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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE WT-07: PENGVIN CERAMICS

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DESL

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Disclaimer

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

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Mr. Himat Bhai, Partner

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

CONVERSION FACTORS

TOE Conversion	Value	Unit	Value	Unit
Electricity	1	kWh	0.000086	TOE/kWh
Coal	1	MT	0.45	TOE/MT
Natural Gas	1	scm	0.00089	TOE/scm
Emissions				
Electricity	1	kWh	0.00082	tCO_2/kWh
Coal	1	MT	2.116	tCO_2/t
Natural Gas	1	scm	0.001923	tCO_2/scm

EXECUTIVE SUMMARY

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

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

Pengvin Ceramics has been selected as one of the 20 units for detailed energy audit. Pengvin Ceramic is a wall tile manufacturing unit. This report has been prepared as an outcome of energy audit activities carried out in the unit.

➨ INTRODUCTION OF THE UNITOF THE UNIT

Name of the Unit	Pengvin Ceramics
Year of Establishment	2004
Address	8A National Highway, Near Makansar, Morbi - 363 642, Gujarat - INDIA.
Products Manufactured	Wall Tiles
Name(s) of the Promoters / Directors	Mr. Himmat Bhai

➨ 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 kiln in which the fuel used is natural gas. The temperature maintained in biscuits kiln is approximately 800°C – 1,150ºC and glaze kiln is 700°C- 1,085°C (in heating zone).

- **Clay Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio as per requirement along with water to form a plastic mass.
- **Glaze ball mill:** For producing glazing material used on wall tiles.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.
- **Agitator:** The plastic 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.
- **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
- **Kiln:** Biscuits are baked in Roller kiln at 1,100-1,150ºC and again baked after glazing
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched

The detailed energy audit covered all equipment which was operational during the field study. The main energy consuming areas are kilns which account for more than 70% of the total energy used.

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in kiln 1: Coal gas is used as fuel in this kiln and oxygen content in flue gas was found to be 7.2 % against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Excess air control in kiln - 2: Coal gas is used as fuel in this kiln and oxygen content in flue gas was found to be 7.3% against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation For combustion air pipes in Biscuit kiln: In this kiln , the recuperator pipes was found to be un-insulated with surface temperature of 177°C which should be maintain at 80 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the recuperator pipes with insulation material for reducing surface heat losses
- Insulation For combustion air header pipe on both sides in Biscuit kiln: In this kiln , the combustion air header pipe was found to be un-insulated with surface temperature of 95°C which should be maintain at 80 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the pipe with insulation material for reducing surface heat losses.

- Optimized Resource Consumption in Clay Section: TDS of water used in clay section was found to be 1,500 ppm against desired level of 400 ppm. It is recommended to install brackish water plant which will blend RO water with raw water.
- Timer controller in 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 upto 12 hour.
- Operational pressure optimization in compressor: Present compressor discharge pressure is 6 kg/cm^2 and the end user pressure requirement were around 4 kg/cm^2. It is recommended to reduce operating pressure of compressor from 7 kg/cm^2 to 6 kg/cm^2.
- Replacement of Inefficient Pumps with EE pumps: Water pumps used for lifting water from underground tank to overhead tank, have low efficiency (around 40-50%). It is recommended to replace these with less efficient pumps with high efficiency (65%).
- Replacement of inefficient light with EE lights: Conventional lights like Fluorescent Tube lights and Compact fluorescent light were present in unit which results in higher electrical consumption. It is recommended to replace the conventional lights with energy efficient LED lamps.
- Cable loss minimization: In sizing section, power factor was in range 0.57-0.60 and in glaze line and digital line was 0.76 & 0.75. It is recommended to install capacitor to improve PF.
- Energy management system: Presently, online data monitoring system are not installed in incomer as well as at various electrical panels. There was no proper fuel monitoring system installed at kiln. It is recommended to install online electrical energy management systems and fuel monitoring system.

Table 1 : Summary of Energy Conservation Measures

Sl No	Energy Conservation Measures	Annual Energy Savings Electricity kWh/y	Coal t/y	TOE TOE/y	Monetary Savings Lakh Rs/y	Investment Lakh Rs	Payback Period Months	Emission Reduction tCO_2/y
1	Excess air control (for biscuit kiln)	6,447	134	74	9.59	18.48	23	288
2	Excess air control (for Glaze kiln)	5,897	160	88	11.34	18.48	20	343
3	Insulation For combustion air header pipe in Biscuit kiln		31	17	2.14	0.660	4	67
4	Insulation For combustion air pipeline in Biscuit kiln		72	39	4.9	11.88	29	152
5	Installation of new recuperator in kiln 1 & 2		1,567	861	106.8	39.60	4	3,315
6	Retrofit of VFD in SFD fan of HAG section	4,910		0.42	0.4	0.30	10	4
7	Optimized Resource Consumption in Clay Section	17,074	1,408	775	182.50	39.60	3	2,993
8	Timer controller in clay ball mill	23,714		2	1.76	0.55	4	19
9	Timer controller in stirrer	43,798	0	4	3.25	0.55	2	36
10	Operational pressure optimization in compressor	9,785	0	0.84	0.73	0.00	0	8
11	Pump replacement with EE pumps	35,422		3	11.45	2.51	3	29
12	Replacement of inefficient light with EE lights	31,966	0	3	2.37	1.37	7	26
13	Cable loss minimization	11,335	0	1	0.84	0.61	9	9
14	Replacement of V belt from REC belt	10,520		1	0.78	1.98	30	9
15	Energy Management system	49,772	0	4	14.44	4.31	4	41
	Total	**250,641**	**3,372**	**1,874**	**353**	**141**	**5**	**7,340**

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

1 Reduction in energy cost by 46.0%
2 Reduction in electricity consumption by 10.07%
3 Reduction in coal consumption by 42.78%
4 Reduction in greenhouse gas emissions by 39.22%

➨ 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 (for biscuit kiln)	18.48	32%	8.58
2	Excess air control (for Glaze kiln)	18.48	41%	7.27
3	Insulation For combustion air header pipe in Biscuit kiln	0.660	243%	1.47
4	Insulation For combustion air pipeline in Biscuit kiln	11.88	20%	10.75
5	Installation of new recuperator in kiln 1 & 2	39.60	207%	1.75
6	Retrofit of VFD in SFD fan of HAG section	0.30	91%	3.79
7	Optimized Resource Consumption in Clay Section	39.60	343%	1.04
8	Timer controller in clay ball mill	0.55	238%	1.50
9	Timer controller in stirrer	0.55	439%	0.82
10	Operational pressure optimization in compressor	0.00	-	-
11	Pump replacement with EE pumps	2.51	344%	1.05
12	Replacement of inefficient light with EE lights	1.37	130%	2.72
13	Cable loss minimization	0.61	102%	3.42
14	Replacement of V belt from REC belt	1.98	18%	11.20
15	Energy Management system	4.31	254%	1.42

1 CHAPTER – 1 INTRODUCTION

1.1 Background and Project Objective

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

The objective of the project includes:

- Increased capacity of suppliers of energy efficiency (EE) and renewable energy (RE) based products, service providers and financing institutions.
- Increasing the levels of end-use demand and implementation of EE and RE technologies and practices by SMEs.
- Scaling up of the project to a national level.
- Strengthening policy, Institutional and decision-making frameworks.

1.2 About the Unit

General details of the unit are given below:

Table 3: Overview of the Unit

Description	Details		
Name of the plant	Pengvin Ceramics		
Plant Address	8A National Highway, Near Makansar, Morbi - 363 642, Gujarat - INDIA		
Constitution	Partneship		
Name of Promoters	Himat Bhai		
Contact person	Name	Himat Bhai	
	Designation	Partner	
	Tel	9825726237	
	Fax		
	Email	info@platinavitrified.com	
Year of commissioning of plant	2004		
List of products manufactured	Wall tile, 250X375 Wall tile, 250X450 Wall tile, 250X600		
Installed Plant Capacity	8,000 boxes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	Not Provided by Unit		

Description	Details		
Net profit	Not Provided by Unit		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
Number of employees	Staff	175	
	Worker		
	Casual labor		
Details of Energy Consumption	Source	Yes/No	Areas of Use
	Electricity (kWh)	Yes	Entire Process and Utility
	Coal (kg)	Yes	Spray Dryer & Kiln through coal gasifier
	Diesel (litres)	Yes	DG – Rarely used
	Natural Gas (scm)	No	
	Other (specify)	No	
Have you conducted any previous energy audit?	No		
Interested in DEA	Yes		
	Very Interested		

1.3 Methodology and Approach

The study was conducted in 3 stages:

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

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

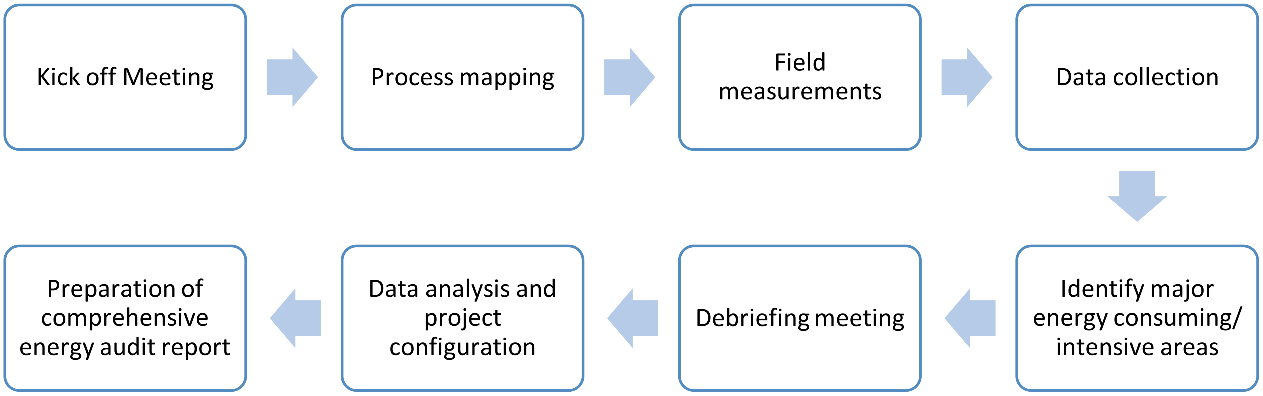

Figure 1: General methodology

The field work was carried out during 30th Nov – 3rd Dec, 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 conservation measurements (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 following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Parameters Measured
1	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
2	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3	AC Amp, AC-DC Volt, Hz, Power Factor, Power

Sl. No.	Instruments	Parameters Measured
	Phase and 1 Phase	
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and Flue gas temperature, Ambient temperature
6	Digital Temperature and Humidity Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

This detailed energy audit report has been organized and presented sequentially in the following order:

- 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 cover the performance evaluation of major energy consuming equipment and sections, thermal and electrical.
- Chapter 5 covers information on energy monitoring practices and best operating 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 (FLOW DIAGRAM)

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

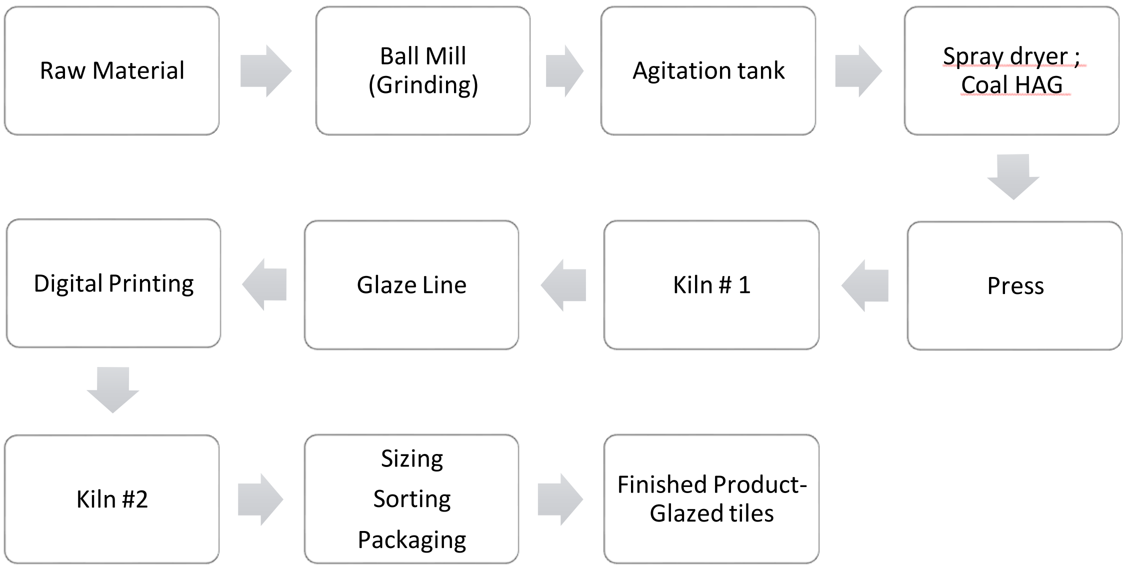

Figure 2: Process Flow Diagram

The process description is as follows:

- The raw materials china clay, talc, calcite, dolomite, silicate, feldspar and scrap are mixed together with water in the ball mill for a period of 65 minutes depending upon residue percentage in slurry.
- The slurry containing about 30-40% moisture and required density is then pumped through hydraulic pump at a pressure of 12-13 bar into spray dryer using nozzles. At the top of spray dryer, hot air is passed at a temperature of 550-650ºC. This hot air is generated by using hot air generator (HAG) using coal as a fuel. Material is dried in spray dryer, thus the moisture added in grinding process in ball mill gets removed from spray dryer. At the outlet of spray dryer, clay in powdered form is collected having moisture of 5-6%. Final products from spray dryer are collected in silos.
- The product from spray dryer is then sent to hydraulic press where the required sizes of biscuit tiles are formed.
- Biscuit tiles are sent to dryer through conveyor system.
- After drying, the biscuit tiles are sent for kiln#1.
- Some biscuits are considered as final product and remaining biscuits are sent for glazing and digital printing.
- After glazing the glazed tiles are sent for final firing in the kiln. Glazed tiles are fired at a temperature of 1,050°C-1,100ºC in the kiln (Kiln-2).

- Tiles coming out of kiln are sent for sizing and calibration; the tiles are cut to proper sizes so that all the tiles are of same dimension.

The major energy consuming equipment in the plant is:

- **Clay Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed along with water to form a plastic mass.
- **Hot Air generator:** Coal is being used as fuel to produce hot air at temperature 540°C to 712°C.
- **Spray dryer:** Slip flows from agitator tanks to spray nozzles and sprayed in the upward direction from the nozzles and hot air coming from hot air generator will pass from top of the spray dryer and slip convert into powder. The moisture content is around 5% to 6% (The powder is carried through conveyors and stored in silos.)
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Horizontal Dryer:** Biscuits are sent to dryer for pre drying after it is passed through kiln. Hot air coming from kiln is being used here. Dryer is connected with biscuit kiln in series.
- **Kiln:** Biscuits are baked in kiln at 1,100-1,150°C and baked again in the second kiln after glazing.
- **Glaze ball mill:** For producing glazing material used on tiles.
- **Air Compressor:** Compressed air is used at several locations in a unit viz. Slurry pumping, Sizing, press bed cleaning, glazing, digital printing, etc.

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 wall tiles of the following specifications:

Table 5: Product Specifications

Product	Size /Piece	Weight	Area per box	Pieces per box
	mmx mm	kg/Box	Sq m	#
Wall Tiles	250 x 375	10.8	0.75	2,666
Wall Tiles	250 x 450	10.2	0.675	4,000
Wall Tiles	250 x 600	12.5	0.75	1,333

The products are mainly exported to foreign market. The month wise production details of various products are given below:

Table 6: Month wise production

Month	Number of Boxes				Corresponding Area (m^2)				Corresponding Mass (MT)			
	200 X 375	250 X 450	250 X 600	300 x 300	200 X 375	250 X 450	250 X 600	300 x 300	200 X 375	250 X 450	250 X 600	300 x 300
Oct-17	80,814	96,085	32,489		62,540	66,949	25,052	-	840	951	398	-
Nov-17	88,811	131,271	-		68,729	91,466	-	-	924	1,300	-	-
Dec-17	45,172	165,828	41,980		34,958	115,544	32,371	-	470	1,642	514	-
Jan-18	88,251	174,819	-		68,296	121,809	-	-	918	1,731	-	-
Feb-18	47,947	98,179	65,505		37,105	68,408	50,511	-	499	972	802	-
Mar-18	25,337	232,550	7,796		19,608	162,034	6,011	-	264	2,302	96	-
Apr-18	99,662	154,821	53		77,127	107,875	41	-	1,036	1,533	1	-
May-18	65,055	143,439	28,479		50,345	99,944	21,960	-	677	1,420	349	-
Jun-18	-	174,735	29,333		-	121,751	22,619	-	-	1,730	359	-
Jul-18	66,790	98,703		2,241	51,688	68,774	-	1,874	695	977	-	30
Aug-18	-	-	-		-	-	-	-	-	-	-	-
Sep-18		185,856	-		-	129,499	-	-	-	1,840	-	-
Average	55,258	138,024	18,694	2,241	39,200	96,171	13,214	156	527	1,366	210	30
	53,554				37,185				533			

2.3 ENERGY SCENARIO

Both electricity and thermal energy is used in different manufacturing processes. The overall energy use pattern in the unit is as follows:

- Electricity is supplied from two different sources:
    - From the Utility, Paschim Gujarat Vij Company Ltd. (PGVCL)
    - Captive backup DG sets for whole plant
- Thermal energy is used for following applications :
    - Coal for spray dryer & kiln through coal gasifier

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	TOE	% of total
Grid – Electricity	181.67	25.3	214	4.7
Thermal-Coal	537.32	74.7	4,330	95.3
Total	719.00	100	4,544	100

This is shown graphically in the figures below:

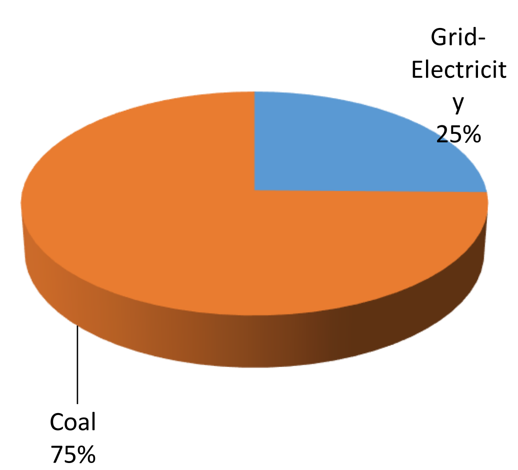

Figure 3 : Energy cost share

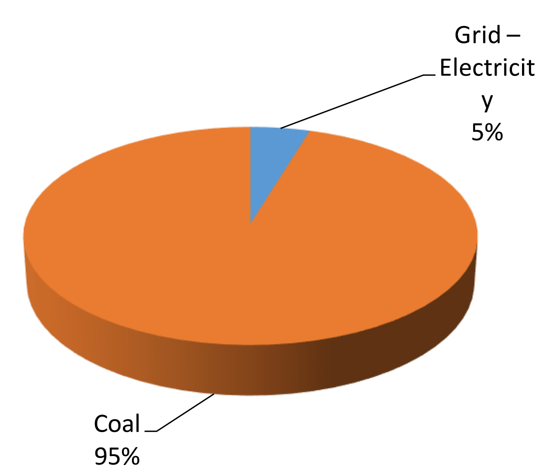

Figure 4 Energy use share

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 in DG sets when the grid power is not available. However, blackouts are infrequent, due to which the diesel consumption is minimal and records are not maintained.
- Electricity used in the utility and process accounts for the 25% of the energy cost and 5% of the overall energy consumption.
- Source of thermal energy is from combustion of coal & coal gas is used in kilns account for 75% of the total energy cost and 95% of overall energy consumption.

