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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE WT-50: SONEX INDUSTRIES (SONEX GOLD)

Submitted to
GEF-UNIDO-BEE Project Management Unit
BUREAU OF ENERGY EFFICIENCY

Submitted by

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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

This **Comprehensive Energy Audit Report** is an output of an exercise undertaken by **Development Environergy Services Ltd.** (DESL) under the GEF-UNIDO-BEE project's initiative for the benefit of MSME units and is primarily intended to assist and build the capability of decision making by the management of MSME units for implementation of EE & RE technologies, BOP etc. While every effort has been made to avoid any mistakes or omissions. However, GEF, UNIDO, BEE or DESL would not be in any way liable to any person or unit or other entity by reason of any mistake/omission in the document or any decision made upon relying on this document.

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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. Sonex Industries 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. Nimesh 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.

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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 monitorable parameters
DESL	Development Environergy Services Limited
ECM	Energy conservation measure
EE	Energy efficiency
FI	Financial institutions
FT	Floor tile
GEF	Global Environmental Facility
GPCB	Gujarat State Pollution Control Board
IRR	Internal rate of return
LPG	Liquefied petroleum gas
MCA	Morbi Ceramic Association
MSME	Micro, small and medium enterprises
NPV	Net present value
PG	Producer gas
PMU	Project management unit
PV	Photovoltaic
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	^0C
Horse power	hp
Hour(s)	h
Hours per year	h/y
Indian Rupee	INR/Rs.
Kilo Calorie	kcal
Kilo gram	kg
Kilo volt	kV
Kilo volt ampere	kVA
Kilo watt	kW
Kilo watt hour	kWh
Kilogram	kg
Litre	L
Meter	m
Meter Square	m^2
Metric Ton	MT
Oil Equivalent	OE
Standard Cubic Meter	scm
Ton	t
Tons of Oil Equivalent	TOE
Ton of CO_2	tCO_2
Ton per Hour	t/h
Ton per Year	t/y
Voltage	V
Watt	W
Year(s)	y

CONVERSION FACTORS

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

EXECUTIVE SUMMARY

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

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

Sonex Industries has been selected as one of the 20 units for detailed energy audit. Sonex Industries 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	Sonex Industries (Sonex Gold)
Year of Establishment	2002
Address	8A National Highway, Opp. Lalpar bus stop, Morbi - 363642, Gujarat – INDIA
Products Manufactured	Wall Tiles
Name(s) of the Promoters / Directors	Mr. Nimesh 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 kiln in which the fuel used is Coal gas. The temperature maintained in biscuits kiln is approximately 1,200°C and glaze kiln is 1,100°C (in heating zone).

- **Storage silo:** Raw material (clay power) is coming from outside and stored in silos.
- **Hydraulic press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Kiln:** Biscuits are baked in Biscuit kiln at 1,200°C and again baked after glazing in Glazing Kiln.
- **Glaze ball mill:** For producing glazing material used on wall tiles.
- **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. The main energy consuming areas are kilns which account for more than 70% of the total energy used.

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in kiln 1: Coal gas is used as fuel in kiln 1 and oxygen content in flue gas was found to be 6.3% against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Excess air control in kiln 2: Coal gas is used as fuel in kiln 2 and oxygen content in flue gas was found to be 8.2% against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation For Glaze kiln: In kiln 2, the recuperator pipes was found to be un-insulated with surface temperature of 100 °C which should be maintain at 80 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the 20 recuperator pipes with insulation material for reducing surface heat losses.
- 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.
- Operational pressure optimization in compressor: As very high pressure compressed air is not necessary in the process area, it is recommended that the existing cut-out pressure setting of 7 kg/cm^2 be lowered to 6 kg/cm^2 which will reduce the energy consumption by 6% (approx.).
- VFD in Screw Compressor: During unload condition; compressor is consuming 30% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy up to 15% of present consumption.

- Replacement of Inefficient Pumps with Energy Efficient Pumps: CT pump -1 & 2 of hydraulic press oil cooling system has efficiency 36.1% & 38.8% respectively. It is recommended to replace the existing pumps with energy efficient pumps (65% efficiency).
- Replacement of inefficient lighting systems: Conventional lights like Fluorescent Tube lights and Compact fluorescent light were present in unit which results in higher electrical consumption. It is recommended to replace the conventional lights with energy efficient LED lamps.
- Voltage optimization in main LT incomer: The present voltage for main LT incomer circuit was found to be 422 V against desired voltage of 415 V. It is recommended to install separate transformer of 700kVA rating for main LT incomer.
- Cable loss minimization: In sizing section, power factor was varies in range of 0.57-0.80. It is recommended to install power factor improvement capacitors for sizing section.
- 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.

Table 1 : Summary of Energy Conservation Measures

Sr. No.	Energy Performance Improvement Action (EPIA)	Annual Energy Savings			Investment Cost	Monetary Energy Cost Saving	Payback Period	Emission Reduction
		Electricity	Coal	Total TOE/y				
		kWh/y	Coal (MT/y)		Lakh Rs.	Lakh Rs.	Months	Tons of CO2/yr
1	Excess air control in kiln 1 (Biscuit kiln)	4,303	221	115	18.48	20.63	11	471
2	Excess air control in kiln 2 (Glaze kiln)	15,305	452	236	18.48	42.66	5	971
3	Insulation in kiln 2 (Glaze kiln)		0.32	0.17	0.05	0.03	19	1
4	Replacement of IE1 motor with IE3 motor in glaze ball mill	12,808		1.10	1.85	0.88	25	11
5	Operational pressure optimization in compressor	14,765		1	Nil	1.01	Immediate	13
6	Retrofit of VFD in compressor	43,972		4	1.98	3.02	8	39
7	Replacement with inefficient Pumps with efficient pump	62,618		5	1.19	4.30	3	56
8	Replacement of inefficient light with EE lights	9,706		0.83	0.99	0.67	18	9
9	Voltage optimization in main LT incomer	81,877		7.04	9.24	5.62	20	73
10	Cable loss minimization	2,629		0.23	0.24	0.18	16	2
11	Replacement of V belt from REC (Raw edged cogged) belt	18,102		1.56	1.85	1.24	18	16
12	Energy Management system	52,030	177	97	3.61	19.89	2	421
	Total	**318,114**	**851**	**470**	**58**	**100**	**7**	**2,084**

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

- Reduction in energy cost by 10.20 %
- Reduction in electricity consumption by 12.23%
- Reduction in thermal energy consumption by 9.60%
- Reduction in greenhouse gas emissions by 9.89%

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

Sr. No	Energy Conservation Measure	Investment Lakh Rs	IRR %	Discounted Payback Period Months
1	Excess air control in kiln 1 (Biscuit kiln)	18.48	84%	4.15
2	Excess air control in kiln 2 (Glaze kiln)	18.48	176%	2.04
3	Insulation in kiln 2 (Glaze kiln)	0.05	42%	7.06
4	Replacement of IE1 motor with IE3 motor in glaze ball mill	1.85	26%	9.40
5	Operational pressure optimization in compressor	-	-	-
6	Retrofit of VFD in compressor	1.98	115%	3.07
7	Replacement with inefficient Pumps with efficient pump	1.19	271%	1.32
8	Replacement of inefficient light with EE lights	0.99	45%	6.79
9	Voltage optimization in main LT incomer	9.24	41%	7.27
10	Cable loss minimization	0.24	52%	6.07
11	Replacement of V belt from REC (Raw edged cogged) belt	1.85	47%	6.63
12	Energy Management system	3.61	412%	0.87
13	Installation of solar PV panel	159.51	-6%	21.26

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	Sonex Industries (SONEX Gold)		
Plant address	8A National Highway, Opp. Lalpar bus stop, Morbi - 363642, Gujarat - INDIA		
Constitution	Private Limited		
Name of promoters	Mr. Nimesh Patel		
Contact person	Name	Mr. Nimesh Patel	
	Designation	Director	
	Tel	9909595595	
	Fax		
	Email	nimeshsonex@gmail.com	
Year of commissioning of plant	2002		
List of products manufactured	Wall tile, 250 x 380 mm Wall tile, 300 x 450 mm Wall tile, 300 x 300 mm		
Installed plant capacity	10,500 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	150	
	Worker		
	Casual labor		
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)	No	
	Other (specify)	No	
Have you conducted any previous energy audit?	No		
Interested in DEA	Yes		
	Interested		

1.3 METHODOLOGY AND APPROACH

The study was conducted in 3 stages:

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

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

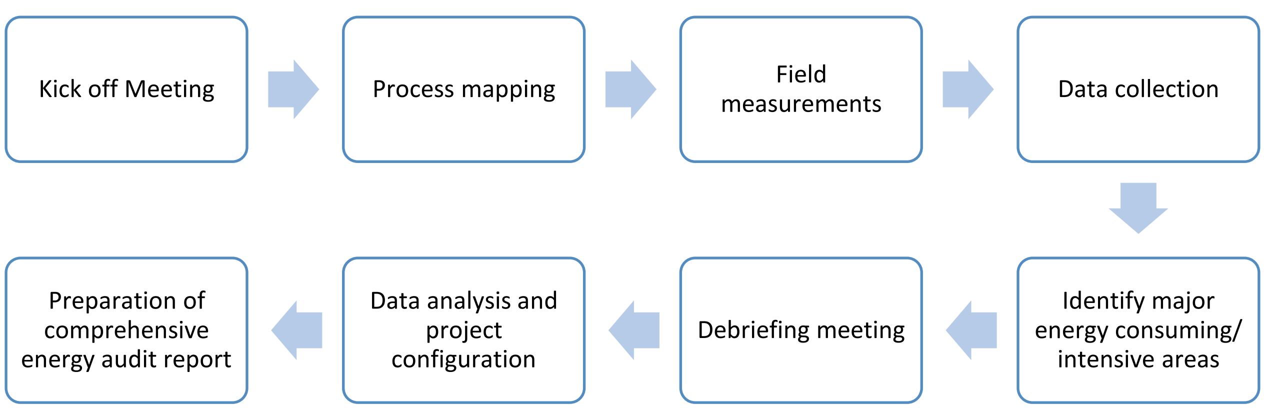

Figure 1: General methodology

The field work was carried out during 6-8th 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 temperature. & Humidity meter	Temperature & Humidity
8	Digital anemometer	Air velocity
9	Vane type anemometer	Air velocity
10	Digital infrared temperature gun	Distant surface temperature
11	Contact type temperature meter	Liquid and Surface temperature
12	High touch probe temperature meter	Temperature upto 1,300°C
13	Lux meter	Lumens

Sl. No.	Instruments	Parameters Measured
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:

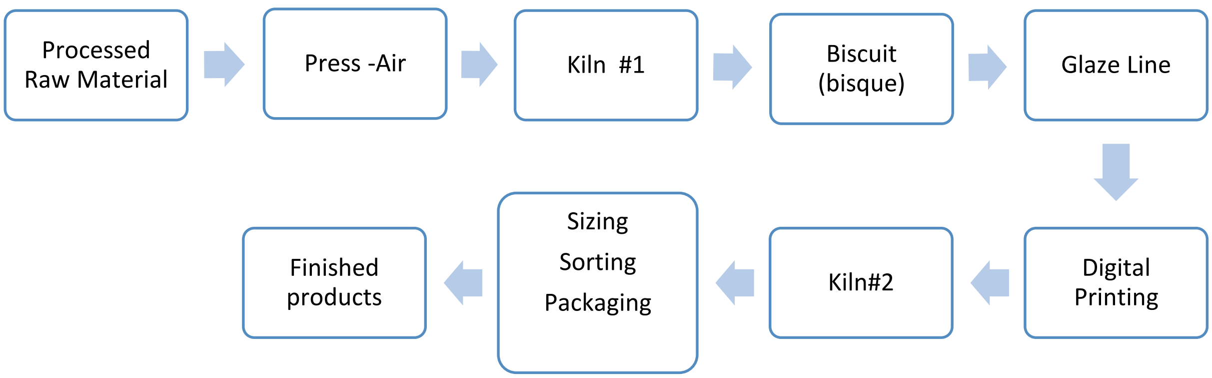

Figure 2: Process Flow Diagram

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:

- **Hydraulic press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Kiln:** Biscuits are baked in kiln at 1,100-1,200°C and baked again in the second kiln after glazing. The kilns are about 150 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone).
- **Glaze ball mill:** For producing glazing material used on tiles.
- **Air compressor:** Compressed air is used at several locations in a unit viz. Slurry pumping, Sizing, press bed cleaning, glazing, digital printing, etc.

- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.
- **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	250 x 380	9	0.76	8
Wall Tiles	300 x 450	14.5	0.81	6
Wall Tiles	300 x 300	11	0.81	9

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	250 x 380	300 x 300	300 x 450	250 x 380	300 x 300	300 x 450	250 x 380
Oct-17	87,047	48,321	87,559	107,465	59,656	115,209	1,182	865	1,037
Nov-17	87,511	48,579	88,026	108,039	59,974	115,824	1,188	870	1,042
Dec-17	91,384	50,729	91,921	112,819	62,628	120,949	1,241	908	1,089
Jan-18	90,145	50,041	90,675	111,290	61,779	119,309	1,224	896	1,074
Feb-18	89,525	49,697	90,051	110,525	61,354	118,489	1,216	890	1,066
Mar-18	92,932	51,589	93,479	114,731	63,690	122,999	1,262	923	1,107
Apr-18	92,520	51,360	93,064	114,223	63,407	122,453	1,256	919	1,102
May-18	83,164	46,166	83,653	102,671	56,995	110,069	1,129	826	991
Jun-18	94,877	52,668	95,435	117,132	65,022	125,572	1,288	943	1,130
Jul-18	88,809	49,299	89,331	109,640	60,863	117,541	1,206	883	1,058
Aug-18	87,632	48,646	88,147	108,188	60,057	115,983	1,190	871	1,044
Sep-18	101,880	56,556	102,479	125,778	69,822	134,841	1,384	1,012	1,214
Average	90,619	50,304	91,152	111,875	62,104	119,936	1,231	901	1,079
	77,358			97,972			1,070		

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 Kiln and for spray dryer

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

Table 7: Energy use and cost distribution

Particular	Energy cost distribution		Energy use distribution	
	Rs. In Lakhs	% of total	TOE	% of total
Grid – Electricity	178.62	18.2	224	4.6
Coal	803.48	81.8	4,610	95.4
Total	982.10	100	4,834	100

This is shown graphically in the figures below:

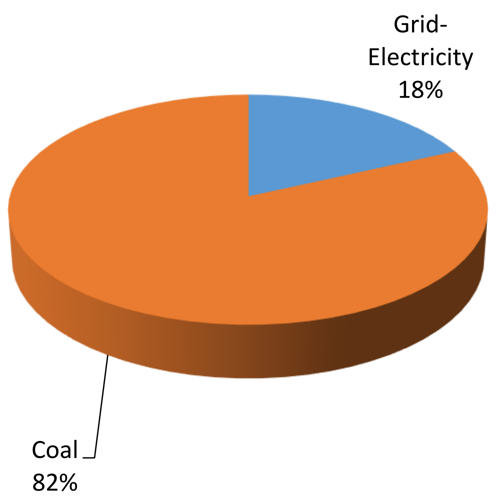

Figure 3 : Energy cost share

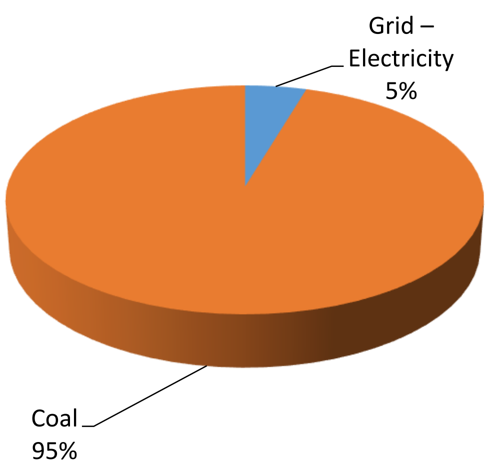

Figure 4 Energy use share

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 18% of the energy cost and 5% of the overall energy consumption.
- Coal used in coal gasifier accounts for 82 % of cost and 95 % of overall energy consumption.

