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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE WT-04: LEXICON 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

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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. Lexicon 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. Narendra P Sanghat, Director

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

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

DESL Team

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ABBREVIATIONS

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

UNITS AND MEASURES

Parameters	UOM
Calorific value	CV
Degree Centigrade	^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.

Lexicon Ceramic Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Lexicon 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	Lexicon Ceramic Pvt. Ltd.
Year of Establishment	2014
Address	S.No 141/1, Halvad Morbi Road At- Unchimandal, Morbi Gujarat - India.
Products Manufactured	Wall Tiles
Name(s) of the Promoters / Directors	Mr. Narendra P. Sanghat

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

A brief description of the manufacturing process is given below: The main energy utilizing equipment is kiln in which the fuel used is coal gas. The temperature maintained in kiln is approximately 800°C – 1,200°C (in heating zone).

- **Storage Silo:** Raw material (clay power) is coming from outside and stored in silos.
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.
- **Kiln:** There was only one Kiln, which Operates for 12 hours in night for baking the biscuits, and in day time for 12 hours for baking the Glaze tiles.
- **Glaze ball mill:** For producing glazing material used on wall tiles.
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The 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: Coal gas is used as fuel in kiln and oxygen content in flue gas was found to be 10.3 % against desired level of 5 %. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation in pipe line in indirect cooling zone: In kiln, the recuperator pipes was found to be un-insulated with surface temperature of 180 °C which should be maintain at 55 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the 130 recuperator pipes with insulation material for reducing surface heat losses.
- Combustion air preheating by recuperator in rapid cooling zone: Pre-heating of combustion air is one of the most popular uses of recovered heat from kilns due to its high efficiency and reduction in primary fuel use. Combustion air temperature at present in the plant was 48°C. After using recuperator to preheat this combustion air temperature can rise to 200°C.
- Optimization of glaze mill operation: currently glaze mill operation time is 14.5 hour per batch which can reduce up to 9.5 hour by changing loose belt/broken belt, by improving time control operation and residue % frequent checking.
- Replacement of convention motor with IE3 motors
- Operational pressure optimization in compressor: It was observed during the energy audit that the Compressor operating pressure was 6.5 kg/cm² that can be reduced to 5.5 kg /cm².
  As very high pressure compressed air is not necessary in the process area. So, it is recommended to maintain operating compressor at 5 kg/cm²

- Installation of VFD with screw compressor: During unload condition; compressor is consuming 30% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy up to 15% of present consumption.
- Suction of air compressor from cold atmosphere in spite of hot atmosphere
- Replacement of V belt with 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.
- Installation of Harmonic filter: During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 2.3 kW. It is recommended to install active harmonics filters (AHF) at main incomer.
- Cable loss minimization: In sizing section, power factor was varies in range of 0.4-0.6. It is recommended to install power factor improvement capacitors for sizing section.
- Energy Management system: Online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption and there were no proper fuel monitoring system installed at hot air generator and kiln. It is recommended to install online electrical energy management systems (smart energy meters) on the main incomer and on the various electricity distribution panels and fuel monitoring system.
- Main LT voltage optimization: The present average voltage on main LT panel was 438V against Standard voltage of 415V. It is recommended to install 600 KVA servo stabilizer.
- Installation of 30 kW solar PV has been recommended at the available roof space above administration building.

Table 1 : Summary of Energy Conservation Measures

Sr. No.	Energy Conservation Measure	Annual Energy Savings			Investment	Energy Cost Saving	Payback Period	Emission Reduction
		Electricity kWh/y	Coal (MT/y)	TOE/y	Rs lakh	Rs. Lakh	Months	Tons of CO_2/y
1	Excess air control	21,358	436	241	18.48	34.62	6	939
2	Insulation in pipe line in indirect cooling zone -		47	26	2.45	3.61	8	100
3	Combustion air preheating by recuperator in rapid cooling zone		834	458		63.76		1766
4	Improvisation of damper controlling of rapid cooling blowers	25,200		2	Nil	1.57		21
5	Optimization of glaze mill operation	127,718		11	9.31	7.98	14	105
6	Replacement of convention motor with IE3 motors	39,235		3	1.69	2.45	8	32
7	Operational pressure reduction in compressor 2	6,156		1		0.38		5
8	Installation of VFD with screw compressor 2	22,498		2	2.10	1.41	18	18
9	Cold air suction of compressor	10,214		1		0.64	0	8
10	Cable loss minimization	3,806		0	0.29	0.39	9	3
11	Installation of Harmonic filter	18,787		2	6.25	1.17	64	15
12	Replacement of V belt with REC belt	13,663		1	0.71	0.85	10	11
13	Installation of energy monitoring system	64,037		6	14.06	16.95	10	53
	Total	**352,671**	**1,317**	**754**	**55**	**136**	**4.89**	**3,076**

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

1 Reduction in energy cost by 16%
2 Reduction in electricity consumption by 11 %
3 Reduction in Thermal Energy consumption by 15.6 %
4 Reduction in greenhouse gas emissions by 15 %

FINANCIAL ANALYSIS

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

Table 2: Financial indicators

Sr. No.	Energy Conservation Measure	Investment Lakh Rs	IRR %	Discounted Payback Period Months
1	Excess air control	18.48	146%	2.51
2	Insulation in pipe line in indirect cooling zone	2.45	112%	3.17
3	Combustion air preheating by recuperator in rapid cooling zone	Nil		
4	Improvisation of damper controlling of rapid cooling blowers	Nil		
5	Optimization of glaze mill operation	9.31	63%	5.27
6	Replacement of convention motor with IE3 motors	1.69	109%	3.23
7	Operational pressure reduction in compressor 2	Nil		
8	Installation of VFD with screw compressor 2	2.10	44%	6.83
9	Cold air suction of compressor	Nil		-
10	Cable loss minimization	0.29	98%	3.55
11	Installation of Harmonic filter	6.25	-6%	20.83
12	Replacement of V belt with REC belt	0.71	89%	3.86
13	Installation of energy monitoring system	14.06	89%	3.87

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	Lexicon Ceramic Pvt. Ltd.		
Plant Address	S.No 141/1, Halvad Morbi Road At- Unchimandal, Morbi, Gujarat - India.		
Constitution	Private Limited		
Name of Promoters	Mr. Narendra P Sanghat		
Contact person	Name	Narendra P Sanghat	
	Designation	DIRECTOR	
	Tel	9825639365	
	Fax		
	Email	lexiconcera@gmail.com	
Year of commissioning of plant	2014		
List of products manufactured	Wall tile, 250 x 375 mm Wall tile, 300 x 450 mm Wall tile, 300 x 300mm		
Installed Plant Capacity	9,000 boxes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	987	2131	2374

Description	Details		
Net profit	35	59	66
No of operational days in a year	Days/Year	335	
	Hours/Day	24	
	Shifts /Day	2	
Number of employees	Staff	25	
	Worker	50	
	Casual labor	40	
Details of Energy Consumption	Source	Yes/No	Areas of Use
	Electricity (kWh)	Yes	Entire Process and Utility
	Coal (kg)	Yes	Only in Kiln through Coal Gasifier
	Diesel (litres)	Yes	DG – Rarely used
	Natural Gas (scm)	No	
	Other (specify)	No	
Have you conducted any previous energy audit?	No		
Interested in DEA	Yes		
	Very Interested		

1.3 Methodology and Approach

The study was conducted in 3 stages:

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

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

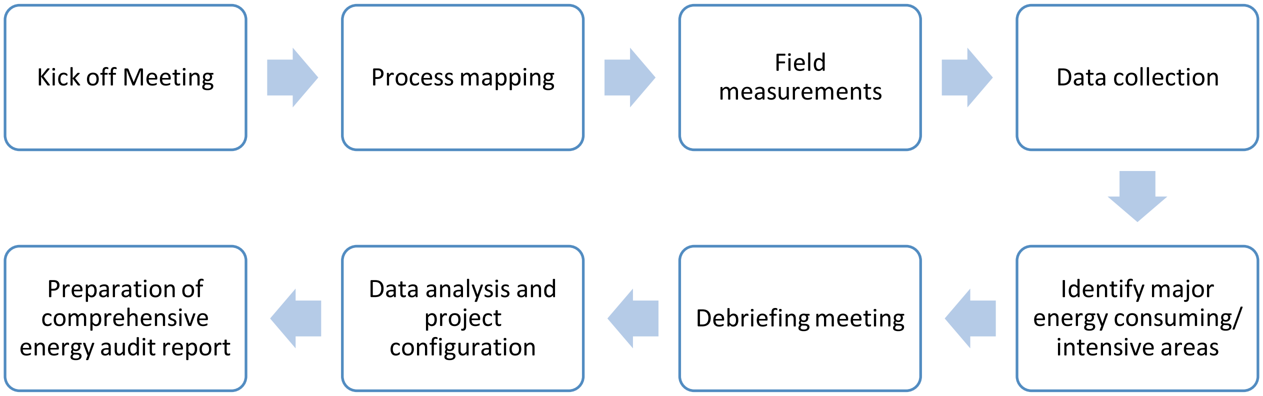

Figure 1: General methodology

The field work was carried out during 21-23th 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

Sl. No.	Instruments	Parameters Measured
4	Digital Clamp on Power Meter – 3 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and Flue gas temperature, Ambient temperature
6	Digital Temperature and Humidity Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°*C*
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

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

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

2 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:

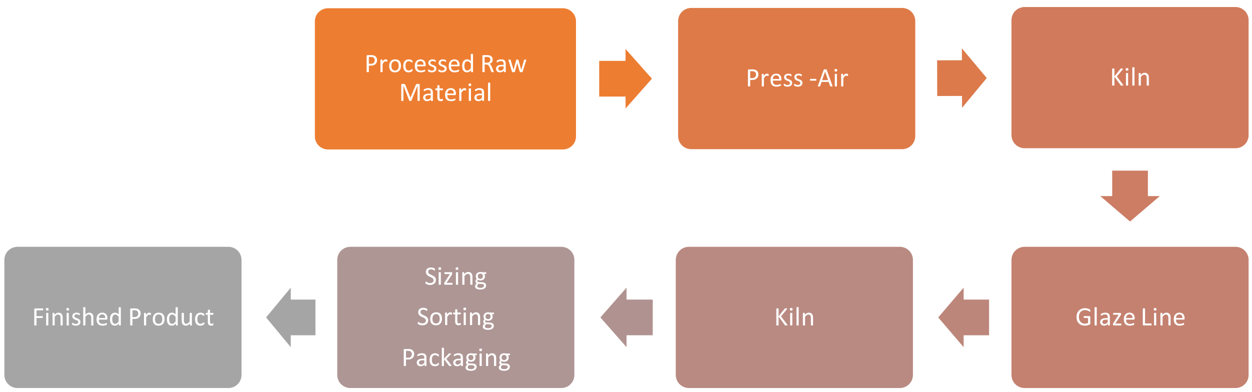

Figure 2: Process Flow Diagram

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 for 24 hours and then conveyed to hydraulic press machine where it is pressed and tiles are formed of required size, output of press is called biscuit.
- Biscuit is then heated in Kiln at about 1,200°C during night time.
- This is followed by the glazing.
- After this, these glazed products make a passage through the same kiln at 1,100°C for final drying and hardening. During day time, kiln is used for baking the glazed tiles.
- Output of kiln is called tiles; these tiles are then passed through cutting, sizing and polishing machines to match exact dimensions required.
- After sizing tiles are packed in boxes and then dispatched.

The major energy consuming equipment in the plant are:

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

- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.
- **Sizing machine and packing:** Output of kiln is called tiles; these tiles are passed through cutting, sizing and polishing machines to match exact dimensions required.

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

2.2 Production Details

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

Table 5: Product Specifications

Product	Size /Piece	Weight/box	Area per box	Pieces per box
	mmx mm	kg	Sq m	#
Wall Tiles	250 x 375	9	0.6	8
Wall Tiles	300 x 450	11	0.81	6
Wall Tiles	300 x 300	10	0.81	9

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

Table 6: Month wise production

Period	Number of Boxes			Corresponding Area (m^2)			Corresponding Mass (MT)		
	250 x 380	300 X 450	300 X 300	250 x 380	300 X 450	300 X 300	250 x 380	300 X 450	300 X 300
Oct-17	142,556	47,972	34,252	237,594	59,225	42,287	2,138	651	423
Nov-17	141,951	21,906	15,077	236,585	27,044	18,613	2,129	297	186
Dec-17	113,913	54,846	20,360	189,855	67,711	25,136	1,709	745	251
Jan-18	131,817	30,876	22,193	219,695	38,118	27,399	1,977	419	274
Feb-18	68,556	62,151	24,156	114,260	76,730	29,822	1,028	844	298
Mar-18	142,939	31,364	13,648	238,231	38,721	16,849	2,144	426	168
Apr-18	116,102	51,740	18,598	193,503	63,877	22,960	1,742	703	230
May-18	104,112	46,850	46,850	173,519	57,840	57,840	1,562	636	578
Jun-18	100,770	45,347	45,347	167,951	55,984	55,984	1,512	616	560
Jul-18	109,751	49,388	49,388	182,919	60,973	60,973	1,646	671	610
Aug-18	105,906	47,658	47,658	176,510	58,837	58,837	1,589	647	588
Sep-18	90,883	40,898	40,898	151,472	50,491	50,491	1,363	555	505
Average	114,105	44,250	31,535	190,175	54,629	38,933	1,712	601	389
	63,297			94,579			901		

2.3 Energy Scenario

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

- Electricity is supplied from two different sources:
  - From the Utility, Paschim Gujarat Vij Company Ltd. (PGVCL)
  - Captive backup DG sets for whole plant
- Thermal energy is used for following applications :
  - Coal Gas for 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 distribution		Energy use distribution	
	Rs. In Lakhs	% of total	TOE	% of total
Grid – Electricity	199.96	23.6	275	5.6
Coal	647.42	76.4	4,655	94.4
Total	847.38	100	4,931	100

This is shown graphically in the figures below:

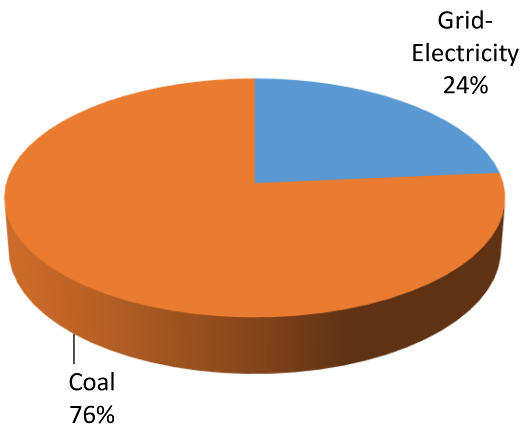

Figure 3 : Energy cost share

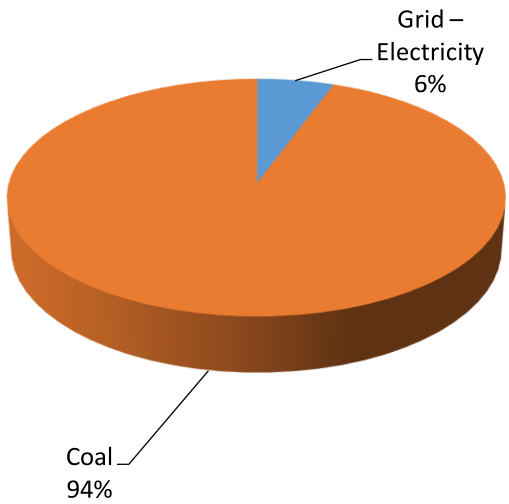

Figure 4 Energy use share

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 24 % of the energy cost and 6 % of the overall energy consumption.
- Source of thermal energy is from coal.
- Coal used in the hot air generator accounts for 76 % of cost and 94 % 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	32858
Tariff Category	HTP-I
Contract Demand, kVA	650
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Tariff structure

Particulars	Tariff structure for Category HTP-1
Demand Charges (Rs./kVA)	
1st 500 kVA	150
2nd 500 kVA	260
Next 297	475
Energy Charges (Rs./kWh)	
Normal Hours	4.2
Peak Hours	0.85
Night Time	0.4
Fuel Surcharge (Rs./kWh)	1.61
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

2.2.1.2 ***Month wise Electricity Consumption and Cost***

Month wise total electrical energy consumption is shown as under:

Table 10 : Electricity consumption & cost

Month	Units Consumed kWh	Total Electricity Cost Rs	Unit Cost Rs/kWh
Oct-17	269,728	1,713,738	6.35
Nov-17	253,064	1,594,573	6.30
Dec-17	274,498	1,717,072	6.26
Jan-18	317,424	1,981,298	6.24
Feb-18	221,908	1,361,192	6.13
Mar-18	220,000	1,393,396	6.33

Apr-18	285,156	1,770,726	6.21
May-18	281,544	1,746,146	6.20
Jun-18	277,712	1,724,581	6.21
Jul-18	271,332	1,698,390	6.26
Aug-18	272,308	1,701,192	6.25
Sep-18	257,196	1,593,510	6.20

Average electricity consumption is 266,823 kWh/month and cost is Rs 16.66 Lakhs per month. The average cost of electricity is Rs. 6.24 /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.

