bole clay, than clay, talc, potash, feldspar and quartz which is mixed along with water to form slurry.
- The raw materials are mixed and ground using pebbles together with water in the ball mill for a period of 7.5-9.0 Hrs.
- Slurry is then pumped using hydraulic piston into spray dryer where moisture content of slurry is reduced from 35-40% by evaporation to about 5-6% and output of spray dryer is in powder form.
- Clay in powdered form is stored in silos for 24 hours for homogeneous mixture of moisture and then conveyed to hydraulic press machine where it is pressed and tile is formed of required size, output of press is called biscuit.
- Biscuit is then baked initially in 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.
- These tiles are then passed through cutting, sizing and polishing machines to match exact dimensions required.
- After sizing and inspection for quality and defect, tiles are packed in boxes and then dispatched.

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

- **Ball mill:** Here different raw materials like clay, feldspar, potash, talc and quartz are mixed in the appropriate ratio along with water to form slurry.

- **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.
- **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.
- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for combustion for drying and baking of tiles.
- **Roller Kiln:** The kiln is the main energy consuming equipment where the product is passed twice, once in the 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°C to 1,200°C depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further goes for cutting, sizing, grinding, finishing and quality check inspection 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 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	#
Floor tiles	400 x 400	16	0.96	6
Floor tiles	300 x 600	28	0.36	4

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 Production details

Period	Production (nos. of boxes) 400 x 400	Production (m^2) 400 x 400	Production (MT) 400 x 400
Oct-17	109,063	104,700	1,745
Nov-17	48,868	46913	782
Dec-17	137,162	131676	2,195
Jan-18	120,218	115,409	1,923
Feb-18	115,959	111,321	1,855
Mar-18			
Apr-18	150,459	144,441	2,407
May-18	165,502	158,882	2,648
Jun-18	151,678	145,611	2,427
Jul-18	73,351	70,417	1,174
Aug-18	114,559	109,976	1,833
Sep-18	175,647	168,621	2,810
Oct-18	142,046	136,364	2,273
Total	**1,504,511**	**1,444,331**	**24,072**

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 grid supply 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 & horizontal dryer

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakh	% of total	TOE	% of total
Grid – Electricity	327.09	29.07	387	6.0
Thermal-Coal	798.15	70.93	6,116	94.0
Thermal – NG	-	-	-	-
Total	**1,125.24**	**100**	**6,503**	**100**

This is shown graphically in the figures below:

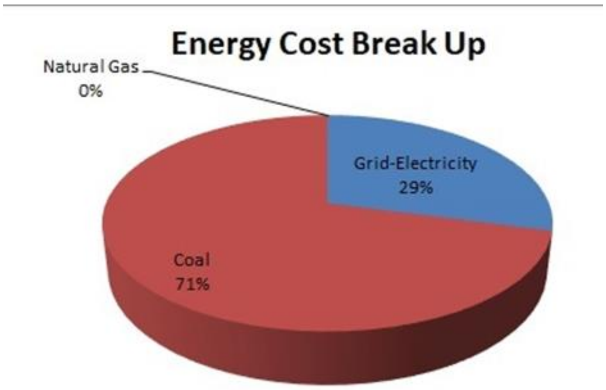


Figure 3: Energy cost share

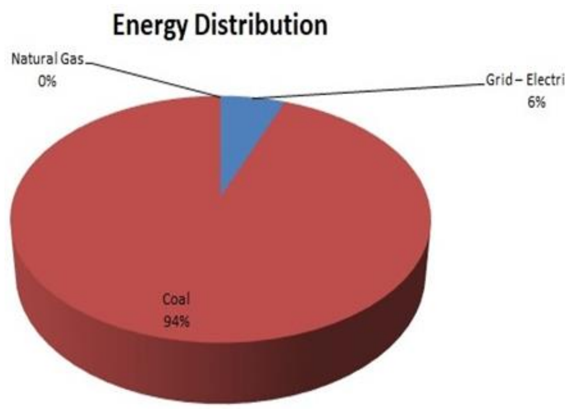


Figure 4: Energy use share

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 seldom, due to which the diesel consumption is minimal and records are not maintained.
- Electricity used in the utility and process accounts for the remaining 29% of the energy cost and 6% of the overall energy consumption.
- Source of thermal energy is from combustion of coal gas, which is used for firing in the kiln and horizontal dryer.
- Coal used (in form of coal gas) in kiln and horizontal dryer and as coal in hot air generator account for 71% of the total energy cost and 94% of overall energy consumption. Coal is also used in hot air generator to generate hot air.

2.3.1 Analysis of Electricity Consumption

2.3.1.1 Supply from Utility

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

Table 8: Details of Electricity Connection

Particulars	Description
Consumer Number	11267
Tariff Category	HTP-I
Contract Demand, kVA	475
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 2nd 500 kVA Next 297	 150 260 475
Energy Charges (Rs./kWh) Normal Hours Peak Hours Night Time	 4.2 0.85 0.4
Fuel Surcharge (Rs./kVAh)	Variable
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill from May-18 to Oct-18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units consumed kWh	Total Electricity cost Rs.	Average unit Cost Rs./kWh
Oct-17	413,915	3,015,345	7.3
Nov-17	47,980	495,977	10.3
Dec-17	325,045	2,396,792	7.4
Jan-18	441,605	3,206,681	7.3
Feb-18	442,890	3,146,803	7.1
Mar-18			
Apr-18	460,010	3,294,946	7.2
May-18	441,655	3,167,021	7.17
Jun-18	444,250	3,186,177	7.17
Jul-18	215,070	1,631,449	7.59
Aug-18	335,895	2,456,235	7.31
Sep-18	515,010	3,685,477	7.16
Oct-18	416,490	3,026,434	7.27

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 374,985 kWh/month and cost is Rs. 27.25 Lakh per month (Oct-17 to Oct-18). The average cost of electricity is Rs. 7.3/kWh, corresponding to the month may 18 to Oct 18. Plant was in shut down in March 2018 as discussed with plant personnel. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

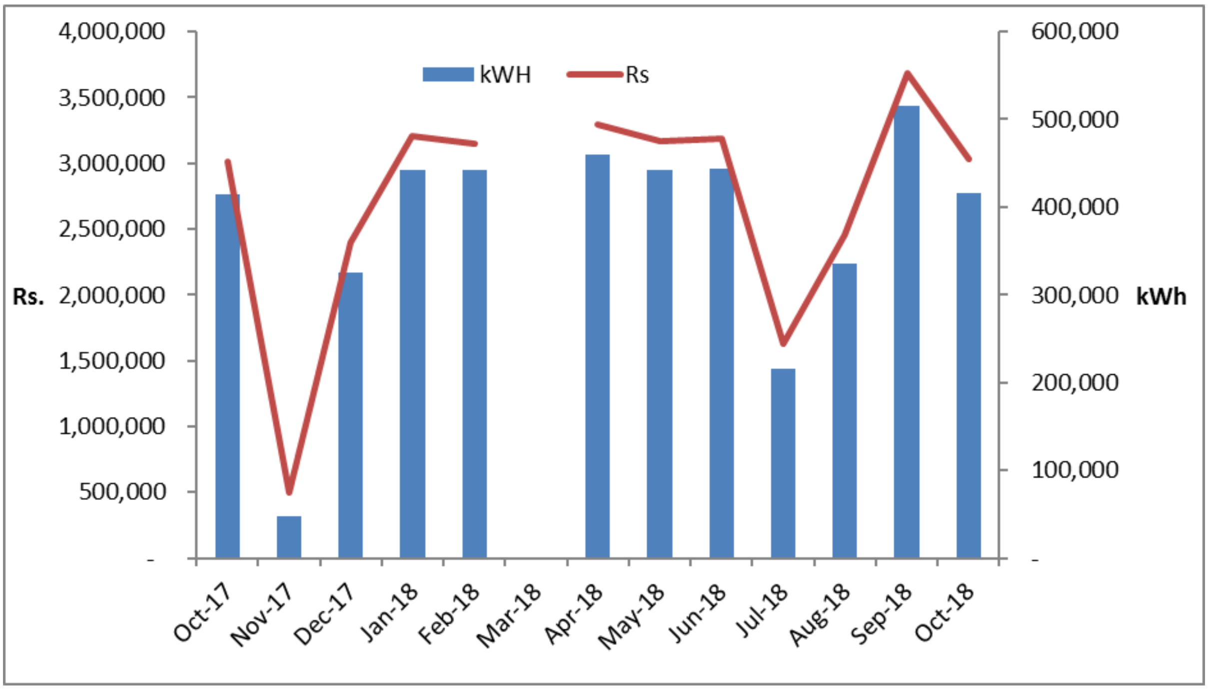
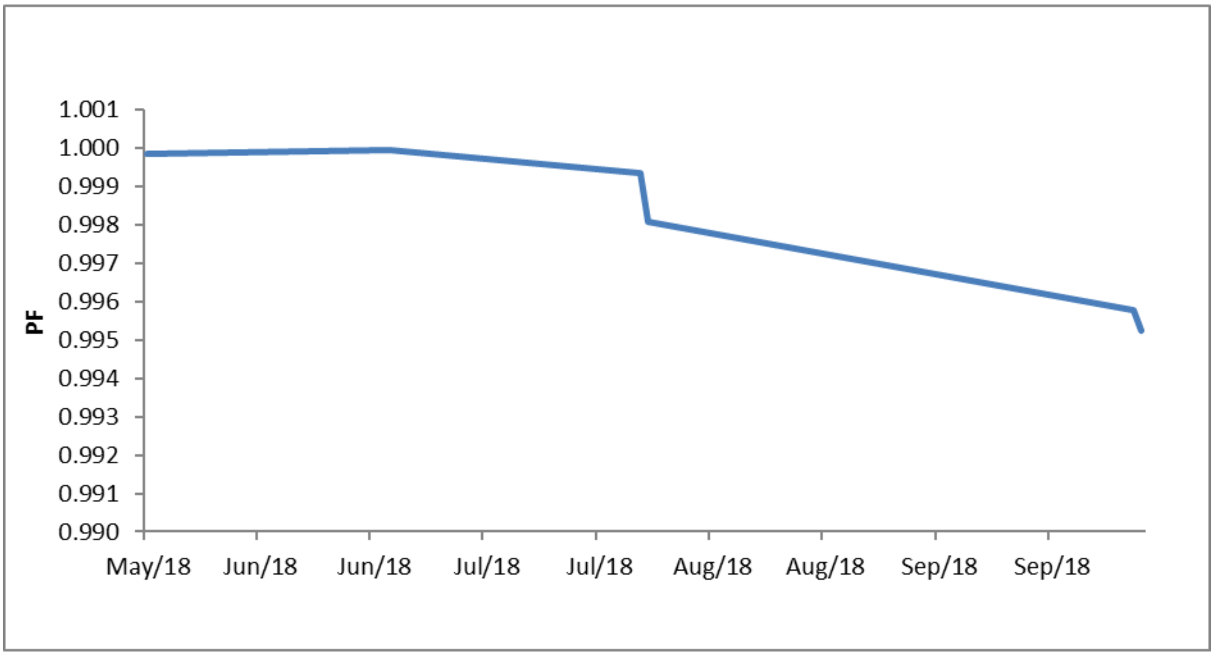


Figure 5: Month wise Variation in Electricity Consumption

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. Historical data was available in duration from May 18 to Oct 18. The average power factor was found to be 0.995 and the maximum being 1.0.

Maximum Demand: Maximum demand as reflected in the utility bill is 923 kVA from the bill analysis.

