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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE WT-30: HITCO CERAMIC PVT. LTD

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

1. Mr. Rajni Patel, MD
2. Mr. Sandeep Patel, Engg. Division Head

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

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

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ABBREVIATIONS

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

UNITS AND MEASURES

Parameters	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.

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

➨ INTRODUCTION OF THE UNITOF THE UNIT

Name of the Unit	Hitco Ceramic Pvt. Ltd.
Year of Establishment	2009
Address	Orsun Ceramic Zone, National Highway, 8-A, Lakhdhirpur - Morbi – 363642, Gujarat
Products Manufactured	Wall Tiles
Name(s) of the Promoters / Directors	Mr. Rajni 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 kilns in which the fuel used is natural gas in kiln-2 while coal gas is used in kiln - 1. The temperature maintained in biscuits kiln is approximately 800°C – 1,150ºC and glaze kiln is 700°C- 1,085°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 biscuit are made in hydraulic press.
- **Glaze mill:** For producing glazing material used on the wall tiles.
- **Kiln:** Biscuits are baked in the roller kiln at 1100-1150ºC and again baked after glazing
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The main utility equipment installed is:

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

The detailed energy audit covered all equipment which was operational during the field study. 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 - 2: Natural gas is used as fuel in kiln-2 and oxygen content in flue gas was 14.48% against desired level of 3%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation of recuperator pipes in kiln - 1 (Biscuit): In kiln - 1, the recuperator pipes was found to be uninsulated with surface temperature of 90 °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 24 recuperator pipes with insulation material for reducing surface heat losses.
- Insulation in delivery pipe in indirect cooling zone in kiln - 1: In kiln - 1, it was found that the delivery pipe for indirect cooling blower was uninsulated with surface temperature of about 160°C. It is recommended to insulate the pipe to maintain surface temperature of about 80 °C.
- Preheating of combustion air through recuperator: Presently, the recuperator is bypassed, the combustion air temperature to kiln-2 is 53°C. It is recommended to take recuperator into service to increase combustion air temperature upto 145 °C.
- Replacement of IE1 induction motor with more efficient IE3 motor in glaze ball mills: Glaze ball mills running with IE1 induction motor. It is recommended to replace with more efficient IE3 induction motor.
- Reduction of pressure of compressed air: Present compressor#1 discharge pressure is 6 kg/cm^2 and the end user pressure requirement were around 4 kg/cm^2. It is recommended to reduce operating pressure of compressor #1 from 6 kg/cm^2 to 5 kg/cm^2.

- Replacement of inefficient pumps: CT pump-1 & 2 of press oil cooling system have efficiency 45.7% & 26.3% respectively. It is recommended to replace the existing pumps with energy efficient pumps (65% efficiency).
- Retrofit of VFD in cooling tower pump: A VFD will take care of variable flow demand by changing RPM of motor coupled with pumps and will help to save energy upto 10% of present consumption.
- Replacement of inefficient lighting systems: Presently Fluorescent Tube lights and Compact fluorescent light are used for lighting. It is recommended to replace these with LED lamps.
- Voltage optimization in lighting circuits: The present voltage for lighting circuit was found to be 422 V against desired voltage of 380V. It is recommended to install separate lighting transformer of 20kVA rating for lighting circuit.
- Cable loss minimization: In sizing section, power factor was in range 0.39-0.42 and in glaze line and sizing line was 0.79 & 0.65. It is recommended to install capacitor to improve PF.
- Replacement of V belt to REC belt: All of blowers used in both kilns are V belt driven. These belts were consuming more power. So it is recommended to replace V belt to raw edge cogged belt which result in 3.6 % of energy saving.
- Energy management system: Presently, online data monitoring system are not installed in incomer as well as at various electrical panels. There was no proper fuel monitoring system installed at kiln. It is recommended to install online electrical energy management systems and fuel monitoring system.

Table 1 : Summary of Energy Conservation Measures

Sl. No.	Energy Conservation Measures	Annual Energy Savings Electricity kWh/y	NG scm/y	Coal t/y	TOE/y	Monetary Savings Lakh Rs/y	Investment Lakh Rs	Payback Period Months	Emission Reduction tCO_2/y
1	Excess air control system	20,511	273,926		248	88.68	18.48	3	544
2	Insulation of recuperator pipes in kiln - 1 (Biscuit)			41	25	3.71	1.32	4	87
3	Insulation in delivery pipe in indirect cooling zone in kiln – 1			20	12	1.79	0.66	4	42
4	Circulate combustion air through recuperator to increase temperature in kiln-2		23,051		21	7.35	Nil	Immediate	44
5	Replacement of motor in Glaze ball mill	8,940			0.8	0.60	2.11	42	7
6	Operational pressure optimization in compressor	21,965			1.9	1.48	Nil	Immediate	18
7	Replacement of cooling tower pumps	36,056			3	2.44	0.79	4	30
8	Retrofit of VFD in cooling tower pumps	4,417			0.38	0.30	0.67	27	4
9	Replacement of inefficient lights with EE lights	55,688			5	3.76	2.35	8	46
10	Servo Stabilizer in Lighting MDB	8,716			0.75	0.59	0.92	19	7
11	Cable loss Minimization	10,895			0.94	0.74	0.53	9	9
12	Replacement of V belt from REC (Raw edged cogged) belt	14,284			1	0.97	2.11	26	12
13	Energy Management System	61,545	25,125	139	113	24.68	3.08	1	393
	Total	**243,015**	**322,102**	**200**	**433**	**137**	**33**	**3**	**1,242**

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

1 Reduction in energy cost by 11.1%
2 Reduction in electricity consumption by 7.90%
3 Reduction in natural gas consumption by 25.64%
4 Reduction in coal consumption by 2.88%
5 Reduction in greenhouse gas emissions by 7.12%

➨ 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

Sl. No.	Energy Conservation Measure	Investment Lakh Rs	Internal Rate of Return %	Discounted Payback Period Months
1	Excess air control system	18.48	371%	1
2	Insulation of recuperator pipes in kiln - 1 (Biscuit)	1.32	214%	1.68
3	Insulation in delivery pipe in indirect cooling zone in kiln – 1	0.66	203%	1.75
4	Circulate combustion air through recuperator to increase temperature in kiln-2	Nil	-	-
5	Replacement of motor in Glaze ball mill	2.11	6%	15
6	Operational pressure optimization in compressor	Nil		-
7	Replacement of cooling tower pumps	0.79	232%	1.53
8	Retrofit of VFD in cooling tower pumps	0.67	25%	9.73
9	Replacement of inefficient lights with EE lights	2.35	120%	2.94
10	Servo Stabilizer in Lighting MDB	0.92	42%	7.13
11	Cable loss Minimization	0.53	107%	3.32
12	Replacement of V belt from REC (Raw edged cogged) belt	2.11	25%	9.73
13	Energy Management System	3.08	597%	0.60

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	Hitco Ceramic Pvt. Ltd.		
Plant Address	Orsun Ceramic Zone, National Highway, 8-A, Lakhdhirpur – Morbi – 363642, Gujrat - India		
Constitution	Private Limited		
Name of Promoters	Mr. Rajni Patel		
Contact person	Name	Mr. Rajni Patel	
	Designation	MD	
	Tel	9913950000	
	Fax		
	Email		
Year of commissioning of plant	2009		
List of products manufactured	Wall tile, 300 x 450 mm Wall tile, 300 x 600 mm Wall tile, 300 x 300 mm		
Installed Plant Capacity	8,000 boxes/day (9000 boxes/day currently)		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17

Description	Details		
Turnover	Not Provided by Unit		
Net profit	Not Provided by Unit		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
Number of employees	Staff	95	
	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 - 1
	Diesel (litres)	Yes	DG – Rarely used
	Natural Gas (scm)	Yes	Only in Kiln-2
	Other (specify)	No	
Have you conducted any previous energy audit?	No		

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.

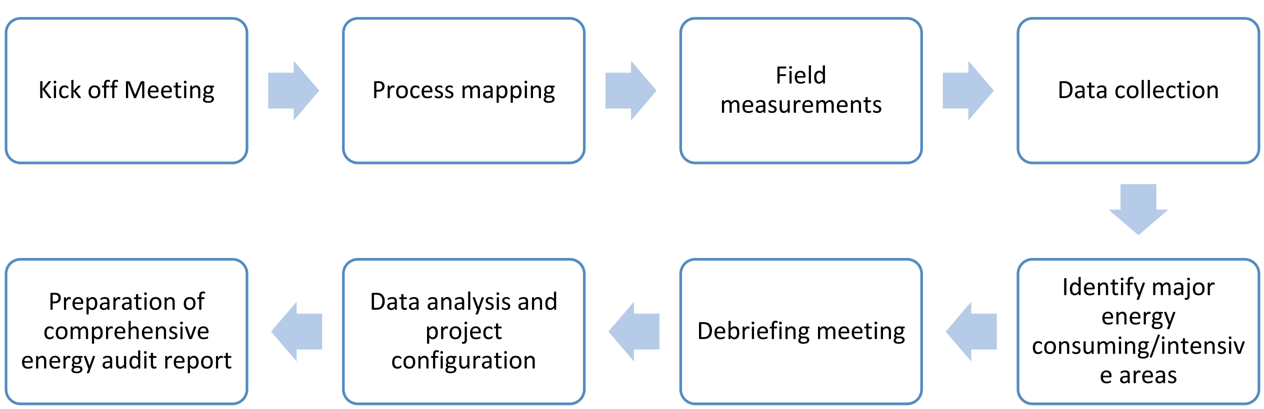


Figure 1: General methodology

The field work was carried out during 26th - 29th Nov 2018.

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

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

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit, are following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Parameters Measured
1	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
2	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and Flue gas temperature, Ambient temperature
6	Digital Temperature and Humidity Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 Structure of the Report

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

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

2 CHAPTER – 2 PRODUCTION AND ENERGY CONSUMPTION

2.1 MANUFACTURING PROCESS WITH MAJOR EQUIPMENT INSTALLED (FLOW DIAGRAM)

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

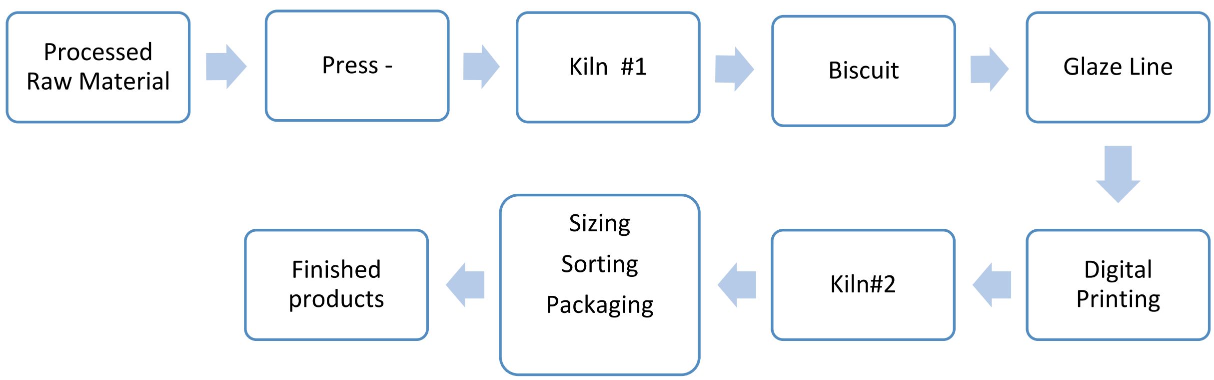


Figure 2: Process Flow Diagram

The process description is as follows:

- The raw 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 is:

- **Glaze ball mill:** For producing glazing material used on tiles.
- **Air compressor:** Pressurized air is used at several locations in a unit viz. instrument air, air cleaning, glazing etc.
- **Hydraulic Press:** Clay in powdered form is stored in silos for 24 hours and then conveyed to hydraulic press machine where it is pressed and tiles is formed of required size, output of hydraulic press is called biscuit.
- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.

- **Kiln:** The kiln is the main energy consuming equipment where the product is passed twice, once in biscuit form and second time after glazing and printing. The kilns are about 150 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150^{o}C to 1,200^{o}C depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further gone for sizing, finishing and quality tested and packed for dispatch.
- **Sizing machine and packing:** Output of kiln is called tiles; these tiles are passed through cutting, sizing and polishing machines to match exact dimensions required.

A detailed mass balance diagram for the unit is included as Annexure - 1 . A detailed list of equipment is included as Annexure - 2.

2.2 Production Details

The unit is currently manufacturing wall tiles of the following specifications:

Table 5: Product Specifications

Product	Size /Piece	Weight/box	Area per box	Pieces per box
	mm x mm	kg	sq m	#
Wall Tiles	300 X 450	14.5	0.135	6
Wall Tiles	300 X 600	14	0.18	5
Wall Tiles	300 X 300	11	0.09	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	300 X 600	300 x 300	300 X 450	300 X 600	300 x 300	300 X 450	300 X 600
Oct-17	27,053	174,381	32,811	21,913	141,249	29,530	311	2,005	476
Nov-17	22,501	140,656	45,537	18,226	113,931	40,983	259	1,618	660
Dec-17	24,885	84,668	120,360	20,157	68,581	108,324	286	974	1,745
Jan-18	20,534	102,636	109,530	16,633	83,135	98,577	236	1,180	1,588
Feb-18	30,239	54,652	121,382	24,494	44,268	109,244	348	628	1,760
Mar-18	26,136	69,020	112,134	21,170	55,906	100,921	301	794	1,626
Apr-18	22,612	107,149	94,879	18,316	86,791	85,391	260	1,232	1,376
May-18	38,474	104,507	45,417	31,164	84,651	40,875	442	1,202	659
Jun-18	33,791	96,402	94,482	27,371	78,086	85,034	389	1,109	1,370
Jul-18	43,016	108,084	66,698	34,843	87,548	60,028	495	1,243	967
Aug-18	27,320	148,710	50,430	22,129	120,455	45,387	314	1,710	731
Sep-18	47,939	87,378	28,115	38,831	70,776	25,304	551	1,005	408
Oct-17	27,053	174,381	32,811	21,913	141,249	29,530	311	2,005	476
Average	30,375	106,520	76,815	24,604	86,281	69,133	349	1,225	1,114
	71,237			60,006			896		

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 :
  - NG (Natural Gas) for kiln
  - Coal for coal gas generation which in turn used in kiln.

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	TOE	% of total
Grid – Electricity	207.91	16.9	265	4.7
Thermal-Coal	625.79	50.7	4,241	75.2
Thermal – NG	400.13	32.4	1,131	20.1
Total	1,233.83	100	5,637	100

This is shown graphically in the figures below:

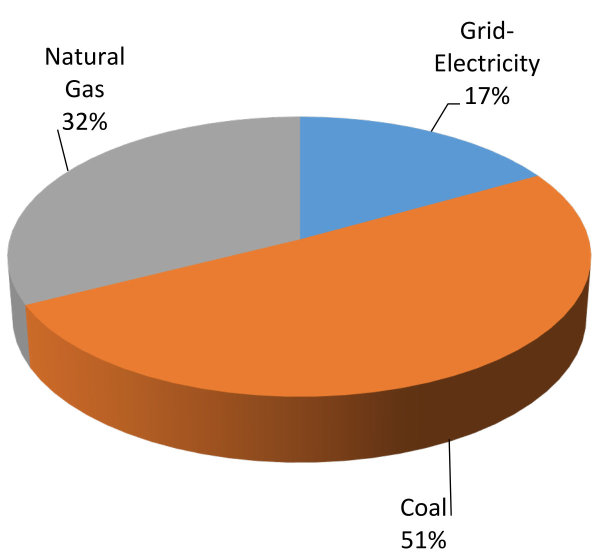


Figure 3: Energy cost share

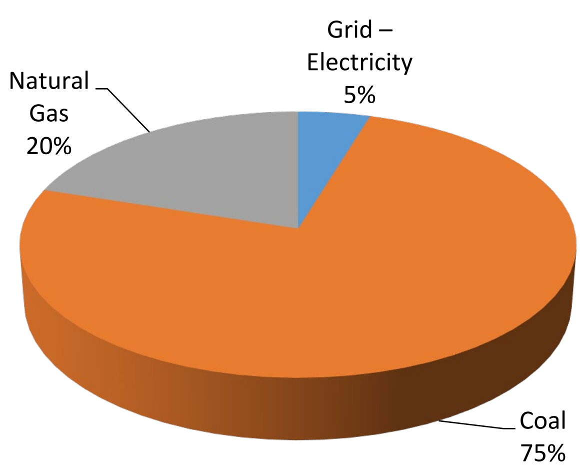


Figure 4: Energy use share

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 17% of the energy cost and 5% of the overall energy consumption.
- Source of thermal energy is from combustion of NG, which is used for firing in the kiln-2, and coal for coal gas generation which in turn used in kiln - 1 .
- NG used in kiln-2 account for 32% of the total energy cost and 20% of overall energy consumption.
- Coal used in coal gasifier accounts for 51% of cost and 75% 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	26,725
Tariff Category	HTP-I
Contract Demand, kVA	495
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) 1st500 kVA 2nd 500 kVA Next 297	 150 260 475
Energy Charges (Rs/kWh) Normal Hours Peak Hours Night Time	 4.2 0.85 0.4
Fuel Surcharge (Rs./kWh)	1.63
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

2.2.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10 : Electricity consumption & cost

Month	Units Consumed kWh	Total Electricity Cost Rs	Unit Cost Rs/kWh
Oct-17	250,314	1,697,692	6.78
Nov-17	252,252	1,710,211	6.78
Dec-17	256,224	1,733,566	6.77
Jan-18	260,970	1,763,163	6.76
Feb-18	258,948	1,728,504	6.68
Mar-18	253,368	1,694,469	6.69
Apr-18	276,210	1,841,131	6.67
May-18	233,514	1,676,072	7.18
Jun-18	264,234	1,778,534	6.73
Jul-18	237,474	1,605,324	6.76
Aug-18	277,950	1,845,845	6.64
Sep-18	255,780	1,716,439	6.71

Average electricity consumption is 256,437 kWh/month and cost is Rs. 17.33 Lakhs per month. The average cost of electricity is Rs. 6.76/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.

