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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE WT-05: SISAM CERAMIC PVT. LTD.

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DESL

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

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Disclaimer

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

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

1. Mr. Harshad Patel, Director

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

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

DESL Team

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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	°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	m2
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.

Sisam Ceramic Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Sisam 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	Sisam Ceramic Pvt. Ltd.
Year of Establishment	2014
Address	Behind Satnam Cera, 8-A, Lalpar, Morbi - 2, Gujarat - India.
Products Manufactured	Wall Tiles
Name(s) of the Promoters / Directors	Mr. Harshad Patel

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

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

- **Storage silo:** Raw material, clay power is coming from outside and stored in silos tank.

- **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 biscuit dryer for pre drying after it is passed through kiln-1.
- **Glaze ball mill:** For producing glazing material used on the product.
- **Kiln:** Biscuits are baked in the kiln at 1100-1150^{o}C and again baked after glazing.
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The main utility equipment installed is:

- **Air compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in kiln-1 & 2: Natural gas is used as fuel in kiln-1 & 2 and oxygen content in flue gas was 7.49% and 13.36% against desired level of 3%. 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 of recuperator pipes in kiln - 1 (Biscuit): In kiln - 1, the recuperator pipes in rapid cooling and indirect cooling zone was found to be uninsulated with surface temperature of 117 °C and 160°C which should be maintain at 70 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the 24 recuperator pipes in rapid cooling and 102 pipes in indirect cooling zone with insulation material for reducing surface heat losses.
- Insulation of recuperator pipes in kiln - 2 (Glaze): In kiln - 2, the recuperator pipes in rapid cooling and indirect cooling zone was found to be uninsulated with surface temperature of 135 °C and 139°C which should be maintain at 70 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the 24 recuperator pipes in rapid cooling and 60 pipes in indirect cooling zone with insulation material for reducing surface heat losses.
- Preheating of combustion air through recuperator in kiln-2: Presently, The recuperator is bypassed, the combustion air temperature to kiln-2 is 50.6°C. It is recommended to take recuperator into service to increase combustion air temperature upto 105 °C.
- Replacement of IE1 induction motor with more efficient IE3 motor in glaze ball mills: Glaze ball mills running with IE1 induction motor. It is recommended to replace with more efficient IE3 induction motor.
- Retrofit of VFD in Glaze ball mill: The glaze ball mill was operating continuously irrespective of load requirement. It is recommended to install VFD and reduce energy consumption.
- Reduction of pressure of compressed air: 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 7.5kg/cm^2 to 6kg/cm^2.
- Replacement of inefficient lighting systems: Presently Fluorescent Tube lights and Compact fluorescent light are used for lighting. It is recommended to replace the 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.
- Replacement of V belt to REC belt: All of blowers used in both kilns are V belt driven. These belts were consuming more power. So it is recommended to replace V belt to raw edge cogged belt which result in 3.6 % of energy saving.
- 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.
- Installation of 301kW solar PV has been recommended at the available roof space.

Table 1 : Summary of Energy Conservation Measures

Sl. No.	Energy Conservation Measures	Annual Energy Savings			Monetary Savings	Investment	Payback Period	Emission Reduction
		Electricity kWh/y	Coal t/y	TOE/y	Lakh Rs/y	Lakh Rs	Months	tCO_2/y
1	Excess air control kiln 1	33,919	142	81	15.07	18.48	15	330
2	Excess air control kiln 2	17,629	607	335	55.85	18.48	4	1,301
3	Insulation in recuperator and indirect cooling zone pipes in kiln 1		28	16	2.56	0.92	4	60
4	Insulation in recuperator and indirect cooling zone pipes in kiln 2		40	22	3.58	1.06	4	84
5	Preheating of combustion air through recuperator in kiln-2		38	21	3.40	0.00	0	80
6	Replacement of IE1 motors with IE3 in glaze ball mill	4,731		0.41	0.32	1.32	49	4
7	Retrofit of VFD in glaze ball mill	8,512		0.73	0.58	1.50	31	8
8	Operational pressure optimization in compressor	14,784		1.27	1.00	Nil	Immediate	13
9	Replacement of inefficient light with EE lights	10,407		0.89	0.71	0.79	13	9
10	Cable loss minimization	3,912		0.34	0.27	0.32	14	3
11	Replacement of V belt with REC (Raw edged cogged) belt	16,015		1.38	1.09	2.97	33	14
12	Energy management system	51,640	171	98.28	18.87	3.96	3	407
	Total	**161,548**	**1,026**	**578**	**103**	**50**	**6**	**2,315**

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

1 Reduction in energy cost by 10.95%
2 Reduction in electricity consumption by 6.26%
3 Reduction in coal consumption by 12%
4 Reduction in greenhouse gas emissions by 11.36%

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	Internal Rate of Return	Discounted Payback Period
		Lakh Rs	%	Months
1	Excess air control kiln 1	18.48	59%	5.61
2	Excess air control kiln 2	18.48	229%	1.57
3	Insulation in recuperator and indirect cooling zone pipes in kiln 1	0.92	208%	1.71
4	Insulation in recuperator and indirect cooling zone pipes in kiln 2	1.06	254%	1.40
5	Preheating of combustion air through recuperator in kiln-2	-		-
6	Replacement of IE1 motor with IE3 in glaze ball mill	1.32	1%	16.99
7	Retrofit of VFD in glaze ball mill	1.50	7%	14.75
8	Operational pressure optimization in compressor	-		-
9	Replacement of inefficient light with EE lights	0.79	67%	5.07
10	Cable loss minimization	0.32	59%	5.51
11	Replacement of V belt from REC (Raw edged cogged) belt	2.97	17%	11.58
12	Energy Management system	3.96	355%	1.01

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	Sisam Ceramic Pvt. Ltd.		
Plant Address	Behind Satnam cera, 8-A, Lalpar, Morbi - 2, Gujarat - India.		
Constitution	Private Limited		
Name of Promoters	Mr. Nilesh Patel		
Contact person	Name	Mr. Harshad Patel	
	Designation	Director	
	Tel	9979840666	
	Fax		
	Email	harshad@sisamceramic.in	
Year of commissioning of plant	2014		
List of products manufactured	Wall tile, 300 x 300 mm Wall tile, 300 x 600 mm Wall tile, 300 X450 mm Wall tile, 250 X 380 mm		
Installed Plant Capacity	11,000 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	365	
	Hours/Day	24	
	Shifts /Day	2	
Number of employees	Staff	25	
	Worker	50	
	Casual labor	40	
Details of energy consumption	Source	Yes/No	Areas of Use
	Electricity (kWh)	Yes	Entire Process and Utility
	Coal (kg)	Yes	Only in kiln
	Diesel (litres)	Yes	DG – Rarely used
	Natural gas (scm)	Yes	Only in Kiln
	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.

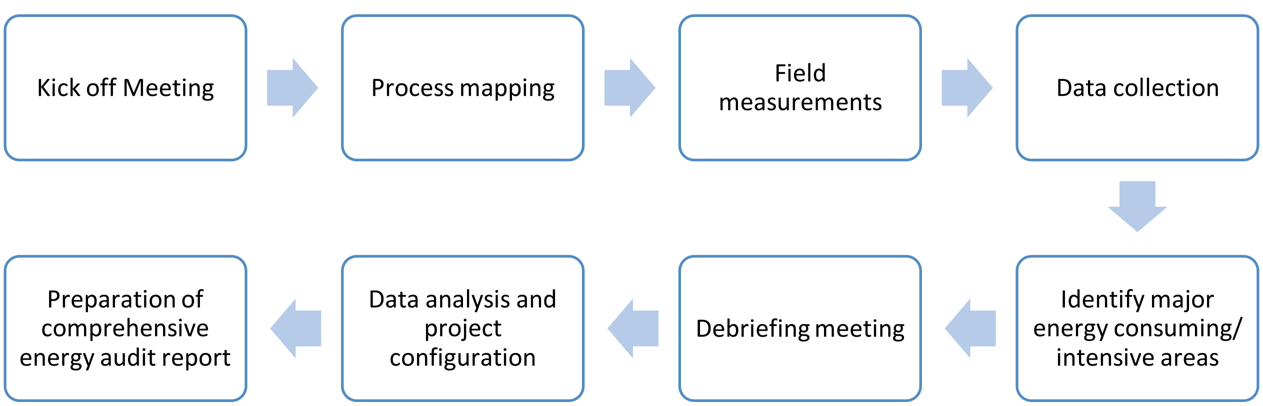


Figure 1: General methodology

The field work was carried out during 5th-6th 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 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and Flue gas temperature, Ambient temperature
6	Digital Temperature and Humidity Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

This detailed energy audit report has been organized and presented sequentially 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 monitoring practices.
- Chapter 6 covers information on renewable energy assessment in the unit.

2 CHAPTER – 2 PRODUCTION AND ENERGY CONSUMPTION

2.1 MANUFACTURING PROCESS WITH MAJOR EQUIPMENT INSTALLED (FLOW DIAGRAM)

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

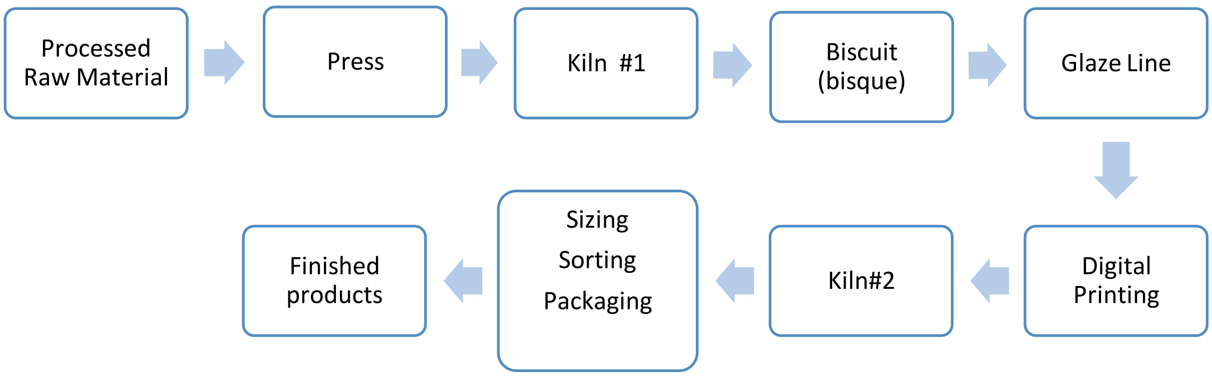


Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is Clay Powder, is coming from outside.
- Clay in powdered form is stored in silos have capacity of 24 hours requirement and then conveyed to hydraulic press machine by conveyors where it is pressed and tiles is formed of required size, output of press is called biscuit.
- Biscuit is then baked in kiln-1 at about 1050 °C–1150 °C and then cooled to room temperature.
- This is followed by the glazing process and digital printing.
- After this the glazed product make a passage through kiln -2 at 1,150-1,200°C for final drying and hardening.
- Output of kiln is called tiles; these tiles are then passed through cutting, sizing and polishing machines to match exact dimensions required.
- After sizing tiles are packed in boxes and then dispatched..

The major energy consuming equipment in the plant are:

- **Glaze ball mill:** For producing glazing material used on tiles.
- **Air compressor:** Pressurized air is used at several locations in a unit viz. instrument air, air cleaning, glazing etc.
- **Hydraulic Press:** Clay in powdered form is stored in silos for 24 hours and then conveyed to hydraulic press machine where it is pressed and tiles is formed of required size, output of hydraulic press is called biscuit.
- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.
- **Kiln:** The kiln is the main energy consuming equipment where the product is passed twice, once in biscuit form and second time after glazing and printing. The kilns are about 150 m long and

the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150°C to 1,200°C depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further gone for sizing, finishing and quality tested and packed for dispatch.

- **Sizing machine and packing:** Output of kiln is called tiles; these tiles are passed through cutting, sizing and polishing machines to match exact dimensions required.

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/box	Area per box	Pieces per box
	mm x mm	kg	Sq m	#
Wall Tiles	300 x 300	11	0.81	9
Wall Tiles	300 x 450	14.5	0.81	6
Wall Tiles	300 x 600	14	0.9	5
Wall Tiles	250 x 380	9	0.76	8

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

Table 6: Month wise production

Period	Number of Boxes				Corresponding Area (m^2)				Corresponding Mass (MT)			
	300 x 300	300 x 450	300 x 600	250x 380	300 x 300	300x 450	300 x 600	250 x 380	300 x 300	300 X 450	300 X 600	250 x 380
Oct-17	19,480	122,754	54,062	-	15,779	99,431	48,656	-	214	1,780	757	-
Nov-17	7,593	77,352	87,365	-	6,150	62,655	78,629	-	84	1,122	1,223	-
Dec-17	11,559	86,386	62,361	-	9,363	69,973	56,125	-	127	1,253	873	-
Jan-18	15,963	92,101	69,889	6,438	12,930	74,602	62,900	4,893	176	1,335	978	58
Feb-18	10,038	107,676	62,296	-	8,131	87,218	56,066	-	110	1,561	872	-
Mar-18	13,154	108,716	75,346	-	10,655	88,060	67,811	-	145	1,576	1,055	-
Apr-18	8,003	61,848	16,653	2,720	6,482	50,097	14,988	2,067	88	897	233	24
May-18	9,663	103,403	84,378	-	7,827	83,756	75,940		106	1,499	1,181	-
Jun-18	14,479	121,887	91,220	-	11,728	98,728	82,098		159	1,767	1,277	-
Jul-18	17,294	125,936	51,219	-	14,008	102,008	46,097		190	1,826	717	-
Aug-18	12,146	111,533	83,666	-	9,838	90,342	75,299		134	1,617	1,171	-
Sep-18	13,204	114,006	86,696	-	10,695	92,345	78,026		145	1,653	1,214	-
Average	10,299	83,268	61,886	994	12,715	102,800	68,763	763	140	1,491	963	7
	39,112				46,260				650			

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 coal gasifier to generate coal gas fed to kiln.
  - NG (Natural Gas) for kiln only during the maintenance period of 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	175.15	19.7	222	4.8
Thermal-Coal	714.14	80.3	4,360	95.2
Total	889.29	100	4,582	100

This is shown graphically in the figures below:

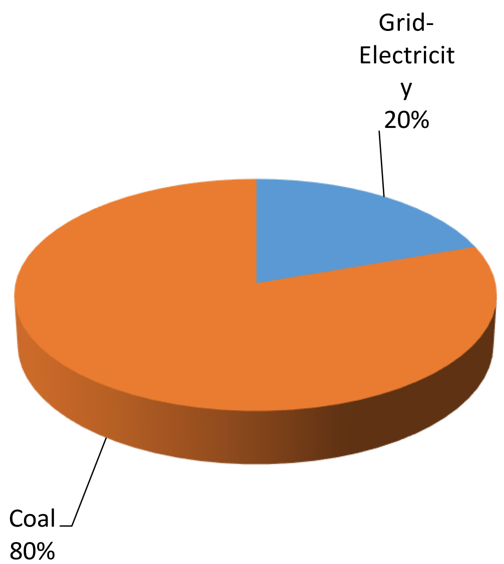


Figure 3: Energy cost share

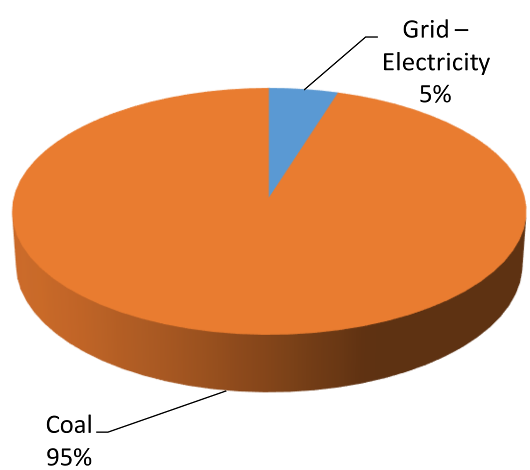


Figure 4: Energy use share

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 20% of the energy cost and 5% of the overall energy consumption.
- Source of thermal energy is from combustion of coal, which is used for generate coal gas which in turn used as a fuel in both kilns.
- Coal used in coal gasifier to generate coal gas, account for 80% of the total energy cost and 95% of overall energy consumption.
- During DEA, coal gasifier was under maintenance and to meet the thermal requirement, NG was used as a fuel in both kilns. There was no NG consumption during the period Oct-17 to Sep-18.