2.2.1 Analysis of Electricity Consumption

2.2.1.1 Supply from Utility

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

Table 8 : Details of Electricity Connection

Particulars	Description
Consumer Number	26895
Tariff Category	HTP-I
Contract Demand, kVA	600
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Tariff structure

Particulars	Tariff structure for Category HTP-1
Demand Charges (Rs./kVA)	
1st 500 kVA	150
2nd 500 kVA	260
Next 297	475
Energy Charges (Rs./kWh)	
Normal Hours	4.0
Peak Hours	0.45
Night Time	0.4
Fuel Surcharge (Rs./kWh)	1.63
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

2.2.1.2 *Month wise Electricity Consumption and Cost*

Month wise total electrical energy consumption is shown as under:

Table 10 : Electricity consumption & cost

Month	Units Consumed kWh	Total Electricity Cost Rs	Unit Cost Rs/kWh
Oct-17	2,31,248	16,80,607	7.27
Nov-17	1,96,284	14,54,891	7.41

Month	Units Consumed kWh	Total Electricity Cost Rs	Unit Cost Rs/kWh
Dec-17	2,29,504	16,71,890	7.28
Jan-18	2,46,708	17,92,182	7.26
Feb-18	2,54,428	18,25,366	7.17
Mar-18	2,26,112	16,39,311	7.25
Apr-18	2,57,140	18,47,645	7.19
May-18	2,38,808	17,18,016	7.19
Jun-18	2,47,904	17,89,225	7.22
Jul-18	2,20,340	15,98,453	7.25
Aug-18	53,680	4,56,674	8.51
Sep-18	86,468	6,93,217	8.02

Average electricity consumption is 207,385 kWh/month and cost is Rs 15.13 Lakh per month. The average cost of electricity is Rs. 7.42/kWh.

2.2.1.3 Analysis of month-wise electricity consumption and cost

The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

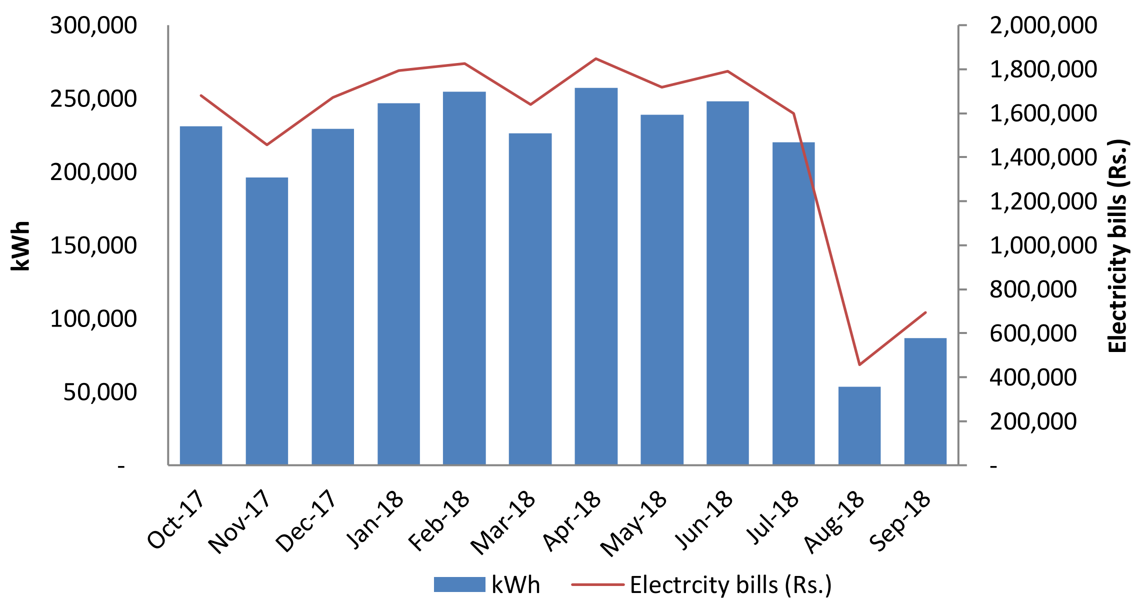

Figure 5: Month wise Variation in Electricity Consumption

Power Factor: Power factor as per electricity bills is shown below:

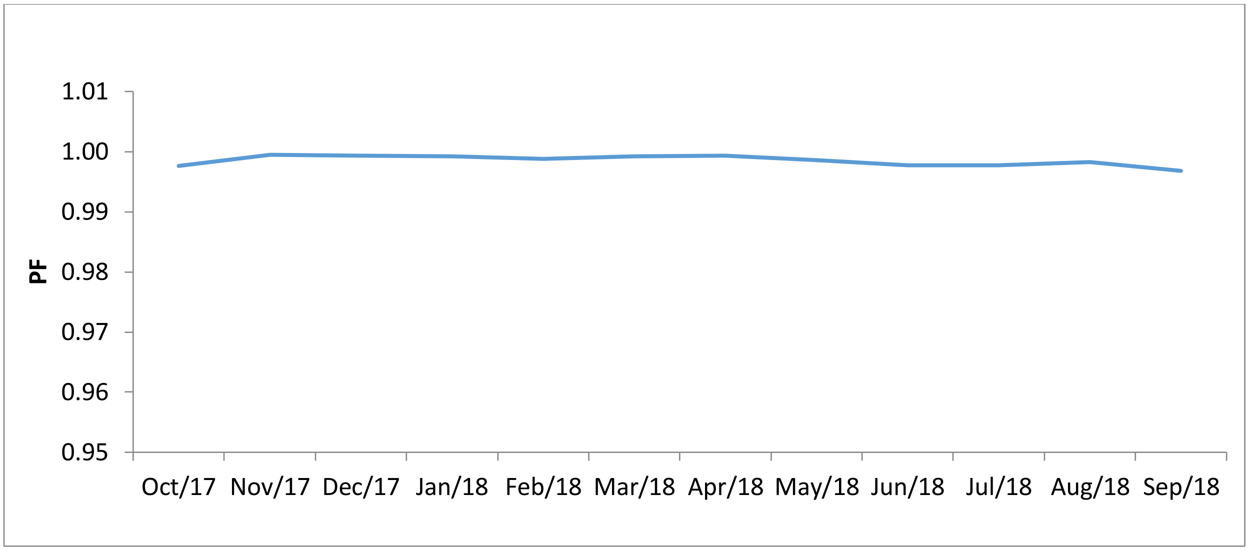

Figure 6 : Month wise variation in Power Factor

The utility bills reflect the power factor. A study was conducted by logging the electrical parameters of the main incomer using a power analyzer. The average power factor was found to be 0.997 with the minimum being 0.989 and the maximum being 1.00.

Maximum Demand: Maximum demand as reflected in the utility bill is 576 kVA from the bill analysis.

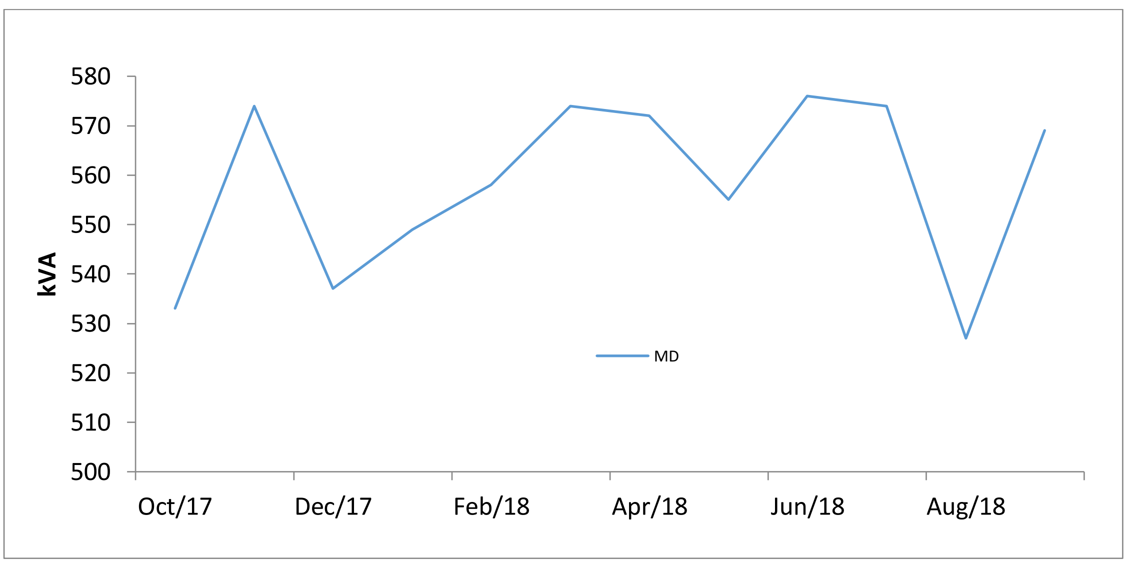

Figure 7 : Month wise variation in Maximum Demand

2.2.1.4 *Single Line Diagram*

Single line diagram of plant is shown in below figure:

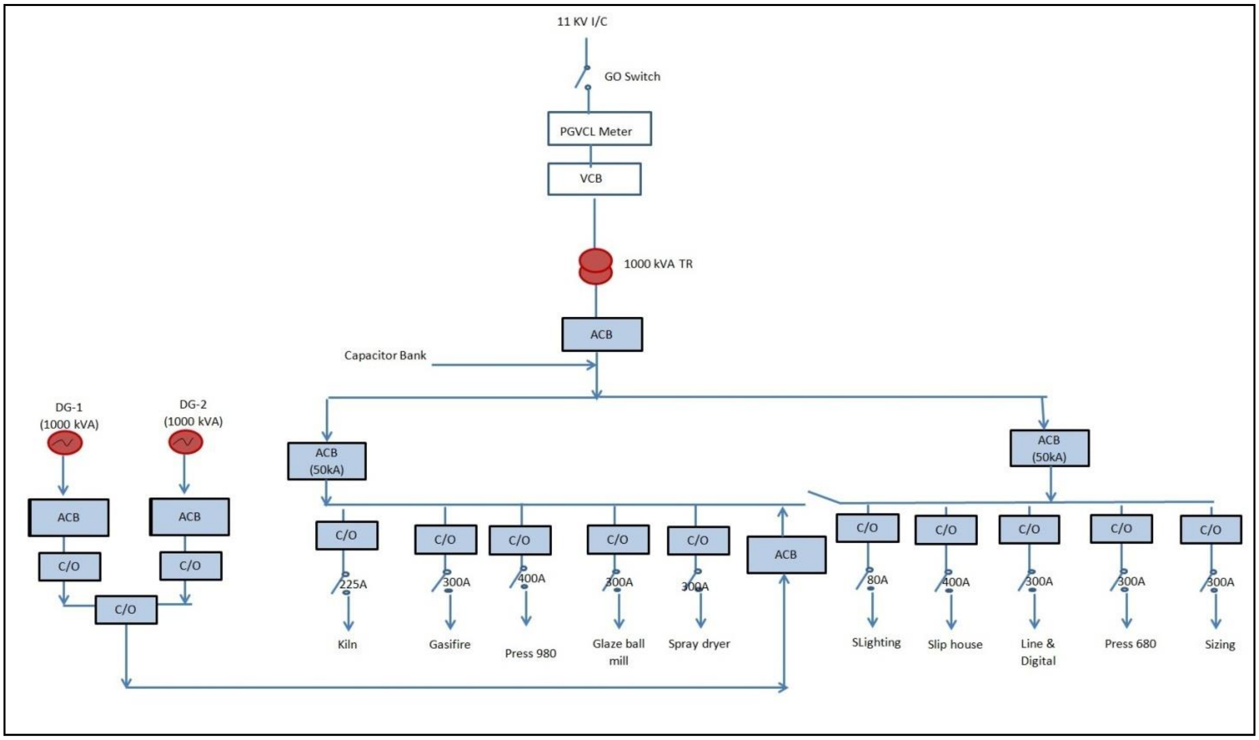

Figure 8: SLD of Electrical Load

2.2.1.5 *Electricity consumption areas*

The plant total connected load is 908.4 kW, which includes:

- The plant and machinery load is 858.09 kW
- The utility load (fan and lighting) is about 37 kW including the single phase load

Table 11 : Equipment wise connected load

Sl. No.	Equipment	Total capacity(kW)
1	Ball Mill section	172
2	Hot Air Generator (HAG	37
3	Spray dryer	60.4
4	Hydraulic press	98
5	Biscuit kiln	150
6	Glaze kiln	95
7	Glaze ball mills	70
8	Horizontal dryer	41
9	Sizing	78
10	Utilities	37
11	Lighting	13
	Total	908.4

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

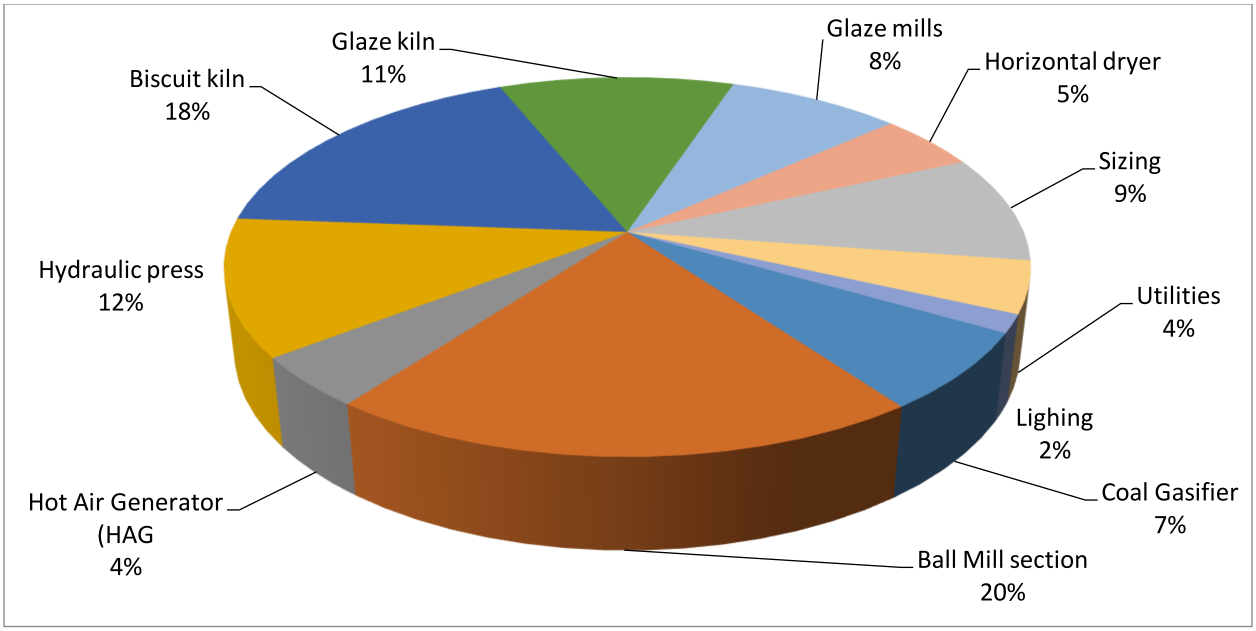

Figure 9 : Details of connected load

As shown in the figure, the maximum share of connected electrical load is for the Ball mill – 20 %, followed by biscuit kiln – 18% , hydraulic press – 12%, Glaze Kiln – 11% ,sizing-9%,Glaze ball mills – 8%, coal gasifier-7%, horizontal dryer-5%, hot air generator-4% .Utilities and lighting consists of 6 % of total connected electrical load.

2.2.1.6 Specific electricity consumption

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

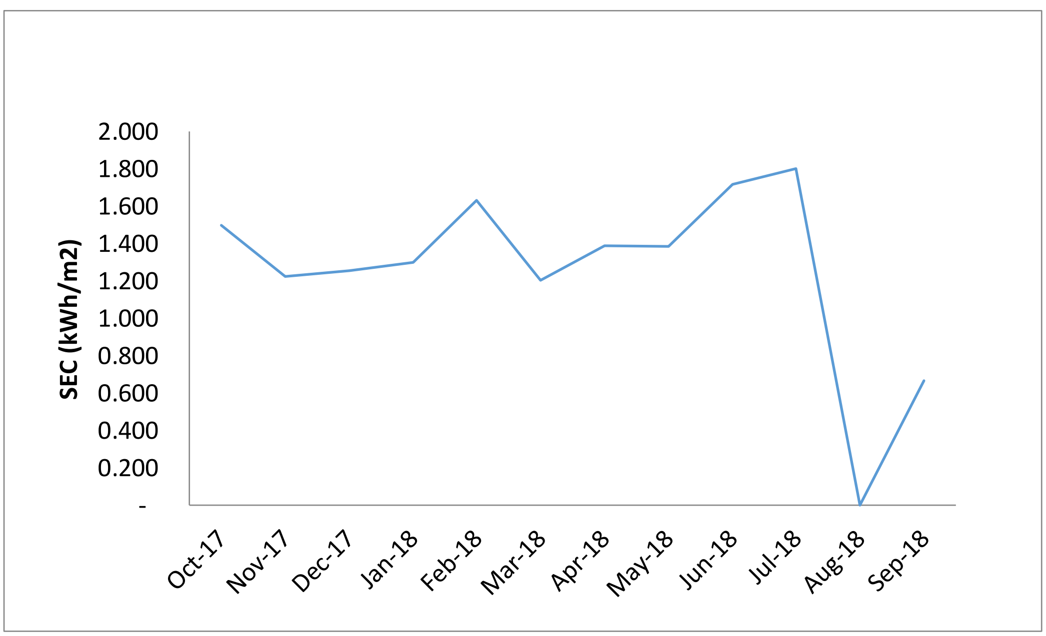

Figure 10 : Month wise variation in Specific Electricity Consumption

The month, Jun-18, Jul-18 and Sept-18 is outliers. Excluding this month, the maximum and minimum values are within ±20% of the average SEC of 1.256 kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in ball mill section, spray dryer section, press section, biscuits kiln, glaze kiln, utility like compressor, pumps etc.

2.2.2 Analysis of Thermal Consumption

2.2.2.1 Month wise Fuel Consumption and Cost

The thermal consumption areas are the hot air generator and the kilns. Coal is used as fuel for the hot air generator and coal gasifier to generate coal gas which in turn used in kiln as a fuel. Coal is purchased from local coal suppliers who in turn import coal from Indonesia. Annual fuel consumption and cost are summarized below:

Table 12 : Monthly fuel consumption and cost

Month	Coal Used	Coal cost
	MT	Rs./MT
Oct-17	605.22	38,81,000
Nov-17	373.225	19,25,000
Dec-17	749.55	50,04,000
Jan-18	925.17	65,34,000
Feb-18	858.72	59,02,000
Mar-18	917.41	65,84,000
Apr-18	890.53	61,45,000
May-18	875.65	62,21,000
Jun-18	793.04	54,43,000
Jul-18	392	26,73,690
Aug-18	Nil	-
Sep-18	501	34,19,758
Average	716	44,77,704

Observation:

- Kiln-1 is used for baking of biscuit (green tiles) whereas Kiln-2 is used for baking of glazed tiles.
- Coal is used in the coal gasifier to produce coal gas which is used to kiln – 1 and kiln 2.
- Average monthly coal consumption in coal gasifier is about 716 MT and average cost is Rs 9,000/MT.

2.2.2.2 Specific Fuel Consumption

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

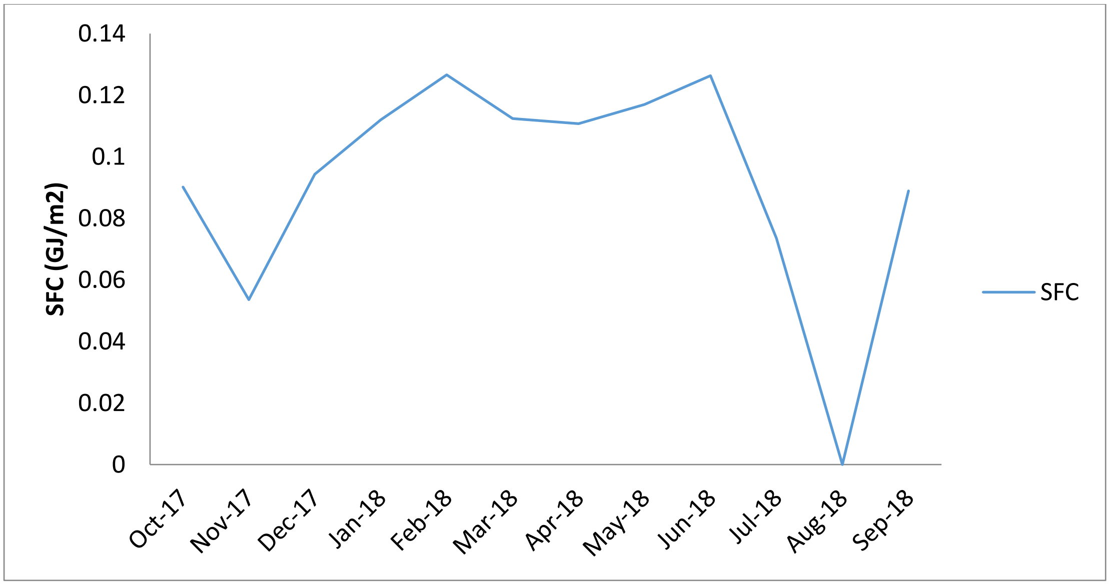

Figure 11 : Month wise variation in Specific Fuel Consumption

The average SFC is 0.092 GJ/m^2, i.e. 0.063 GJ/m^2 for the kilns and 0.156 GJ/m^2 for the hot air generator. Excluding the month of Nov-17, Jun-18, Jul-18 and Aug-18 (plant shutdown), the coal consumption varied between 0.053-0.126 GJ/m^2 and was within ±10% of the average value. This is because coal data is based on purchase and actual information on consumption is not being maintained. The SEC therefore does not follow the production.