2.2.1 Analysis of Electricity Consumption

2.2.1.1 Supply from utility

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

Table 8 : Details of Electricity Connection

Particulars	Description
Consumer number	26040
Tariff category	HTP-I
Contract demand, kVA	575
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
Peak hours	0.85
Night time	0.4
Fuel surcharge (Rs./kWh)	1.61
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	212,952	1,480,430	6.95
Nov-17	230,994	1,595,114	6.91
Dec-17	218,944	1,515,615	6.92
Jan-18	216,456	1,502,914	6.94
Feb-18	214,696	1,460,125	6.80
Mar-18	201,384	1,384,101	6.87
Apr-18	220,152	1,503,168	6.83
May-18	197,888	1,360,170	6.87
Jun-18	225,760	1,541,826	6.83
Jul-18	211,320	1,448,496	6.85
Aug-18	208,520	1,425,765	6.84
Sep-18	242,424	1,644,341	6.78

Average electricity consumption is 213,423kWh/month and cost is Rs 14.67 Lakhs per month. The average cost of electricity is Rs. 6.88 /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.

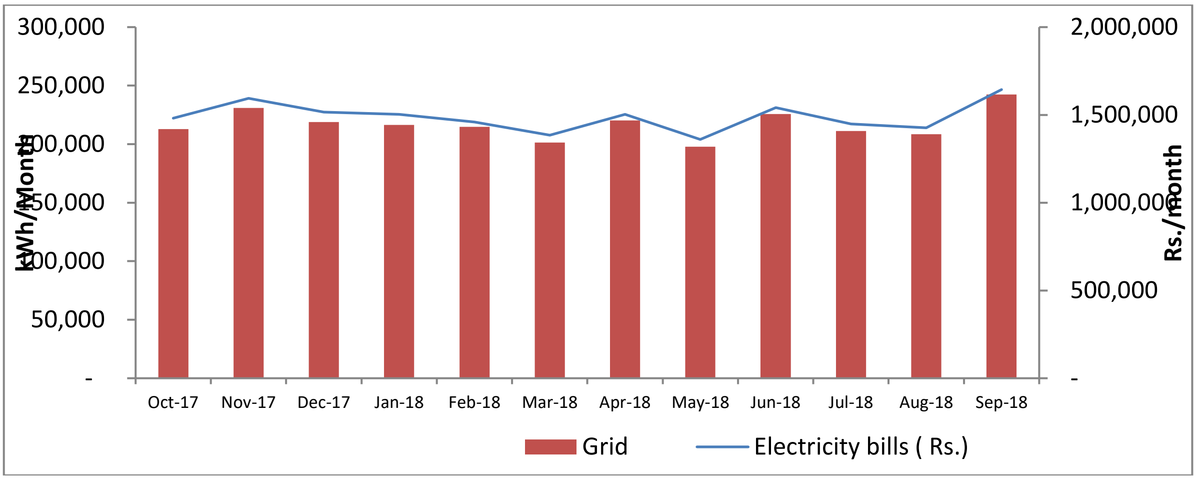

Figure 5: Month wise Variation in Electricity Consumption

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

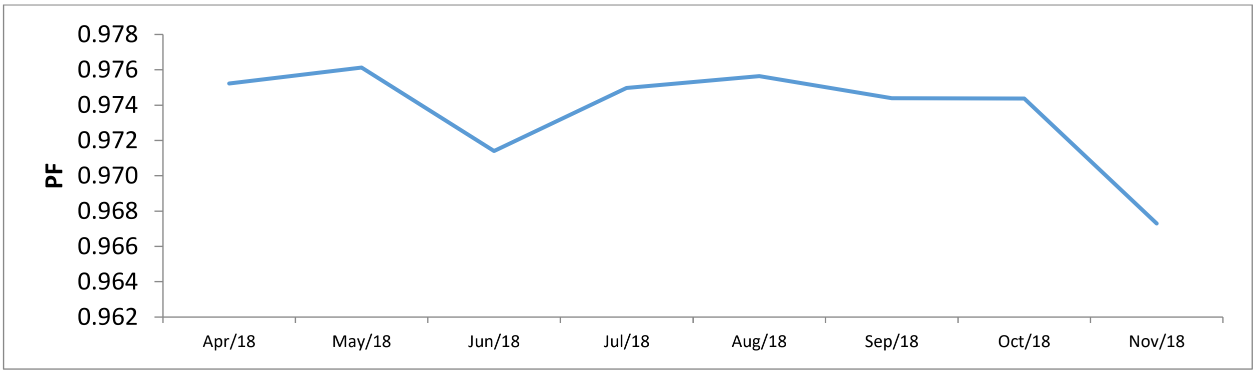

Figure 6 : Month wise variation in Power Factor

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 0.99 with the minimum being 0.974 and the maximum being 0.976.

Maximum Demand: Maximum demand as reflected in the utility bill is 459 kVA from the bill analysis.

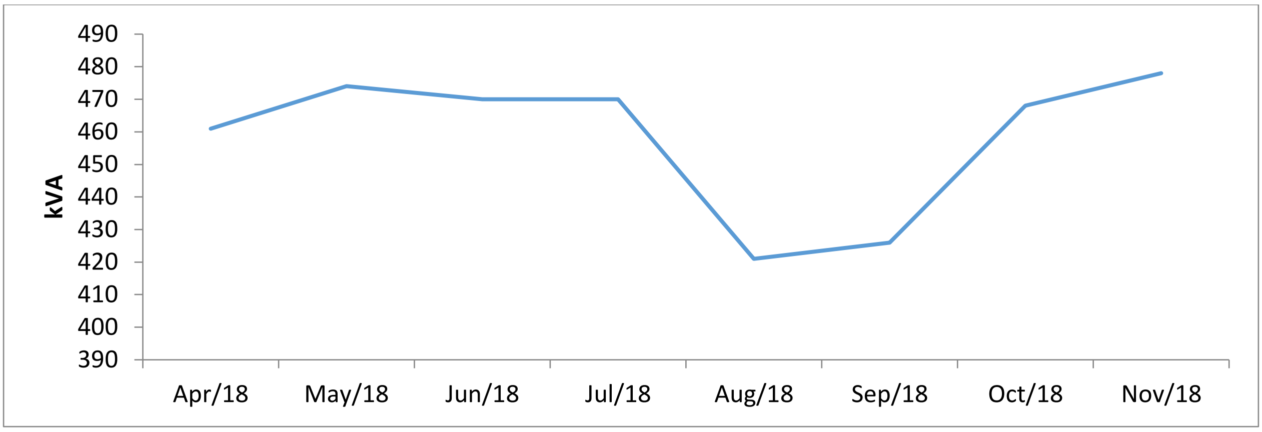

Figure 7 : Month wise variation in Maximum Demand

2.2.1.4 *Single line diagram*

Single line diagram of plant is shown in below figure:

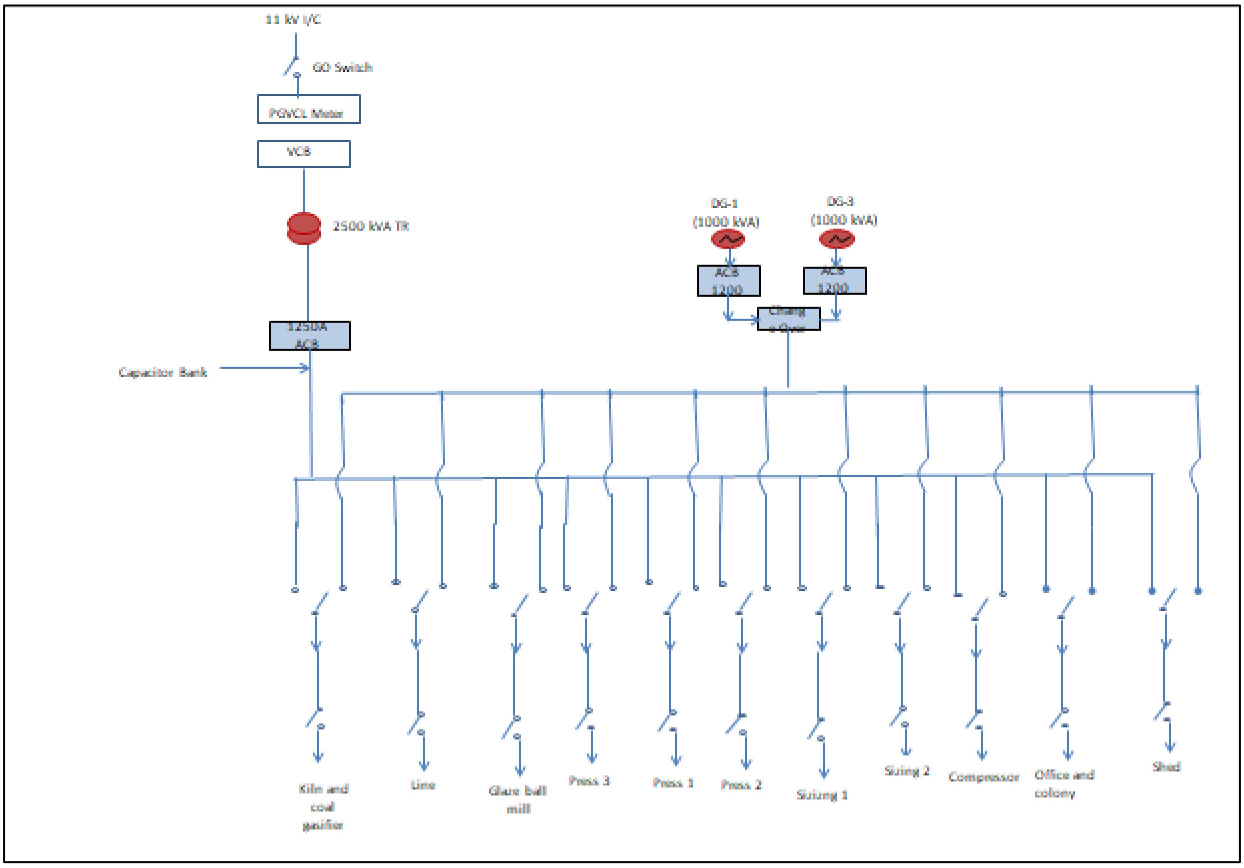

Figure 8: SLD of Electrical Load

2.2.1.5 *Electricity consumption areas*

The plant total connected load is 1,085.8 kW, which includes:

- The plant and machinery load is 988.19 kW
- The utility load (fan and lighting) is about 97.65 kW including the single phase load

Table 11 : Equipment wise connected load

Sr.No.	Connected Load	Unit	Values
1	Compressors	kW	59
2	Hydraulic presses	kW	210
3	Press cooling towers	kW	20
4	Glazed tiles kiln	kW	141
5	Dryer	kW	29.5
6	Biscuit kiln	kW	122
7	Final sizing machine 1	kW	147
8	Final sizing machine 2	kW	219
9	Coal gasifier	kW	62
10	Glaze ball mill	kW	67.5
11	Lights	kW	8.64
	Total	kW	1,085.8

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

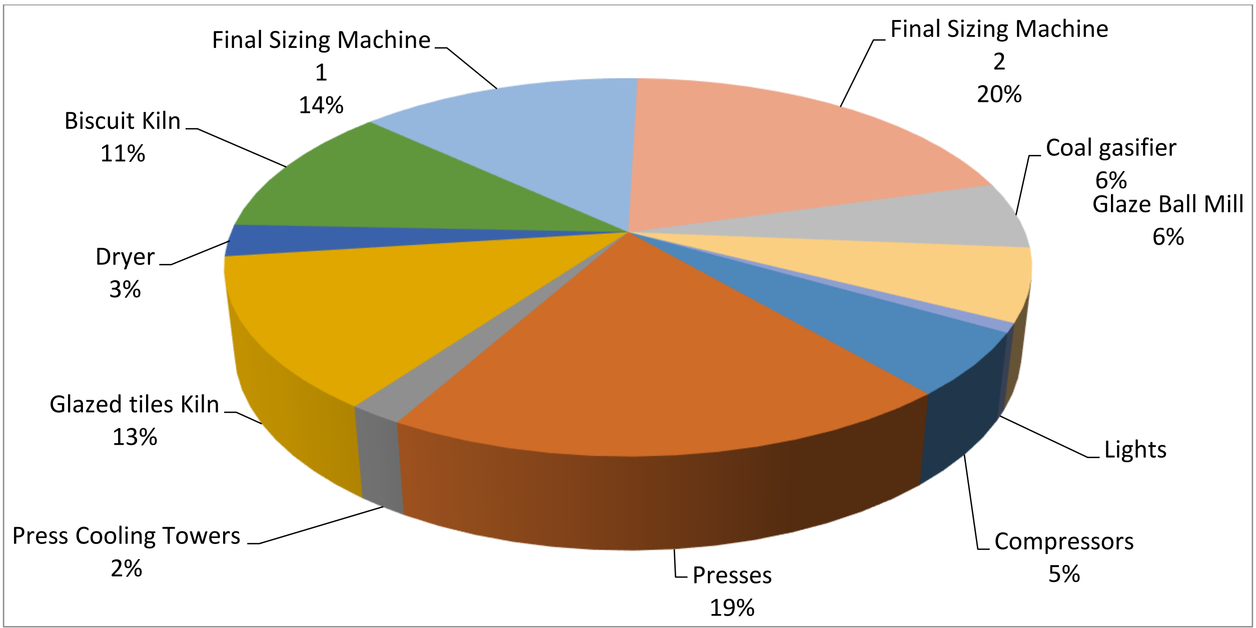

Figure 9 : Details of connected load

As shown in the figure, the maximum share of connected electrical load is for the Final Sizing Machine 2 – 20 %, hydraulic Press - 19%, Final Sizing Machine 1 - 14%, followed by Glazed tiles Kiln – 13 % ,Biscuit Kiln – 11 %, Glaze Ball Mill –6 %, Compressor– 5 %, Coal Gasifier – 6% ,Dryer – 3% ,Press Cooling Tower-2% and other electrical loads.