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	26880
Tariff Category	HTP-I
Contract Demand, kVA	475
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	4.2
Peak Hours	0.85
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	196,575	1,359,809	6.92
Nov-17	228,020	1,554,417	6.82
Dec-17	192,335	1,315,381	6.84
Jan-18	212,653	1,448,850	6.81
Feb-18	226,395	1,518,293	6.71
Mar-18	211,085	1,421,119	6.73
Apr-18	157,890	1,079,150	6.83
May-18	214,905	1,471,344	6.85
Jun-18	241,973	1,646,422	6.80
Jul-18	231,520	1,562,511	6.75
Aug-18	229,123	1,542,677	6.73
Sep-18	239,545	1,594,650	6.66

Average electricity consumption is 215,168 kWh/month and cost is Rs 14.82 Lakhs per month. The average cost of electricity is Rs. 6.79/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.

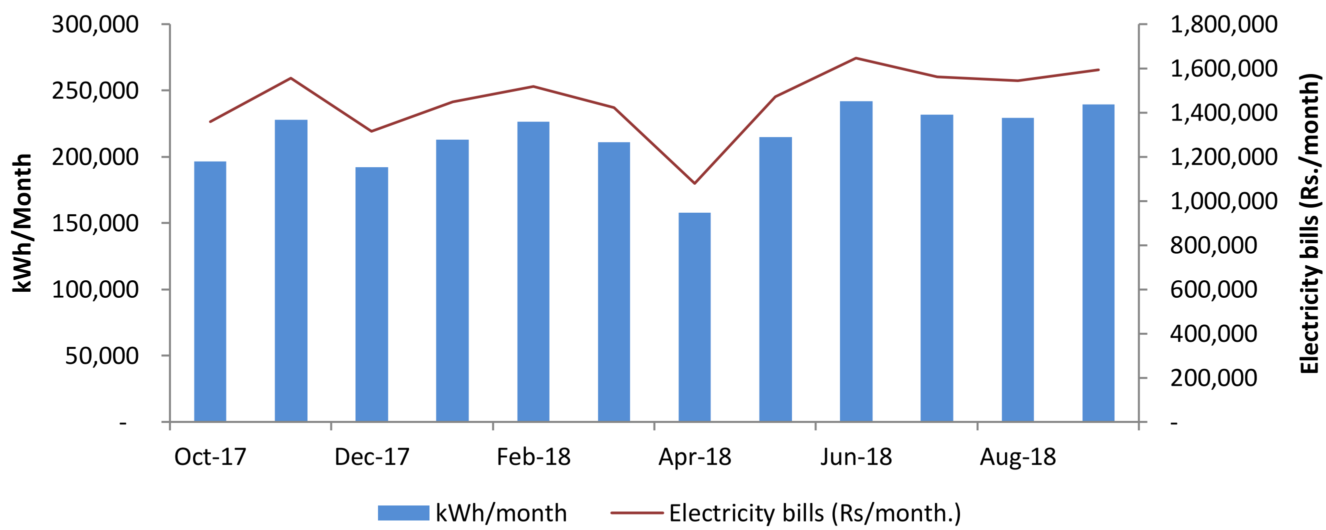


Figure 5: Month wise Variation in Electricity Consumption

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

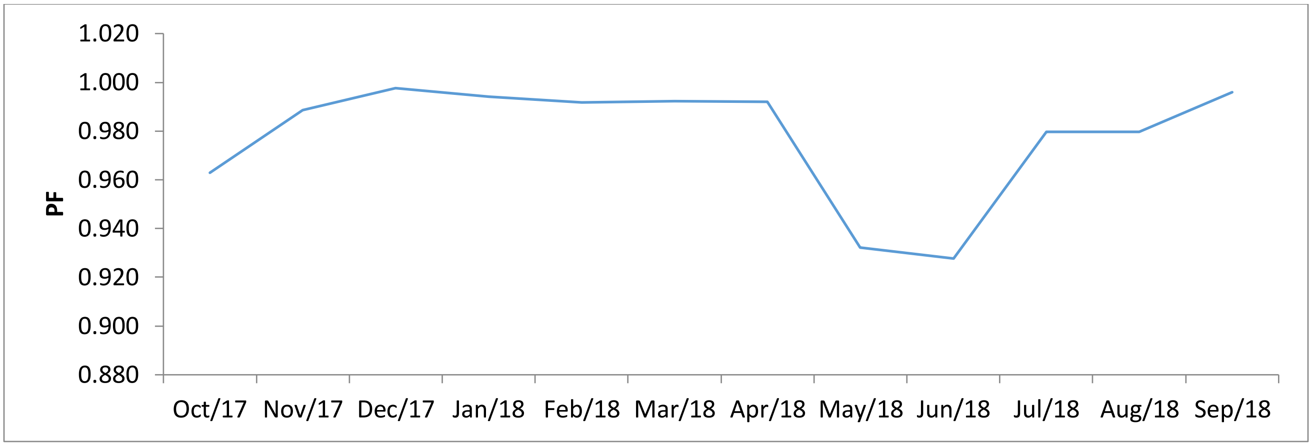


Figure 6: Month wise variation in Power Factor

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 0.98 with the minimum being 0.96 and the maximum being 1.00.

Maximum Demand: Maximum demand as reflected in the utility bill is 445 kVA from the bill analysis.

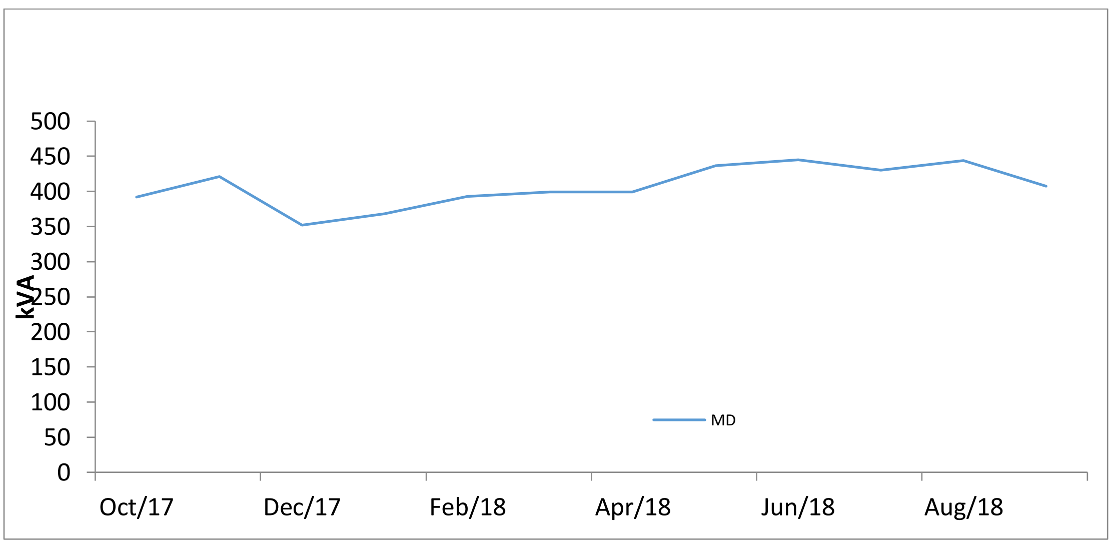


Figure 7: Month wise variation in Maximum Demand

2.2.1.4 Single Line Diagram

Single line diagram of plant is shown in below figure:

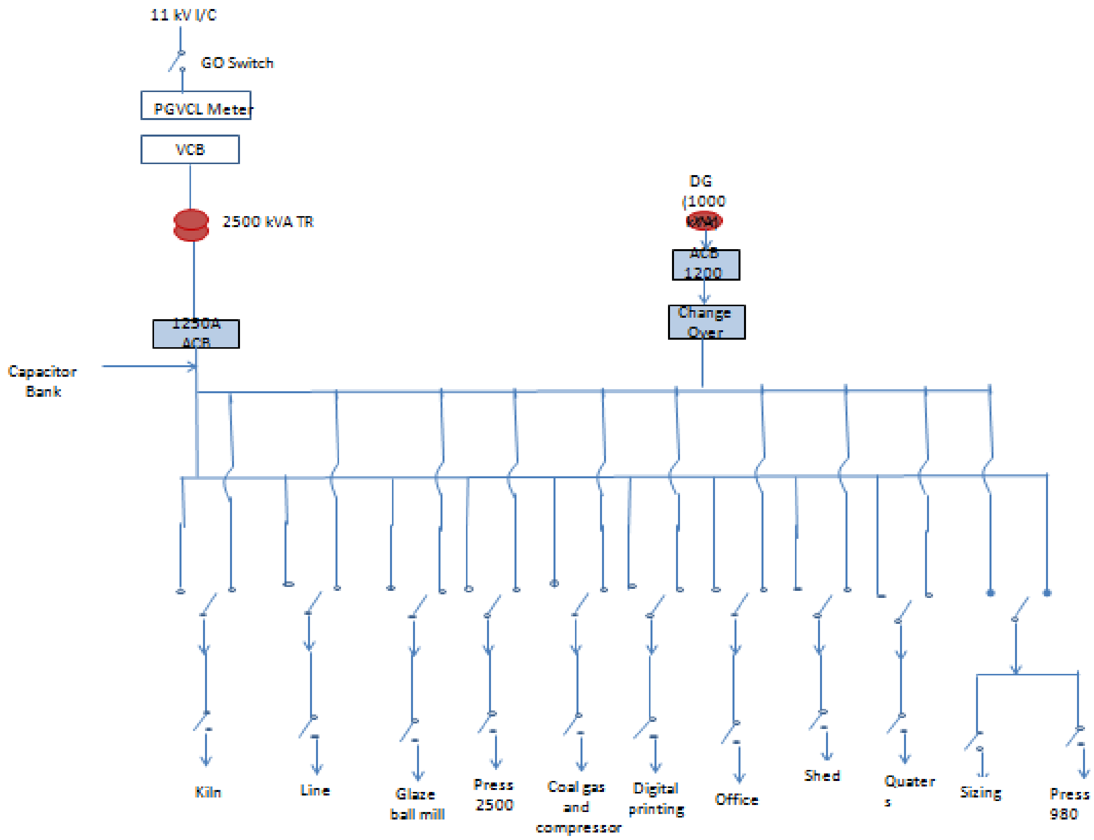


Figure 8: SLD of Electrical Load

2.2.1.5 *Electricity consumption areas*

The plant total connected load is 913.2 kW, which includes:

- The plant and machinery load is 848.73 kW
- The utility load (fan and lighting) is about 64.48 kW including the single phase load

Table 11 : Equipment wise connected load

Sl. No.	Equipment	Numbers	Total capacity(kW)
1	Compressors	1	37
2	Presses	2	130
3	Press Cooling Towers	1	11
4	Glazed tiles Kiln	1	170.5
5	Dryer	1	61
6	Biscuit Kiln	1	193
7	Sizing Machine 1	2	50.5 each
8	Glaze Ball Mill	3	67.75
9	Glaze line	1	125
10	Lights	594	16.4
	Total	607	913.2

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

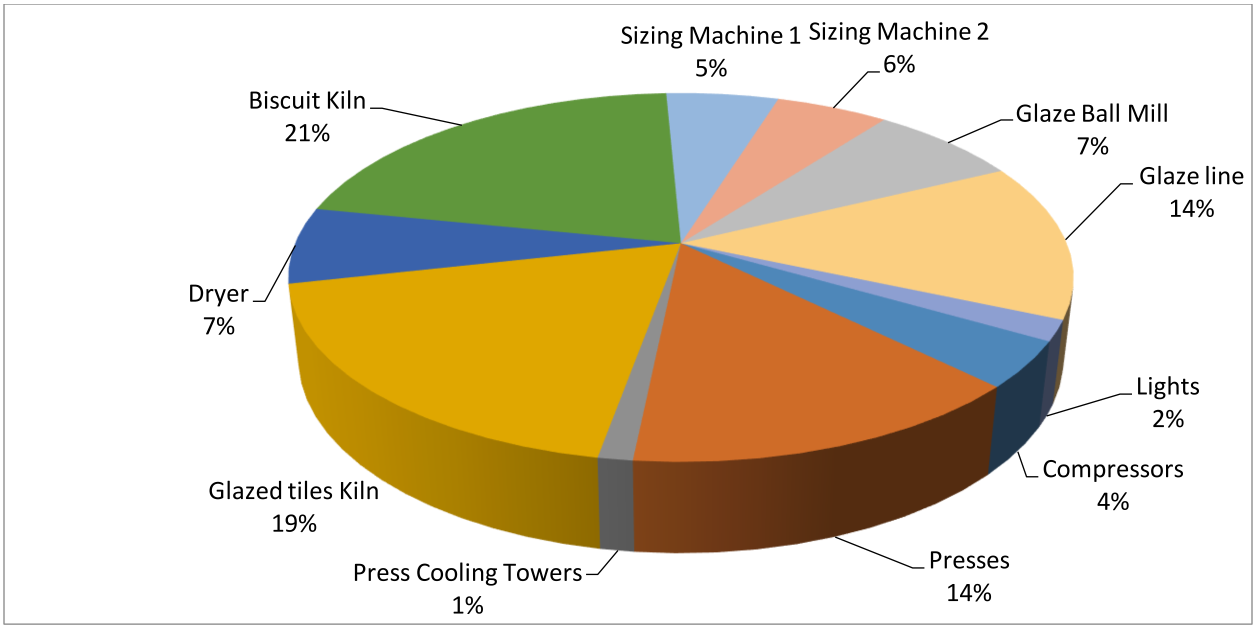


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for the kilns – 40 %, followed by presses and glaze line 14% , sizing – 11 %, dryer – 7%, Glaze mills – 7%. 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:

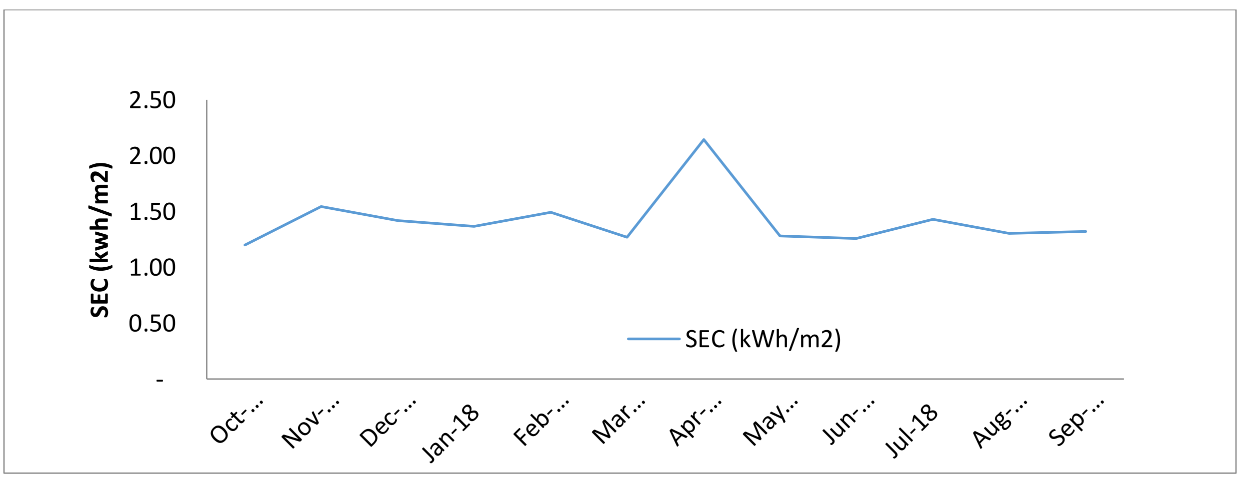


Figure 10: Month wise variation in Specific Electricity Consumption

The month, Apr-18 is outliers. Excluding this month, the maximum and minimum values are within ±20% of the average SEC of 1.42kWh/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 glaze ball mill section, press section, biscuits kiln, glaze kiln, utility like compressor, pumps etc.