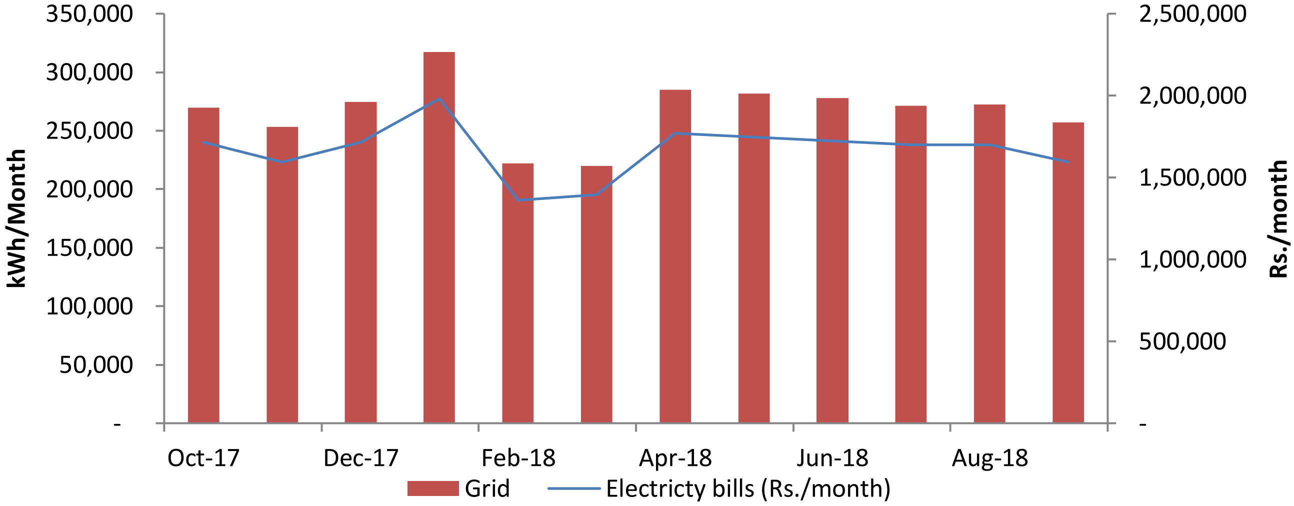

Figure 5: Month wise Variation in Electricity Consumption

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

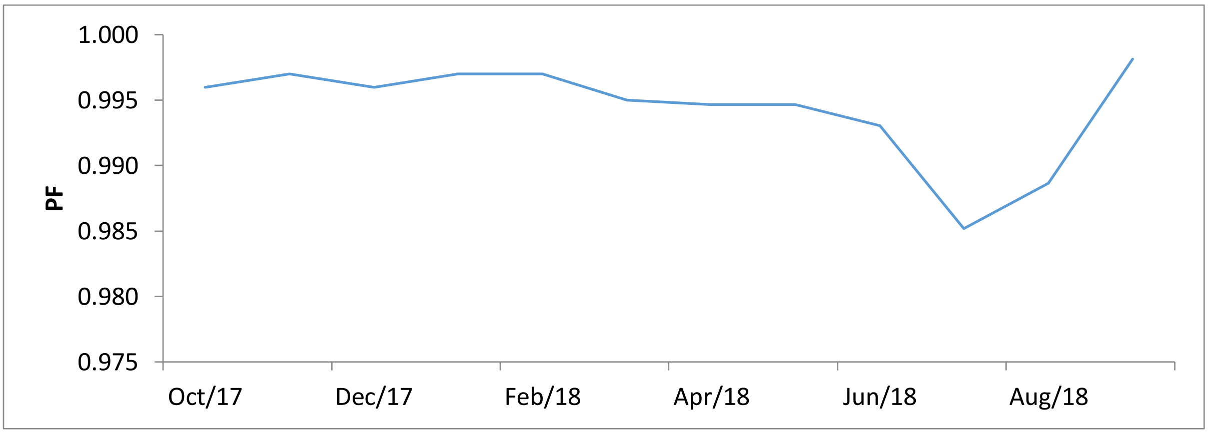

Figure 6 : Month wise variation in Power Factor

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 0.994 with the minimum being 0.985 and the maximum being 0.998.

Maximum Demand: Maximum demand as reflected in the utility bill is 599 kVA from the bill analysis.

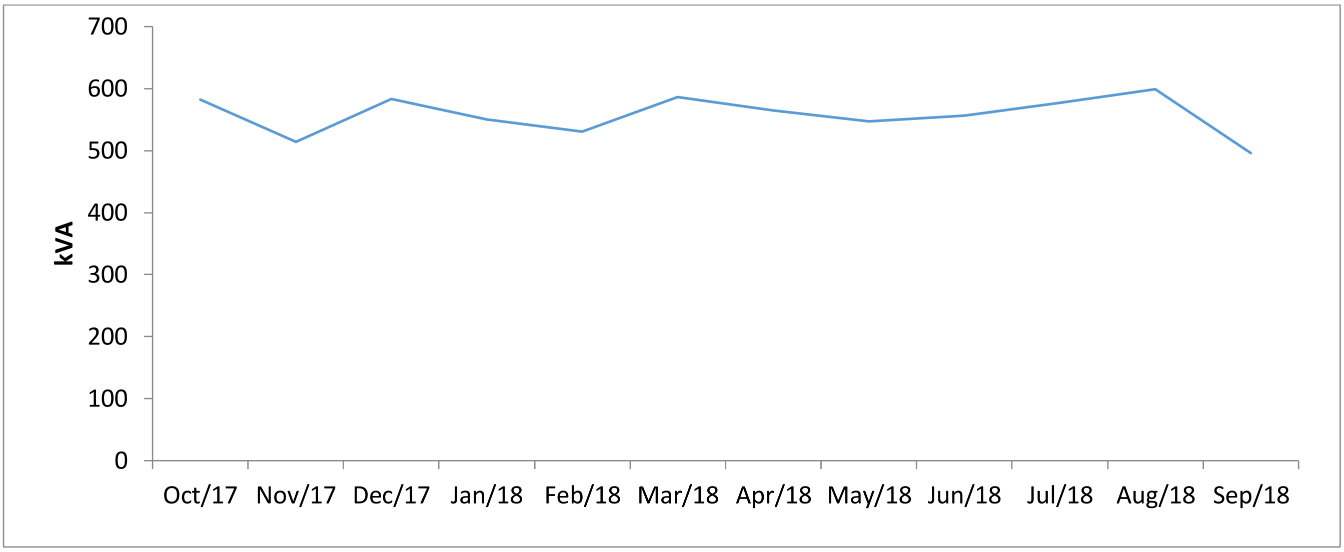

Figure 7 : Month wise variation in Maximum Demand

2.2.1.4 *Single Line Diagram*

Single line diagram of plant is shown in below figure:

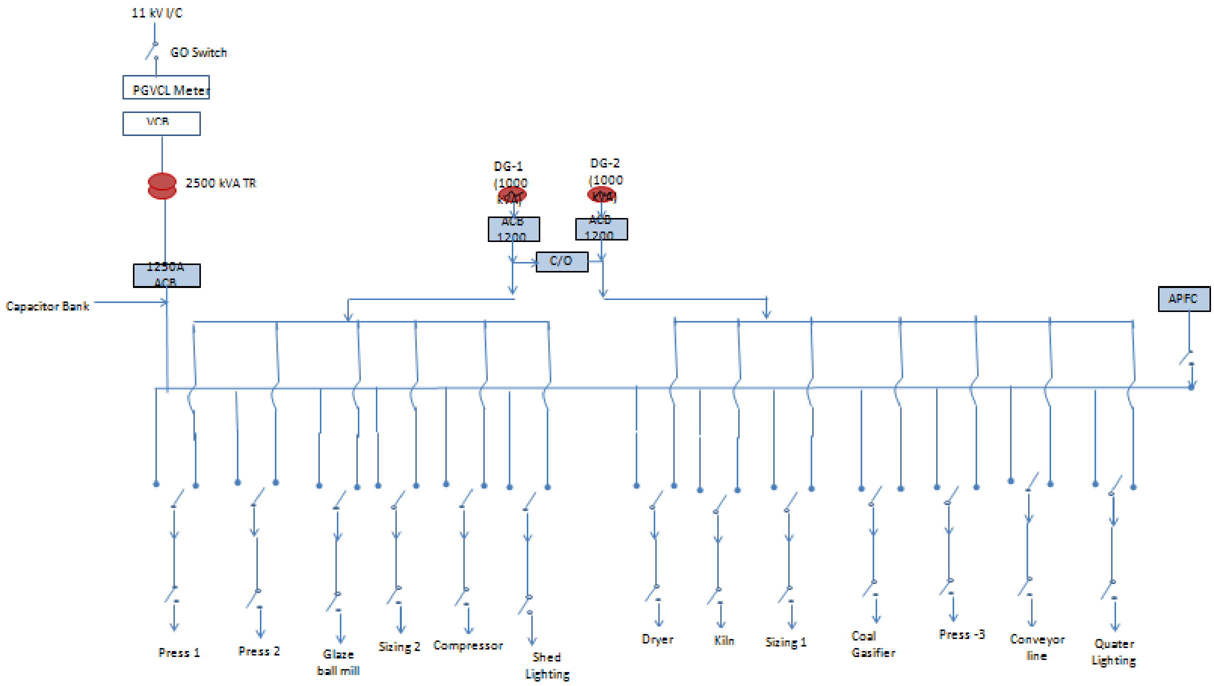

Figure 8: SLD of Electrical Load

2.2.1.5 *Electricity consumption areas*

The plant total connected load is 1,348.8 kW, which includes:

- The plant and machinery load is 1,269.76 kW
- The utility load (fan and lighting) is about 79.05 kW including the single phase load

Table 11 : Equipment wise connected load

Sr.No.	Connected Load	Unit	Values
1	Compressors	kW	52
2	Presses	kW	220
3	Press Cooling Towers	kW	6.71
4	Kiln	kW	387.8
5	Dryer	kW	58.2
6	Final Sizing Machine 1	kW	190.0
7	Final Sizing Machine 2	kW	242.4
8	Coal Gasifier	kW	55.9
9	Glaze Ball Mill	kW	123.0
10	Lights	kW	12.9
Total		**kW**	**1,348.8**

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

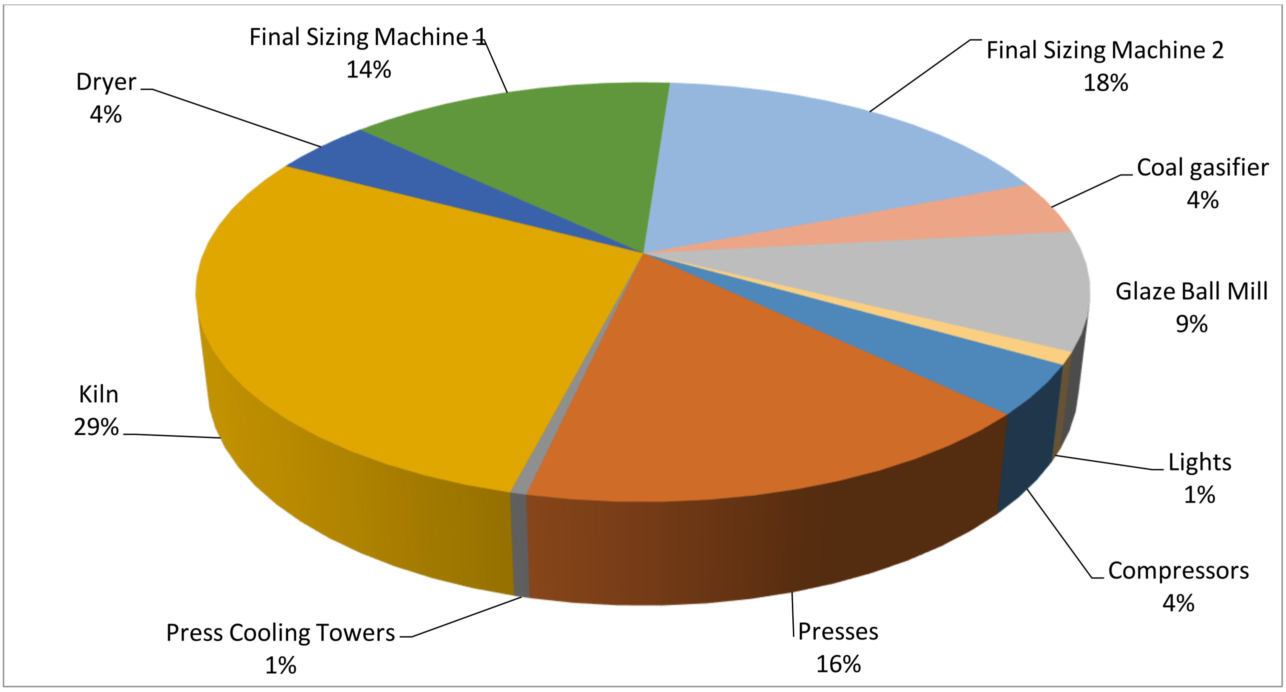

Figure 9 : Details of connected load

As shown in the figure, the maximum share of connected electrical load is for the Kiln- 29%, followed by Final Sizing Machine 1 & 2 – 18 % & 14% respectively, for presses– 16 % ,Glaze ball Mill–9 %,Coal Gasifier –4 %,Dryer – 4%, Compressor– 4% ,Press Cooling Tower – 1% .Utilities and lighting consists of 1 % of total connected electrical load.