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:

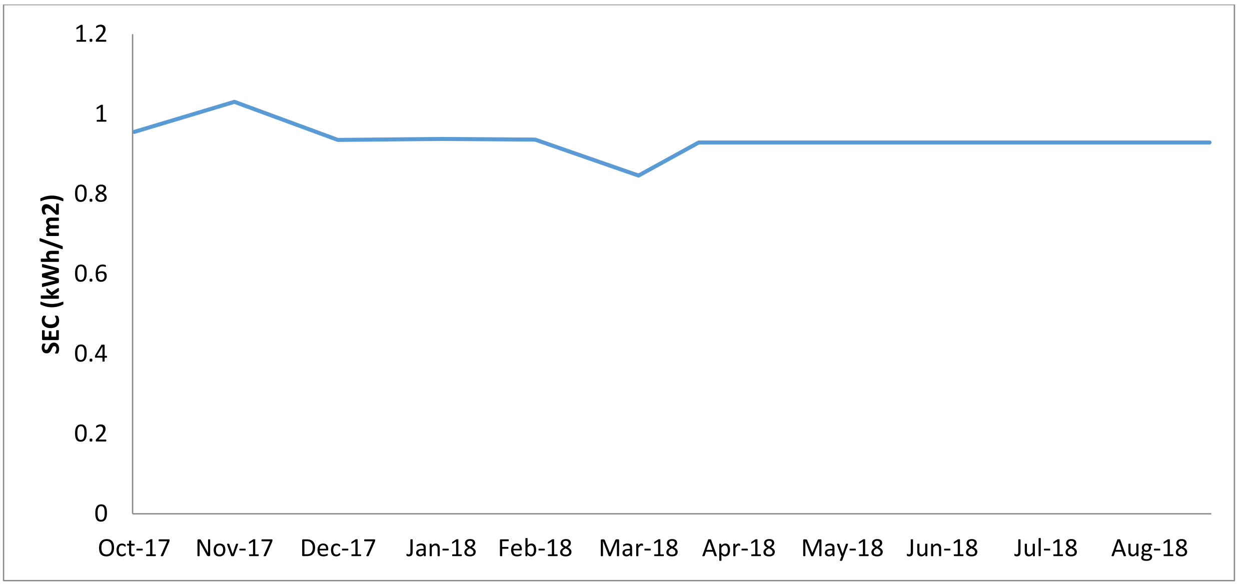

Figure 10 : Month wise variation in Specific Electricity Consumption

In all the months, the maximum and minimum values are within ±20% of the average SEC of 1 kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in ball mill section, spray dryer section, press section, biscuits kiln, glaze kiln, utility like compressor, pumps etc.

2.2.2 Analysis of thermal consumption

2.2.2.1 Month wise fuel consumption and cost

The thermal consumption area is the kilns. Coal is used as fuel for coal gasifier to generate coal gas used in kiln – 1 and Kiln - 2. Coal is purchased from local coal suppliers who in turn import coal from Indonesia. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Coal Consumption and Cost in Kiln-1(Biscuit Kiln)

	Coal consumption		
Months	Coal Used MT	Coal Cost Rs	Coal Cost Rs/MT
Oct-17	729	6,706,800	9,200
Nov-17	728	6,697,600	9,200
Dec-17	734	6,752,800	9,200
Jan-18	732	6,734,400	9,200
Feb-18	728	6,697,600	9,200
Mar-18	736	6,771,200	9,200
Apr-18	755	6,944,952	9,200
May-18	679	6,242,609	9,200
Jun-18	774	7,121,863	9,200
Jul-18	725	6,666,337	9,200
Aug-18	715	6,578,007	9,200
Sep-18	831	7,647,549	9,200

Observation:

- Kiln-1 is used for baking of biscuit 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 as a primary fuel in kiln – 1 and kiln – 2.
- Average monthly coal consumption in coal gasifier is 739 MT and average cost is Rs.9,200/MT.

2.2.2.2 Specific fuel consumption

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

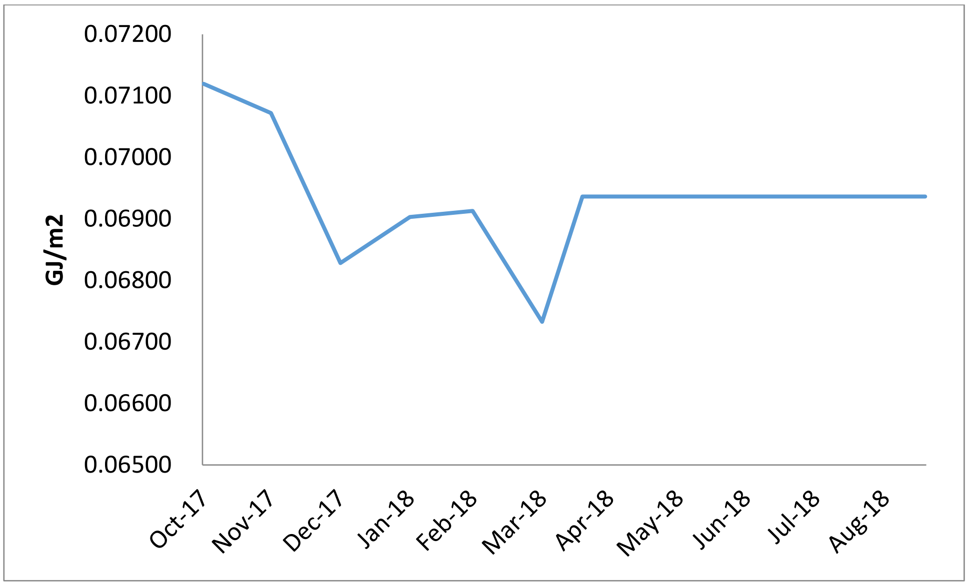

Figure 11 : Month wise variation in Specific Fuel Consumption

The average SFC is 0.069 GJ/m^2. The coal consumption was nearly 0.003 GJ/m^2. This is because coal data is based on purchase and actual information on consumption is not being maintained. The SEC therefore does not follow the production.

For better quality information, sub-metering /data logging is required for monitoring thermal energy consumption.

2.2.3 Specific energy consumption

2.2.3.1 Based on data collected during EA

Specific energy on the basis of data collected during energy audit is shown in below table:

Table 13: Specific energy consumption

Particulars	Units	Value
Average production	m^2/h	317
Power consumption	kW	289
Coal consumption	kg/h	1041.67
Energy consumption	TOE/h	0.566
SEC of plant	TOE/m^2	0.0018

2.2.3.2 *Section wise energy consumption*

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

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

Particulars	Coal	Electricity
	kg/t	kW/t
Hydraulic Press 980		23.28
Hydraulic press 1400		22.92
Hydraulic Press 2000		11.81
Biscuit kiln	119	106.4
Glaze kiln	108.8	5.92
Sizing unit 1		5.18
Sizing unit 2		8.75

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 15: Overall: specific energy consumption

Parameters	Units	Value
Annual Grid Electricity Consumption	kWh/y	2,601,490
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	2,601,490
Annual Thermal Energy Consumption (Imported Coal)	t/y	8,865
Annual Thermal Energy Consumption (NG)	scm/y	0
Annual Energy Consumption	TOE	4,834
Annual Energy Cost	Rs. Lakh	982
Annual production	m^2	2,784,896
	t	38,527
SEC; Electrical	kWh/m^2	0.93
	kWh/t	67.52
SEC; Thermal	GJ/m^2	0.07
	GJ/t	5.01
SEC; Overall	TOE/ m^2	0.0017
	TOE/t	0.13
SEC; Cost Based	Rs./m^2	35.27
	Rs./t	2,549.13

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

- Conversion Factors
  - Electricity from the Grid : 860 kcal/kWh
- GCV of Imported Coal : 5,200 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 16: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs./ kWh	6.87
Cost of coal	Rs./MT	9,200
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	2,784,896

2.4 WATER USAGE & DISTRIBUTION

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

Water from outside tanker is 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 -120 m^3/day as informed by unit.

Water distribution diagram is shown below.

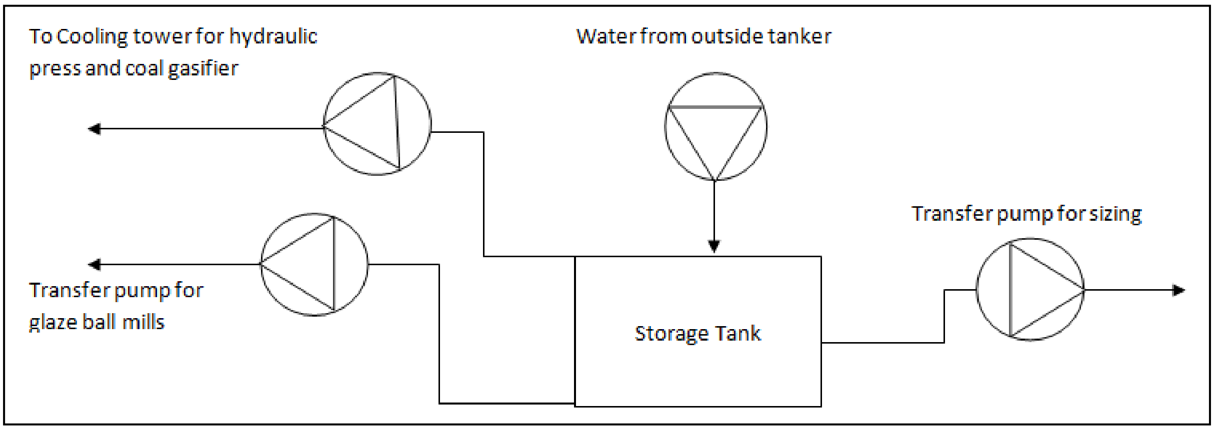

Figure 12: Water Distribution Diagram

Water are procured from tanker suppliers to meet the process requirements, having TDS of about 445 ppm. 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:

Rating of cooling tower circulation pumps are given below:

Table 17: Press cooling water circulation pump details

Parameters	Unit	Cooling Water Pumps
Make	-	-
Motor rating	kW	10
RPM	rpm	2,900
Quantity	number	2

3 CHAPTER -3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Coal gas is used as a fuel in both the kilns to heat the ceramic tiles to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan).

Cooling blower and rapid cooling blowers are used for cooling the tiles after combustion zone to get required tile quality and at the starting point, a smoke blower is installed which preheats the tiles before combustion zone of kiln.

Connected Electric Load for Kiln-1(Biscuit Kiln) is 122 kW, whereas Kiln-2 (Glazed Tile Kiln) is 141 kW. Kiln - 1 includes 22 kW smoke blower, two combustion blowers of 15 kW each, 5.5 kW for rapid cooling, 22 kW for Hot air blower, 22 kW for final cooling blowers, and 5.5 kW for indirect cooling blower and connected load of 20 roller motor is 15 kW.

Kiln - 1 has a dryer connected in series. Biscuit (green tiles) from press is firstly dried in dryer before entering into preheating zone of kiln – 1. As dryer is in series with kiln -1, hot air is used as a fuel to dry tiles. Dryer consists of one smoke blower of 7.5 kW and one booster blower of 22 kW.

Kiln - 2 includes 22 kW smoke blower, two combustion blowers of 15 kW each, 15 kW for rapid cooling, 22 kW for Hot air blower, 22 kW for final cooling blower & 15 kW indirect cooling blower and connected load of 20 roller motor is 15 kW.

Table 18: Kiln Details

Sl. No	Parameter	Unit	Kiln-1 (Biscuit Kiln)	Kiln-2 (Glaze Kiln)
	Make		Modema	Modema
1	Kiln operating time	h	24	24
2	Average fuel consumption	sm^3/h	2,121	1,909
3	Number of burner to left	-	96	52
4	Number of burner to right	-	96	52
5	Cycle time	Minutes	59	40
6	Pressure in firing zone	mmWC	60	60
7	Maximum temperature	^oC	1,200	1,100
8	Waste heat recovery option		Yes	Yes
9	Kiln dimensions (Length x Width x Height)			
	Preheating zone	m	38 x 1 x 2.7	29 x 1 x 1.8
	Firing zone	m	50 x 1 x 2.7	37 x 1 x 1.8
	Rapid cooling zone	m	9 x 1 x 2.7	7 x 1x1.8
	Indirect cooling zone	m	20 x 1 x 2.7	15 x 1 x 1.8
	Final cooling zone	m	25 x 1 x 2.7	19 x 1 x 1.8

3.1.2 Field measurement and analysis

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

Table 19: FGA study of kilns

Parameter	Kiln-1(Biscuit Kiln)	Kiln-2(Glaze Kiln)
Oxygen Level measured in Flue Gas	6.3%	8.2%
Ambient Air Temperature	40.2°C	40.2°C
Exhaust Temperature of Flue Gas	130 °C	150 °C

From the above table, it is clear that the oxygen level measured in flue gas was high in both the Kilns. So, Energy Conservation Measure is suggested .The inlet temperature of raw material in Kiln-1 and in Kiln-2 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 20: Surface temperature of kilns

Kiln Surface Temperatures (°C)	Kiln-1(Biscuit Kiln)	Kiln-2(Glaze Kiln)
Ambient Temperature	40.2	40.2
Pre-heating zone average surface temperature	53.2	43.1
Heating zone average surface temperature	75.8	62.9
Rapid cooling zone average surface temperature	66.2	63.4
Indirect cooling zone average surface temperature	59.2	72.6
Final cooling zone average surface temperature	56.8	57.2

The temperature profile of the kilns is shown below:

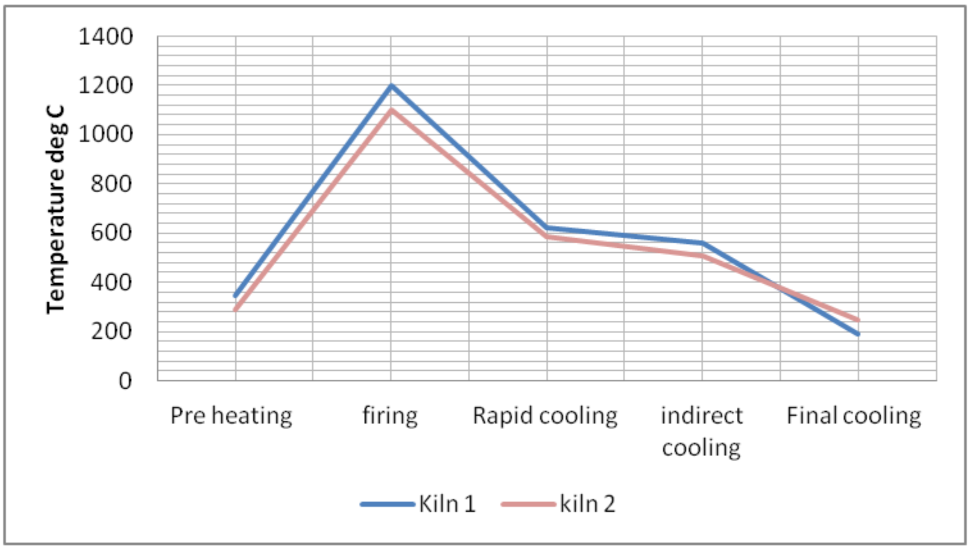

Figure 13: Temperature Profile of Kiln-1 & Kiln-2

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

Table 21: Power measurements of all blowers

Equipment	Kiln 1 (Biscuit Kiln)		Kiln 2 (Glaze Kiln)	
	Average Power (kW)	PF	Average Power (kW)	PF
Final cooling blower	5.78	1		
Hot air blower	7.27	1	4.09	1

Equipment	Kiln 1 (Biscuit Kiln) Average Power (kW)	PF	Kiln 2 (Glaze Kiln) Average Power (kW)	PF
Rapid cooling blower	1.76	0.98	2.38	1
Combustion blower-1	2.42	0.9	3.96	1
Smoke blower-1	9.7	1	6.1	1
Indirect cooling blower	2.03	1	1.54	1

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln-1 (Biscuit Kiln) is 42.89 % and kiln-2 (Glaze Kiln) 42.87 %. Summary of all losses is shown in below figure:

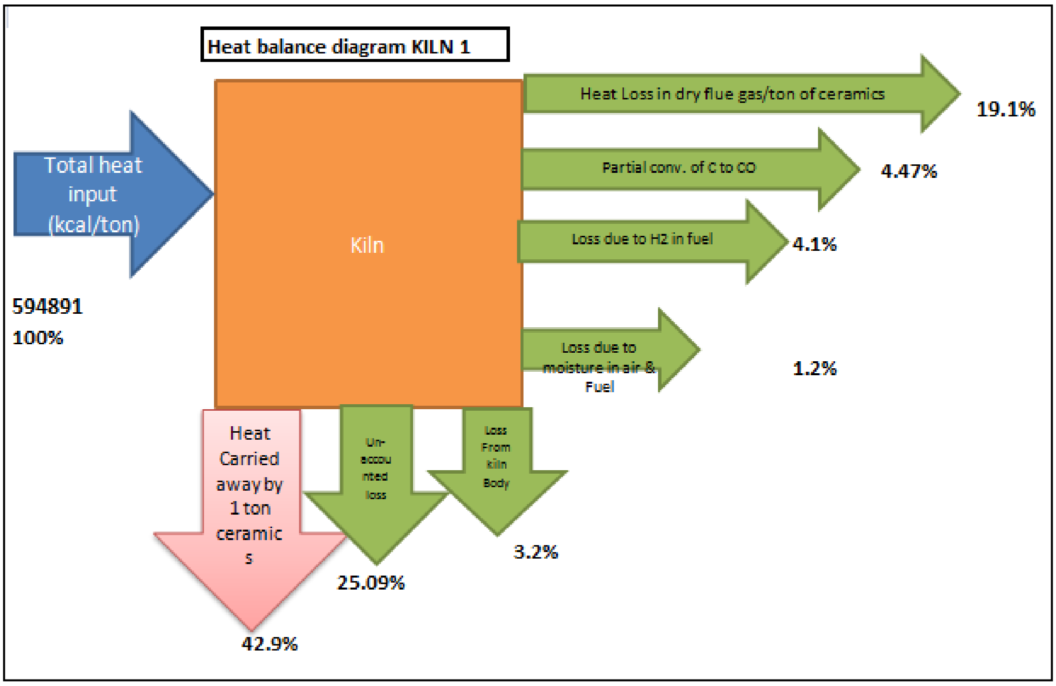

Figure 14: Heat Balance Diagram of Kiln-1

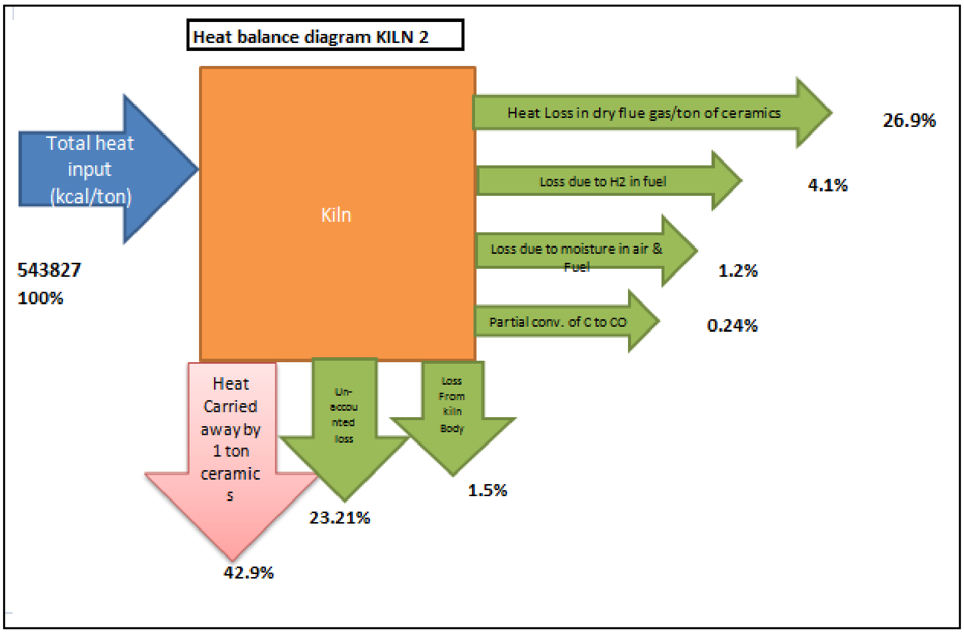

Figure 15: Heat Balance Diagram of Kiln-2

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** oxygen level is 6.3 %, which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

Table 22: Cost benefit analysis for Kiln 1 (ECM-1)

Parameters	UOM	Kiln 1 - Biscuit Present	Kiln 1 - Biscuit Proposed
Oxygen level in flue gas just before firing zone	%	6.3	5.0
Excess air percentage in flue gas	%	42.9	31.3
Dry flue gas loss	%	4%	

Parameters	UOM	Kiln 1 - Biscuit Present	 Proposed
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	kg/t	483	499
Average production in Kiln	t/h	5	5
Saving in specific fuel consumption	kg/h		27.90
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual fuel saving	t/y		221
Fuel cost	Rs/t		9,200
Annual fuel cost saving	Lakh Rs/y		20.3
Power saving in combustion blower			
Mass flow rate of air	t/h	26.52	24.37
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	6	5.5
Measured power of blower	kW	2.42	1.88
Total power saving	kW	0.54	
Operating hours per day	h/d	330	
Operating days per year	d/y	24	
Annual energy saving	kWh/y	4,303	
Weighted electricity cost	Rs/kWh	6.87	
Annual energy cost saving	Lakh Rs/y	0.30	
Overall energy cost saving	Lakh Rs/y	21	
Estimated investment cost	Lakh Rs	18.48	
Payback period	Months	11	
IRR	%	84%	
Discounted payback period	Months	4	

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** oxygen level is 8.2% which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

Table 23: Cost benefit analysis for Kiln 2 (ECM-2)

		Kiln 2 – Glaze	
Parameters	**UoM**	**Present**	**Proposed**
Oxygen level in flue gas just before firing zone	%	8.2	5.0
Excess air percentage in flue gas	%	64.1	31.3
Dry flue gas loss	%	27 %	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	kg/t	421	407
Average production in Kiln	t/h	4.1	4.1
Saving in specific fuel consumption	kg/h	0	57.10
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual fuel saving	t/y		452
Fuel cost	Rs/t		9,200
Annual fuel cost saving	Lakh Rs/y		41.6
Power saving in combustion blower			
Mass flow rate of air	t/h	23.15	18.52
Density of air	kg/m3	1.23	1.23
Mass flow rate of air	m^3/s	5.3	4.2
Measured power of blower	kW	3.96	2.03
Total power saving	kW	1.93	
Operating hours per day	h/d	330	
Operating days per year	d/y	24	
Annual energy saving	kWh/y	15,305	
Weighted electricity cost	Rs/kWh	6.87	
Annual energy cost saving	Lakh Rs/y	1.05	
Overall energy cost saving	Lakh Rs/y	43	
Estimated investment cost	Lakh Rs	18.48	
Payback period	Months	5	
IRR	%	176%	
Discounted payback period	Months	2	

3.1.4.3 *Energy conservation measures (ECM) - ECM #3 Insulation in recuperator pipe in kiln – 2 (Glaze)*

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

Study and investigation

There are 20 uninsulated pipes in recuperator in rapid cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80 °C and it was measured as 100°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

Recommended action

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

Table 24: Cost benefit analysis (ECM-3)

Parameter	UoM	Present	Proposed
		Kiln – 2 (Glaze kiln)	
No of un-insulated pipe in Recuperator	#	20	20
Recuperator pipe size	mm	6	6
Pipe length	m	1.8	2
Total surface area	m^2	0.69	0.69
Average surface temperature	°C	100	80
Ambient air temperature	°C	35	35
Heat loss	kcal/h/m^2	861	551
Total heat loss	kcal/h	591	378
GCV of fuel	kcal/kg	5,200	5,200
Heat loss in terms of fuel	kg/h	0.114	0.073
Fuel saving	kg/h		0.041
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	kg/y	324	
Fuel cost	Rs/kg	9.2	
Annual fuel cost saving	Rs Lakh/y	0.03	
Estimated investment	Rs Lakh	0.05	
Payback period	Months	19	

Parameter	UoM	Present	Proposed
IRR	%	42	
Discounted payback period	Months	7	

3.2 Coal Gasifier

3.2.1 *Specifications*

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

Table 25: Specifications of coal gasifier

Particular	UoM	Value
Make		-
Coal consumption	t/d	25
Water consumption	l/d	2,000
Tar generation	kg/d	400
FD blower	kW	2 x 15
ID blower	kW	1 x 22
Cooling water pump	kW	2 x 5

3.2.2 *Field measurement and analysis*

During DEA, the following activities were carried out:

- Measurement of power consumption of cooling water pumps, FD blower and ID blower.
- Air flow measurement of FD blower

Coal consumption is recorded by the plant in terms of lifts as per kiln cycle time. Kiln cycle time varies between 40-60 minutes in both the kilns. During the DEA, the kiln-1 and kiln-2 cycle time was 59 minutes and 40 minutes respectively.

FD blower and ID blower has operate on VFDs. Air flow measured of FD blower is 0.65 m^3/hr.

The measurement of ID blower, FD blower and cooling tower pumps are given below:

Table 26 : Measurement of Coal gasifier equipments:

Equipment	kW	PF
FD blower	1.83	1
ID blower	0.06	0.91
CT pump 1	3.6	0.83
CT pump 2	3.84	0.77

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

3.2.3 *Observations and performance assessment*

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, the specific energy consumption of coal gasifier was 0.26 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm of coal gas generation in plant which is 0.0074 kWh/scm.

4 CHAPTER -4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 HYDRAULIC PRESSES

4.1.1 Specifications

There are 3 hydraulic presses - Press 980, Press 1400, Press 2000. Hydraulic presses give shape for powder that is coming from storage silos, in tiles form by pressing powder with high pressure. Hydraulic oil gets heated when pressed so that it is required to be cooled in heat exchanger where water circulates as cold media. The specifications of hydraulic presses and its accessories are given below:

Table 27: Specifications of hydraulic press

Particular	Units	SACMI - Press 980	SACMI - Press 1400	SACMI - Press 2000
Cycle (stock) per minute	N/m	8	8	9
Nos. of tiles per stock	#	4	4	4
Tile size	mm × mm	250 x 380	250 x 380	300 x 450
Tile thickness	mm	7	7	8.5
Tiles weight	kg	1.2	1.2	2.1
Power rating	kW	55	75	80
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 Table 27.

Average power consumption of hydraulic press 980 was 53.6 kW (PF 0.82), hydraulic press 1400 was 52.8 kW (PF 0.81), and in hydraulic press 2000 was 53.6 kW (PF 0.69). Water circulation pump-1 and pump-2 were consuming power as 8.3 kW and 8.8 kW.

4.1.3 Observation and performance assessment

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

Performances of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of hydraulic press 980 was 23.28 kW/ton, hydraulic press 1400 was 22.92 kW/ton, and hydraulic press 2000 was 11.8 kW/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 glazing mills are given below:

Table 28: Specifications of glazing machine

Particular	UoM	Glaze mill
Numbers of glazing mills	Nos.	5
Capacity of glaze ball mill 1	Ton/batch	1.5
Capacity of glaze ball mill 2	Ton/batch	1.5
Capacity of glaze ball mill 3	Ton/batch	1.5
Capacity of glaze ball mill 4	Ton/batch	1.5
Capacity of glaze ball mill 5	Ton/batch	1
Connected load of glaze ball mill 1	kW	15
Connected load of glaze ball mill 2	kW	15
Connected load of glaze ball mill 3	kW	15
Connected load of glaze ball mill 4	kW	15
Connected load of glaze ball mill 5	kW	7.5

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of two glaze ball mills which were in operation.
- Mass consumption (t/batch) as per Table 28.

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

Table 29: Power consumption and P.F. of glaze mills

Equipment	kW	PF
Glaze ball mill 2	11.4	0.78
Glaze ball mill 4	9.07	0.79

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 mills were 4.95 kW/ton.

4.2.4 Energy conservation Measures

The energy conservation measures recommended are:

4.2.4.1 Energy conservation measures (ECM) - ECM #4: 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 two glaze ball mills were in operation. The motors used in these glaze ball mills are IE1 class.

Recommended action

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

Table 30: Cost benefit analysis (ECM-4)

Particular	Unit	Present	Proposed	Present	Proposed
		Glaze ball mill – 2		Glaze ball mill – 4	
Rated power of motor	kW	15	15	15	15
Motor efficiency class		IE1	IE3	IE1	IE3
Existing efficiency of motor	%	88.7	92.1	88.7	92.1
Existing power consumption	kW	11.40	10.50	9.07	8.35
Energy loss in motor	kW	1.3	0.4	1.0	0.3
Estimated energy saving	kW		0.9		0.7
Operating hours/day	d/y	330	330	330	330
Operating days/year	h/d	24	24	24	24
Annual energy consumption	kWh/y	90,288	83,155	71,834	66,159
Annual energy savings	kWh/y		7,133		5,675
Total energy savings	kWh/y	12,808			
Unit cost of electricity	Rs/kWh	6.87			
Annual monetary savings	Lakh Rs/y	0.88			
Estimated Investment	Lakh Rs	1.85			
Payback period	Months	25			
IRR	%	26%			
Discounted payback period	Months	9			

4.3 Sizing

4.3.1 Specifications

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

Table 31: Specifications of sizing machine

Particular	UoM	Value
Numbers of sizing machines	Nos.	4
Sizing machine 1	kW	73.5
Sizing machine 2	kW	73.5
Sizing machine 3	kW	89.5
Sizing machine 4	kW	89.5

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 4.13 t/h.

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

Table 32 : Measured Parameters of sizing machine

Equipment	Unit	Value	PF
Average power (M/c#1)	kW	10.4	0.8
Average power (M/c#2)	kW	11	0.78
Average power (M/c#3)	kW	19.9	0.71
Average power (M/c#4)	kW	16.3	0.57

4.3.3 Observation and performance assessment

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

Table 33 : SEC of sizing machine

Equipment	Unit	Value
Sizing Unit #1	kW/t	5.17
Sizing Unit # 2	kW/t	8.76

4.4 Air Compressors

4.4.1 Specifications

Three air compressors are installed in plant. Out of which two are reciprocating and one is screw compressor .The specifications of compressors are given below:

Table 34: Specifications of compressors

Particular	Units	Screw compressor	Reciprocating compressor 1	Reciprocating Compressor 2
Power rating	kW	37	11	11
Maximum pressure	bar (a)	7	7	7
Rated capacity	m^3/min	7.08	-	-

All compressors have a common receiver. The reciprocating compressor is only used when screw compressor is under maintenance.

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all compressor
- Loading and unloading time

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

Table 35: Measured parameters of Compressors

Equipment	Average Power (kW)	PF	% of time on load	Air flow rate (m^3/min)
Screw compressor	41.1	0.89	68.85	2.7
Reciprocating compressor-1	8.81	0.68	-	-
Reciprocating compressor-2	10.3	0.82	-	-

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

4.4.3 Observation and performance assessment

Based on observations during DEA, it was observed that operating pressure was higher in the compressor which can be reduced as per requirement. VFD installation is recommended for Screw compressor to avoid power consumption during unloading.

4.4.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.4.4.1 Energy conservation measures (ECM) - ECM #5: 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 etc.

Study and investigation

It was observed during the energy audit that the cut-in pressure was 6 kg/cm^2 and cut-out pressure was 7 kg/cm^2. Compressor was running in unload/load condition.