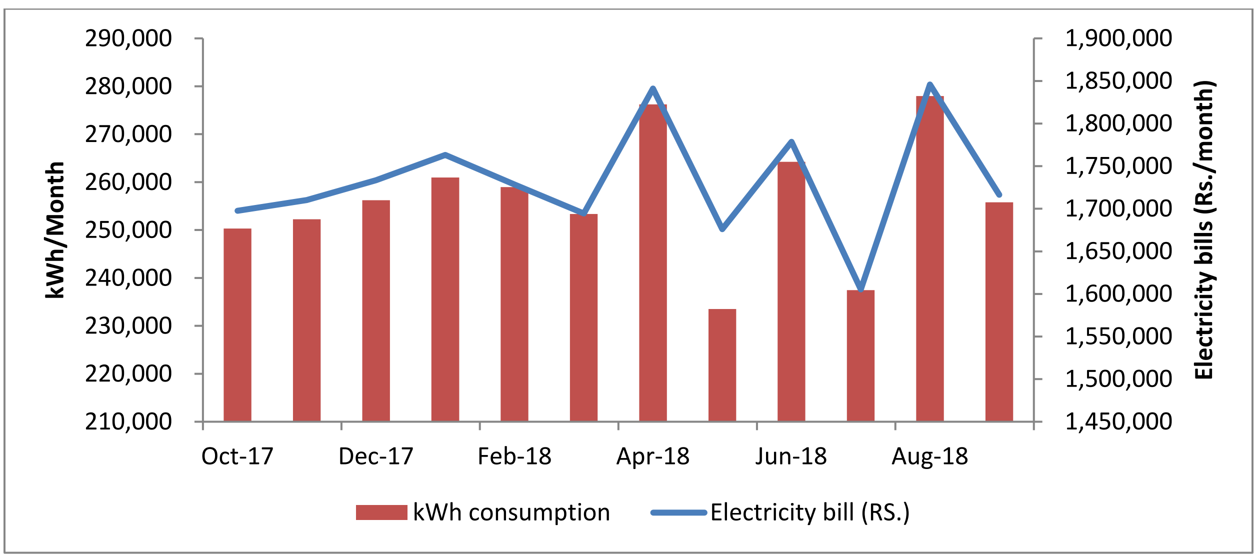


Figure 5: Month wise Variation in Electricity Consumption

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

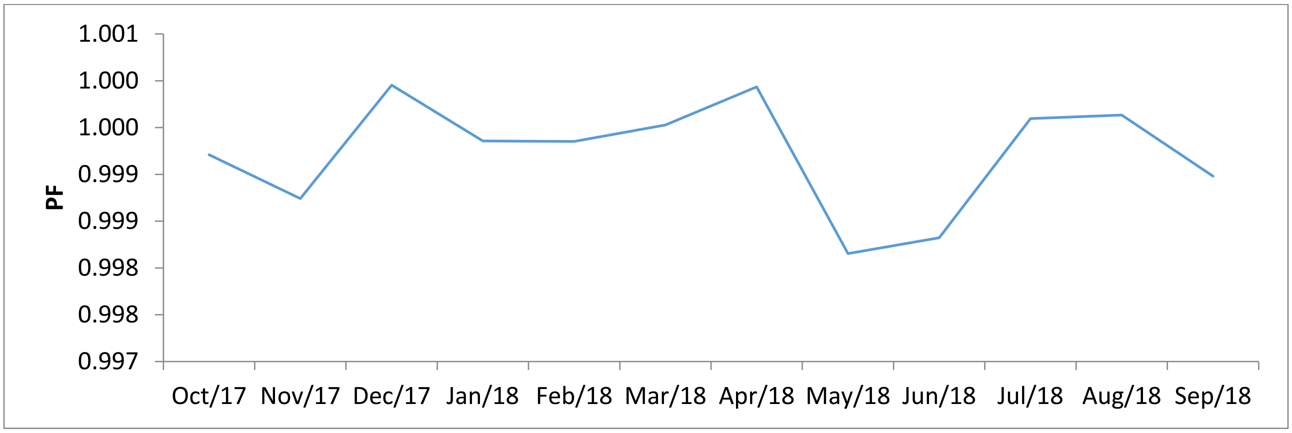


Figure 6 : Month wise variation in Power Factor

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 0.99 and the maximum being 1.00.

Maximum Demand: Maximum demand as reflected in the utility bill is 507 kVA from the bill analysis.

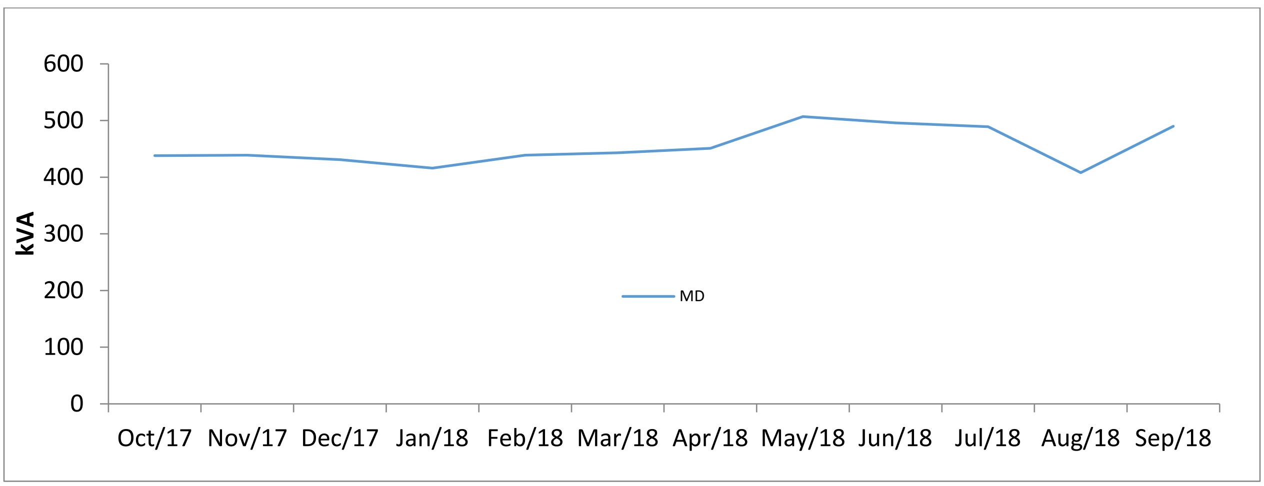


Figure 7 : Month wise variation in Maximum Demand

2.2.1.4 *Single Line Diagram*

Single line diagram of plant is shown in below figure:

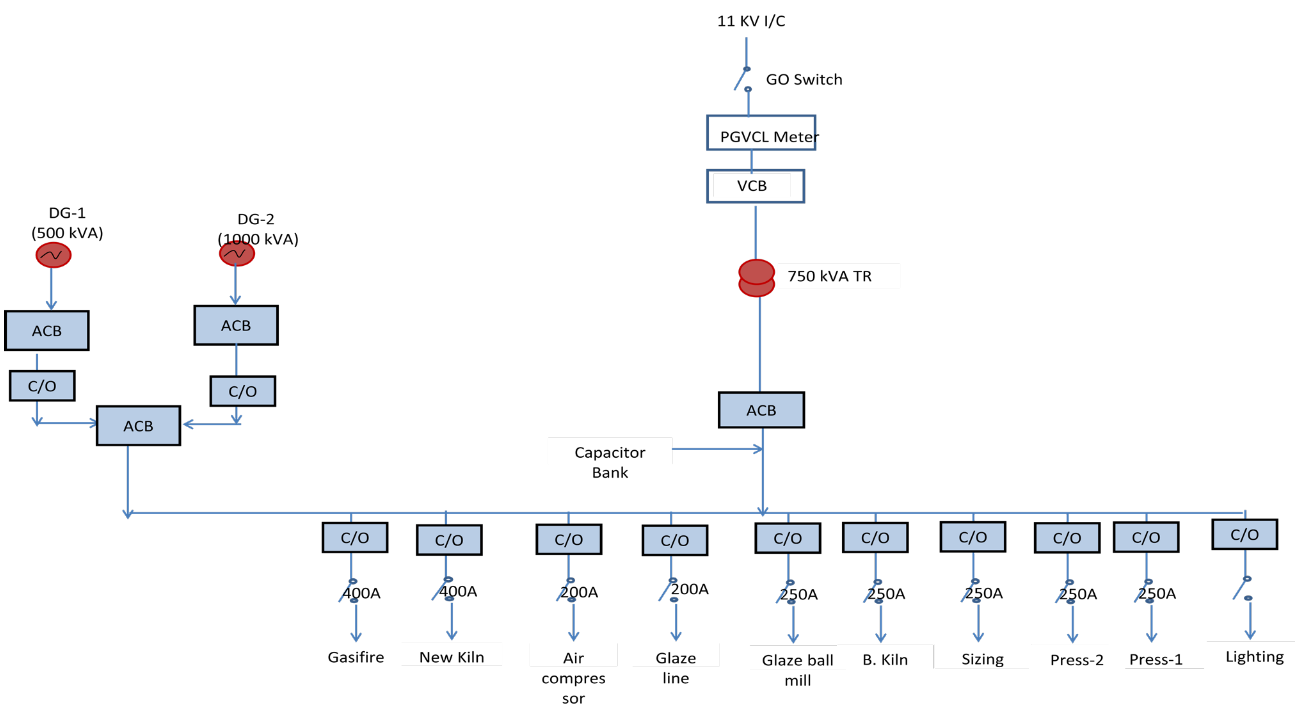


Figure 8: SLD of Electrical Load

2.2.1.5 *Electricity consumption areas*

The plant total connected load is 1,211 kW, which includes:

- The plant and machinery load is 1,133 kW.
- The utility load (fan and lighting) is about 78 kW including the single phase load.

Table 11 : Equipment wise connected load

Sl. No.	Equipment	Numbers	Connected load (kW)
1	Compressors	1	37
2	Presses	2	175
3	Press Cooling Towers	1	20
4	Glazed tiles Kiln	1	282
5	Dryer	1	61
6	Biscuit Kiln	1	281
7	Sizing Machine 1	1	116
8	Sizing Machine 2	1	104
9	Glaze Ball Mill	4	113
10	Glaze line	1	62
11	Lights	447	21
	Total		1,211

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

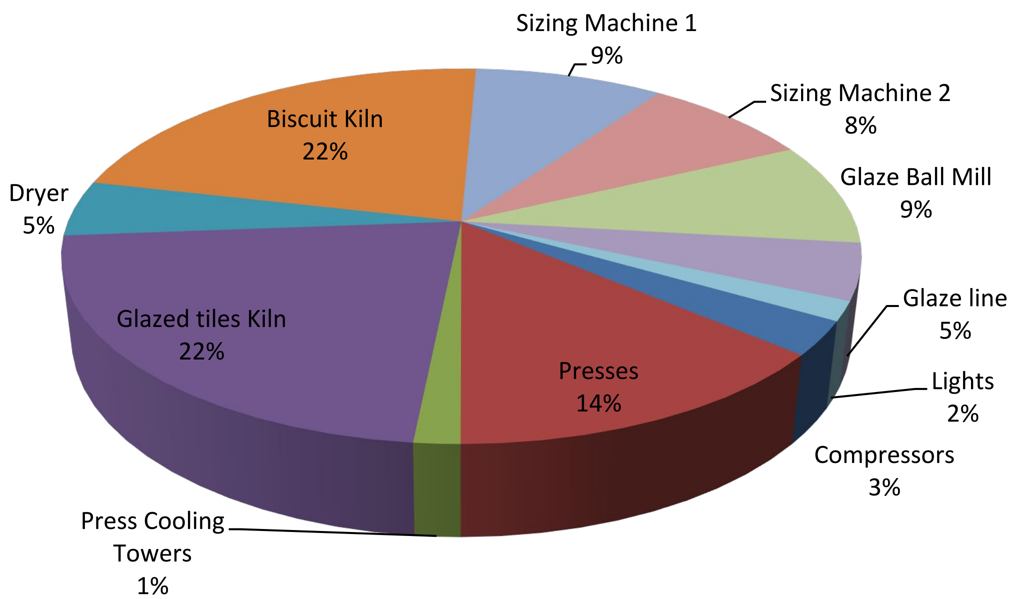


Figure 9 : Details of connected load

As shown in the figure, the maximum share of connected electrical load is for both kilns – 22 % each Sizing Line – 17%, followed by Press – 14%, Glaze ball Mill – 9%, Glaze Line - 5% , Compressor- 3%, Other machinery including Conveyer and Cooling Tower– 1% each and Lighting load of 2%.

2.2.1.6 Specific electricity consumption

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

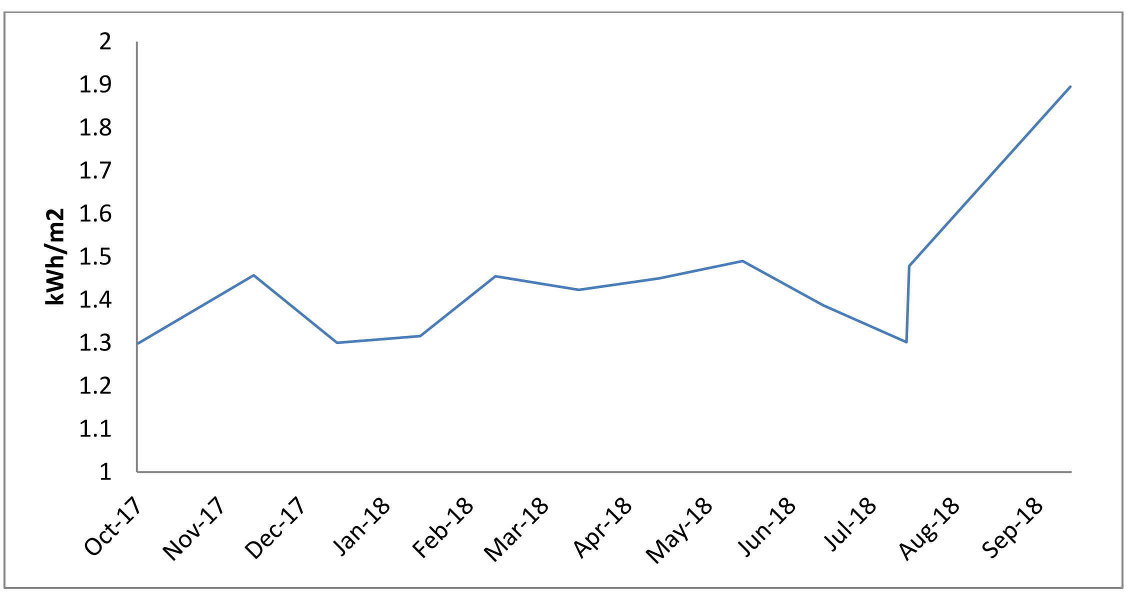


Figure 10: Month wise variation in Specific Electricity Consumption

The months, Sep-18 is outliers. Excluding this month, the maximum and minimum values are within ±20% of the average SEC of 1.44kWh/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 press section, biscuits kiln, glaze kiln, utility like compressor, pumps etc.