For better quality information, sub-metering /data logging is required at hot air generator (HAG) and vertical dryers for monitoring thermal energy consumption.

2.2.3 Specific energy consumption

2.2.3.1 Based on data collected during EA

Specific energy 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	219.69
Power consumption	kW	287
Coal consumption	kg/h	815.42
Energy consumption	TOE/h	0.473
SEC of plant	TOE/m^2	0.0022

2.2.3.2 *Section wise 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	Coal	Electricity
	kg/t	kW/t
Ball mill		2.06
Agitator		0.489
HAG (Chain stoker)	179.6	1.68
Spray Dryer		3.17
Hydraulic Press- 980		12.17
Hydraulic Press- 680		8.11
Biscuit kiln	117.4	2.95
Glaze kiln	107.3	4.72
Sizing Section 1		5.13
Sizing Section 2		3.54

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

2.2.3.3 *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	24,88,624
Self-Generation from DG Set	kWh/y	0
Annual Total Electricity Consumption	kWh/y	24,88,624
Annual Thermal Energy Consumption (Imported Coal)	t/y	7,881
Annual Energy Consumption	TOE	4,544
Annual Energy Cost	Rs. Lakh	719
Annual production	m^2	17,84,888
	t	25,268
SEC; Electrical	kWh/m^2	1.39
	kWh/t	98
SEC; Thermal	GJ/m^2	0.101571
	GJ/t	7.17
SEC; Overall	TOE/m^2	0.0025
	TOE/t	0.18
SEC; Cost Based	$Rs./m^2$	40.3
	Rs./t	2,846

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

- Conversion Factors
  - Electricity from the Grid : 860 kcal/kWh
- GCV of Imported Coal : 6,681 kcal/kg

- CO_2 Conversion factor
    - Grid : 0.82 kg/kWh
    - Imported Coal : 2.116 t/t

2.2.3.4 *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	8.51
Cost of Coal	Rs./MT	6,829
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	17,84,888

2.4 WATER USAGE & DISTRIBUTION

Water usage and pumping efficiencies (including water receipt, storage, distribution, utilization etc.) pump specs, breakdown maintenance etc.

Water requirement is met by own bore-well from where it is extracted and stored in storage tank. From this storage 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 informed by unit.

Water distribution diagram is shown below.

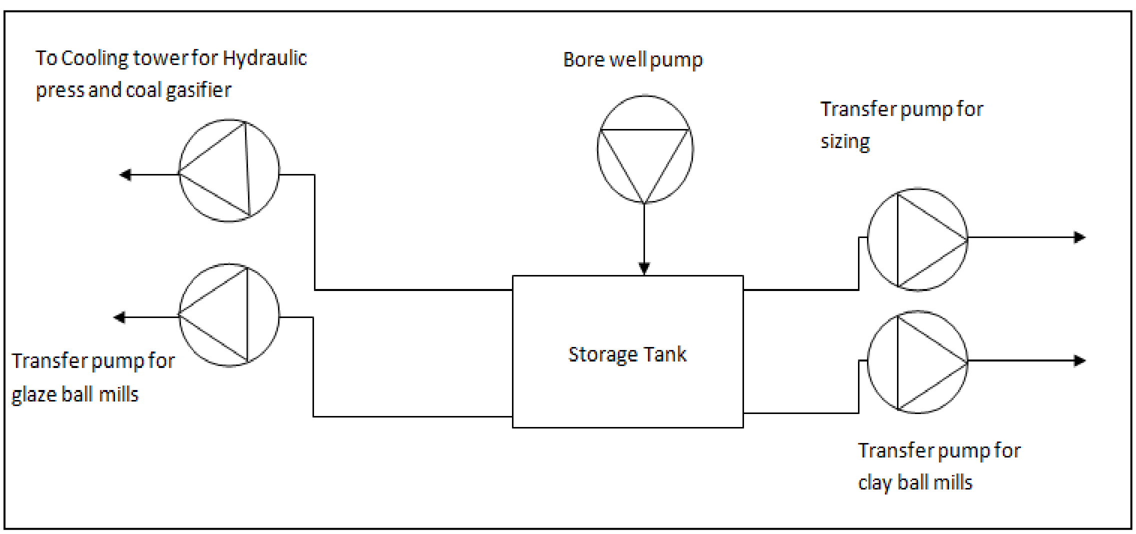

Figure 12: Water Distribution Diagram

Unit has own bore-well from where water is extracted and used in clay ball mills and glaze ball mills. Flow measurements could not be done for any of the pumps due to poor condition of pipe lines. Rating of bore well pump and cooling tower circulation pumps are given below:

Table 17: Press cooling water circulation pump details

Parameters	Unit	Bore well pump	Press Cooling pump 1	Press Cooling pump 2
Make	-	-		
Motor rating	kW	7.5	5.5	5.5
RPM	rpm	1480	1480	1480
Quantity	number	1	1	1

Water is extracted from own bore-well and have TDS of >1100 ppm and major water consuming areas like clay ball Mills and Glaze ball mills are being monitored.

3 CHAPTER – 3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Coal gas is used as a fuel in both the kilns to heat the ceramic tiles to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan). Cooling blower and rapid cooling blowers are used for cooling the tiles after combustion zone to get required tile quality and at the starting point, a smoke blower is installed which preheats the tiles before combustion zone of kiln. Biscuit Kiln consists of 150 kW electrical loads whereas Glaze Kiln has 95 kW of electrical load.

Biscuit Kiln includes 25 hp smoke blower, 2 hp combustion blowers, 15 hp for rapid cooling, 25 hp for Hot air blower, 15 hp for final cooling blowers. Biscuit kiln has a dryer at its first section used to dry tiles before entering in preheating zone. Dryer has one smoke blower of 25 hp and a booster blower of 25 hp.

Glaze Kiln includes 25 hp smoke blower, 7.5 hp combustion blowers, 7.5 hp for rapid cooling blower, 25 hp for final cooling blower, 25 hp for hot air blower & 15 hp final exhaust blower and remaining electrical load of kiln roller motors.

Table 18: Kiln Details

Sl. No	Parameter	Unit	Biscuit Kiln	Glaze Kiln
	Make		Local	Local
1	Kiln operating time	h	24	24
2	Fuel Consumption	scm/h	1,640	1,514
3	Number of burner to left	-	60	40
4	Number of burner to right	-	60	40
5	Cycle Time	Minutes	48	36
6	Pressure in firing zone	mm WC	45	48
7	Maximum temperature	°C	1,056	1,013
8	Waste Heat recovery option		Yes	Yes
9	Kiln Dimensions (Length X Width X Height)			
	Preheating Zone	m	27.3 x 0.8 x 3	25.2 x 0.8 x 3
	Firing Zone	m	27.3 x 0.8 x 3	23.1 x 0.8 x 3
	Rapid Cooling Zone	m	6.3 x 0.8 x 3	6.3x 0.8 x 3
	Indirect cooling Zone	m	12.6 x 0.8 x 3	12.6 x 0.8 x 3
	Final cooling zone	m	14.7 x 0.8 x 3	23.1 x 0.8 x 3

3.1.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, measurement of power consumption for all blowers, surface temperature of the kiln, flue gas analysis, air flow measurement of blowers and section wise temperature profile of both the kilns were done. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 19: FGA study of kilns

Parameter	Biscuit Kiln	Glaze Kiln
Oxygen Level measured in Flue Gas	7.2%	7.5%
Ambient Air Temperature	39 °C	39 °C
Exhaust Temperature of Flue Gas	110 °C	169 °C

From the above table, it is clear that the oxygen level measured in flue gas was high in Glaze Kiln. The inlet temperature of raw material in Biscuit Kiln was in the range of 39°C whereas in Glaze Kiln it was in the range of 39°C.

Surface temperature was high, throughout the surface of the kilns as shown in the table below:

Table 20: Surface temperature of kilns

Kiln Surface Temperatures (°C)	Biscuit Kiln	Glaze Kiln
Ambient Temperature	39	39
Pre-heating zone average surface temperature	53.2	43.1
Heating zone average surface temperature	75.8	62.9
Rapid cooling zone average surface temperature	66.2	63.4
Indirect cooling zone average surface temperature	59.2	72.6
Final cooling zone average surface temperature	56.8	57.2

The temperature profile of the kilns is shown below:

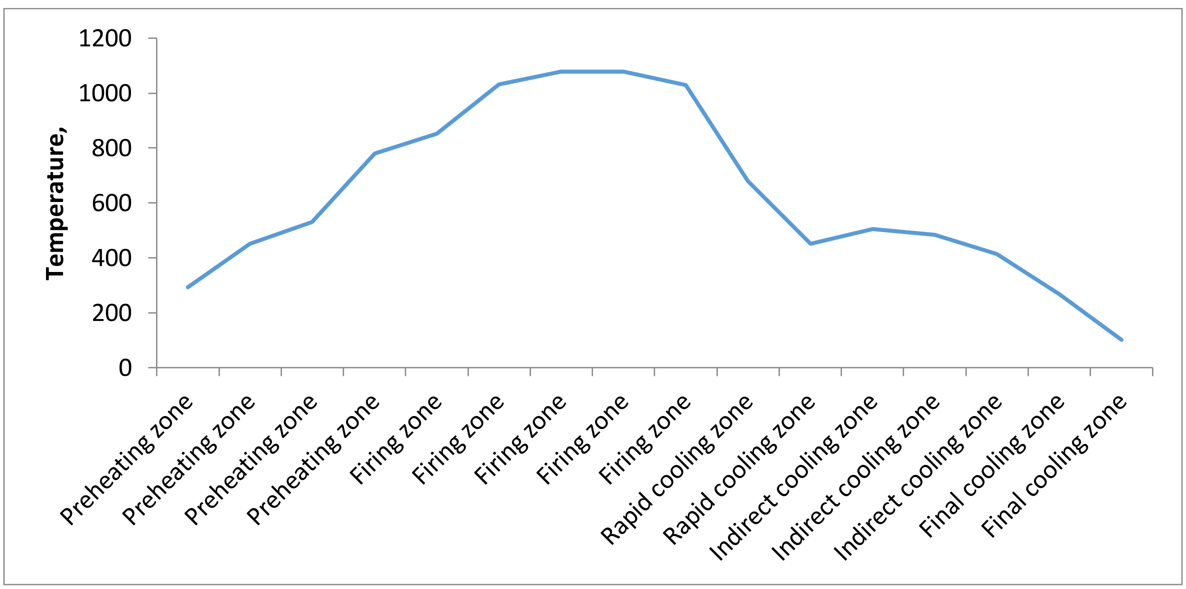

Figure 13: Temperature Profile of Kilns

Measured data of power for all blowers is given in below table, details are provided in Annex-4: Electrical Measurements.

Table 21: Power measurements of all blowers

Equipment	Biscuit Kiln Average Power (kW)	PF	Glaze Kiln Average Power (kW)	PF
Smoke Blower	3.3	0.999	3.38	0.998
Hot air Blower	2.58	0.999	6.77	0.994
Combustion Blower	2.15	0.932	1.84	0.981
Rapid Cooling Blower	1.25	0.958	1.57	0.981
Final Cooling Blower	1.92	0.976	2.67	0.993

3.1.3 OBSERVATIONS AND PERFORMANCE ASSESSMENT

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the Biscuit kiln is 44% and Glaze kiln is 41.4 %. Summary of all losses is shown in below figure:

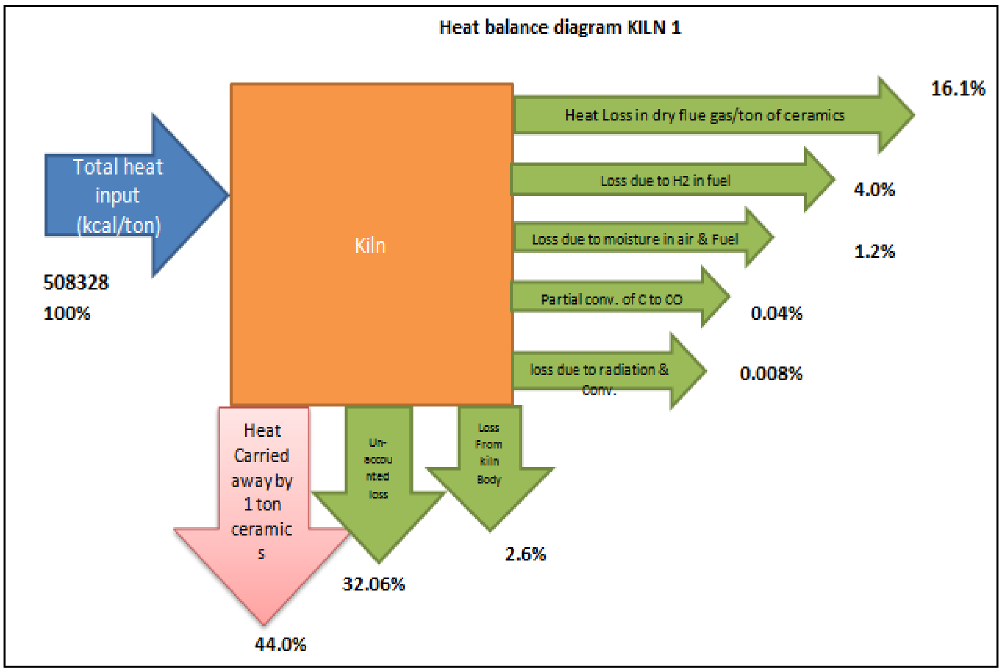

Figure 14: Heat Balance Diagram of Biscuit Kiln

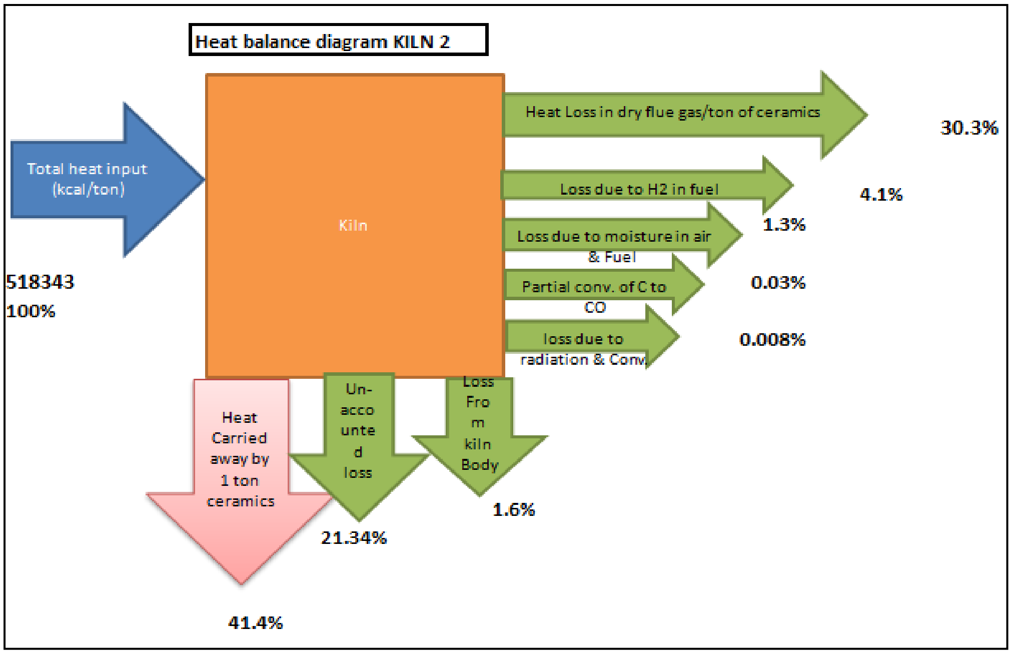

Figure 15: Heat Balance Diagram of Glaze Kiln

The unaccounted loss occurred in kiln -1 and kiln-2 includes heat gained by rollers, small openings at side of kiln causes loss in heat and Fan body are at higher temperature causing loss in heat Detailed calculation is included in Annexure - 5.

3.1.4 Energy Conservation Measures (ECM)

Energy conservation measures are described below:

3.1.4.1 Energy conservation measures (ECM) - ECM #1: Excess air control system in Biscuit kiln

Technology description

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of 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 process requires certain amount of excess air in addition to the theoretical air supplied. Excess air supplied needs to be maintained at optimum levels, as, too much excess air results in excessive heat loss through the flue gases whereas too little excess air results in in-complete combustion of fuel and formation of black colored smoke in flue gases.

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

A PID controller, if installed, measures 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) is regulated and subsequently proper temperature and optimum excess air for combustion is attained in the kiln.

Study and investigation

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

Recommended action

Separate blowers for Biscuit Kiln have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. For **Biscuit Kiln** oxygen level is 7.2% which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

Table 22: Cost benefit analysis for Excess Air control in Biscuit Kiln (ECM-1)

Parameters	Unit	Present	Proposed
Oxygen level in flue gas just before firing zone	%	7.2	5.0
Excess air percentage in flue gas	%	52.0	31.3
Dry flue gas loss	%	16%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	413	405
Average production in Kiln	t/h	3.8	3.8
Saving in specific fuel consumption	scm/h		32.50
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual fuel saving	scm/y		257
Fuel cost	Rs/scm		6,818
Annual fuel cost saving	Lakh Rs/y		9.1
Power saving in combustion blower			
Mass flow rate of air	t/h	18.42	15.91
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	4.2	3.6
Measured power of blower	kW	2.29	1.48
Total power saving	kW		0.81
Operating days per year	d/y		330
Operating hours per day	h/d		24
Annual energy saving	kWh/y	6,447	
Weighted electricity cost	Rs/kWh	7.42	
Annual energy cost saving	Lakh Rs/y	0.48	
Overall energy cost saving	Lakh Rs/y	9.59	
Estimated investment	Lakh Rs	18.48	

Parameters	Unit	Present Proposed
Payback period	Months	23
IRR	%	41
Discounted Payback period	Months	7.34

3.1.4.2 Energy conservation measures- ECM #2: Excess air control system in Glaze kiln

Technology description

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of 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 process requires certain amount of excess air in addition to the theoretical air supplied. Excess air supplied needs to be maintained at optimum levels, as, too much excess air results in excessive heat loss through the flue gases whereas too little excess air results in in-complete combustion of fuel and formation of black colored smoke in flue gases.

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

A PID controller, if installed, measures 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) is regulated and subsequently proper temperature and optimum excess air for combustion is attained in the kiln.

Study and investigation

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

Recommended action

Separate blowers for Glaze Kiln have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. For Glaze **Kiln** oxygen level is 7.5 % which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

Table 23: Cost benefit analysis for Excess Air Control in Kiln 2 (ECM-2)

Parameters	Unit	Present	Proposed
Oxygen level in flue gas just before firing zone	%	7.5	5.0
Excess air percentage in flue gas	%	56.0	31.3

Parameters	Unit	Present	Proposed
Dry flue gas loss	%	30	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	Kg of fuel/t	421	411
Average production in Kiln	t/h	3.4	3.4
Saving in specific fuel consumption	kg/h		35.89
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual fuel saving	t /y		284
Fuel cost	Rs/t		6,818
Annual fuel cost saving	Lakh Rs/y		10.9
Power saving in combustion blower			
Mass flow rate of air	t/h	17.46	14.69
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	4.0	3.3
Total pressure rise	Pa	2,412	2,412
Measured power of blower	kW	1.84	1.10
Total power saving	kW		0.74
Operating days per year	d/y		330
Operating hours per day	h/d		24
Annual energy saving	kWh/y	5,897	
Weighted electricity cost	Rs/kWh	7.42	
Annual energy cost saving	Lakh Rs/y	0.44	
Overall energy cost saving	Lakh Rs/y	11.34	
Estimated investment	Lakh Rs	18.48	
Payback period	Months	20	
IRR	%	32	
Discounted Payback period	Months	8.49	

3.1.4.3 Energy conservation measures (ECM) - ECM #3 Insulation in recuperator pipes of Biscuit Kiln

Technology description

A significant portion of the losses in a kiln occurs as radiation and convection loss from the combustion air carrying pipes. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of insulation should be provided on these pipes to maintain the skin temperature of the furnace at around 80^{o}C, so as to avoid heat loss due to radiation and convection.