Recommended action

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

The cost benefit analysis is given in the table below:

Table 36: Cost benefit analysis (ECM-5)

Parameter	UoM	Present	Proposed
Operating pressure required	kg/cm^2	4	4
Compressor loading pressure	kg/cm^2	6	5
Compressor unloading pressure	kg/cm^2	7	6

Parameter	UoM	Present	Proposed
Reduction in pressure	kg/cm²		1
% of energy saving	%		6%
Average load	kW	31.1	29.21
Average compressor operating hours per day	h/d	24	24
Compressor annual operating days	d/y	330	330
Annual energy consumption	kWh/y	246,078	231,314
Annual energy savings	kWh		14,765
Weighted avg. cost of electricity	Rs/kWh	6.87	6.9
Annual monetary saving	Rs Lakh/y		1.01
Estimated investment	Rs Lakh		Nil
Payback period	Months		Immediate
IRR	%		-
Discounted payback period	Months		Nil

4.4.4.2 Energy conservation measures (ECM) - ECM #6: Installation of VFD in compressor

Technology description

In any industry, compressor requirement keeps on varying based on the production demand and hence air compressor will run in load/unload sequence as per demand. During the unload condition air compressor will consume about 30% power without doing any work. A VFD can take care of this variable air demand by changing the RPM of compressor motor based on pressure feedback received from pressure sensor. As the demand reduces, pressure will increase, hence compressor RPM will reduce. Similarly, when there is high demand pressure will reduce during this period VFD will raise the RPM of motor to meet the demand.

Study and investigation

Power cycles of all three compressors were captured to understand unload/load pattern of air compressor it was found that Screw compressor is getting unloaded for 31.1 % of the time. There was only one receiver and it was not possible to conduct FAD test for compressor.

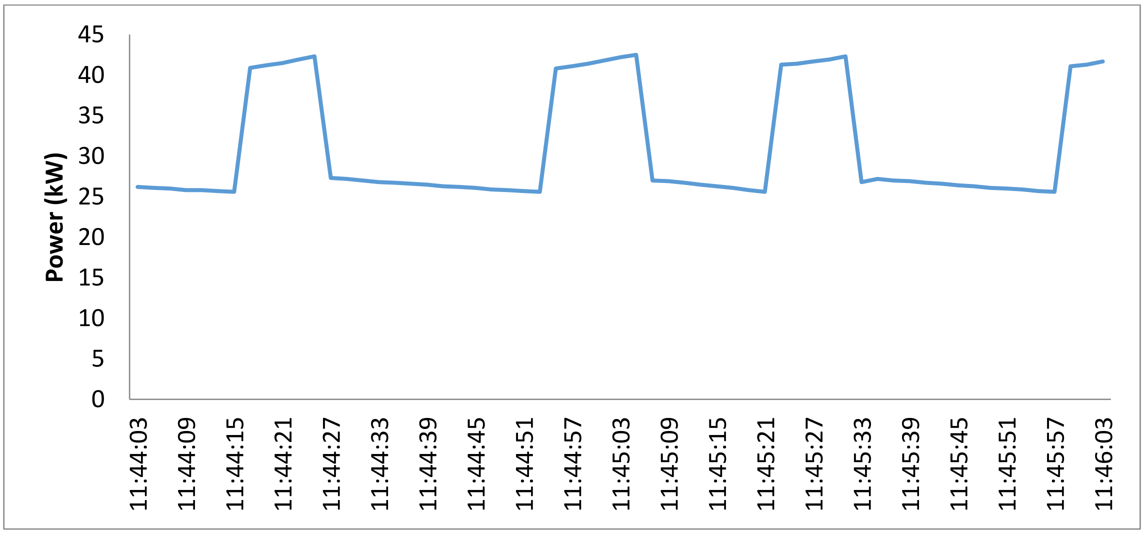

Figure 16: Load and unload pattern of Screw Compressor

Recommended action

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

Table 37: Cost benefit analysis (ECM-6)

Parameters	UOM	Present	Proposed
Compressor motor rating	kW	37	37
Average power consumption during loading	kW	41	
Average power consumption during unloading	kW	28.2	
On load time in percentage	%	68.85	
Off load time in percentage	%	31.15	
Average power consumption	kW	37.01	31.46
Compressor operating hours	h/d	24	24
Compressor annual operating days	d/y	330	330
Annual energy consumption	kWh/y	293,144	249,172
Annual energy saving	kWh/y	43,972	
Weighted average electricity cost	Rs/kWh	6.87	
Annual monetary savings	Rs Lakh/y	3.02	
Estimate of Investment	Rs Lakh	1.98	
Simple payback period	Months	8	
IRR	%	115	
Discounted payback period	Months	3	

4.5 Water Pumping System

4.5.1 Specifications

Pumping system comprises two Cooling Tower pumps as shown in Figure 12.

4.5.2 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 is given in below table:

Table 38: Operating details of pump

Particulars	Unit	Pump 1	Pump 2
Actual power consumption	kW	3.6	3.84
Power factor		0.83	0.77

4.5.3 Energy conservation measures

The energy conservation measures recommended are:

4.5.3.1 Energy conservation measures (ECM) - ECM #7: Replacement of inefficient pump with efficient pumps in Hydraulic press

Technology description

Oil from hydraulic press is heated during operation. So, it cooled in a heat exchanger by circulating cooling water using cooling tower pump.

Study and investigation

The unit is having two cooling tower pumps. Efficiency of existing pumps is 36.1% and 38.8% respectively.

Recommended action

It is recommended to replace inefficient pumps with energy efficient pumps. New pumps shall have efficiency up to 65%. The cost benefit analysis is given below:

Table 39: Cost benefit analysis (ECM-7)

Particulars	UoM	Value		Value	
		CT Pump-1 (Press)		CT Pump-2 (Press)	
Pump efficiency			65		65
Motor I/P power	kW	10	3.85	10	4.43
Motor efficiency	%	85	91	85.00	91.20
Measured parameters		**Present**	**Proposed**	**Present**	**Proposed**
Flow rate Q	m^3/h	46.5	46.5	53.5	53.5
Suction pressure	kg/cm^2	0.0	0.0	0.00	0.0
Discharge pressure	kg/cm^2	2.0	2.0	2.0	2.0
Motor input power	kW	8.3	3.21	8.8	3.69
Saving assessment		**Present**	**Proposed**	**Present**	**Proposed**
Flow rate Q	m^3/s	0.013	0.013	0.015	0.015
Total head developed	M	20.0	20.0	20.0	20.0
Liquid horse power	kW	2.5	1.9	2.2	2.2
Motor input power	kW	8.3	4.28	8.8	4.92
Nearest standard pump size	kW		5.5		5.5
Motor loading	%	82.6	70.0	88.4	80.5
Overall system efficiency	%	30.7	59.3	33.0	59.3
Pump efficiency	%	36.1	65.0	38.8	65.0
Average working hours	h/d	24.0	24.0	24.0	24.0
Annual working days	d/y	330.0	330.0	330.0	330.0
Annual energy consumption	kWh/y	65,419	33,858	70,013	38,955
Annual energy saving	kWh/y		31,561		31,057
Weighted average cost	Rs/kWh	6.9	6.9	6.9	6.9
Annual energy cost saving	Rs Lakh/y		2.17		2.13
Percentage of energy saving	%		48.2		44.4
Estimated investment	Rs Lakh		0.594		0.594
Total annual energy saving	kWh/y	62,618			
Total annual monetary saving	Rs Lakh/y	4.30			
Total investment	Rs Lakh	1.19			
Simple payback period	Month	3			
IRR	%	271			
Discounted payback period	Months	1.3			

4.6 LIGHTING SYSTEM*Specifications*

The plant's lighting system includes:

Table 40: Specifications of lighting load

Particular	Units	LED	FTL-8	FTL-8
Power consumption per fixture	W	15	36	42
Numbers of fixtures	#	7	104	19

4.6.2 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
Kiln area	80
Kiln control room	105
Press area	80
Glaze ball mill	70
Inventory	90
Sizing machine	90

4.6.3 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.

4.6.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.6.4.1 Energy conservation measures (ECM) - ECM #8: 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 8)

Parameter	Unit	Present	Proposed	Present	Proposed
Type of fixture		FTL T18	LED Tube	FTL T18	LED Tube
Type of choke if applicable		Magnetic	Driver	Magnetic	Driver
Number of fixtures	#	104	104	19	19

Parameter	Unit	Present	Proposed	Present	Proposed
Rated power of fixture	W/Unit	36	20	42	20
Consumption of choke	W	3	0	3	0
Operating power	W/fixture	39	20	45	20
Operating hour per day	h/d	12	12	12	12
Operating days per year	d/y	330	330	330	330
Annual energy consumption		16,062	8,237	3,386	1,505
Annual energy saving	kWh/y	7,825		1,881	
Total Energy savings	kWh/y	9,706			
Weighted average cost of electricity	Rs/kWh	6.87			
Annual monetary saving	Rs Lakh/y	0.7			
Estimated investment	Rs Lakh	0.99			
Payback period	Months	18			
IRR	%	45			
Discounted Payback Period	Months	7			

4.7 Electrical Distribution System

4.7.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (422 V) by step down transformer (0.75 MVA). Automatic power factor correction system is installed in parallel to main supply. There were two DGs (capacity of 1 MVA and 0.35 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 8.

4.7.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.7.3 Observations and performance assessment

After analyzing feeder power profiling, it was observed that the maximum kVA recorded during study period was **541.25 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **422 V.** Maximum voltage was **434.7 V** and minimum was **400 V**.

Average total voltage and current harmonics distortion found **7.0 %** & **15.9 %** respectively during power profile recording.

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

It was observed that some of the outgoing feeders to sizing section has low poor power factor. Poor power factor leads to cable losses (I^2R) in the electrical distribution system. So, Loss due to cable length should be minimized.

4.7.4 Energy conservation measures (ECM)

4.7.4.1 Energy conservation measures (ECM) - ECM #9: Voltage optimization in main LT incomer

Technology description

A Servo stabilizer is a servo motor controlled stabilization system that performs optimum voltage supply using a Buck\Boost transformer booster that captures voltage fluctuations from input and regulates current to the correct output. An AC synchronous motor adjusts voltage in clockwise or anticlockwise direction and manages the output voltage with components like control card, dimmer, comparator, transistors, ~~mocs~~, etc.

Study and investigation

During field measurements, it was found that the present voltage was higher than the standard voltage which is 415V. According to the main LT Power Profiling, maximum voltage was 446 & average voltage is 436V found.

Recommended action

A 0.7 MVA servo stabilizer is suggested to install on main LT panel to optimize voltage. Servo stabilizer rating is suggested according to Electricity monthly billing demand. The cost benefit analysis for this project is given below:

Table 43: Main LT Optimization [ECM-9]

Parameter	UoM	Present	Proposed
Maximum load (Measured)	kW	432	432
	kVA	541	541
Maximum demand as per electricity bill	kVA	485	485
Maximum voltage		435	415
Average voltage	V	422	410
Reduction in voltage	%		2.7%
% reduction in energy consumption	%		5.41%
Average power factor of system	PF	0.83	0.83
Annual electricity consumption	kWh/y	2,601,490	2,601,490
Savings estimate from other EPIAs	kWh/y		212,460
Actual energy considered for voltage regulation	kWh/y		2,389,030
Actual energy consumption after voltage regulation	kWh/y		2,259,750
Efficiency of servo stabilizer	%		95%
Period for which voltage regulation is required	Months/y		8
Net saving from voltage regulation	kWh/y		81,877
Unit cost of electricity	Rs/kWh		6.87
Annual monetary saving	Lakh Rs/y		5.62
Sizing of servo stabilizer	kVA		690
Rating of servo stabilizer	kVA		700
Estimated investment	Lakh Rs		9.24
Payback period	Months		19.72
IRR	%		41

Parameter	UoM	Present	Proposed
Discounted Payback Period	Months		7.3

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

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted that in sizing section power factor was between 0.57-0.80.

Recommended action

It is recommended to install power factor improvement capacitors for sizing section.

The cost benefit analysis for this project is given below:

Table 44 : Cost benefit analysis of cable loss minimization (ECM -10)

Location/Parameter	Unit	Section 2 Sizing Machine 1	Section 2 Sizing Machine 2	Section 1 Sizing Machine 1	Section 1 Sizing Machine 2
Existing power factor	pf	0.71	0.57	0.78	0.8
Proposed power factor	pf	0.99	0.99	0.99	0.99
Existing load	kW	19.9	16.3	11	10.4
Cable losses	Watts	145.4	151	112	95
Capacitor required	kVAr	17	21	7	6
Annual savings	Rs/y	3,780	5.431	4,809	4,032
Total annual savings	Lakh Rs/y	0.18			
Estimated investment	Lakh Rs	0.23			
Payback period	months	16			
IRR	%	52			
Discounted payback period	months	6			

4.8 Belt Operated Drives

4.8.1 Specifications

There are 14 drives operated with V Belt of total capacity of 263 kW. Locations include

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

4.8.2 Field measurement and analysis

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

4.8.3 Observations and performance assessment

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

4.8.4 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 14 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 45: Replacement of conventional belt with REC belt [ECM-11]

Particulars	UoM	AS IS	TO BE
Measured power of all belt driven blowers	kW	63	61[1]
Running hours of blowers	h/d	24	24
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	502,841	484,739
Annual energy saving	kWh/y		18,102
Electricity cost	Rs./kWh	6.87	
Annual energy cost saving	Rs. Lakh	1.24	
Estimated investment	Rs. Lakh	1.85	
Payback Period	Months	18	
IRR	%	47%	
Discounted Pay back period	Months	7	

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

Parameters	Unit	Present	Proposed
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	2,601,490	2,549,460
Annual electricity saving per year	kWh/y		52,030
Cost of electricity	Rs/kWh		6.87
Annual monetary savings	Rs Lakh/y		3.57
Number of equipment/system	#	23	23
No. of energy meters	#	0	23
Estimated investment	Rs Lakh		1.32
Thermal energy monitoring system	%	2.00	
Current coal consumption in Gasifier	kg/y	8,865,404	8,688,096
Annual coal saving per year	kg/y		177,308
Cost of coal	Rs/kg		9.20
Total annual monetary savings	Rs Lakh/y		16.31
Number of equipment /system	#	3	3
Number of coal weighing machines			1
Estimated investment	Rs Lakh		2.29
Annual monetary savings (Electrical + Thermal)	Rs Lakh/y		19.89
Estimated (Electrical + Thermal)	Rs Lakh		3.61
Payback period	Months		2.18
IRR	%		409
Discounted payback period	Months		1

5.2 BEST OPERATING PRACTICES

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

Table 47: Unique Operating practices

Sl No	Equipment/System	Best Operating Practices
1	Transformer	APFC installed to maintain power factor
2	Hydraulic press	None
3	Glaze ball mill	Timer control in each ball mill.
4	Glaze line	None
5	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
6	Sizing	Fully automatic system. Dust collected system installed.
7	Printing	Automated digital printing with fully auto control system
8	Lighting	LED lights

5.3 NEW/EMERGING TECHNOLOGIES

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

5.3.1 DRY CLAY GRINDING TECHNOLOGY: "Magical Grinding System "Technology description

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

Table 48 : Specifications of dry clay grinding technology

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

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

The working principle is as follows:

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

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

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

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

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

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

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

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

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

Figure 17 : 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.