2.2.2 Analysis of Thermal Energy Consumption

2.2.2.1 Month wise fuel consumption and cost

The thermal consumption areas are the kilns. Coal is used as fuel for coal gasifier to generate coal gas used in kiln 1 and in kiln 2. Coal is purchased from local coal suppliers who in turn import coal from Indonesia. An NG connection is also available for use in the kilns (including a separate set of burners.)

During DEA, The coal gasifier of unit was under maintenance. Hence to fulfill the thermal energy requirements, NG was being used from end Oct-18 in both the kilns. NG is purchased from GSPC (Gujarat State Petroleum Company).

Table 12: Month Wise Fuel Consumption and Cost

Month	Kiln-1 (biscuit)			Kiln -2 (Glaze)		
	Coal Used	Coal Cost	Coal Cost	Coal Used	Coal Cost	Coal Cost
	MT	Rs	Rs/MT	MT	Rs	Rs/MT
Oct-17	384	3,460,158	9,000	341	3,068,442	9,000
Nov-17	361	3,249,324	9,000	320	2,881,476	9,000
Dec-17	56	506,574	9,000	50	449,226	9,000
Jan-18	388	3,494,025	9,000	344	3,098,475	9,000
Feb-18	389	3,499,272	9,000	345	3,103,128	9,000
Mar-18	434	3,903,768	9,000	385	3,461,832	9,000
Apr-18	259	2,332,530	9,000	230	2,068,470	9,000
May-18	427	3,844,620	9,000	379	3,409,380	9,000
Jun-18	418	3,763,530	9,000	371	3,337,470	9,000
Jul-18	416	3,741,588	9,000	369	3,318,012	9,000
Aug-18	381	3,430,584	9,000	338	3,042,216	9,000
Sep-18	292	2,623,500	9,000	259	2,326,500	9,000
Total	4,205	37,849,473		3,729	33,564,627	

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 579 MT and average cost is Rs 9,000/MT.
- NG is used only when coal gasifier is under maintenance. The daily consumption of NG used in unit during the period preceding the DEA is given below:

Table 13 : Daily NG consumption and cost

Date	Kiln-1 (biscuit)			Kiln -2 (Glaze)		
	NG Used	NG Cost	NG Cost	NG Used	NG Cost	NG Cost
	scm	Rs	Rs/scm	scm	Rs	Rs/scm
16/11/2018	5,363	233,399	43.5	4,388	190,962	43.5
17/11/2018	5,418	233,399	43.1	4,433	190,963	43.1
18/11/2018	5,574	238,181	42.7	4,561	194,875	42.7
19/11/2018	5,304	226,711	42.7	4,339	185,491	42.7
20/11/2018	5,349	228,639	42.7	4,377	187,068	42.7
21/11/2018	6,012	260,409	43.3	4,919	213,062	43.3
22/11/2018	6,110	264,782	43.3	4,999	216,640	43.3
23/11/2018	6,391	277,704	43.5	5,229	227,213	43.5
24/11/2018	6,203	269,127	43.4	5,076	220,195	43.4
25/11/2018	6,252	271,767	43.5	5,116	222,355	43.5
26/11/2018	6,297	272,113	43.2	5,152	222,638	43.2
27/11/2018	5,460	232,438	42.6	4,467	190,177	42.6
28/11/2018	4,878	208,205	42.7	3,991	170,349	42.7
29/11/2018	4,757	202,826	42.6	3,892	165,948	42.6
30/11/2018	4,846	206,038	42.5	3,965	168,576	42.5
Average	5,614	241,716		4,594	197,767	

The average cost of NG for kilns is Rs 43.0/scm.

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:

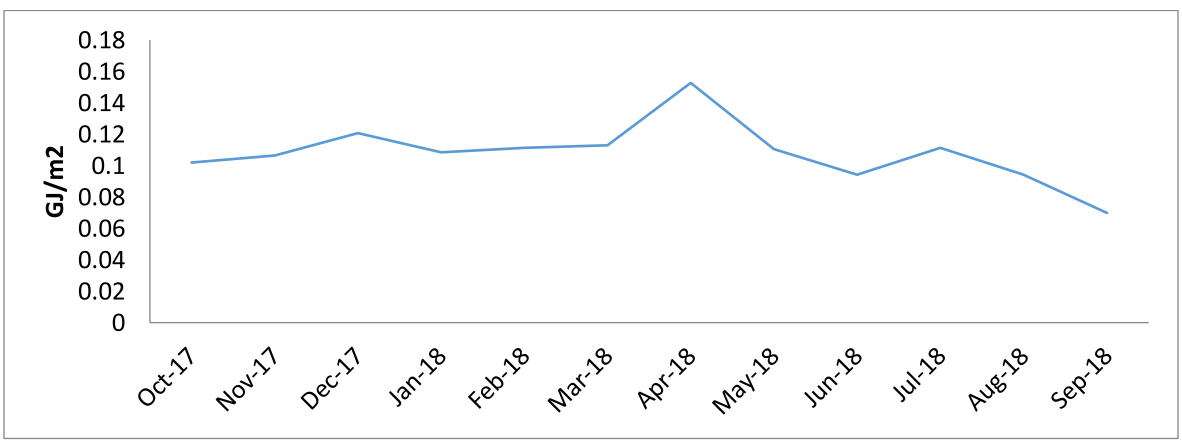


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.107GJ/m^2 for the kilns. Excluding the month of Apr-18, the coal consumption varied between 0.06 – 0.12 GJ/m^2 and was within ±10% of the average value. The SFC for coal varied between 0.12 and 0.06 GJ/m^2 which is a very wide variation.

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 14: Specific energy consumption

Particulars	Units	Value
Average production	m^2/h	234.5
Power consumption	kW	235
Coal consumption	kg/h	-
NG consumption	scm/h	425.3
Energy consumption	TOE/h	0.89
SEC of plant	TOE/m^2	0.0038

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 15: Section wise specific energy consumption (per unit production)

Particulars	NG	Coal	Electricity
	scm/t	kg/t	kW/t
Hydraulic press 980			12.21
Hydraulic press 2500			34.35
Biscuit kiln	55.0		5.097
Glaze kiln	47.8		4.139
Glaze ball mill			3.49
Sizing machine 1			4.32
Sizing machine 2			4.54

The above consumption parameters based on the detailed mass balance diagram as given in 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 16: Overall: specific energy consumption

Parameters	Units	Value
Annual grid electricity consumption	kWh/y	2,582,019
Self-generation from DG set	kWh/y	-
Annual total electricity consumption	kWh/y	2,582,019
Annual thermal energy consumption (Imported Coal)	t/y	8,539
Annual thermal energy consumption (NG)	scm/y	0
Annual energy consumption	TOE	4,582
Annual energy cost	Rs. Lakh	944
Annual Production	m^2	1,872,397
	t	37,535

SEC; Electrical	kWh/ m^2	1.38
	kWh/t	68.8
SEC; Thermal	GJ/ m^2	1.05
	GJ/t	5.23
SEC; Overall	TOE/ m^2	0.0026
	TOE/t	0.13
SEC; Cost based	Rs./ m^2	50.40
	Rs./t	2,514

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

- Conversion Factors
  - Electricity from the Grid : 860 kcal/kWh
- GCV of NG : 9,000 kcal/scm
- GCV of Imported Coal : 5,495 kcal/kg
- CO_2 Conversion factor
  - Grid : 0.82 kg/kWh
  - Imported Coal : 2.116 t/t
  - NG : 0.001923 tCO_2/SCM

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 17: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs./ kWh	6.73
Cost of NG	Rs./scm	43
Cost of Coal	Rs./MT	9,000
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	1,872,397

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 purchase of water 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 100 m3/day as informed by unit consumed in glaze ball mill.

Water distribution diagram is shown below.

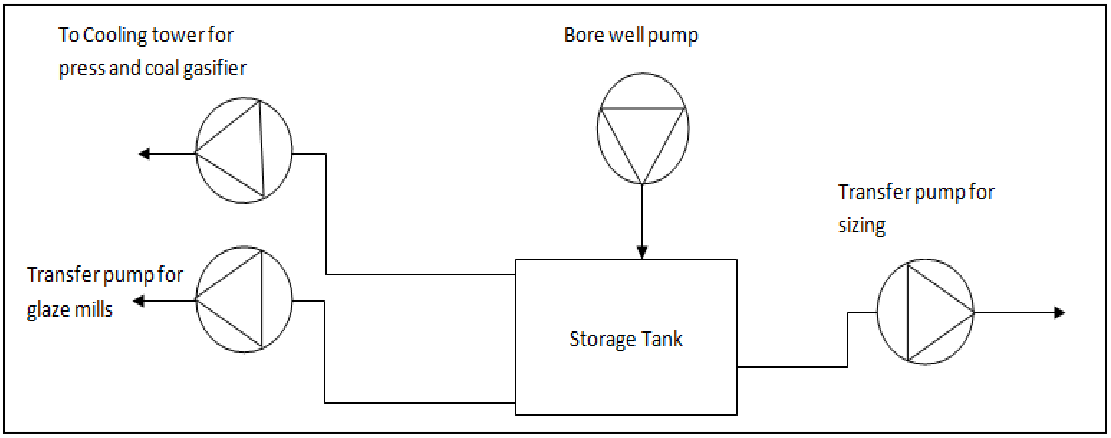


Figure 12: Water distribution diagram

Water are procured from bore well pump to meet the process requirements, having TDS of about 445 ppm. RO plant is installed to purify water and reduce TDS upto 100 ppm. This purified water used in glaze ball mill. Whereas ground water is having TDS of more than 1,000 ppm. Hence unit is not using ground water. Technical details of pumps are as follows:

Table 18: Press cooling water circulation pump details

Parameters	Unit	Cooling Water Pumps
Make	-	-
Motor rating	kW	5.5
RPM	rpm	2,900
Quantity	number	2

3 CHAPTER – 3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Coal gas from coal gasifier is the primary fuel in kiln - 1 (biscuit) and kiln – 2 to heat the ceramic tiles to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan). However, both the kilns have a separate set of burners, to use NG, when coal gas is not available. NG was being used during the energy audit, as the coal gasifier was under maintenance.

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. Connected electric load of Kiln-1 is 253.7 kW, it includes 61.17 kW electric load of dryer attached with kin – 1. Connected electric load of Kiln-2 is 170.5 kW.

Kiln - 1 consists of 30 kW smoke blower, 37 kW combustion blowers, 18.5 kW for rapid cooling blower, 37 kW for hot air blower, 22 kW for final cooling blowers. Kiln-1 also consists of a dryer who have 19 kW smoke blower and one booster blower of 37 kW & remaining electrical load includes 22 roller motor of 0.75 kW each.

Kiln-2 consists of 30 kW smoke blower, 19 kW combustion blowers, 18.5 kW for rapid cooling, 37 kW for Hot air blower, 22 kW for indirect cooling section, 22 kW for final cooling blowers and remaining electrical load of kiln roller motors (20 Nos.) is 15 kW.

Table 19: Kiln details

Sl. No	Parameter	Unit	Kiln-1	Kiln-2
	Make		Modena	Modens
1	Kiln operating time	h	24	24
2	Fuel Consumption	scm/h	233	191
3	Number of burner to left	-	76	60
4	Number of burner to right	-	76	60
5	Cycle Time	Minutes	70	60
6	Pressure in firing zone	mmWC	40	40
7	Maximum temperature	^oC	1,123	1,074
8	Waste Heat recovery option		Yes	Yes
9	Kiln Dimensions (Length X Width X Height)			
	Preheating Zone	m	16.8 x 3 x 1	35.7 x 3x 1
	Firing Zone	m	39.9 x 3 x 1	33.6 x 3 x 1
	Rapid Cooling Zone	m	6.3 x 3 x 1	8.4 x 3 x 1
	Indirect cooling Zone	m	12.6 x 3 x 1	14.7 x 3 x 1
	Final cooling zone	m	18.9 x 3 x 1	25.2 x 3 x 1

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. The kilns were being operated on NG. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 20: FGA study of kilns

Parameter	Kiln-1	Kiln-2
Oxygen Level measured in Flue Gas	7.5%	13.8%
Ambient Air Temperature	41°C	41°C
Exhaust Temperature of Flue Gas	150 °C	200 °C

From the above table, it is clear that the oxygen level measured in flue gas was high in both kilns. The inlet temperature of raw material in Kiln-1 was in the range of 40.2°C whereas in Kiln-2 it was in the range of 40.2 °C.