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

Recuperator pipes is made by combination of insulation layers and cladding, with the objective of retaining the desired temperature of air inside the pipes and avoids losses from pipe walls

Study and investigation

There are 36 uninsulated pipes in recuperator in rapid cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 177°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

Recommended action

Recommended surface temperature of the pipe surface has to be reduced to within 80°C to reduce the heat loss due to radiation and convection and utilize the useful heat. The amount of heat lost through radiation and convection in each zone is given in the table below.

Table 24: Cost benefit analysis (ECM-3)

Parameter	Unit	Present	Proposed
No of un-insulated pipe in recuperator	#	36	36
Recuperator pipe size	mm	45	45
Pipe length	m	2	2
Total surface area	m^2	10.07	10.07
Average surface temperature	°C	177	80
Ambient air temperature	°C	35	35
Heat loss	$kCal/h.m^2$	2,428	551
Total heat loss	kCal/h	24,441	5,549
GCV of fuel	kCal/scm	1,231	1,231
Heat loss in terms of fuel	scm/h	19.9	4.5
Fuel saving	kg/h		4.0
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual fuel saving	t/y	31	
Fuel cost	Rs/t	6,818	
Annual fuel cost saving	Rs Lakh/y	2.14	
Estimated investment	Rs Lakh	0.660	
Payback period	Months	4	
IRR	%	243%	
Discounted Payback period	Months	2	

3.1.4.4 Energy conservation measures (ECM) - ECM #4 Insulation in Combustion air header pipe of Biscuit Kiln

Technology description

A significant portion of the losses in a kiln occurs as radiation and convection loss from the combustion air carrying pipes. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of insulation should be provided on these pipes to maintain the skin temperature of the furnace at around 80°C, so as to avoid heat loss due to radiation and convection.

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

Combustion air pipe header is made by combination of insulation layers and cladding, with the objective of retaining the desired temperature of air inside the pipes and avoids losses from pipe walls

Study and investigation

There are header pipe in rapid cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 90°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

Recommended action

Recommended surface temperature of the pipe surface has to be reduced to within 80°C to reduce the heat loss due to radiation and convection and utilize the useful heat. The amount of heat lost through radiation and convection in each zone is given in the table below

Table 25: Cost benefit analysis (ECM-4)

Parameter	Unit	Present	Proposed
Combustion air main header (bottom)	#	1	1
Combustion air main header (bottom) pipe size	m	5	5
Length of combustion pipe header	m	6	6
Total surface area	m^2	188.50	188.50
Average surface temperature	°C	95	80
Ambient air temperature	°C	35	35
Heat loss	$kCal/h/m^2$	780	551
Total heat loss	kCal/h	147,027	103,908
GCV of coal gas	$kCal/sm^3$	1,231	1,231
Heat loss in terms of fuel (coal gas) in Kiln	sm^3/h	119.5	84.4
Gas to coal ratio of Gasifier	sm^3/kg	3.87	3.87
Heat loss in terms of coal in gasifier	kg/h	30.9	21.8
Fuel saving	kg/h	9.1	
Operating hours per day	h/d	24	
Annual operating days	d/y	330	
Annual fuel saving	t/y	72	
Fuel cost	Rs/t	6,818	
Annual fuel cost saving	Rs Lakh/y	5	
Estimated investment	Rs Lakh	11.88	
Payback period	Months	29	
IRR	%	20%	
Discounted payback period	Months	10.7	

3.1.4.5 Energy conservation measures (ECM) - ECM # 5: Installation of new recuperator in kiln – 1 & kiln - 2

Technology description

The flue gas from firing zone of kiln are at high temperature of around 800-900°C. This will cause loss in heat. To recover this heat, combustion air is preheated in a recuperator installed adjacent to firing zone of kiln. The recuperator is a type of heat exchanger which is used to preheat combustion air by the exiting flue gas.

Study and investigation

During field measurement, it was found that in both the kilns, the combustion air from the recuperator is at 65°C and recuperator size is less. This will cause in loss in thermal energy and increase in coal consumption in coal gasifier.

Recommended action

It is recommended to replace existing recuperator with new recuperator of large size. This will increase combustion air temperature upto 180 – 200 °C and reduce in fuel consumption. The cost benefit analysis is given below:

Table 26 : Cost benefit analysis for new recuperator in kiln 1 & 2

Parameters	UoM	Present	Proposed	Present	Proposed
Equipment	#	Kiln-1		Kiln-2	
Actual volume of supplied air	kg/h	18,420.2	18,420.2	17,458.0	17,458.0
Combustion air temperature	°C	65.0	150.0	54.0	150.0
Ambient air temperature	°C	25.0	25.0	25.0	25.0
Specific heat of air	kCal/kg °C	0.24	0.24	0.24	0.24
GCV of Fuel (coal gas)	kCal/SCM	1,231.0	1,231.0	1,231.0	1,231.0
Additional fuel required	SCM/h		305.3		326.8
Operating hours per day	h/d	24.0	24.0	24.0	24.0
Annual operating days	d/y	300.0	300.0	300.0	300.0
Annual fuel saving in Kiln	SCM/y		2,197,850.7		2,352,617.7
Gas to coal ratio of Gasifier	SCM/kg		3.9		3.9
Reduction in fuel (coal) in gasifier	t/y		568.1		608.1
Annual coal savings	t/y	1,176.2			
Fuel Cost	Rs/t	6,818.1			
Annual fuel cost saving	Lakh Rs/y	106.8			
Estimated investment	Lakh Rs	39.6			
Payback period	months	4			
IRR	%	207			
Discounted payback period	Months	1.75			

3.2 Coal Gasifier

3.2.1 Specifications

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

Table 27: Specifications of coal gasifier

Particular	UOM	Value
Make		Mach tech Pvt Ltd.
Coal consumption	t/d	19.7
Water consumption	l/d	1500
FD Blower	hp	2 x 15
Cooling water pump	hp	2 x 15

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Coal input to gasifier
- Volume of gas produced by gasifier
- Power measurement of ID blower

The coal input to the gasifier was 815 kg/h. The power consumption for ID was 2.7 kW.

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 0.25 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm coal gas in plant which is 0.012 kW/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed.

3.3 Hot Air Generator & Spray Dryer

3.3.1 Specifications

Bubbling bed type hot air generator is used for evaporating water from slurry which is coming from ball mill. Spray dryer is the heat exchanging unit for power generation from slurry by taking heat from hot air of HAG. Specifications of HAG are given below:

Table 28: Specifications of Hot air generator (HAG)

Particular	Units	Chain stoker
Fuel type		Coal
Air handling capacity	m^3/sec	2
Fuel consumption	kg/sec	2.5
Flue gas temperature	˚C	640 °C
FD Blower	kW	1 x 22.3
PA Fan	kW	1 x 7.46

The specification of spray dryer is given below:

Table 29: Specifications of spray dryer

Particular	Units	Value
Powder generation capacity	MT	-
Inlet slurry moisture	%	31
Outlet powder moisture	%	6
Hydraulic pump	kW	2x14.9

3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Hot air generators & Spray dryer
    - Power consumption of FD and ID fan
    - Air flow measurement of FD fan , PA fan 1 & 2
    - Power consumption of PA fan 1 & 2

Details of measurements on HAG are given below:

Table 30: Field measurement at site

Particular	Units	
Air velocity at FD fan suction	m/s	11.92
Suction area	m^2	0.17
Exit temperature of air	°C	740°C
Surface temperature	°C	92.5°C
Average power consumption-FD Blower	kW	12.93
Average power consumption-ID Fan	kW	43.25
Average power consumption-HAG PA fan	kW	7.46

All blowers are operating with VFDs.

3.3.3 Observations and performance assessment

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

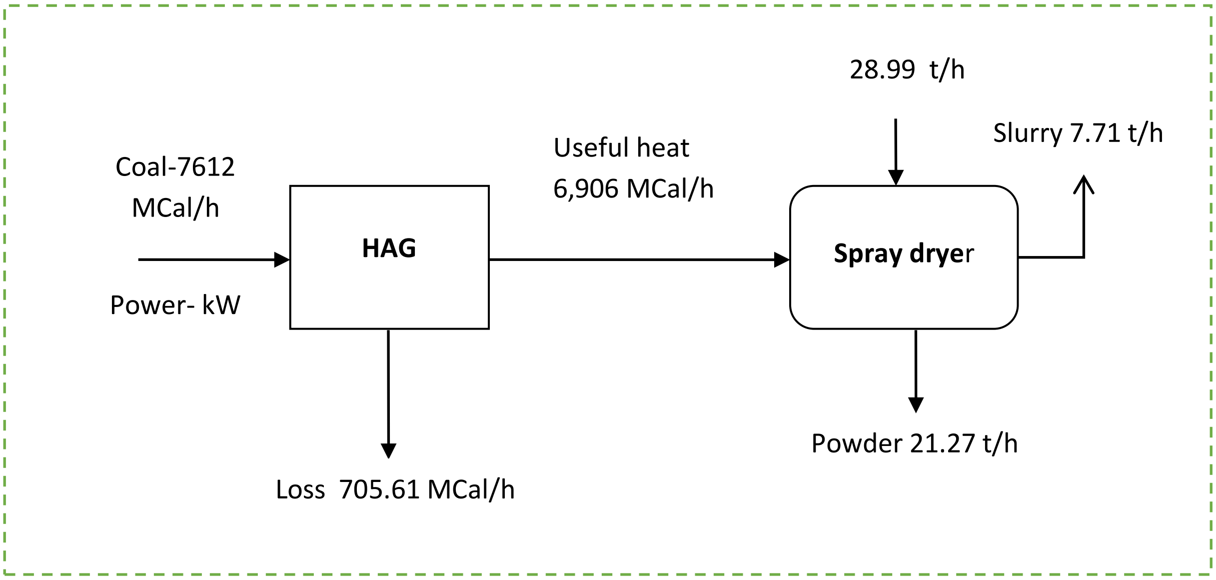

Figure 16: Energy and mass balance of Chain Stoker HAG and New spray dryer

Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for evaporating one kg water from slurry) and specific thermal energy measure (fuel used for evaporating 1 kg of water in slurry). Based on observations during DEA, the chain stoker HAG corresponding values are 1.68 kW/ton and 179.6 of coal/ton.

Performance of spray dryer measures in terms of specific electricity consumption (electrical energy used for delivering one kg of powder). Based on observations during DEA, the specific electricity consumption of spray dryer was 3.17 kW/ton. Since blowers are VFD controlled and operation is optimized.

3.3.4 ENERGY CONSERVATION MEASURES (ECM)

3.3.4.1 Energy conservation measures (ECM) - ECM # 6: Retrofit of VFD in SFD fan in Hot air generator (HAG)

Technology description

VFD is for AC motor speed control which changes the output voltage as well as frequency and for motor starting by just changing the output voltage.

Study and investigation

During field measurement, it was found that the FD fan of HAG was running continuously which results in excess power consumption.

Recommended action

It is recommended to install VFD for SFD fan in HAG section.

Table 31: Cost benefit analysis of retrofit of VFD in cooling tower pump (ECM 6)

Parameter	UoM	Present	Proposed
		SFD fan	
Rated power	kW	7.5	7.5

Parameter	UoM	Present	Proposed
Measured power	kW	6.20	5.6
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	49,104	44,194
Annual energy savings	kWh/y		4,910
Unit cost of electricity	Rs/kWh		7.42
Annual monetary saving	Lakh Rs/y		0.36
Estimated Investment	Lakh Rs	0.30	
Payback period	Months	10	
IRR	%	91	
Discounted payback period	Months	3.79	

4 CHAPTER – 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 Clay Ball Mills

4.1.1 Specifications

Clay ball mills produce slurry by mixing clay, water and chemicals SMS and STPP. Clay ball mills take 65 minutes for slurry preparation. The specifications of clay ball mills and its accessories are given below:

Table 32: Specifications of ball mills

Particular	Units	Value
Numbers of clay ball mills	#	1
Capacity of each clay ball mill	t/batch	40
Water consumption in each clay ball mill	t/batch	18
SMS (chemical consumption)	kg/batch	100
Water TDS	ppm	1500
Nos. of batch per day		12
Power consumption	kW	143.7

4.1.2 Field Measurement and Analysis

During DEA, the following measurements were done:

- Power consumption of all clay ball mills
- Mass consumption as per Table 32.

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

Table 33: Average power consumption and PF of ball mills

Equipment	Average Power (kW)	PF
Ball Mill#1	143.7	0.94

4.1.3 Observations and Performance Assessment

Mass balance of Ball mills based on measurements for Clay ball Mill is given below:

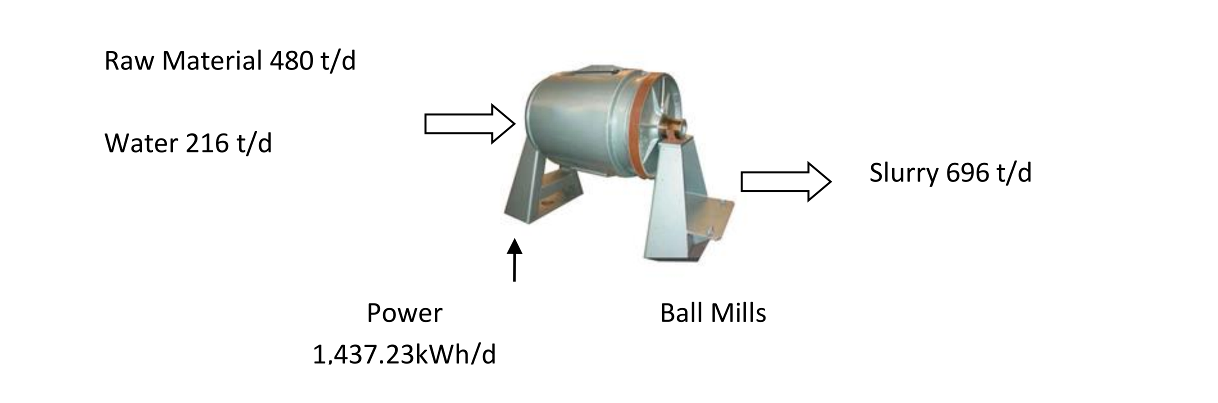

Figure 17: Energy and mass balance of Ball Mills

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 ball mills was 2.06 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)

Detailed ECM is explained in below section:

4.1.4.1 Energy conservation measures (ECM) - ECM # 7 –Optimized Resource Consumption in Clay Section

Technology description

It was observed that the TDS of water used in clay section is 1,100 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 400ppm) 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 34: Saving and cost benefit by [ECM-7]

Particulars	Unit	Present	Proposed
TDS of Water	ppm	1500	400
Assumption : Water Saving			15%
Assumption : Electricity Saving			3%
Assumption : Fuel Saving			30%
Assumption : Chemical Saving			30%
Water used per batch	m^3	18.00	15.30
Water saving	m^3		2.70
Electricity used per batch	kWh	144	139
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kcal/kg	5,495	5,495
Eff. Of HAG	%	85%	85%
Coal saving per batch	kg		356
Chemical saving per batch			

Particulars	Unit	Present	Proposed
SMS	kg	100	70
STPP		70	49
Per Unit Cost			
Water	Rs./m^3	5.00	5.00
Electricity	Rs/kWh	7.42	7.42
Coal	Rs/kg	6.82	6.82
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		3,194
Total batches per day	#	12	12
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		10,692.0
Electricity	kWh/y		17,074.30
Coal	t/y		1,407.95
Chemical	kg/y		2,01,960.00
Annual cost savings	Lakh Rs/y		194.62
Operating cost- Water Treatment	Rs/m^3		20.00
	Lakh Rs/y		12.12
Net monetary savings	Lakh Rs/y		183
Estimated investment	Lakh Rs		39.60
Payback period	Months		2.60
IRR	%	343	
Discounted Payback period	Months	1.04	

4.1.4.2 Energy conservation measures (ECM) - ECM # 8: Timer Controller for clay ball mill

Technology description

Clay ball mill are used to grind and mixing of raw material to form slurry. Slurry is formed after a particular time of missing and grinding in clay ball mill. Most of the time, clay ball mill runs even slurry is prepared. So, A timer-based control can help save energy.

Study and investigation

It was observed that clay ball mill running more as their batch time. This will cause in energy loss as well as quality of slurry is reduce.

Recommended action

It is recommended to install timer based control for clay ball mill to save energy. Timing of clay ball mill can be decided based on requirement and configuration. By installing, there will reduce energy consumption by 5%. The cost benefit analysis for this project is given below:

Table 35: Cost benefit analysis for Stirrer Time Controller [ECM-8]

Particulars	Unit	Present	Proposed
Rated power of clay ball mill	kW	160	160

Particulars	Unit	Present	Proposed
Batch of clay ball mill	Min	50	50
Running hours of clay ball mill	h/d	10	
Operating power of stirrer motor	kW	143.7	143.7
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	474,286.1	450,571.8
Annual energy saving	kWh/y		23,714
Cost of Electricity	Rs./kWh		7.42
Annual energy cost saving	Lakh Rs./y		1.8
Estimated investment	Lakh Rs.		0.6
Payback Period	Months	4	
IRR	%	238%	
Discounted payback period	Months	1.5	

Note: Using timer controller, the unnecessary running of clay ball mill is reduced as the running time of clay ball mill can be controlled automatically. There is no change in batch time in a day of clay ball mill.

4.2 Hydraulic Presses

4.2.1 Specifications

There are 2 hydraulic presses. Hydraulic presses give shape for powder that is coming from spray dryer in tiles form by pressing powder with high pressure. Hydraulic oil gets heated when pressed so that it is required to be cooled in heat exchanger where water circulates as cold media. The specifications of hydraulic presses and its accessories are given below:

Table 36: Specifications of hydraulic press

Particular	Units	Sacme Press 680	Sacme Press 980
Cycle (stock) per minute	N/m	8.6	9.6
Nos. of tiles per stock		2	3
Tile size	mm × mm	250 x 600	250 x 600
Tile thickness	mm	7.5	7.5
Tiles weight	kg	1.6	1.6
Power rating	kW	37	55
Water Circulation Pump	#	1	1

4.2.2 Field Measurement and Analysis

During DEA, the following measurements were done:

- Power consumption of hydraulic presses and water circulation pumps
- Count of tiles processed as per above Table 36.

Average power consumption of press 680 was 32.45 kW (PF 0.71) and Press 980 was 48.71 kW (PF 0.81) during DEA. Water circulation pumps were consuming power as 4.07 KW (PF 0.83).

4.2.3 Observation and Performance Assessment

Both circulation pumps operates 24 hours in a day while press has frequent shut down, however it is not advisable to regulate pump based on oil temperature as the temperature will suddenly rise if circulation pump is stopped.

Performances of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of presses was 20.3 kW/ ton.

4.3 Agitator

4.3.1 Specifications

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

Table 37: Specifications of agitators

Particular	Units	Value
Numbers of agitators in tank	#	9
Capacity of each agitator motor	kW	2.2
Number of motors	#	9

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 38: Power consumption and P.F. of agitator motors

Equipment	kW	PF
Agitator Stirrer motor-1	2.17	0.83
Agitator Stirrer motor-2	2.16	0.76
Agitator Stirrer motor-3	2.14	0.78
Agitator Stirrer motor-4	2.18	0.82
Agitator Stirrer motor-5	2.17	0.79
Agitator Stirrer motor-6	2.19	0.78
Agitator Stirrer motor-7	2.18	0.81
Final tank stirrer 1	2.16	0.84
Final tank stirrer 2	2.21	0.81

4.3.3 Observations and Performance Assessment

Based on measurement it can be seen that power factor of agitator motor is in the range of 0.75-0.85.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry). Based on observations during DEA, the specific energy consumption of agitator motors were 0.337 kW/ton.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 Energy conservation measures (ECM) - ECM #9: Timer Controller for stirrer motor

Technology description

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

Study and investigation

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

Recommended action

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

Table 39: Cost benefit analysis for Stirrer Time Controller [ECM-9]

Particulars	Unit	Present	Proposed
No of agitator stirrer	Nos.	7	7
No of agitator stirrer running	Nos.	7	7
Rated power of agitator stirrer motor	kW	2.2	2.2
Running of each stirrer motor	h/d	18	12
Operating power of stirrer motor	kW	3.16	3.2
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	1,31,393	87,895
Annual energy saving	kWh/y		43,798
Cost of Electricity	Rs./kWh		7.42
Annual energy cost saving	Lakh Rs./y	3.25	
Estimated investment	Lakh Rs.	0.55	
Payback Period	Months	2	
IRR	%	436%	
Discounted payback period	Months	0.82	

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 40: Specifications of glazing machine

Particular	Units	Glaze ball mill
Numbers of glazing mills	Nos.	6
Capacity of glaze ball mill 1	Ton/batch	2.3
Capacity of glaze ball mill 2	Ton/batch	2.3
Capacity of glaze ball mill 3	Ton/batch	2
Capacity of glaze ball mill 4	Ton/batch	2
Capacity of glaze ball mill 5	Ton/batch	1.2
Capacity of glaze ball mill 6	Ton/batch	0.5
Power consumption of mill 1	kW	22
Power consumption of mill 2	kW	22
Power consumption of mill 3	kW	15
Power consumption of mill 4	kW	15
Power consumption of mill 5	kW	3.7
Power consumption of mill 6	kW	3.7

4.4.2 Field Measurement and Analysis

During DEA, the following measurements were done:

- Power consumption of four glaze ball mills which were in operation.
- Mass consumption (t/batch) is as per Table 40.