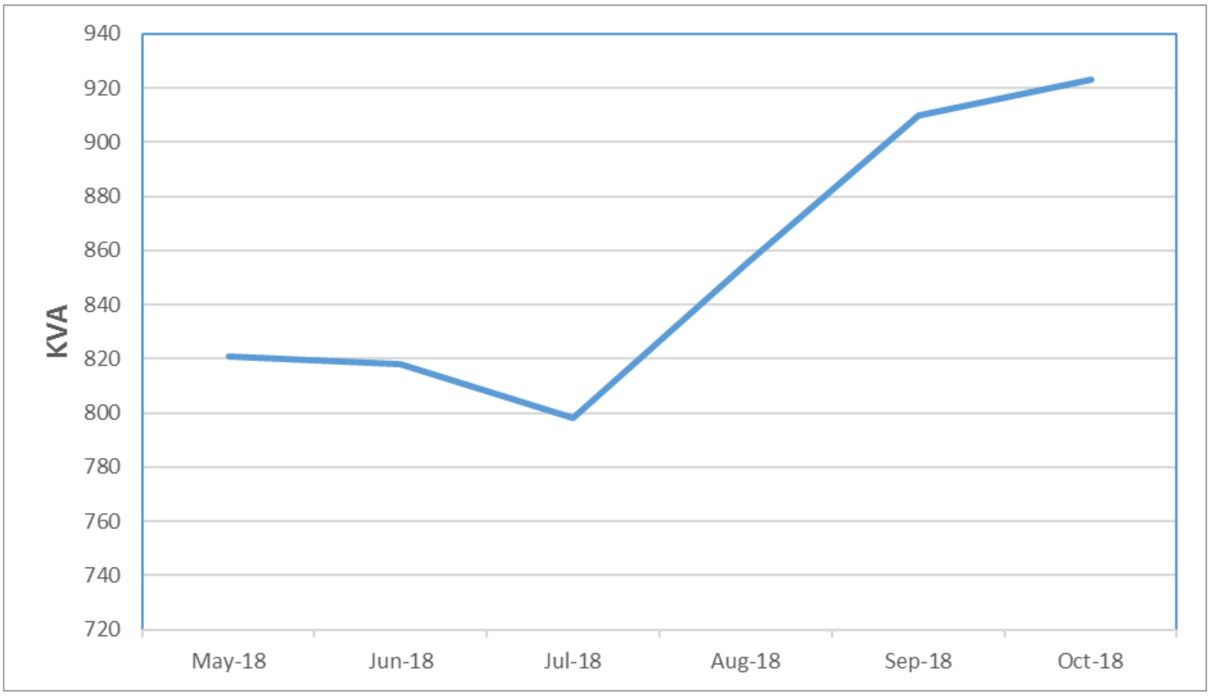


Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

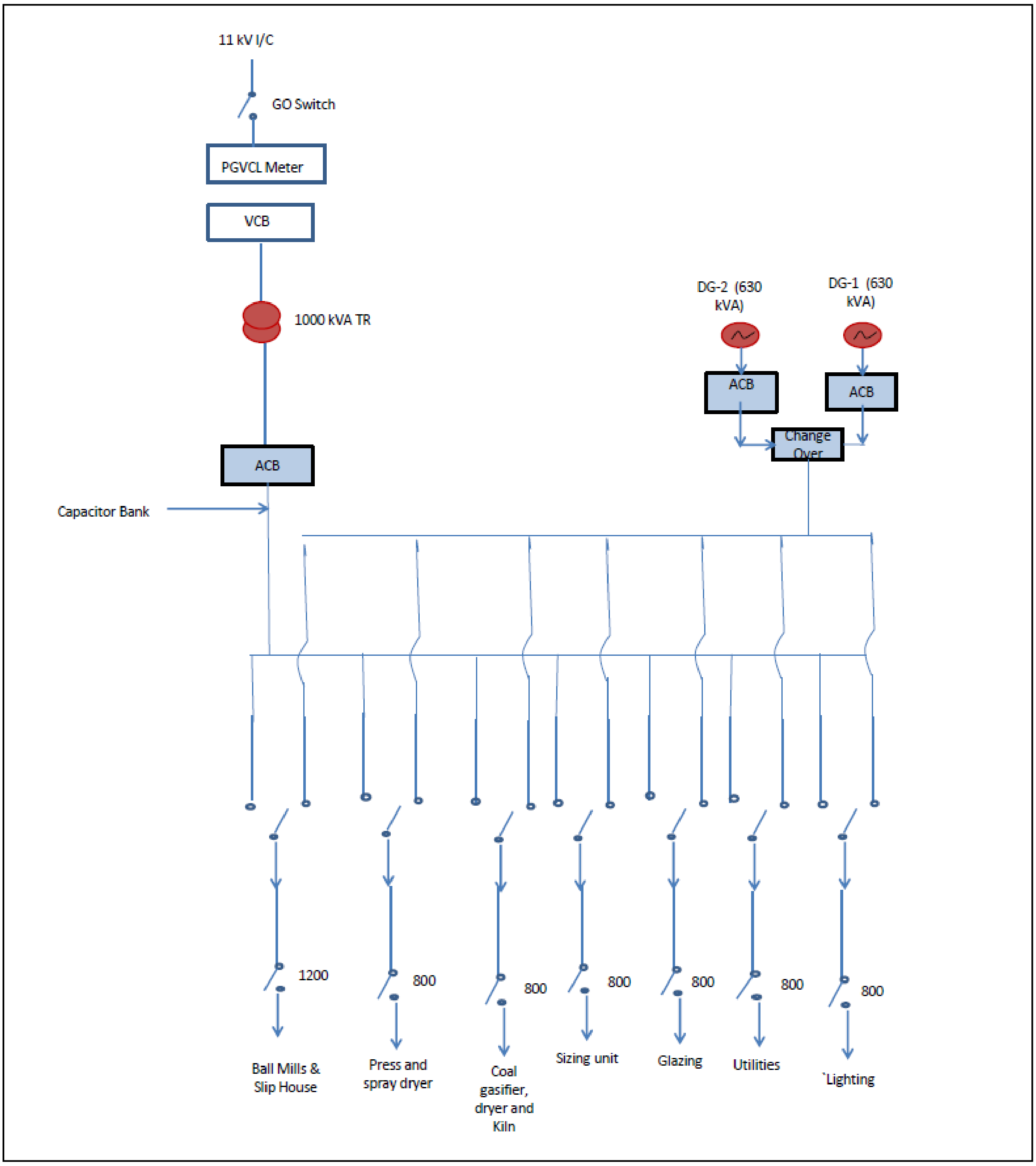


Figure 8 Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 1,741 kW, which includes:

- Plant and machinery load is 1,668 kW.
- Utility load is (lighting, air compressor and fans) about 72 kW including the single phase load.

Table 11 : Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Coal Gasifier	59
2	Ball Mill section	460

Sl. No.	Equipment	Capacity (kW)
3	Hot Air Generator (HAG	239
4	Hydraulic press	232
5	Main Kiln	250
6	Glaze mills	159
7	Horizontal dryer	48
8	Sizing	182
9	Utilities	50
10	Lighting	22
11	Spray dyer	37
Total Connected Load		**1741**

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

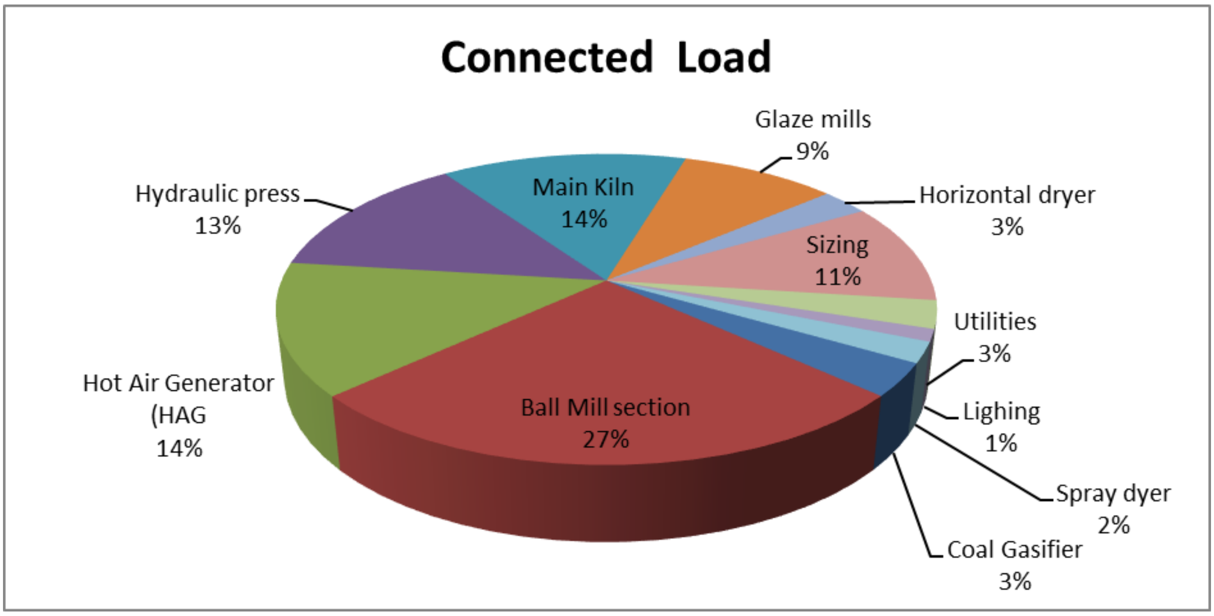


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Ball Mill section-27%, for the Hot air generator – 14%, for Main kiln – 14%, for hydraulic press- 13%, for sizing - 11%, 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:

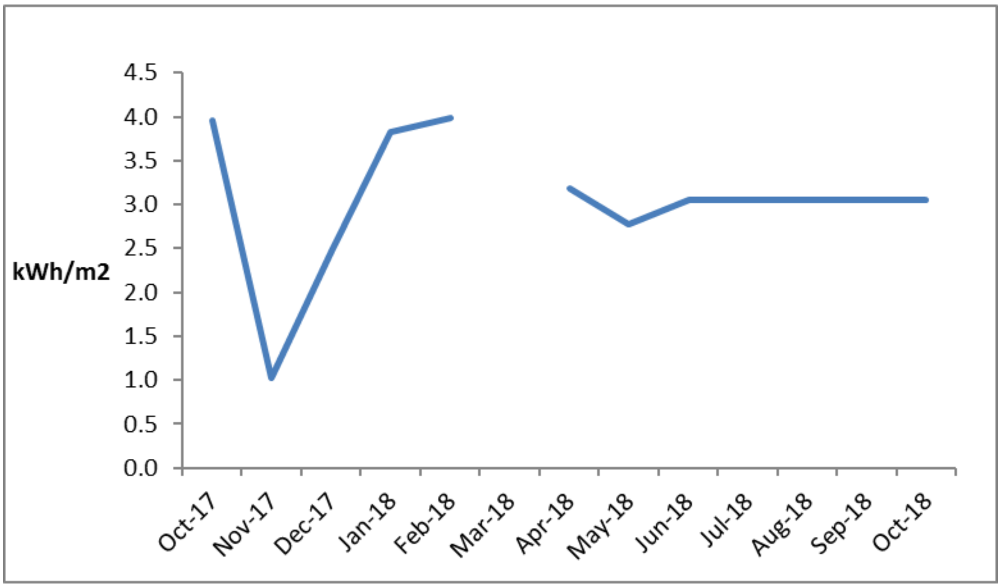


Figure 10: Month wise variation in Specific Electricity Consumption

The maximum and minimum values are within ±25% of the average SEC of 3.04 kWh/m^2 indicating that electricity consumption follows the production. Plant was not in operation during month of march-18. 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. Based on the gas bill shared for the month of Oct-17 to Oct-18 annual fuel cost has been derived as under. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	Coal Used MT	Coal Cost Rs	Coal cost Rs./MT
Oct-17	899	6,291,478	6998
Nov-17	870	6,088,530	6998
Dec-17	899	6,291,478	6998
Jan-18	899	6,269,946	6974
Feb-18	812	5,682,622	6998
Mar-18		Data not available	
Apr-18	899	6,762,619	7,522
May-18	888	6,679,863	7,522
Jun-18	899	6,762,608	7,522
Jul-18	590	4,205,126	7,127
Aug-18	921	6,567,540	7,127
Sep-18	1,413	10,069,661	7,127

Month	Coal Used MT	Coal Cost Rs	Coal cost Rs./MT
Oct-18	1,143	8,143,362	7,127
Average	928	6,651,236	7,170

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

- Average monthly coal consumption is 928 tons and average cost Rs. 66.5 Lakh/month

2.3.2.2 Specific Fuel Consumption.

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

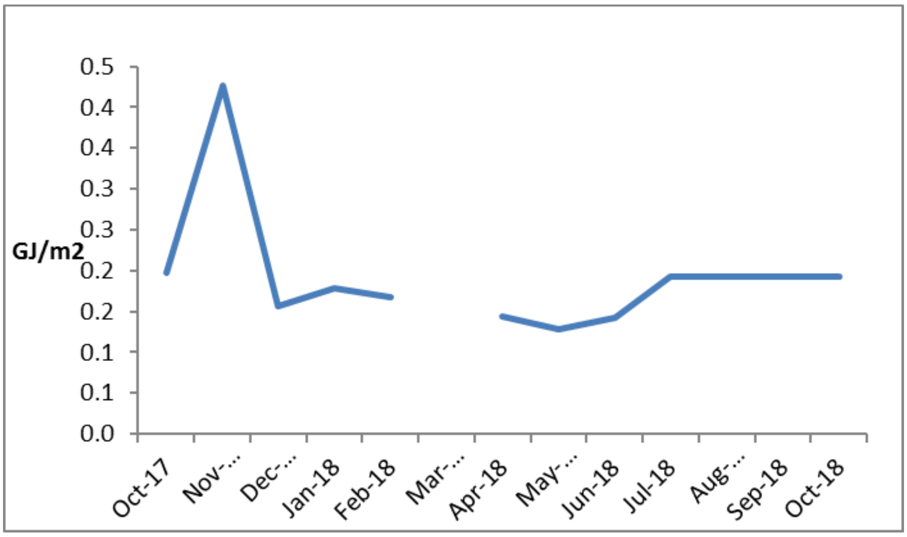


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.193 GJ/m^2. SFC is high in the months of Nov-17 (production was 46,913 m^2 and thermal consumption was 20000 GJ) and low in the month of May-18 (production was 158,882m^2 and thermal consumption was 20414 GJ). 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 dryer are required.

2.3.3 Specific energy consumption

2.3.3.1 Based on data collected during EA.

Plant doesn't maintain record for coal consumption data in plant so it came from general discussion with plant personnel. 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	242
Power consumption	kW	6,48
Coal consumption	kg/h	1,250
NG consumption	scm/h	Nil
Energy consumption	MTOE/h	0.74
SEC of plant	MTOE/m^2	0.003

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 scm/t	Coal kg/t	Electricity kW/t
Ball Mill #1			12.8
Agitator			1.2
HAG		125	12.1
Spray Dryer (New)			2.1
Horizontal Dryer		17.7	
Hydraulic Press			10.4
Kiln		168	13.5
New sizing unit			22.6

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	4,499,815
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	4,499,815
Annual Thermal Energy Consumption (Imported Coal)	t/y	11,132
Annual Thermal Energy Consumption (NG)	scm/y	0
Annual Energy Consumption	TOE	6,503
Annual Energy Cost	Rs. Lakh	1,125
Annual production	m^2	1,444,331
	t	24,072
SEC; Electrical	kWh/m^2	3.12
	kWh/t	187
SEC; Thermal	GJ/m^2	0.177
	GJ/t	10.64
SEC; Overall	TOE/m^2	0.0045
	TOE/t	0.27
SEC; Cost Based	$Rs./m^2$	77.9
	Rs./t	4,674

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

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

- Conversion Factors
  - Electricity from the Grid : 860 kCal/kWh
- GCV of NG : 8,902 kCal/scm
- GCV of Indonesian Coal : 5,495 kCal/kg
- CO_2 Conversion factor
  - Grid : 0.82 kg/kWh

- Indonesian 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 May-2018 to Oct-2018	7.28
Cost of Coal	Rs./MT	
Annual operating days	d/y	7,170
Operating hours per day	h/d	330
Annual production	m^2	24

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.

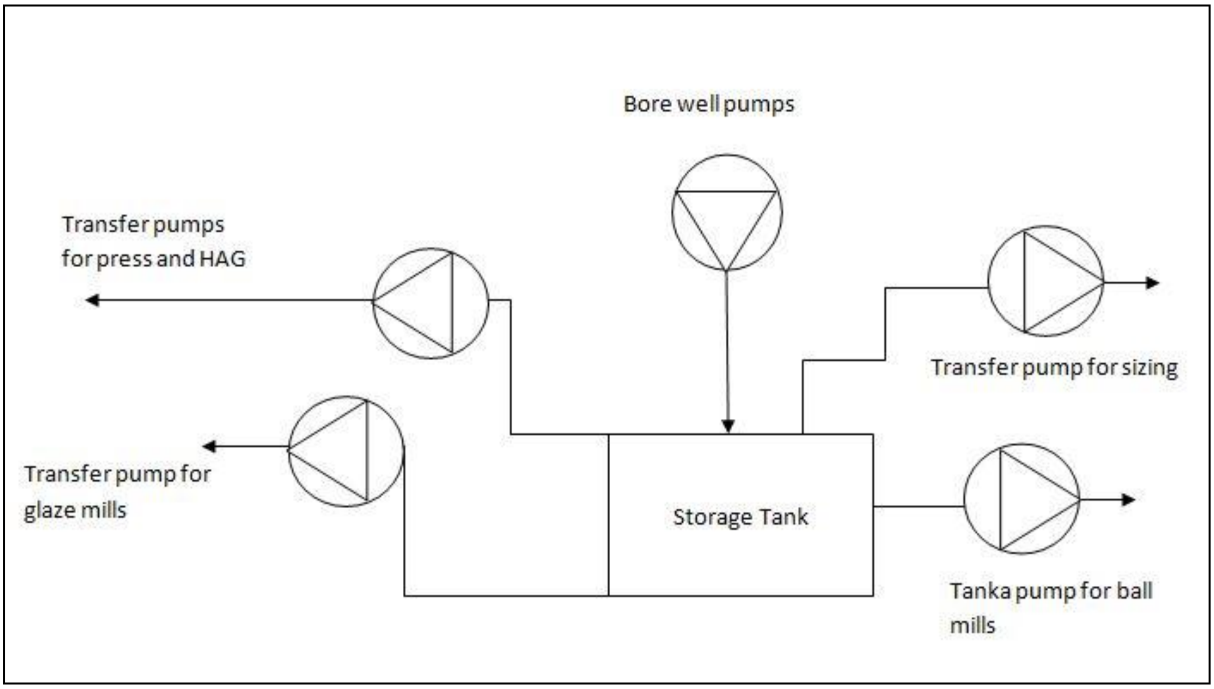


Figure 12: Water Distribution Diagram

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	HP	15
RPM	rpm	2,900
Quantity	Number	2

It was discussed with production team in clay preparation department that the bore well water quality is poor and TDS level is high in the range of 1500 PPM. This hard water impacts the operating hours of ball mill, higher quantity of water required and water treatment chemicals are used in large quantity in each batch of ball mill grinding. Higher quantity of water is also required to evaporate from slip slurry from 45 % to 5-6 % moisture in clay which is used for preparing tiles with hydraulic pressing. Factory does not have any water treatment plant and since good quality water is required for desired final quality of tile, it is recommended to install water treatment plant with water 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). The main Kiln has five major zones with preheating, combustion zone, rapid cooling, indirect cooling followed by final cooling zone. 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 to evacuate fumes and gases evaporated in the preheating zone before combustion zone of kiln. Kiln consists 336 HP electrical load of which 125 HP is for smoke blowers, 60 HP for combustion blowers, 20 HP for rapid cooling, 50 HP for Hot air blower, 20 HP for cooling section, 73 HP for final cooling blowers & remaining electrical load of kiln roller motors.