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

Table 21: Surface temperature of kilns

Kiln Surface Temperatures (°C)	Kiln-1	Kiln-2
Ambient Temperature	41.0	41.0
Pre-heating zone average surface temperature	54.5	44.2
Heating zone average surface temperature	75.8	63.9
Rapid cooling zone average surface temperature	68.5	65.4
Indirect cooling zone average surface temperature	60.5	78.6
Final cooling zone average surface temperature	55.8	58.9

The temperature profile of the kilns is shown below:

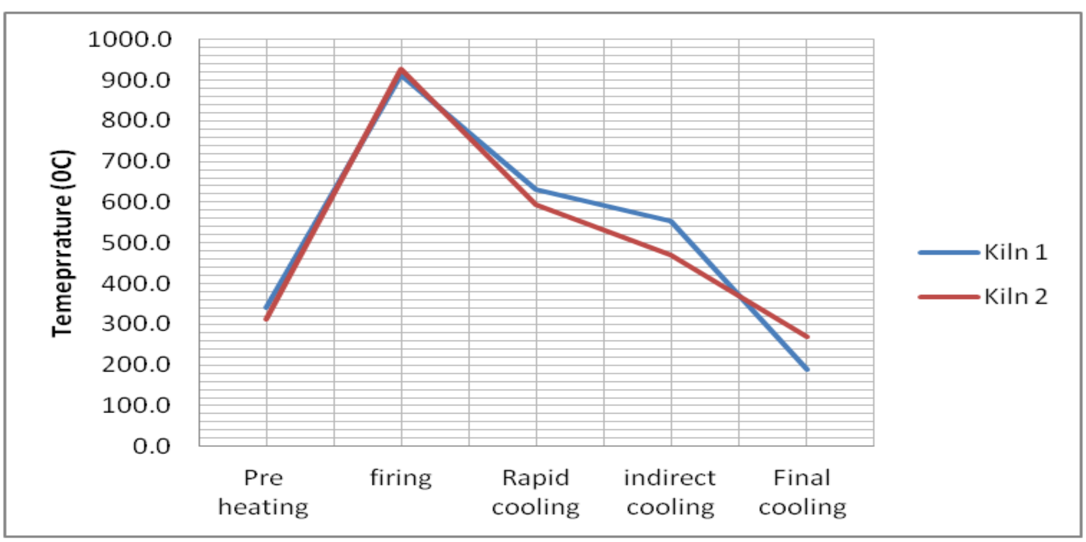


Figure 13: Temperature Profile of Kilns

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

Table 22: Power measurements of all blowers

Equipment	Kiln 1 Average Power (kW)	PF	Kiln 2 Average Power (kW)	PF
Final Cooling Blower	1.92	1	1.73	0.997
hot air Blower	2.74	0.989	1.86	0.991
Rapid Cooling Blower	2.16	0.994	1.65	0.996
Smoke Blower	4.46	0.996	4.99	0.990
Combustion Blower	7.42	0.995	2.41	0.998

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Heat utilized by the kiln-1 is 42.9% and kiln-2 53.5%. Summary of all losses is shown in below figure:

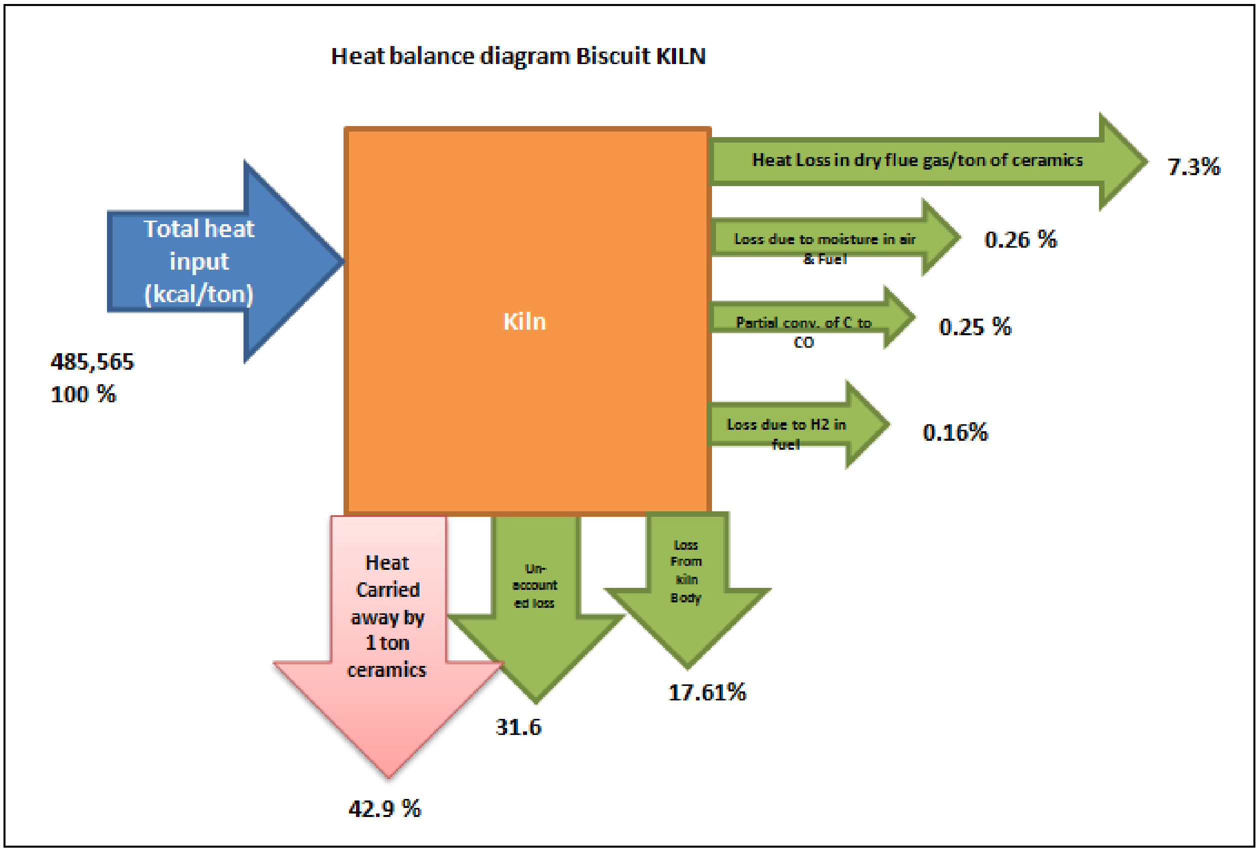


Figure 14: Heat balance diagram of Kiln-1

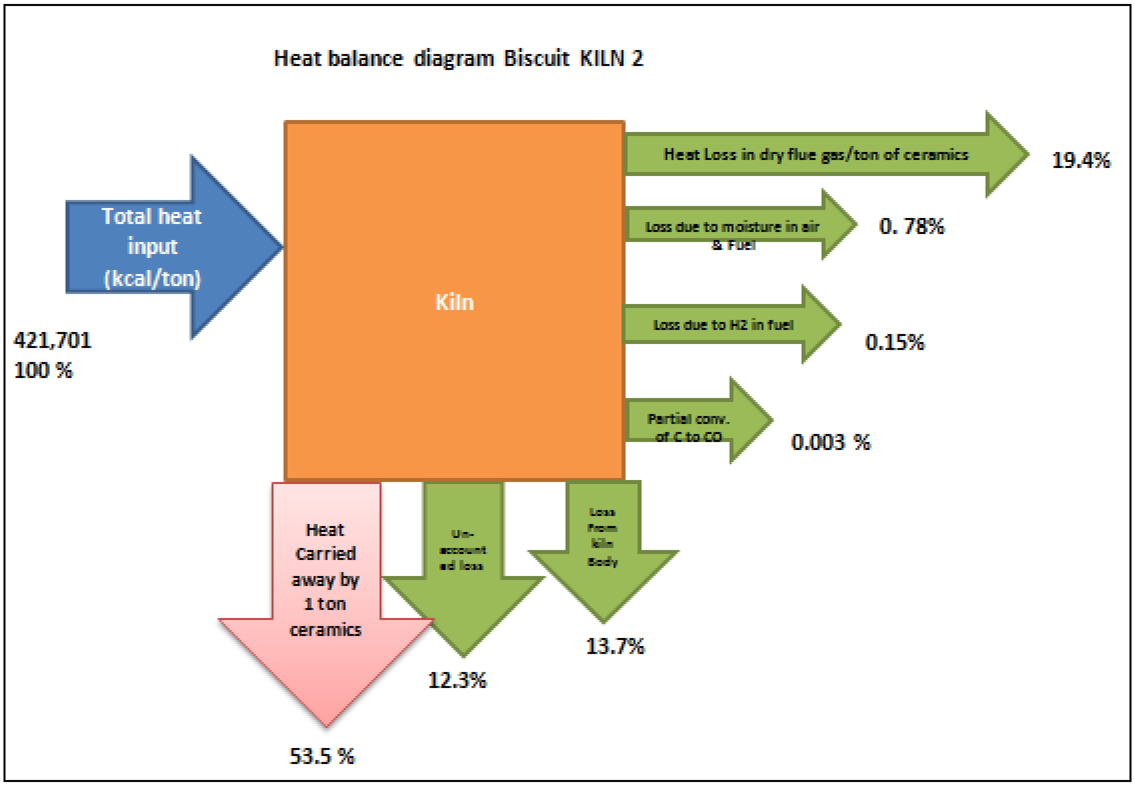


Figure 15: Heat balance diagram of Kiln-2

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 kiln 1 (Biscuit)

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 Kiln-1 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 Kiln 1 (biscuit kiln) oxygen level is 7.5% which is to be controlled. The oxygen level in the flue gas when operating on coal gas would also be different when working on NG - it is recommended to maintain the oxygen level at 5.0%, as against 3.0% with NG. The savings in terms of coal gas have been estimated considering a kiln heat utilization of 41.2% when using coal gas as against 42.9% when working with NG in kiln 1 (biscuit). Heat utilization by kiln 1 when operating on coal gas was found to be in the range of 35% to 41.2% in other units where energy audit was done. The basis for the savings NG which has higher cost as compared to coal gas. In order to be conservative in the estimate of savings, the highest efficiency value of coal gas kiln has been considered.

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

Table 23: Cost benefit analysis for Kiln 1 (ECM-1)

Parameters	UOM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	7.5	3.0
Excess air percentage in flue gas	%	55.4	16.7
Dry flue gas loss	%	7%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	55	53
Average production in Kiln	t/h	4.3	4.3
Saving in specific fuel consumption	scm/h		9.07
Operating hours per day	h/d		330
Annual operating days	d/y		24
Annual natural gas (NG) saving	scm/y		71,837
Ratio of scm of coal gas to scm of NG considering efficiency of 42.9% for NG and 41.2% for coal gas			8
Annual coal gas savings	scm/y		548,833
Coal gas produced per kg of coal consumption	scm/kg		3.87
Annual coal savings	kg/y		141,868

Parameters	UOM	Present	Proposed
Coal cost	Rs/kg		9
Annual fuel cost saving	Lakh Rs/y		12.8
Power saving in combustion blower			
Mass flow rate of air	t/h	4.57	3.43
Density of Natural gas	kg/m^3	0.73	
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m3/s	1.0	0.8
Measured power of blower	kW	7.42	3.14
Total power saving	kW		4.28
Operating days per year	d/y		24
Operating hours per day	h/d		330
Annual energy saving	kWh/y	33,919	
Weighted electricity cost	Rs/kWh	6.79	
Annual energy cost saving	Lakh Rs/y	2.30	
Overall energy cost saving	Lakh Rs/y	14.71	
Estimated investment	Lakh Rs	18.48	
Payback period	Months	15.52	
IRR	%	59%	
Discounted payback period	Months	5.6	

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

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 Kiln-2 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 Kiln 2 (Glaze kiln) oxygen level is 13.4% which is to be controlled.

The oxygen level in the flue gas when operating on coal gas would also be different when working on NG - it is recommended to maintain the oxygen level at 5.0%, as against 3.0% with NG. The savings in terms of coal gas have been estimated considering a kiln heat utilization of 41.2% when using coal gas as against 53.5% when working with NG in kiln 2 (Glaze). Heat utilization by kiln - 2 when operating on coal gas was found to be in the range of 35% to 41.2% in other units where energy audit was done. The basis for the savings NG which has higher cost as compared to coal gas. In order to be conservative in the estimate of savings, the highest efficiency value of coal gas kiln has been considered.

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

Table 24: Cost benefit analysis for Kiln 2 (ECM-2)

Parameters	UoM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	13.4	3.0
Excess air percentage in flue gas	%	175.0	16.7
Dry flue gas loss	%	19%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	48	40
Average production in Kiln	t/h	4.0	4.0
Saving in specific fuel consumption	scm/h		30.30
Operating hours per day	h/d		330
Annual operating days	d/y		24
Annual natural gas (NG) saving	scm/y		239,949
Ratio of scm of coal gas to scm of NG considering efficiency of 53.5% for NG and 41.2% for coal gas			10
Annual coal gas savings	scm/y		2,349,101
Coal gas produced per kg of coal consumption	scm/kg		3.87
Annual coal savings	kg/y		607,219
Coal cost	Rs/kg		9
Annual fuel cost saving	Lakh Rs/y		54.6
Power saving in combustion blower			
Mass flow rate of air	t/h	6.62	2.81

Parameters	UoM	Present	Proposed
Density of natural gas	kg/m^3	0.73	0.73
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m3/s	1.5	0.6
Measured power of blower	kW	2.41	0.18
Total power saving	kW		2.23
Operating days per year	d/y		24
Operating hours per day	h/d		330
Annual energy saving	kWh/y	17,629	
Weighted electricity cost	Rs/kWh	6.79	
Annual energy cost saving	Lakh Rs/y	1.20	
Overall energy cost saving	Lakh Rs/y	55.85	
Estimated investment	Lakh Rs	18.48	
Payback period	Months	3.97	
IRR	%	229%	
Discounted payback period	Months	1.57	

3.1.4.3 Energy conservation measures (ECM) - ECM #3 Hot face insulation in recuperator pipes of Kiln-1

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 are made by combination of insulation layers and cladding, with the objective of retaining the desired temperature of air inside the pipes and avoid losses from pipe walls.

Study and investigation

There are 24 un-insulated pipes in recuperator in rapid cooling zone and 60 pipes in indirect cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80^{o}C and it was measured as 135˚C and 139°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^{o}C to reduce the heat loss due to radiation and convection and utilize the useful heat. As coal gas is primary fuel in kiln – 1 and during DEA, NG was being used, the savings in coal gas is estimated as described in ECM – 1. The amount of heat lost through radiation and convection in each zone is given in the table below.

The cost benefits analysis for insulation in recuperator pipes are given below:

Table 25: Cost benefit analysis for hot face insulation in kiln - 1(ECM-3)

Parameter	Unit	Present	Proposed
No of un-insulated pipe in recuperator	#	24	24
No of un-insulated pipe in indirect cooling zone	#	60	60
pipe size in rapid zone	mm	64	64
Pipe length in rapid zone	m	2.0	2.0
Pipe size in indirect cooling zone	mm	45	45
Pipe length in indirect cooling zone	m	0.50	0.50
Rapid zone surface area	m^2	9.59	9.59
indirect cooling zone surface area	m^2	4.19	4.19
Average surface temperature of pipes in indirect cooling zone	°C	139	70
Average surface temperature of pipes in rapid zone	°C	135	70
Ambient air temperature	°C	35	35
Heat loss in firing zone	$kcal/h/m^2$	1,581	411
Heat loss in rapid zone	$kcal/h/m^2$	1,500	411
Heat loss in firing zone	kcal/h	6,630	1,725
Heat loss in rapid zone	kcal/h	14,386	3,944
Total heat loss	kcal/h	21,016	5,669
GCV of fuel	kcal/scm	8,829	8,829
Heat loss in terms of fuel	scm/h	2.4	0.6
Fuel saving	scm/h		1.7
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual natural gas (NG) saving	scm/y		13,766
Ratio of GCV of NG to GCV of coal gas			8
Annual coal gas savings	scm/y	125,856	
Coal gas produced per kg of coal consumption	scm/kg	4	
Annual coal savings	kg/y	32,532	
Coal cost	Rs/kg	9	
Annual fuel cost saving	Rs Lakh/y	2.93	
Estimated investment	Rs Lakh	1.1	
Simple payback period	Months	4.33	
IRR	%	208%	
Discounted Payback period	Months	2	

3.1.4.4 Energy conservation measures (ECM) - ECM #4 Hot face insulation in recuperator pipes of Kiln-2

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.

Recuperator pipes are 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 24 uninsulated pipes in recuperator in rapid cooling zone and 102 pipes in indirect cooling zones. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 160°C and 117 °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. As coal gas is primary fuel in kiln – 2 and during DEA, NG was being used, the savings in coal gas is estimated as described in ECM – 2.

The amount of heat lost through radiation and convection in each zone is given in the table below.

Table 26: Cost benefit analysis (ECM-4)

Parameter	UoM	Present	Proposed
No of un-insulated pipe in recuperator	#	20	20
No of un-insulated pipe in indirect cooling zone	#	102	102
pipe size in rapid zone	mm	89	89
Pipe length in rapid zone	m	2.0	2.0
Pipe size in indirect cooling zone	mm	45	45
Pipe length in indirect cooling zone	m	0.40	0.40
Rapid zone surface area	m^2	11.20	11.20
indirect cooling zone surface area	m^2	5.70	5.70
Average surface temperature of pipes in indirect cooling zone	°C	160	70
Average surface temperature of pipes in rapid zone	°C	117	70
Ambient air temperature	°C	35	35
Heat loss in firing zone	$kcal/h/m^2$	2,024	411
Heat loss in rapid zone	$kcal/h/m^2$	1,156	411
Heat loss in firing zone	kcal/h	11,543	2,346
Heat loss in rapid zone	kcal/h	12,946	4,605
Total heat loss	kcal/h	24,489	6,950
GCV of fuel	kcal/scm	8,829	8,829
Heat loss in terms of fuel	scm/h	2.8	0.8
Fuel saving	scm/h		2.0
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual Natural gas (NG) saving	scm/y		15,732
Ratio of NG to GCV of Coal gas			10

Parameter	UoM	Present	Proposed
Annual Coal gas savings	scm/y	154,016	
Coal gas produced per kg of Coal consumption	scm/kg	4	
Annual coal savings	kg/y	39,811	
Coal cost	Rs/kg	9	
Annual fuel cost saving	Rs Lakh/y	3.58	
Estimated investment	Rs Lakh	1.1	
Simple payback period	Months	3.5	
IRR	%	254%	
Discounted Payback period	Months	2	

3.1.4.5 Energy conservation measures (ECM) - ECM #5 Preheating of combustion air through recuperator in kiln - 2

Technology description

The recuperator is present just after the firing zone. Recuperator is used to utilize heat from the flue gas to preheat the combustion air before entering in firing zone.