2.2.2 Analysis of Thermal Consumption

2.2.2.1 Month wise Fuel Consumption and Cost

The thermal consumption areas are the kilns. Coal is used as fuel for coal gasifier to generate coal gas used in kiln - 1 while NG is used as fuel for the kiln-2. Coal is purchased from local coal suppliers who in turn import coal from Indonesia. NG is purchased from GSPC (Gujarat State Petroleum Company). Annual fuel consumption and cost are summarized below:

Table 12 : Month Wise Fuel Consumption and Cost

Month	Kiln-2 (Glaze)			Kiln -1 (biscuit)		
	NG Use	NG Cost	NG Cost	Coal Used	Coal Cost	Coal Cost
	scm	Rs	Rs/scm	MT	Rs	Rs/MT
Oct-17	117,267	3,288,878	28.0	644	5,797,800	9,000
Nov-17	101,538	2,879,618	28.4	574	5,165,100	9,000
Dec-17	104,307	2,996,305	28.7	632	5,690,700	9,000
Jan-18	98,666	2,966,837	30.1	639	5,746,500	9,000
Feb-18	95,046	2,938,064	30.9	568	5,111,100	9,000
Mar-18	107,518	3,299,325	30.7	568	5,114,700	9,000
Apr-18	109,192	3,421,122	31.3	618	5,560,200	9,000
May-18	100,570	3,258,067	32.4	518	4,662,900	9,000
Jun-18	104,317	3,563,185	34.2	561	5,048,820	9,000
Jul-18	109,491	3,822,818	34.9	594	5,348,160	9,000
Aug-18	111,422	4,002,444	35.9	586	5,278,230	9,000
Sep-18	96,906	3,576,571	36.9	451	4,054,860	9,000

Observation:

- Kiln-1 is used for baking of biscuit (green tiles) whereas Kiln-2 is used for baking of glazed tiles. Kiln-1 is using coal gas generated from coal gasifier.
- Monthly gas consumption of NG in Kiln-2 is about 104,687 scm and average cost is about Rs. 33.34 Lakh/month. Cost of natural gas in Kiln-2 is Rs. 31.85/SCM
- Coal is used in the coal gasifier to produce coal gas which is used to kiln - 1. Average monthly coal consumption in coal gasifier is about 579 MT and average cost is Rs 9,000/MT.

2.2.2.2 *Specific Fuel Consumption*

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

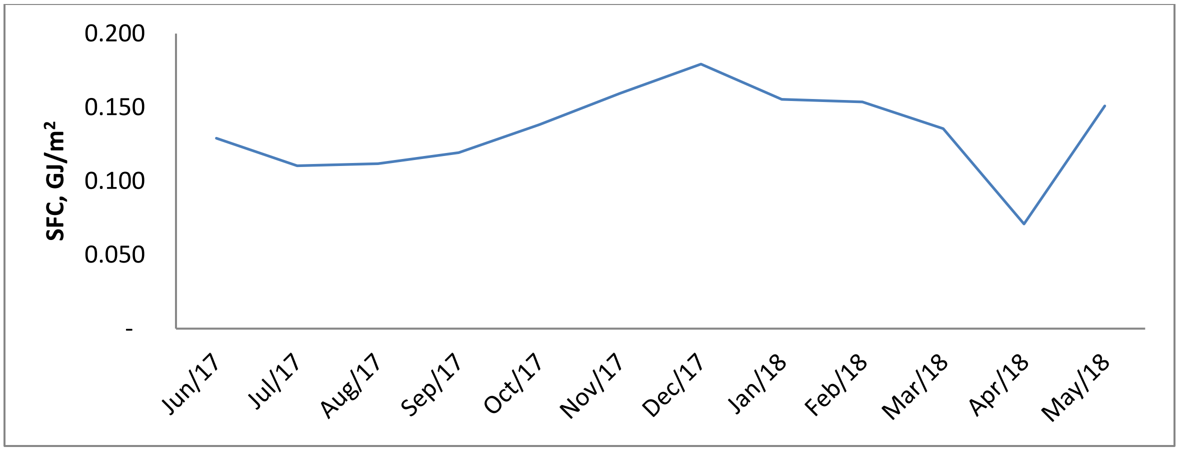


Figure 11 : Month wise variation in Specific Fuel Consumption

The average SFC is 0.104 GJ/m^2, i.e. 0.082 GJ/m^2 for the kiln-1 (biscuit) and 0.022 GJ/m^2 for kiln-2 (Glaze). Excluding the month of Jan-18 & Sept - 18, the NG consumption varied between 0.018-0.027 GJ/m^2 and was within ±10% of the average value. The SFC for coal varied between 0.075 and 0.085 GJ/m^2.

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	324.41
Power consumption	kW	363.35
Coal consumption	kg/h	337.50
NG consumption	scm/h	155.00
Energy consumption	TOE/h	0.38
SEC of plant	TOE/m^2	0.00116

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	NG	Coal	Electricity
	scm/t	kg/t	kW/t
Hydraulic Press- 1600			26.67
Hydraulic Press-1400			17.45
Biscuit kiln		117.9	14.57
Glaze kiln	33.65		5.61
Sizing unit 1			3.48
Sizing unit 2			4.27

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	3,077,238
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	3,077,238
Annual Thermal Energy Consumption (Imported Coal)	t/y	6,953
Annual Thermal Energy Consumption (NG)	scm/y	1,256,240
Annual Energy Consumption	TOE	5,637
Annual Energy Cost	Rs. Lakh	1,234
Annual production	m^2	2,160,280
	t	32,258
SEC; Electrical	kWh/m^2	1.42
	kWh/t	95.39
SEC; Thermal	GJ/m^2	0.104
	GJ/t	6.972
SEC; Overall	TOE/m^2	0.0026
	TOE/t	0.17
SEC; Cost Based	$Rs./m^2$	57.11
	Rs./t	3,825

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

- Conversion Factors
    - Electricity from the Grid : 860 kcal/kWh
- GCV of NG : 9,000 kcal/scm
- GCV of Imported Coal : 6,681 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	Unit	Value
Cost of electricity	Rs./ kWh	6.64
Cost of NG	Rs./scm	31.87
Cost of Coal	Rs./MT	9,000
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	2,160,280

2.4 WATER USAGE & DISTRIBUTION

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

Water requirement is met by purchase of water and stored in storage tank. From this storage water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 10 m^3/day as informed by unit consumed in glaze ball mill.

Water distribution diagram is shown below.

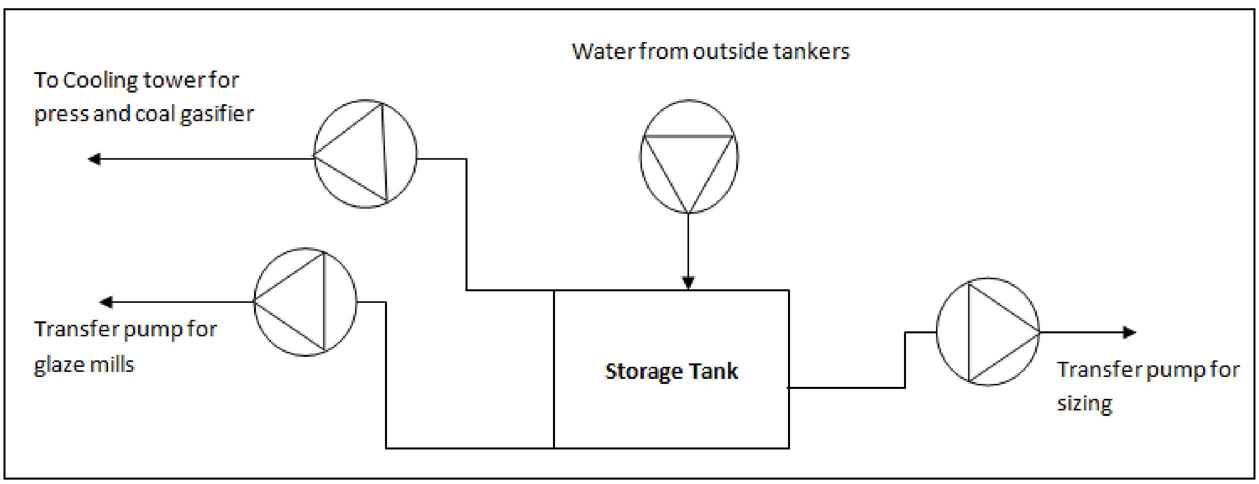


Figure 12: Water Distribution Diagram

Water are procured from 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:

Table 17: Press cooling water circulation pump details

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

3 CHAPTER – 3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 Roller Kiln

3.1.1 Specifications

Coal gas from coal gasifier is used as a fuel in the kiln - 1 (biscuit) and Natural gas is used as a fuel in kiln-2 (Glaze) 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 of Kiln-1 is 281 kW whereas Kiln-2 is 282 kW.

Kiln - 1 consists of 45 kW smoke blower, 45 kW combustion blowers, 30 kW for rapid cooling blower, 37 kW for hot air blower, 15 kW for final cooling blowers. Kiln-1 also consists of a dryer who have 15 kW smoke blower and one booster blower of 15 kW & remaining electrical load includes 15 roller motor of 0.75 kW each.

Kiln-2 consists of 45 kW smoke blower, 45 kW combustion blowers, 30 kW for rapid cooling, 37 kW for Hot air blower, 18.5 kW for indirect cooling section, 15 kW for final cooling blowers & 15 kW final exhaust blower and remaining electrical load of kiln roller motors (13 Nos.) is 9.75 kW.

Table 18: Kiln Details

Sl. No.	Parameter	Unit	Kiln-1	Kiln-2
	Make		-	-
1	Kiln operating time	h	24	24
2	Fuel used		Coal gas	NG
3	Fuel Consumption	scm/h	1,306	155
4	Number of burner to left	-	56	64
5	Number of burner to right	-	56	64
6	Cycle Time	Minutes	59	80
7	Pressure in firing zone	mmWC	60	60
8	Maximum temperature	ºC	1,136	1,071
9	Waste Heat recovery option		Yes	Yes
10	Kiln Dimensions (Length X Width X Height)			
	Preheating Zone	m	23.1 x 0.8 x 3	27.3 x 0.8 x 3
	Firing Zone	m	37.8 x 0.8 x 3	44.1 x 0.8 x 3
	Rapid Cooling Zone	m	6.3 x 0.8 x 3	8.4 x 0.8 x 3
	Indirect cooling Zone	m	18.9 x 0.8 x 3	18.9 x 0.8 x 3
	Final cooling zone	m	23.1 x 0.8 x 3	27.3 x 0.8 x 3

3.1.2 Field measurement and analysis

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

Table 19: FGA study of kilns

Parameter	Kiln-1	Kiln-2
Oxygen Level measured in Flue Gas	6.0%	14.82%
Ambient Air Temperature	37.4°C	37.4°C
Exhaust Temperature of Flue Gas	130 °C	140 °C

From the above table, it is clear that the oxygen level measured in flue gas was high in Kiln-2. The inlet temperature of raw material in Kiln-1 was in the range of 70 °C whereas in Kiln-2 it was in the range of 45 °C which was the ambient air temperature.

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	Kiln-2
Ambient Temperature	43.4	43.4
Pre-heating zone average surface temperature	43.08	45.9
Heating zone average surface temperature	54.07	57.18
Rapid cooling zone average surface temperature	77.87	58.25
Indirect cooling zone average surface temperature	84.4	55.81
Final cooling zone average surface temperature	54.7	44.3

The temperature profiles of the kilns are identical is shown below:

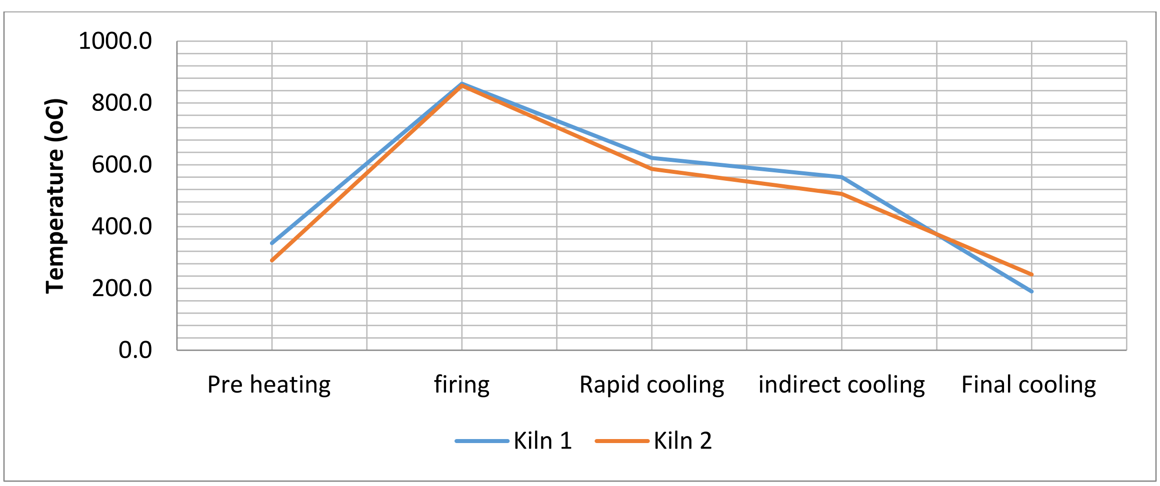


Figure 13: Temperature Profile of Kilns

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

Table 21: Power measurements of all blowers

Equipment	Kiln - 1 Average Power (kW)	PF	Kiln-2 Average Power (kW)	PF
Final Cooling Blower	9.09	0.998	2.86	0.997
hot air Blower	2.56	0.999	2.56	0.999
Rapid Cooling Blower	2.79	0.947	2.15	0.999
Smoke Blower	5.07	0.999	3.22	0.999
Combustion Blower	2.22	0.947	2.69	0.999

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall heat utilization of the kiln-1 is 36.5% and kiln-2 is 68%. Summary of all losses is shown in below figure:

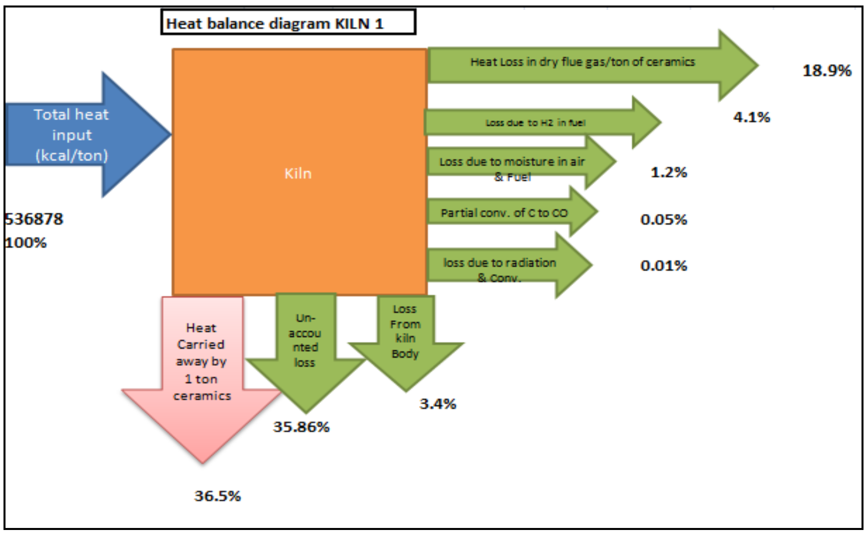


Figure 14 : Heat Balance Diagram of Kiln-1

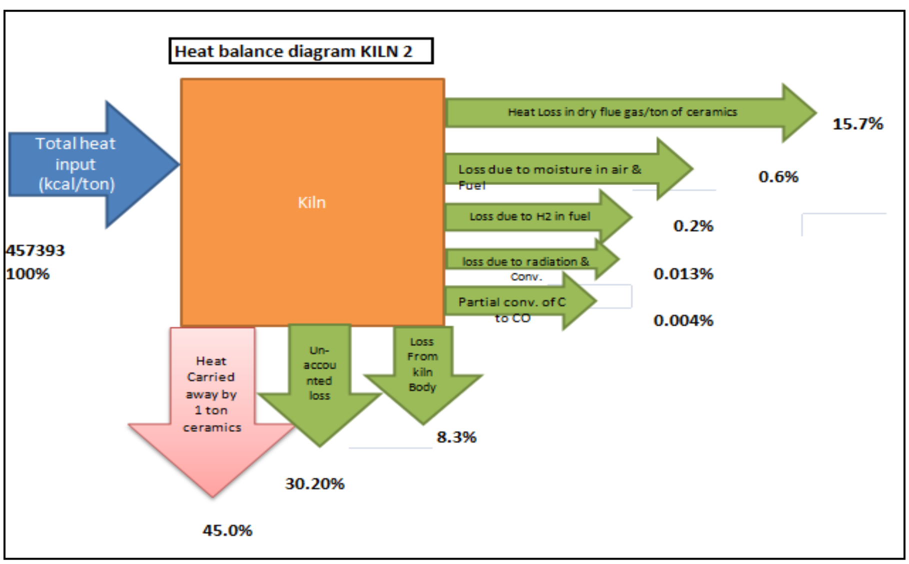


Figure 15: Heat Balance Diagram of Kiln-2

The unaccounted loss occurred in kiln -1 and kiln-2 includes heat gained by rollers, small openings at side of kiln and gap in rollers 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-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 blower for Kiln-2 has 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% of excess air will save one percent in specific fuel consumption. For Kiln-2 oxygen level is 14.8% which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