2.2.1.6 Specific electricity consumption

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

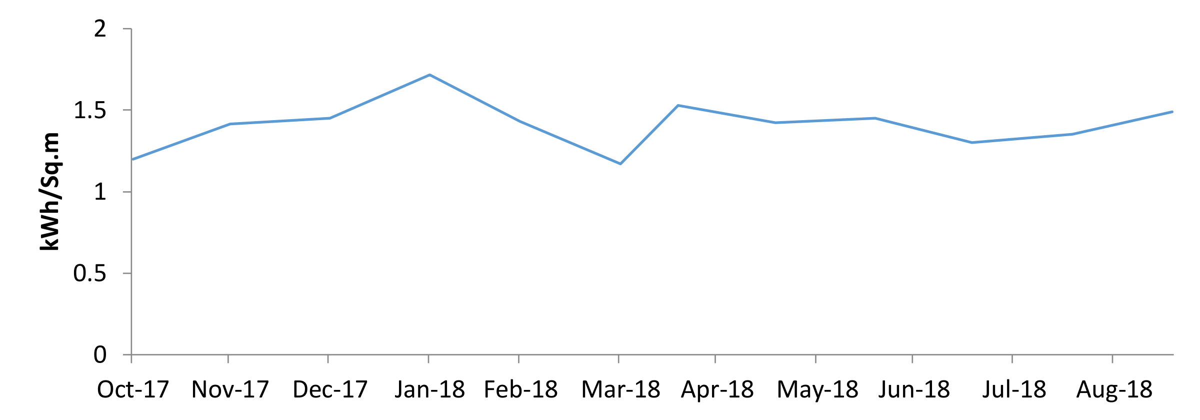

Figure 10 : Month wise variation in Specific Electricity Consumption

The month, Jan-18 is outliers. Excluding this month, the maximum and minimum values are within ±20% of the average SEC of 1.41 kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in 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 kilns. Coal is used as fuel. Coal is purchased from local coal suppliers who in turn import coal from Indonesia. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	Kiln		
	Coal Used MT	Coal Cost Rs	Coal Cost Rs/MT
Oct-17	822	6,279,863	7,642
Nov-17	654	4,998,978	7,642
Dec-17	691	5,283,548	7,642
Jan-18	676	5,165,280	7,642
Feb-18	566	4,326,517	7,642
Mar-18	687	5,250,896	7,642
Apr-18	768	5,869,056	7,642
May-18	649	4,956,372	7,642
Jun-18	732	5,592,034	7,642
Jul-18	834	6,370,983	7,642
Aug-18	699	5,344,815	7,642
Sep-18	694	5,303,854	7,642

Observation: During night Kiln is used for baking of biscuit tiles whereas during day Kiln is used for baking of glazed tiles. Average monthly coal consumption in Kiln is about 706 MT and average cost is Rs 53.95 Lakhs/month. Average cost of coal is Rs. 7,642/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:

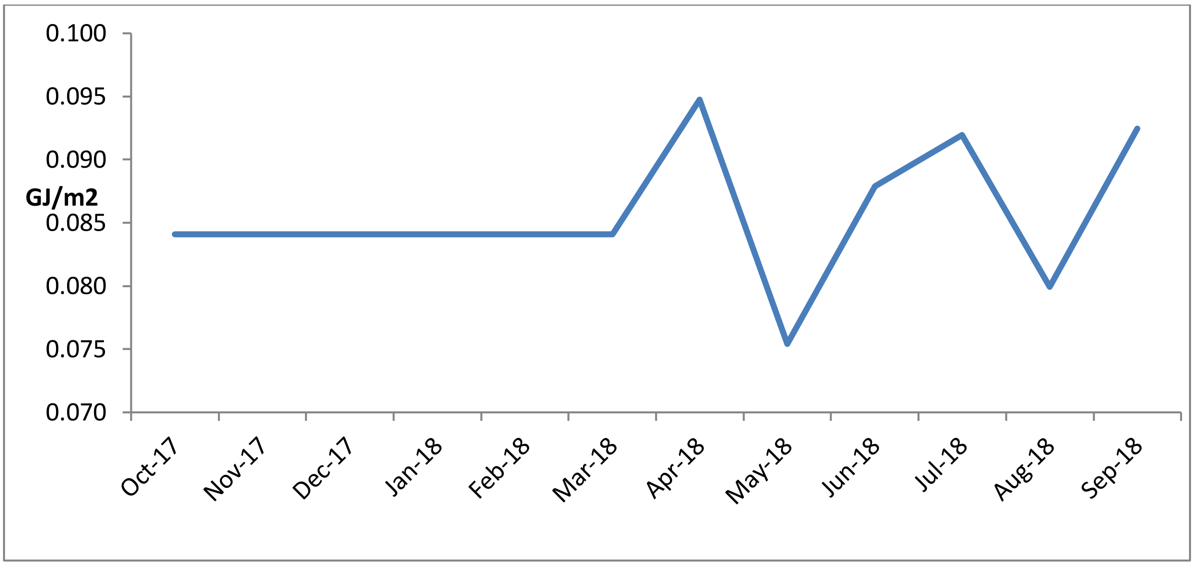

Figure 11 : Month wise variation in Specific Fuel Consumption

The average SFC is 0.86 GJ/m^2. The SFC for coal varied between 0.075 and 0.0948 GJ/m^2 which is a very wide variation. This is because coal data is based on purchase and actual information on consumption is not being maintained. The SEC therefore does not follow the production.

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

2.2.3 Specific energy consumption

2.2.3.1 Based on data collected during EA

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

Table 13: Specific energy consumption

Particulars	Units	Value
Average production	m^2/h	535
Power consumption	kW	339
Coal consumption	kg/h	833.33
Energy consumption	kgOE/h	458
SEC of plant	kgOE/m^2	0.86

2.2.3.2 Section wise energy consumption

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

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

Particulars	Coal	Electricity
	kg/t	kW/t
Hydraulic Press		12.26
Kiln	117	5.6
Sizing machine		6.9

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

2.2.3.3 *Based on yearly data furnished by unit*

Based on the available information, various specific energy consumption (SEC) parameters have been estimated as shown in the following table:

Table 15: Overall: specific energy consumption

Parameters	Units	Value
Annual Grid Electricity Consumption	kWh/y	3,201,870
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	3,201,870
Annual Thermal Energy Consumption (Imported Coal)	t/y	8,472
Annual Energy Consumption	TOE	4,931
Annual Energy Cost	Rs. Lakh	847
Annual production	m^2	2,278,676
	t	32,422
SEC; Electrical	kWh/m^2	1.41
	kWh/t	98.76
SEC; Thermal	GJ/m^2	0.086
	GJ/t	6.012
SEC; Overall	TOE/ m^2	0.002
	TOE/t	0.15
SEC; Cost Based	$Rs./m^2$	37.19
	Rs./t	2,614

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

- Conversion Factors
- Electricity from the Grid : 860 kCal/kWh
- GCV of Imported Coal : 5,495 kcal/kg
- CO_2 Conversion factor
  - Grid : 0.82 kg/kWh
  - Imported Coal : 2.116 t/t

2.2.3.4 *Baseline Parameters*

The following are the general baseline parameters, which have been considered for the techno-economic evaluation of various identified energy cost reduction projects as well as for the purpose of comparison post implementation of the projects. The costs shown are landed costs.

Table 16: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs./ kWh for Aug-2018	6.25
Cost of Coal	Rs./MT	7,642
Annual operating days	d/y	335
Operating hours per day	h/d	24
Annual production	m^2	2,278,676

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 50 m^3/d about based on measurement.

Water distribution diagram is shown below.

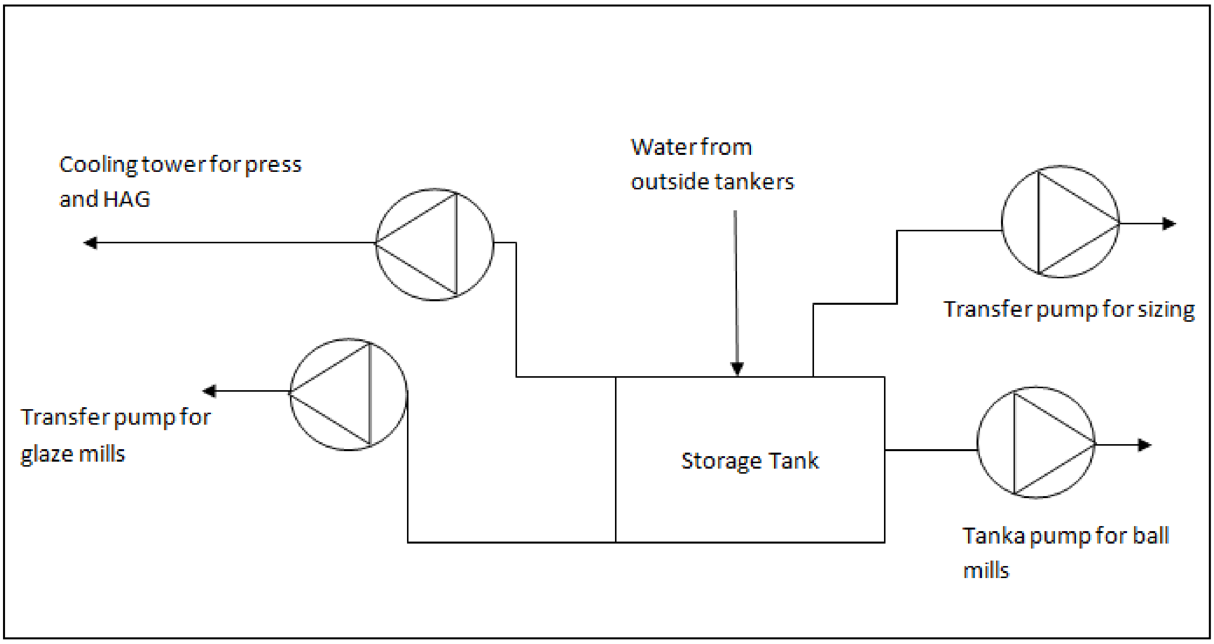

Figure 12: Water Distribution Diagram

Water tankers are procured from tanker suppliers to meet the water requirements of process, water supplied has TDS of about 445ppm whereas ground water at the unit has TDS>1,000 ppm; hence unit is not using ground water (cooling water pumps for press, pump for ball mills, and domestic use. Flow measurements were not done due to internal rusting and poor pipes condition.

3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Coal gas is used as a fuel in kilns to heat the ceramic tiles to the required temperature. There was only one Kiln, which Operates for 12 hours in night for baking the biscuits, and in day time for 12 hours for baking the Glaze tiles. 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.

Kiln consists of 388 kW electrical loads, which includes two smoke blowers of 56kW each, two combustion blower of 45 kW each, two rapid cooling blower of 45 kW each, one final cooling blower of 22 kW and two hot air blower of 19 kW and 56 kW respectively.

Kiln has one dryer connected in series with kiln. Tiles were dries before entering into preheating zone of kiln. Dryer has one smoke blower of 19 kW, booster blower of 37 kW and one combustion blower of 2.2 kW. Dryer is only in operation when kiln is used for baking the biscuit (green tiles) at night.

Table 17: Kiln Details

Sl. No	Parameter	Unit	Kiln
	Make		Modena
1	Kiln operating time	h	24
2	Fuel Consumption	scm/h	3,223
3	Number of burner to left	-	56
4	Number of burner to right	-	56
5	Cycle Time	Minutes	49
6	Pressure in firing zone	mmWC	45
7	Maximum temperature	°C	1,200
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	m	52.5 x 3.6 x 1.2
	Firing Zone	m	29.4 x 3.6 x 1.2
	Rapid Cooling Zone	m	16.8 x 3.6 x 1.2
	Indirect cooling Zone	m	21 x 3.6 x 1.2
	Final cooling zone	m	31.5 x 3.6 x 1.2

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 the kiln were done. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 18: FGA study of kilns

Parameter	Kiln
Oxygen Level measured in Flue Gas	10.3%
Ambient Air Temperature	40.2°C
Exhaust Temperature of Flue Gas	130 °C

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

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

Table 19: Surface temperature of kilns

Kiln Surface Temperatures (°C)	Kiln-1
Ambient Temperature	40.2
Pre-heating zone average surface temperature	56
Heating zone average surface temperature	63.0
Rapid cooling zone average surface temperature	64.6
Indirect cooling zone average surface temperature	83.4
Final cooling zone average surface temperature	58.7

The temperature profile of the kilns is shown below:

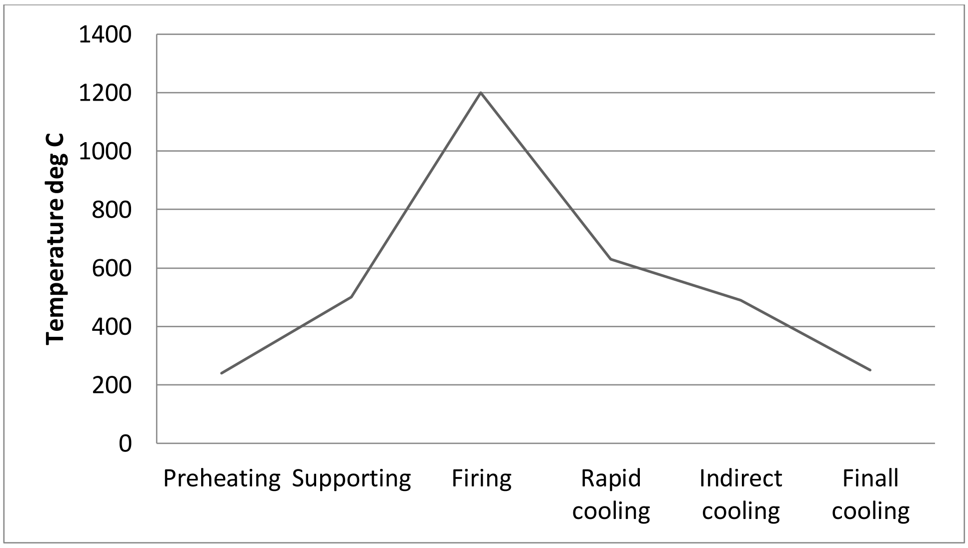

Figure 13: Temperature Profile of Kilns

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

Table 20: Power measurements of all blowers

Equipment	Kiln	
	Average Power (kW)	PF
Hot air Blower	16.6	1
Smoke Blower	12.5	1
Combustion Blower	3.79	1
Cooling Combustion Blower	7.14	0.88

3.1.3 Observations and Performance Assessment

Kiln heat utilization has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln is 39.6%. Summary of all losses is shown in below figure:

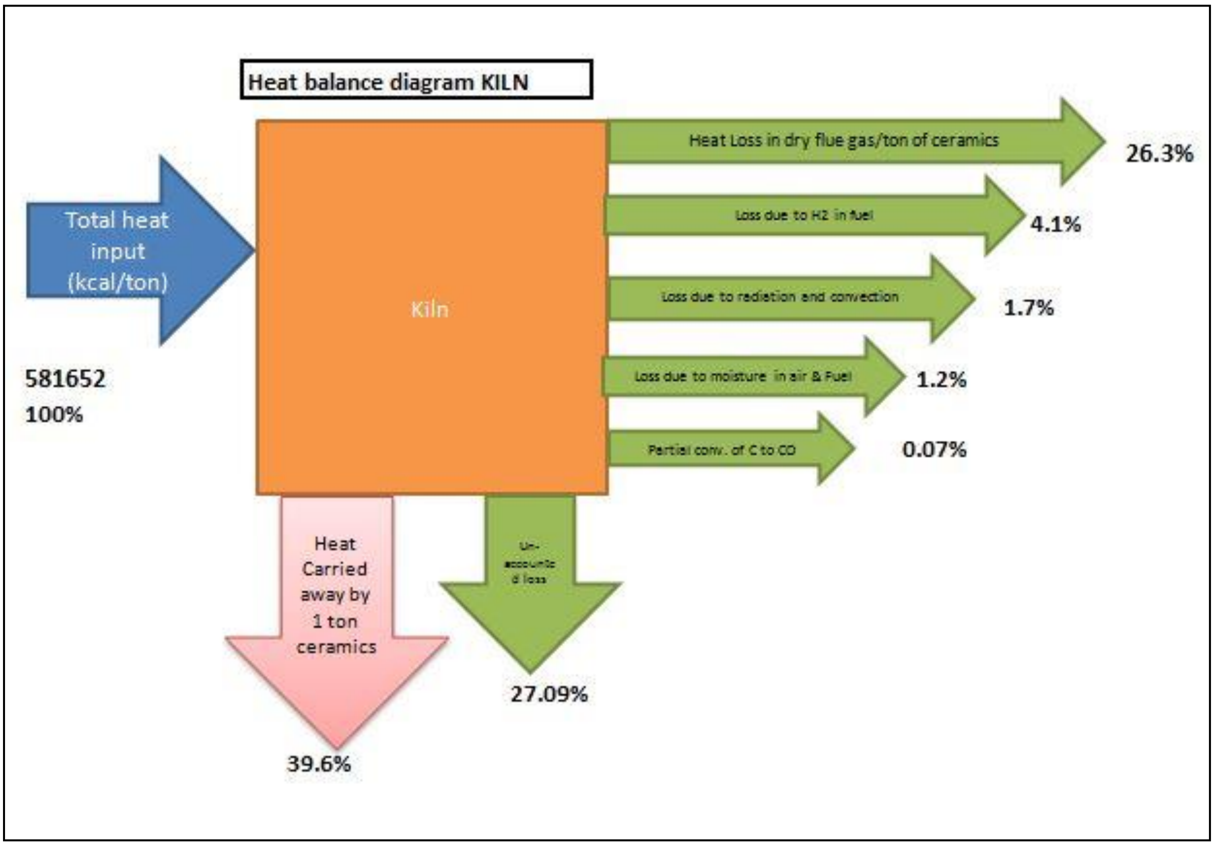

Figure 14: Heat Balance Diagram of Kiln

Causes of unaccounted losses arising due to following reasons:

1. Kiln leakage observed
2. Rollers are gettinng heated itself by kiln heat
3. Inspection holes are closed by aluminnum dart which increases radiation loss
4. Hot air fans body are uninsulated
5. Atmopsheric air dilution in kiln

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*

Technology description

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of fuel. The excess air levels are calculated based on oxygen content in the flue gases. The theoretical air required for combustion of any fuel can be known from the ultimate analysis of the fuel. All combustion process requires certain amount of excess air in addition to the theoretical air supplied. Excess air supplied needs to be maintained at optimum levels, as, too much excess air results in excessive heat loss through the flue gases whereas too little excess air results in in-complete combustion of fuel and formation of black colored smoke in flue gases.