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

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[4] SACMI Kiln Revamping catalogue for roller kilns

[5] SACMI Kiln Revamping catalogue for roller kilns

c. Instantaneous pressure and temperature readings
d. Easy calibration

Figure 18: NG consumption monitoring kit

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

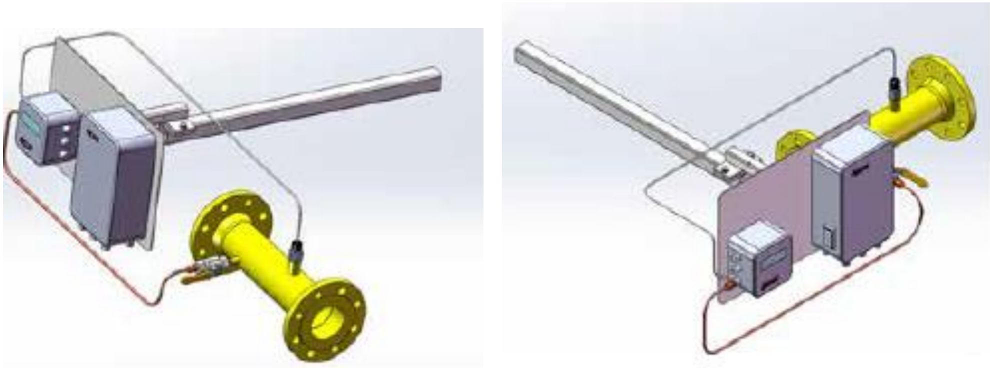


Figure 19: Combustion air control for burner

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 optimization
- 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 20: 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

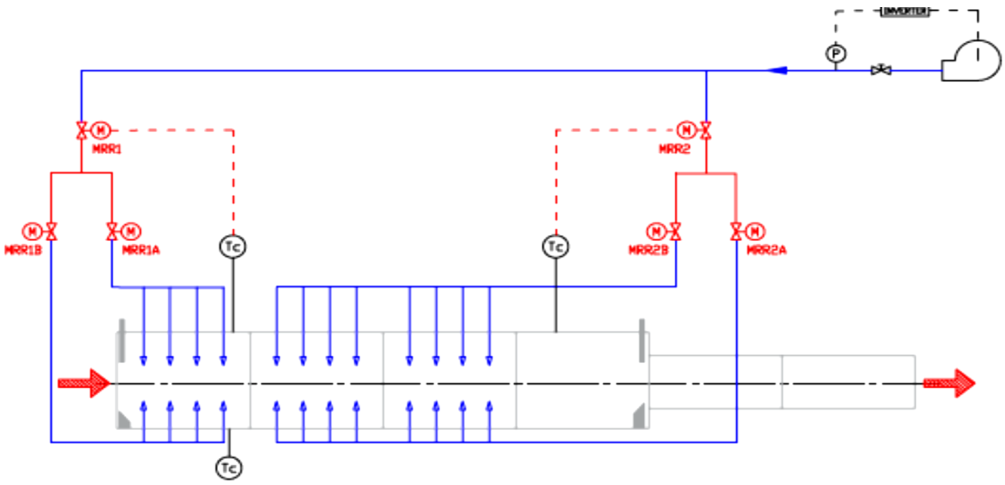


Figure 21: Fast cooling air management

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 22: 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

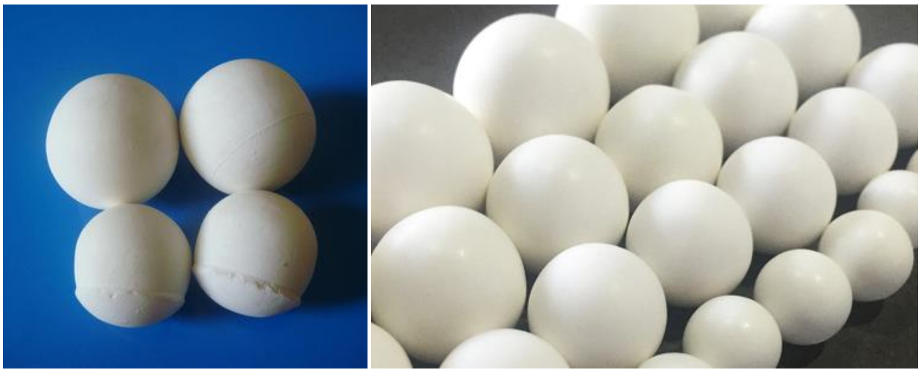


Figure 23: - High Alumina pebbles for Ball mill

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.

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 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.

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

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

- Conversely, during each process stage, if water is absorbed, there is loss of strength. Organic binders ensures that sufficient strength is maintained to withstand all the process stages thus reducing rejections due to cracks, damaged edges and breakages.

Advantages of using Binder for Vitrified tiles include:

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

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

5.3.7 USE OF DIRECT BLOWER FANS INSTEAD OF BELT DRIVE:

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

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

Figure 24: Direct drive blower fan

6 CHAPTER – 6 RENEWABLE ENERGY APPLICATIONS

The roof top PV potential is estimated as 290 kW. Cost benefit analysis is given below:

6.1 ENERGY CONSERVATION MEASURES (ECM) - ECM#13: INSTALLATION OF SOLAR PV SYSTEM

Technology description

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

Study and investigation

It was observed during energy audit that 3,021 m^2 of area is available on the roof top for installation of solar PV panels.

Recommended action

It is recommended to install 290 kW solar panel capacities. The average electricity generation is estimated at 444,595 kWh/y. The cost benefit analysis is given below:

Table 49: Cost benefit analysis for installing solar PV system (ECM 13)

Parameters	Unit	Proposed
Available area on roof	m^2	3,021
Estimated total solar PV panel area	m^2	1,813
Number of panels (1m X 2m) of 320 Wp	#	906
Estimated installed capacity of solar panel	kW	290
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	1,218
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	444,595
Cost of electricity	Rs/kWh	6.87
Annual monetary savings	Rs Lakh/y	31
Estimated investment	Rs Lakh	160
Payback period	Months	63
IRR	%	-6%
Discounted payback period	Months	21

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

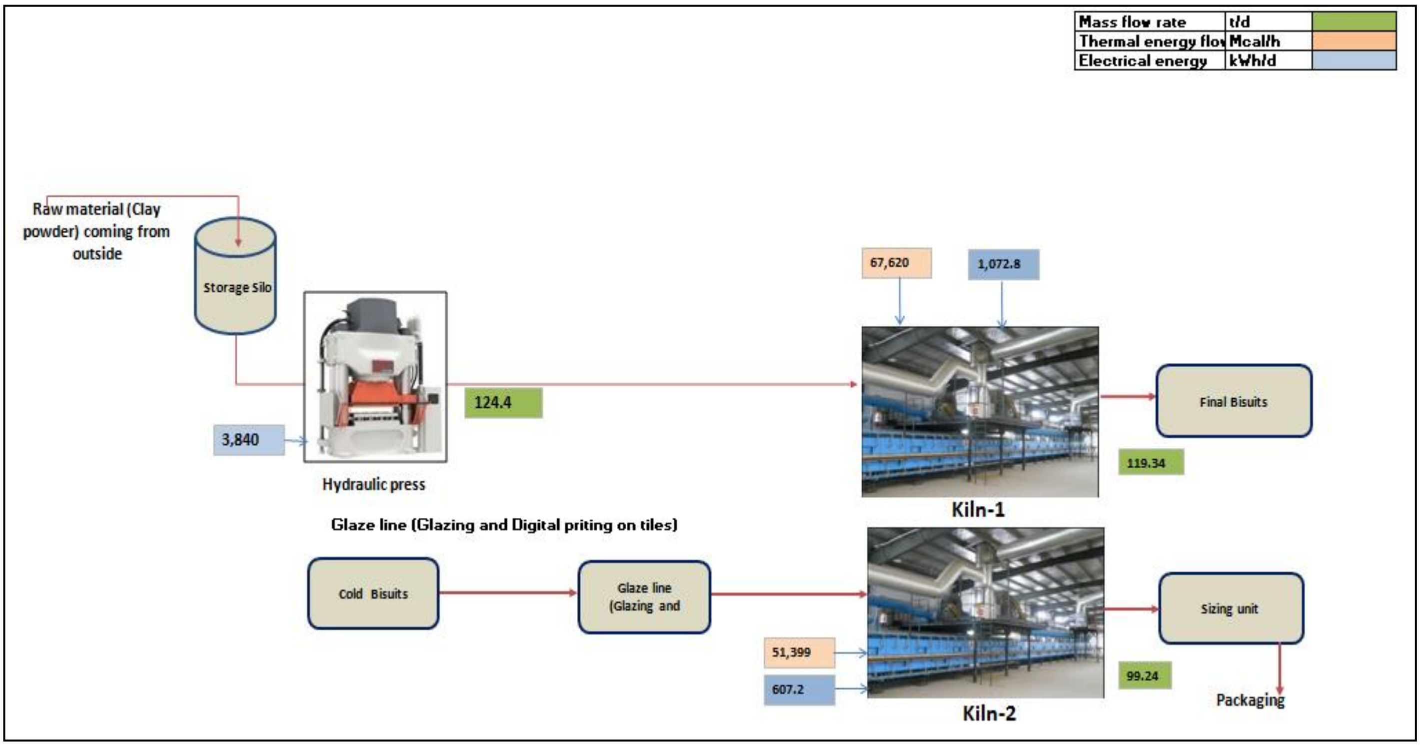


Figure 25: Process Flow Diagram of Plant

ANNEX-2: DETAILED INVENTORY

Equipment	Connected Load	Rating (kW)
Compressor	Screw Compressor	45
	Reciprocating Compressor-1	11
	Reciprocating Compressor-2	11
Hydraulic presses	Press-1 (980)	55
	Press-2 (1400)	75
	Press-2 (2000)	80
Cooling tower	Pump	20
Kiln	Kiln-1 (Biscuit Kiln)	122
	Kiln-2 (Glaze Kiln)	141
Sizing line	Sizing M/c-1	73.5
	Sizing M/c-2	73.5
	Sizing M/c-3	89.5
	Sizing M/c-4	129.5
Dryer	Smoke Blower	7.5
	Booster Blower	22
Glaze ball mill	Glaze ball mill (4 Nos., 15kW each)	60
	Glaze ball mills (1 No., 7.5 kW)	7.5
Coal gasifier		62
Lighting		8.67

ANNEX-3: SINGLE LINE DIAGRAM

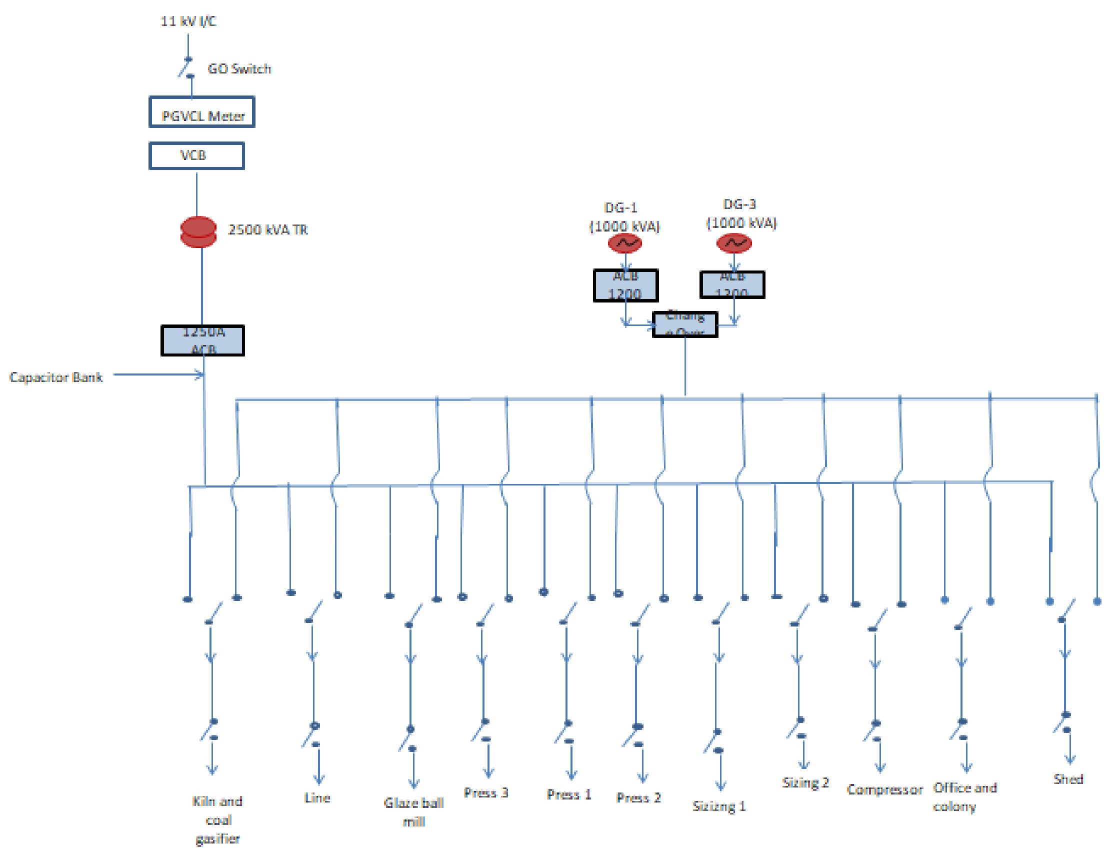
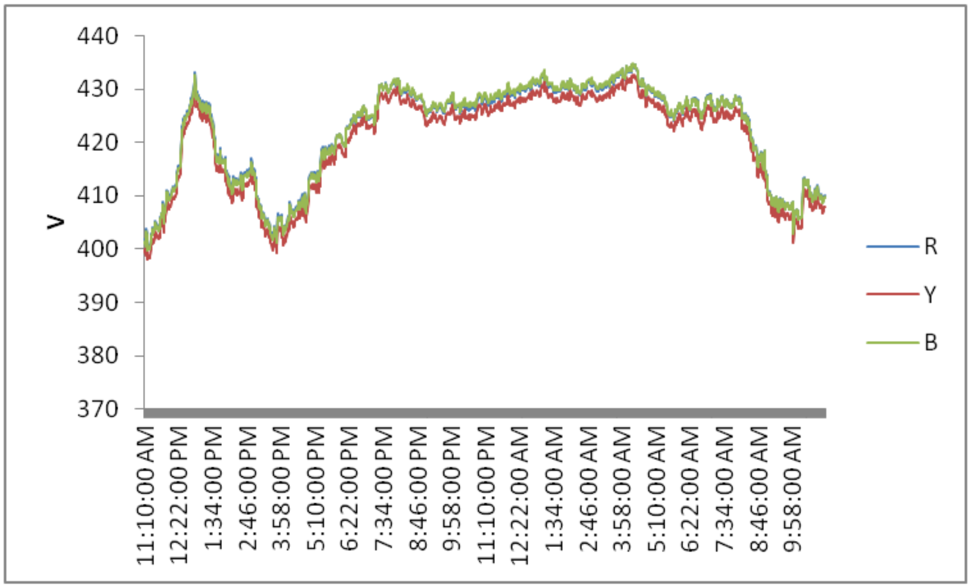


Figure 26: Single Line Diagram (SLD)