Table 18: Kiln Details

Sr. No	Parameter	Unit	Value
	Make		Modena
1	Kiln operating time	H	24
2	Fuel consumption	scm/h	2,625
3	Number of burner on left side	-	87
4	Number of burner on right side	-	87
5	Cycle Time for passage of tile from kiln	Minutes	49 (variable)
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	71.4 x 0.8 x 3.6
	Firing Zone	M	18.9 x 1.87 x 3.6
	Rapid Cooling Zone	M	18.9 x 0.8 x 3.6
	Indirect cooling Zone	M	18.9 x 0.8 x 3.6
	Final cooling zone	M	14.7x 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 of coal gas in kiln has been calculated based on heat load of the kiln during DEA. Flue gas analysis (FGA) study was conducted in combustion zone and result of same is summarized in the table below:

Table 19: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	8.5%

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 (Biscuit) 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	51.0
Heating zone Average Surface Temperature	69.2
Rapid cooling zone Average Surface Temperature	55.0
Indirect cooling zone Average Surface Temperature	60.0
Final cooling zone Average Surface Temperature	55.0

The temperature profile of the kiln is shown below:

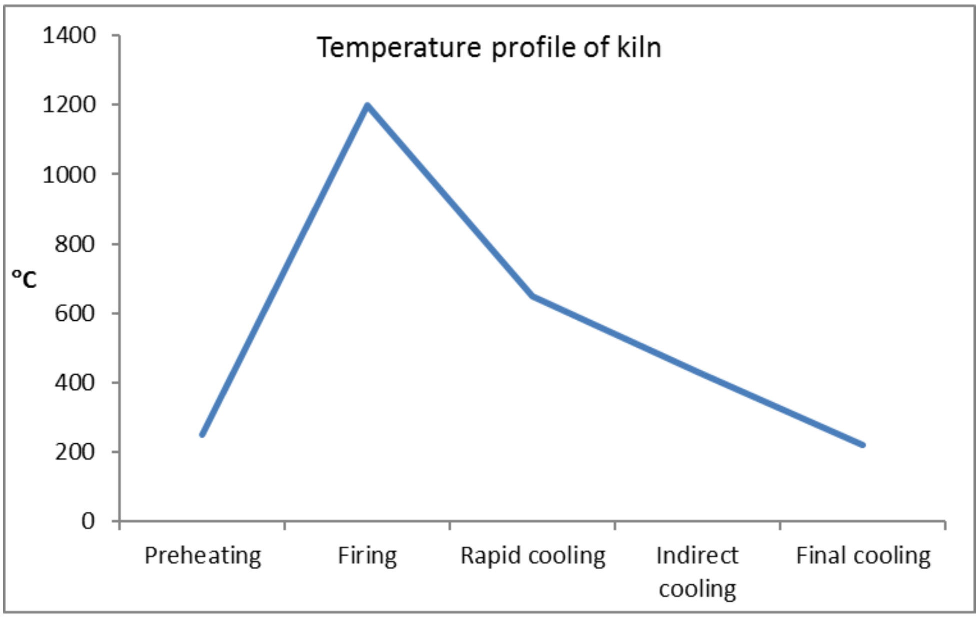


Figure 13 : Temperature Profile of Kiln

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	3.32	0.95
Hot air blower	9.7	0.96
Rapid Cooling Blower	4.3	0.89

Smoke Blower	25.18	0.97
Combustion Blower	11	0.96

3.1.3 Observations and performance assessment

Kiln performance has been evaluated based on the flue gas analysis study conducted during visit. Overall heat mass balance summary of all losses is shown in below figure:

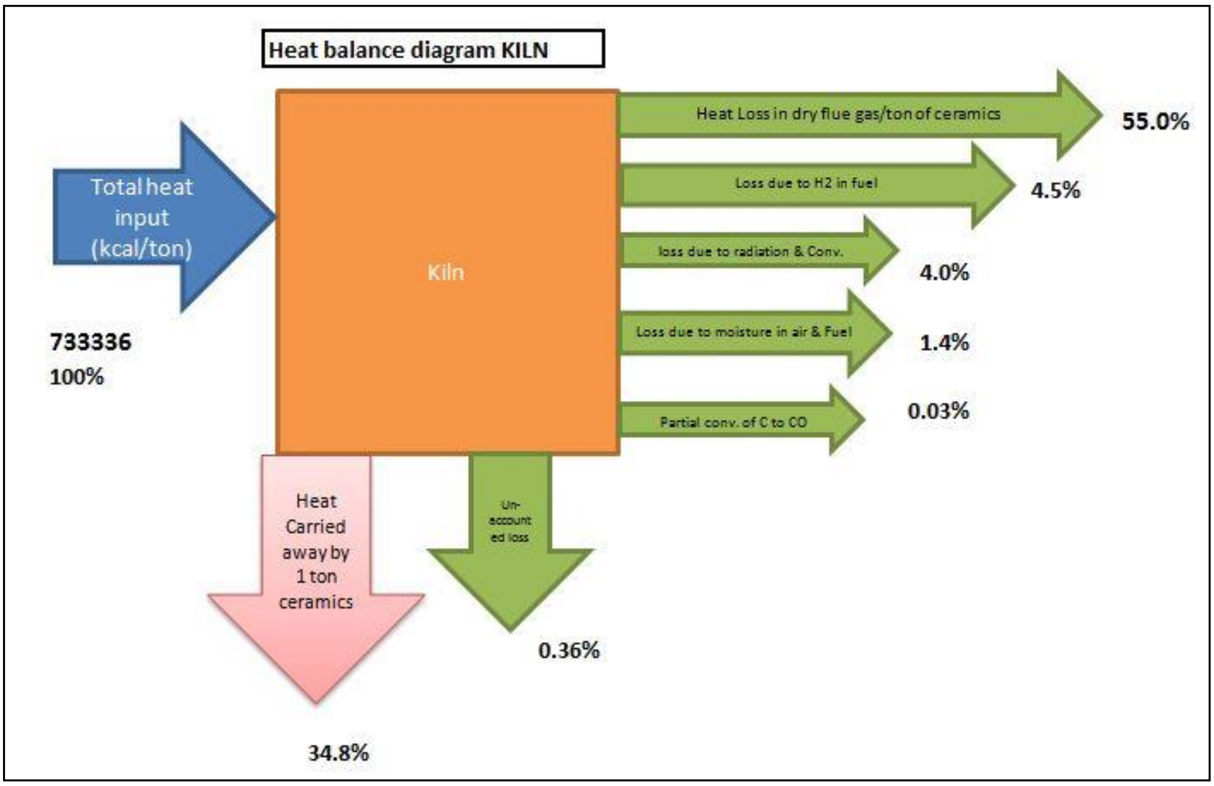


Figure 14 Heat balance diagram of Kiln

Detailed calculation is included in Annexure-5.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in sections below:

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 to gas burner 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 stoichiometric air to ensure complete combustion of carbon particles by oxygen in the 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 carbon monoxide and 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. It is also observed that for various size and quality of tile, the temperature is increased or decreased in combustion zone by changing coal gas quantity and static pressure, but combustion air quantity is normally unchanged.

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 dampers) 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	%	8.5
CO_2 in flue gas	%	7.3
CO in flue gas	ppm	20

Recommended action

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

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

Parameters	Units	Present	Proposed
A. Fuel Saving			
Oxygen level in flue gas	%	8.5	5.00
Excess air control	%	68.0	31.3
Dry flue gas loss	%	55%	
Saving in fuel (Every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%)	Scm/t	651	627
Specific fuel consumption	kg/ton of tile	622.75	603.71
Saving in specific fuel consumption	scm/h		96.47
Operating hours per day	h/d		24
Operating days per year	d/y		330
Annual fuel savings	scm/y		764
Annual coal saving	t/yr		197
Fuel cost	Rs/MT		7,170
Annual fuel cost saving	Rs Lakh /y		14.2
B. Power saving at combustion blower			
Mass flow rate of air	t/h	32.59	25.46

Parameters	Units	Present	Proposed
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	7.4	5.8
Total pressure rise	Pa	2,412	2,412.4
Measured power of blower	kW	11.41	8.91
Total power saving	kW		2.50
Operating hours per day	h/d		24.00
Operating days per year	d/y		330.00
Annual energy saving	kWh/y	19,766	
Weighted Cost of electricity	Rs/kWh	7.28	
Annual energy cost saving	Lakh Rs/y	1.44	
Overall energy cost saving	Lakh Rs/y	16	
C. Summary of Savings			
Coal saving	kg/y	197,000	
Electricity saving	kWh/y	19,766	
Monetary savings	Lakh Rs/y	16	
Estimated investment	Lakh Rs	18.5	
Payback Period	Months	14	
IRR	%	61	
Discounted payback period	Months	5.43	

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. In roller kilns, the ceramic rollers and inspection openings are also resulting in high heat loss if not insulated properly. Refractory 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 like cera wool or stone wool is 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 should be in the range of 60-70°C and it was measured as 69.8°C; hence the kiln surface does not have significant heat loss. But there were uninsulated air pipes in rapid cooling zone and firing zone which takes the heat of the tiles where these pipe surface were uninsulated and temperature was observed as 170 °C which is to be properly insulated to keep the heat loss as minimum possible because this hot air is then used in pre dryer as heat recovery. Some photographs of kiln surface are shown below:

Figure 15: Kiln surface

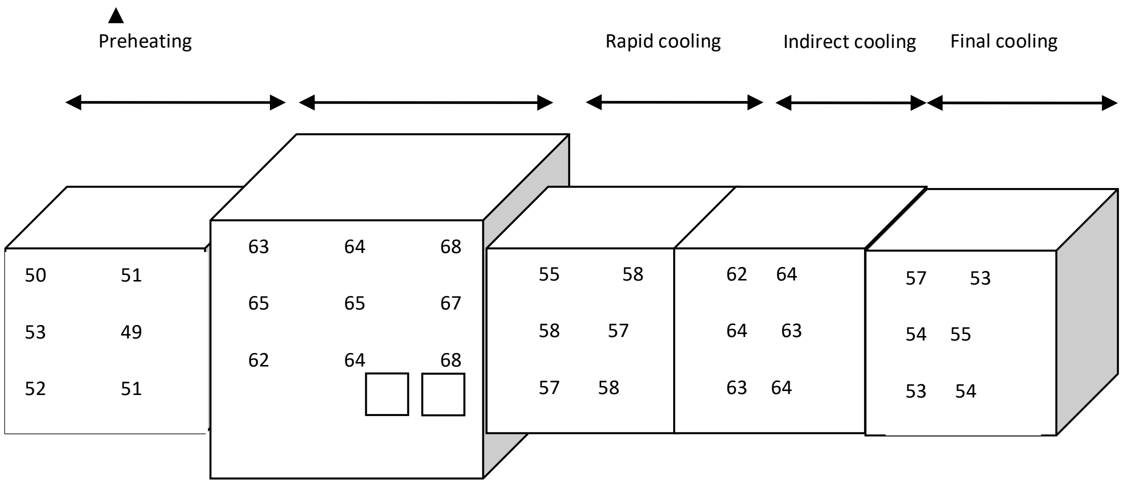


Figure 16: Kiln surface temperature schematic diagram

Recommended action

Recommended surface temperature of the firing zone has to be brought to within 55°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.

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

Table 24: Cost benefit analysis (ECM 2)

Parameter	Units	As IS	To Be
No of uninsulated pipe in recuperator	#	24	24
No of uninsulated pipe in indirect cooling zone	#	104	104
Recuperator pipe size	mm	80	80
Pipe length	m	1.5	1.5
Pipe size in indirect cooling zone	mm	50	50
Pipe length	m	0.60	0.60
Total surface area	m^2	25.38	25.38
Average surface temperature	°C	170	55
Ambient air temperature	°C	35	35
Heat loss	$kcal/h/m^2$	2,261	220
Total heat loss	kcal/h	57,400	5,584

GCV of coal gas	kcal/scm	1,231	1,231
Coal gas consumption	scm/h	47	5
Coal gas savings	scm/h		42
Coal saving	kg/h		10.9
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	kg/y		86,142
Fuel cost	Rs/MT		7,170
Annual fuel cost saving	Rs Lakh/y		6.18
Estimated investment	Rs Lakh		1.7
Simple payback period	Months		3
IRR	%		278
Discounted payback period	Months		1.3

3.1.4.3 ECM #3: Waste heat recovery from flue gas

Technology description

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

Study and investigation

It was observed during the field visit that the flue gas (smoke) temperature at kiln exit was 250ºC. So, to improve efficiency levels of kiln and to save fuel, it is suggested to utilize this additional heat content in the flue gases (that is presently being wasted) to increase the temperature of air at the FD blower of hot air generator (HAG), thereby also bringing down the flue gas temperatures at stack

Recommended action

It is recommended to decrease the smoke temperature at kiln so that the outlet temperature could be decreased from 250ºC to 200ºC, 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 25: Waste heat recovery from flue gas [ECM-3]

Particulars	Units	Value
Temperature at smog blower	ºC	250.0
Smog flow rate	t/h	35.10
Waste gas flow	kg/h	
Specific heat of waste gas	kCal/kg K	0.24
Smog temperature after recuperator	ºC	200.0
Heat available in smog	kCal/h	21,04,004
Heat recovered	%	26%
Specific heat of FD blower air	kCal/kg degK	0.24
Thermic fluid temperature at ambient	ºC	35.0
Combustion air flow	m^3/h	
Density of combustion air	kg/m^3	1.2
Mass flow rate of FD blower air	kg/h	32,588.5
Effectiveness of HE-1	%	60.0
FD blower air temperature after recuperator	ºC	76.8
Heat saving	kCal/h	327,290
GCV of coal	kCal/scm	1231
Fuel savings	scm/h	265.8

Operating hours per day	d/y	330
Operating days per year	h/d	24
Coal price	Rs./kg	7.17
Annual running hours	h/y	7,920
Annual coal saving	t/y	544
Annual Monetary saving	Lakh Rs/y	39
Estimated Investment	Lakh Rs	66
Payback Period	months	20
IRR	%	37
Discounted payback period	Months	7.7

3.2 COAL GASIFIER

3.2.1 Specifications

Coal gasifier produces coal gas from coal by partial combustion using coal and water vapor. Coal gas is used in kiln and horizontal dryer. The output of the coal gasifier is Coal gas, Tar and condensed water having impurities. The specification of coal gasifier is given below:

Table 26 Specifications of coal gasifier

Particular	Units	Value
Make		Radhey
Average Coal consumption	t/d	18
Average Water consumption	l/d	2,000
FD Blower	hp	2 x 25
Cooling water pump	hp	2 x 20

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Measurement of power consumption of cooling water pumps and FD blower
- Air flow measurement of FD blower
- Cooling water pumps flow

Coal consumption data is not maintained by plant. Kiln cycle time varies between 45-60 minute depending on the production size and quality which requires to vary the coal gas supply which is increased and decreased by varying FD fan speed i.e. by varying air quantity. During the DEA, the kiln cycle time was 49 minutes. Cooling water pumps measurement data is given in below table:

Table 27 Cooling water pumps data

Measured Parameters	Unit	CWP 1	CWP 2
Flow rate Q	m^3/h	113.3	113.6
Suction Pressure	kg/cm^2	0.1	0.1
Discharge Pressure	kg/cm^2	1.7	1.7
Motor Input Power	kW	12.8	12.2

FD blower and cooling water pumps was operating with VFDs. Average power consumption of FD blower was 4.26 kW (PF 1). Air flow is 1,740 m^3/h at FD fan suction.