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

A PID controller, if installed, measures the oxygen levels in the flue gases at the exit of the kiln and based on that the combustion air flow from FD fan (blower) is regulated and subsequently proper temperature and optimum excess air for combustion is attained in the kiln.

Study and investigation

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

Recommended action

Separate blowers for Kiln have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. For **Kiln** oxygen level is 10.3% which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

Table 21: Cost benefit analysis for Excess Air Control in Kiln (ECM-1)

Parameters	UOM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	10.3	5.0
Excess air percentage in flue gas	%	96.3	31.3
Dry flue gas loss	%	26%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	kg of fuel/ton of tile	473	442
Average production in Kiln	t/h	7.1	7.1
Saving in specific fuel consumption	kg/h		219.03
Operating hours per day	h/d		335
Annual operating days	d/y		24
Annual fuel saving	t/y		1761
Coal gas to coal ratio	kg/kg	4.04	4.04
Coal saving in Gasifire	MT/y		436
Fuel cost	Rs/t		7,642
Annual fuel cost saving	Lakh Rs/y		33.3
Power saving in combustion blower			
Mass flow rate of air	t/h	51.06	34.15
Density of air	kg/m3	1.23	1.23
Mass flow rate of air	m^3/s	11.6	7.7
Total pressure rise	Pa	2,412	2,412
Measured power of blower	kW	3.79	1.13

Parameters	UOM	Present	Proposed
Total power saving	kW		2.66
Operating days per year	d/y		24
Operating hours per day	h/d		335
Annual energy saving	kWh/y	21,358	
Weighted electricity cost	Rs/kWh	6.25	6.25
Annual energy cost saving	Lakh Rs/y		1.33
Overall energy cost saving	Lakh Rs/y		34.62
Estimated investment	Lakh Rs		18.48
Payback period	Months		6
IRR	%		146
Discounted Payback Period	Months		2.5

3.1.4.2 Energy conservation measures (ECM) - ECM #2 Insulation in Pipe Line in indirect cooling Zone

Technology description

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

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

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

Study and investigation

There are 130 uninsulated pipes in recuperator in indirect cooling zone. The surface temperature of pipes was measured. The average surface temperature of pipe surface must be 75-80°C and it was measured as 180°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 60°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 22: Cost benefit analysis of Insulation in Pipeline in Cooling Zone (ECM-2)

Parameter	UOM	Present	Proposed
No of uninsulated pipe in recuperator	#	130	130
Recuperator pipe size	mm	50	50
Pipe length	m	0.6	0.6
Total surface area	m^2	12.25	12.25
Average surface temperature	°C	180	55
Ambient air temperature	°C	35	35
Heat loss	$kCal/h/m^2$	2,501	220

Parameter	UOM	Present	Proposed
Total heat loss	kCal/h	30,646	2,695
GCV of coal gas	kCal/sm^3	1,231	1,231
Heat loss in terms of fuel (coal gas) in Kiln	sm^3/h	24.9	2.2
Gas to coal ratio of Gasifier	sm^3/kg	3.87	3.87
Heat loss in terms of coal in Gasifier	kg/h	6.4	0.6
Coal saving	kg/h		5.9
Operating hours per day	h/d	24	24
Annual operating days	d/y	335	335
Annual fuel saving	t/y		47
Fuel cost	Rs/t		7,642
Annual fuel cost saving	Rs Lakh/y		3.61
Estimated investment	Rs Lakh		2.45
Payback period	Months		8
IRR	%	112	
Discounted Payback Period	Months	3.2	

3.1.4.3 Energy conservation measures (ECM) - ECM #3 Combustion air preheating by Recuperator in Rapid cooling Zones

Technology description

Pre-heating of combustion air is one of the most popular uses of recovered heat from kilns due to its high efficiency and reduction in primary fuel use.

Study and investigation

Combustion air temperature at present in the plant was 48°C. After using recuperator to preheat this combustion air temperature can rise to 200°C.

Recommended action

It is recommended to preheat the combustion air by using Recuperator. Recuperator was already installed in rapid cooling but not in line which may be due to improper damper working or may be due to manual operation of damper control. That why investment is not required in such ECM.

Table 23: Cost benefit Analysis of Preheating Combustion air by Recuperator (ECM-3)

Particulars	UOM	Value
Combustion air flow	m3/h	11,056.0
Density of air	kg/m3	1.225
Combustion air flow	kg/h	13,544
Combustion air temperature in present scenario	°C	48.0
Combustion air temperature after recuperator	°C	200
Heat required	kcal/h	494,071
Effectiveness of recuperator	%	60
Heat supply at recuperator inlet	kcal/h	823,451
GCV of coal gas	kcal/scm	1,231
Coal gas savings	scm/h	401.5
Coal savings	kg/h	103.8
Operating hours per day	d/y	335
Operating gays per year	h/d	24
Annual running hours	h/y	8,040.0

Particulars	UOM	Value
Annual coal savings	kg/y	834,385
Coal price	Rs./kg	7.6
Monetary saving	Rs. Lakh/y	63.8
Investment	Lakhs	nil
Payback Period	months	Immediate
IRR	%	-
Discounted Payback Period	Months	-

3.1.4.4 Energy conservation measures (ECM) - ECM #4 Improvisation of damper controlling of rapid cooling blowers

Technology description

Dampers operation improvisation to avoid short circuit of rapid cooling air between both rapid cooling blowers

Study and investigation

During DEA it was observed that rapid cooling air was coming back from stand by blowers due to improper working of dampers (dampers was not fully closed).

Recommended action

It is recommended to avoid short circuiting of rapid cooling air by improving dampers controlling. Investment is also not required for same since damper is already there. Cost benefit analysis is given below:

Table 24 Improvisation of damper's controlling [ECM 4]

Particulars	Units	Value
Rated flow of rapid cooling blower	m^3/h	11,056
Leakage of air	%	10%
Leakage air quantity	m^3/h	1,106
Specific electricity consumption of rapid cooling blower	kWh/m^3	0.0027
Power loss due to short circuit of air	kW	3.0
Operating hours per day	d/y	350
Operating gays per year	h/d	24
Annual running hours	h/y	8,400
Annual coal savings	kWh/y	25,200
Unit rate	Rs./kWh	6.25
Monetary saving	Rs. Lakh/y	1.6
Investment	Lakhs	Nil
Simple payback Period	months	immediate

3.2 Coal Gasifier

3.2.1 Specifications

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

Table 25: Specifications of coal gasifier

Particular	Units	Value
Make		-
Coal consumption	t/d	20-21
Water consumption	l/d	5,000
FD Blower	Hp	2 x 25
ID Blower	Hp	1 x 15
Cooling water pump	Hp	2 x 5

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Numbers of lifts daily basis
- Measurement of power consumption of cooling water pumps and FD blower
- Air flow measurement of FD blower

Table 26 Numbers of lifts per day

Date	Numbers of lift (n/d)
14/11/2018	44
15/11/2018	41
16/11/2018	41
17/11/2018	40
18/11/2018	43
19/11/2018	40
20/11/2018	41
21/11/2018	40

Coal consumption is recorded by the plant in terms of lifts as per kiln cycle time. During the DEA, the kiln cycle time was 49 minutes. FD blower and cooling water pumps was operating with VFDs. Average power consumption of FD blower is 1.65 kW (PF 1), ID Fan is 0.614 kW (PF 0.95). Air flow at FD blower suction was measure, is 1,648 m^3/h

There is monitoring system for coal gas generation quantity but not reflecting qualitative data.

3.2.3 Observation and Performance assessment

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, the specific energy consumption of coal gasifier was 0.25 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm coal in plant which is 0.01 kWh/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed

4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 HYDRAULIC PRESSES

4.1.1 Specifications

There are 3 hydraulic presses. Hydraulic presses give shape for powder that is coming from spray dryer in tiles form by pressing powder with high pressure (15.5MPa). Hydraulic oil gets heated when pressed so that it is required to be cooled in heat exchanger where water circulates as cold media. The specifications of presses and its accessories are given below:

Table 27: Specifications of hydraulic press

Particular	Units	Press 1	Press 2	Press 3
Cycle (stock) per minute	N/m	8.5	8	6.5
Nos. of tiles per stock		4	4	4
Tile size	mm × mm	300 ×300	250 ×380	300 ×450
Tiles weight	kg	1.2	1.95	1.18
Power rating	kW	55	90	75
Water Circulation Pump	#	1	1	1

4.1.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

- Power consumption of presses and water circulation pumps

Average power consumption of press 2 was 54 kW (PF 0.87), press 3 was 38.3 kW (PF 0.92) and Press 1 was not in operation during DEA. All presses come in operation in night operation only so circulation pumps measurement could not complete.

4.1.3 OBSERVATION AND PERFORMANCE ASSESSMENT

Both circulation pumps operates 12 hours in a day while press has frequent shut down, however it is not advisable to regulate pump based on oil temperature as the temperature will suddenly rise if circulation pump is stopped

Performances of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press was 12.3 kW/ton.

4.2 GLAZING

4.2.1 Specifications

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

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

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

The specifications of glazing mills are given below:

Table 28: Specifications of glazing machine

Particular	Units	Glaze mill
Numbers of glazing mills	Nos.	5
Capacity of glaze mill 1	Ton/batch	2.5
Capacity of glaze mill 2	Ton/batch	2.5
Capacity of glaze mill 3	Ton/batch	2.5
Capacity of glaze mill 4	Ton/batch	2.5
Capacity of glaze mill 5	Ton/batch	0.2
Power consumption of mill 1	HP	40
Power consumption of mill 2	HP	40
Power consumption of mill 3	HP	40
Power consumption of mill 4	HP	40
Power consumption of mill 5	HP	5

4.2.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

- Power consumption of four glaze mills which were in operation.

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

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

Equipment	kW	PF
Glaze ball mill 1	17.20	0.99
Glaze ball mill 3	19.06	0.99
Small glaze ball mill 5	3.48	0.998

4.2.3 OBSERVATIONS AND PERFORMANCE ASSESSMENT

Mass of tiles is considered is as same as coming from presses. Performance of glaze mill can be measured in terms of specific energy consumption (power consumed for glazing 1 ton of tiles). Based on observations during DEA, the specific energy consumption of glaze mills were 5.63 kW/ton.

4.2.3.1 Energy conservation measures (ECM) - ECM #5 Optimization of operation of glaze Ball Mill

Technology description

Operation optimization of glaze mills by improving belt condition, time controller and by checking residue% frequently.

Study and investigation

During DEA it was observed that glaze ball mill was taking 14.5 hour for one batch preparation against 9.5 hours.

Recommended action

It is recommended to change least slippage in belt, appropriate pebbles size, proper working of timer controller and frequent checking of residue in day for optimization of glaze ball mill operation.

Table 30: Cost benefit Analysis of Resource Optimization in Glaze Ball Mill (ECM-5)

Parameters	Unit	Present	Proposed
Power consumption of glaze mills	kW	76.25	76.25
Operating hours of day	h/d	14.5	9.5
Daily power consumption of mills	kWh/d	1,106	724
Power savings	kWh/d		381
Annual operating days	d/y		335
Annual power savings	kWh/y		127,718
Unit rate	Rs/kWh	6.25	6
Monetary savings	Lakh Rs/y	7.98	
Estimated investment	Lakh Rs	9.31	
Payback period	Months	14.00	
IRR	%	63	
Discounted Payback Period	Months	5	

4.2.3.2 Energy conservation measures (ECM) - ECM # 6 Replacement of existing motor with IE3/IE4 motor

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 31: Cost Benefit Analysis of Replacement of Motors in Glaze Ball Mill (ECM-6)

Particular	Unit	Present	Proposed
Rated power of glaze ball mill motor	kW	30	30
Numbers of glaze ball mills	#	4	4
Existing efficiency of motor	%	92.3	93.6
Existing power consumption	kW	76.25	71.37
Energy loss in motor	kW	5.9	1.0
Estimated energy saving	kW		4.9
Operating hours/day	d/y	335	335
Operating days/year	h/d	24	24
Annual energy consumption	kWh/y	613,046	573,811
Annual energy savings	kWh/y	39,235	
Unit cost of electricity	Rs/kWh	6.25	
Annual monetary savings	Lakh Rs/y	2.45	
Estimated Investment	Lakh Rs	1.69	
Payback Period	Months	8.29	
IRR	%	109	
Discounted payback Period	Months	3	

4.3 Sizing

4.3.1 *Specifications*

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

Table 32: Specifications of sizing machine

Particular	Units	
Numbers of sizing machines	Nos.	4
Sizing Machine 1	kW	95
Sizing Machine 2	kW	95
Sizing Machine 3	kW	242

4.3.2 *Field Measurement and Analysis*

During DEA, the following measurements were done:

- Power consumption of each sizing machines

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

Table 33 : Measured Parameters of sizing machine

Equipment	Unit	Value	PF
Average Power (M/c#1)	kW	17	0.62
Average Power (M/c#2)	kW	16	0.62

4.3.3 *Observation and Performance Assessment*

Mass of tile is considered as same as coming from kiln. Based on observations during DEA, the specific energy consumption was 6.9 kW/t.

4.4 Air Compressors

4.4.1 Specifications

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

Table 34: Specifications of compressors

Particular	Units	Screw compressor 1	Screw compressor 2
Power rating	kW	22	30
Maximum pressure	Bar (a)	8	8
Rated Capacity	m^3/min	2.97	4.54

All compressors have a common receiver.

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all compressor
- Loading and unloading time
- Volumetric flow of air

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

Table 35: Measured parameters of Compressors

Equipment	Average Power (kW)	PF	% of time on load	Air flow rate (m^3/min)
Compressor-1	18.65	0.89	91	
Compressor-2	20.72	0.99		

FAD of compressors could not be conducted as there was only one receiver for whole plant. Compressor 2 was VFD operated while compressor 1 was running at loading and unloading pattern.

4.4.3 Observation and performance assessment

Air flow measurement for compressor 1 was not done due to suction was not proper. Based on observations during DEA, specific energy consumption of compressor 2 was it was observed that operating pressure was 0.16 kW/cfm. Compressor VFD installation is recommended for compressor 1 to avoid power consumption during unloading. Another observation was that suction of both compressors from hot air discharge side which affect compressor performance. Pressure reduction also proposed as per plant requirement.

4.4.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.4.4.1 Energy conservation measures (ECM) - ECM #7: Operational pressure optimization in compressor-2

Technology description

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

Study and investigation

It was observed during the energy audit that the Compressor operating pressure was 6.5 kg/cm² that can be reduced to 5.5 kg /cm².

Recommended action

As very high pressure compressed air is not necessary in the process area. So, it is recommend to operate compressor at 5 kg/cm²

The cost benefit analysis is given in the table below:

Table 36: Cost benefit analysis of Pressure Reduction in Compressor (ECM-7)

Parameter	UOM	Present	Proposed
Operating pressure required	kg/cm²	5	5
Compressor operating pressure	kg/cm²	6.5	5.5
Reduction in pressure	kg/cm²	-	1
% of energy saving	%	-	6%
Average load	kW	20.7	19.48
Operating hours/day	h/d	15	15
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	102,594	96,439
Annual energy savings	kWh/y		6,156
Unit cost of electricity	Rs/kWh		6.25
Annual monetary saving	Lakh Rs/y		0.38
Estimated Investment	Lakh Rs		Nil
Payback period	Months		Immediate
IRR	%		-
Discounted Payback Period	Months		-

4.4.4.2 Energy conservation measures (ECM) - ECM #8: Installation of VFD on Compressor 2

Technology description

For fluctuating loads, it is always recommended to install a variable frequency drive (VFD) to control the speed of the motor. A VFD will reduce the power consumption accordingly to the load variation in the compressor. During loading periods, the current drawn by the compressor will be high but during no load / unloading periods, the motor of compressor will draw some current which is 1/3 or $1/4^{th}$ of the total current. Hence, this unload power of the compressor can be totally avoided by installing VFD, compressor motor RPM will be raised when compressed air demand is high and when compressed air demand is reduced the RPM of the motor will be lowered based on the pressure feedback given to VFD.