Power consumption and P.F. of all glaze ball mills are given in below table:

Table 41: Power consumption and P.F. of glaze ball mills

Equipment	kW	PF
Glaze ball mill 1	38.3	0.69

4.4.3 Observations and Performance Assessment

Performance of glaze ball mill can be measured in terms of specific energy consumption (power consumed for glazing 1 ton of tiles). Based on observations during DEA, the specific energy consumption of glaze ball mills were 11.13kW/ton.

4.5 Sizing

4.5.1 Specifications

There were 2 sizing lines; each holding two sizing machines each comprising many grinders along with dust collector blower. The specifications of sizing machines are given below:

Table 42: Specifications of sizing machine

Particular	Units	New sizing
Numbers of sizing machines	Nos.	2
Sizing Machine 1	kW	49
Sizing Machine 2	kW	49
Sizing line – Conveyors	kW	3.74

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of each sizing machines
- Tile production in sizing section is 3.43 t/h.

Average power consumption and power factor (PF) from sizing machines are tabulated below:

Table 43 : Measured Parameters of sizing machine

Equipment	Unit	Value	PF
Average Power (M/c#1)	kW	17.64	0.6
Average Power (M/c#2)	kW	12.18	0.53

4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were:

Table 44 : SEC of sizing machine

Equipment	Unit	Value
Sizing Machine # 1	kW/t	5.13
Sizing Machine # 2	kW/t	3.54

4.6 Air Compressors

4.6.1 Specifications

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

Table 45: Specifications of compressors

Particular	Units	Air compressor (Kaeser)	ELGI compressor (Standby)
Power rating	kW	30	22
Maximum pressure	Bar (a)	8	8
Rated Capacity	m^3/min	-	3.96

All compressors have a common receiver.

4.6.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

- Power consumption of all compressor
- Loading and unloading time

Average power consumption and loading/unloading of the compressors is given below:

Table 46: Measured parameters of Compressors

Equipment	Average Power (kW)	PF	% of time on load	Air flow rate (m^3/min)
Kaeser Compressor	20.6	0.7	25	5.14

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, it was observed that operating pressure was higher in both the compressors which can be reduced as per requirement. VFD installation is recommended for Kaeser compressor to avoid power consumption during unloading.

4.6.4 ENERGY CONSERVATION MEASURES (ECM)

The energy conservation measures recommended are:

4.6.4.1 Energy conservation measures (ECM) - ECM #10: Operational pressure optimization in compressor

Technology description

Compressed air is one of the most costly utilities for any production process. In ceramic industry, compressors are used for press, sizing, and digital printing. For the purpose of cleaning, very high pressure compressed air is not necessary. Compressed air is also used for operation of pneumatic valves to different equipment's used in ceramic process like press, kiln, spray dryer etc.

Study and investigation

It was observed during the energy audit that the cut-in pressure was 5.6 kg/cm^2 and cut-off pressure was 7 kg/cm^2. Both compressors were running in unload/load condition.

Recommended action

As very high pressure compressed air is not necessary in the process area. it is recommended that the existing cut-out pressure setting of 7 kg/cm^2 be lowered to 6 kg/cm^2 which will reduce the energy consumption by 6% (approx). The cost benefit analysis is given in the table below:

Table 47: Cost benefit analysis (ECM-10)

Parameter	Unit	Present	Proposed
		For compressor	
Operating pressure required	kg/cm^2	4.5	4.5
Compressor loading pressure	kg/cm^2	5.6	5
Compressor unloading pressure	kg/cm^2	7	6

Parameter	Unit	Present	Proposed
Reduction in pressure	kg/cm²	-	1
% of energy saving	%	-	6%
Average load	kW	20.59	19.36
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	1,63,083	1,53,298
Annual energy savings	kWh/y		9,785
Unit cost of electricity	Rs/kWh		7.42
Annual monetary saving	Lakh Rs/y		0.70
Estimated Investment	Lakh Rs		Nil
Payback period	Months		Nil
IRR	%		Nil
Discounted Payback period	Months		Nil

Note: By reducing compressor unloading pressure by 1 kg/cm^2, if the unloading percentage time will be greater than 30%, it will recommend to retrofit the compressor with variable frequency drive (VFD) of same motor power. By implemented this, the power consumption will reduce.

4.7 Water Pumping System

4.7.1 Specifications

Pumping system comprises four transfer pumps as shown in Figure 12.

4.7.2 Field Measurement and Analysis

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

- Power consumption of bore well pump and hydraulic press heat exchanger circulating water pumps
- Flow measurements for same pump.
- Other pumps are having smaller size and internal corrosion problems

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

Table 48: Measured parameters of pump

Particulars	Unit	Bore well Pump	Press Pump 1	Press Pump 2
Flow	m^3/h	28.6	25.9	32.37
Total Head	m	45	20	20
Actual power consumption	kW	8.3	4.1	4.6
Power factor		0.89	0.83	0.72

4.7.3 Energy Conservation Measures (ECM)

4.7.3.1 Energy conservation measures (ECM) - ECM #11: Replacement of inefficient pumps with efficient pump

Technology description

The bore-well & press pumps are running at lower efficiency and are recommended to be replaced with new high efficiency pumps.

Study and investigation

The bore-well pump is running throughout the day as per requirement. Pump is operating for about 20 hours/day to meet the water requirement.

Recommended action

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

Table 49: Replace bore-well pump by energy efficient pump [ECM-11]

Particulars	Units	Bore well Pump		CT Pump-1(Press)		CT Pump-2(Press)	
Design Parameters		Present	Proposed	Present	Proposed	Present	Proposed
Pump Efficiency			75		75		75
Motor I/P Power	kW	7.5	6.28	5.5	2.55	5.5	3.19
Motor Efficiency	%	85	89.6	85	88.6	85.00	88.6
Overall Efficiency	%						
VFD	Y/N	N	N	N	N	N	N
Measured Parameters							
Flow rate Q	m3/h	28.7	28.7	25.9	25.9	32.4	32.4
Suction Pressure	kg/cm2	0.0	0.0	0.0	0.0	0.00	0.0
Discharge Pressure	kg/cm2	4.50	4.5	2.00	2.0	2.0	2.0
Motor Input Power	kW	8.3		4.1		4.6	2.66
Saving Assessment							
Flow rate Q	m^3/s	0.00796	0.00796	0.00720	0.00720	0.00899	0.00899
Total head developed	m	45.0	45.0	20.0	20.0	20.0	20.0
Liquid horse power	kW	3.5	3.5	1.4	1.4	1.8	1.8
Motor Input power	kW	8.3	5.23	4.1	2.13	4.6	2.66
Nearest standard motor size	kW		5.5		4.0		4.00
Motor Loading	%	110.7	114.1	74.0	63.8	82.7	79.7
Overall system efficiency	%	42.4	67.2	34.7	66.5	38.8	66.5
Pump efficiency	%	49.8	75.0	40.8	75.0	45.6	75.0
Average working hours	h/d	20.0	20.0	20.0	20.0	20.0	20.0
Annual working days	d/y	330.0	330.0	330.0	330.0	330.0	330.0
Annual energy consumption	kWh/y	54,780	34,525	26,862	14,033	30,030	17,525
Annual energy saving	kWh/y	-	20,255	-	12,829	-	12,505
Percentage of energy	%	-	37.0	-	47.8	-	41.6

Particulars	Units	Bore well Pump		CT Pump-1(Press)		CT Pump-2(Press)	
saving							
Estimated investment	Rs Lakh	-	0.924	-	0.792	-	0.792
Total annual energy saving	kWh/y	45,589					
Cost of Electricity	Rs./kWh	7.4					
Total annual monetary saving	Rs Lakh/y	3.38					
Total investment	Rs Lakhs	2.51					
Simple payback period	Month	9					
IRR	%	266%					
Discounted Payback Period	Months	1					

4.8 Lighting System

4.8.1 Specifications

The plant's lighting system includes:

Table 50: Specifications of lighting load

Particular	Units	T-8	T-12	CFL	CFL	MH	AC
Power consumption per fixture	W	36	40	65	85	250	
Numbers of fixtures	#	145	5	3	4	2	6

4.8.2 Field measurement and analysis

During DEA, the following measurements were done by :

- Recording Inventory
- Recording Lux Levels

Measured values are summarized below:

Table 51: Lux measurement at site

Particular	Measured Value Lumen/m²	Particular	Measured Value Lumen/m²
Office	180	Ball mill and agitators	83
Kiln panel	110	HAG and spray dryer new	80
Kiln area	90	Glaze line	112
Sizing Machine	90	Inventory	90

4.8.3 Observations and performance assessment

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

4.8.4 Energy conservation measures (ECM)

4.8.4.1 Energy conservation measures (ECM) - ECM #12: Replacement of Inefficient light with EE LIGHTS

Technology description

Replacing conventional lamps with LED lights helps in reducing the power consumption and also results in higher illumination (lux) levels for the same power consumption.

Study and investigation

Most of the installed luminaries are of conventional type.

Recommended action

It is recommended to replace the above mentioned light fixtures with energy efficient LED lamps which shall help reduce present lighting energy consumption. The cost benefit analysis is given below:

Table 52 : cost benefit analysis (ECM 12)

Parameter	Unit	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Type of fixture		FTL T8	LED tube	FTL T12	LED tube	CFL (65 W)	LED	CFL (85 W)	LED (36 W)	MH flood light	LED
Type of choke		Magnetic	Driver	Magnetic	Driver					Magnetic	Driver
Number of fixtures	#	145	145	5	5	3	3	4	4	2	2
Rated power of fixture	W/Unit	36	20	40	20	65	36	85	36	250	100
Consumption of choke	W	12	0	12	0	0	0	0	0	30	0
Operating power	W/fixture	48	20	52	20	65	36	85	36	280	100
Operating hours/day	h/d	20	20	20	20	20	20	18	18	20	20
Operating days/year	d/y	330	330	330	330	330	330	330	330	330	330
Annual energy consumption	kWh/y	45,936	19,140	1,716	660	1,287	713	2,020	855	45,936	19,140
Annual energy saving	kWh/y		26,796		1,056		574		1,164		26,796
Cost of Electricity	Rs./kWh	7.42									
Total savings	Lakh Rs/y	2.37									
Estimated investment	Lakh Rs	1.37									
Payback period	Months	7									
IRR	%	134%									
Discounted Payback period	Months	3									

4.9 Electrical Distribution System

4.9.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415 V) by step down transformer (1.00 MVA). Automatic power factor correction system is installed in parallel to main supply. There were two DGs (capacity of 1 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeders which are shown in single line diagram in Figure 20.

4.9.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.9.3 Observations and performance assessment

After analyzing feeder power profiling, it was observed that the maximum kVA recorded during study period was **340 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **414 V.** Maximum voltage was **425 V** and minimum was **392 V**.

Average total voltage and current harmonics distortion found **6.8 %** & **15** % respectively during power profile recording.

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

It was observed that some of the outgoing feeders to sizing and press section has low poor power factor. Poor power factor leads to cable losses (I^2R) in the electrical distribution system. However since cable length is very less no recommendation is given.

4.9.4 Energy conservation measures (ECM)

4.9.4.1 Energy conservation measures (ECM) - ECM #13: Cable loss minimization

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted that in sizing section power factor was between 0.59-0.75.

Recommended action

It is recommended to install power factor improvement capacitors for sizing whereas for press section automatic power factor controller is recommended.

The cost benefit analysis for this project is given below:

Table 53 : Cost benefit analysis of cable loss minimization (ECM -13)

Particulars	Unit	Sizing Machine (Section 1)	Sizing Machine (Section 2)	Coal Gasifier	Glaze ball mill MDB	Slip House MDB
Existing Power Factor	PF	0.60	0.53	0.74	0.69	0.37
Proposed Power Factor	PF	0.99	0.99	0.99	0.99	0.99
Existing load	kW	17.6	12.2	35.5	38.3	13.7
Cable Losses Present	W	256.0	205.7	627.9	1104	350.5
Cable Losses Proposed	W	105.6	56.4	354.1	545.3	51.6
Capacitor Required	kVAr	21	18	27	35	32
Annual Energy Saving	kWh/y	1,191	1,182	2,169	4,425	2,367
Savings Estimated	Rs Lakh/y	8,336	8,274	15,184	30,978	16,571
Total Savings	Rs Lakh/y	0.84				
Investment	Rs Lakh	0.61				
Simple Payback Period	Months	9				
IRR	%	102%				
Discounted Payback period	Months	3.4				

4.10 Belt Operated Drives

4.10.1 Specifications

There are 15 drives operated with V Belt of total capacity of 231 kW. Locations include

- Kiln 1 (8)
- Kiln 2 (5)
- Horizontal dryer (2)

4.10.2 Field measurement and analysis

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

4.10.3 Observations and performance assessment

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

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

Technology description

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

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

Study and investigation

The unit is having about 15 belt driven blowers in plant

Recommended action

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

Table 54: Replacement of conventional belt with REC belt [ECM-14]

Particulars	UoM	AS IS	TO BE
Number of belt driven blowers	#	15	15
Measured power of all belt driven blowers	kW	36.9	35.6[1]
Running hours of blowers	h/d	24	24
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	292,214	281,694
Annual energy saving	kWh/y	10,520	
Electricity cost	Rs./kWh	7.42	
Annual energy cost saving	Rs. Lakh	0.78	
Estimated investment	Rs. Lakh	1.98	
Payback Period	Months	30	
IRR	%	18	
Discounted payback period	Months	11.2	

[1] 3.6% energy saving is claimed as per latest suppliers

5 CHAPTER – 5 ENERGY CONSUMPTION MONITORING

5.1 Energy Consumption Monitoring

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

5.1.1 Energy conservation measures (ECM) - ECM#15: Energy Monitoring System

Technology description

Installation of energy monitoring system on a unit will monitor the energy consumed by various machines. From this, the energy consumption benchmark 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 being done on various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed in kilns 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. This measure will help in reduction in energy consumption by approximately 2% from its present levels. The cost benefit analysis for this project is given below:

Table 55: Cost benefit analysis for energy monitoring system (ECM-15)

Parameters	Unit	Present	Proposed
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	24,88,624	24,38,852
Annual electricity saving per year	kWh/y		49,772
Cost of Electricity	Rs/kWh		7.42
Annual monetary savings	Lakh Rs/y		3.69
Number of equipments/system	#	30	30
No. of energy meters	#	0	30
Estimated investment	Lakh Rs		2.99
Thermal energy monitoring system	%	2.00	
Current coal consumption in HAG	kg/y	78,80,805	77,23,189
Annual coal saving per year	kg/y		1,57,616
Cost of Coal	Rs/kg		6.82
Total annual monetary savings	Lakh Rs/y		10.75
Number of equipments/system	#	1	1
Number of coal weighing machines			1

Parameters	Unit	Present	Proposed
Estimated investment	Lakh Rs		1.32
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		14.44
Estimated (Electrical + Thermal)	Lakh Rs		4.31
Payback period	Months		4
IRR	%		254%
Discounted Payback period	Months		1.4

5.2 Best Operating Practices

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

Table 56: Unique Operating practices

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. Alumina balls are used in ball mills
3	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing pollution
3	Press	PRV installed for usage of compressed air
5	VT Dryer	Waste heat from kiln is used in VT dryer.
6	Glaze ball mill	Timer control in each ball mill. Alumina balls are used in glaze ball mills
7	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
8	Sizing	Fully automatic system. Dust collected system installed.
9	Printing	Automated digital printing with fully auto control system
10	Lighting	LED lights in a few locations

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 57 : 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%

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

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

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

The working principle is as follows:

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

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

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

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

[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

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.

Figure 18 : 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 °C at burner
- Easy installation

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

[4] SACMI Kiln Revamping catalogue for roller kilns

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

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

Figure 19: NG consumption monitoring kit

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

[5] SACMI Kiln Revamping catalogue for roller kilns

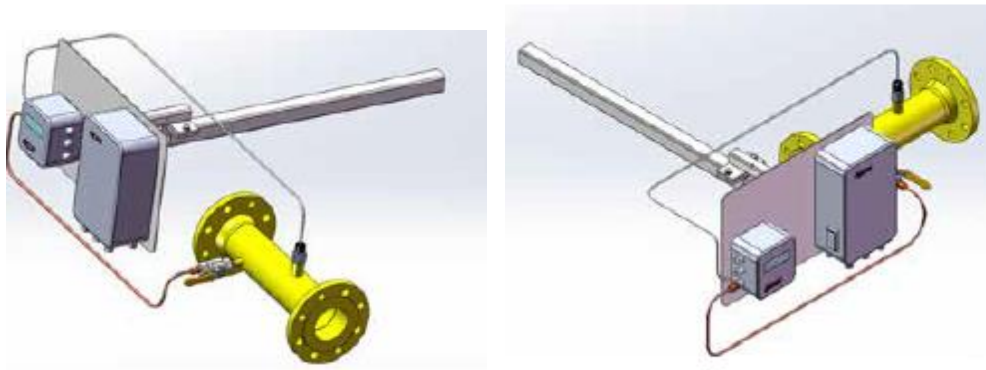

Figure 20: Combustion air control for burner

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

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

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

Figure 21: 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

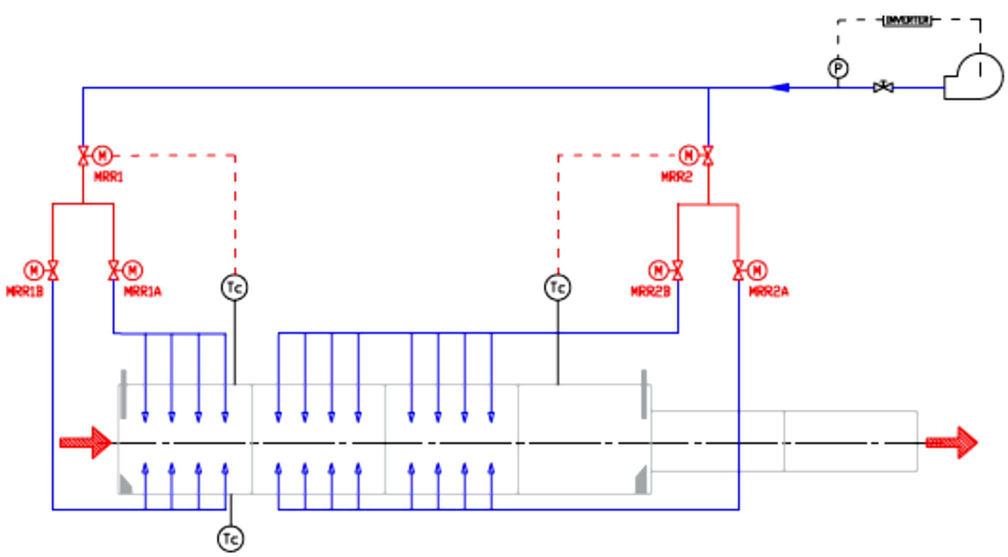

Figure 22: Fast cooling air management

7. **Industry 4.0 system for easiness in operation and real-time information:** Industry 4.0 system provides opportunity to make full use of data control and management system. These systems are modern, compatible with the most widely used data platforms and ensure machines can be used flexibly with excellent usability of collected data. The technical features of such a system includes:
    - Network connected PLC system for automation and operator/machine safety
    - Simple user-friendly man-machine interface that can be used by operators in any situation
    - Continuous monitoring of process parameters and working conditions using suitable sensors
    - Adaptive - behavior system control in the event of any process drift
    - Remote tele-assistance service allows modification of process parameters and updating the software
    - PC/SCADA system allows monitoring, control and supervision of the machine using connection network
    - Complete consumption and production database available to corporate network and to management software using internet or database SQL protocols.