Table 22: Cost benefit analysis (ECM-1)

Parameters	Unit	Present	Proposed
Oxygen level in flue gas just before firing zone	%	14.8	3.0
Excess air percentage in flue gas	%	239.8	16.7
Dry flue gas loss	%	16%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	51	39
Average production in Kiln	t/h	3.0	3.0
Saving in specific fuel consumption	scm/h		34.59
Operating hours per day	h/d		24
Annual operating days	d/y		330
Annual Natural gas (NG) saving	scm/y		273,926
Fuel cost	Rs/scm		32
Annual fuel cost saving	Lakh Rs/y		87.3
Power saving in combustion blower			
Mass flow rate of air	t/h	6.62	2.27
Density of Natural gas	kg/m^3	0.73	0.73
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	1.5	0.5
Measured power of blower	kW	2.70	0.11
Total power saving	kW		2.59
Operating days per year	d/y		330
Operating hours per day	h/d		24
Annual energy saving	kWh/y	20,511	
Weighted electricity cost	Rs/kWh	6.76	6.76
Annual energy cost saving	Lakh Rs/y		1.39
Overall energy cost saving	Lakh Rs/y		88.68
Estimated investment	Lakh Rs		18.48
Payback period	Months		3
IRR	%		371%
Discounted	Months		1.00

3.1.4.2 Energy conservation measures - ECM #2 Hot surface insulation in recuperator pipes of Kiln-1

Technology description

A significant portion of the losses in a kiln occurs as radiation and convection loss from the combustion air carrying pipes. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of insulation should be provided on these pipes to maintain the skin temperature of the furnace at around 80^{o}C, so as to avoid heat loss due to radiation and convection.
Thermal insulations are used for reduction in heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact or in range of radiative influence.

Recuperator pipes 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 24 uninsulated pipes in recuperator in rapid cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe must be 75-80°C and it was measured as 90°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

Recommended action

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

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

Parameter	Unit	Present	Proposed
No of uninsulated pipe in recuperator	#	108	108
Uninsulated main header	#	1	1
Recuperator pipe size	mm	30	30
Pipe length	m	1	1
Surface area of header line	m2	10	10
Total surface area	m2	19.68	19.68
Average surface temperature	°C	150	80
Ambient air temperature	°C	35	35
Heat loss	kcal/h/m^2	1,811	551
Total heat loss	kcal/h	35,643	10,848
GCV of coal gas	kcal/scm	1,231	1,231
Heat loss in terms of fuel (coal gas) in Kiln	scm/h	29.0	8.8
Gas to coal ratio of Gasifier	scm/kg	3.87	3.87
Heat loss in terms of coal in gasifier	kg/h	7.5	2.3
Fuel saving	kg/h		5.2
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	t/y		41
Fuel cost	Rs/t		9,000
Annual fuel cost saving	Rs Lakh/y		3.71
Estimated investment	Rs Lakh		1.32
Payback period	Months		4
IRR	%		214%
Discounted Payback period	Months		1.68

3.1.4.3 Energy conservation measures (ECM) - ECM #3 Insulation in delivery pipe of indirect cooling blower of Kiln-1

Technology description

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

Delivery 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

The delivery pipe in indirect cooling blower is uninsulated in rapid cooling zone. The surface temperature of pipe was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 160°C, hence the pipe surface has to be properly insulated to keep the surface temperature within the specified range.

Recommended action

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

Table 24: Cost Benefit analysis (ECM-3)

Parameter	Unit	Present	Proposed
Delivery pipeline of intermediate blower	#	1	1
Circumference of delivery pipe	cm	129	129
Length of delivery pipeline	m	6.25	6.25
Total surface area	m^2	8.06	8.06
Average surface temperature	°C	160	80
Ambient air temperature	°C	35	35
Heat loss	$kcal/h/m^2$	2,031	551
Total heat loss	kcal/h	16,377	4,444
GCV of coal gas	kcal/scm	1,231	1,231
Heat loss in terms of fuel (coal gas) in Kiln	sm^3/h	13.3	3.6
Gas to coal ratio of gasifier	sm^3/kg	3.87	3.87
Heat loss in terms of coal in gasifier	kg/h	3.4	0.9
Fuel saving	kg/h		2.5
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	t/y		20
Fuel cost	Rs/t		9,000
Annual fuel cost saving	Rs Lakh/y		1.79
Estimated investment	Rs Lakh		0.66
Payback period	Months		4
IRR	%		203%
Discounted Payback period	Months		1.75

3.1.4.4 Energy conservation measures (ECM) - ECM #4 Preheating of combustion air through recuperator

Technology description

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

Study and investigation

During energy audit, it was found that the recuperator was bypassed. So, 80% of combustion air was entered in firing zone at 53 °C and only 20% was preheated in recuperator.

Recommended action

It is recommended to take recuperator into service to increase combustion air temperature upto 145 °C by changing bypass valve position to 80%. The cost benefit analysis is given below:

Table 25: Cost benefit analysis (ECM-4)

Parameters	Unit	Present	Proposed
Equipment	#	Glaze Kiln	
Measured air velocity	m/s	3.23	3.23
Blower air inlet area	m^2	0.11	0.11
Actual volume of supplied air	m^3/s	0.37	0.37
Actual air delivered	CFM	776	776
Hot air damper opening % to combustion blower	%	20	80
Combustion air temperature	°C	53	145
Ambient air temperature	°C	45	45
Specific heat of air	kcal/kg °C	0.24	0.24
Density of air	kg/m^3	0.90	0.90
GCV of Fuel	kcal/scm	9,000	9,000
Additional fuel required	scm/h		3
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving in Kiln	scm/y		23,051
Fuel Cost	Rs/scm		32
Annual fuel cost saving	Lakh Rs/y		7.35
Estimated investment	Lakh Rs		Nil
Payback period	months		Immediate
IRR	%		-
Discounted Payback period	Months		-

4 CHAPTER – 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 Hydraulic presses

4.1.1 Specifications

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

Table 26: Specifications of hydraulic press

Particular	Units	Press 1 – 1400	Press 2-1600
Cycle (stroke) per minutes	N/m	8	6
Nos. of tiles per stroke		3	3
Tile size	mm × mm	300 × 450	300 × 450
Tile thickness	mm	7.2	7.2
Tiles weight	kg	2.15	2.15
Power rating	kW	67	75
Water Circulation Pump	#	1	1

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of presses and cooling water circulation pumps
- Count of tiles processed as per above Table 26.

Average power consumption of press 1 was 54.7 kW (PF 0.8) and press 2 was consuming 61.9 kW (P.F. 0.8). Two water circulation pumps were consuming power as 5.97 kW and 4.16 kW.

4.1.3 Observation and performance assessment

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

Performance of hydraulic press is measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press 1 was 17.45kW/ton and that off the press 2 was 26.67kW/ton.

4.2 Glazing

4.2.1 Specifications

Ceramic glaze is an impervious layer or coating of a vitreous substance which is fused to a ceramic body through firing. Glaze can serve to color, decorate or waterproof an item. It also gives a tougher surface. Glaze is also used on stoneware and porcelain. In addition to their functionality, glazes can form a variety of surface finishes, including degrees of glossy or matte finish and color. Glazes may also enhance the underlying design or texture unmodified or inscribed, carved or painted.

Glazes need to include a ceramic flux which functions by promoting partial liquefaction in the clay bodies and the other glaze materials. Fluxes lower the high melting point of the glass formers silica, and sometimes boron trioxide. These glass formers may be included in the glaze materials, or may be drawn from the clay beneath.

Raw materials of ceramic glazes generally include silica, which will be the main glass former. Various metal oxides, such as sodium, potassium, and calcium, act as flux and therefore lower the melting temperature. Alumina, often derived from clay, stiffens the molten glaze to prevent it from running off the piece. Colorants, such as iron oxide, copper carbonate, or cobalt carbonate and sometimes opacifiers like tin oxide or zirconium oxide, are used to modify the visual appearance of the fired glaze.

The specifications of glaze ball mills are given below:

Table 27: Specifications of glazing machine

Particular	Units	Glaze mill
Numbers of glazing mills	Nos.	6
Capacity of glaze ball mill 1	Ton/batch	2
Capacity of glaze ball mill 2	Ton/batch	2
Capacity of glaze ball mill 3	Ton/batch	2
Capacity of glaze ball mill 4	Ton/batch	2
Capacity of glaze ball mill 5	Ton/batch	0.7
Capacity of glaze ball mill 6	Ton/batch	0.1
Connected load of glaze ball mill 1	kW	22
Connected load of glaze ball mill 2	kW	22
Connected load of glaze ball mill 3	kW	22
Connected load of glaze ball mill 4	kW	22
Connected load of glaze ball mill 5	kW	5.5
Connected load of glaze ball mill 6	kW	1.5

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of two glaze mills which were in operation.
- Mass consumption (t/batch) is as per Table 27.

Power consumption and P.F. of two glaze mills which was in operation are given in below table:

Table 28: Power consumption and P.F. of glaze mills

Equipment	kW	PF
Glaze ball mill 1	20.1	0..79
Glaze ball mill 2	18.6	0.7

4.2.3 Observations and performance assessment

Performance of glaze ball mill can measure in terms of specific energy consumption (power consumed for glazing 1 ton of tiles). Based on observations during DEA, the specific energy consumption of glaze ball mill 1 & glaze ball mill 2 were 10.05 & 9.3 kW/ton respectively.

4.2.4 Energy conservation Measures

The energy conservation measures recommended are:

4.2.4.1 Energy conservation measures (ECM) - ECM #5: 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 six glaze ball mill IE1 motor with more efficient IE3 motor.
The cost benefit analysis is given in the table below:

Table 29: Cost benefit analysis (ECM-5)

Particular	Unit	Present	Proposed	Present	Proposed
		Glaze ball mill – 1		Glaze ball mill – 2	
Rated power of motor	kW	22	22	22	22
Motor efficiency class		IE1	IE3	IE1	IE3
Existing efficiency of motor	%	89.9	93	89.9	93
Existing power consumption	kW	20.10	18.69	18.60	17.30
Energy loss in motor	kW	2.0	0.6	1.9	0.6
Estimated energy saving	kW		1.4		1.3
Operating hours/day	d/y	330	330	330	330
Operating days/year	h/d	10	10	10	10
Annual energy consumption	kWh/y	66,330	61,687	61,380	57,083
Annual energy savings	kWh/y		4,643		4,297
Total energy savings	kWh/y	8,940			
Unit cost of electricity	Rs/kWh	6.76			
Annual monetary savings	Lakh Rs/y	0.60			
Estimated Investment	Lakh Rs	2.11			
Payback Period	Months	42			
IRR	%	6			
Discounted Payback period	Months	15			

4.3 SIZING

4.3.1 Specifications

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

Table 30: Specifications of sizing machine

Particular	Units	New sizing
Numbers of sizing machines	Nos.	4
Sizing Machine 1	kW	56.5
Sizing Machine 2	kW	56.5
Sizing Machine 3	kW	50.5
Sizing Machine 4	kW	50.5
Sizing line 1 – Conveyors	kW	2.97
Sizing line 2 – Conveyors	kW	2.60

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of sizing machines
- Daily tiles production of sizing section is 4.6 t/h.

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

Table 31: Measured Parameters of sizing machine

Equipment	Unit	Value	PF
Average Power (M/c#1)	kW	14.33	0.92
Average Power (M/c#2)	kW	11.50	0.39
Average Power (M/c#3)	kW	5.64	0.48
Average Power (M/c#4)	kW	14.0	0.41

4.3.3 Observation and performance assessment

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

Table 32 : Measured Parameters of sizing machine

Equipment	Unit	Value
Sizing Machine # 1	kW/t	3.11
Sizing Machine # 2	kW/t	2.50
Sizing Machine # 3	kW/t	1.23
Sizing Machine # 4	kW/t	3.04

4.4 AIR COMPRESSORS

4.4.1 Specifications

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

Table 33: Specifications of compressor

Particular	Units	Air compressor
Power rating	kW	37
Maximum pressure	bar (a)	8
Rated Capacity	m^3/min	6.35
Type of motor		Permanent magnet (PM)

The compressor has a receiver.

4.4.2 Field measurement and analysis

Presently, compressor is under maintenance. Thus, for fulfilling air requirement, unit hired a screw compressor with same specifications and has VFD for the maintenance period of compressor. The following measurements were done on hired compressor:

- Power consumption of hired compressor

Average power consumption of the compressor is given below:

Table 34: Measured parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)
Screw Compressor	23.11	0.98	Not possible to measure

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 compressor which can be reduced as per requirement. Another observation was that pressure drop in line was higher which can also be reduced by changing line size.

4.4.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.4.4.1 Energy conservation measures (ECM) - ECM #6: Operational pressure optimization in compressor

Technology description

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

Study and investigation

It was told by plant in charge that set pressure of compressor observed during the energy audit that the operating pressure of compressor is 8 kg/cm^2.

Recommended action

As end user air pressure requirement is 4 kg/cm^2, it is recommended that the existing operating pressure setting of 8.0 kg/cm^2 be lowered to 6.0 kg/cm^2 which will reduce the energy consumption by 12%.

The cost benefit analysis is given in the table below:

Table 35: Cost benefit analysis (ECM-6)

Parameter	Unit	Present	Proposed
Compressor operating pressure	kg/cm²	8	6
Reduction in pressure	kg/cm²	-	2
% of energy saving	%	-	12%
Average load based on other compressor experience	kW	23.1	20.34
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	183,040	161,075
Annual energy savings	kWh/y		21,965
Unit cost of electricity	Rs/kWh		6.76
Annual monetary saving	Lakh Rs/y		1.48
Estimated Investment	Lakh Rs		Nil
Payback period	Months		Immediate
IRR	%		Nil
Discounted payback period	Months		Nil

4.5 Water Pumping System

4.5.1 Specifications

Pumping system comprises three transfer 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 pumps
- Flow measurements for same pump
- Other pumps are having smaller size and internal corrosion problems

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

Table 36: Measured parameters of pump

Particulars	Unit	Pump 1	Pump 2
Flow	m³/h	42.54	17.05
Total head	m	20	20
Power consumption	kW	5.97	4.16

4.5.3 Observation and performance assessment

Based on observations during DEA, the pump efficiencies were calculated as 45.7% and 26.3%.

4.5.4 Energy Conservation Measures

4.5.4.1 Energy conservation measures (ECM) - ECM#7: Replacement of cooling tower pump

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 45.7% and 26.3% 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 37: Cost benefit analysis (ECM-7)

Parameter	Unit	Present	Proposed	Present	Proposed
		CT Pump (Press 1400)		CT Pump (Press 1600)	
Design Parameters		**As is**	**To be**	**As is**	**To be**
Pump Efficiency			65		65
Motor I/P Power	kW	5.5	4.78	5.5	1.92
Motor Efficiency	%	85	89.6	85	89.6
VFD	Y/N	N	N	N	N
Measured Parameters		**As is**	**To be**	**As is**	**To be**
Flow rate Q	m^3/h	42.5	42.5	17.1	17.1
Suction Pressure	kg/cm^2	0.0	0.0	0.0	0.0
Discharge Pressure	kg/cm^2	2.0	2.0	2.0	2.0
Motor Input Power	kW	6.0		4.2	
Saving Assessment		**As is**	**To be**	**As is**	**To be**
Flow rate Q	m^3/s	0.01182	0.01182	0.00474	0.00474
Total head developed	m	20.0	20.0	20.0	**20.0**
Liquid horse power	kW	2.3	2.3	0.9	0.9
Motor Input power	kW	6.0	3.98	4.2	1.60
Nearest standard pump size	kW		5.5		3.0
Motor Loading	%	108.5	86.9	75.6	63.8
Overall system efficiency	%	38.8	58.2	22.3	58.2
Pump efficiency	%	45.7	65.0	26.3	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	47,282	31,534	32,947	12,640
Annual energy saving	kWh/y		15,749		20,307
Weighted average cost	Rs/kWh	6.8	6.8	6.8	6.8
Annual energy cost saving	Rs Lakh/y		1.06		1.37
Percentage of energy saving	%		33.3		61.6

Parameter	Unit	Present	Proposed	Present	Proposed
Estimated investment	Rs Lakh		0.508		0.277
Total annual energy saving	kWh/y	36,056			
Total annual monetary saving	Rs Lakh/y	2.44			
Total investment	Rs Lakh	0.79			
Simple payback period	Month	4			
IRR	%	232%			
Discounted payback period	Months	1.53			

4.5.4.2 ECM # 8: Retrofit of VFD in cooling tower pump

Technology description

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

Study and investigation

During field measurement, it was found that the cooling tower pump was running continuously which results in excess power consumption.