Study and investigation

During measurements, it was found that the compressor#2 is operating in unload/load condition. From the power cycle, it was concluded that about 9% of the time the compressor is running in unload condition.

Recommended action

It is recommended to install VFD with the compressor# 2. This will ensure that the compressor does not get unloaded and only the RPM of the compressor motor is varied based on air demand. The cost benefit analysis of the energy conservation measure is given below:

Table 37: Cost benefit analysis of installation of VFD on Compressor (ECM-8)

Parameters	UOM	Present	Proposed
Compressor rated volumetric flow	CFM	160	160
Compressor operating volumetric flow	CFM	126	126
Compressor motor rating	kW	30	30
Average power consumption during loading	kW	19.73	-
Average power consumption during unloading	kW	7.76	-
On load time in percentage	%	90.99%	-
Off load time in percentage	%	9.01%	-
Average power consumption	kW	18.65	15.86
Operating hours/day	h/d	24	24
Operating days/year	d/y	335	335
Annual energy consumption	kWh/y	149,985	127,487
Annual energy saving	kWh/y	22,498	
Unit cost of electricity	Rs/kWh	6.25	
Annual monetary savings	Lakh Rs/y	1.41	
Estimated Investment	Lakh Rs	2.10	
Payback period	Months	17.9	
IRR	%	44	
Discounted Payback Period	Months	7	

4.4.4.3 Energy conservation measures (ECM) - ECM #9: Cold air suction of compressors

Technology description

Cold atmospheric air at suction in spite of hot air from discharge of radiator in compressor.

Study and investigation

During DEA it was observed that compressor suction are coming from hot air discharge of radiator which increase compressor load and compressor consumes more power

Recommended action

It is recommended that suction of compressor can be shifted to cold atmospheric air by changing suction location

Table 38: Savings from suction of air from cold atmosphere (ECM-9)

Parameter	Units	Present	Proposed
Suction air temperature	° C	45	35
Compressor rated flow	kg/min	5.0	5.0
Compressor operating volumetric flow	kg/min	4.0	4.0
Density of air	kg/m3	1.113	1.06
Volumetric flow of air	m3/min	3.6	3.8
Volumetric flow of air	CFM	126.0	132.8
SEC of compressor	kW/cfm	0.19	0.2
Power consumption	kW	23.6	24.9

Parameter	Units	Present	Proposed
Power savings	kW		1.3
Operating hours/day	h/d	24	24
Operating days/year	d/y	335	335
Power savings	kWh/y		10,214
Unit rate	Rs/kWh	6.25	6
Monetary savings	Lakh Rs/y		0.64
Estimated investment	Lakh Rs		Nil
Payback period	Months		Immediate

4.5 Lighting System

4.5.1 *Specifications*

The plant's lighting system includes:

Table 39: Specifications of lighting load

Particular	Units	LED	CFL
Power consumption per fixture	W	28	85
Numbers of fixtures	#	250	50

4.5.2 *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

Particular	Measured Value Lumen/m²
Office	180
Kiln control room	110
Kiln area	90
Press	110
Inventory	90

4.5.3 *Observations and Performance Assessment*

Adequate day lighting is used wherever possible. There is no cope to replace luminaries with more energy efficient types which are currently available.

4.6 Electrical Distribution System

4.6.1 *Specifications*

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (422 V) by step down transformer (2.5 MVA). Automatic power factor correction system is installed in parallel to main supply. There were three DGs (capacity of 1 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeders which are shown in single line diagram.

4.6.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

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

4.6.3 OBSERVATIONS AND PERFORMANCE ASSESSMENT

After analyzing feeder power profiling, it was observed that the maximum kVA recorded during study period was **550.4 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **422 V.** Maximum voltage was **438 V** and minimum was **408 V**.

Average total voltage and current harmonics distortion found **6.9 %** & **13.6 %** 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 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.

4.6.4 ENERGY CONSERVATION MEASURES (ECM)

4.6.4.1 ECM #10: CABLE LOSS MINIMIZATION

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted that in sizing section power factor was between 0.4-0.62.

Recommended action

It is recommended to install power factor improvement capacitors for sizing section .
The cost benefit analysis for this project is given below:

Table 41 : Cost benefit analysis of cable loss minimization (ECM -10)

Particulars	Unit	Sizing Machine 1 (both Sections)	Sizing Machine 2 (Section 1)	Sizing Machine 2 (Section 2)
Existing Power Factor	PF	0.62	0.48	0.4
Proposed Power Factor	PF	0.99	0.99	0.99
Existing load	kW	49.2	17	15.9
Cable Losses	W	620.9	129.3	130.8
Capacitor Required	kVAr	55	29	31
Annual Energy Saving	kWh/y	3021	785	839
Savings Estimated	Rs Lakh/y	25,526	13,235	14,377
Investment	Rs Lakh		29365	
Payback Period	Months		9	
IRR	%		98	
Discounted Payback period	Months		3.5	

4.7.4.2 ECM# 11: Installation of active harmonics Filter

Technology description

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

Some of the effects of harmonics are mentioned hereunder.

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

Study and investigation

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 2.3 kW.

Table 42: Measured Harmonics Level at Main Incomer

Name & Sr. No.	Phase		Voltage	Amp.	THD V (%)	THD I (%)	Individual Current Harmonics A3%	A5%	A7%	A9%	A11%
Main Incomer	R	Average	423	491	6.97	13.6	1.64	12.3	5.2	0.42	1.8
		Minimum	409	236	5.70	6.5	0.60	5.1	1.60	0.00	0.0
		Maximum	438	766	8.50	24.3	3.90	28.7	9.1	2.20	15.5
	Y	Average	420	488	7.00	12.8	1.30	11.8	4.6	0.50	1.6
		Minimum	406	236	5.80	5.9	0.10	4.8	0.80	0.00	0.00
		Maximum	434	754	8.50	22.2	4.00	28.7	7.6	1.70	15.3
	B	Average	422	444	6.97	14.4	0.65	13.3	4.9	0.42	2.09
		Minimum	408	203	5.80	6.7	0.10	5.7	1.60	0.00	0.00
		Maximum	437	697	8.40	25.1	2.70	29.1	8.6	1.50	14.50

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

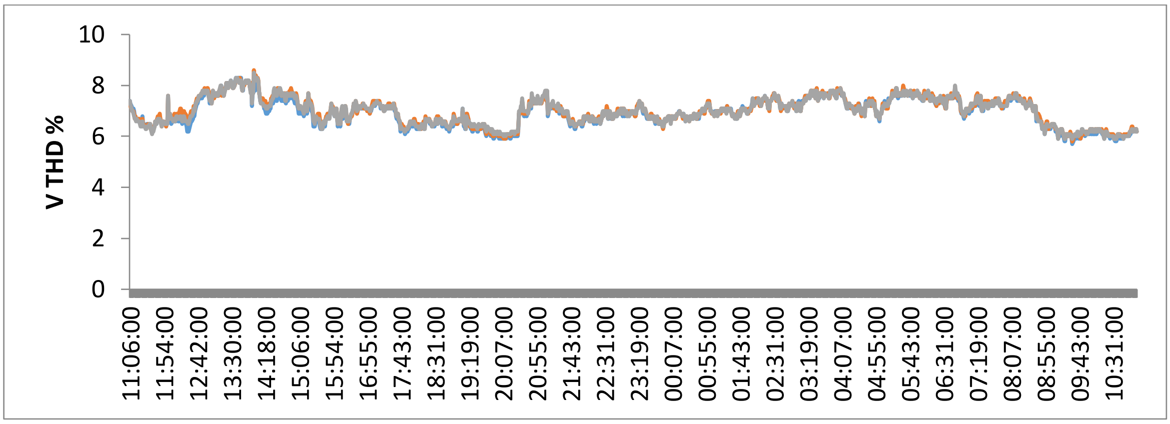

Figure 15: Voltage THD profile

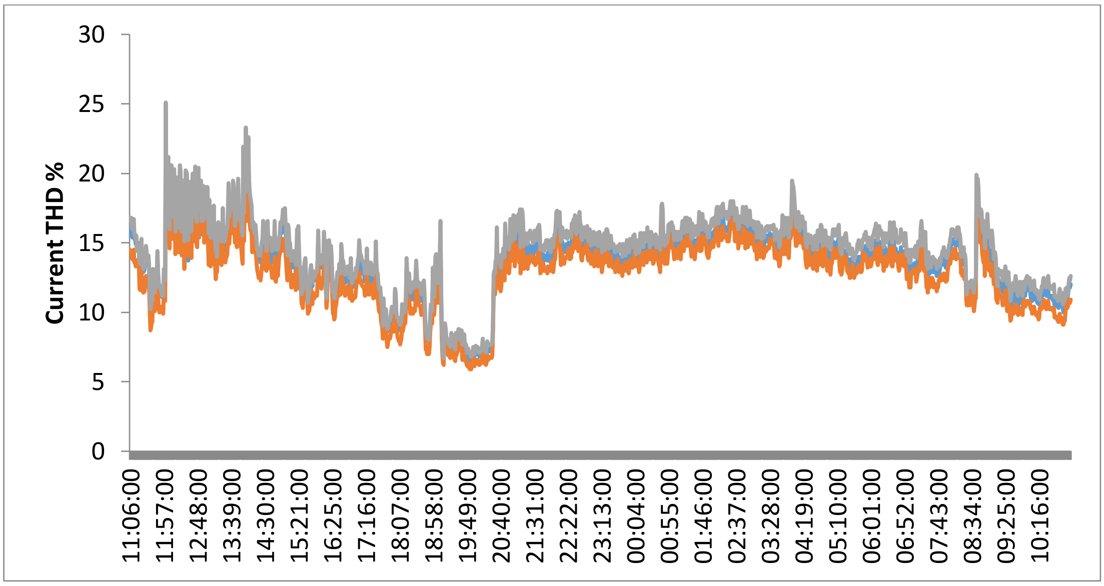

Figure 16: Ampere THD profile

Recommended action

It is recommended to install active harmonics filters (AHF) at main incomer; further study can be conducted to find out exact source of harmonics generation. Estimation of ratings for AHF is done on the basis of power cycles captured during field visit.

- It is a known fact that if harmonics are present in any system, then power factor improvement capacitors will further amplify the existing harmonics.
- It is strongly recommend installing active harmonic filter at locations where THD is exceeding the prescribed limits.
- The active harmonic filter will take care of harmonics in the system and maintain the desired power factor as per requirement.
- Active harmonic filters can also take care of unbalanced load problems
- It is further recommended that all VFDs, UPS should be procured only with 12-pulse or 18-pulse rectifier circuit.
- All electronic ballasts to be procured in future shall be specified for less than 10% THD (Current).

The cost benefit analysis for this project is given below:

Table 43: Install active harmonics Filter [ECM-11]

Parameters	UOM	Present	Proposed
Estimated losses due to Harmonics	kW	2.3	0
Saving potential by installation of active harmonics filter	kW		2.3
Operating hours per day	h/d		24
Operating days per year	d/y		335
Annual electricity savings	kWh/y		18,787
Cost of electricity	Rs/kWh		6.25
Annual electricity cost saving	Lakh Rs /y		1.17
Estimated rating of active harmonics filter (Ampere)	A		50
Estimated investment	Lakh Rs		6.25
Payback period	months		64
IRR	%		-6%
Discounted Payback Period	Months		21

4.7 Belt Operated Drives

4.7.1 Specifications

There are 4 drives operated with V Belt of total capacity of 338 kW. Locations include

- Kiln have 4 blowers

4.7.2 Field measurement and analysis

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

4.7.3 Observations and performance assessment

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

4.7.4 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 4 belt driven blowers in plant

Recommended action

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

Table 44: Cost benefit analysis of replacement of conventional belt with REC belt [ECM-12]

Parameters	UOM	Present	Proposed
Name of the belt driven blower	#	V belt driven blowers	
Rated power of blower	kW	388	388
Energy Saving	%		3.60%
Measured power the blower	kW	47	46
Operating hours per day	h/d	24	24
Operating Days per year	d/y	335	335
Annual energy consumption	kWh/y	379,533	365,870
Annual energy saving	kWh/y	13,663	
Unit cost of electricity	Rs/kWh	6.25	
Annual monetary savings	Lakh Rs/y	0.85	
Estimated Investment	Lakh Rs	0.71	
Payback Period	Months	9.93	
IRR	%	89	
Discounted Payback Period	Months	4	

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: Installation of energy Monitoring System

Technology description

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

Study and investigation

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

Recommended action

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

Table 45: Cost benefit analysis for energy monitoring system (ECM-13)

Parameters	Unit	Present	Proposed
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	3,201,870	3,137,833
Annual electricity saving per year	kWh/y		64,037
Cost of Electricity	Rs/kWh	6.25	
Annual monetary savings	Lakh Rs/y	4.00	
Number of equipment/system	#	21	21
No. of energy meters	#	0	21
Estimated investment	Lakh Rs	3	
Thermal energy monitoring system	%	2.00	
Current coal consumption in coal gasifier	kg/y	8,471,891	8,302,454
Annual coal saving per year	kg/y		169,438
Total annual monetary savings	Lakh Rs/y		12.95
Number of equipment/system	#	3	3
Number of coal weighing machines			1
Estimated investment	Lakh Rs	2.64	

Parameters	Unit	Present	Proposed
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		16.95
Estimated (Electrical + Thermal)	Lakh Rs		14.06
Payback period	Months		9.96
IRR	%		89
Discounted Payback Period	Months		4

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

5.3 New/Emerging Technologies

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

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

"Magical Grinding System", a technology offered by Boffin - China, is a high-efficiency energy-saving ceramic raw material grinding process, which overcomes the drawbacks of traditional milling process in ceramic production, viz. high energy consumption and high cost of mill materials and consumables[1]. The main technical specifications are as follows:

Table 47 : Specifications of dry clay grinding technology

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

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

Parameter	UOM	Scenario-1	Scenario-2	Scenario-3
				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[2]:

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

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

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

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

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

[2] 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

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[3]:

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

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

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

The roller kiln is major energy consuming system in ceramic tile unit. Over a period of time, the losses from kiln increases for various reasons like operating practices, insulation deterioration, poor maintenance, high breakdown level etc. It is beneficial to upgrade the kiln performance by total kiln revamping including following systems[4]:

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

[3] SACMI Kiln Revamping catalogue for roller kilns

[4] SACMI Kiln Revamping catalogue for roller kilns

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.