Study and investigation

During energy audit, it was found that the recuperator was bypassed. So, 80% of combustion air was entered in firing zone at 50.6 °C and only 20% was preheated in recuperator.

Recommended action

It is recommended to take recuperator into service to increase combustion air temperature upto 105 °C by changing bypass valve position to 80%. As coal gas is primary fuel in kiln – 2 and during DEA, NG was being used, the savings in coal gas is estimated as described in ECM – 2.

The cost benefit analysis is given below:

Table 27: Cost benefit analysis (ECM-5)

Parameter	UoM	Present	Proposed
Equipment	#	Kiln 2	
Measured air velocity	m/s	1.45	1.45
Blower air inlet area	m^2	0.27	0.27
Actual volume of supplied air	m^3/s	0.39	0.39
Actual air delivered	CFM	833	833
Hot air damper opening % to combustion blower	%	20	80
Combustion air temperature	°C	50.6	105
Ambient air temperature	°C	45	45
Specific heat of air	kcal/kg °C	0.24	0.24
Density of air	kg/m^3	0.90	0.90
GCV of Fuel	kcal/SCM	8,829	8,829
Additional fuel required	SCM/h		2

Parameter	UoM	Present	Proposed
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	scm/y		14,918
Ratio of GCV of NG to GCV of coal gas			10
Annual Coal gas savings	scm/y	146,050	
Coal gas produced per kg of coal consumption	scm/kg	4	
Annual coal savings	kg/y	37,752	
Coal cost	Rs/kg	9	
Annual fuel cost saving	Lakh Rs/y	3.40	
Estimated investment	Lakh Rs	Nil	
Payback period	months	Immediate	
IRR	%	-	
Discounted payback period	months	-	

4 CHAPTER – 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 HYDRAULIC PRESSES

4.1.1 Specifications

There are 2 nos. of hydraulic presses. Hydraulic presses used to produce biscuit by pressing powders in moulds. The specifications of hydraulic presses and its accessories are given below:

Table 28: Specifications of hydraulic press

Particular	Units	Press - 1	Press - 2
Cycle (stock) per minute	N/m	7.1	3.4
Nos. of tiles per stock		2	4
Tile size	mm × mm	300 x 600	300 × 450
Tile thickness	mm	9	9
Tiles weight	kg	3.1	2.1
Power rating	kW	55	75
Water Circulation Pump	#	1	1

4.1.2 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.

Average power consumption of press 1 was 33 kW (PF 0.94) and press 2 was consuming 60.8 kW (P.F. 0.86). Two water circulation pumps were consuming power as 4.41 kW and 4.47 kW.

4.1.3 Observation and performance assessment

Both circulation pumps operate 24 hours in a day. However, when there is shutdown of press, the pump is not stopped. It is not advisable to regulate pump based on oil temperature as the temperature will suddenly rise if circulation pump is stopped.

Performance of hydraulic press is measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press 1 was 12.21kW/ton and that of the press 2 was 34.35kW/ton.

4.2 GLAZING

4.2.1 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 glaze ball mills are given below:

Table 29: Specifications of glazing machine

Particular	Units	Glaze mill
Numbers of glazing mills	Nos.	3
Capacity of glaze ball mill 1	Ton/batch	3
Capacity of glaze ball mill 2	Ton/batch	1
Capacity of glaze ball mill 3 (Engob)	Ton/batch	3
Connected load of glaze ball mill 1	kW	30
Connected load of glaze ball mill 2	kW	7.5
Connected load of glaze ball mill 3	kW	22

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of one glaze ball mill which was in operation.
- Mass consumption (t/batch) is as per Table 29

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

Table 30: Power consumption and P.F. of glaze mills

Equipment	kW	PF
Glaze ball mill 1	14	0.7

4.2.3 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 mill was 3.49kW/ton.

4.2.4 Energy conservation Measures

The energy conservation measures recommended are:

4.2.4.1 Energy conservation measures (ECM) - ECM #6: Replacement of IE1 motor of glaze ball mill with IE3

Technology description

The efficiency class of induction motor is IE1, IE2, IE3 and IE4. IE1 induction motors have standard efficiency and IE3 have premium efficiency motor as defined by international efficiency (IEC 60034-30-1). IE3 motors have higher efficiency than IE1 and IE2 motors.

Study and investigation

It was observed during the energy audit that the one glaze ball mills were in operation. The motors used in these glaze ball mills are IE1 class.

Recommended action

It is recommended to replace one out of three glaze ball mill IE1 motor with more efficient IE3 motor. The cost benefit analysis is given in the table below:

Table 31: Cost benefit analysis of ECM 6

Particular	Unit	Present	Proposed
		Glaze ball mill – 1	
Rated power of motor	kW	30	30
Motor efficiency class		IE1	IE3
Existing efficiency of motor	%	90.7	93.6
Existing power consumption	kW	14.00	13.10
Energy loss in motor	kW	1.3	0.4
Estimated energy saving	kW		0.9
Operating hours/day	d/y	330	330
Operating days/year	h/d	16	16
Annual energy consumption	kWh/y	73,920	69,189
Annual energy savings	kWh/y		4,731
Unit cost of electricity	Rs/kWh		6.79
Annual monetary savings	Lakh Rs/y		0.32
Estimated investment	Lakh Rs		1.32
Payback period	Months		49.33
IRR	%		1%
Discounted payback period	Months		17

4.2.4.2 Energy conservation measures (ECM) - ECM# 7: Retrofit of VFD in Glaze ball mill

Technology description

VFD is a type of adjustable-speed drive used in electro-mechanical drive systems to control motor speed by varying motor input frequency and voltage to cater the variable demand.

Study and investigation

During field measurement, it was found that glaze ball mill was running continuously irrespective of load requirement.

Recommended action

It is recommended to install VFD on glaze ball mills and thereby reduce energy consumption. The cost benefit analysis is given below:

Table 32 : Cost benefit analysis of retrofit in glaze ball mill (ECM 7)

Particulars	UOM	Present	Proposed
Motor capacity	kW	30	30
Measured motor power	kW	14.00	11.2
Working time	h	16	16
Annual working days	d	330	330
VFD saving	%		20
Annual energy consumption	kWh/y	73,920	65,408
Energy saving	kWh/y		8,512
Unit cost	Rs/kWh	6.79	6.79
Cost saving	Lakh Rs/y		0.58
Investment	Lakh Rs.		1.50
Simple payback Period	Months		31
IRR	%		7%
Discounted payback Period	Months		14.75

4.3 Sizing

4.3.1 Specifications

There was one 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 33: Specifications of sizing machine

Particular	Units	New sizing
Numbers of sizing machines	Nos.	2
Sizing Machine 1	kW	50.5
Sizing Machine 2	kW	50.5
Sizing line 1 – Conveyors	kW	2.98

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of each sizing machines
- Tile production in sizing section is 6 t/h.

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

Table 34 : Measured Parameters of sizing machine

Equipment	Unit	Value	PF
Average Power (M/c#1)	kW	17.3	0.57
Average Power (M/c#2)	kW	18.2	0.60

4.3.3 Observation and performance assessment

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

Table 35 : SEC of sizing machine

Equipment	Unit	Value
Sizing Machine # 1	kW/t	4.32
Sizing Machine # 2	kW/t	4.54

4.4 Air Compressors

4.5.1 Specifications

There is an air compressors are installed in plant. The specifications of compressors are given below:

Table 36: Specifications of compressors

Particular	Units	Air compressor
Power rating	kW	37
Maximum pressure	bar (a)	8
Rated Capacity	m^3/min	6.63

Compressors have an air receiver.

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of compressor
- Air flow rate

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

Table 37: Measured parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)
Compressor	20.74	0.939	2.75

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

4.5.3 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.

4.5.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.5.4.1 Energy conservation measures (ECM) - ECM #8: 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, sizing etc.

Study and investigation

It was told by plant in charge that set pressure of compressor observed during the energy audit that the operating pressure of compressor is 7.3 kg/cm^2.

Recommended action

As end user air pressure requirement is 4 kg/cm^2, it is recommended that the existing operating pressure setting of 7.5 kg/cm^2 be lowered to 6.0 kg/cm^2 which will reduce the energy consumption by 9%.

The cost benefit analysis is given in the table below:

Table 38: Cost benefit analysis (ECM-8)

Parameter	UoM	Present	Proposed
Compressor operating pressure	kg/cm²	7.5	6
Reduction in pressure	kg/cm²	-	1.5
% of energy saving	%	-	9%
Average load	kW	20.7	18.87
Average compressor operating hours per day	h/d	24	24
Compressor annual operating days	d/y	330	330
Annual energy consumption	kWh/y	164,263	149,479
Annual energy savings	kWh	-	14,784
Cost of electricity	Rs/kWh	6.79	6.8
Annual monetary saving	Rs Lakh/y	-	1.00
Estimated investment	Rs Lakh	-	Nil
Simple payback period	Months	-	Immediate
IRR	%		Nil
Discounted payback period	Months		Immediate

4.6 Water Pumping System

4.6.1 Specifications

Pumping system comprises three transfer pumps as shown in **Figure** 12.

4.6.2 Field measurement and analysis

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

- Power consumption of press heat exchanger circulating water pump
- Other pumps are having smaller size and internal corrosion problems.
- Flow could not be measured due to internal corrosion problems.

Power measured for pumps are given in below table:

Table 39: Measured parameters of pump

Particulars	Unit	CT Pump 1	CT pump 2
Actual power consumption	kW	4.41	4.47

Power factor		0.8	0.81

4.7 LIGHTING SYSTEM

4.7.1 Specifications

The plant's lighting system includes:

Table 40: Specifications of lighting load

Particular	Units	T-8	CFL	CFL	LED	LED	LED	LED
Power consumption per fixture	W	36	65	36	9	15	30	50
Numbers of fixtures	#	69	24	6	55	368	12	1

4.7.2 Field measurement and analysis

During DEA, the following measurements were done by:

- Recording Inventory
- Recording Lux Levels

Measured values are summarized below:

Table 41: Lux measurement at site

Particular	Measured Value Lumen/m^2	Particular	Measured Value Lumen/m^2
Office	180	Inventory	90
Kiln control room	110	Sizing Machine	90
Kiln area	90	Glaze ball mill	85
Press	110		

4.7.3 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.

4.7.4 Energy conservation measures (ECM) - ECM #9: Energy Efficient Lighting

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 42 : cost benefit analysis (ECM 9)

Parameter	Unit	Present	Proposed	Present	Proposed
Type of fixture		FTL T8	LED Tube	CFL (65 W)	LED flood light
Type of choke if applicable		Magnetic	Driver	Magnetic	Driver
Number of fixtures	#	69	69	24	24
Rated power of fixture	W/Unit	36	20	65	36
Consumption of choke	W	12	0	0	0
Operating power	W/fixture	48	20	65	36
Operating hour per day	h/d	12	12	12	12
Operating days per year	d/y	330	330	330	330
Annual energy consumption		13,116	5,465	6,178	3,421
Annual energy saving	kWh/y	7,651		2,756	
Annual energy saving	kWh/y	10,407			
cost of electricity	Rs/kWh	6.79			
Annual monetary saving	Rs Lakh/y	0.71			
Estimated investment	Rs Lakh	0.79			
Simple payback period	Months	13			
IRR	%	67%			
Discounted payback period	Months	5.07			

4.8 Electrical Distribution System

4.8.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415 V) by step down transformer (2.00 MVA). Automatic power factor correction system is installed in parallel to main supply. There were three 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.

4.8.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.8.3 Observations and performance assessment

After analyzing feeder power profiling, it was observed that the maximum kVA recorded during study period was **248.2 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **420 V.** Maximum voltage was **422 V** and minimum was **415 V**.

Average total voltage and current harmonics distortion found **6.4%** & **11.05%** respectively during power profile recording.

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

4.8.4 Energy conservation measures (ECM) - ECM #10: Cable loss minimization

Technology description

It was observed that some of the outgoing feeders to sizing and digital printing 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 0.57-0.60.

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 43 : Cost benefit analysis of cable loss minimization (ECM -10)

Particulars	Unit	Sizing M/c 1 (Section 1)	Sizing M/c 1 (Section 2)	Digital	Glaze line
Existing Power Factor	PF	0.57	0.60	0.75	0.76
Proposed Power Factor	PF	0.99	0.99	0.99	0.99
Existing load	kW	17.3	18.2	14.6	19.1
Cable Losses	W	229.8	217.1	16.9	13.9
Capacitor Required	kVAr	22	22	11	14
Annual Energy Saving	kWh/y	1,820	1,719	192	181
Savings Estimated	Rs Lakh/y	0.12	0.11	0.013	0.012
Total Savings	Rs Lakh/y	0.26			
Investment	Rs Lakh	0.31			
Simple Payback Period	Months	14			
IRR	%	67%			
Discounted Payback period	Months	5.07			

4.9 Belt Operated Drives

4.9.1 Specifications

There are 15 drives operated with V Belt of total capacity of 393 kW. Locations include

- Kiln -1 (6)
- Kiln – 2 (7)
- Dryer (2)

4.9.2 Field measurement and analysis

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

4.9.3 Observations and performance assessment

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

4.9.4 Energy conservation measures (ECM) - ECM #11: 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 44: Replacement of conventional belt with REC belt [ECM-11]

Particulars	UoM	AS IS	TO BE
No. of V belt driven blowers	#	15	15
Measured power of all belt driven blowers	kW	56.17	54.15[1]
Running hours of blowers	h/d	24	24
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	444,849	428,835
Annual energy saving	kWh/y		16,015
Electricity cost	Rs./kWh	6.79	
Annual energy cost saving	Rs. Lakh	1.09	
Estimated investment	Rs. Lakh	3	
Payback Period	Months	33	
IRR	%	17%	
Discounted payback period	Months	12	

[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#12: 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 45: Cost benefit analysis for energy monitoring system (ECM-12)

Parameter	UoM	Present	Proposed
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	2,582,019	2,530,379
Annual electricity saving per year	kWh/y		51,640
Cost of Electricity	Rs/kWh		6.79
Annual monetary savings	Lakh Rs/y		3.51
Number of equipments/system	#	17	17
No. of energy meters	#		17
Estimated investment	Lakh Rs		2.64
Thermal energy monitoring system	%	2.00	
Current coal consumption in Gasifier	kg/y	8,538,700	8,367,926
Annual coal saving per year	kg/y		170,774
Cost of Coal	Rs/kg		9.00
Total annual monetary savings	Lakh Rs/y		15.37
Number of equipments/system	#	3	3
Number of coal weighing machines			1
Estimated investment	Lakh Rs		1.32

Parameter	UoM	Present	Proposed
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		18.87
Estimated (Electrical + Thermal)	Lakh Rs		3.96
Payback period	Months		2.52
IRR	%		355%
Discounted payback period	Months		1.01