Recommended action

It is recommended to install VFD for both of cooling tower pump of press section. VFD will install after the replacement of inefficient pump with efficient pump as recommended in ECM # 7.

Table 38: Cost benefit analysis of (ECM 8)

Parameter	UoM	As Is	To Be	As Is	To Be
		Pump 1		Pump 2	
Rated power of cooling tower pump	kW	5.5	5.5	3	3
Measured power of cooling tower pump	kW	3.98	3.6	1.60	1.4
Operating hours/day	h/d	24	24	24	24
Operating days/year	d/y	330	330	330	330
Annual energy consumption	kWh/y	31,534	28,380	12,640	11,376
Annual energy savings	kWh/y		3,153		1,264
Unit cost of electricity	Rs/kWh		6.76		6.76
Annual monetary saving	Lakh Rs/y		0.21		0.09
Total Annual monetary savings	Lakh Rs/y	0.30			
Estimated Investment	Lakh Rs	0.67			
Payback period	Months	27			
IRR	%	25%			
Discounted payback period	Months	9.73			

4.6 Lighting System

4.6.1 Specifications

The plant's lighting system includes:

Table 39: Specifications of lighting load

Particular	Units	T-8	T-12	CFL	CFL	CFL	MH
Power consumption per fixture	W	36	40	65	36	13	250
Numbers of fixtures	#	270	1	8	8	52	2

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 40: Lux measurement at site

Area	Measured Value Lumen/m^2
Office	180
Kiln control room	120
Kiln area	90
Hydraulic Press	90
Glaze ball mill	85
Inventory	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) - ECM #9: Energy Efficient Lighting

Technology description

Lighting required in various sections to maintain high lux level. 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 in

Table 41, light fixtures with energy efficient LED lamps which shall help reduce present lighting energy consumption. The cost benefit analysis is given below:

Table 41 : Cost benefit analysis of lighting replacement (ECM 9)

Parameter	Unit	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Type of fixture		FTL T8	LED	CFL (65 W)	LED	CFL (36 W)	LED	MH flood light	LED	CFL (13 W)	LED
Type of choke if applicable		Magnetic	Driver					Magnetic	Driver		
Number of fixtures	#	270	270	8	8	8	8	2	2	52	52
Rated power of fixture	W/Unit	36	20	65	36	36	18	250	100	13	9
Consumption of choke	W	12	0	0	0	0	0	30	0	0	0
Operating power	W/fixture	48	20	65	36	36	18	280	100	13	9
Operating hours/day	h/d	20	20	20	20	18	18	20	20	15	15
Operating days/year	d/y	330	330	330	330	330	330	330	330	330	330
Annual energy consumption	kWh/y	85,536	35,640	3,432	1,901	1,711	855	3,696	1,320	3,346	2,317
Annual energy saving	kWh/y		49,896		1,531		855		2,376		1,030
Total Energy saving	kWh/y	55,688									
Unit cost of electricity	Rs/kWh	6.76									
Annual Monetary savings	Lakh Rs/y	3.76									
Estimated Investment	Lakh Rs.	2.35									
Pay back period	Months	8									
IRR	%	120%									
Discounted payback period	Months	2.94									

4.7 Electrical Distribution System

4.7.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (433V) 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 1.5MVA) 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 **440.9 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **420.3 V.** Maximum voltage was **431.7 V** and minimum was **394.5 V**.

Average total voltage and current harmonics distortion found **7.8%** & **9.6%** respectively during power profile recording.

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

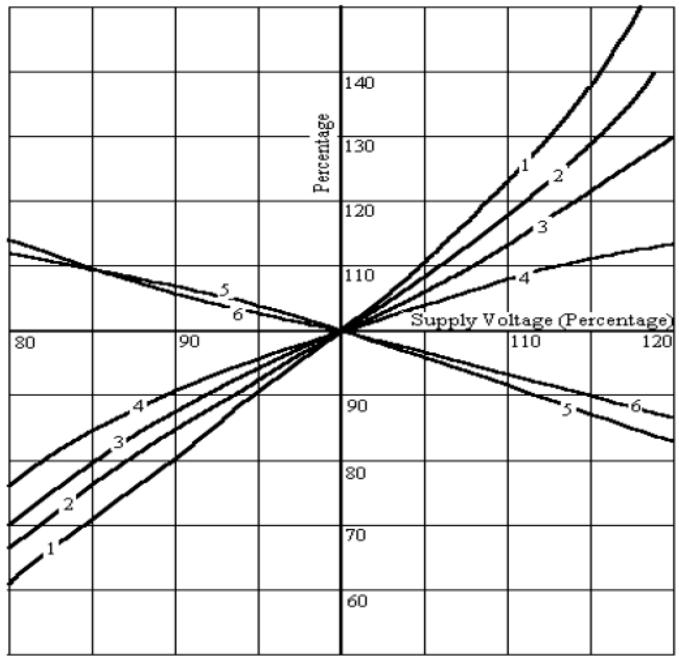
It was observed that some of the outgoing feeders to sizing and press section has low poor power factor. Poor power factor leads to cable losses (I^2R) in the electrical distribution system. However since cable length is very less no recommendation is given.

4.7.4 Energy conservation measures (ECM) - ECM #10: Servo stabilizer for lighting MDB

Technology description

Single phase loads such as lighting and fan loads require only 220 V instead of 230 V. A separate servo stabilizer in lighting MDB with reduced voltage can serve the purpose.

In most of the industries, lighting load varies between 2-10%. Most of the problems faced by lighting equipment and the gears are due to the voltage fluctuations. Hence, the lighting circuit should be isolated from the power feeders. This provided a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lighting system. In many industries night time grid voltages are higher than normal; hence reduction in voltage can save energy and also provide the rated light output. A large number of industries have used these devices and have saved to the tune of 5-15%. Industries having a problem of higher night time voltage can get an additional benefit of reduced premature failure of lamps.



1. Lamp Current 2. Circuit Power 3. Lamp Power 4. Lamp Output
5. Lamp Voltage 6. Lamp Efficacy

Figure 16: Effect of supply voltage on lamp parameters

Study and investigation

Currently, the single phase loads are operating at 243 V and there is no separate stabilizer for lighting loads. Maximum operating load in lighting circuit is about 12 kW.

Recommended action

Reduction of voltage from 243 V to 220 V for lighting and fan loads. The cost benefit analysis of energy conservation measure is given below:

Table 42: Cost benefit analysis (ECM-10)

Parameter	Unit	Present	Proposed
Maximum load	kW	12	12
Maximum load	KVA	12.86	12.86
Maximum Voltage (P to P)	V	432	380
Maximum voltage	V	249	219
Average Voltage (P to P)	V	422	380
Average voltage	V	243	220
% reduction in voltage	%	9.6%	
% reduction in energy consumption	%	18.36%	
Average power factor		0.96	0.96
Annual lighting energy consumption	kWh/y	130,632	130,632
Savings estimate from lighting EPIAs	kWh/y		55,688
Actual energy considered for voltage regulation	kWh/y		74,943
Actual energy consumption after voltage regulation	kWh/y		61,182
Efficiency of Servo Stabilizer	%		95%

Parameter	Unit	Present	Proposed
Assumption : Period for which voltage regulation is required	Months/y		8
Net saving from voltage regulation	kWh/y		8,716
Electricity tariff from grid only	Rs/kWh	6.76	
Annual monetary saving	Lakh Rs	0.6	
Sizing of servo stabilizer	kVA	14	
Rating of servo stabilizer	kVA	20	
Estimate investment	Lakh Rs	0.92	
Simple payback period	Months	19	
IRR	%	42%	
Discounted payback period	Months	7.13	

4.7.5 Energy conservation measures (ECM) - ECM #11: Cable loss minimization

Technology description

It was observed that some of the outgoing feeders to sizing and glaze line 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 0.39-0.42, in glaze line MDB was 0.79 and sizing line was 0.65.

Recommended action

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

Table 43: Cost benefit analysis (ECM-11)

Particulars	Unit	Sizing Machine 1 (Section 2)	Sizing Machine 2 (Section 1)	Sizing Machine 2 (Section 2)	Glaze line	Sizing line
Existing Power Factor	PF	0.39	0.49	0.42	0.79	0.65
Proposed Power Factor	PF	0.99	0.99	0.99	0.99	0.99
Existing load	kW	11.5	5.6	14	24.7	34.0
Cable Losses	W	279.1	132.1	314.1	80.2	569.8
Capacitor Required	kVAr	25	9	29	16	35
Annual Energy Saving	kWh/y	2,211	1,046	2,409	635	4,512
Savings Estimated	Rs Lakh/y	0.15	0.07	0.17	0.04	0.30
Total Savings	Rs Lakh/y	0.74				
Investment	Rs Lakh	0.53				
Simple Payback Period	Months	9				
IRR	%	107%				
Discounted Payback period	Months	3				

4.8 Belt Operated Drives

4.8.1 Specifications

There are 16 drives operated with V Belt of total capacity of 520 kW. Locations include 8 in Kiln-1 and 8 in Kiln 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 #12: 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 16 belt driven blowers in plant.

Recommended action

Cost benefit is given below:

Table 44: Replacement of conventional belt with REC belt [ECM-12]

Particulars	UoM	AS IS	TO BE
Number of belt driven blowers	#	16	16
Measured power of all belt driven blowers	kW	50.10	48.29[1]
Annual power consumption	kWh/y	396,775	382,491
Annual energy saving	kWh/y		14,284
Electricity cost	Rs./kWh	6.76	
Annual energy cost saving	Rs. Lakh	0.97	
Estimated investment	Rs. Lakh	2.11	
Payback Period	Months	26	
IRR	%	25%	
Discounted payback period	Months	9.73	

[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#13: Energy Management System

Technology description

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

Study and investigation

It was observed during the audit that online data measurement is not being done on various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed in kilns like on-line flow-meters.

Recommended action

It is recommended to install online electrical energy monitoring systems (smart energy meters) on the main incomer and on the various electricity distribution panels. This measure will help in reduction in energy consumption by approximately 2% from its present levels. The cost benefit analysis for this project is given below:

Table 45: Cost benefit analysis (ECM-13)

Parameters	Unit	As Is	To Be
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	3,077,238	3,015,693
Annual electricity saving per year	kWh/y		61,545
Cost of Electricity	Rs/kWh		6.76
Annual monetary savings	Lakh Rs/y		4.16
Number of equipments/system	#	17	17
No. of energy meters	#		17
Estimated investment	Lakh Rs		1.69
Thermal energy monitoring system	%	2.00	
Current coal consumption in Biscuit kiln	kg/y	6,953,230	6,814,165
Annual coal saving per year	kg/y		139,065
Cost of Coal	Rs/kg		9.00
Annual NG consumption in Glaze kiln	SCM/y	1,256,240	1,231,115
Annual fuel saving	SCM/y		25,125
Density of Natural gas	kg/scm	0.73	0.73
Annual NG savings	kg/y		18,336
Average NG cost	Rs/scm		31.87

Parameters	Unit	As Is	To Be
Total annual monetary savings	Lakh Rs/y		20.52
Number of equipments/system	#	3	3
Number of coal weighing machines			1
Number of NG Meters			2
Estimated investment	Lakh Rs		1.39
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		24.68
Estimated (Electrical + Thermal)	Lakh Rs		3.08
Payback period	Months		1.50
IRR	%		597%
Discounted Payback period	Months		0.60

5.2 BEST OPERATING PRACTICES

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

Table 46: Unique Operating practices

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Press	PRV installed for usage of compressed air
3	Glaze ball mill	Timer control in each ball mill. Alumina balls are used in glaze ball mills Low TDS water is used in glaze ball mill process
4	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
5	Sizing	Fully automatic system. Dust collected system installed.
6	Printing	Automated digital printing with fully auto control system
7	Lighting	LED lights in a few locations

5.3 NEW/EMERGING TECHNOLOGIES

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

5.3.1 DRY CLAY GRINDING TECHNOLOGY: "MAGICAL GRINDING SYSTEM "TECHNOLOGY DESCRIPTION

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

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

Table 47 : Specifications of dry clay grinding technology

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

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

The working principle is as follows:

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

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

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

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

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

5.3.2 WASTE HEAT RECOVERY FROM KILN: SACMI DOUBLE HEAT RECOVERY TECHNOLOGY DESCRIPTION

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

Cooling air may have temperature ranging from 120^{o}C to 250 ^{o}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^{o}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 ^{o}C depending upon the product and kiln temperature.

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 ^{o}C at burner
- Easy installation

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

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[4] SACMI Kiln Revamping catalogue for roller kilns

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

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

Figure 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.

[5] SACMI Kiln Revamping catalogue for roller kilns

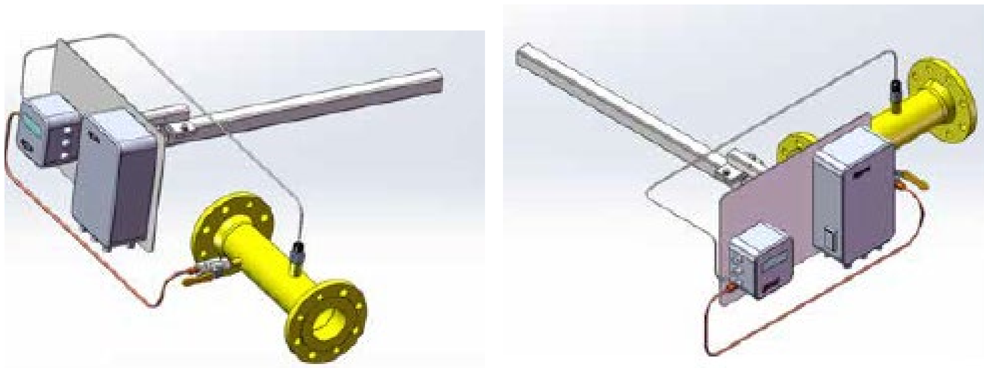


Figure 19: Combustion air control for burner

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

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

Figure 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

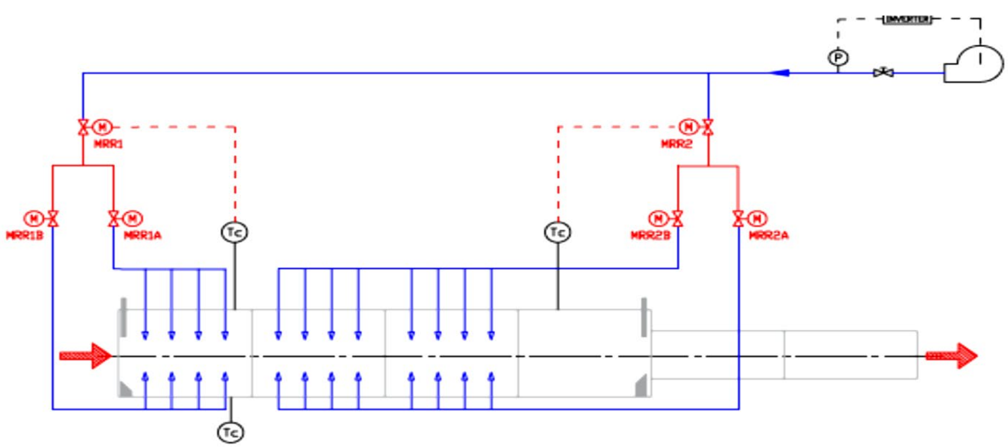


Figure 21: Fast cooling air management

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

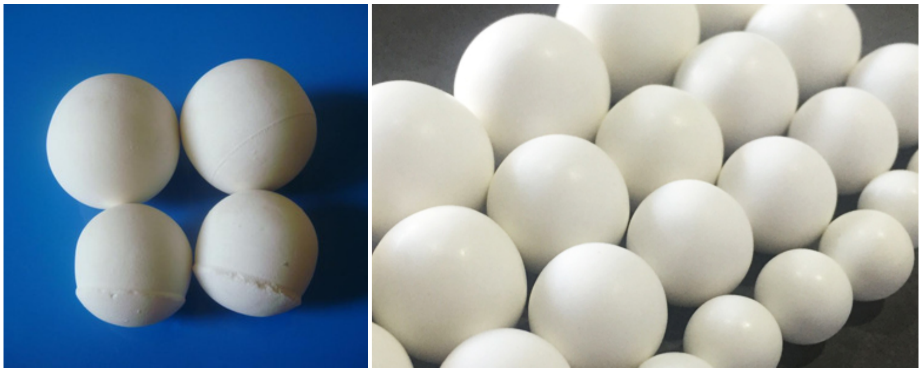


Figure 23: - High Alumina pebbles for Ball mill

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.