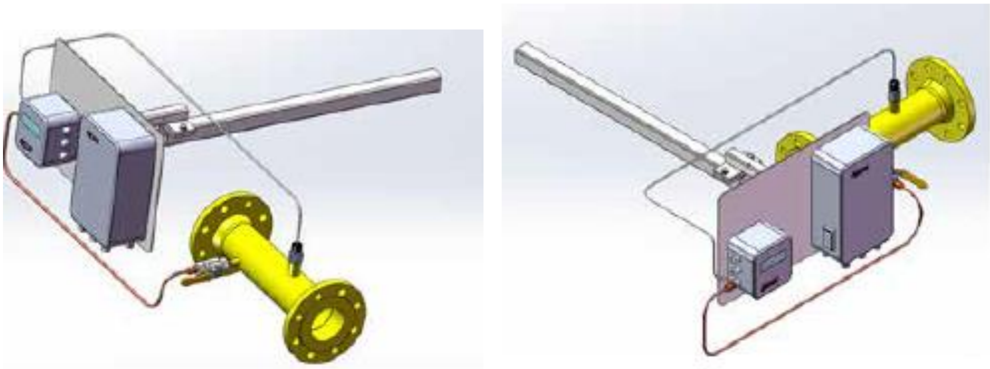

Figure 19: Combustion air control for burner

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

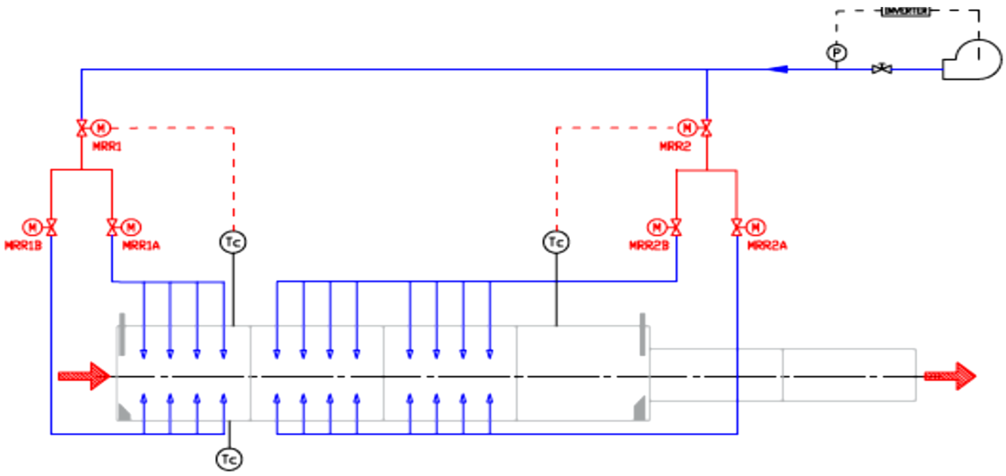

Figure 21: Fast cooling air management

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[5]) to save fuel cost during spray drying. Slip is stored in tanks which will be sieved for sending to spray drying.

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

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

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

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

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

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

In ceramic bodies where highly plastic clays are used, sufficient green and dry strength is achieved due to the inherent binding ability of the clays hence the use of external binders is not necessary. However, in the manufacturing process of vitrified/granite tiles, almost 75 % of raw materials are non-plastic in nature which contribute very less to green and dry strength. Special white firing clays which are not highly plastic are used in small quantity and do not impart sufficient strength. Organic binders like FLOBIND[6] can be used very effectively to increase the green and dry strength as well as edge strength of the tiles. The working principle of the binder is as follows:

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

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

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

Advantages of using Binder for Vitrified tiles include:

- Lower dosage or effective binder cost.
- The product is non-fouling which is not susceptible to bacteriological contamination during slip storage, hence no need to use biocides.
- Minimum or no adverse effect on the rheological properties of slip (The rheological behavior of non-Newtonian fluids such as cement paste, mortar, or concrete is often characterized by two parameters, yield stress, τ0, and plastic viscosity, μ, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.
- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost

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

5.3.7 Use of Direct blower fans instead of belt drive:

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

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

Figure 24: - Direct drive blower fan

6 RENEWABLE ENERGY APPLICATIONS

The roof top PV potential is estimated as 30 kW. Cost benefit analysis is given below:

6.1 ENERGY CONSERVATION MEASURES (ECM) - ECM#14: INSTALLATION OF SOLAR PV SYSTEM

Technology description

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

Study and investigation

It was observed during energy audit that 300 m^2 of area is available on the roof top for installation of solar PV panels.

Recommended action

It is recommended to install 30 kW solar panel capacities. The average electricity generation is estimated at 87,600 kWh/y. The cost benefit analysis is given below:

Table 48: Cost benefit analysis for installing solar PV system (ECM 14)

Parameters	UOM	Value
Available area on roof	m^2	300
Capacity of solar panel	kW	30
Energy generation from solar panel	kWh/d	144
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	52,560
W. Average Electricity Tariff	Rs/kWh	6.25
Annual monetary savings	Rs Lakh/Y	3.3
Estimate of Investment	Rs Lakh	15.6
Payback	Months	57
IRR	%	-2
Discounted Payback Period	Months	19

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 ANNEXES

ANNEX-1: PROCESS FLOW DIAGRAM

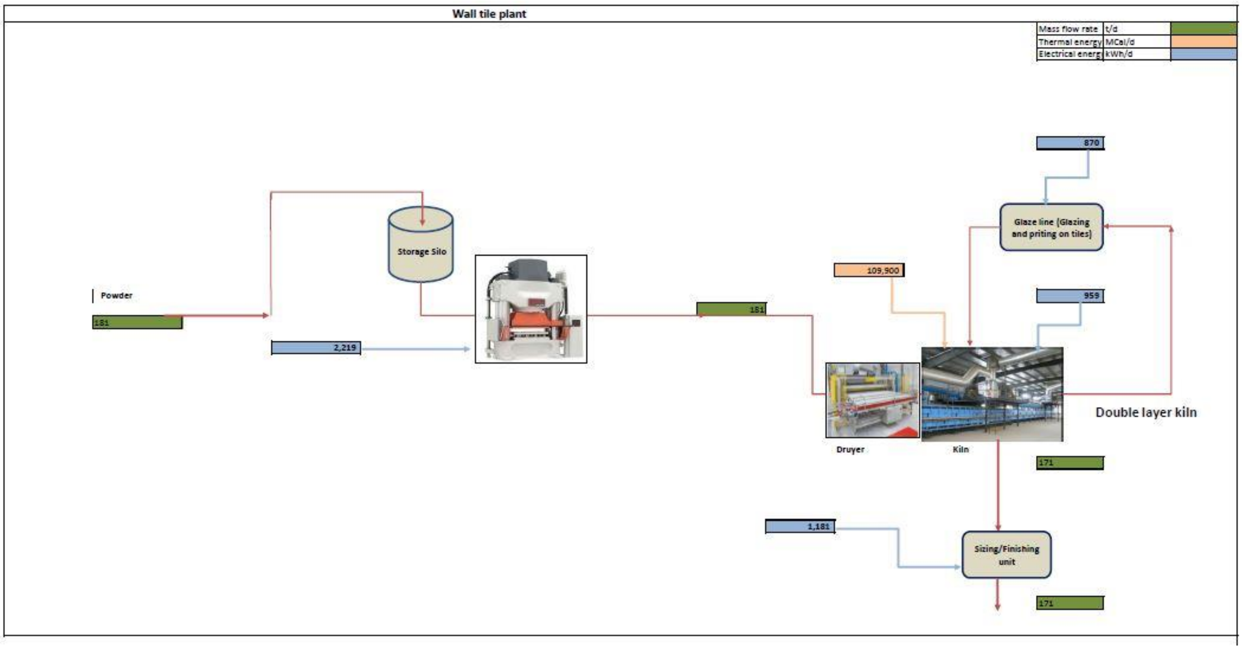


Figure 25: Process Flow Diagram of Plant

ANNEX-2: DETAILED INVENTORY

Equipment Name	Connected Load (kW)
Compressors	
Screw Compressor 1	30
Screw Compressor 2	22
Presses	
Press 1	55
Press 2	90
Press 3	75
Press Cooling Towers	
CT Pumps	6.7
Glazed tiles Kiln	
Smoke Blower	112
Combustion Blower	89
Hot Air Blower	19
	56
Rapid Cooling Blower	89
Final Cooling Blower	22
Dryer	
Smoke blower	18.6
Booster Blower	37.3
Combustion blower	2.2
Final Sizing Machine	
Sizing Machine 1	
Head Motors	67.1
Main Belt Motor	5.5
Inclined Belt Motor	22.4
Machine-2	
Head Motors	67.1
Main Belt Motor	5.5
Inclined Belt Motor	22.4
Sizing Machine 2	
Head Motors	216.3
Main Belt Motor	11.2
Sizing Blower	14.9
Coal gasifier	
ID fan	11.2
FD fan	37.3
CT pump	7.5
Glaze Ball Mill	
Ball Mill	119.3
Ball Mill	3.7
Lights	12.88
Total	**1348.8**

ANNEX-3: SINGLE LINE DIAGRAM

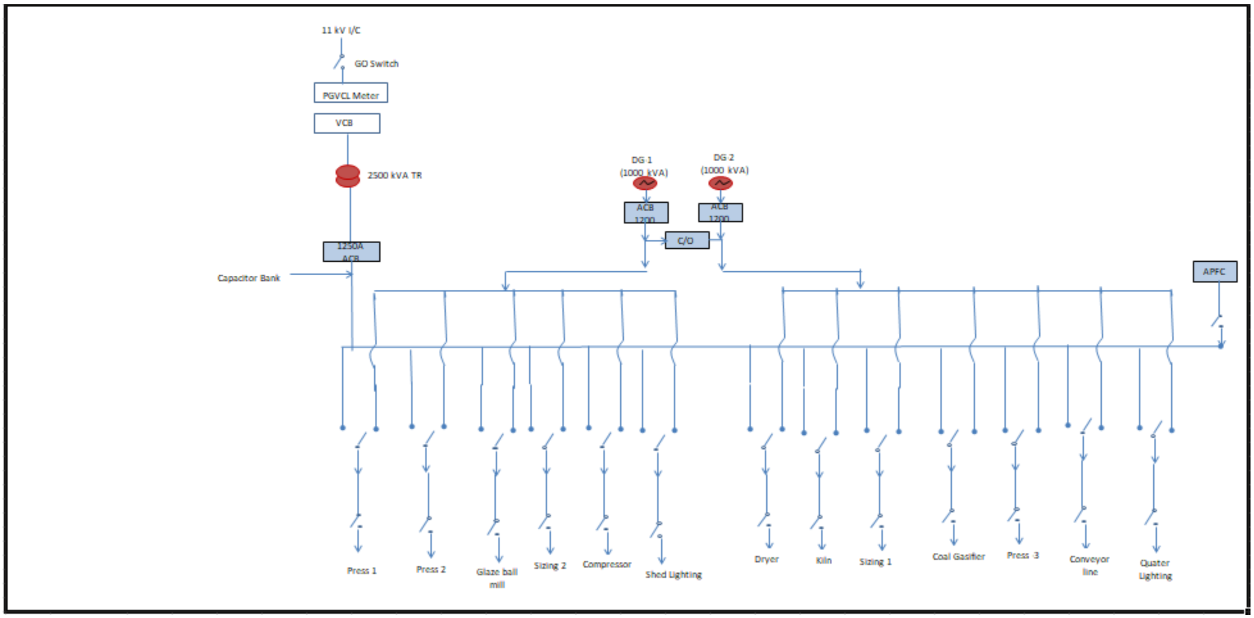
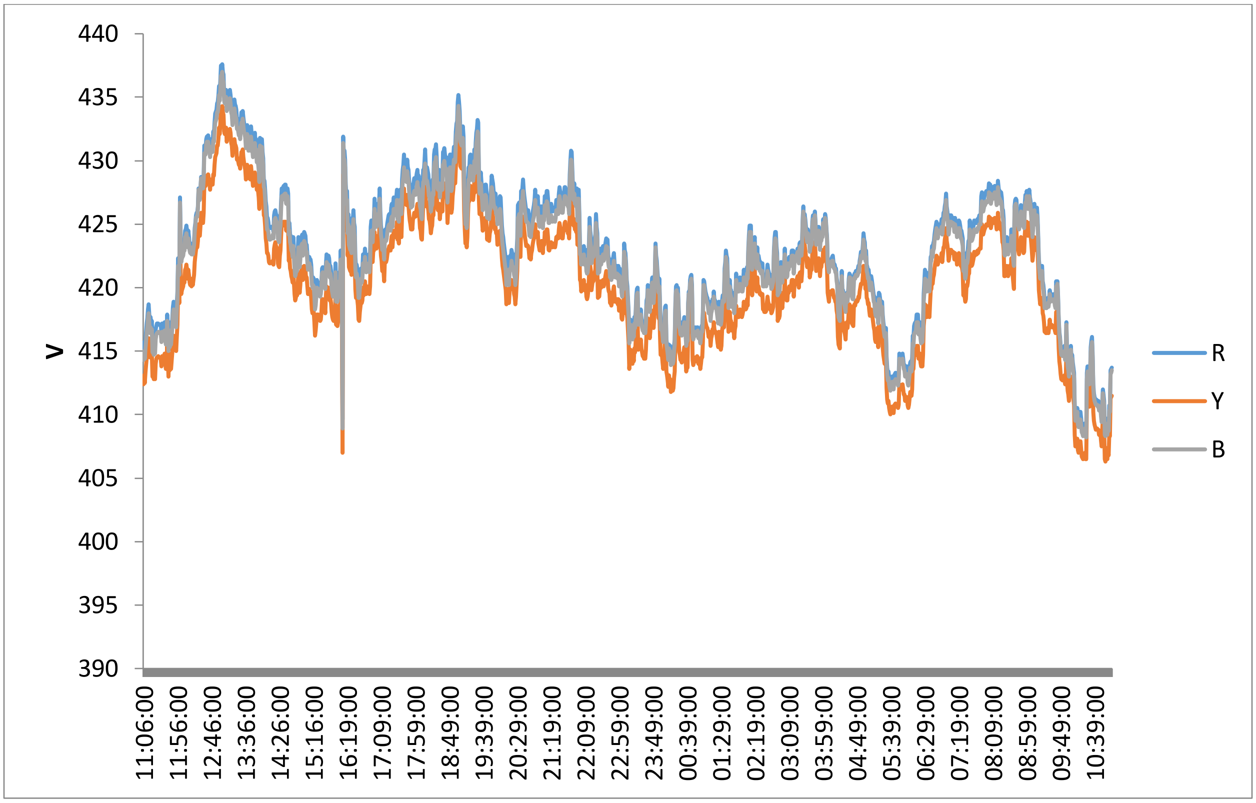
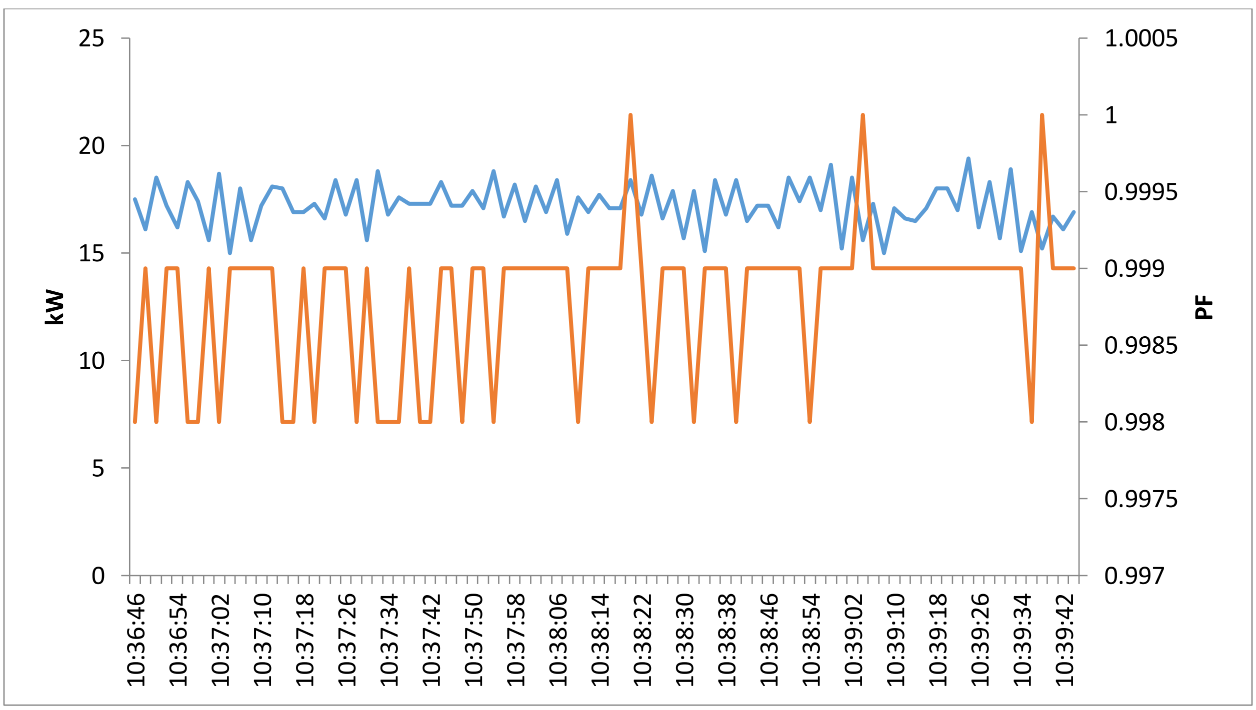