5.2 Best Operating Practices

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

Table 46: Unique Operating practices

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Clay 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	Hydraulic press	PRV installed for usage of compressed air
5	Glaze ball mill	Timer control in each ball mill. Alumina balls are used in glaze ball mills
6	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
7	Sizing	Fully automatic system. Dust collected system installed.
8	Printing	Automated digital printing with fully auto control system
9	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 47 : Specifications of dry clay grinding technology

Parameter	UOM	Scenario-1	Scenario-2	Scenario-3
Moisture content of input material	%	5-7%	7-8%	8-10%
Production output	t/h	≥60	≤50	≤15

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

Parameter	UOM	Scenario-1	Scenario-2	Scenario-3
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 16 : 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 17: 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

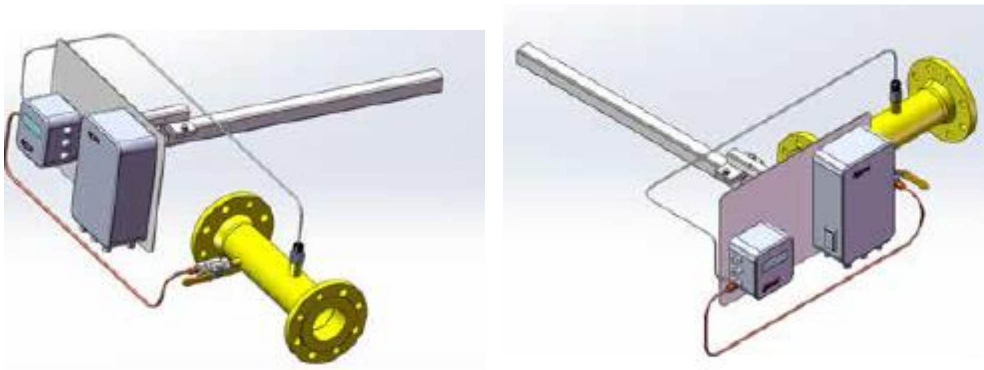


Figure 18: Combustion air control for burner

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 19: 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

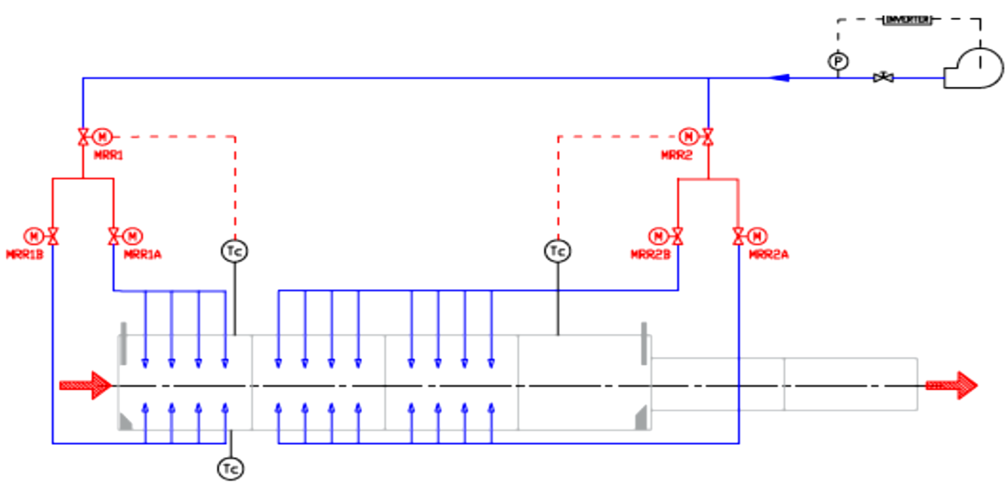


Figure 20: Fast cooling air management

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 21: 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

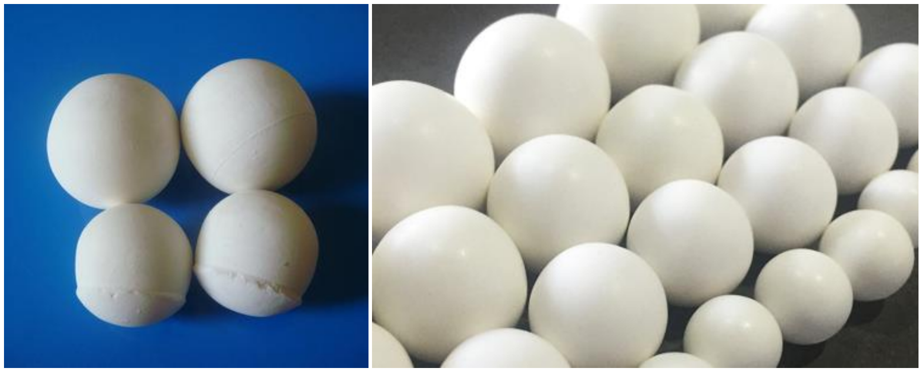


Figure 22: - High Alumina pebbles for Ball mill

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.

[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 23: - Direct drive blower fan

6 CHAPTER – 6 RENEWABLE ENERGY APPLICATIONS

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

6.1 INSTALLATION OF SOLAR PV SYSTEM

The possibility of adopting renewable energy measures was evaluated during the DEA. A roof top area of 1,880 m^2 is available in the unit. The feasibility of installing solar PV in this area was evaluated. The corresponding solar energy generation potential is shown below.

The cost benefit analysis for solar PV installation is given below:

Table 48: Cost benefit analysis of Solar PV installation

Parameters	Unit	Proposed
Available area on roof	m^2	3,134
Estimated total Solar PV panel area	m^2	1,880
Number of panels (1m X 2m) of 320 Wp	#	940
Estimated installed capacity of solar panel	kW	301
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	1,264
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	461,225
Cost of electricity	Rs/kWh	6.79
Annual monetary savings	Lakh Rs/y	31
Estimated investment	Lakh Rs	165
Payback period	Months	63
IRR	%	-6%
Discounted payback period	Months	22

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
    a. Increased cleaning frequency
    b. Requirement of DM water for cleaning the panels twice a day.

7 CHAPTER – 7 ANNEXES

ANNEX-1: PROCESS FLOW DIAGRAM

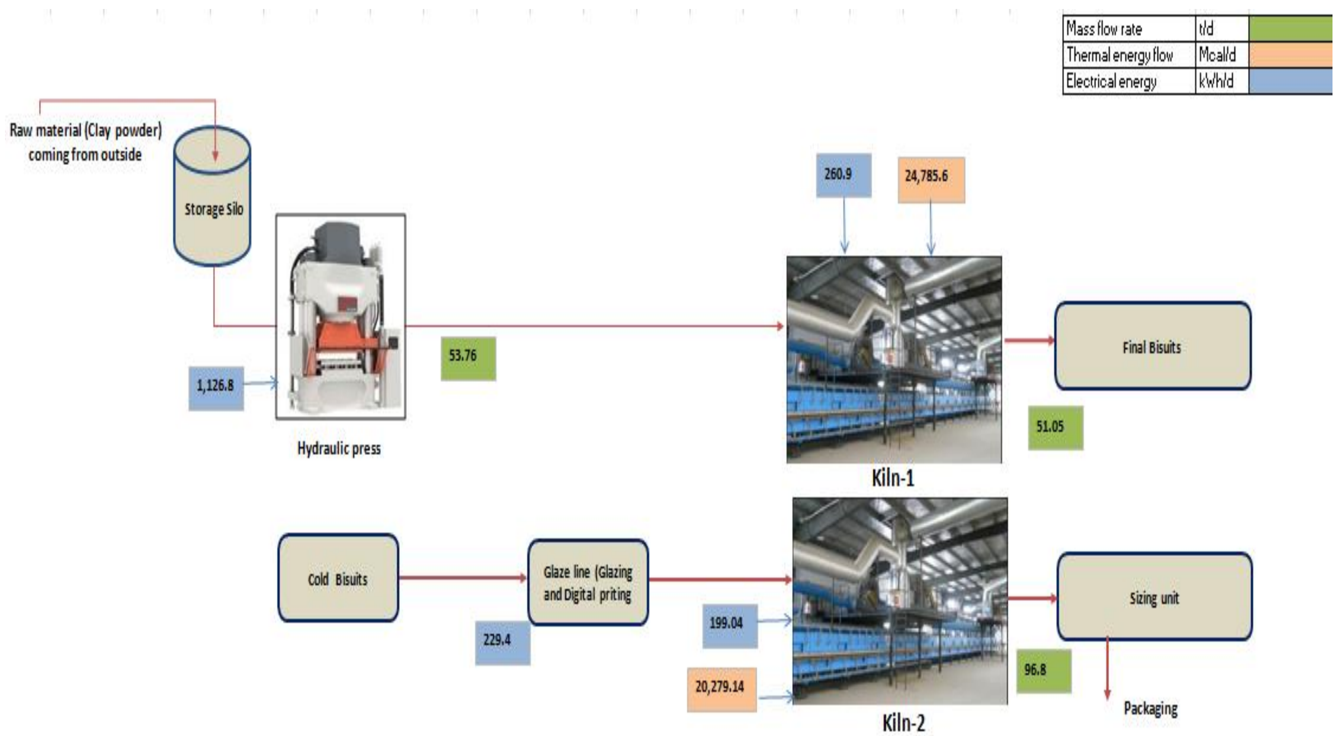


Figure 24: Process Flow Diagram of Plant

ANNEX-2: DETAILED INVENTORY

Equipment	Connected Load	Rating (kW)
Hydraulic press	Press-1 (980)	55
	Press-2 (2500)	75
Cooling tower	Pump	11
Printing	Printing	11.4
Kiln	Kiln-1 + Dryer	254
	Kiln-2	170.5
Sizing line	Sizing M/c-1	50.5
	Sizing M/c-2	50.5
	Sizing Line-1	2.98
Glaze line	Line	96.5
	Pump	20.25
	Stirrer	1.5
	Vibrator	7.5
Glaze ball mills	Ball mill 1 (2 ton)	3.3
	Ball mill 2 (2 ton)	22
	Ball mill 3 (2 ton)	22
	china clay tank	4.5
	Vibrator	2.25
	Pump	1.5
Lighting		16.48

ANNEX-3: SINGLE LINE DIAGRAM

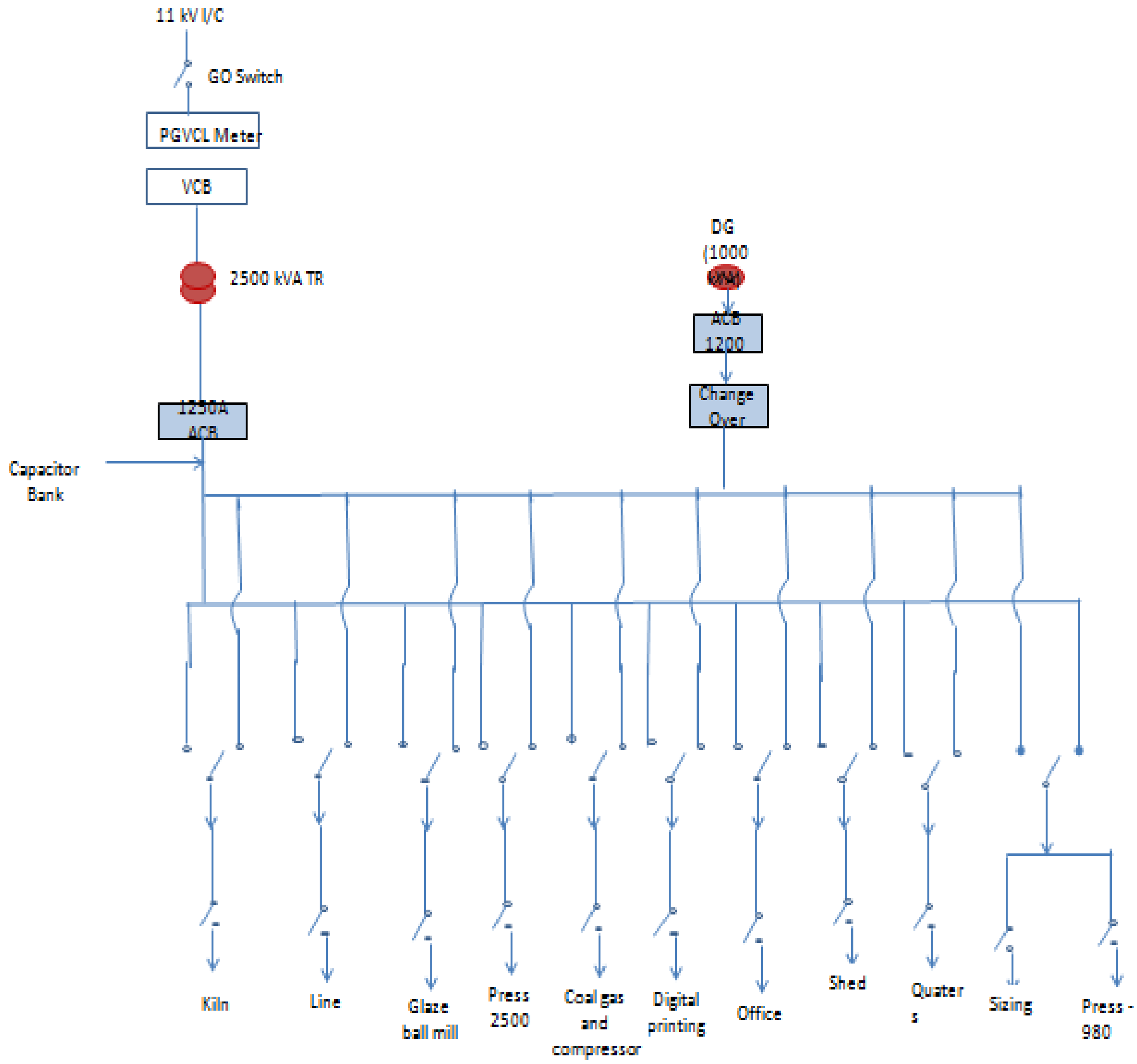


Figure 25: Single Line Diagram (SLD)