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

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

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

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

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

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

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

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

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

Advantages of using Binder for Vitrified tiles include:

- Lower dosage or effective binder cost.

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

- The product is non-fouling which is not susceptible to bacteriological contamination during slip storage, hence no need to use biocides.
- Minimum or no adverse effect on the rheological properties of slip (The rheological behavior of non-Newtonian fluids such as cement paste, mortar, or concrete is often characterized by two parameters, yield stress, $\tau 0$, 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 possibility of adopting renewable energy measures was evaluated during the DEA.

6.1 Installation of Solar PV system

The possibility of adopting renewable energy measures was evaluated during the DEA. A roof top area of 2,040 m^2 is available in the unit. The feasibility of installing solar PV in this area was evaluated. The corresponding solar energy generation potential is shown below.

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

Table 48: Cost benefit analysis of Solar PV installation

Parameters	Unit	Proposed
Available area on roof	m^2	3,400
Estimated Total Solar PV panel area	m^2	2,040
Number of panels (1m X 2m) of 320 Wp	#	1,020
Estimated installed Capacity of solar panel	kW	326
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	1,371
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	500,371
Cost of Electricity	Rs/kWh	6.76
Annual monetary savings	Lakh Rs/y	34
Estimated Investment	Lakh Rs	180
Payback Period	Months	64
IRR	%	-7%
Discounted payback period	Months	21.69

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

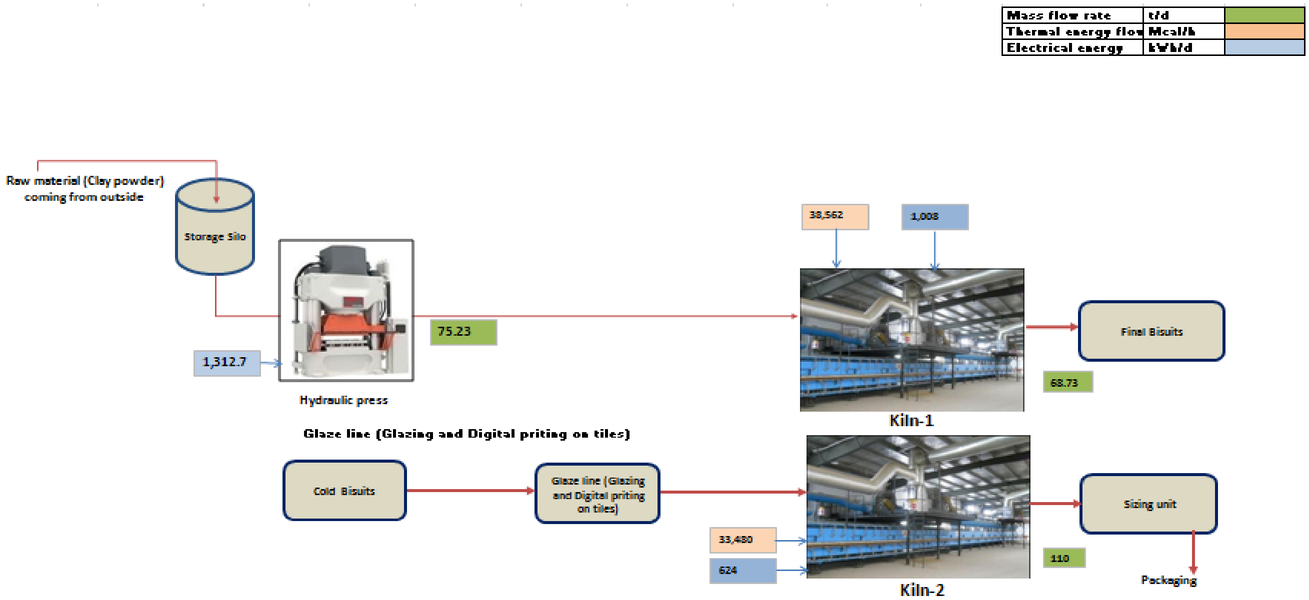


Figure 25: Process Flow Diagram of Plant

Annex-2: Detailed Inventory

Equipment	Connected Load	Rating (kW)
Press	Press-1 (1400)	88.62
	Press-2 (1600)	86.7
Cooling Tower	Pump	15
Printing	Printing	4.83
Kiln	Kiln-1	282.25
	Kiln-2	281.35
Sizing line	Sizing M/c-1	56.5
	Sizing M/c-2	56.5
	Sizing M/c-3	50.5
	Sizing M/c-4	50.5
	Sizing Line-1	2.97
	Sizing Line-2	2.60
Glaze line	Line	55.41
	Stirrer	2.8
	Vibrator	3.3
Glaze ball mill	Ball mill 1 (2 ton)	22
	Ball mill 2 (2 ton)	22
	Ball mill 3 (2 ton)	22
	Ball mill 4 (2 ton)	22
	Ball mill 5 (0.7 ton)	5.5
	Ball mill 6 (0.1 ton)	1.5
	china clay tank	10.43
	Vibrator	3.72
	Pump	3.72
	Lighting	21.146

ANNEX-3: SINGLE LINE DIAGRAM

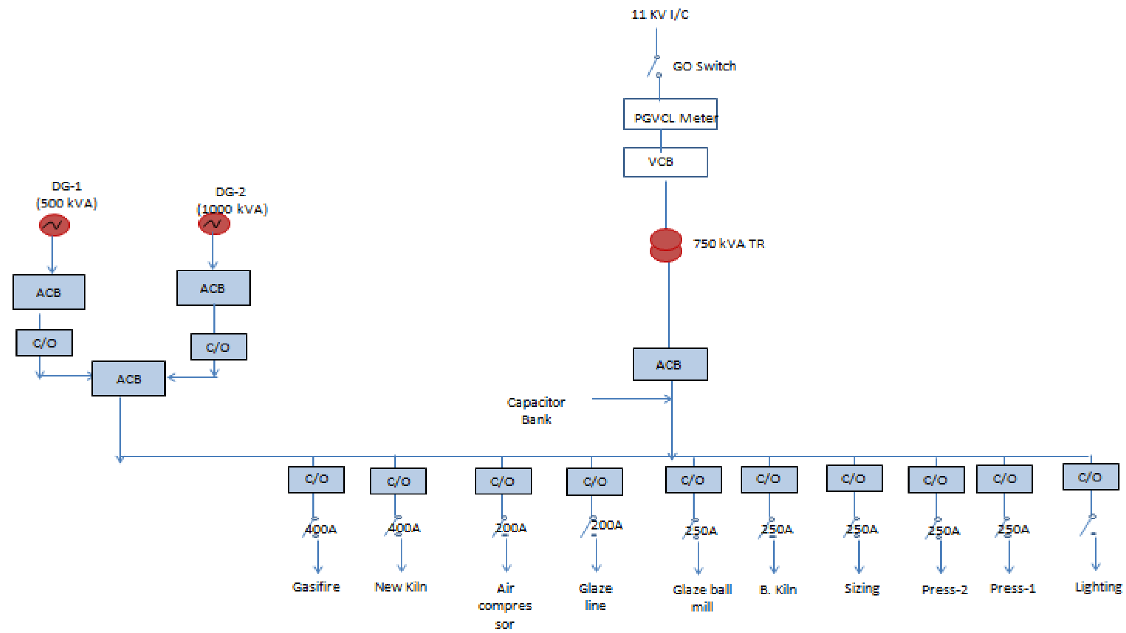
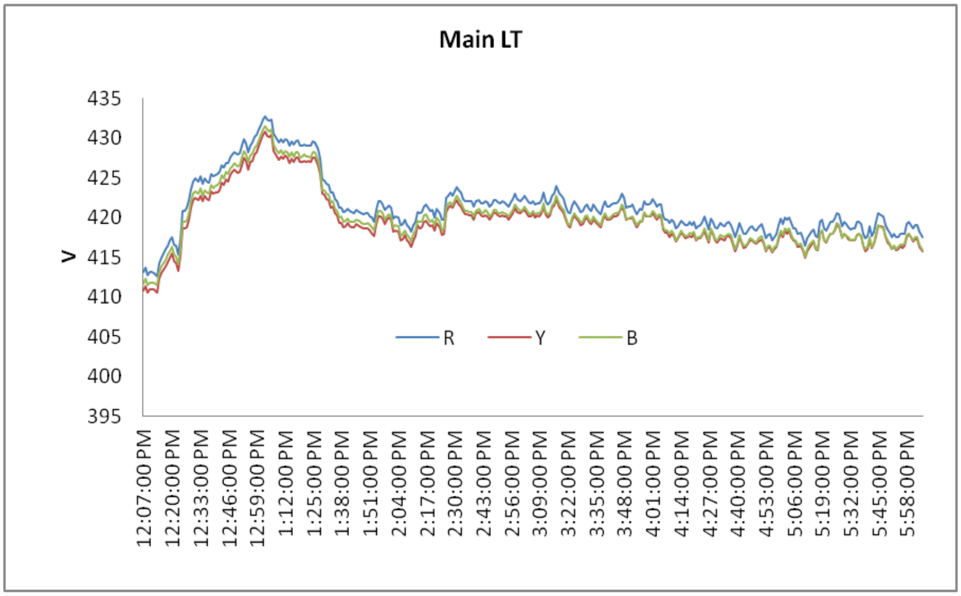


Figure 26: Single Line Diagram (SLD)