There is no monitoring system for coal gas generation quantity or quality. Average GCV of coal gas for calculation purpose is considered from DESL data base

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 0.26 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm coal in plant which is 0.010 kWh/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed. Efficiencies of both cooling water pumps were calculated as 45% and 48% which were lower side and required to be replaced with energy efficient pumps.

3.1.1.1 ECM#4: Replacement existing cooling water pump with energy efficient pump

Technology description

Replacing inefficient cooling tower pump with energy efficient pump to reduce the power consumption.

Study and investigation

The unit is having two cooling tower pump. Efficiency of existing pumps are 45 % and 48% respectively.

Recommended action

It is recommended to replace inefficient pump with energy efficient pump. New pumps shall have efficiency up to 70%. The cost benefit analysis is given below:

Table 28: Cost benefit analysis (ECM-4)

Parameter	Unit	Present	Proposed	Present	Proposed
Design Parameters		Cooling Tower pump-1		Cooling Tower Pump-2	
Pump Efficiency			70		70
Motor I/P Power	kW	15	15	15	15
Motor Efficiency	%	85.00	85.00	85.00	85.00
Measured Parameters	Unit	AS IS	TO BE	AS IS	TO BE
Flow rate Q	m3/h	113.3	113.3	113.6	113.6
Suction Pressure	kg/cm2	0.1	0.1	0.1	0.1
Discharge Pressure	kg/cm2	1.7	1.7	1.7	1.7
Motor Input Power	kW	12.8	8.30	12.2	8.32
Saving Assessment	Unit	AS IS	TO BE	AS IS	TO BE
Flow rate Q	m3/s	0.03146	0.03146	0.03155	0.032
Delta P		16.0	16.0	16.0	16.0
Total Head	m	4.94	4.94	4.95	4.95
Liquid Horse Power	kW	12.80	8.30	12.20	8.32
Motor Input Power	kW	85	55	81	55
Overall System Efficiency	%	39	60	41	60
Pump Efficiency	%	45	70	48	70
Daily working hours	h/d	24	24	24	24
Annual working days	d/y	330	330	330	330

Annual working hours	h/y	7,920	7,920	7,920	7,920
Power Saving	kW	-	4.5	-	3.88
Energy Consumption per Year	kWh/y	101,376	65,725	96,624	65,917
Energy Saving	kWh/y	-	35,651		30,707
Electricity cost	Rs/kWh	7.28	7.28	7.28	7.28
Monetary Saving	Rs Lakh/y	-	3		2.23
Percentage of Energy Saving on Pump Consumption	%	-	54	-	46
Investment of New Pump	Rs Lakh	-	3	-	2.23
Total annual energy saving	kWh/y	66358			
Total annual monetary saving	Lakh Rs	4.8			
Total investment	Lakh Rs	2.8			
Simple Payback Period	Month	6.89			
IRR	%	131			
Discounted payback period	Months	2.7			

3.3 DRYERS

3.3.1 Specifications

There are only horizontal dryers installed for pre drying of tiles before entering into kiln. The specifications of dryers are given below table:

Table 29 Specifications of horizontal dryer

Particular	Units	Horizontal dryer
Capacity	Nos. of tiles/h	1,755
Fuel type		Coal Gas
Exit temperature of tiles	°C	135
Smoke Blower	hp	1 x 25
Combustion Blower	hp	1 x 3
Booster fan	hp	1 x 25

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 to derive specific fuel consumption:

Table 30 Field measurement at site

Particular	Units	Horizontal dryer
Tiles counter reading at start		6,440
Tiles counter reading at end		8,195
Mass of each tile at entry	g	4,595
Mass of each tile at exit	g	4,324
Temperature of tile at exit	° C	135

Gas consumption	scm/h	71

Hot air blower discharge from kiln is utilized in only in horizontal dryer as heat recovery which helps in fuel saving in dryer. Coal gas also used as secondary firing in dryer to maintain desired temperature in dryer. All blowers are operating with VFDs. The power profile and PF profile of blowers installed in horizontal dryer are given below:

Figure 17 Power and PF profile of ID & FD blowers of Horizontal Dryer

Average power consumption of ID blower is 4 kW (PF 0.993) and for FD blower is 14 kW (PF 0.98).

3.3.3 Observation and Performance assessment

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

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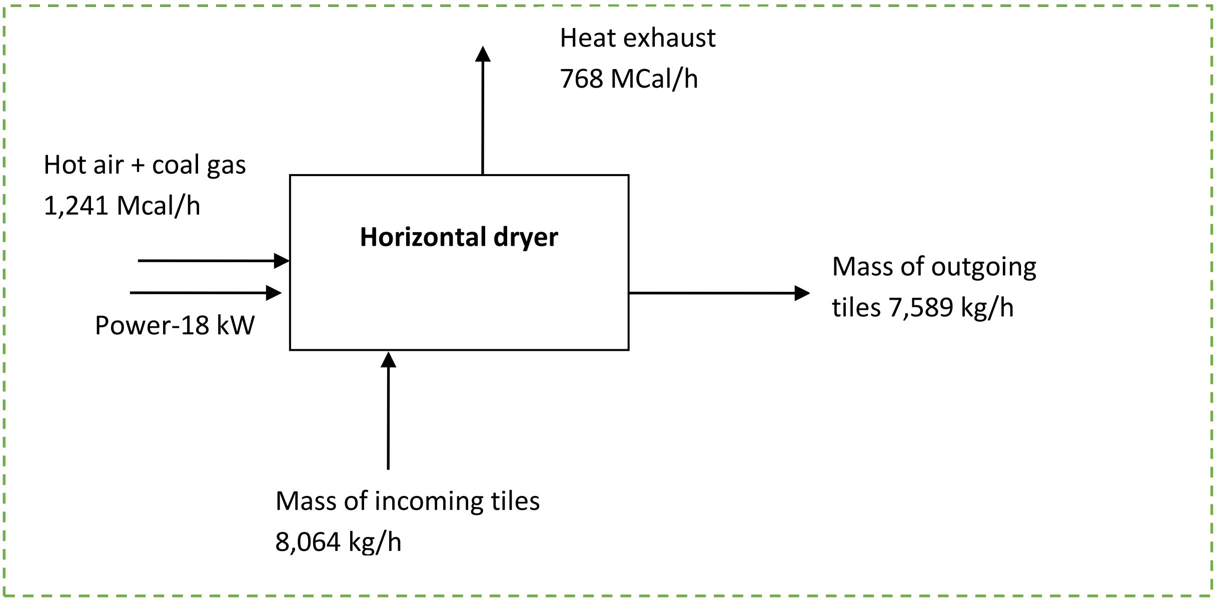

Figure 18 Mass and energy balance of horizontal dryer

Based on observations during DEA, the specific electricity consumption of horizontal dryer is 2.4 kWh/ton of tile and specific thermal energy is 9.4 scm/ton of tile respectively.

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

3.3.4 Energy conservation measures (ECM) – ECM # 5 – Insulation of hot air pipe for horizontal dryer

Technology description

Horizontal dryer is used to pre heat tiles before entering into glazing section then kiln. Hot air from kiln and supplementary firing of coal gas is used in horizontal dryer.

Study and investigation

During field measurements, it was found that the insulation of hot air pipe coming from booster fan are not insulated where surface temperature was 107 °C which is leading loss of hot air and increases coal gas consumption.

Recommended action

It is recommended to insulate these hot air pipes at horizontal dryer.
Estimated cost benefit is given in the table below:

Table 31 Saving and cost benefit by Insulation of hot air pipe at horizontal dryer [ECM-5]

Parameter	Units	As IS	To Be
No of uninsulated pipe in horizontal dryer	#	70	70
Pipe size	mm	168	168
Pipe length	m	0.18	0.18
Total surface area	m^2	6.65	6.65
Average surface temperature	°C	107	55
Ambient air temperature	°C	35	35
Heat loss	$kcal/h/m^2$	979	220
Total heat loss	kcal/h	6,512	1,463
GCV of coal gas	kcal/scm	1,231	1,231

Parameter	Units	As IS	To Be
Coal gas consumption	scm/h	5	1
Coal gas savings	scm/h		4
Coal saving	kg/h		1
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	kg/y		8,393
Fuel cost	Rs/MT		7,170
Annual fuel cost saving	Rs Lakh/y		0.6
Estimated investment	Rs Lakh		0.4
Simple payback period	Months		9
IRR	%		105
Discounted payback period	Months		3.4

3.4 Hot Air Generators & Spray Dryers

3.4.1 Specifications

There bubbling bed type hot air generator were using for evaporating water from slurry which is coming from ball mill. Spray dryer is the heat exchanging unit for evaporation of moisture from slurry by taking heat from hot air of HAG. Specifications of HAG are given below:

Table 32 Specifications of Hot air generator (HAG)

Particular Fuel type	Units	Value Indonesian coal
Exhaust air temperature	°C	750
FD fan	hp	30
ID fan	hp	225
Coal crusher	hp	15

The specifications of spray dryers are given below:

Table 33 Specifications of spray dryer

Particular	Units	Value
Clay production capacity	t/d	200
Inlet slurry moisture	%	35
Outlet powder moisture	%	6
Slip house pump	hp	30

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
    - Power consumption of slip house pump
    - Ball mill motor power consumption for the batch

Details of measurements on HAG are given below:

Table 34 Field measurement at site

Particular	Units	Value
Air velocity at FD fan suction	m/s	7.2
Suction area	m^2	0.126
Exit temperature of air	° C	750
Surface temperature	° C	140
Average power consumption-FD Fan	kW	26.4 (PF=1)
Average power consumption-ID Fan	kW	72.4 (PF=1)

Both fans and slip pump was operating with VFDs. Average power consumption of ID fan 72.4 kW (PF 1.), FD fan was 26.4 kW (PF 1) and slip house pump was 17.5 kW (PF 0.87) 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:

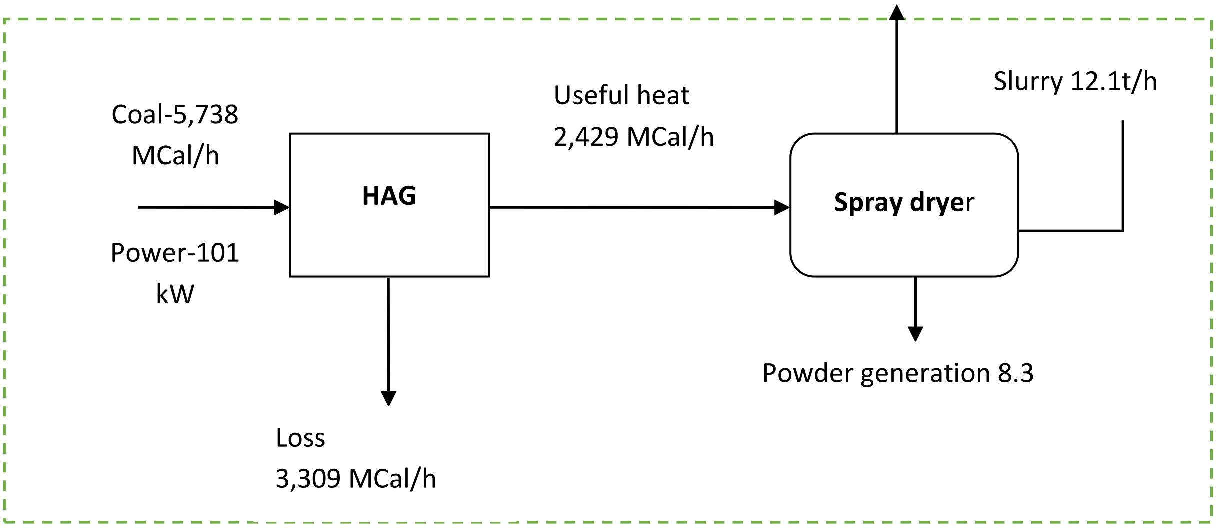

Figure 19 Energy and mass balance of bubbling bed HAG and spray dryer

Above mass balance is prepared on the basis of data they provided in general discussion since they don't maintain any record of coal and powder generation. Same data is verified during DEA also. Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for generating 1 ton powder) and specific thermal energy measure (fuel used for generating one ton powder). Based on observations during DEA, for the bubbling bed stoker HAG, the specific electricity consumption is 12.1 kW/ton and specific fuel consumption is 125 kg of coal/ton.

Operation is optimized and no energy conservation measure is proposed.

3.4.4 Energy conservation measures (ECM) – ECM # 6 – Insulation of HAG duct

Technology description

The HAG is used to generate the hot gas using coal as input fuel. The hot air produced is passed to cyclone separator and then used in spray dryer.

Study and investigation

During field measurements, it was found that the insulation of HAG duct connecting to cyclone separator was poor which results in increased heat loss leading to increase in coal consumption.

Recommended action

It is recommended to insulate the HAG duct connecting cyclone separator.
Estimated cost benefit is given in the table below:

Table 35: Saving and cost benefit by Insulating HAG duct [ECM-6]

Parameters	Unit	AS IS	To Be	AS IS	To Be
Location of HAG		Cyclone separator		Connecting dust to Cyclone separator	
Diameter of cyclone separator	m	3		2	
Length of cyclone separator	m	3.5		4	
Total surface area	m^2	33.0	33.0	25.1	25.1
Average surface temperature	°C	138	55	120	55
Average coal loss due to high skin temperature	kg/h	7.2	1.8	4.3	1.4
Average coal saving	kg/h		5.4		2.9
Annual operating hour	h/y	7,920	7,920	7,920	7,920
Annual coal saving	MT/y		43		23
Fuel cost	Rs/MT	7170	7170	7170.0	7170.0
Annual fuel cost saving	Rs Lakh/y		3.06		1.62
Net saving	Rs Lakh/y	4.69			
Estimated insulation cost	Rs Lakh	3.84			
Payback period	Month	10			
IRR	%	91			
Discounted payback period	Months	3.8			

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 BALL MILLS

4.1.1 Specifications

Ball mills produce slurry by mixing clay, water and chemicals ISMS and STPP. Ball mills take 6 to 8 hours for slurry preparation. The specifications of ball mills and its accessories are given below:

Table 36 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	M^3/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 37 Average power consumption and PF of ball mills

Equipment	Average Power (kW)	PF
Ball Mill#1	120	0.92
Ball Mill#2	155.2	0.93
Glaze Ball Mill	12.35	0.5

Average power consumption of ball mill #1 was 120 kW (PF0.99) and Ball Mill#2 was 155.2 kW (PF0.99).