Figure 26: Single Line Diagram (SLD)

Annex-4: Electrical Measurements





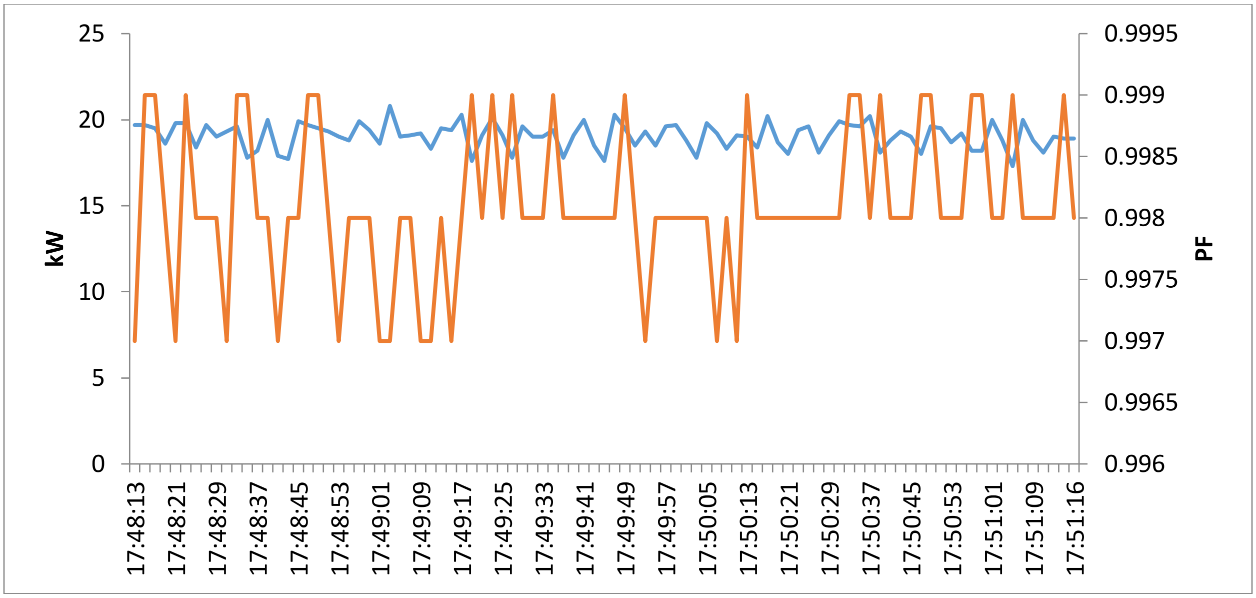
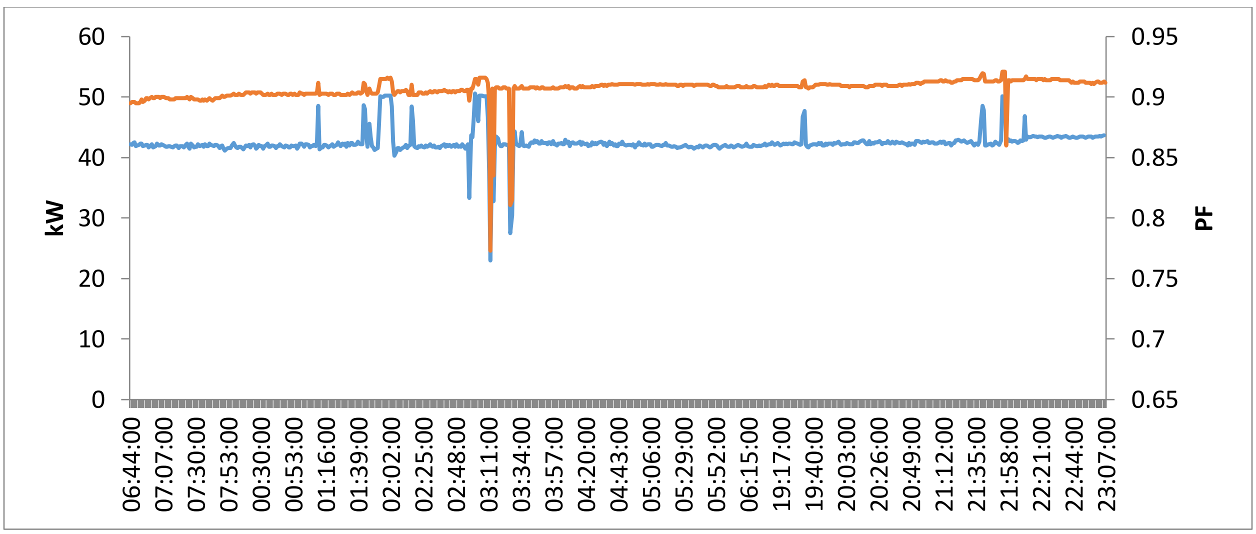


Figure 27: Power and voltage profile of Ball mill-1 & 3 respectively



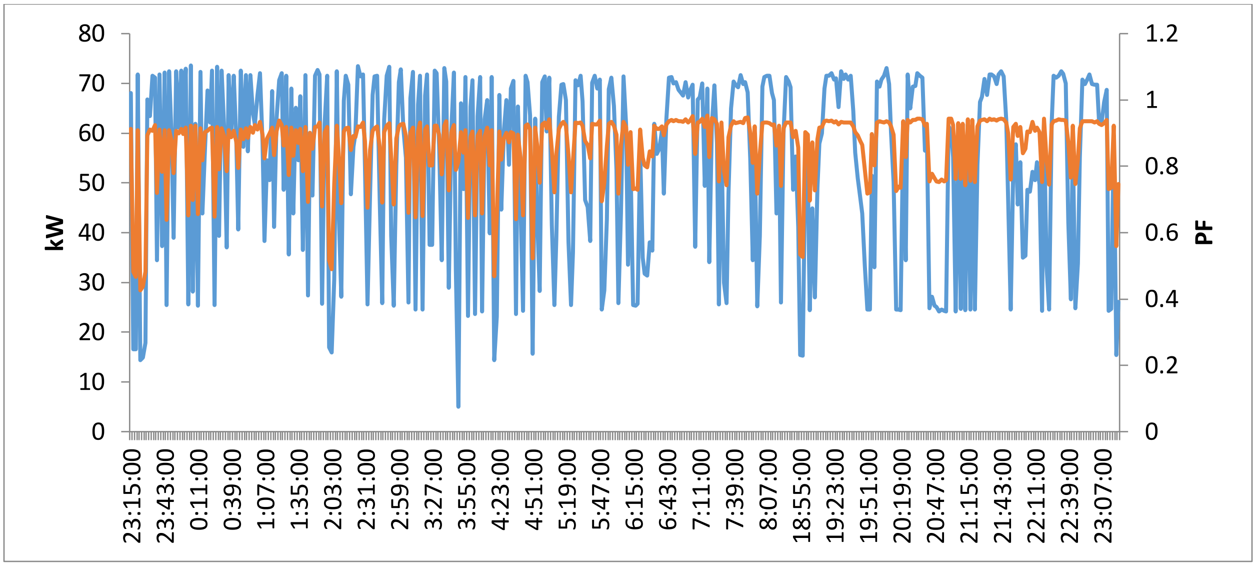
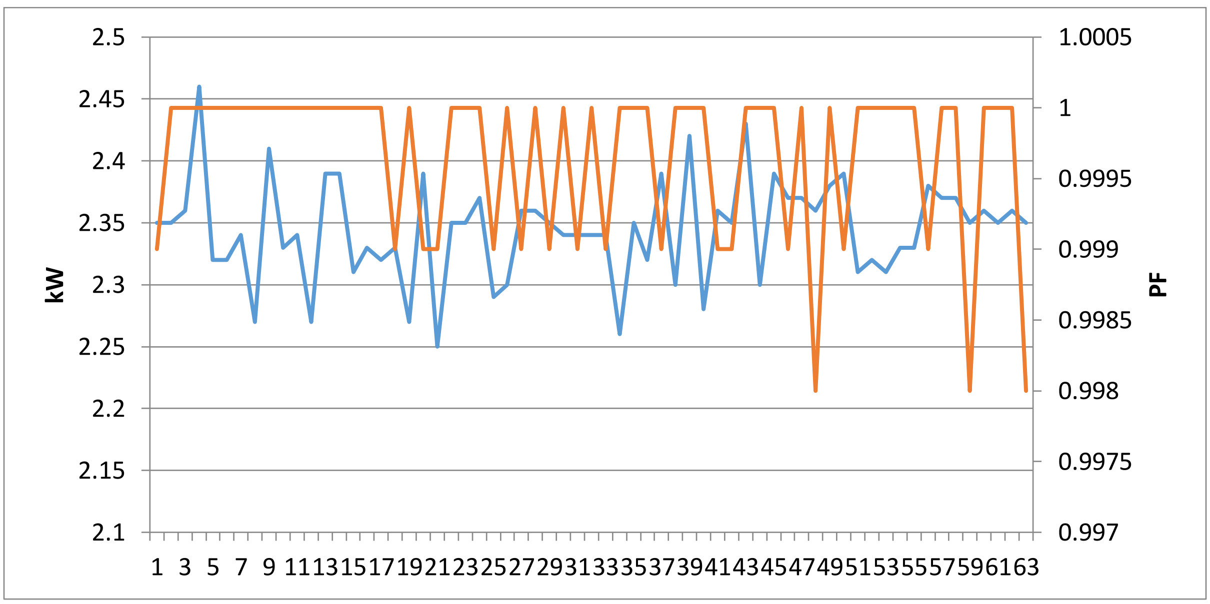


Figure 28: Power and PF profile of Press-2 & 3 respectively



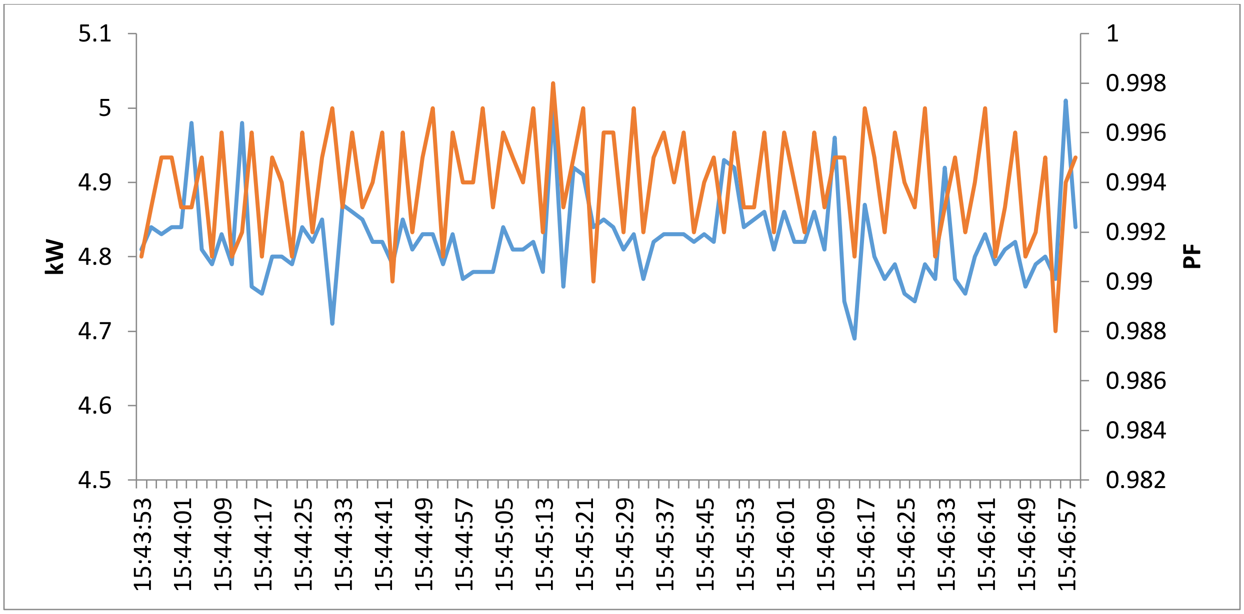
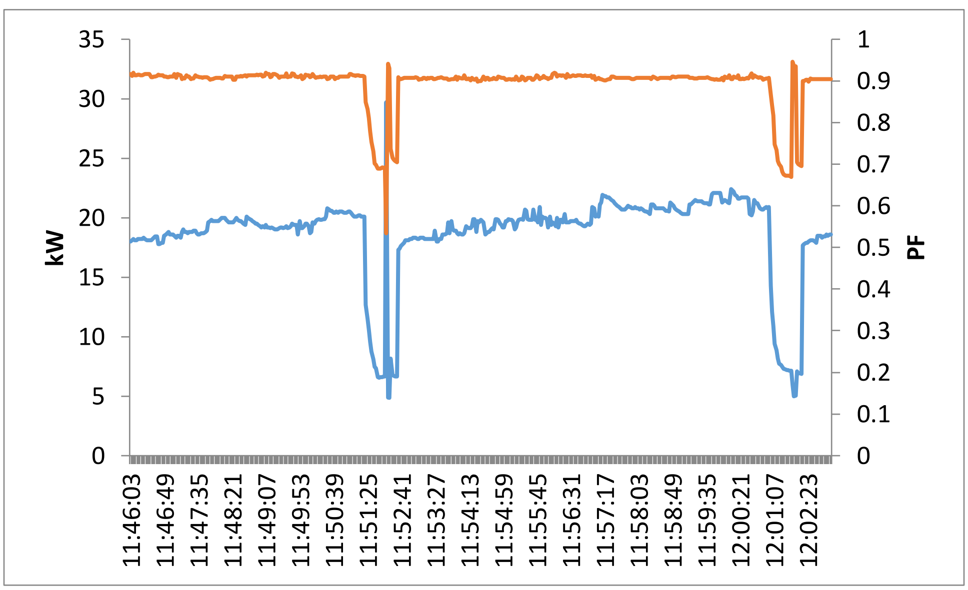