ANNEX-4: ELECTRICAL MEASUREMENTS



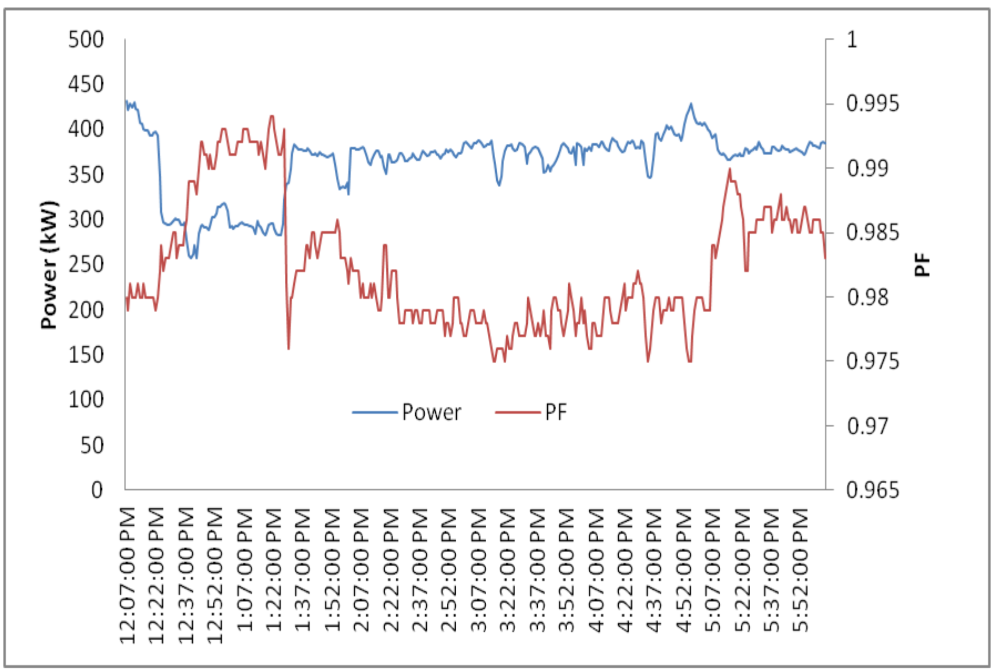


Figure 27: Power and voltage profile of Main Income

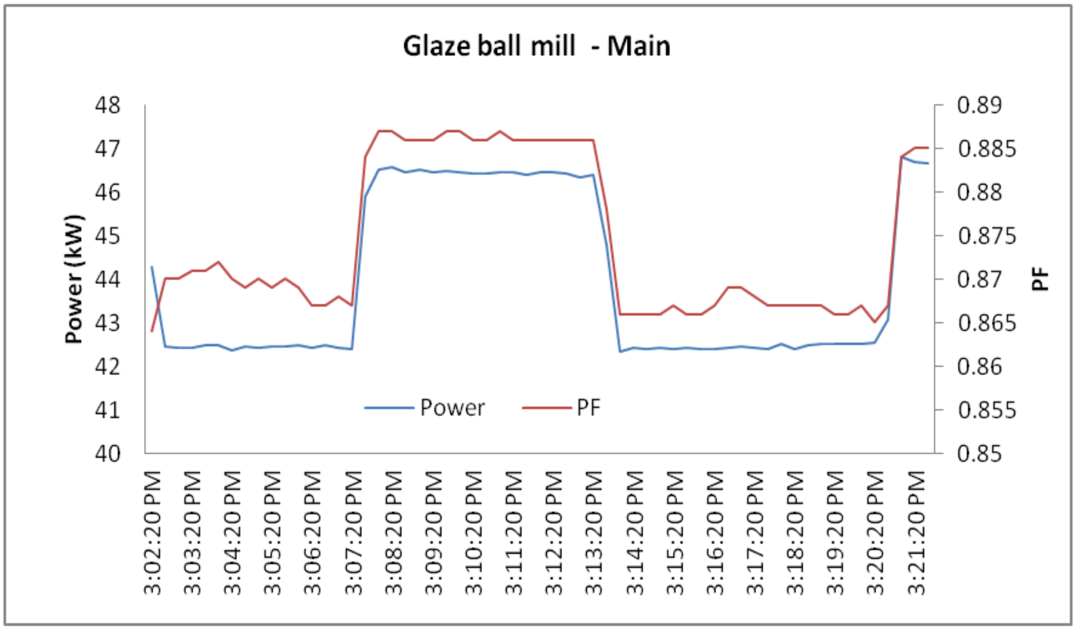


Figure 28: Power and PF profile of Glaze ball Mill – Main

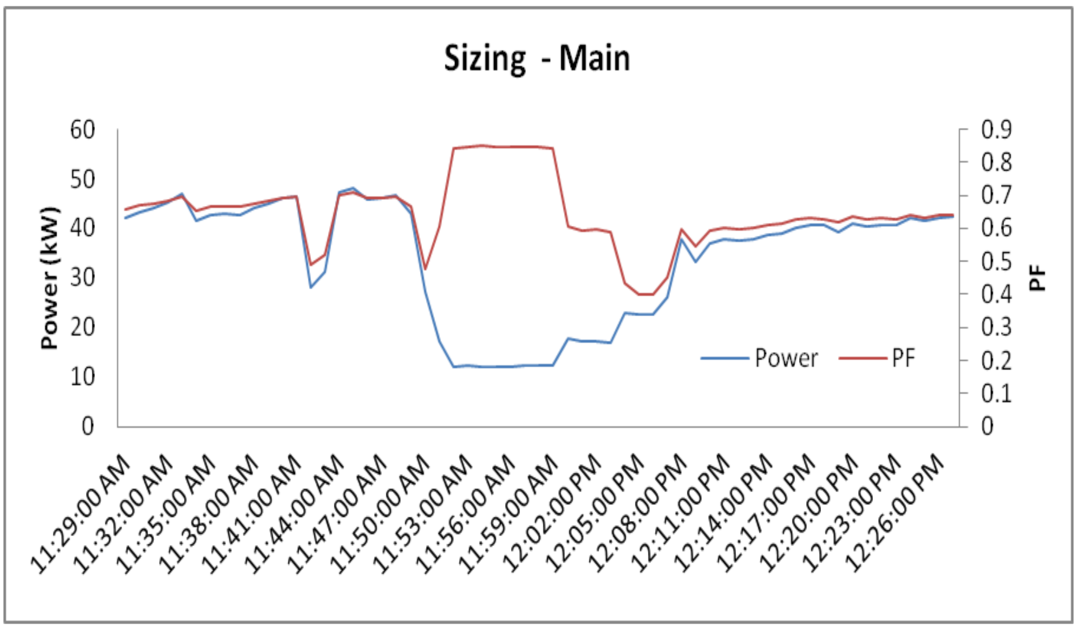
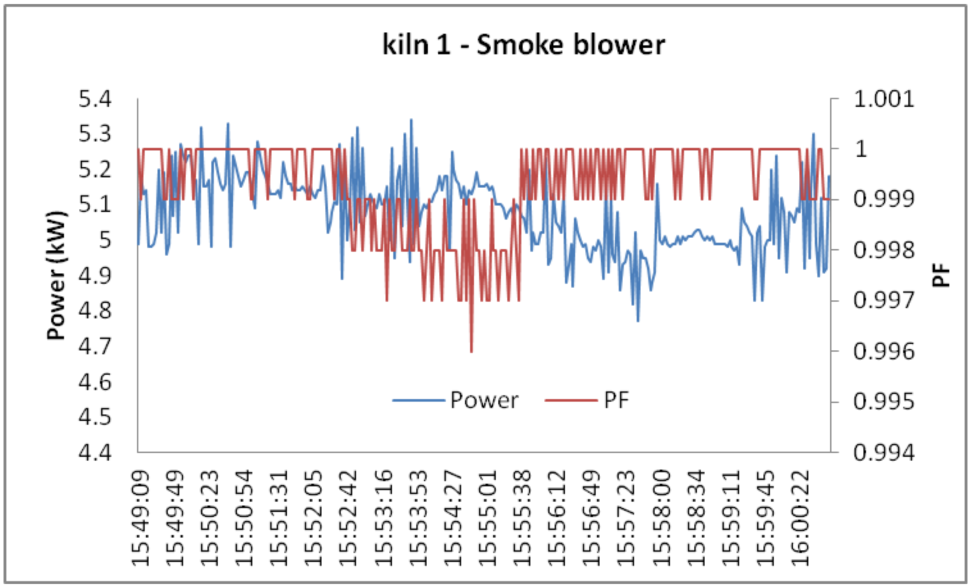
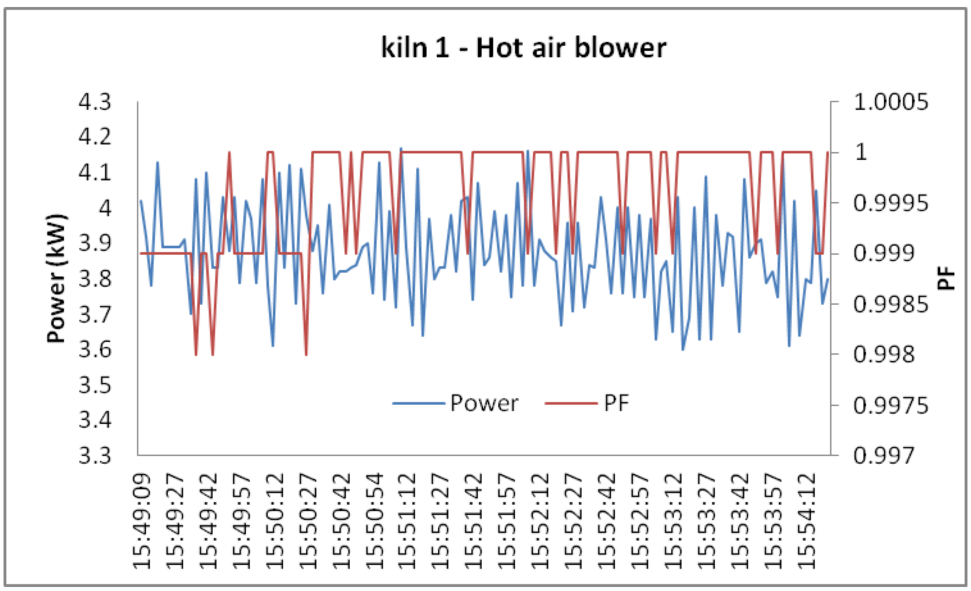


Figure 29: Power and PF profile of Sizing Section – Main


kiln 1 - Smoke blower
Power (kW)
PF
Power
PF
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
1.001
1
0.999
0.998
0.997
0.996
0.995
0.994
15:49:09
15:49:49
15:50:23
15:50:54
15:51:31
15:52:05
15:52:42
15:53:16
15:53:53
15:54:27
15:55:01
15:55:38
15:56:12
15:56:49
15:57:23
15:58:00
15:58:34
15:59:11
15:59:45
16:00:22


kiln 1 - Hot air blower
Power (kW)
PF
Power
PF
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
1.0005
1
0.9995
0.999
0.9985
0.998
0.9975
0.997
15:49:09
15:49:27
15:49:42
15:49:57
15:50:12
15:50:27
15:50:42
15:50:54
15:51:12
15:51:27
15:51:42
15:51:57
15:52:12
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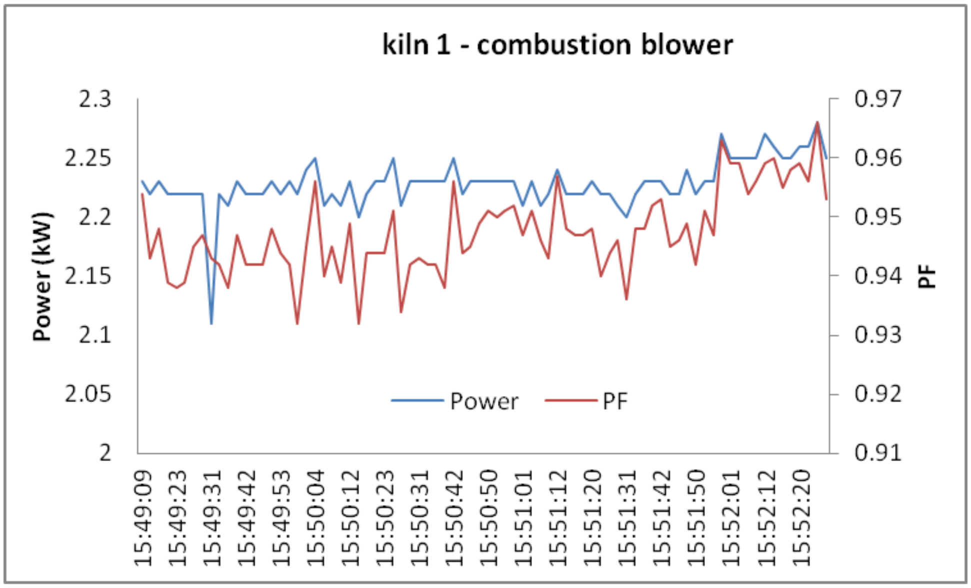
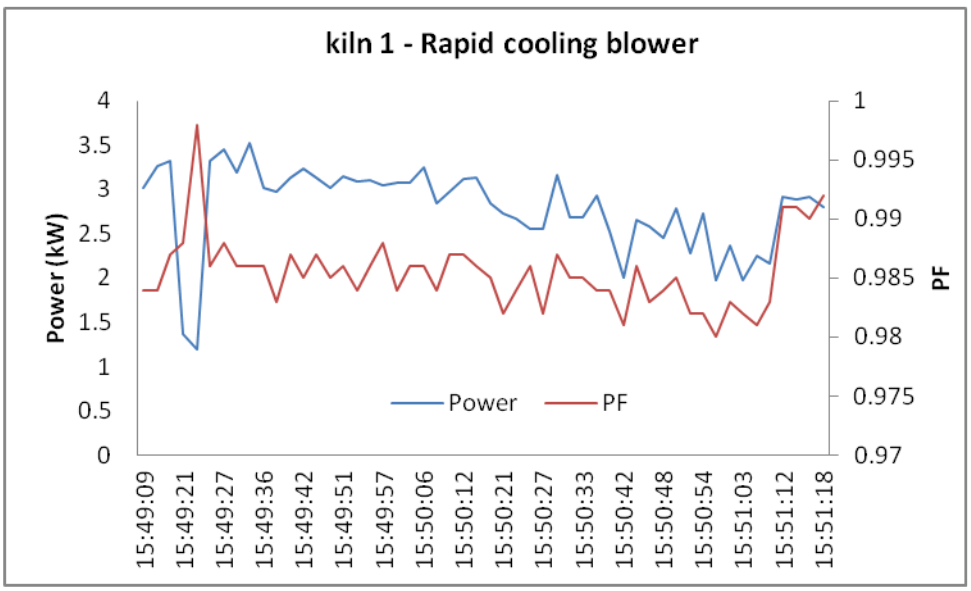
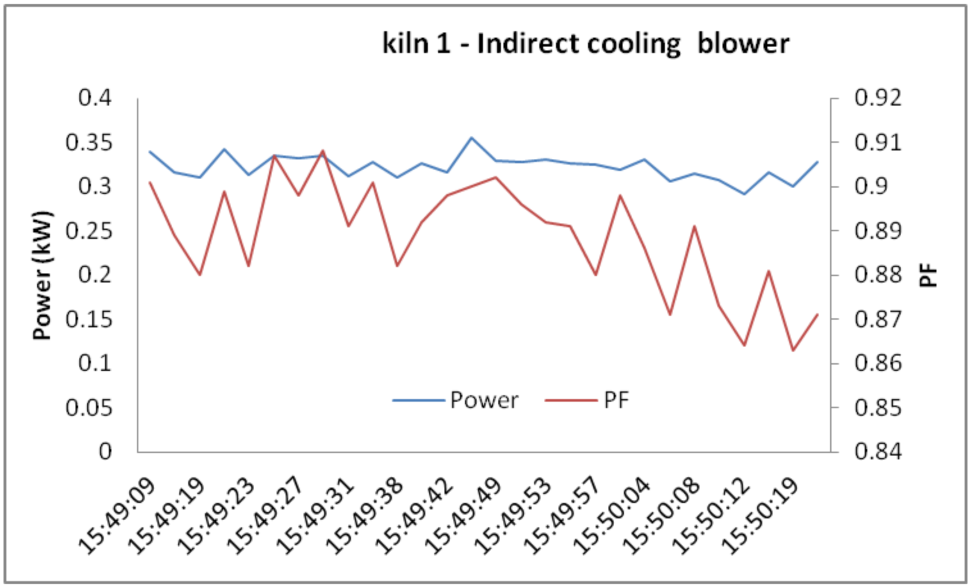
15:52:57
15:53:12
15:53:27
15:53:42
15:53:57
15:54:12


kiln 1 - combustion blower
Power (kW)
PF
2.3
2.25
2.2
2.15
2.1
2.05
2
0.97
0.96
0.95
0.94
0.93
0.92
0.91
Power
PF
15:49:09
15:49:23
15:49:31
15:49:42
15:49:53
15:50:04
15:50:12
15:50:23
15:50:31
15:50:42
15:50:50
15:51:01
15:51:12
15:51:20
15:51:31
15:51:42
15:51:50
15:52:01
15:52:12
15:52:20


kiln 1 - Rapid cooling blower
Power (kW)
PF
4
3.5
3
2.5
2
1.5
1
0.5
0
1
0.995
0.99
0.985
0.98
0.975
0.97
Power
PF
15:49:09
15:49:21
15:49:27
15:49:36
15:49:42
15:49:51
15:49:57
15:50:06
15:50:12
15:50:21
15:50:27
15:50:33
15:50:42
15:50:48
15:50:54
15:51:03
15:51:12
15:51:18



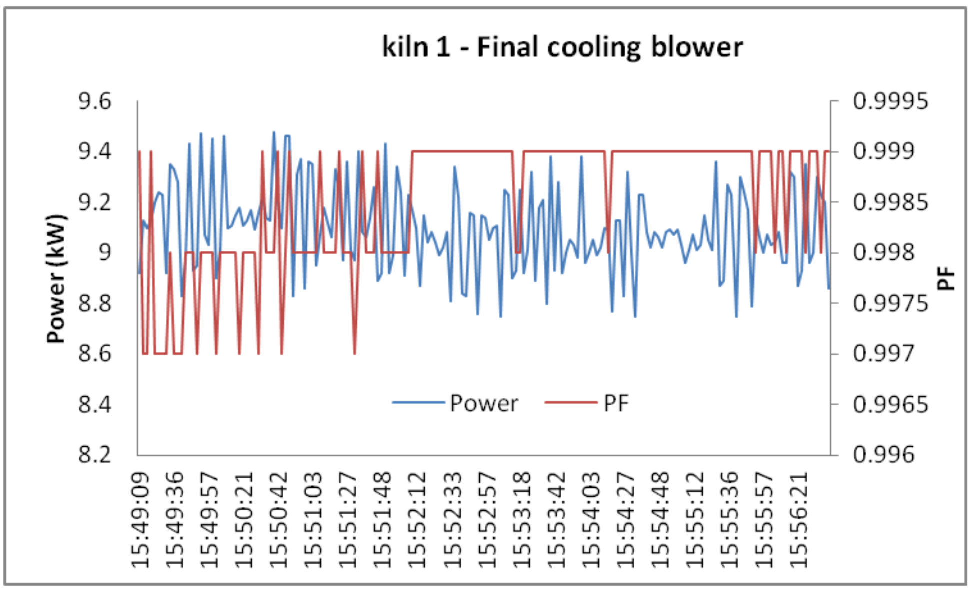
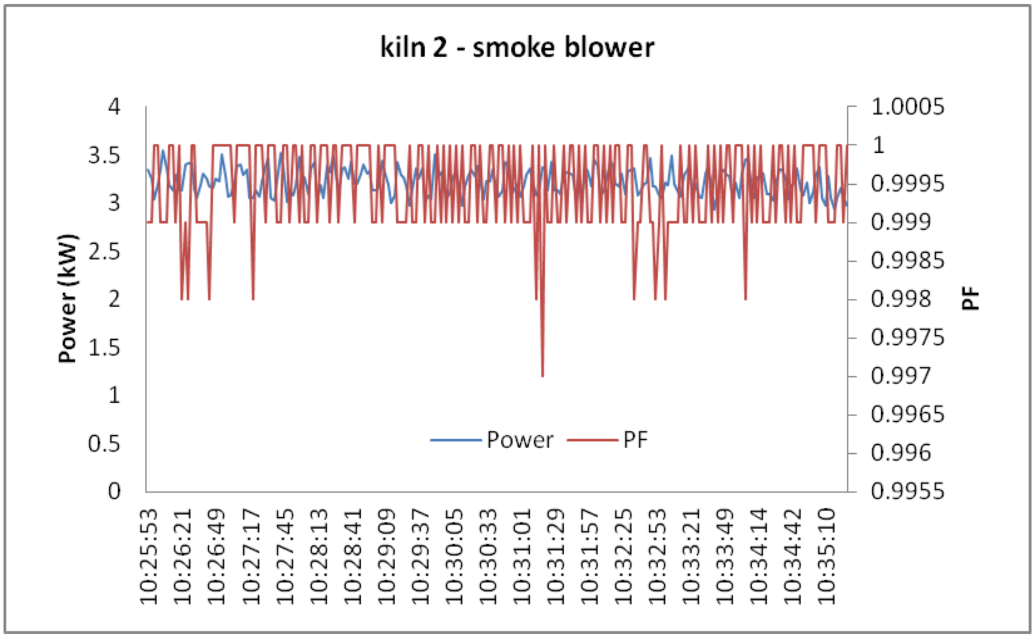
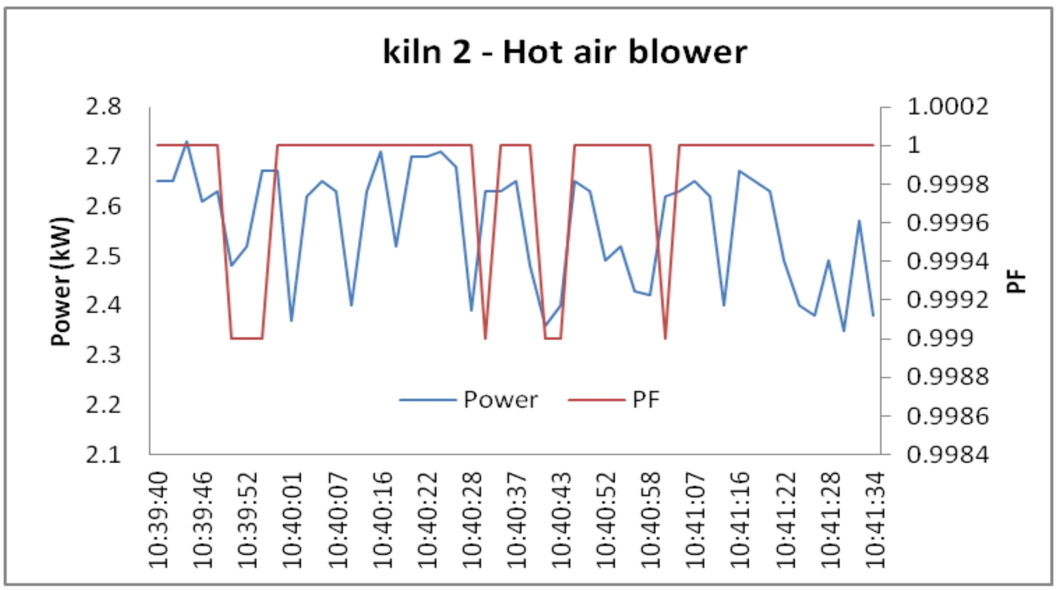
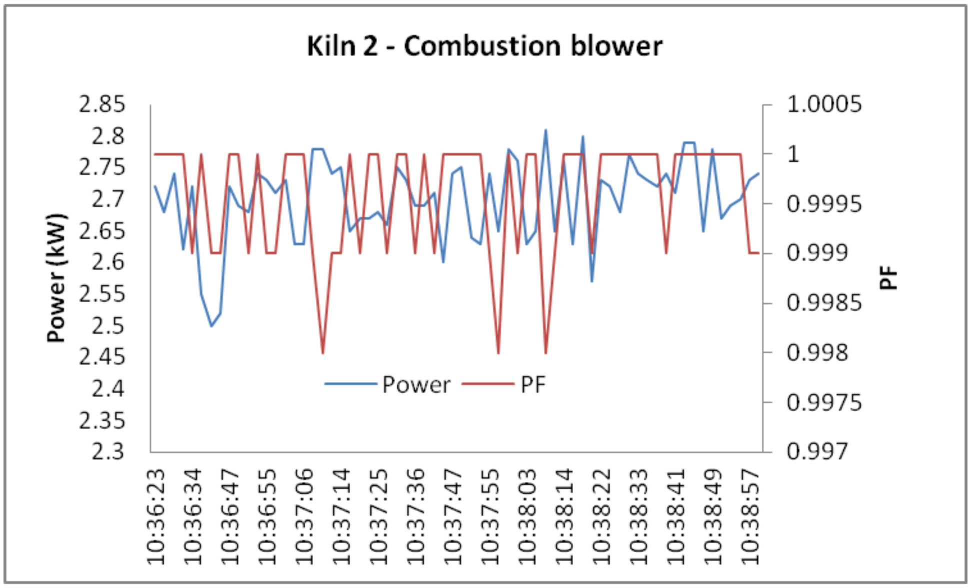
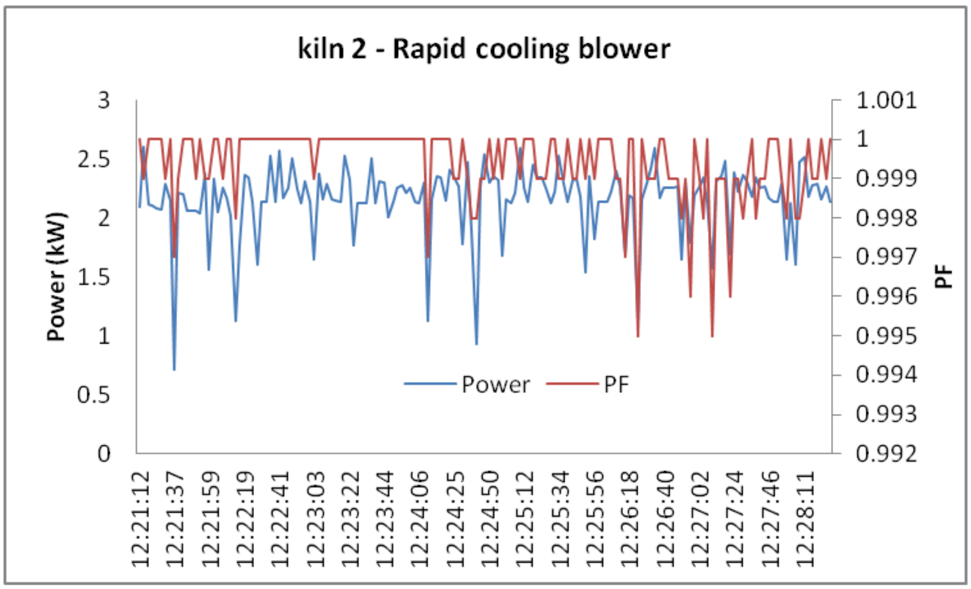