4.1.3 Observations and performance assessment

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

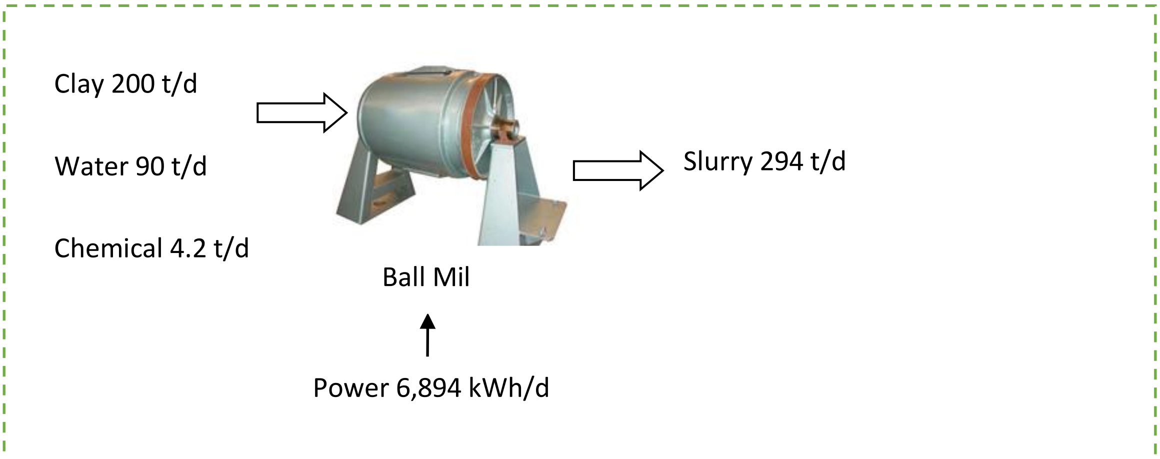

Figure 20 Energy and mass balance of Ball Mill

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 12.84 kW/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 # 7 –Optimization of Resource Consumption in Clay Section

Technology description

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

Study and investigation

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

Recommended action

It is recommended to install brackish water plant which will blend RO water with raw water to get desired TDS of water(less than 300 ppm) to be used in 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 38: Saving and cost benefit by using improved water quality [ECM-7]

Particulars	Unit	As Is	To Be
Existing TDS of Water	ppm	1,500	400
Water consumption per batch	m^3	18	15
Power consumption per batch	kWh	287	279
Electricity saving per batch	kWh	23	
Water saving per batch	m^3	2.70	
Coal saving per batch	kg/batch	356	

Particulars	Unit	As Is	To Be
Water Cost	Rs /m³	5	
Cost of Electricity	Rs/kWh	7.28	
Chemical Cost(SMS)	Rs /kg	22	
Chemical cost (STPP)	Rs/kg	85	
Electricity cost saving per batch	Rs/batch	62.75	
Water cost saving per batch	Rs/batch	13.5	
Coal saving per batch	Rs/batch	2549	
Chemical Cost(SMS) savings per batch	Rs/batch	990	
Chemical cost (STPP) savings per batch	Rs/batch	637.5	
Total cost saving per batch	Rs/batch	4,253	
Total batches per day	batches/d	5	
Cost saving per day	Rs/d	21,265	
Operating days	d/y	330	
Cost saving per annum	Lakh Rs/y	70.17	
RO Operating cost per m³	Rs/m³	20.0	
Annual operating cost for RO	Lakh Rs/y	5.05	
Annual monetary savings (net)	Lakh Rs/y	65.12	
Estimated Investment	Lakh Rs	39.6	
Payback Period	months	7.30	
IRR	%	123	
Discounted payback period	Months	2.8	

4.2 HYDRAULIC PRESSES

4.2.1 Specifications

Hydraulic presses give shape for clay powder that is coming from spray dryer in tiles form by pressing clay 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 latest technology hydraulic presses are used in Morbi cluster which are energy efficient. The specifications of presses and its accessories are given below:

Table 39 Specifications of hydraulic press

Particular	Units	Value
Cycle (stock) per min	N/m	12
Nos. of tiles per stock		3
Water Circulation Pump	#s	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 was 4.23kW (PF 0.78) and CT fan was consuming 22.9kW.

Tiles produced from new press were 1,755 per hour during study.

4.2.3 Observation and performance assessment

Water circulation was provided for oil cooling in heat exchanger which was cooling down in cooling tower with help of CT fan. When press operation interrupted, press pump and CT fan operates continuously without controlling. CT fan can be controlled by installing PID controller which will operate CT fan by sensing return temperature of oil from press. Cooling water pump controlling may affect press so it is advised to control CWP.

Performances of hydraulic presses can measures in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press was 10.4 kW/ton.

4.2.3.1 Energy conservation measures (ECM) - ECM #8: PID Controller for CT fan of press

Technology description

CT fan is dedicated to cool down returning water from oil heat exchanger of hydraulic press which helps to control hydraulic oil temperature in press. A PID controller for cooling tower fan will ensure operation of fan only when it is required based on temperature set point.

Study and investigation

It was observed that cooling tower fan is running continuously irrespective of the operation of the press this CT fan is drawing 22.9 kW. It was also observed that even when press is not in operation CT fan is running.

Recommended action

It is recommended to install PID based controller which will ensure that CT fan 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 40: PID Controller for Press CT fan [ECM-8]

Parameters	Units	As Is	To Be
No. of cooling tower	#	2	2
No. of cooling tower fan	#	2	2
Rated power of fan	kW	28.7	28.7
Operating power	kW	22.9	22.9
Operating hours/day	h/d	24	15
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	81,526	113,454
Annual electricity saving	kWh/y		68,072
Unit cost of electricity	Rs/kWh		7.28
Annual monetary savings	Lakh Rs/y		4.95
Estimated Investment	Lakh Rs		0.53
Payback Period	Months		1.3
IRR	%		690
Discounted payback period	Months		0.5

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 solid particles in slurry. The specifications of agitator motors are given below:

Table 41 Specifications of agitators

Particular	Units	Value
Numbers of agitators in tank	#	1
Capacity of each agitator motor	hp	7.5
Number of motors	#	16

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 42 Power consumption and P.F. of agitator motors

Equipment	kW	PF
Agitator#1	0.768	1.00
Agitator#4	0.74	0.84
Agitator#6	1.1	1.00
Agitator#10	0.811	1.00
Agitator#12	1.18	1.00
Agitator#16	1.1	1.00
Agitator#15	3.03	1.00

4.3.3 Observations and performance assessment

Excluding one agitator motors (#4), 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 1.2 kW/ton.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 ECM #9: Timer Controller with stirrer motors

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 43: Stirrer Time Controller [ECM-9]

Particulars	Unit	AS IS	TO BE
No of agitator stirrer	Nos.	7	7
No of agitator stirrer running	Nos.	7	7
Rated power of agitator stirrer motor	kW	5.6	5.6
Running of each stirrer motor	h/d	24	12
Average power of stirrer motor	kW	2.0	2.0
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	112,279	56,140
Annual energy saving	kWh/y	0	56,140
Cost of Electricity	Rs./kWh	7.28	7.28
Annual energy cost saving	Lakh Rs./y	4.09	
Estimated investment	Lakh Rs.	0.55	
Payback Period	Months	2	
IRR	%	550	
Discounted payback period	Months	0.65	

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 44 Specifications of glazing machine

Particular	Units	Value
Numbers of glazing mills	Nos.	4
Capacity of 2 glazing mills	HP	30
Capacity of 2 glazing mills	HP	25

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of glaze mills

During DEA, power consumption of glaze mill was 15.5 kW (PF 0.78)

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 45 Specifications of sizing machine

Particular	Units	
Numbers of grinders	Nos.	46
Capacity of grinders	hp	4.5
Capacity of dust collectors blower	hp	7.5

During DEA, sizing line was not in operation so measurement couldn't possible

4.6 Air Compressors

4.6.1 Specifications

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

Table 46 Specifications of compressors

Particular	Units	Air compressor 1
Power rating	HP	30
Maximum pressure	Bar (a)	7
Air handling capacity	m^3/min	3.96

- Receiver

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	26.09	0.76	3.62	65.71

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 was 0.21 kW/cfm

4.6.4 Energy conservation measures (ECM) - ECM #10: VFD installation with compressor

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 the compressor is getting unloaded for 35% of the time. There was only one receiver and it was not possible to conduct FAD test for compressor.

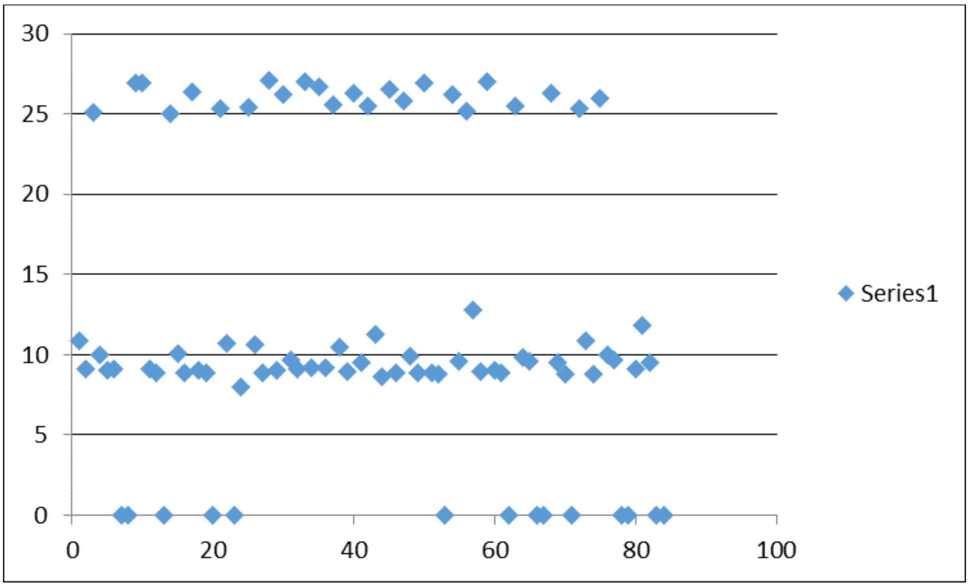

Figure 21: Load/Unload pattern of Compressor

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 [ECM-10]

Particulars	Unit	Values
Present Power Consumption of compressor	kWh/d	490
Unload Power of Compressor	kW	9.53
Percentage Unload	%	34.29
Saving Potential	kWh/d	73.48
Operating days	d	330
Saving Potential	kWh/y	24,248
Cost of Electricity	Rs/kWh	7.28
Saving Potential	Lakh Rs/y	1.76
Estimated Investment	Lakh Rs	1.98
Payback Period	months	13.46
IRR	%	63
Discounted payback period	Months	5.2

4.6.5 Energy conservation measures (ECM) - ECM #11: pressure reduction for compressor

Technology description

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

Study and investigation

During DEA, it was found that the compressed air was generating compressed air at 7 kg/cm^2 and the pressure requirement at the end utilities were around 5 kg/cm^2.

Recommended action

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

Table 49: VFD for compressor 1 [ECM-11]

Parameter	Unit	Present	Proposed
Operating pressure required	kg/cm²	7	5
Cut off pressure	kg/cm²	8	8
Reduction in pressure	kg/cm²	-	2
% of energy saving	%	-	12%
Average load	kW	20.4	17.96
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	161,655	142,256
Annual energy savings	kWh/y		19,399
Unit cost of electricity	Rs/kWh		7.28
Annual monetary saving	Lakh Rs/y		1.41
Estimated Investment	Lakh Rs		0.40

Parameter	Unit	Present	Proposed
Payback period	Months		3.37
IRR	%		270
Discounted payback period	Months		1.33

4.7 Water Pumping System

4.7.1 Specifications

Pumping system comprises two 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 cooling water pumps at coal gasifier
- Flow measurements for same pump

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

Table 50 Operating details of pump

Particulars	Unit	CWP 1	CWP 1
Measured flow	m^3/h	113.3	113.6
Total head	M	16	16
Actual power consumption	kW	12.8	12.6

4.7.3 Observation and performance assessment

Based on observations during DEA, the pump efficiencies were determined as 45% and 48% respectively. Detailed energy conservation measure (ECM) is explained in earlier section of water pumping system.

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
Press	Lumen/m^2	70
Ball mill and agitators	Lumen/m^2	70
HAG and spray dryer new	Lumen/m^2	75
Horizontal dryer	Lumen/m^2	65

4.8.3 Observations and performance assessment

Adequate day lighting is used wherever possible. Already they have changed most of the fixtures with EE fixtures. Measured voltage was higher in lighting feeder which must be optimized.

4.8.4 Energy conservation measures (ECM) - ECM #12: Voltage optimization in lighting MDB

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.

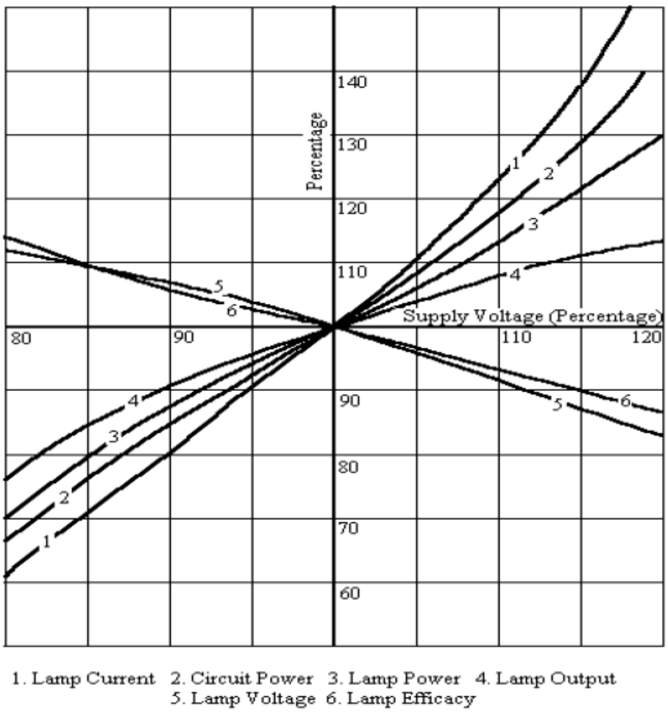

Figure 22: Effect of supply voltage on lamp parameters

Study and investigation

Lighting feeder measurements were carried out to estimate existing lighting load and the voltage level in the lighting circuit. Present lighting load in the plant is 22 kW and measured voltage level is 400 V.