Figure 23: 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 24: - High Alumina pebbles for Ball mill

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

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

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

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

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

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:

- 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.

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

- 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, τ0, and plastic viscosity, μ, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.
- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost

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

5.3.7 Use of Direct blower fans instead of belt drive:

There are a numbers of fans used in tile manufacturing, most of which are using belt drive system. The major application of blower fans in kiln is for combustion heating, cooling, recovery of hot air, exhaust / flue air etc. There are also other applications viz. FD and ID fans on Hot Air Generators. In most of these applications, the air temperature is high and overall system is working in handling high temperature air with whole mechanical structure including fan and shaft are at higher temperature compared to atmospheric air temperature. The fans are working with heavy inertia load of fan impeller and air flow which continuously create stress on V-belts resulting in belt elongation and slippage. In order to avoid energy loss in belt drive slippage, direct mounted fans on motor shaft eliminates the slippage issue and depending upon size and application, @ 3-5 % of energy loss can be reduced using direct motor mounted fans along with Inverter drive for speed control.

A few units in Morbi cluster are using direct drive fans.

Figure 25: Direct drive blower fan

6 CHAPTER – 6 RENEWABLE ENERGY APPLICATIONS

The roof top PV potential is estimated as 252 kW. Cost benefit analysis is given below:

6.1 ENERGY CONSERVATION MEASURES (ECM) - ECM#16: INSTALLATION OF SOLAR PV SYSTEM

Technology description

Solar Photovoltaic system is one of the renewable energy sources which use PV modules to convert sunlight into electricity. The electricity generated can be stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy sources.

Study and investigation

It was observed during energy audit that 2620 m^2 of area is available on the roof top for installation of solar PV panels.

Recommended action

The average electricity generation is estimated at 385,580 kWh/y. The cost benefit analysis is given below:

Table 58: Cost benefit analysis for installing solar PV system (ECM 16)

Parameters	Unit	Proposed
Available area on roof	m^2	2,620
Estimated total Solar PV panel area	m^2	1,572
Number of panels (1m X 2m) of 320 Wp	#	786
Estimated installed capacity of solar panel	kW	252
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	1,056
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	385,580
Cost of electricity	Rs/kWh	7.42
Annual monetary savings	Lakh Rs/y	29
Estimated investment	Lakh Rs	138
Payback period	Months	58
IRR	%	-4%
Discounted payback period	Months	19.89

There is a generation of 2.5Wp electricity per kW of panel installed due to orientation of building. The project IRR is negative and hence the project is not 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 increased cleaning frequency and requirement of DM water for cleaning the panels twice a day.

7 CHAPTER – ANNEXES

ANNEX-1: PROCESS FLOW DIAGRAM

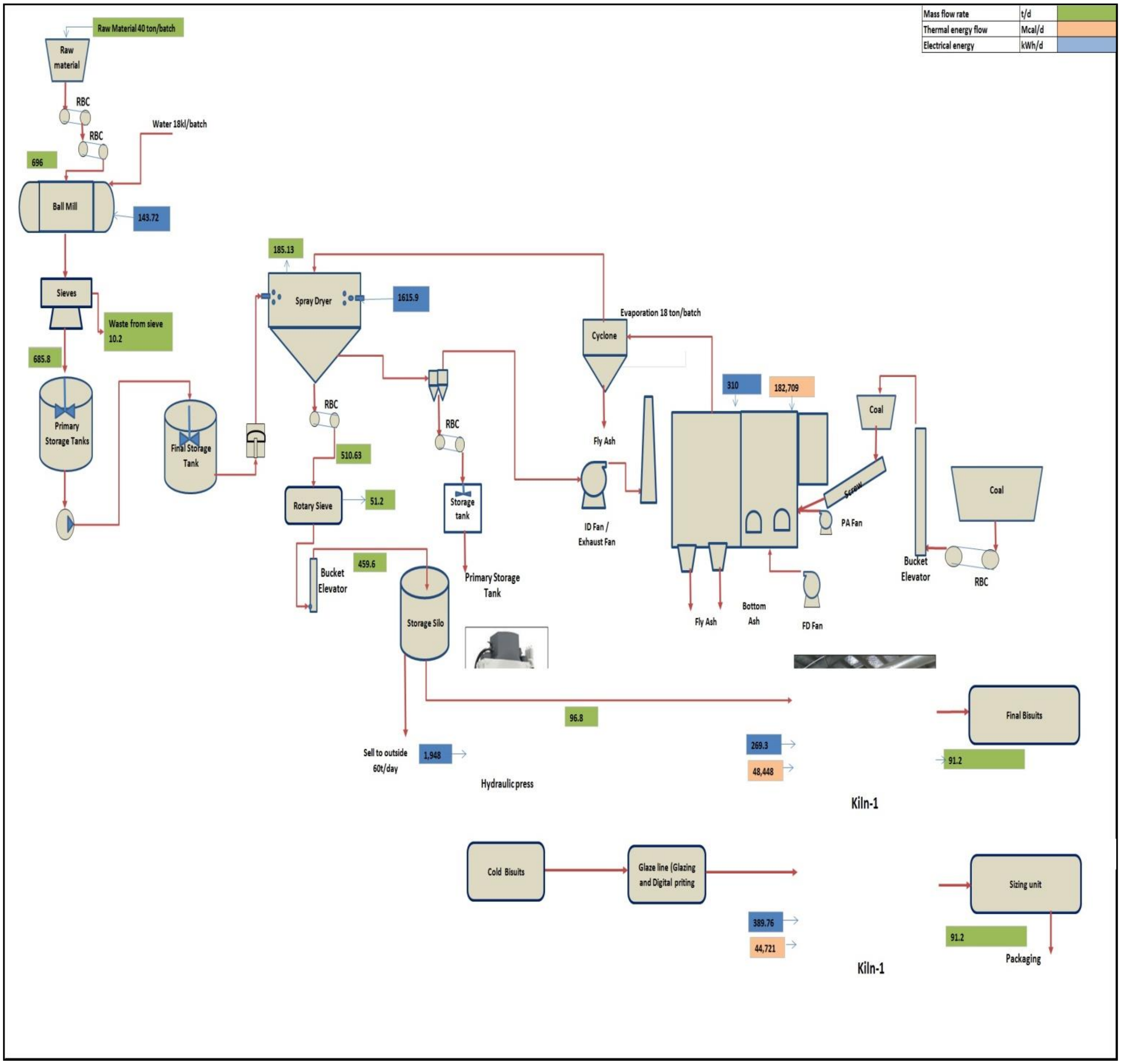


Figure 26: Process Flow Diagram of Plant

Annex-2: Detailed Inventory

Equipment	Connected Load	Rating (kW)
Ball Mill	Ball mill	119
	Weighting machine	7.5
	Conveyer	6.0
	Mud Pump	5.6
Agitator Tank	Stirrer-1	2.24
	Stirrer-2	2.24
	Stirrer-3	2.24
	Stirrer-4	2.24
	Stirrer-5	2.24
	Stirrer-6	2.24
	Stirrer-7	2.24
Final Tank	Stirrer-1	2.24
	Stirrer-2	2.24
Spray Dryer	Slurry pump-1	14.9
	Slurry pump-2	14.9
	Spray dryer pump	22.4
	Conveyer 1	4.47
	Conveyer 2	2.24
	Conveyer 3	1.5
Hot Air Generator	PA Fan	7.5
	FD Fan	22.4
	Varam	1.49
	Coal Conveyer	1.49
	Coal elevator	3.73
Press	Press-1	55
	Press-2	37.3
Cooling Tower	Pump	
Horizontal dryer	Rollers	3.73
	Smoke blower	18.65
	Booster fan	18.65
Printing	Printing	
Kiln	Biscuit Kiln	150
	Glaze Kiln	95
Sizing line	sizing machine 1	49
	sizing machine 2	49
	sizing line	3.74
Glaze line	Stirrer	2.24
	Vibrator	7.5
	Pump	8.9
	Drives	40.2
Glaze ball mills	Glaze Ball mill	123

Equipment	Connected Load	Rating (kW)
	Stirrer	5.6
	Vibrator	2.24
	Glaze pump	3.73

ANNEX-3: SINGLE LINE DIAGRAM

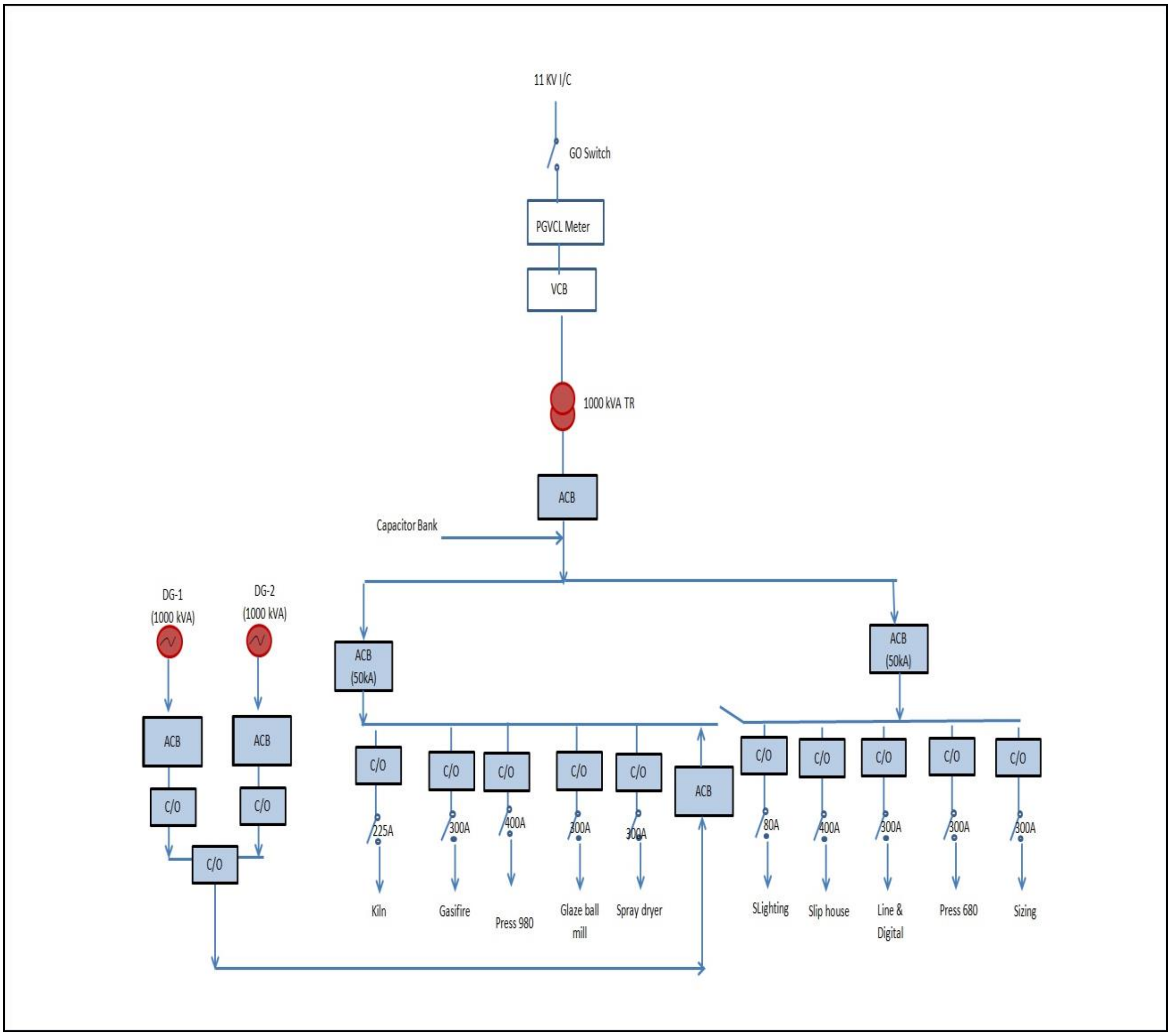
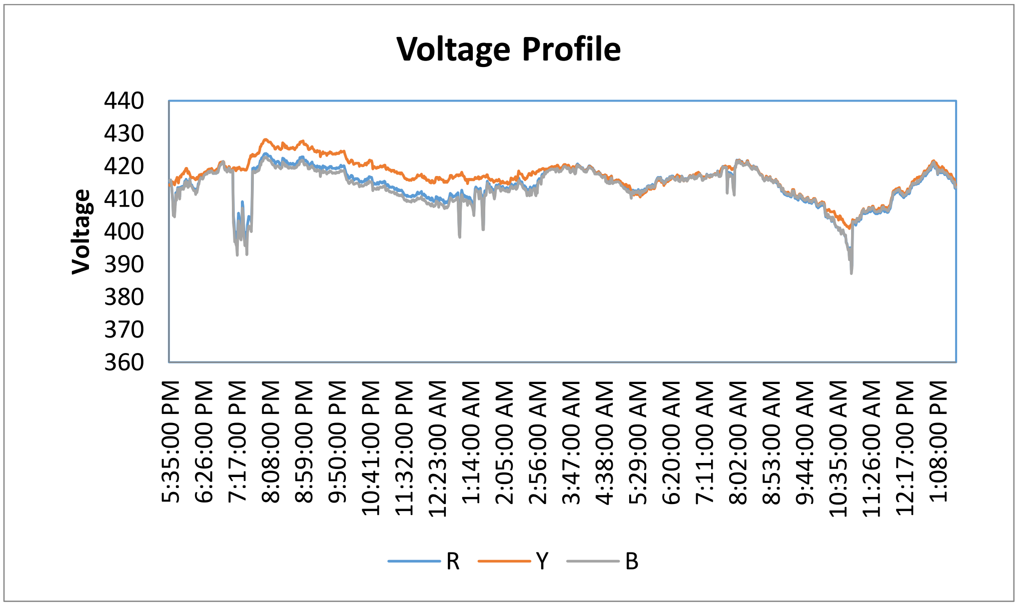


Figure 27: Single Line Diagram (SLD)