ANNEX-4: ELECTRICAL MEASUREMENTS



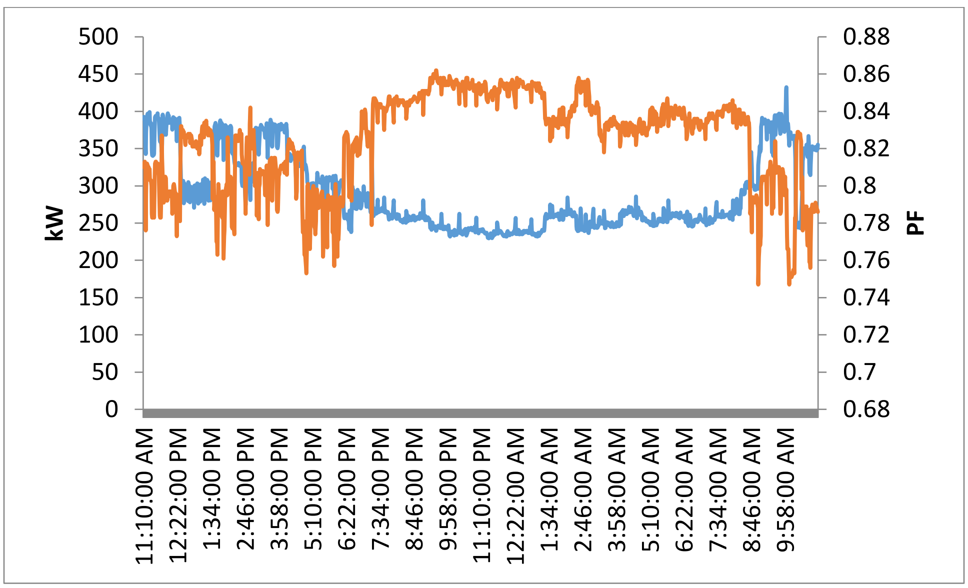


Figure 27: Power and PF profile of Main LT

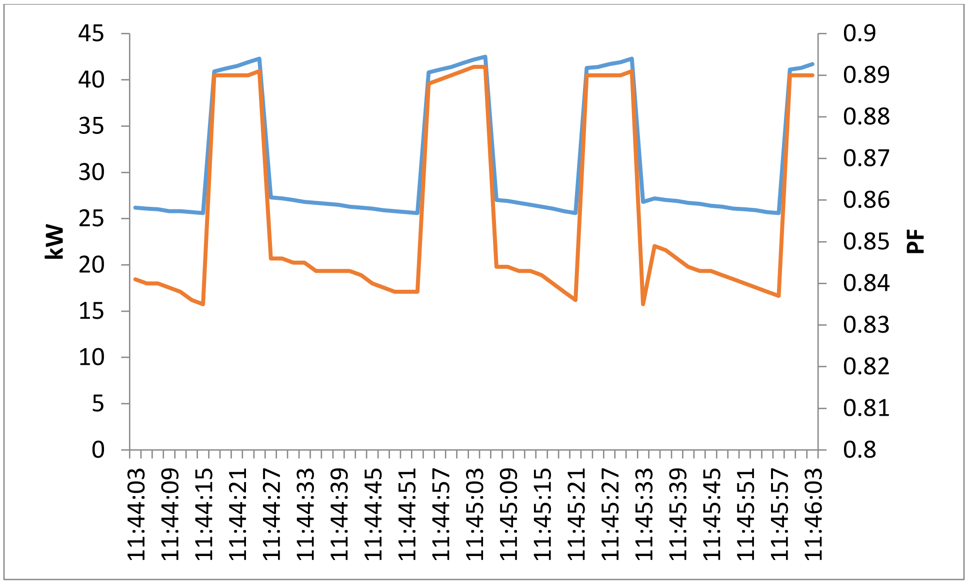


Figure 28: Power and PF profile of Screw Compressor

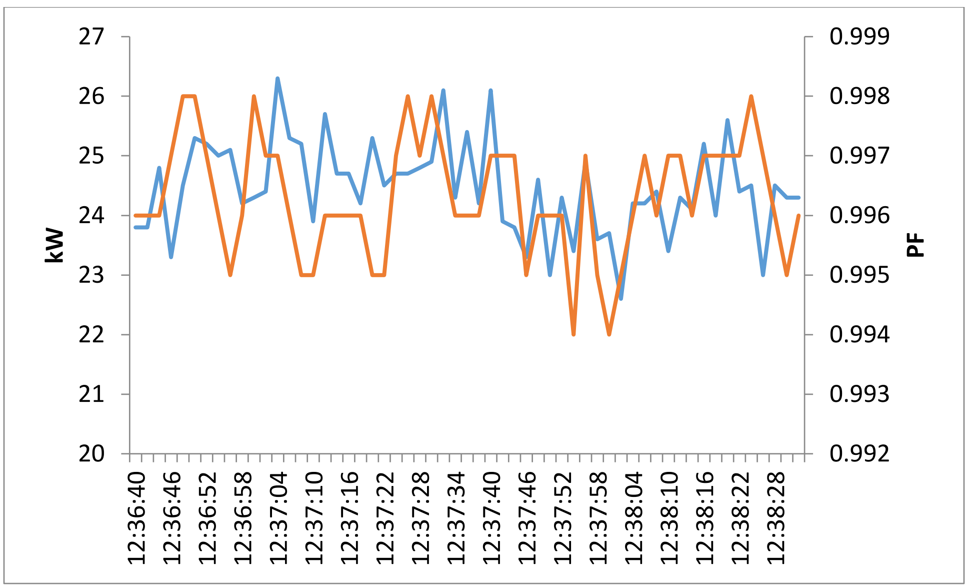


Figure 29: Power and PF profile of Glaze Kiln Main

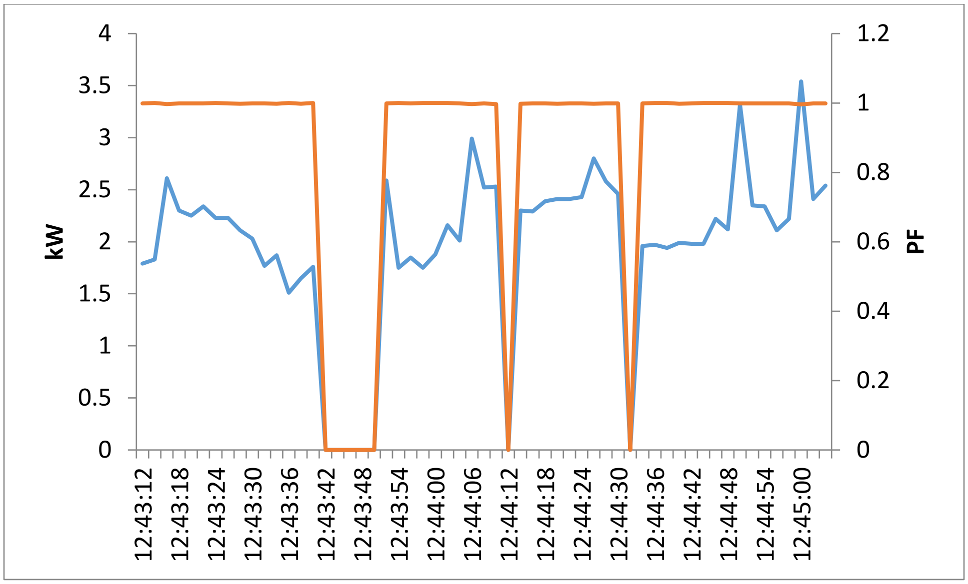


Figure 30: Power and PF profile of Glaze Kiln Rapid Cooling Blower

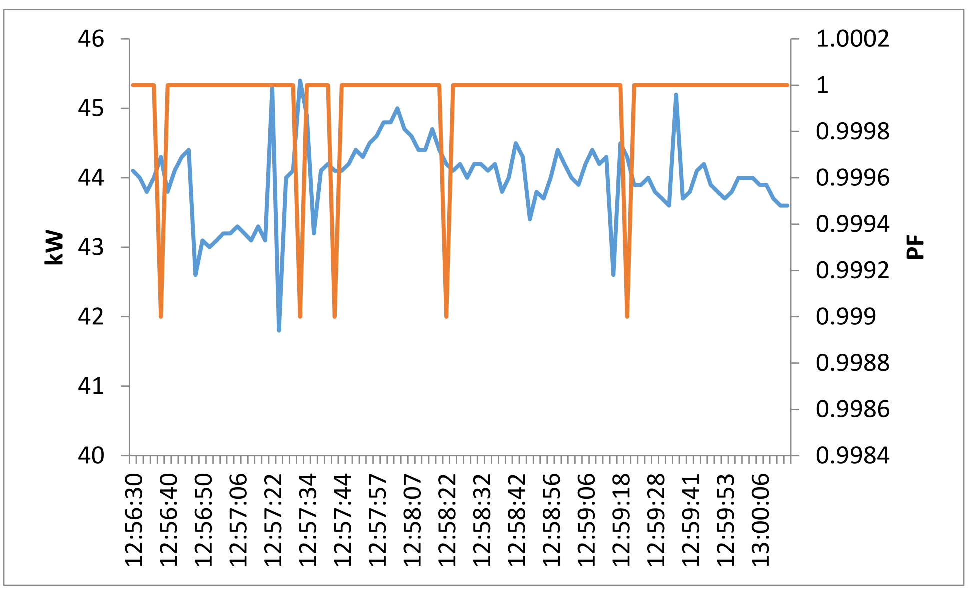


Figure 31 : Power and PF profile of Biscuit Kiln + Dryer

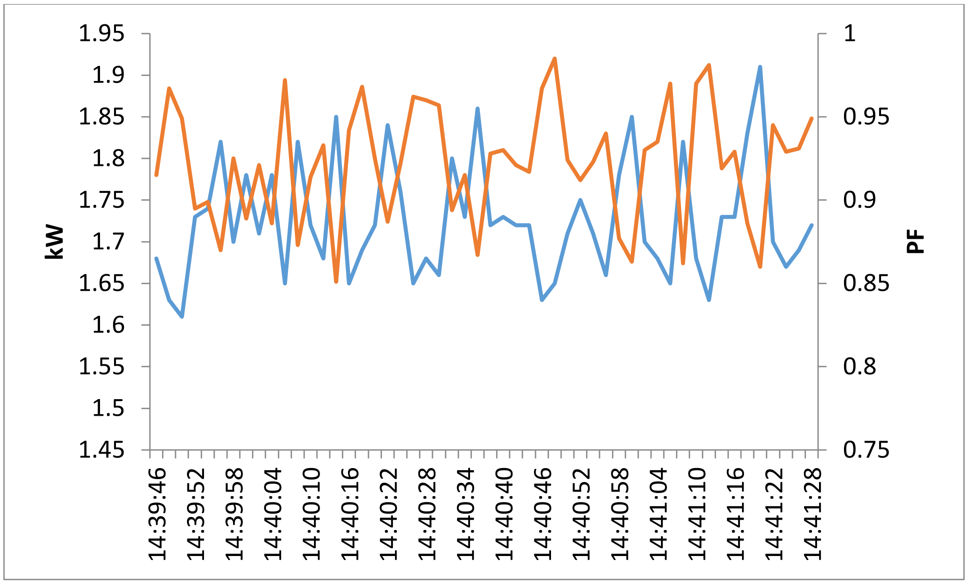


Figure 32: Power and PF profile of Biscuit Kiln Rapid Cooling Blower

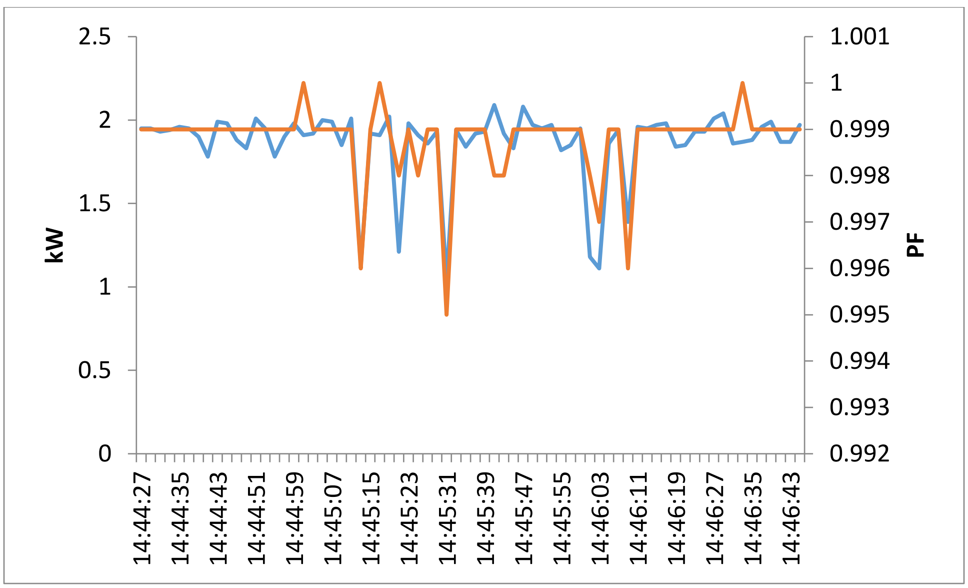


Figure 33: Power and PF profile of Biscuit Kiln Indirect Cooling Blower

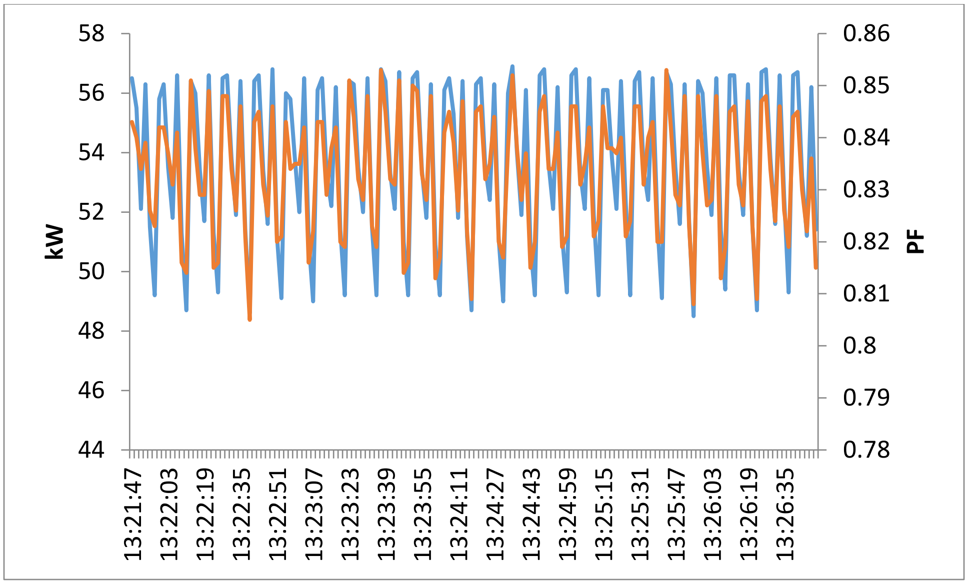


Figure 34 : Power and PF profile of Press 980 Main

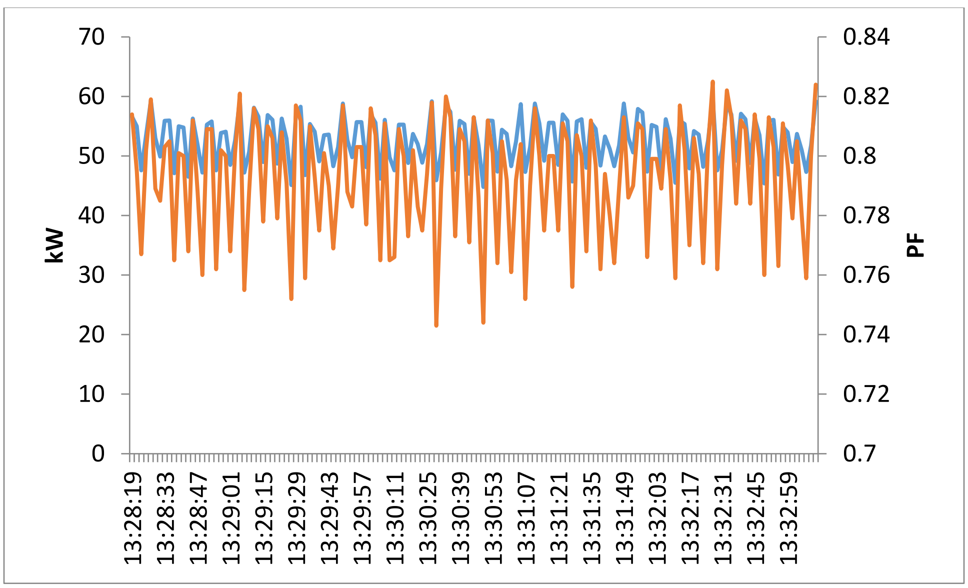


Figure 35: Power and PF profile of Press 1400 Main

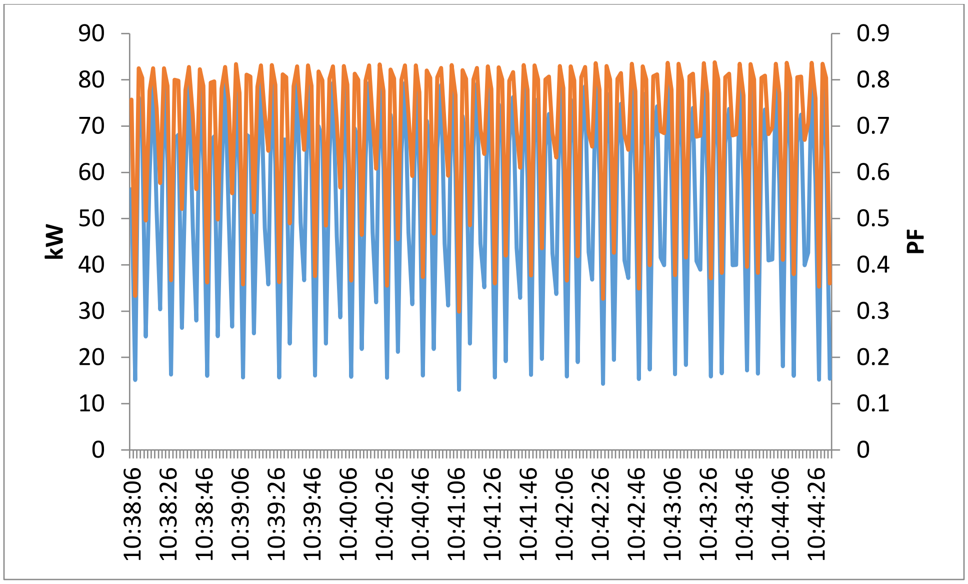


Figure 36 : Power and PF profile of press 2000 pneumatic pump

Annex-5: Thermal Measurements, Heat utilization of kilns

1. Kiln-1 heat utilization calculations

Input parameters of Kiln-1

Input Data Sheet		
Type of fuel	Coal Gas	
Source of fuel	Local Vendor	
	Biscuit Kiln	
Particulars	**Value**	**Unit**
~~Tunne~~l kiln operating temperature (Heating Zone)	1200	Deg C
Initial temperature of kiln tiles	40.2	Deg C
Average fuel consumption	2,404	kg/h
Density of coal gas	1.05	kg/sm3
Avg. fuel consumption	2,290	sm3/h
Flue Gas Details		
Flue gas temp. at smog blower	230	*deg C*
Preheated air temp./ambient	40	deg C
O2 in flue gas	6.3	*%*
CO2 in flue gas	10.42	*%*
CO in flue gas	4,340	*ppm*
Atmospheric Air		
Ambient temp.	40.2	*Deg C*
Relative humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
O	*0.00*	%
S	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	*1,231*	*kcal/kg*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un-burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kcal/kg
GCV of fly ash	*0*	kcal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	4,973	*Kg/Hr*
Weight of stock	0	*kg/hr*
Specific heat of clay material	0.22	*Kcal/kgdegC*
Avg. specific heat of fuel	0.51	*Kcal/kgdegC*
fuel temp	40.2	*deg C*
Specific heat of flue gas	0.24	*Kcal/kgdegC*
Specific heat of superheated vapour	0.45	*Kcal/kgdegC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	9,369	*kcal/hr*

Radiation and convection from heating zone surface	12,327	*kcal/hr*
Radiation and convection from rapid cooling	7,524	kcal/hr
Radiation and convection from indirect cooling	11,288	kcal/hr
Radiation and convection from final cooling	11,916	kcal/hr
Heat loss from all zones	94,137	*kcal/hr*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.98	*Hr*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*deg K*

Heat utilization calculations of Kiln-1 (Biscuit Kiln)

Calculations	Kiln 1 (Biscuit kiln)	Unit
Theoretical air required	7.72	*kg/kg of fuel*
Excess air supplied	42.86	*%*
Actual mass of supplied air	11.03	*kg/kg of fuel*
Mass of dry flue gas	10.91	*kg/kg of fuel*
Amount of wet flue gas	12.03	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*Kg of H2O/kg of fuel*
Amount of dry flue gas	10.92	*kg/kg of fuel*
Specific fuel consumption	483.81	*Kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	594,891	*Kcal/ton of tiles*
Sensible heat of fuel	0	*Kcal/ton of tile*
Total heat input	594,891	*Kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	255,156	*Kcal/ton of tile*
Heat loss in dry flue gas	113,720	*Kcal/ton of tile*
Loss due to H2 in fuel	24,169	*Kcal/ton of tile*
Loss due to moisture in combustion air	445.83	*Kcal/ton of tile*
Loss due to partial conversion of C to CO	26,609.17	*Kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	28.40	*Kcal/ton of tile*
Loss due to evaporation of moisture present in fuel	6,562	*Kcal/ton of tile*
Total heat loss from kiln (surface) body	18,930	*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	149,271	*Kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	18,930	*Kcal/tons*
Kiln Efficiency	42.89	*%*

2. Kiln-2 heat utilization calculations

Input parameters of Kiln-2

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Local Vendor	
	Glaze Kiln	
Particulars	**Value**	**Unit**
Tunnel Kiln Operating temperature (Heating Zone)	1100	*Deg C*
Initial temperature of kiln tiles	40.2	*Deg C*
Average fuel consumption	1,827	
Density of coal gas	1.05	
Avg. fuel consumption	1,740	*sm3/hr*
Flue Gas Details		
Flue gas temp. at smog blower	200	*deg C*
Preheated air temp./Ambient	40	
O2 in flue gas	8.2	*%*
CO2 in flue gas	6.09	*%*
CO in flue gas	131.7	*ppm*
Atmospheric Air		
Ambient temp.	40.2	*Deg C*
Relative humidity	47	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
O	*0.00*	%
S	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	*1,231*	*kcal/kg*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un-burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kcal/kg
GCV of fly ash	*0*	kcal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	4,135	*Kg/hr*
Weight of Stock	0	*kg/hr*
Specific heat of clay material	0.22	*Kcal/kgdegC*
Avg. specific heat of fuel	0.51	*Kcal/kgdegC*
fuel temp	40.2	*deg C*
Specific heat of flue gas	0.26	*Kcal/kgdegC*
Specific heat of superheated vapour	0.45	*Kcal/kgdegC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	1,041	*kcal/hr*