ANNEX-4: ELECTRICAL MEASUREMENTS

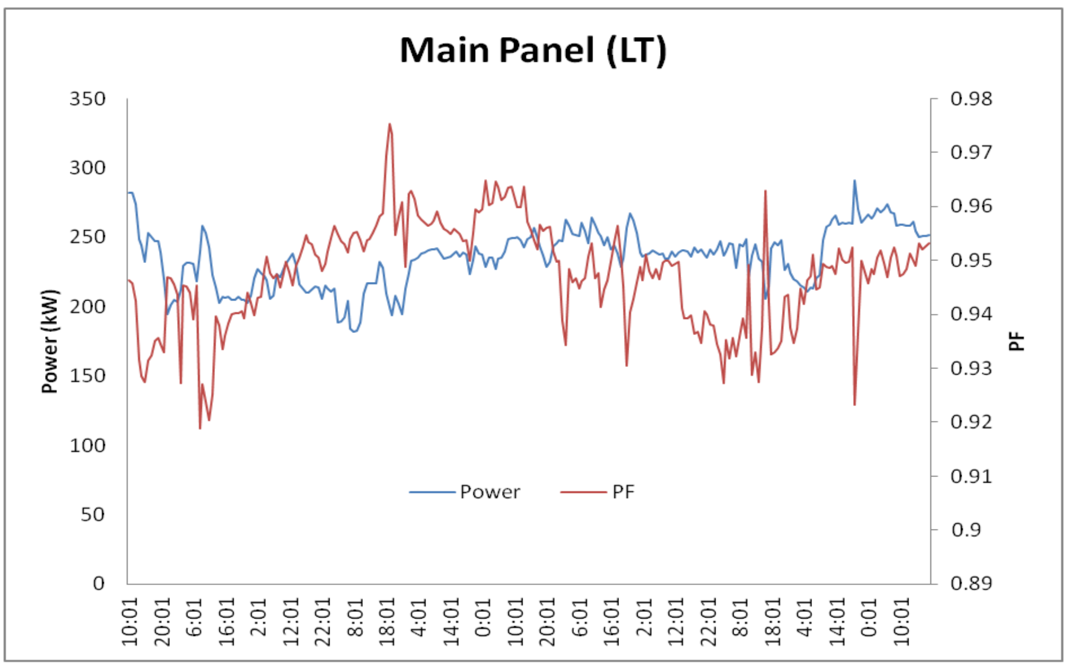


Figure 26: Power and voltage profile of Main Incomer

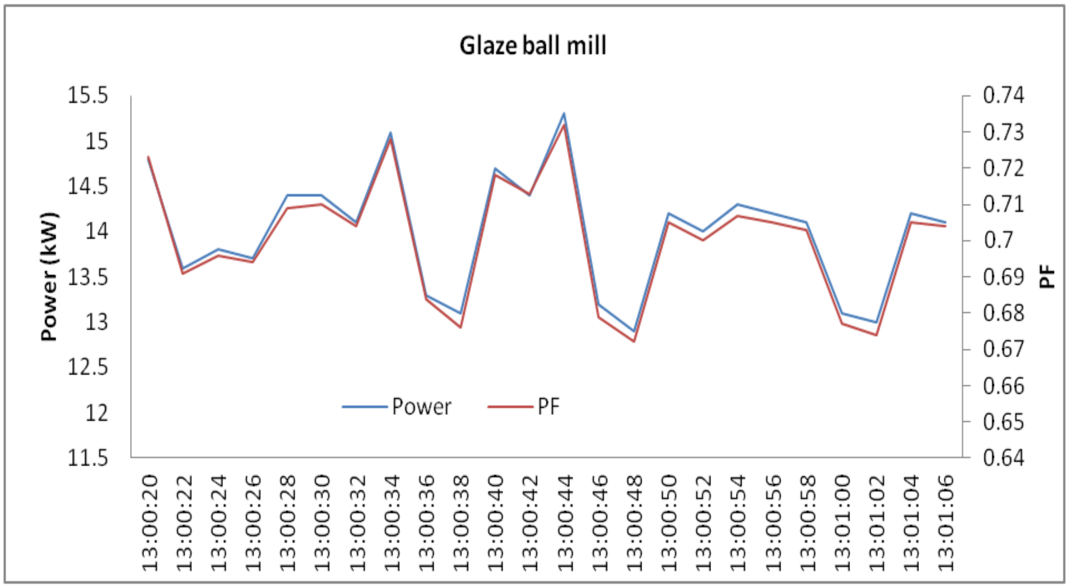
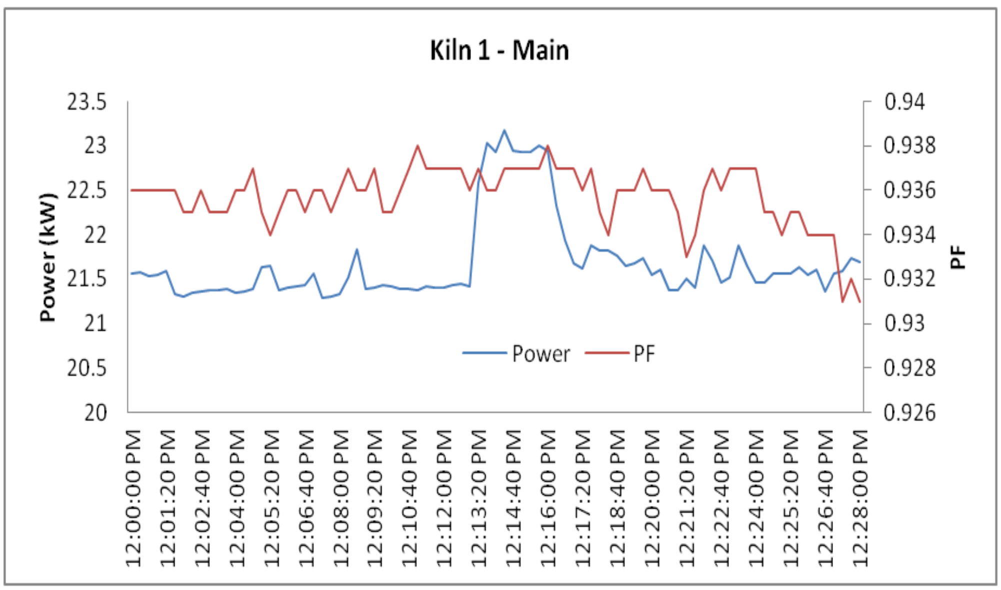
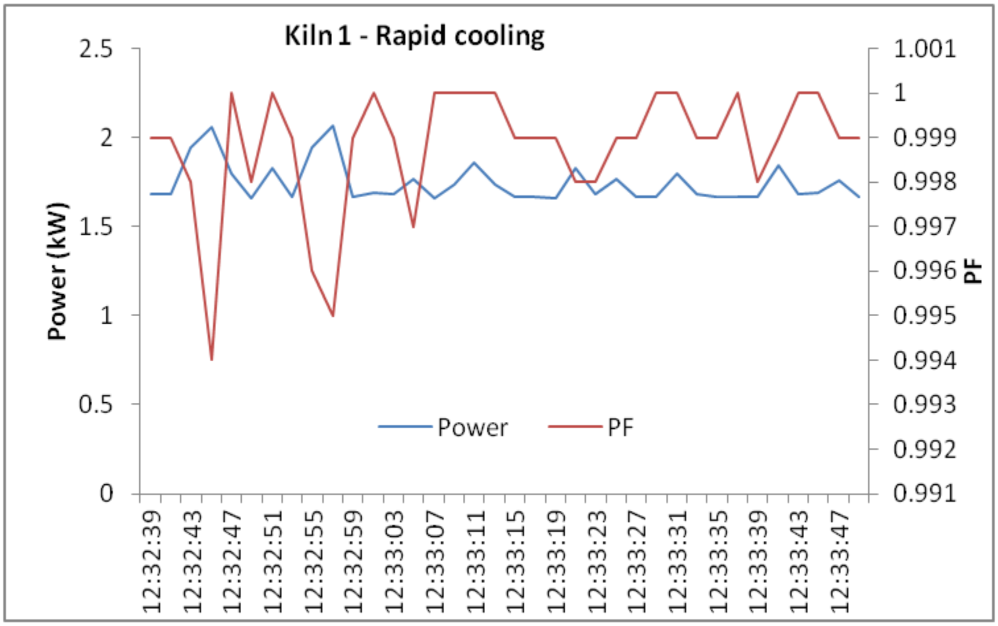


Figure 27: Power and PF profile of Glaze Ball mill 1




Kiln 1 - Rapid cooling
Power (kW)
PF
Power
PF
2.5
2
1.5
1
0.5
0
1.001
1
0.999
0.998
0.997
0.996
0.995
0.994
0.993
0.992
0.991
12:32:39
12:32:43
12:32:47
12:32:51
12:32:55
12:32:59
12:33:03
12:33:07
12:33:11
12:33:15
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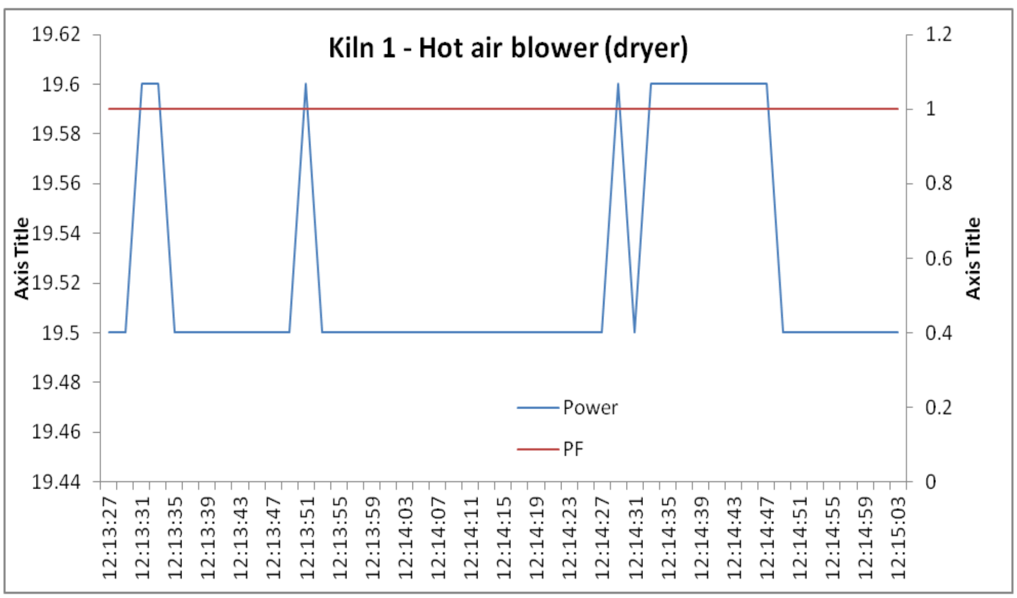
12:33:35
12:33:39
12:33:43
12:33:47


Kiln 1 - Hot air blower (dryer)
Axis Title
Axis Title
Power
PF
19.62
19.6
19.58
19.56
19.54
19.52
19.5
19.48
19.46
19.44
1.2
1
0.8
0.6
0.4
0.2
0
12:13:27
12:13:31
12:13:35
12:13:39
12:13:43
12:13:47
12:13:51
12:13:55
12:13:59
12:14:03
12:14:07
12:14:11
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12:15:03

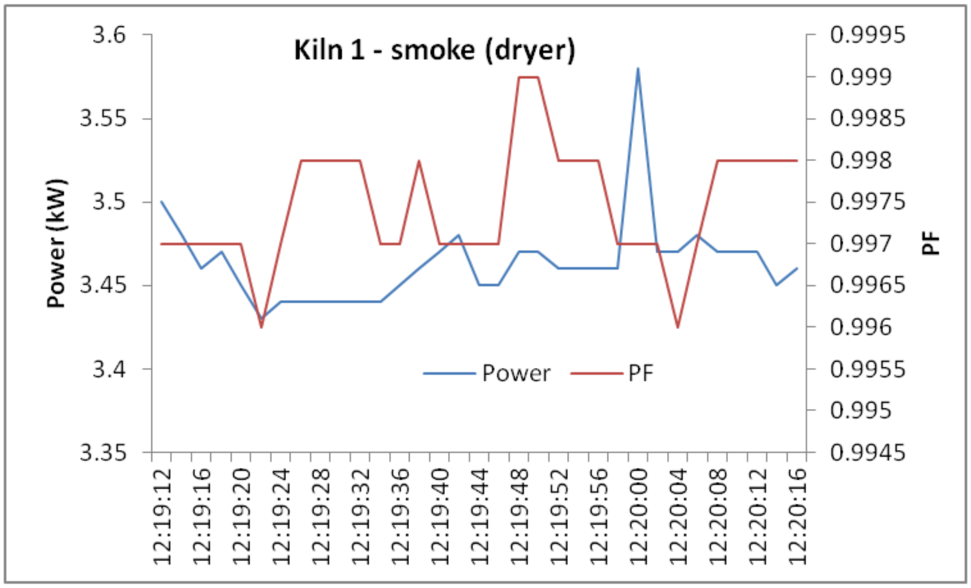
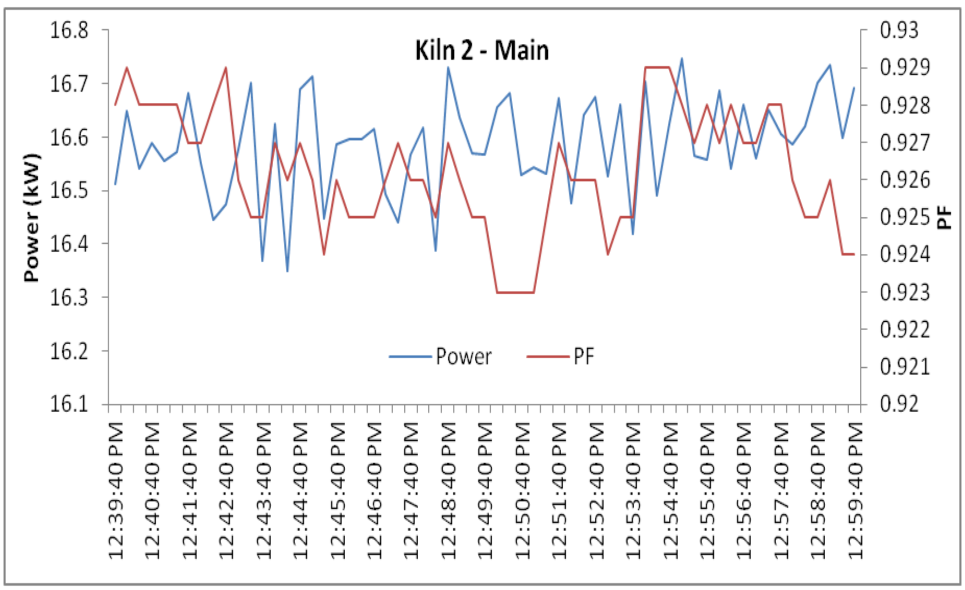
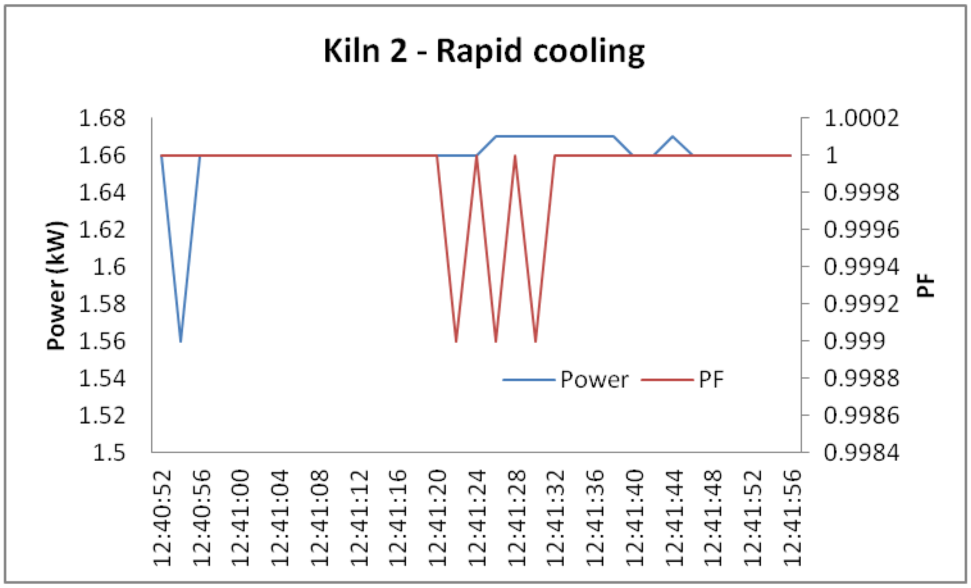