ANNEX-4: ELECTRICAL MEASUREMENTS



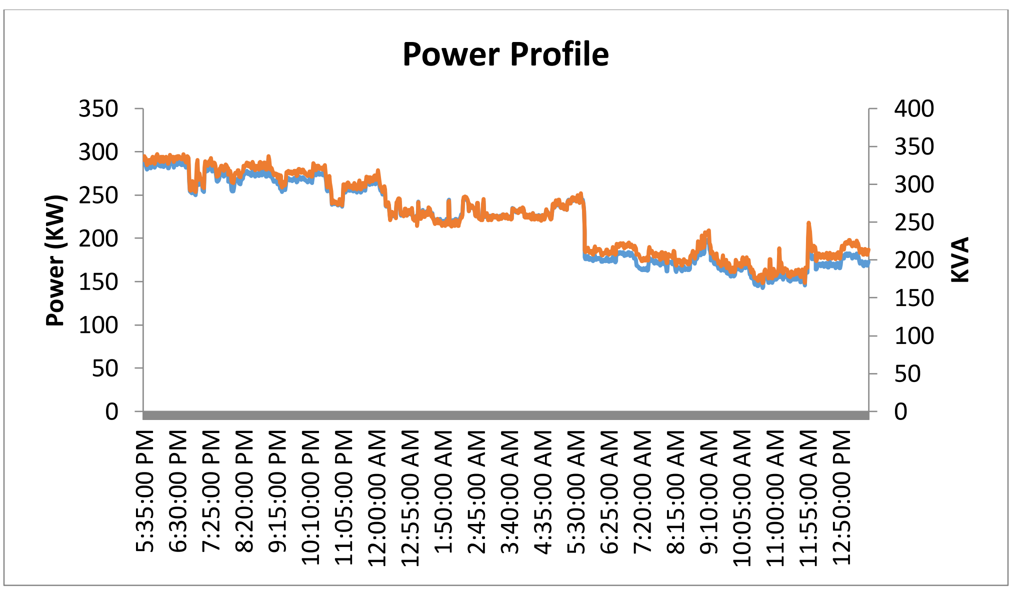


Figure 28: Power and voltage profile of Main Incomer

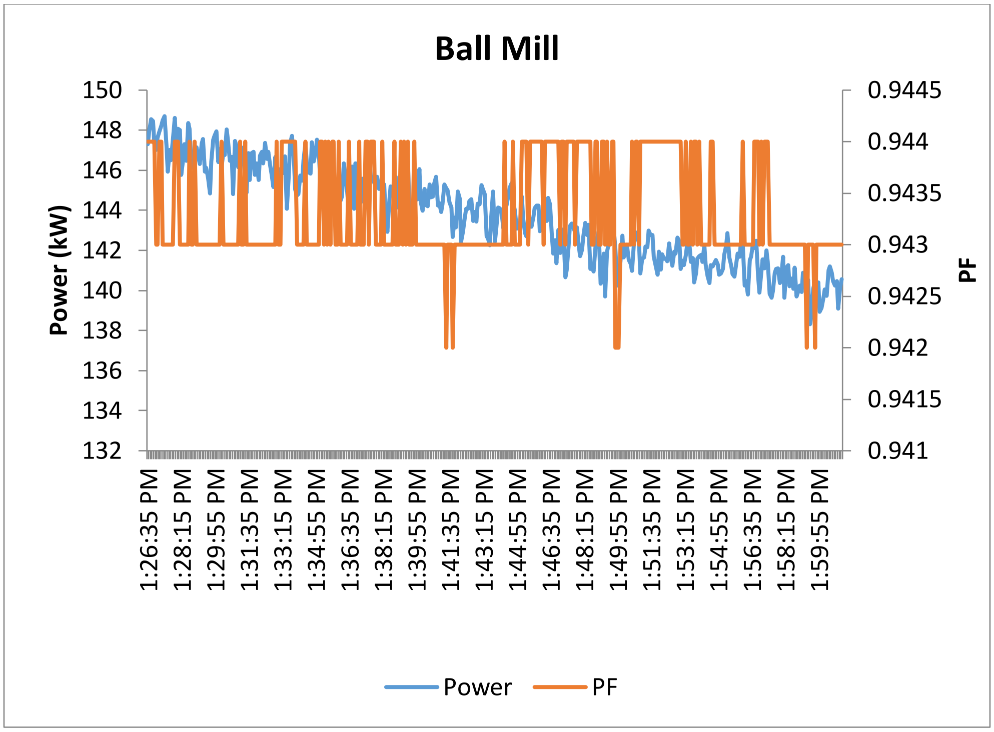


Figure 29: Power and PF profile of Ball Mill

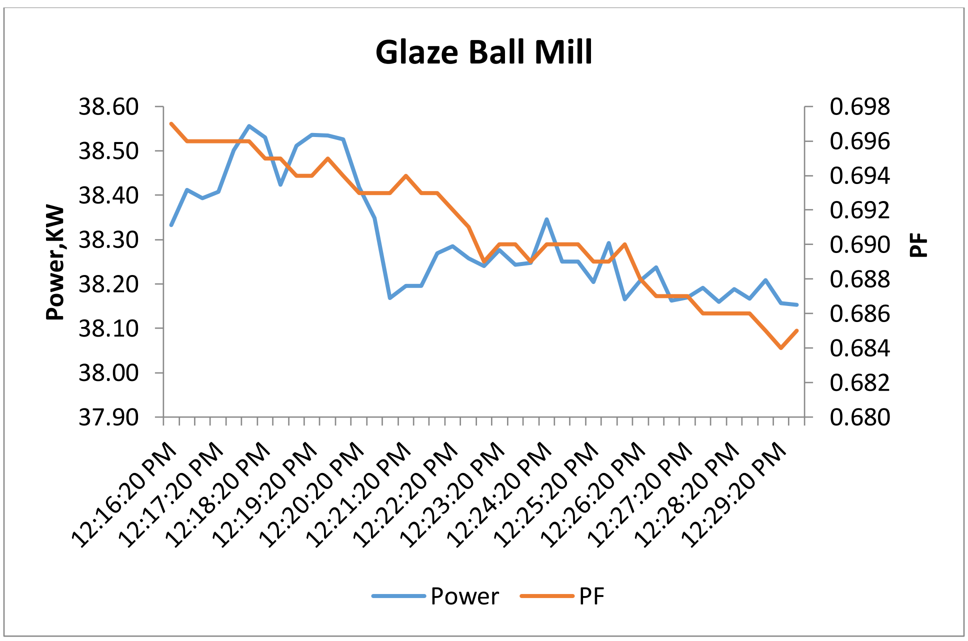


Figure 30: Power and PF profile of Glaze ball mill

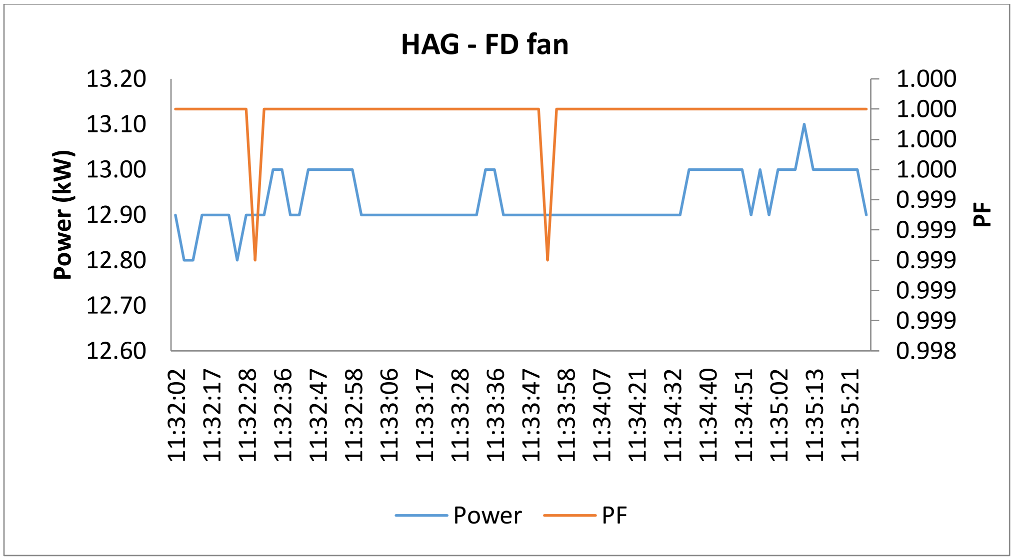


Figure 31 : Power and PF profile of HAG - FD fan

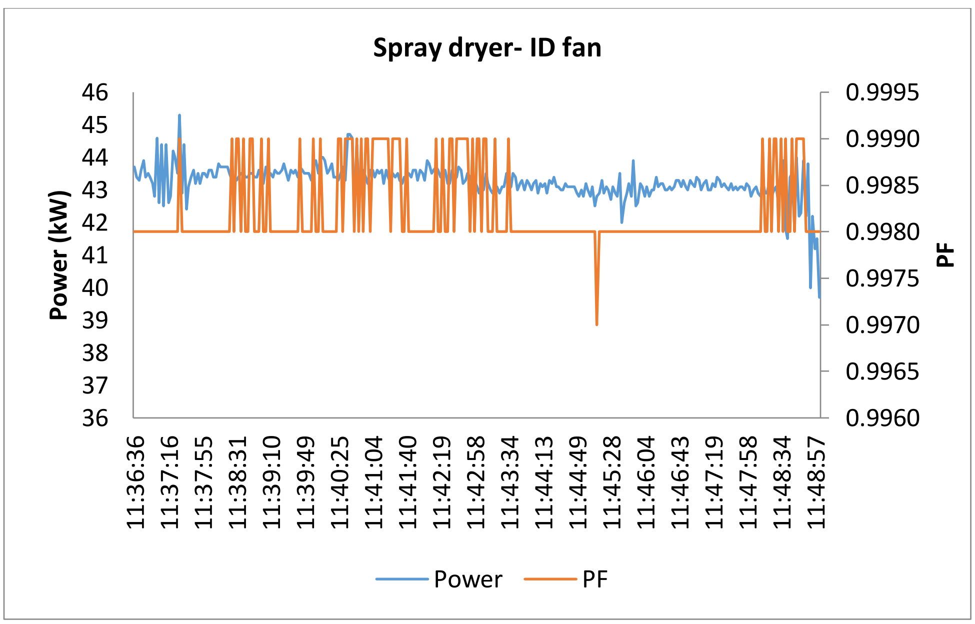
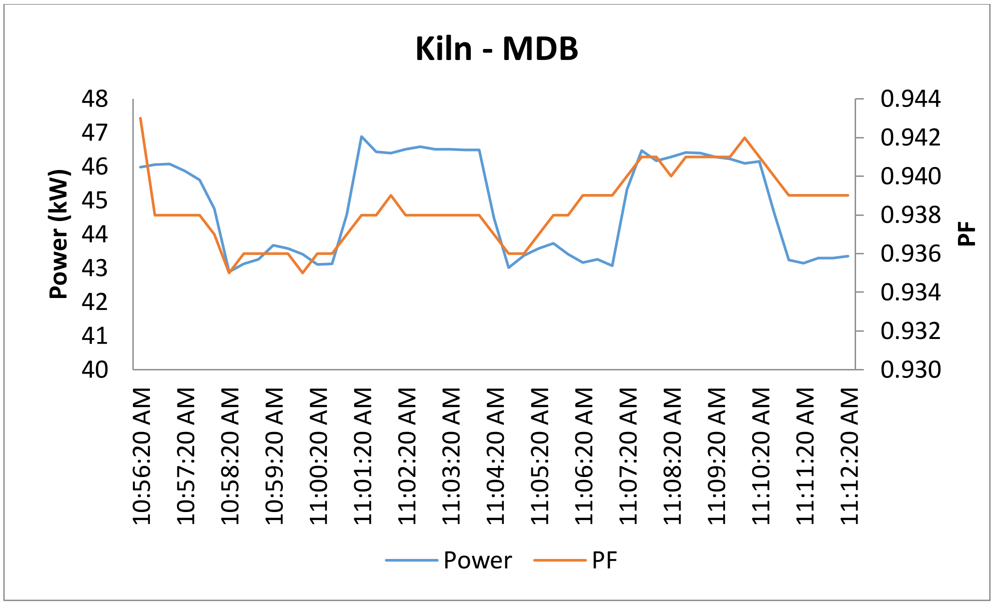
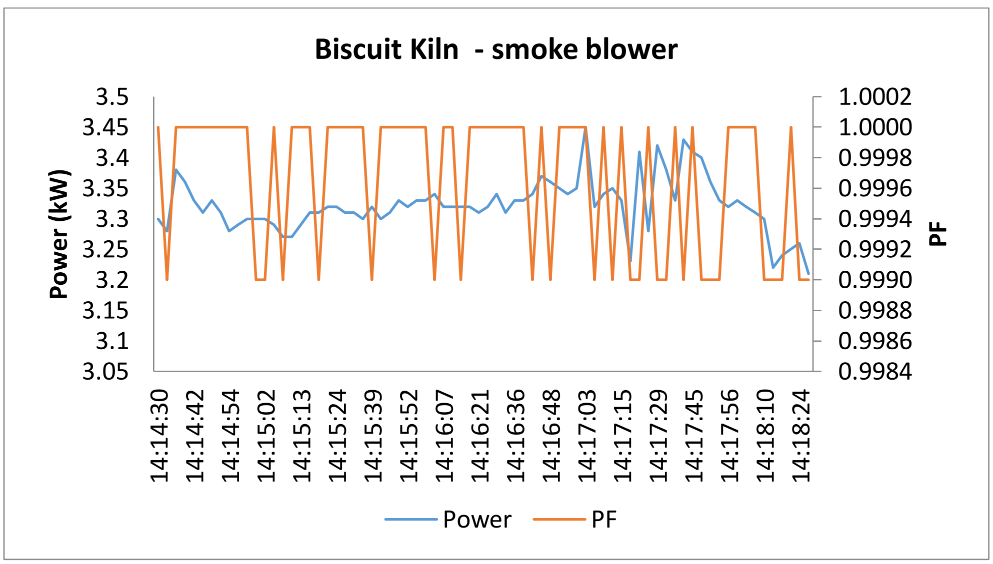
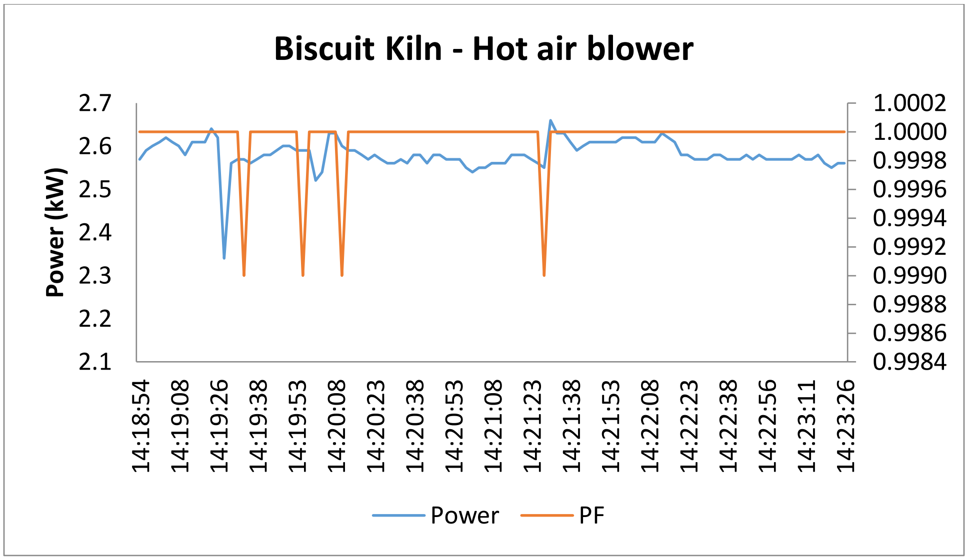
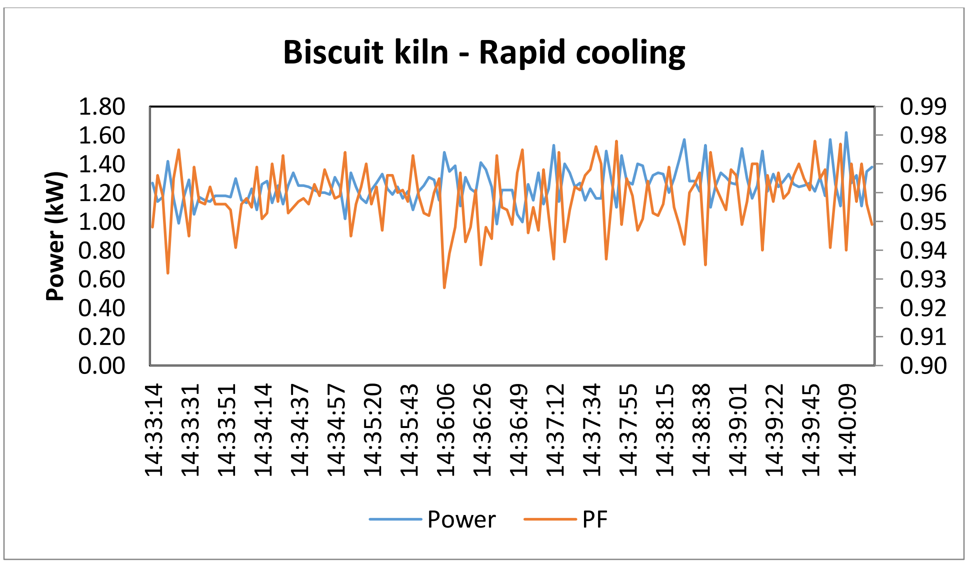


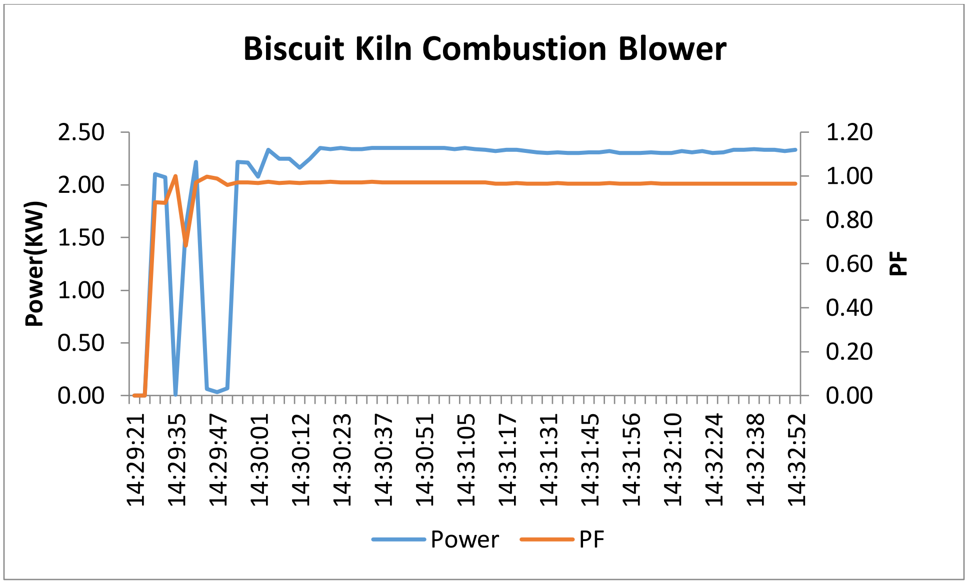
Figure 32 : Power and PF profile of spray dryer - ID fan

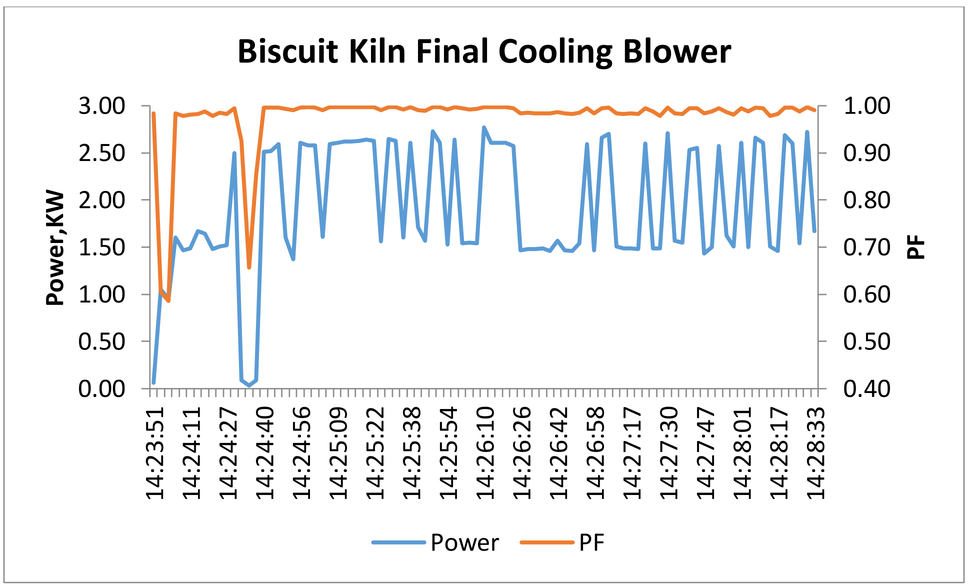

Kiln - MDB
Power (kW)
48
47
46
45
44
43
42
41
40
PF
0.944
0.942
0.940
0.938
0.936
0.934
0.932
0.930
10:56:20 AM
10:57:20 AM
10:58:20 AM
10:59:20 AM
11:00:20 AM
11:01:20 AM
11:02:20 AM
11:03:20 AM
11:04:20 AM
11:05:20 AM
11:06:20 AM
11:07:20 AM
11:08:20 AM
11:09:20 AM
11:10:20 AM
11:11:20 AM
11:12:20 AM
Power
PF

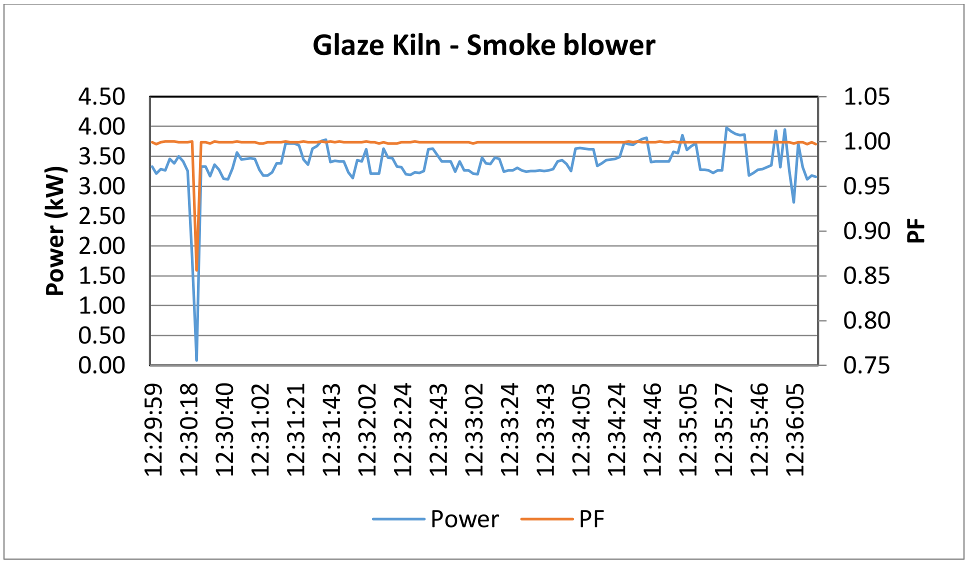

Biscuit Kiln - smoke blower
Power (kW)
3.5
3.45
3.4
3.35
3.3
3.25
3.2
3.15
3.1
3.05
PF
1.0002
1.0000
0.9998
0.9996
0.9994
0.9992
0.9990
0.9988
0.9986
0.9984
14:14:30
14:14:42
14:14:54
14:15:02
14:15:13
14:15:24
14:15:39
14:15:52
14:16:07
14:16:21
14:16:36
14:16:48
14:17:03
14:17:15
14:17:29
14:17:45
14:17:56
14:18:10
14:18:24
Power
PF

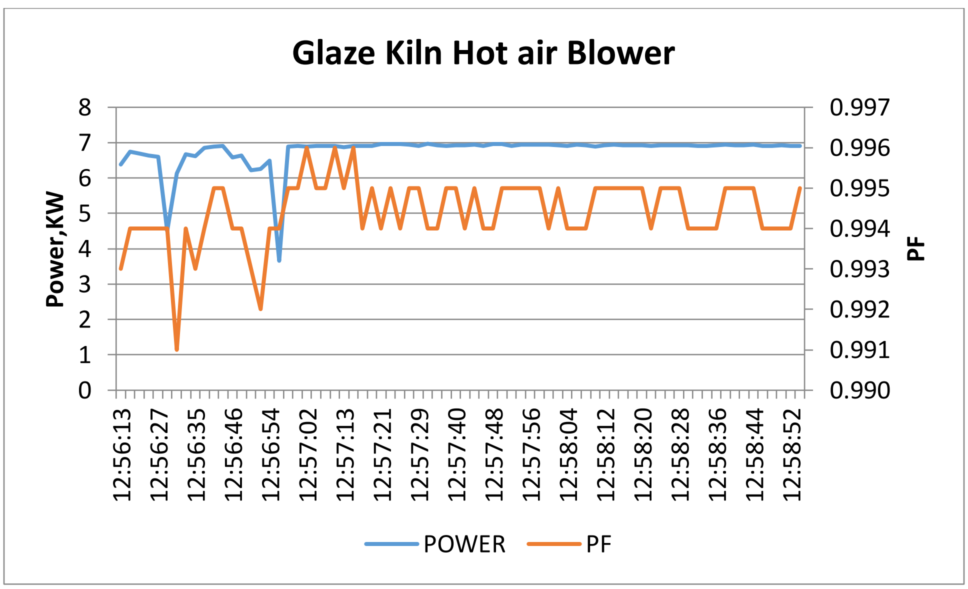

Biscuit Kiln - Hot air blower
Power (kW)
2.7
2.6
2.5
2.4
2.3
2.2
2.1
1.0002
1.0000
0.9998
0.9996
0.9994
0.9992
0.9990
0.9988
0.9986
0.9984
14:18:54
14:19:08
14:19:26
14:19:38
14:19:53
14:20:08
14:20:23
14:20:38
14:20:53
14:21:08
14:21:23
14:21:38
14:21:53
14:22:08
14:22:23
14:22:38
14:22:56
14:23:11
14:23:26
Power
PF