Radiation and convection from heating zone surface	17,396	*kcal/hr*
Radiation and convection from rapid cooling	3,382	kcal/hr
Radiation and convection from indirect cooling	11,015	kcal/hr
Radiation and convection from final cooling	6,220	kcal/hr

Heat loss from all zones	**31,760**	*kcal/hr*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.67	*hr*
Area of entry opening	1	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	371	*deg K*

Heat utilization calculations For Kiln -2 (Glaze Kiln)

Calculations	Kiln 2 (Glaze kiln)	UoM
Theoretical air required	7.72	*kg/kg of fuel*
Excess air supplied	64.06	*%*
Actual mass of supplied air	12.67	*kg/kg of fuel*
Mass of dry flue gas	12.55	*kg/kg of fuel*
Amount of wet flue gas	13.67	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*Kg of H2O/kg of fuel*
Amount of dry flue gas	12.55	*kg/kg of fuel*
Specific fuel consumption	441.92	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	543,827	*Kcal/ton of tiles*
Sensible heat of fuel	0	*Kcal/ton of tile*
Total heat input	543,827	*Kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	233,156	*Kcal/ton of tile*
Heat loss in dry flue gas	146,183	*Kcal/ton of tile*
Loss due to H_2 in fuel	22,283	*Kcal/ton of tile*
Loss due to moisture in combustion air	626.04	*Kcal/ton of tile*
Loss due to partial conversion of C to CO	1,312.7	*Kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	27.88	*Kcal/ton of tile*
Loss due to evaporation of moisture present in fuel	6,085	*Kcal/ton of tile*
Total heat loss from kiln (surface) body	7,941	*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	126,213	*Kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	7,941	*Kcal/tons*
Kiln efficiency	42.87	*%*

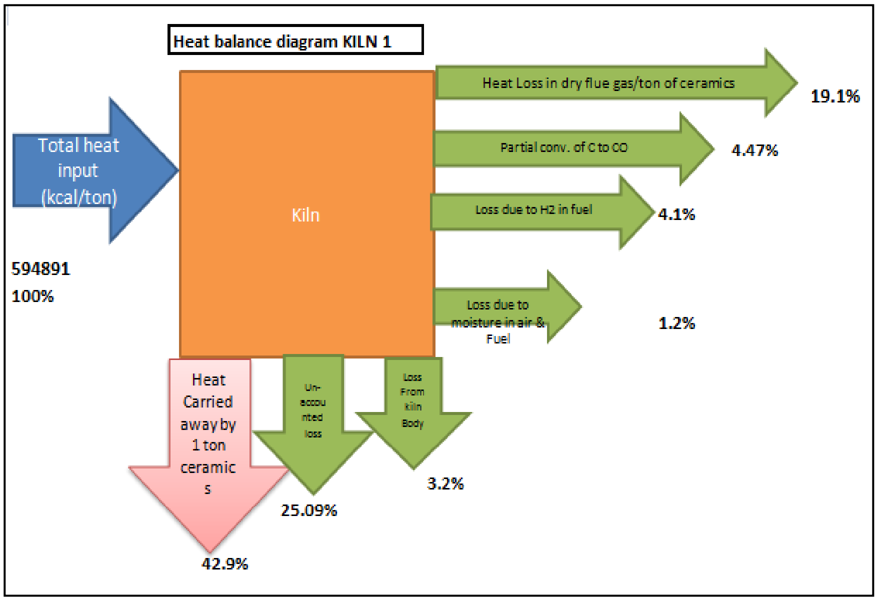


Figure 37 : Heat Mass Balance kiln-1

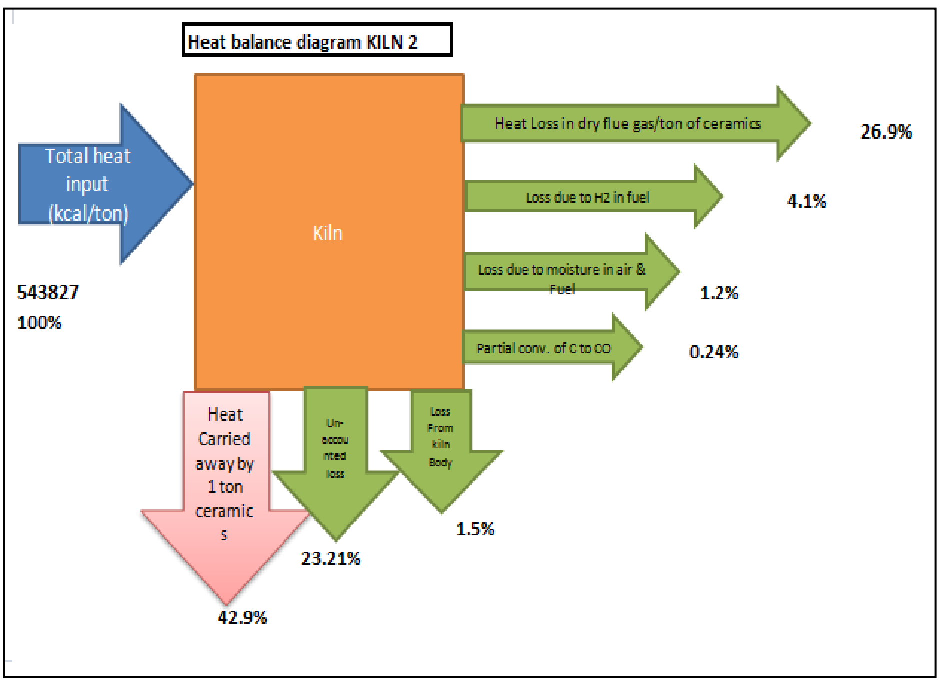


Figure 38 : Heat Mass Balance kiln-1

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	Knack well Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	Darshan Thanawala, Ravi Thanawala (Proprietor) 8079452278, 9428597582, 9327013773	www.knackwellengineers.com darshan@kanckwell.com, ravi@kanckwell.com

ECM 3: Insulation in combustion air pipe & near burner in kiln 2

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

ECM-4: Replacement of IE1 motor with IE3 motor of glaze ball mill

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	The General Electric Agency	Crompton House, Ganesh Shopping Centre, Opp. Dr. Beck & Co. GIDC, Ankleshwar	Mr. Nimesh Patel 9925152416	generalagenc@sify.com
2	Siemens Limited	3rd floor, Prerna Arbour, Girish Cold Drinks Cross	Mr. Paresh Prajapati 079-40207600	paresh.prajapati@siemens.com

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
		Road, Off. C.G.Road, Ahmedabad		
3	Crompton Greaves	909-916, Sakar-II, Near Ellisbridge, Ahmedabad	079-40012000 079-40012201 079-40012222	sagar.mohbe@cgglobal.com

ECM-6: VFD in screw compressor

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

ECM-7: Replacement of Inefficient Pumps

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Varuna Pumps Pvt Ltd.	La-Gajjar Machineries Pvt.Ltd. Acidwala estate, Nagarwel Hanuman Road, Amraiwadi, Ahmedabad – 380 026	79- 22777485 / 487	www.varunapumps.com crm@lgmindia.com
2	Kirloskar Brothers Ltd	1st floor, Kalapi Avenue, Opp. Vaccine Institute, Old Padra Road, Vadodara	Mr. Sanjeev Jadhav 0265-2338723/2338735	aksur@bdq.kbl.co.in
3	KSB Pumps Ltd	Neel Kamal, Ashram Road, Opposite Sales India, Ashram Road, Ahmedabad, Gujarat 382410	Mr. Jayesh Shah 098794 83210	https://www.ksb.com/ksb-in/ksb-in-india/

ECM-8: Replacement of inefficient lighting systems

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

ECM-9: Voltage optimization for main LT incomer

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

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	ESTERN CHAWLA COLONY, NEAR	Mob: 9015877030,	krishnaautomationsystems@gmail.com

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
	System Contact Person: Vikram Singh Bhati	KAUSHIK VATIKA, GURGAON CANAL BALLBGARH FARIDABAD 121004	9582325232	
3	Next Gen Power controls	8, Rashmi Growth Hub Estate, Near Shree Sai Palace Hotel Odhav, Ahmedabad-382415, Gujarat, India	08048110759	NA

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
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 (INDD) ABW Tower,7th Floor, Sector 25, IFFCO Chowk, MG Road,Gurgaon - 122001, Haryana,	9650015288	neeraj.vashisht@in.panasonic.com

ECM 13: Solar PV system

PF Improvement				
Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	GREEN EARTH INFRACON & SOLAR	348, Avadh Viceroy, Sarthana Jakatnaka, Varachha Road, Surat, Gujarat, 395006, India	Mr. Dhaval Patel 7210113608	NA
2	CITIZEN Solar Pvt. Ltd	711, Sakar-2 Ellisbridge corner, Ahmedabad-380006	Girishsinh Rav Jadeja 9376760033	www.citizensolar.com sales@citizensolar.com
3	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 50: Assumptions for Financial Analysis

Particulars	Units	Value
Debt Equity Ratio for Bank Loan		2: : 1
Interest Rate on Bank Loan	%	13.5
Project Implementation Period	Y	0.50
Moratorium Period	Y	0.50
Loan Repayment Period	Y	5.00
Depreciation Rate (IT Act)	%	80
Depreciation Rate (Co's Act)	%	15
Effective Income Tax Rate	%	26.7
Effective MAT Rate	%	21.6
Discount factor	%	15