Figure 30: Power and PF profile of blowers of Kiln - 1


kiln 2 - smoke blower
Power (kW)
PF
Power
PF
4
3.5
3
2.5
2
1.5
1
0.5
0
1.0005
1
0.9995
0.999
0.9985
0.998
0.9975
0.997
0.9965
0.996
0.9955
10:25:53
10:26:21
10:26:49
10:27:17
10:27:45
10:28:13
10:28:41
10:29:09
10:29:37
10:30:05
10:30:33
10:31:01
10:31:29
10:31:57
10:32:25
10:32:53
10:33:21
10:33:49
10:34:14
10:34:42
10:35:10


kiln 2 - Hot air blower
Power (kW)
PF
Power
PF
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
1.0002
1
0.9998
0.9996
0.9994
0.9992
0.999
0.9988
0.9986
0.9984
10:39:40
10:39:46
10:39:52
10:40:01
10:40:07
10:40:16
10:40:22
10:40:28
10:40:37
10:40:43
10:40:52
10:40:58
10:41:07
10:41:16
10:41:22
10:41:28
10:41:34


Kiln 2 - Combustion blower
Power (kW)
PF
2.85
2.8
2.75
2.7
2.65
2.6
2.55
2.5
2.45
2.4
2.35
2.3
1.0005
1
0.9995
0.999
0.9985
0.998
0.9975
0.997
Power
PF
10:36:23
10:36:34
10:36:47
10:36:55
10:37:06
10:37:14
10:37:25
10:37:36
10:37:47
10:37:55
10:38:03
10:38:14
10:38:22
10:38:33
10:38:41
10:38:49
10:38:57


kiln 2 - Rapid cooling blower
Power (kW)
PF
3
2.5
2
1.5
1
0.5
0
1.001
1
0.999
0.998
0.997
0.996
0.995
0.994
0.993
0.992
Power
PF
12:21:12
12:21:37
12:21:59
12:22:19
12:22:41
12:23:03
12:23:22
12:23:44
12:24:06
12:24:25
12:24:50
12:25:12
12:25:34
12:25:56
12:26:18
12:26:40
12:27:02
12:27:24
12:27:46
12:28:11

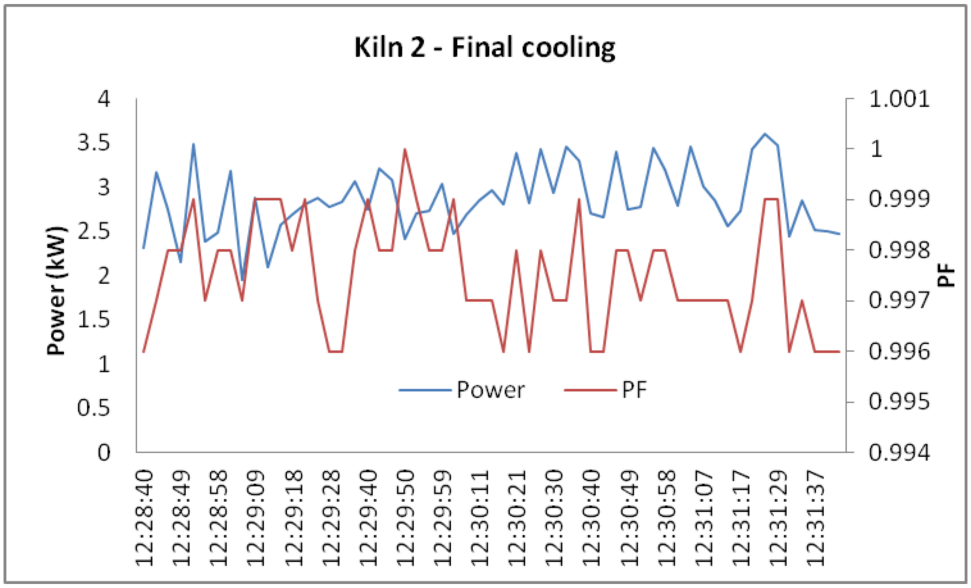


Figure 31: Power and PF profile of blowers of Kiln-2

Annex-5: Thermal Measurements, Kiln Efficiency

1. Kiln-1 efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**Unit**
Average kiln Operating temperature (Heating Zone)	930	*°C*
Initial temperature of kiln tiles	39	*°C*
Avg. fuel Consumption	1,249	*kg/h*
Density of coal gas	0.96	*kg/sm3*
Avg. fuel consumption	1,306	*sm3/h*
Flue Gas Details		
Flue gas temp at smog blower	130	°C
Preheated air temp./Ambient	60	°C
O2 in flue gas	6.0	*%*
CO2 in flue gas	8.2	*%*
CO in flue gas	33.1	*ppm*
Atmospheric Air		
Ambient Temp.	39	*°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	1231	*kcal/scm*
Ash Analysis		
Unburnt in bottom ash	*0.00*	%
Unburnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kcal/kg
GCV of fly ash	*0*	kcal/kg
Material and flue gas data		
Weight of Kiln car material	0	*kg/h*

Input Data Sheet		
Weight of ceramic material being heated in Kiln	2,864	*kg/h*
Weight of Stock	2,864	*kg/h*
Specific heat of clay material	0.22	*kcal/kg-oC*
Avg. specific heat of fuel	0.51	*kcal/kg-oC*
fuel temp	39	*°C*
Specific heat of flue gas	0.24	*kcal/kg-oC*
Specific heat of superheated vapour	0.45	*kcal/kg-oC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	15,929	*kcal/h*
Radiation and convection from heating zone surface	36,350	*kcal/h*
Heat loss from all zones	52,278	*kcal/h*
For radiation loss in Kiln		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.82	*h*
Area of entry opening	1.2	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*K*

Efficiency calculations

Calculations	Kiln - 1	Unit
Theoretical Air Required	7.72	kg/kg of fuel
Excess Air supplied	39.53	%
Actual Mass of Supplied Air	10.78	kg/kg of fuel
Mass of dry flue gas	10.66	kg/kg of fuel
Amount of Wet flue gas	11.78	Kg of flue gas/kg of fuel
Amount of water vapour in flue gas	1.12	Kg of H_2O/kg of fuel
Amount of dry flue gas	10.66	kg/kg of fuel
Specific Fuel consumption	436.27	kg of fuel/ton of tile
Heat Input Calculations		
Combustion heat of fuel	536,878	kcal/ton of tiles
Total heat input	536,878	kcal/ton of tile
Heat Output Calculation		
Heat carried away by 1 ton of tile	196,075	kcal/ton of tile
Heat loss in dry flue gas	101,557	kcal/ton of tile
Loss due to H2 in fuel	21,823	kcal/ton of tile
Loss due to moisture in combustion air	441.28	kcal/ton of tile
Loss due to partial conversion of C to CO	242.74	kcal/ton of tile
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	51.03	kcal/ton of tile
Loss Due to Evaporation of Moisture Present in Fuel	5,927	kcal/ton of tile
Total heat loss from kiln (surface) body	18,255	kcal/ton of tile
Heat loss due to unburnts in Fly ash		kcal/ton of tile

Calculations	Kiln - 1	Unit
Heat loss due to unburnts in bottom ash	-	kcal/ton of tile
Heat loss due to kiln car	-	kcal/ton of tile
Unaccounted heat lossess	192,506	kcal/ton of tile
Heat loss from kiln body and other sections		
Total heat loss from kiln	18,255	kcal/ton
Kiln Efficiency	36.52	%

Kiln-2 efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujarat gas	
Particulars	**Value**	**Unit**
Average kiln Operating temprature (Heating Zone)	981	*°C*
Initial temperature of kiln tiles	45	*°C*
Avg. fuel Consumption	155.0	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	140	*°C*
Preheated air temp./Ambient	52	*°C*
O2 in flue gas	14.82	*%*
CO2 in flue gas	3.59	*%*
CO in flue gas	3.25	*ppm*
Atmospheric Air		
Ambient Temp.	37.4	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*73.80*	%
H	*24.90*	%
N	*1.30*	%
O	*0.00*	%
S	*0.00*	%
Moisture	*0.00*	%
Ash	*0.00*	%
GCV of fuel	9000	*kcal/scm*
Ash Analysis		
Unburnt in bottom ash	*0.00*	%
Unburnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kcal/kg
GCV of fly ash	*0*	kcal/kg
Material and flue gas data		
Weight of Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	4,606	*kg/h*
Weight of Stock	4,606	*kg/h*
Specific heat of clay material	0.22	*kcal/kg-°C*
Avg. specific heat of fuel		*kcal/kg-°C*

Input Data Sheet		
fuel temp	30	°C
Specific heat of flue gas	0.24	*kcal/kg-°C*
Specific heat of superheated vapour	0.45	*kcal/kg-°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	605	*kcal/h*
Radiation and convection from heating zone surface	37,510	*kcal/h*
Heat loss from all zones	38,115	kcal/h
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.82	*h*
Area of entry opening	1.2	*m2*
Coefficent based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*deg K*

Efficiency Calculation

Calculations	Kiln	Unit
Theoretical Air Required	17.23	kg/kg of fuel
Excess Air supplied	239.81	%
Actual Mass of Supplied Air	58.53	kg/kg of fuel
Mass of dry flue gas	57.29	kg/kg of fuel
Amount of Wet flue gas	59.53	kg of flue gas/kg of fuel
Amount of water vapour in flue gas	2.24	kg of H_2O/kg of fuel
Amount of dry flue gas	57.29	kg/kg of fuel
Specific Fuel consumption	33.65	scm of fuel/ton of tile
Heat Input Calculations		
Combustion heat of fuel	302,879	kcal/ton of tiles
Total heat input	302,879	kcal/ton of tile
Heat Output Calculation		
Heat carried away by 1 ton of tile	205,938	kcal/ton of tile
Heat loss in dry flue gas	47,478	kcal/ton of tile
Loss due to H_2 in fuel	472	kcal/ton of tile
Loss due to moisture in combustion air	2,702.56	kcal/ton of tile
Loss due to partial conversion of C to CO	12.70	kcal/ton of tile
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	39.34	kcal/ton of tile
Loss Due to Evaporation of Moisture Present in Fuel	-	kcal/ton of tile
Total heat loss from kiln (surface) body	38,115	kcal/ton of tile
Heat loss due to unburnts in Fly ash	-	kcal/ton of tile
Heat loss due to unburnts in bottom ash	-	kcal/ton of tile
Heat loss due to kiln car	-	kcal/ton of tile
Unaccounted heat lossess	8,122	kcal/ton of tile
Heat loss from kiln body and other sections		
Total heat loss from kiln	38,115	Kcal/ton
Kiln Efficiency	68.0	%

ANNEX-6: VENDORS

ECM-1: Excess air control in 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 2 & 3: Heat loss reduction from surface of kiln – 1 and delivery pipe from kiln-1

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 / 7**5** **Fax: +91-11-44-30882894 /95** Mr. Rajneesh Phone : 0161-2819388 Mobile : 9417004025	Email: kk.mitra@lloydinsulation.com
3	Shivay Insulation	20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009	Mobile- 9712030444	shivayinsulation@gmail.com

ECM-5: Replacement of IE1 motor with IE3 motor of glaze ball mill

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	The Indian Electric Co.	Bharat Bhavan A, Dajisaheb Natu Rd, Natu	Mob: +91 8049443859 Tel: 020-27426370	

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
		Baag, Shukrawar Peth, Pune, Maharashtra 411002		
2	Siemens Limited	3rd floor, Prerna Arbour, Girish Cold Drinks Cross Road, Off. C.G.Road, Ahmedabad	Mr. Paresh Prajapati 079-40207600	paresh.prajapati@siemens.com
3	Crompton Greaves	909-916, Sakar-II, Near Ellisbridge, Ahmedabad	079-40012000 079-40012201 079-40012222	sagar.mohbe@cgglobal.com

ECM-7: Replacement of inefficient pumps with efficient 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: VFD installation on cooling tower pump motor

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	B-117 & 118 GIDC	Mr. V.Jaikumar	v_jaikumar@hitachi-hirel.

	Electronics Pvt. Ltd	Electronics Zone, Sector 25, Gandhinagar- 382044	079 2328 7180 - 81	com

ECM-9: Replacement of Inefficient lights with EE lights

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

ECM-10: Voltage Optimization by Servo stabilizer

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.	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-11: Cable loss minimization

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

ECM-12: 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-13: 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

ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 49: Assumptions for Financial Analysis

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

2.2.3.4.1