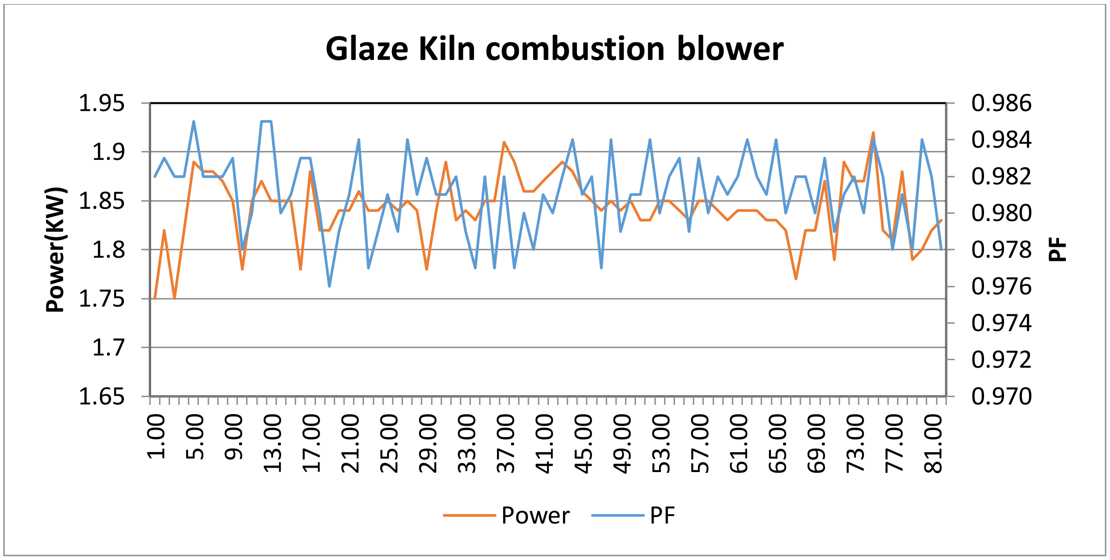

Biscuit kiln - Rapid cooling
Power (kW)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.90
14:33:14
14:33:31
14:33:51
14:34:14
14:34:37
14:34:57
14:35:20
14:35:43
14:36:06
14:36:26
14:36:49
14:37:12
14:37:34
14:37:55
14:38:15
14:38:38
14:39:01
14:39:22
14:39:45
14:40:09
Power
PF

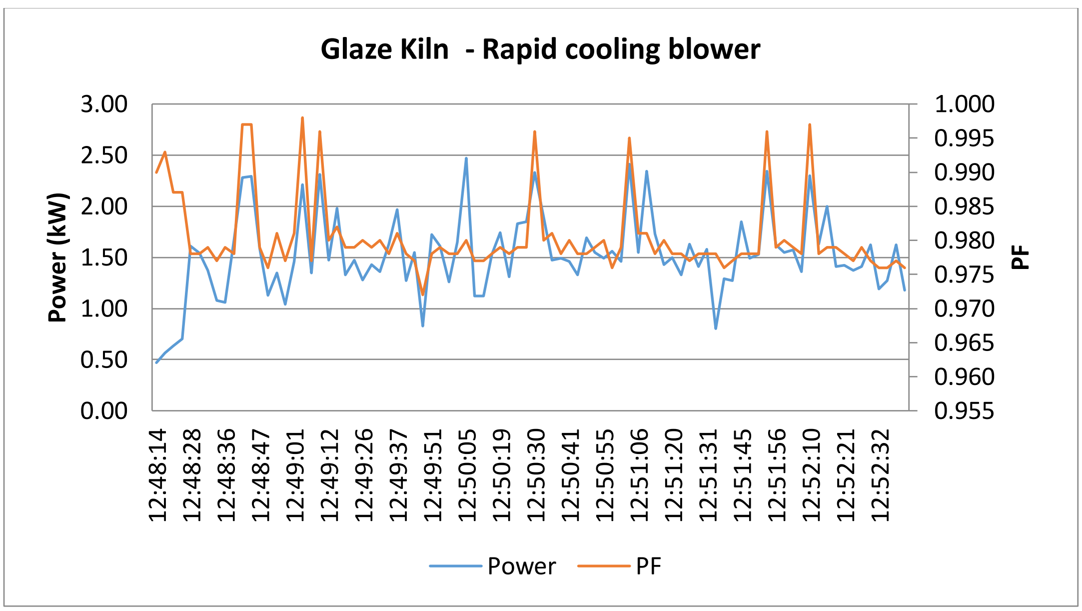

Biscuit Kiln Combustion Blower
Power(KW)
PF
2.50
2.00
1.50
1.00
0.50
0.00
1.20
1.00
0.80
0.60
0.40
0.20
0.00
14:29:21
14:29:35
14:29:47
14:30:01
14:30:12
14:30:23
14:30:37
14:30:51
14:31:05
14:31:17
14:31:31
14:31:45
14:31:56
14:32:10
14:32:24
14:32:38
14:32:52
Power
PF


Biscuit Kiln Final Cooling Blower
Power,KW
PF
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
14:23:51
14:24:11
14:24:27
14:24:40
14:24:56
14:25:09
14:25:22
14:25:38
14:25:54
14:26:10
14:26:26
14:26:42
14:26:58
14:27:17
14:27:30
14:27:47
14:28:01
14:28:17
14:28:33
Power
PF


Glaze Kiln - Smoke blower
Power (kW)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
PF
1.05
1.00
0.95
0.90
0.85
0.80
0.75
12:29:59
12:30:18
12:30:40
12:31:02
12:31:21
12:31:43
12:32:02
12:32:24
12:32:43
12:33:02
12:33:24
12:33:43
12:34:05
12:34:24
12:34:46
12:35:05
12:35:27
12:35:46
12:36:05
Power
PF


Glaze Kiln Hot air Blower
Power,KW
8
7
6
5
4
3
2
1
0
PF
0.997
0.996
0.995
0.994
0.993
0.992
0.991
0.990
12:56:13
12:56:27
12:56:35
12:56:46
12:56:54
12:57:02
12:57:13
12:57:21
12:57:29
12:57:40
12:57:48
12:57:56
12:58:04
12:58:12
12:58:20
12:58:28
12:58:36
12:58:44
12:58:52
POWER
PF


Glaze Kiln combustion blower
Power(KW)
PF
1.95
1.9
1.85
1.8
1.75
1.7
1.65
0.986
0.984
0.982
0.980
0.978
0.976
0.974
0.972
0.970
1.00
5.00
9.00
13.00
17.00
21.00
25.00
29.00
33.00
37.00
41.00
45.00
49.00
53.00
57.00
61.00
65.00
69.00
73.00
77.00
81.00
Power
PF


Glaze Kiln - Rapid cooling blower
Power (kW)
PF
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.000
0.995
0.990
0.985
0.980
0.975
0.970
0.965
0.960
0.955
12:48:14
12:48:28
12:48:36
12:48:47
12:49:01
12:49:12
12:49:26
12:49:37
12:49:51
12:50:05
12:50:19
12:50:30
12:50:41
12:50:55
12:51:06
12:51:20
12:51:31
12:51:45
12:51:56
12:52:10
12:52:21
12:52:32
Power
PF

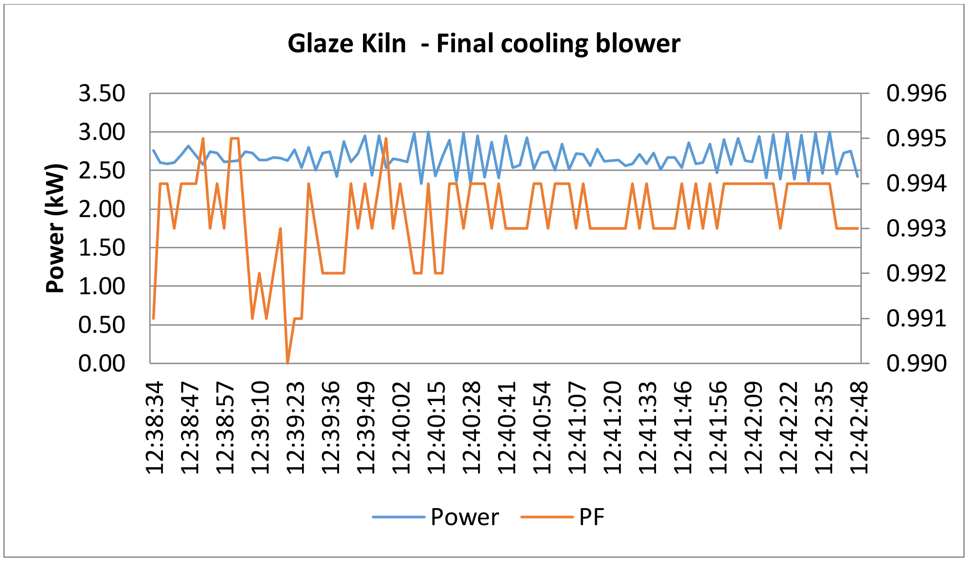


Figure 33: Power and PF profile of all blowers of Biscuit & Glaze Kiln

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

1. Biscuit 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)	1,056	*°C*
Initial temperature of kiln tiles	39	*°C*
Avg. fuel Consumption	1,570	*kg/h*
Density of coal gas	0.96	*kg/scm*
Avg. fuel Consumption	1,640	*M^3/h*
Flue Gas Details		
Flue gas temp at smog blower	110	*°C*
Preheated air temp./Ambient	60	*°C*
O_2 in flue gas	7.2	*%*
CO_2 in flue gas	7.8	*%*
CO in flue gas	28.1	*ppm*
Atmospheric Air		
Ambient Temp.	39	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
O	*0.00*	%
S	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	1,231	*kcal/scm*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un-burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	*kcal* l/kg
GCV of fly ash	*0*	*kcal* /kg
Material and flue gas data		
Weight of Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	3,800	*kg/h*
Weight of Stock	3,800	*kg/h*
Specific heat of clay material	0.22	*kcal /kg- °C*
Avg. specific heat of fuel	0.51	*kcal /kg-°C*
fuel temp	39	*°C*
Specific heat of flue gas	0.24	*kcal /kg-°C*
Specific heat of superheated vapour	0.45	*kcal/kg-oC*

Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	22,087	*kcal/h*
Radiation and convection from heating zone surface	28,272	*kcal/h*
Heat loss from all zones	50,359	*kcal/h*
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.82	*h*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*deg K*

Efficiency calculations

Calculations	Kiln	Unit
Theoretical Air Required	7.72	*kg/kg of fuel*
Excess Air supplied	51.95	*%*
Actual Mass of Supplied Air	11.74	*kg/kg of fuel*
Mass of dry flue gas	11.62	*kg/kg of fuel*
Amount of Wet flue gas	12.74	*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	11.62	*kg/kg of fuel*
Specific Fuel consumption	413.07	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	5,08,328	*kcal/ton of tiles*
Total heat input	5,08,328	*kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	2,23,685	*kcal /ton of tile*
Heat loss in dry flue gas	81,774	*kcal /ton of tile*
Loss due to H_2 in fuel	20,486	*kcal/ton of tile*
Loss due to moisture in combustion air	374.94	*kcal/ton of tile*
Loss due to partial conversion of C to CO	205.81	*kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	38.46	*kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	5,531	*kcal/ton of tile*
Total heat loss from kiln (surface) body	13,252	*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	1,62,981	*kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	13,252	*Kcal/ton*
Kiln Efficiency	44.00	*%*

Glaze 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)	1,013	*°C*
Initial temperature of kiln tiles	39	*°C*
Avg. fuel Consumption	1,449	*kg/h*
Density of Natural gas	0.96	*kg/m^3*
Avg. fuel Consumption	1,514	*kg/h*
Flue Gas Details		
Flue gas temp at smog blower	169	*° C*
Preheated air temp./Ambient	60	*°C*
O_2 in flue gas	7.5	*%*
CO_2 in flue gas	7.8	*%*
CO in flue gas	19.8	*ppm*
Atmospheric Air		
Ambient Temperature	39	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg of dry air*
Fuel Analysis		
C	*24.35*	*%*
H	*12.17*	*%*
N	*46.09*	*%*
O	*0*	*%*
S	*15.22*	*%*
Moisture	*2.17*	*%*
Ash	*0.00*	*%*
GCV of fuel	1,231	*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 Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	3,440	*kg/h*
Weight of Stock	3,440	*kg/h*
Specific heat of clay material	0.22	*kcal/kg-°C*
Avg. specific heat of fuel	0.51	*kcal/kg-°C*
fuel temp	39	*°C*
Specific heat of flue gas	0.24	*kcal/kg-°C*
Specific heat of superheated vapour	0.45	*kcal/kg-°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	3,446	*kcal/h*
Radiation and convection from heating zone surface	25,238	*kcal/h*
Heat loss from all zones	28,684	*kcal/h*

For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.82	*h*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*K*

Efficiency Calculation

Calculations	Kiln	Unit
Theoretical Air Required	7.72	*kg/kg of fuel*
Excess Air supplied	56.02	*%*
Actual Mass of Supplied Air	12.05	*kg/kg of fuel*
Mass of dry flue gas	11.93	*kg/kg of fuel*
Amount of Wet flue gas	13.05	*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	11.93	*kg/kg of fuel*
Specific Fuel consumption	421.21	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	5,18,343	*kcal/ton of tiles*
Total heat input	5,18,343	*kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	2,14,368	*kcal/ton of tile*
Heat loss in dry flue gas	1,56,801	*kcal/ton of tile*
Loss due to H_2 in fuel	21,421	*kcal/ton of tile*
Loss due to moisture in combustion air	704.87	*kcal/ton of tile*
Loss due to partial conversion of C to CO	147.73	*kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	42.48	*kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	5,883	*kcal/ton of tile*
Total heat loss from kiln (surface) body	8,339	*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	1,10,637	*kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	8,339	*kcal/ton*
Kiln Efficiency	41.36	*%*

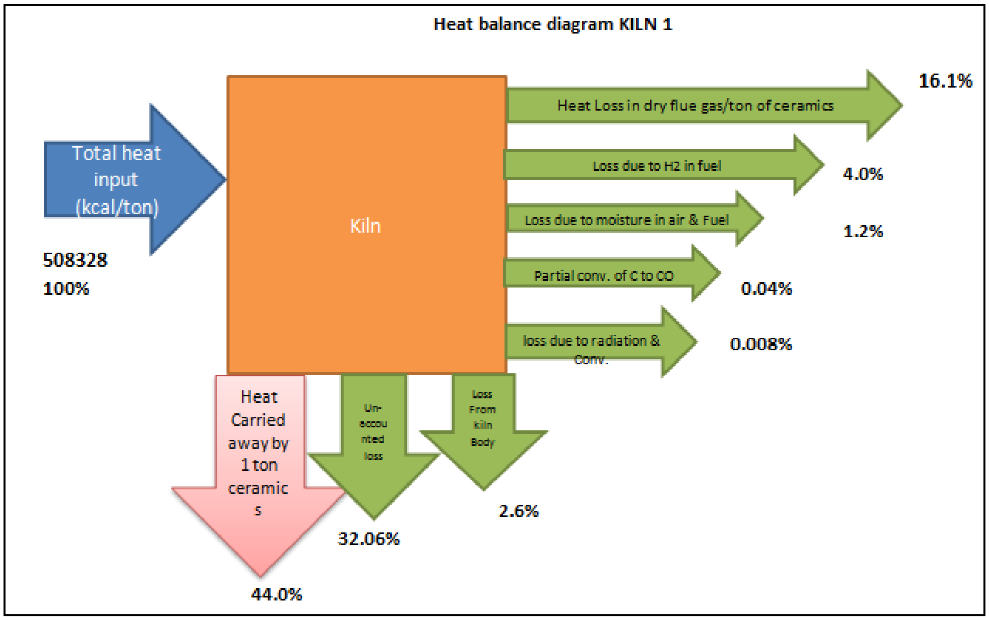


Figure 34 : Heat Mass balance of kiln-1

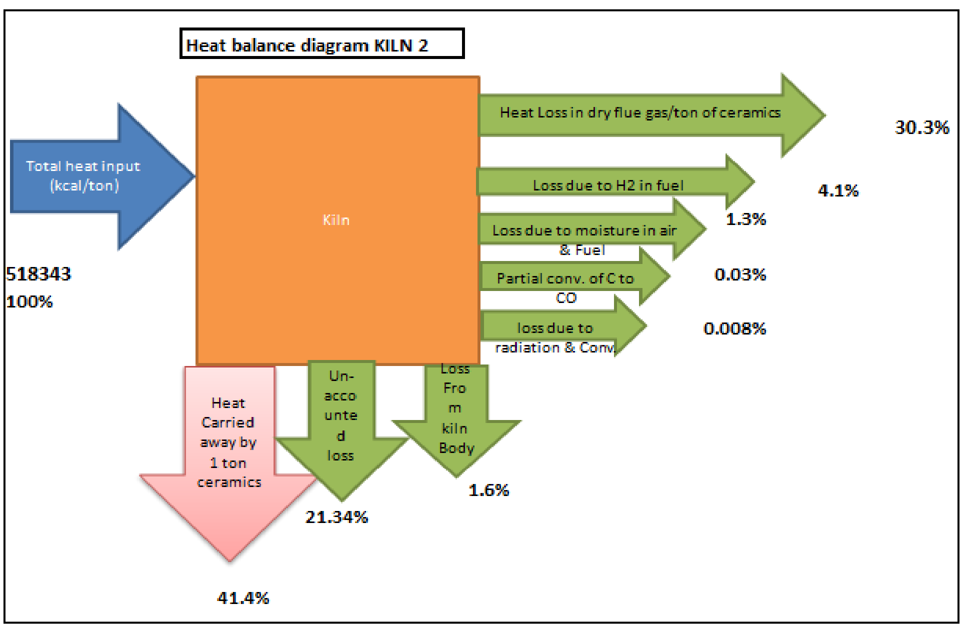


Figure 35 : Heat Mass balance of kiln-2

Annex-6: Vendors

ECM-1 &2: Excess air control in kiln 1&2

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

ECM 3&4: Radiation and convection loss reduction from surface of kiln 1&2

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

ECM-5: WHR from kiln 1&2 using recuperator

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Knackwell Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445,	9824037124, 9624042423	http://www.knackwellengineers.com/ darshan@kanckwell.com ravi@kanckwell.com

Sl. No.	Name of Company	Address	Phone No.	E-mail
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 6: VFD installation in HAG FD fan

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: 7- Optimized Resource consumption using soft water in Clay ball mill

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

ECM –8 &9 : Installation of Electronic timer controller

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-11: Replacement of inefficient pumps with efficient pumps

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Trivium Power Engineers Pvt. Ltd.	F 73, SECTOR 11, ace honda showroom, Noida, Uttar Pradesh, 201301, India	Mob: +91 9999684606 Fax: 0120 4269637	
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-12: Replacement of inefficient lighting systems

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Osram Electricals Contact Person: Mr. Vinay Bharti	OSRAM India Private Limited,Signature Towers, 11th Floor,Tower B, South City - 1,122001 Gurgaon, Haryana	Phone: 011-30416390 Mob: 9560215888	vinay.bharti@osram.com
2	Philips Electronics Contact Person: Mr. R. Nandakishore	1st Floor Watika Atrium, DLF Golf Course Road, Sector 53, Sector 53 Gurgaon, Haryana 122002	9810997486, 9818712322(Yogesh-Area Manager), 9810495473(Sandeep-Faridabad)	r.nandakishore@phillips.com sandeep.raina@phillips.com

3	Bajaj Electricals Contact Person: Mr. Kushgra Kishore	Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002	9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341(Mr. Rahul Khare),	kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com; sanjay.adlakha@bajajelectricals.com

ECM-13: Cable loss minimization

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

ECM-14: Replacement of V belt to REC belt

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Reitz India Limited	New Alipore Market Complex, Block - M; Phase - I, Room No. 414 (Fourth Floor), Kolkata - 700 053, India.	Mr. Tarun Roy Mob: +91 94330 32474	tr@reitzindia.com
2.	Mangal singh Bros. Pvt Ltd	24-B, Raju Gardens, Near Krishnasamy nagar, Sowripalayamp Post, Coimbatore-641028	Ramiz Parker +91 77381 86851	mangalsinghcbe@gmail.com
3	Shreeji Traders	Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001	+91 94281 01565	NA

ECM-15: Energy Management system

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

	Director	Mohammadpur, New Delhi, DL 110075		
2	Aimil Limited Contact Person: Mr. Manjul Pandey	Naimex House A-8, Mohan Cooperative Industrial Estate, Mathura Road, New Delhi - 110 044	Office: 011-30810229, Mobile: +91-981817181	manjulpandey@aimil.com
3	Panasonic India Contact Person: Neeraj Vashisht	Panasonic India Pvt Ltd Industrial Device Division (INDD) ABW Tower,7th Floor, Sector 25, IFFCO Chowk, MG Road,Gurgaon - 122001, Haryana,	9650015288	neeraj.vashisht@in.panasonic.com

ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 59: 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%