Recommended action

It is recommended to install separate lighting transformer of 40 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 53: Voltage Optimization in lighting circuit [ECM-12]

Particulars	Units	Values
Present Power Consumption in Lighting	kWh/d	496
Present Voltage Level in Lighting Circuit	V	400
Proposed Voltage Level in Lighting Circuit	V	380
Saving Potential	%	9.9
Saving Potential	kWh/d	49
Operating days per year	d	330
Saving Potential	kWh/y	16,218
Cost of Electricity	Rs/kWh	7.28
Estimated Savings	Lakh Rs/y	1.18
Lighting voltage transformer rating	kVA	1.18
Estimated Investment	Lakh Rs	26.00
Payback Period	months	1.32
IRR	%	64
Discounted payback period	Months	5.2

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 (1 MVA). Automatic power factor correction system is installed in parallel to main supply. There were two DGs (capacity of 0.630 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeder which is shown in Figure 8.

4.9.2 Field measurement and analysis

During DEA, the following measurements were done:

- Whole plant load measurement by installing power analyzer at 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 **907 kVA** at the plant feeder

The voltage profile of the unit is satisfactory and average voltage measured was **417 V.** Maximum voltage was **432 V** and minimum was

Average total voltage and current Harmonics distortion found **5.03%** & **7.74%** respectively during power profile recording.

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

4.9.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.9.4.1 ECM #13: Installation of harmonics Filter

Technology description

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

Some of the effects of harmonics are mentioned hereunder.

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

Study and investigation

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 3.17 kW.

Table 54: 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	417	929	10.8	16.6	1.83	13.6	8.12	0.28	1.33
		Minimum	404	518	6.3	8.9	0.20	6.60	2.90	0.00	0.10
		Maximum	428	1230	15.9	28.1	4.20	24.6	13.9	1.30	4.30
	Y	Average	418	975	11.1	16.7	2.18	12.7	9.60	0.37	1.22
		Minimum	405	533	6.5	8.2	0.50	5.70	3.10	0.00	0.10
		Maximum	429	1307	16.0	28.7	5.50	23.2	16.6	2.20	3.50
	B	Average	415	933	11.2	17.7	3.77	14.1	8.92	0.63	1.14
		Minimum	402	517	6.7	8.8	1.90	6.30	3.10	0.00	0.00
		Maximum	425	1245	16.2	29.0	7.00	24.1	15.4	2.30	3.50

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

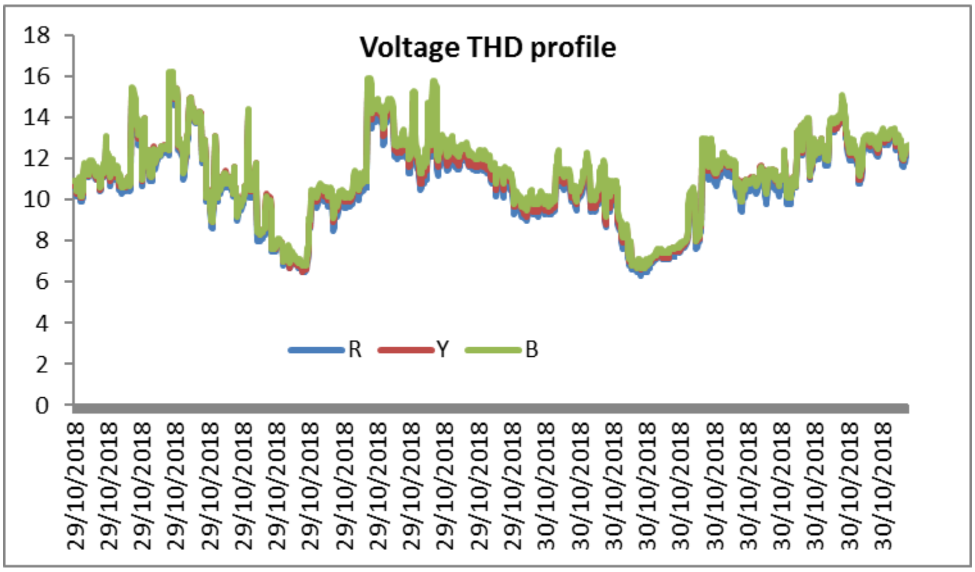

Figure 23: Voltage THD profile

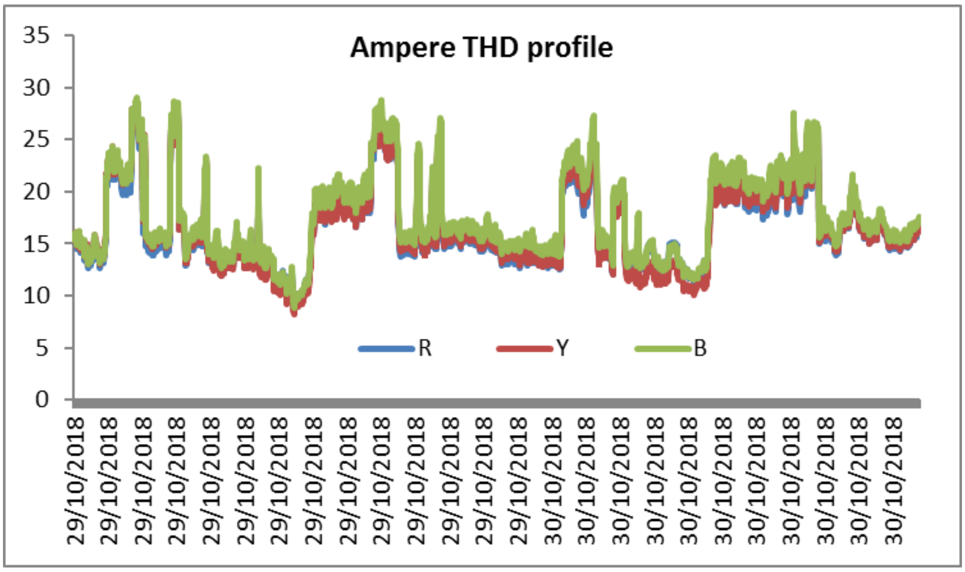

Figure 24: Ampere THD profile

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 120 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 installing 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 55: Install active harmonics Filter [ECM-13]

Particulars	Unit	As Is	To be
Estimated losses due to Harmonics	kW	3.20	0
Saving potential by installation of active harmonics filter	kW	3.20	
Operating days	d	330	
Operating hours	h	24	
Saving potential	kWh/y	25,078	
Cost of Electricity	Rs./kWh	7.28	
Annual Saving	Rs./y	182,496	
Estimated rating of active harmonics filter	Ampere	120	
Estimated Investment	Rs	950,400	
Payback Period	months	62	
IRR	%	-6	
Discounted payback period	Months	21.3	

4.9.4.2 ECM #14: Installation of energy monitoring system

Technology description

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

Study and investigation

It was observed during the audit that online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed at 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 56: Cost benefit analysis [ECM-14]

Parameters	Unit	As Is	To Be
Energy monitoring saving for electrical system	%		2.00

Parameters	Unit	As Is	To Be
Energy consumption of major machines per year	kWh/y	3,176,340	3,112,813
Annual electricity saving per year	kWh/y		63,527
Unit Cost	Rs/kWh		7.28
Annual monetary savings	Lakh Rs./y		4.62
Number of equipments	Nos.	-	28
Estimate of Investment	Lakh Rs.	9.36	
Simple Payback	months	15.33	
Energy monitoring saving for thermal system	%		2.00
Current fuel consumption for kiln	kg/y	11,131,849	10,909,202
Annual fuel saving per year	kg/y		222,637
Unit Cost	Rs./kg		7.2
Annual monetary savings	Lakh Rs./y		20
Number of equipments	Nos.	3	
Estimate of Investment	Lakh Rs.	25.56	
Payback Period	months	15.53	
IRR	%	54	
Discounted payback period	Months	5.9	

4.10 Belt Operated Drives

4.10.1 Specifications

There are 11 drives operated with V Belt of total capacity of 207 kW. Locations include

- Kiln (5)
- HAG (2)
- Horizontal dryer (4)

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 #15: V Belt replacement with REC belt

Technology description

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

Benefits of Cogged belts & Pulley over V belts:

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

Study and investigation

The unit is having about 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 57: Replacement of conventional belt with REC belt [ECM-15]

Particulars	Units	AS IS	TO BE
Measured power of all belt driven blowers	kW	201	194
Running hours of blowers	h/d	24	24
Average power of blowers	kWh/d	4,829.5	4,655.6
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	1,593,723	1,536,349
Annual energy saving	kWh/y	57,374	
Electricity cost	Rs./kWh	7.28	
Annual energy cost saving	Rs. Lakh/y	4.18	
Estimated investment	Rs. Lakh	1.85	
Payback Period	Months	5.31	
IRR	%	173	
Discounted payback period	Months	2	

5. Chapter -5 Energy consumption monitoring

5.1 ENERGY CONSUMPTION MONITORING

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

5.2 BEST OPERATING PRACTICES

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

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Ball mill	VFD for energy saving. Timer control system
3	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing pollution
3	Press	
5	Horizontal Dryer	Waste heat from kiln is used in horizontal dryer with supplementary firing of coal gas.
6	Glaze ball mill	Timer control in each ball mill.
7	Kiln	VFD in each blower, waste heat used in air preheating section and horizontal dryer. PID control system for controlling chamber temperature in firing zone.
8	Sizing	Fully automatic system. Dust collection system installed.
9	Printing	Automated digital printing with fully auto control system
10	Lighting	LED lights

5.3 NEW/EMERGING TECHNOLOGIES

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

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

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

Table 58 : Specifications of dry clay grinding technology

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

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

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

The working principle is as follows:

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

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

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

a) Reduction in thermal energy consumption -70%
b) Reduction in water consumption- 75.4%
c) Reduction in power consumption -1%
d) Reduction in use of chemical additives – 100%
e) Overall reduction in manufacturing costs – 44%
f) Reduction in abrasion
g) Reduction in ball milling time
h) Reduction in floor area required

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

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

Cooling air may have temperature ranging from 120°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.

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

Figure 25 : Heat recovery system for combustion air

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

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

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

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

2. **Heat recovery systems** – Sin**gle and double heat r**ecovery for combustion air.

[4] SACMI Kiln Revamping catalogue for roller kilns

[5] SACMI Kiln Revamping catalogue for roller kilns

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 26: 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.

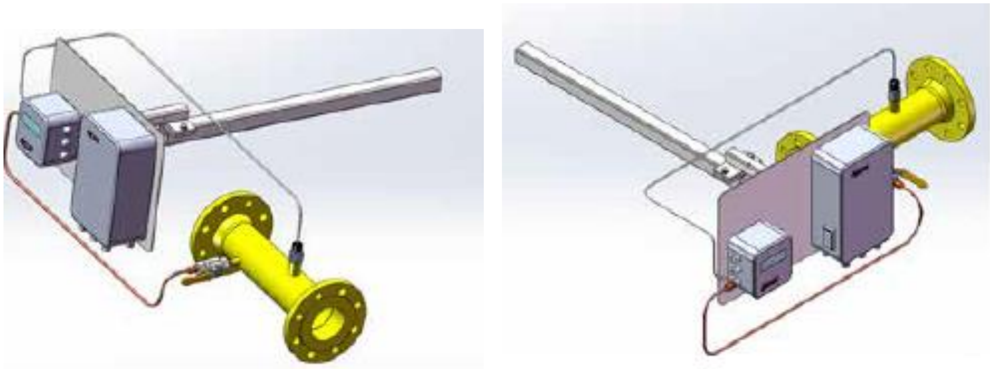

Figure 27: Combustion air control for burner

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

- Flexibility – Air volume can be ser according to the product

- Fuel consumption optimisation
- Reduced consumption if there is gap in production
- 3 independent macro zones can be controlled separately

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

Figure 28: 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

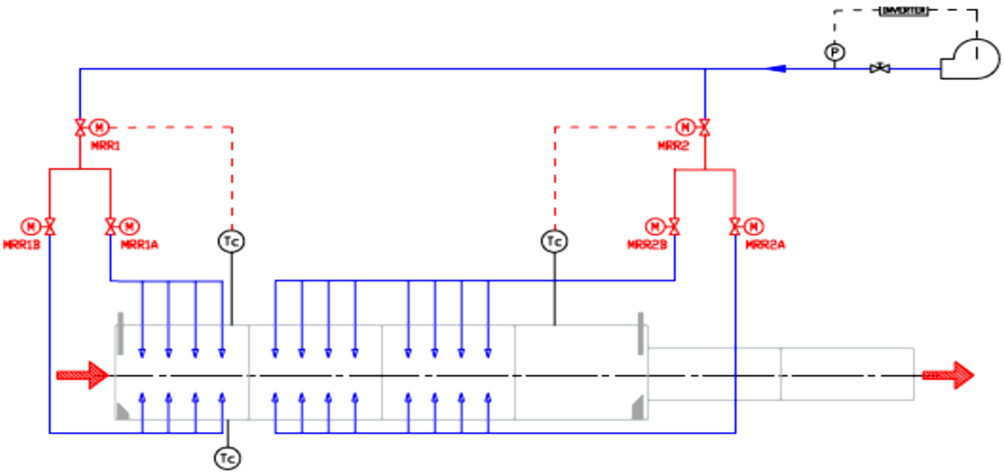

Figure 29: Fast cooling air management

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
   - Compelete consumption and production database available to corporate network and to management software using internet or database SQL protocol

Figure 30: 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 31: - High Alumina pebbles for Ball mill

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

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

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

In the tile manufacturing process different raw materials which include one or more clays are mixed in specific Ratio (Clay Body). Clay body is subjected to wet grinding in a ball mill to get required density and viscosity. For efficient grinding, inorganic dispersants like STPP, SHMP or sodium silicate are used. These can be replaced either partially or fully by organic deflocculant (Brand name FLOSPERSE[6]) to save fuel cost during spray drying. Slip is stored in tanks which will be sieved for sending to spray drying.

Purpose of using deflocculants is to avoid increase in the viscosity of the slurry due to thixotropy. Lower viscosity during wet-grinding makes the grinding operation faster, thus reducing power consumption. Lower viscosity also prevents choking of pipelines & spray drier nozzles, thus ensuring proper granulometry of spray dried dust/clay, which is essential for achieving green tile strength. Deflocculants allows for achieving higher slurry density (more solids loading per litre of slurry) without increasing viscosity. For spray drying operation, achieving higher slurry density is important since more solids in slurry, less water to be evaporated in spray drier and less fuel consumption, making the operation viable commercially.

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

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

- STPP dosage is reduced by more than 50%
- For the same treatment cost as STPP alone, by using FLOSPERSE in combination, a higher density slip can be achieved at the same viscosity thus saving much more in terms of fuel cost in spray dryer

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

5.3.6 Use of Organic Binder in Porcelain/Granite Tiles Manufacture:

In ceramic bodies where highly plastic clays are used, sufficient green and dry strength is achieved due to the inherent binding ability of the clays hence the use of external binders is not necessary. However, in the manufacturing process of vitrified/granite tiles, almost 75 % of raw materials are non-plastic in nature which contribute very less to green and dry strength. Special white firing clays which are not highly plastic are used in small quantity and do not impart sufficient strength. Organic binders like FLOBIND[7] can be used very effectively to increase the green and dry strength as well as edge strength of the tiles. The working principle of the binder is as follows:

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

[7] 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 32: -Direct drive blower fan

6 Chapter -6 Renewable Energy Applications

The possibility of adopting renewable energy measures was evaluated during the DEA (details below).