Figure 28: Power and PF profile of Main incomer and blowers of kiln 1





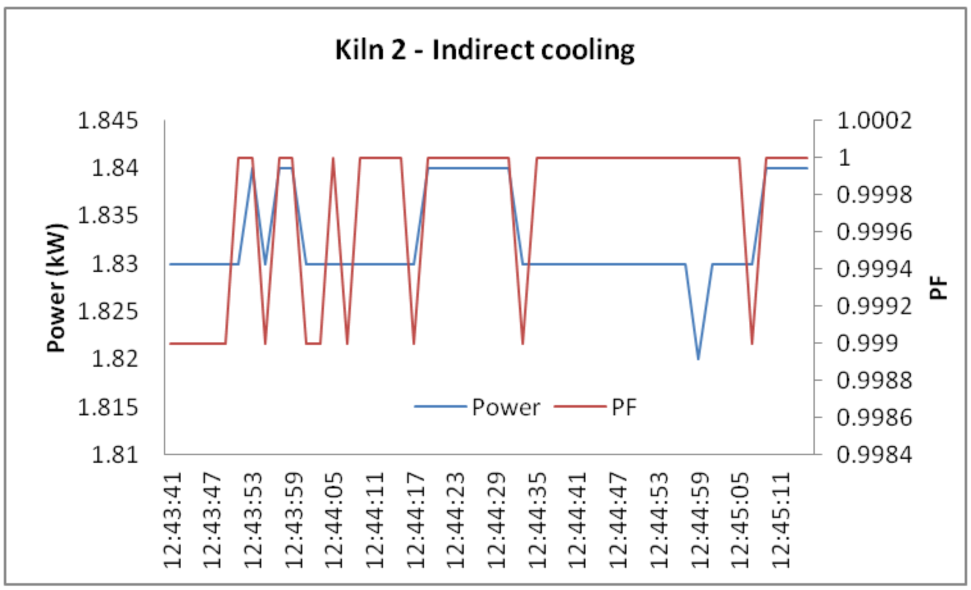


Figure 29: Power and PF profile of main panel and blowers of kiln 2

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

1. *Kiln-1 efficiency calculations*

Input parameters

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujrat Gas	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	986.58	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	233.93	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	150	*°C*
Preheated air temp./Ambient	40	*°C*
O2 in flue gas	7.49	*%*
CO2 in flue gas	7.9	*%*
CO in flue gas	417.4	*ppm*
Atmospheric Air		
Ambient Temp.	45	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
NG Fuel Analysis		
C	73.80	*%*
H	24.90	*%*
N	1.30	*%*
O	0.00	*%*
S	0.00	*%*
Moisture	0.00	*%*
Ash	0.00	*%*
GCV of fuel	8,829	*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		*kg/h*
Weight of ceramics material being heated in Kiln	4253.7	*kg/h*

Weight of Stock	4,254	*kg/h*
Specific heat of clay material	0.22	*kcal /kg- °C*
Avg. specific heat of fuel		*kcal /kg-°C*
fuel temp	30	*°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	11,442	*kcal/h*
Radiation and convection from heating zone surface	47,193	*kcal/h*
Radiation and convection from rapid cooling section	8,856	*kcal/h*
Radiation and convection from indirect cooling zone	9,336	*kcal/h*
Radiation and convection from final cooling zone	8,394	*kcal/h*
Heat loss from all zones	85,221	*kcal/h*
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	1.17	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	17.23	*kg/kg of fuel*
Excess Air supplied	55.44	*%*
Actual Mass of Supplied Air	26.78	*kg/kg of fuel*
Mass of dry flue gas	25.53	*kg/kg of fuel*
Amount of Wet flue gas	27.78	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*Kg of H2O/kg of fuel*
Amount of dry flue gas	25.54	*kg/kg of fuel*
Specific Fuel consumption	54.99	*SCM of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	485,565	*kcal/ton of tiles*
Total heat input	485,565	*kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	208,204	*kcal /ton of tile*
Heat loss in dry flue gas	35,388	*kcal /ton of tile*
Loss due to H2 in fuel	791	*kcal/ton of tile*
Loss due to moisture in combustion air	1,265.17	*kcal/ton of tile*
Loss due to partial conversion of C to CO	1,206.90	*kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	60.85	*kcal/ton of tile*

Calculations	Kiln	Unit
Loss Due to Evaporation of Moisture Present in Fuel	-	*kcal/ton of tile*
Total heat loss from kiln (surface) body	85,221	*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	153,429	*kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	85,221	*Kcal/ton*
Heat utilized by tiles	42.88	*%*

Kiln-2 efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujarat gas	
Particulars	**Value**	***Unit***
Kiln Operating temperature (Heating Zone)	1,066	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	191.40	*scm/h*
Density of Natural gas	0.73	*kg/scm*
Avg. fuel Consumption	168.2	*kg/h*
Flue Gas Details		
Flue gas temp at smog blower	200	*° C*
Preheated air temp./Ambient	40	*°C*
O2 in flue gas	13.36	*%*
CO2 in flue gas	4.24	*%*
CO in flue gas	3.13	*ppm*
Atmospheric Air		
Ambient Temperature	45	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg of dry air*
Fuel Analysis		
C	73.80	*%*
H	24.90	*%*
N	1.30	*%*
O	0.00	*%*
S	0.00	*%*
Moisture	0.00	*%*
Ash	0.00	*%*
GCV of fuel	8,829	*kcal/scm*
Ash Analysis		

Input Data Sheet		
Un-burnt in bottom ash	0.00	*%*
Un-burnt in fly ash	0.00	*%*
GCV of bottom ash	0	*kcal/kg*
GCV of fly ash	0	*kcal/kg*
Material and flue gas data		
Weight of ceramics material being heated in Kiln	4,007	*kg/h*
Weight of Stock	4,007	*kg/h*
Specific heat of clay material	0.22	*kcal/kg-°C*
Avg. specific heat of fuel		*kcal/kg-°C*
fuel temp	30	*°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	2,035	*kcal/h*
Radiation and convection from heating zone surface	24,024	*kcal/h*
Radiation and convection from rapid cooling section	4,908	
Radiation and convection from indirect cooling zone	17,838	
Radiation and convection from final cooling zone	9,169	
Heat loss from all zones	57,974	*kcal/h*
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	1.00	*h*
Area of entry opening	1.2	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*K*

Efficiency Calculation

Calculations	Kiln	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	174.96	*%*
Actual Mass of Supplied Air	47.36	*kg/kg of fuel*
Mass of dry flue gas	46.12	*kg/kg of fuel*
Amount of Wet flue gas	48.36	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*Kg of H2O/kg of fuel*
Amount of dry flue gas	46.12	*kg/kg of fuel*
Specific Fuel consumption	47.76	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	421,701	*kcal/ton of tiles*
Total heat input	421,701	*kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	225,676	*kcal/ton of tile*
Heat loss in dry flue gas	81,947	*kcal/ton of tile*

Calculations	Kiln	Unit
Loss due to H2 in fuel	655	*kcal/ton of tile*
Loss due to moisture in combustion air	3,303.67	*kcal/ton of tile*
Loss due to partial conversion of C to CO	14.69	*kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	55.36	*kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	-	*kcal/ton of tile*
Total heat loss from kiln (surface) body	57,974	*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	52,075	*kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	57,974	*kcal/ton*
Heat utilized by tiles	53.52	*%*

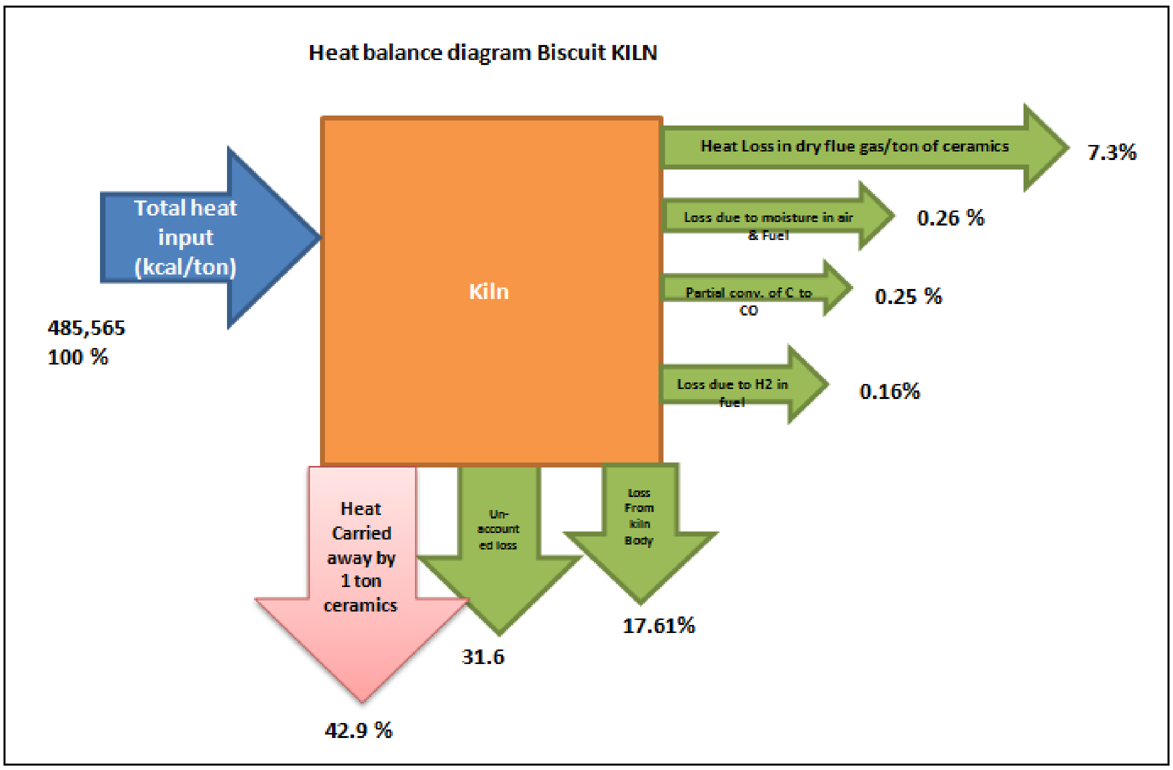


Figure 30: Heat Balance diagram of biscuit kiln

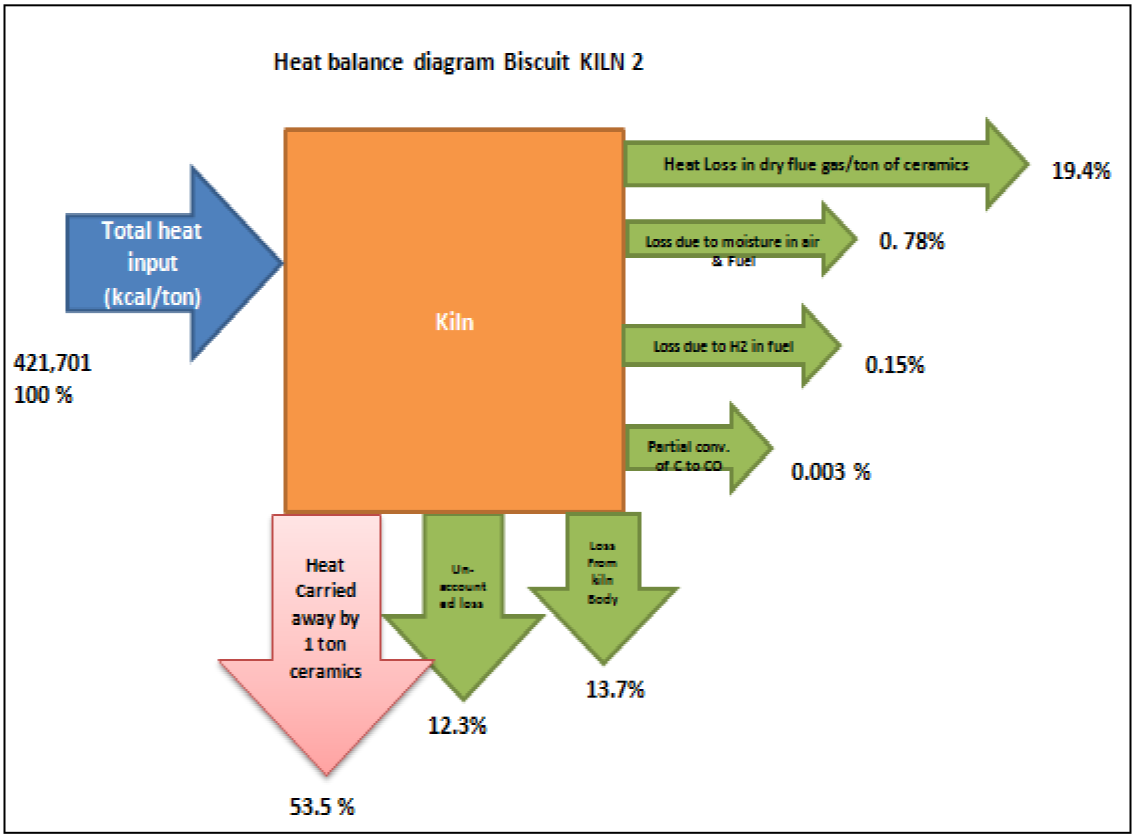


Figure 31: Heat Balance diagram of kiln-2

ANNEX-6: VENDORS

ECM-1&2: Excess air control in kiln 1 & kiln 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	Knackwell Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	Darshan Thanawala, Ravi Thanawala (Proprietor) 8079452278, 9428597582, 9327013773	www.knackwellengineers.com darshan@kanckwell.com, ravi@kanckwell.com

ECM 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** ramaswamy.pondian@morganplc.com
2	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 Fax: +91-11-44-30882894 /95 Mr. Rajneesh Phone : 0161-2819388 Mobile : 9417004025	Email: kk.mitra@lloydinsulation.com
3	Shivay Insulation	20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009	Mobile- 9712030444	shivayinsulation@gmail.com

ECM-6: Replacement of IE1 motor with IE3 motor of glaze ball mill

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	The Indian Electric Co.	Bharat Bhavan A, Dajisaheb Natu Rd, Natu Baag, Shukrawar Peth, Pune, Maharashtra 411002	Mob: +91 8049443859 Tel: 020-27426370	
2	Siemens Limited	3rd floor, Prerna Arbour, Girish Cold Drinks Cross Road, Off. C.G.Road, Ahmedabad	Mr. Paresh Prajapati 079-40207600	paresh.prajapati@siemens.com
3	Crompton Greaves	909-916, Sakar-II, Near Ellisbridge, Ahmedabad	079-40012000 079-40012201 079-40012222	sagar.mohbe@cgglobal.com

ECM-7: Retrofit of VFD in glaze ball mill

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-9: Replacement of inefficient lighting systems

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

Sl. No.	Name of Company	Address	Phone No.	E-mail
	R. Nandakishore	Sector 53 Gurgaon, Haryana 122002	Area Manager), 9810495473(Sandeep-Faridabad)	sandeep.raina@phillips.com
3	Bajaj Electricals Contact Person: Mr. Kushgra Kishore	Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002	9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341 (Mr. Rahul Khare),	kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com;sanjay.adlakha@bajajelectricals.com

ECM-10: 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-11: 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

Sl. No.	Name of Company	Address	Phone No.	E-mail
3	Shreeji Traders	Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001	+91 94281 01565	NA

ECM-12: Energy Management system

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

ECM-13: Solar PV installation

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Zodiac Energy Ltd.	A-1204, Siddhi Vinayak Towers, Near DCP Office, Beside Kataria Auto, Makarba, S. G. Highway, Ahmedabad-380051 Gujarat, India.	Tel : +91 7929704116 +91 79 66170307 Mob: +91 9879106443	info@zodiacenergy.com
2	CITIZEN Solar Pvt. Ltd	711, Sakar-2 Ellisbridge corner, Ahmedabad-380006	Girishsinh Rav Jadeja 9376760033	www.citizensolar.com sales@citizensolar.com
3	Sun gold Enterprise	D-134, Udhna Sangh Commercial Complex, Near Divya Bhaskar press, Central Road, Udhna Udhyog nagar, Surat-394010	Mr. Pravin Patel 98251 94488	sungoldindia@gmail.com

ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 49: 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%