The RCC roof top space available is 600 m^2 and corresponding solar power potential will be 60 kW. Other roof areas are sloping structures, where structural enhancement is required for solar PV installation. There is no ground space available for solar PV installation. As per discussion with vendors, due to high dust content in the region, installation of solar PV is not feasible. The extent of degradation on account of dust is upto 40% (for 6g of dust per panel). Therefore Solar PV installation is not recommended.

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

Technology description

The RCC roof top space available in plant is 600m^2 under office admin and administrative building.

Study and investigation

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

Recommended action

The cost benefit analysis for this project is given below:

Table 59: Installation of solar PV system [ECM-16]

Parameters	Units	Value
Available area on roof	m^2	600
Capacity of solar panel	kW	60
Energy generation from solar panel	kWh/d	288
Solar radiation day per year	d/y	330
Average electricity generation per year	kWh/y	95,040
Cost of Electricity	Rs/kWh	7.28
Annual monetary savings	Rs Lakh/Y	6.9
Estimate of Investment	Rs Lakh	31.7
Simple Payback Period	Months	55
IRR	%	-3
Discounted payback period	Months	19.1

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

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

7 ANNEXES

7.3 Annex-1: Process Flow Diagram

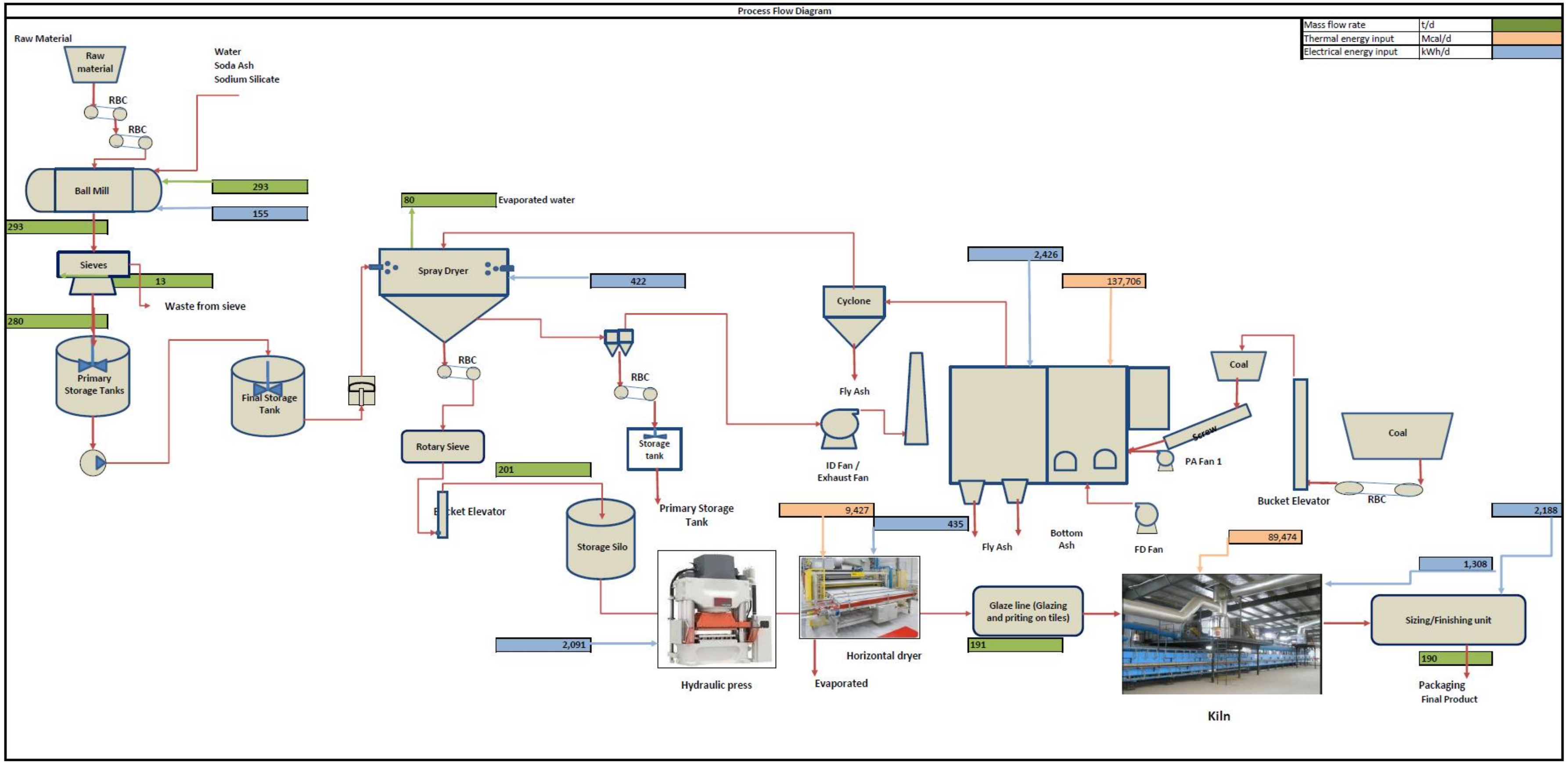


Figure 33: Process Flow Diagram of Plant

7.4 Annex-2: Detailed Inventory

Table 60: Detailed Inventory list

Parameters	Units	Value
Glaze Mills	kW	159
Horizontal Dryer	kW	48
Spray dryer	kW	37
Hydraulic Press	kW	232
Utilities	kW	50
Sizing	kW	182
Hot air generator	kW	239
Main kiln	kW	250
Spray Dryer	kW	37
Ball mill section	kW	460
Coal Gasifier	kW	59
Single phase load	kW	22
Total	kW	1740.7

7.5 Annex-3: Single Line Diagram

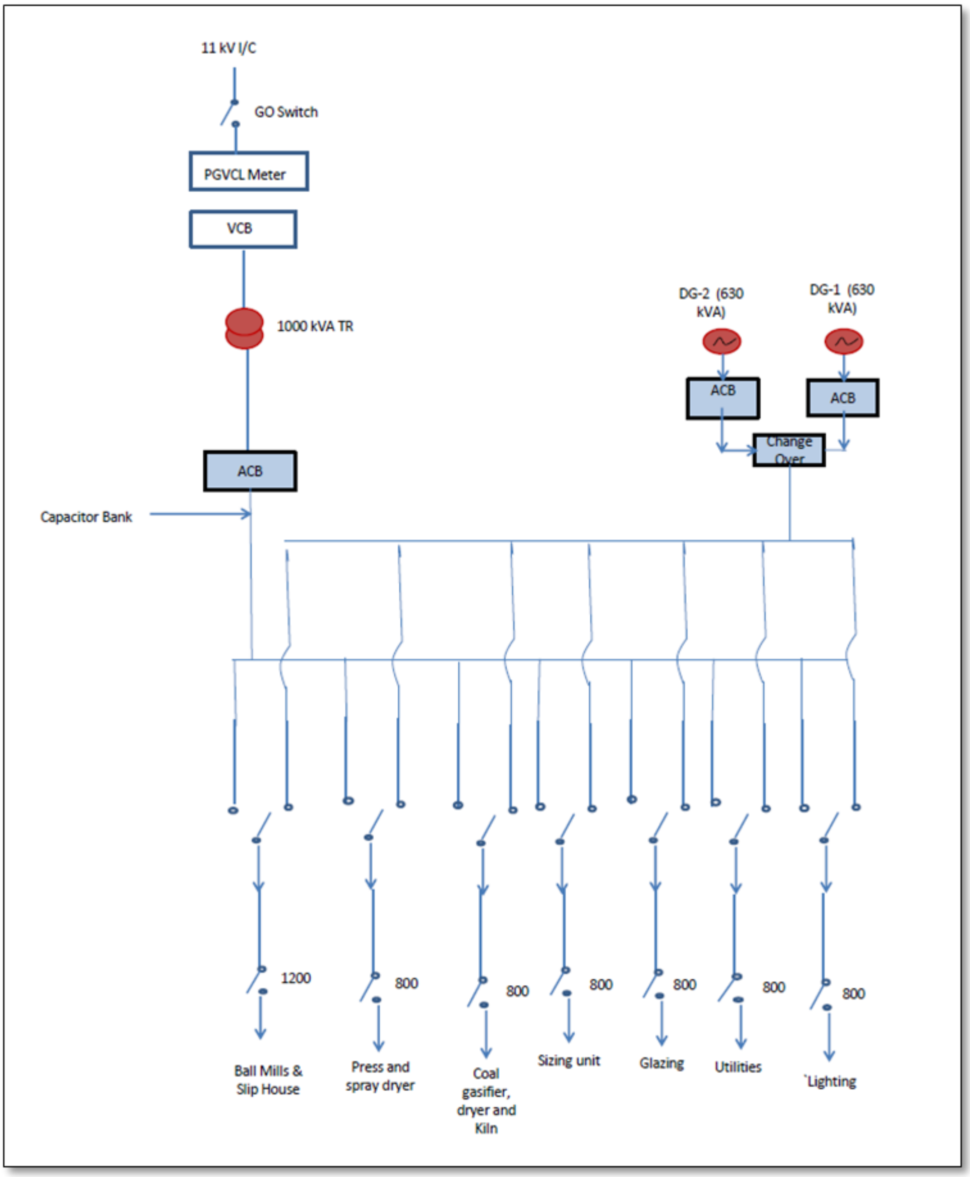


Figure 34: Single Line Diagram (SLD)

7.6 Annex-4: Electrical Measurements

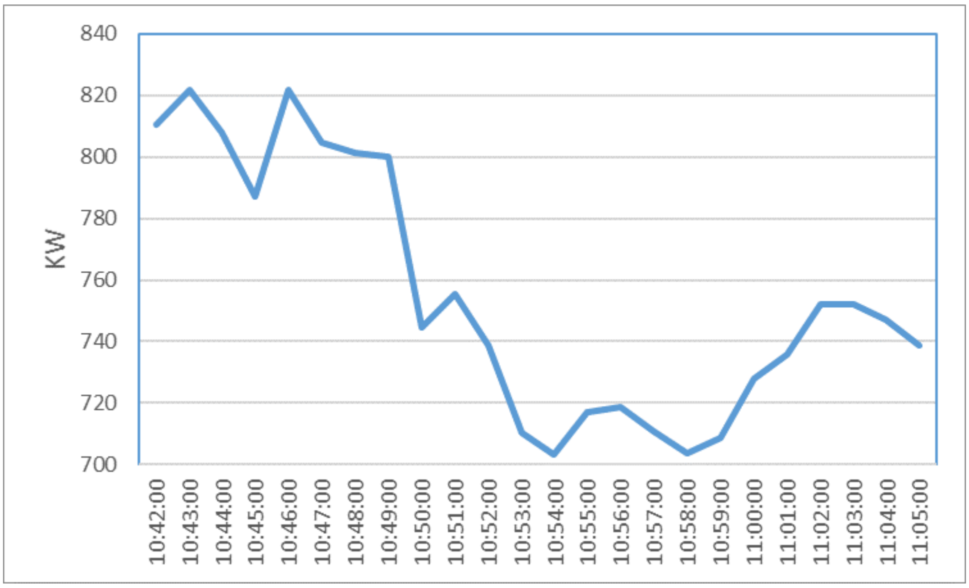
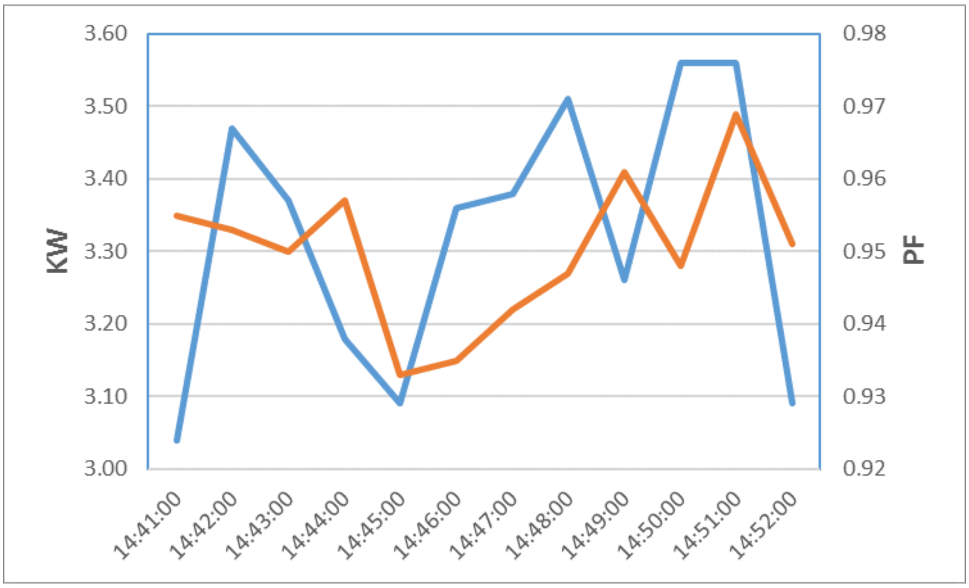
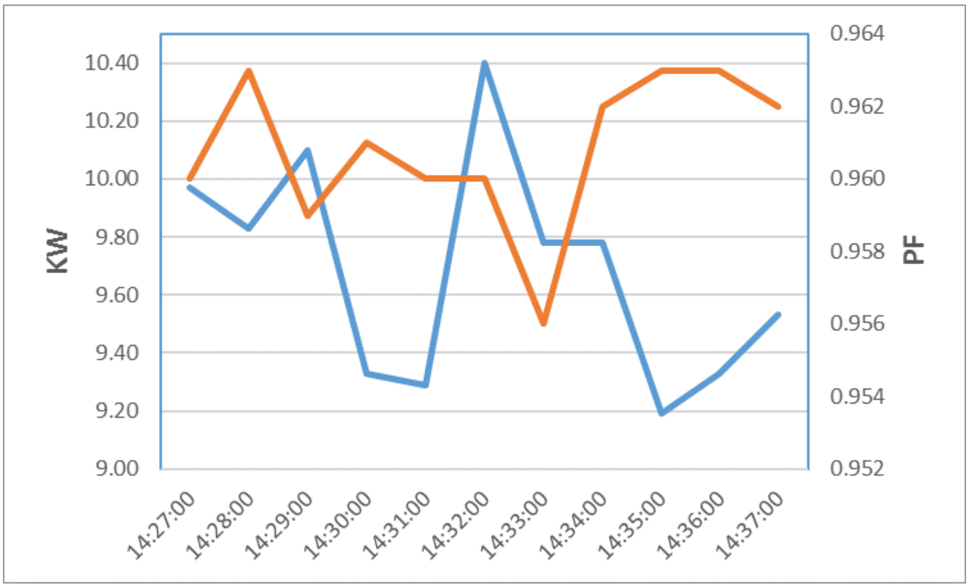


Figure 35: Power profile (kW) of Main Incomer




KW
PF
10.40
10.20
10.00
9.80
9.60
9.40
9.20
9.00
0.964
0.962
0.960
0.958
0.956
0.954
0.952
14:27:00
14:28:00
14:29:00
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14:31:00
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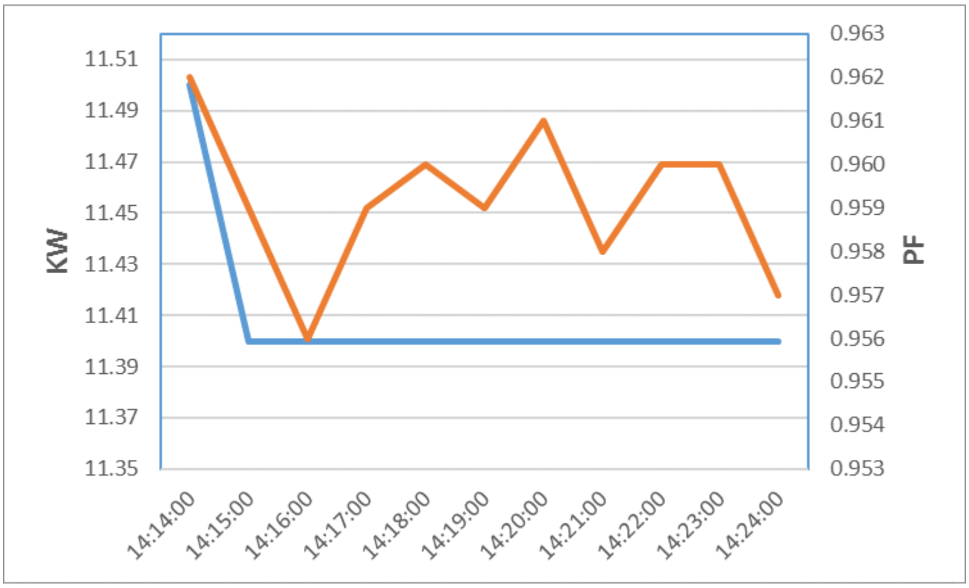
14:37:00


KW
PF
11.51
11.49
11.47
11.45
11.43
11.41
11.39
11.37
11.35
0.963
0.962
0.961
0.960
0.959
0.958
0.957
0.956
0.955
0.954
0.953
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14:15:00
14:16:00
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14:23:00
14:24:00

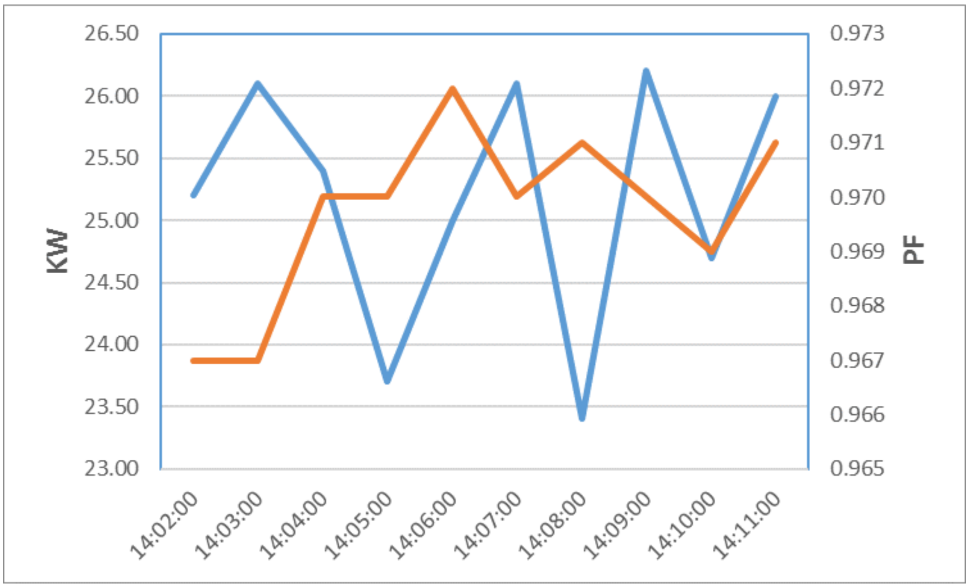
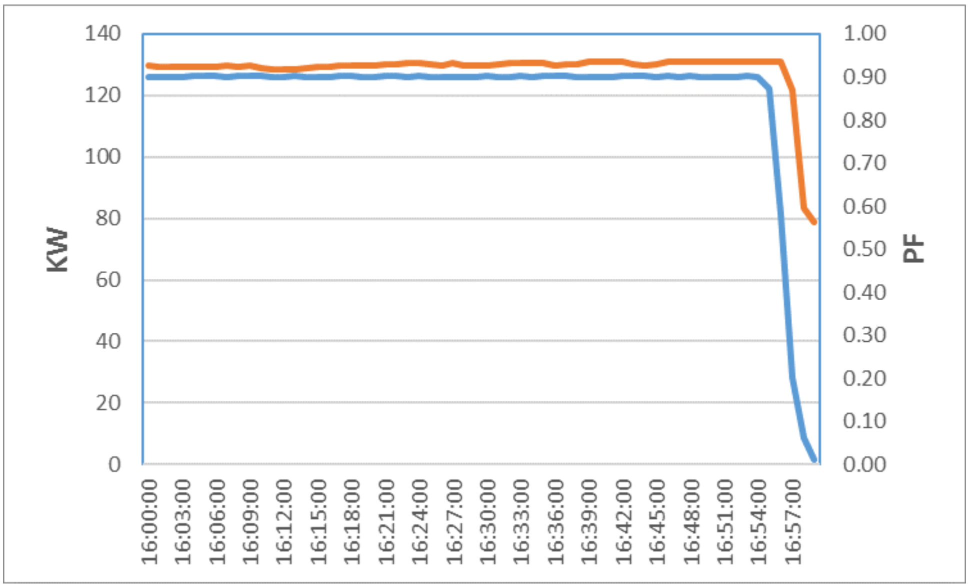

KW
PF
26.50
26.00
25.50
25.00
24.50
24.00
23.50
23.00
0.973
0.972
0.971
0.970
0.969
0.968
0.967
0.966
0.965
14:02:00
14:03:00
14:04:00
14:05:00
14:06:00
14:07:00
14:08:00
14:09:00
14:10:00
14:11:00

Figure 36 Power and PF profile of blowers of kiln



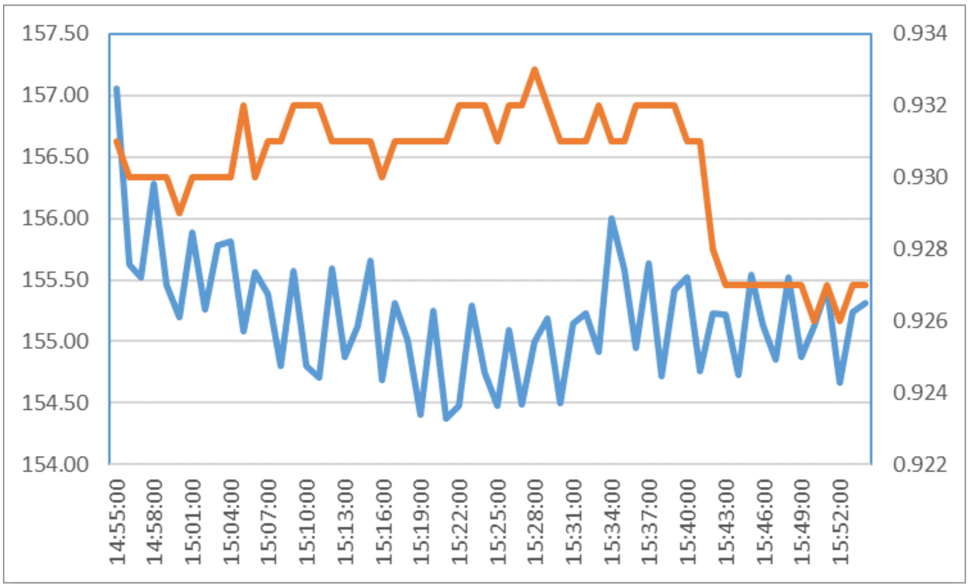


Figure 37 Power and PF profile of blowers of Ball Mills

7.7 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	2625	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	250	*°C*
Preheated air temp./Ambient	180	*°C*
O2 in flue gas	8.5	*%*
CO2 in flue gas	7.3	*%*
CO in flue gas	20	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.0213	*kg/kg dry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
O	*15.22*	%
S	*0.0*	%

Moisture	*2.50*	%
Ash	*0.00*	%
GCV of fuel	1231	*kCal/scm*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un=burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kCal/kg
GCV of fly ash	*0*	kCal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	4033	*Kg/h*
Weight of Stock	0	*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	3,681	*kCal/h*
Radiation and convection from heating zone surface	16,384	*kCal/h*
Heat loss from all zones	20,065	*kCal/h*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.75	*h*
Area of entry opening	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	7.72	*kg/kg of fuel*
Excess Air supplied	68.00	*%*
Actual Mass of Supplied Air	12.97	*kg/kg of fuel*
Mass of dry flue gas	12.86	*kg/kg of fuel*
Amount of Wet flue gas	13.97	*kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*kg of H_2O/kg of fuel*
Amount of dry flue gas	12.86	*kg/kg of fuel*
Specific Fuel consumption	622.75	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	733,336	*kCal/ton of tiles*
Sensible heat of fuel		*kCal /ton of tile*
Total heat input	733,336	*kCal /ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	255,156	*kCal /ton of tile*

Parameters	Value	Unit
Heat loss in dry flue gas	403,153	*kCal /ton of tile*
Loss due to H2 in fuel	32,732	*kCal /ton of tile*
Loss due to moisture in combustion air	1225	*kCal /ton of tile*
Loss due to partial conversion of C to CO	235	*kCal /ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	20,065	*kCal /ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	9,184	*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	-	*kCal /ton of tile*
Unaccounted heat losses	11,585	*kCal /ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln		*kCal /tons*
Kiln Efficiency	34.8	*%*

2. Heat Balance Diagram

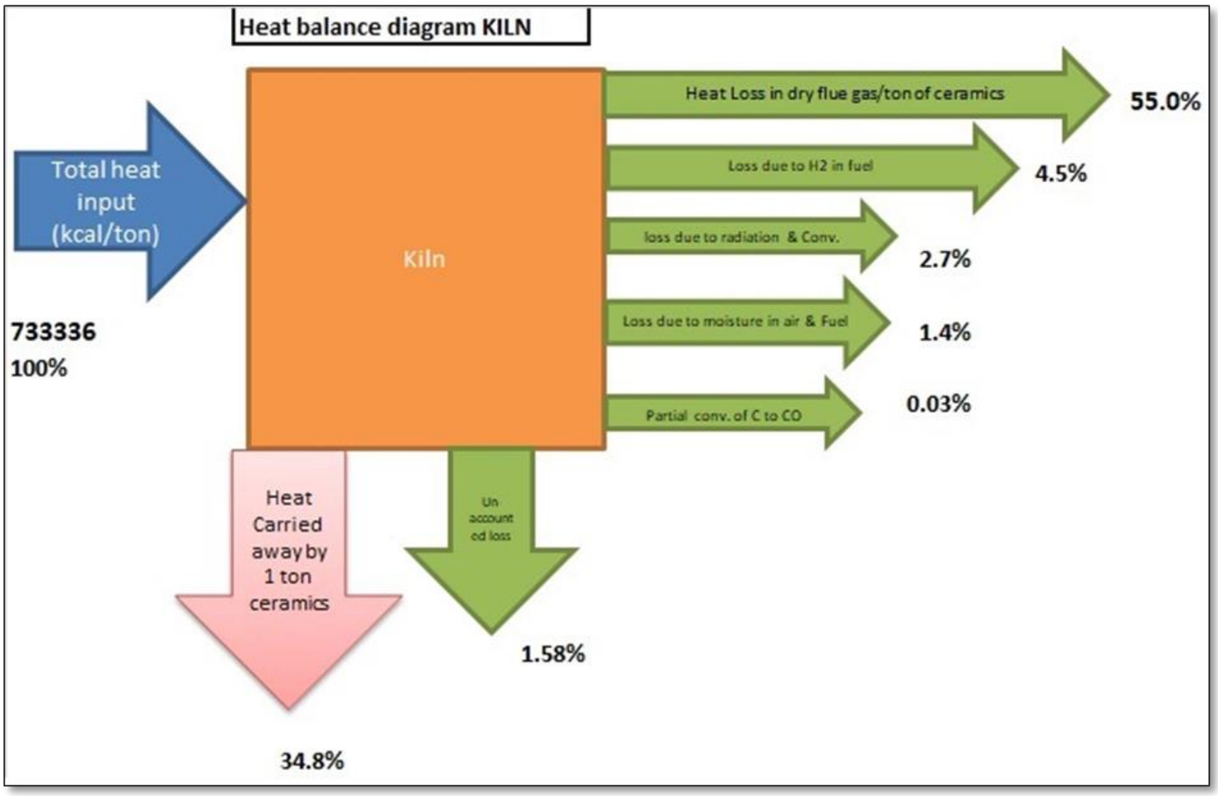


Figure 38 Heat Mass Balance diagram of kiln

7.8 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 HE

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Knack well	C/2, Akshardham Industrial Estate, Near	9824037124,	http://www.knackwellengineers.com/

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

ECM - 4: 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 5&6: Heat loss reduction for hot air pipes for horizontal dryer

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA	Tel:+ 91 44 2530 6888 Fax: 91 44 2534 5985 Mob: 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com ramaswamy.pondian@morganplc.com
2.	Divine Cera Wool India LLP	Survey 397, Nr. Bhalpura, Village - Khavad,	+91 9824655778	www.divinecerallp.com sales@divinecerallp.com

Sl. No.	Name of Company	Address	Phone No.	E-mail
		Kadi to Sachana Road, Taluka - Kadi, District - Mahesana, Gujarat, India - 382 165		
3.	Ravani Ceramic	Jadeshwar Chamber – 1 Shop No. 101 / 102 First Floor, N.H.8/A Near Zanjar Cinema Wankaner – 363621 Dist – Morbi, Gujarat	Dipak Patel: +91 93280 42126 General Manager Aliasgar Ghiyawadwala: +91 99242 47069	ravanicera@yahoo.com

ECM 7: Optimization of resource consumption in Clay ball mill using treated water

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 – 8 & 9 : Installation of Electronic timer and temperature controller /Sensor

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 10: VFD installation on compressor

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 - 12: Voltage optimization in lighting circuits 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.	Servokon House,C-13, Radhu palace road, opp.Scope minar,Laxmi Nagar, Delhi-110092	75330088 Toll free:18002001786	http://www.servokonstabilizer.com/contact-us.html
3	SERVOMAX INDUSTRIES LIMITED (Manufacturer)	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033 BRANCH: #166A, 2nd Floor,Pratap Nagar, Mayur Vihar,Phase-I, New Delhi- 110092	+91 9111234567	customercare@servomax.in www.wervomax.in

ECM - 13: 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,	Mob: +91 8048412433	info@infinityenterprise.net

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
		Odhav, Ahmedabad – 382415, Gujarat, India.		
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 14: Energy Monitoring System

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

ECM-15: V Belt with REC belt replacement

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

ECM 16 : Solar PV system

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

7.9 Annex-7: Financial analysis of project

Table 61 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%