Figure 29: Power and PF profile of dryer smoke and booster blower



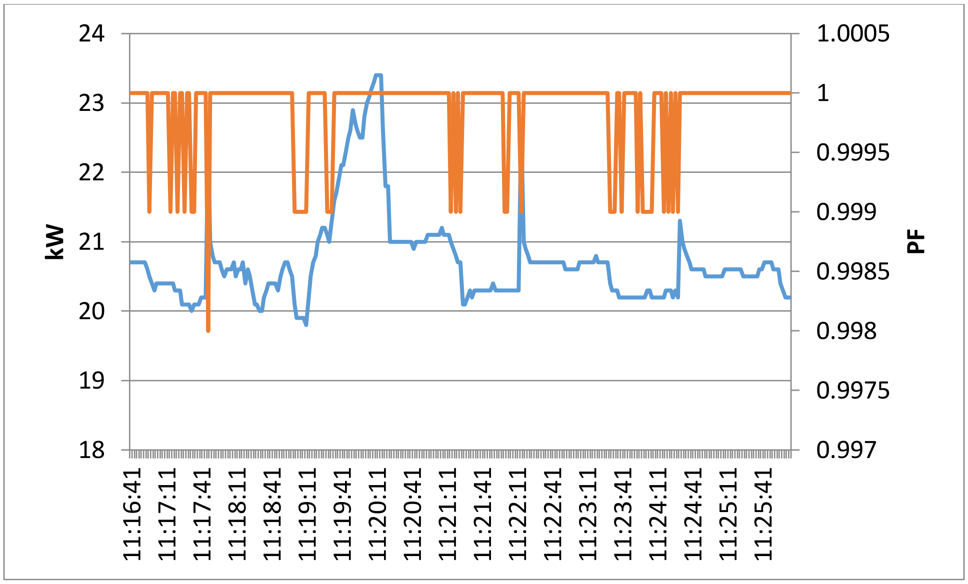
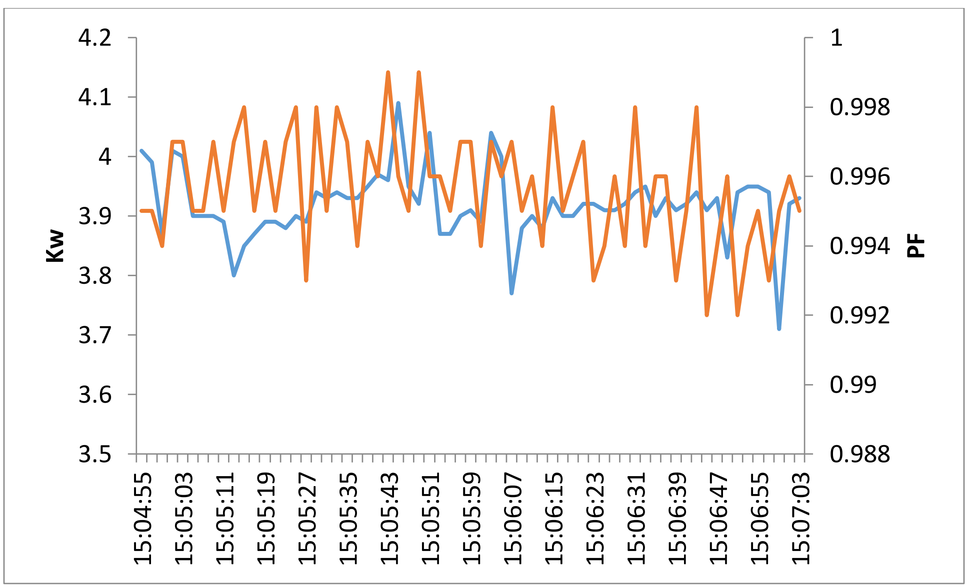
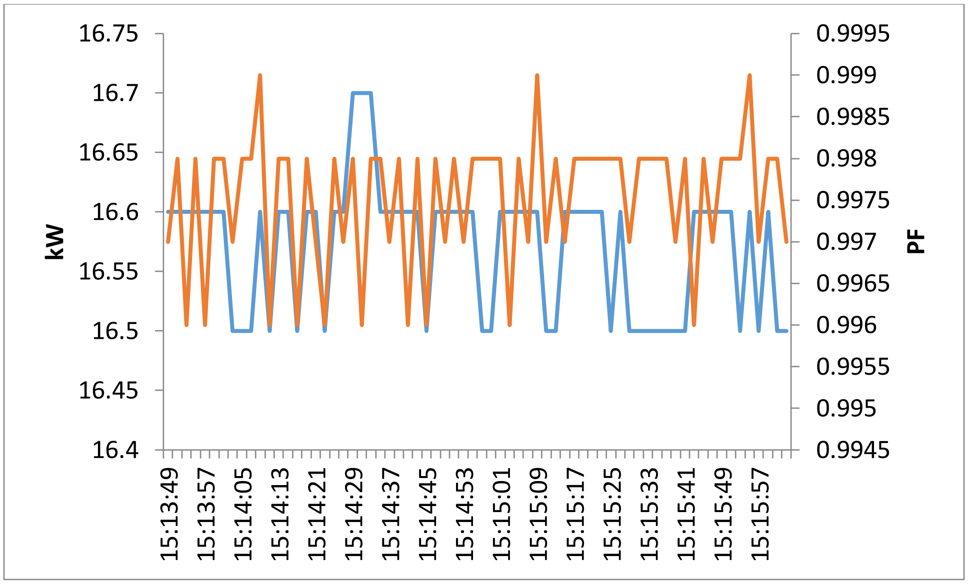


Figure 30: Power and PF profile of Compressor 1 and 2 respectively




16.75
16.7
16.65
16.6
16.55
16.5
16.45
16.4
kW
0.9995
0.999
0.9985
0.998
0.9975
0.997
0.9965
0.996
0.9955
0.995
0.9945
PF
15:13:49
15:13:57
15:14:05
15:14:13
15:14:21
15:14:29
15:14:37
15:14:45
15:14:53
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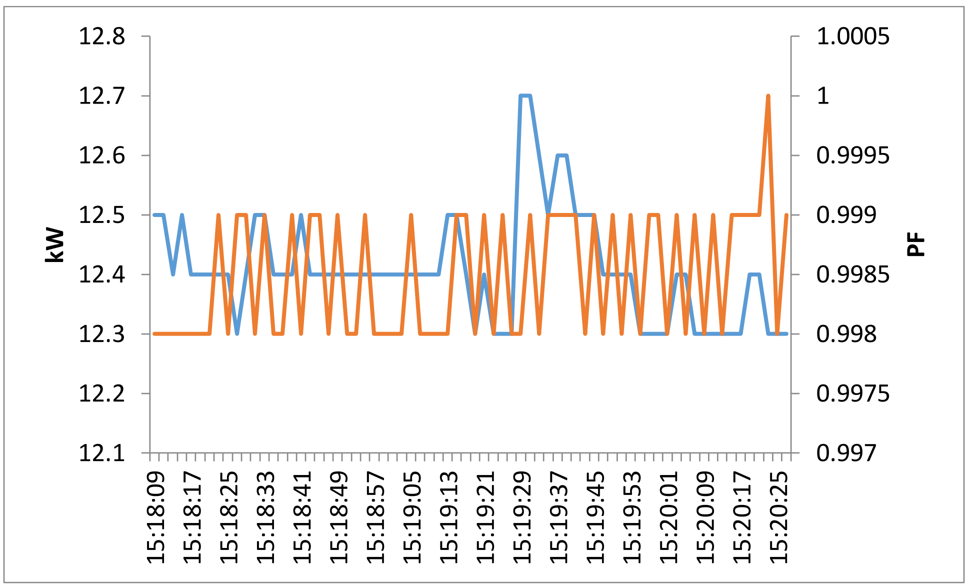
15:15:49
15:15:57


12.8
12.7
12.6
12.5
12.4
12.3
12.2
12.1
kW
1.0005
1
0.9995
0.999
0.9985
0.998
0.9975
0.997
PF
15:18:09
15:18:17
15:18:25
15:18:33
15:18:41
15:18:49
15:18:57
15:19:05
15:19:13
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15:20:25

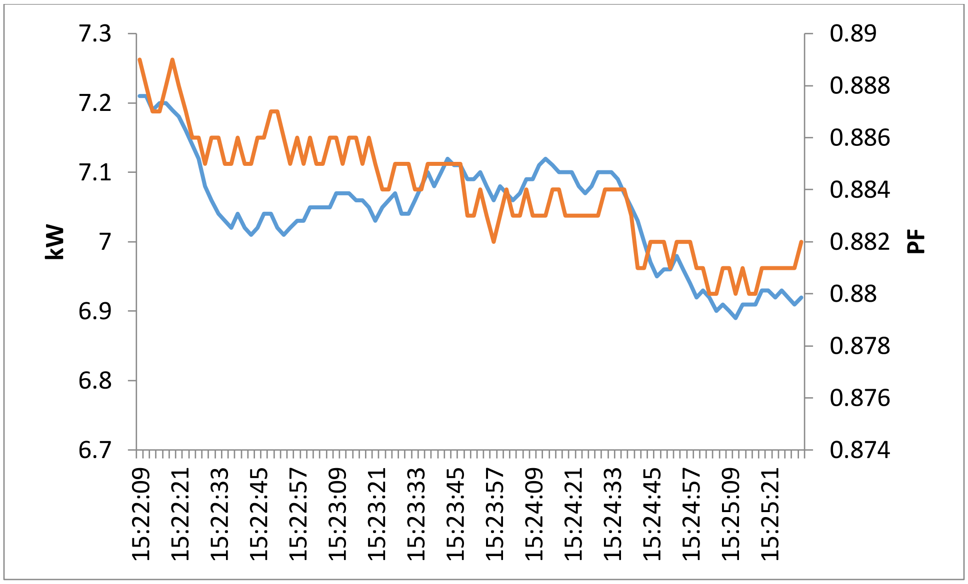

Figure 31: Power and PF Profile of all the blowers of Kiln

ANNEX-5: THERMAL MEASUREMENTS, KILN'S HEAT UTILIZATION

1. *Kiln heat utilization calculations*

Input parameters

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1,087	*Deg C*
Initial temperature of kiln tiles	40.2	*Deg C*
Avg. fuel consumption	3,224	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	130	*deg C*
Preheated air temp./Ambient	40	*deg C*
O2 in flue gas	10.3	*%*
CO2 in flue gas	6.045	*%*
CO in flue gas	36	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*Deg C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
O	*0.00*	%
S	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	1,231	*kCal/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*
Weight of ceramic material being heated in Kiln	7,128	*kg/h*
Weight of Stock	7,128	*kg/h*
Specific heat of clay material	0.22	*kCal/kg-oC*
Avg. specific heat of fuel	0.51	*kCal/kg-oC*
fuel temp	40.2	*deg 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	11,326	*kCal/h*
Radiation and convection from heating zone surface	10,204	*kCal/h*
Radiation and convection from rapid cooling zone surface	6,279	

Radiation and convection from indirect cooling zone surface	17,413	
Radiation and convection from final cooling zone surface	10,071	
Heat loss from all zones	**45,222**	*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	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*deg K*

Efficiency calculations

Calculations	Kiln	Unit
Theoretical Air Required	7.72	*kg/kg of fuel*
Excess Air supplied	96.26	*%*
Actual Mass of Supplied Air	15.16	*kg/kg of fuel*
Mass of dry flue gas	15.04	*kg/kg of fuel*
Amount of Wet flue gas	16.16	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*Kg of H2O/kg of fuel*
Amount of dry flue gas	15.04	*kg/kg of fuel*
Specific Fuel consumption	472.65	*kg of fuel/ton of tile*
Combustion heat of fuel	581,652	*kCal/ton of tiles*
Total heat input	581,652	*kCal/ton of tile*
Heat carried away by 1 ton of tile	230,232	*kCal/ton of tile*
Heat loss in dry flue gas	153,202	*kCal/ton of tile*
Loss due to H2 in fuel	23,631	*kCal/ton of tile*
Loss due to moisture in combustion air	612.49	*kCal/ton of tile*
Loss due to partial conversion of C to CO	387.26	*kCal/ton of tile*
Loss due to radiation and convection	9,621	*kCal/ton of tile*
Total heat loss from kiln (surface) body	9,542	*kCal/ton of tile*
Unaccounted heat losses	157,550	*kCal/ton of tile*
Heat utilization of kiln	39.6	*%*

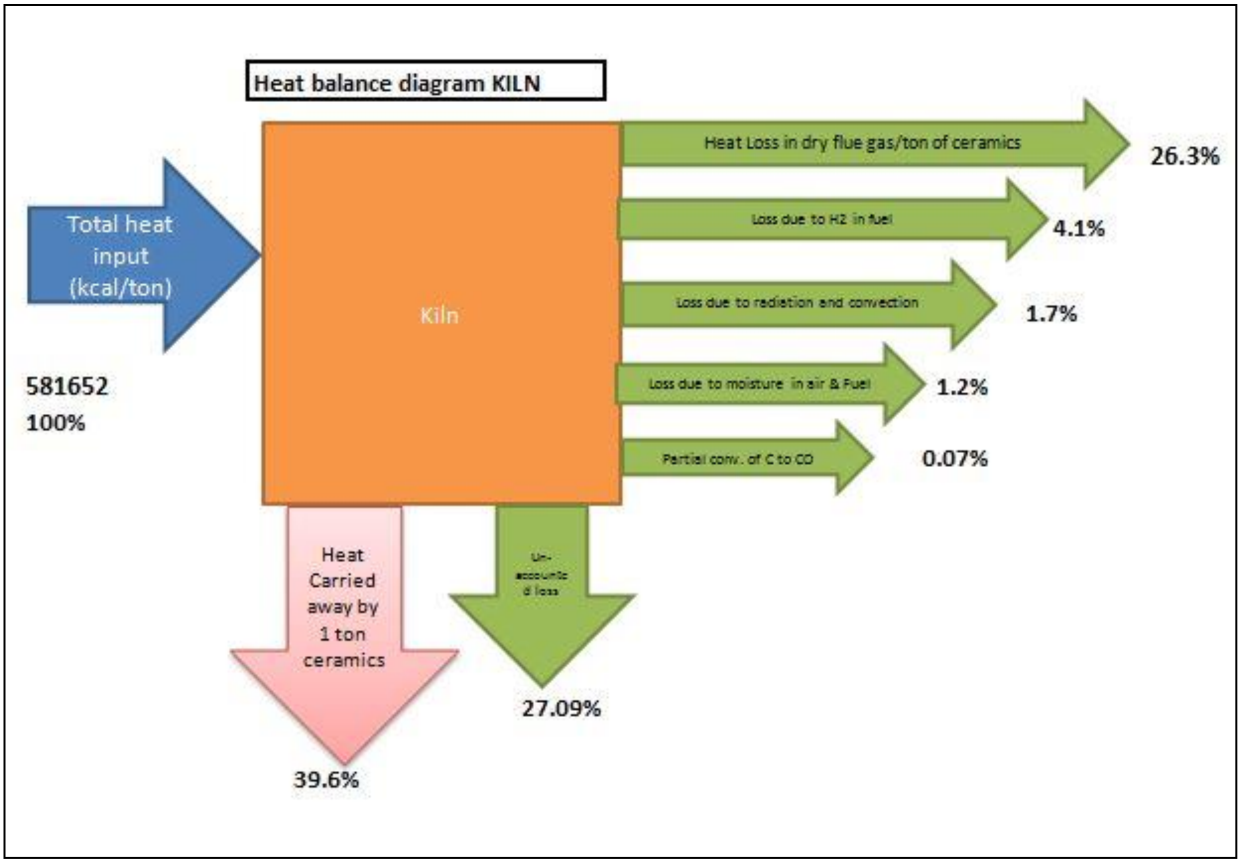

Figure 32: Heat Mass Balance of Kiln

ANNEX-6: VENDORS

ECM-1: Excess air control in kiln

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Nevco Engineers	90-A (2nd floor), Amrit Puri B, Main Road, East of Kailash, New Delhi – 110065	Tel : 011 – 26285196/197 Fax: 011 – 26285202	Nevco_delhi@yahoo.co.in
2	High-tech controls for ABB Oxygen Analysers	A 5, Vrindavan Tenament, Gorwa Behind SBI Bank, Near Sahyog Garden, Vadodara - 390016, Gujarat, India	Mr. Bhavik Parikh M: 8071640984	NA
3	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: Radiation and convection loss reduction from surface of kiln

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA	T 91 44 2530 6888 F 91 44 2534 5985 M 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com
2	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 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: Optimized Resource Consumption in glaze mill

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Aqualux Water India	A/2, Pawan Apartment, Nr. Ahmedabad Homiopathic Medical College, Bopal - Ghuma Road, Ghuma, Ahmedabad, Gujarat 380058	Mob: 9924312411	sales@aqualuxwater.com
2	Aquatechplus Pvt.	Shree Khodiyar Park, behind	Mr. Bhavesh Dabhi	www.aquatechro.com

Sl.No.	Name of Company	Address	Phone No.	E-mail
	Ltd.	Ruda Transportnagar,Rajkot-Amdavad Highway, Rajkot-363670	9512301122	bhavesh@aquatechro.com
3	Raj Water Technology (Gujarat) Pvt Ltd	Plot-27, Survey-47, Jivraj Industrial Area Near Falcon Pump, Gondal Rd, Vavdi, Rajkot, Gujarat 360004	70439 55777	marketing@rajwater.com www.rajwater.com

ECM 6: Replacement of motors by EE motor

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	The General Electric Agency	Crompton House, Ganesh Shopping Centre, Opp. Dr. Beck & Co. GIDC, Ankleshwar	Mr. Nimesh Patel 9925152416	generalagenc@sify.com
2	Siemens Limited	3rd floor, Prerna Arbour, Girish Cold Drinks Cross 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-8: Retrofit of VFD in compressor #2

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

ECM-10: Cable loss minimization

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

ECM - 11: Installation of Harmonics filter

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Infinity Enterprise Private Limited	13, Crystal Avenue & Industrial Park, near Odhav Ring road circle, Odhav, Ahmedabad – 382415, Gujarat, India.	Mob: +91 8048412433	info@infinityenterprise.net
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com
3	Hitachi Hi-Rel Power Electronics Pvt. Ltd	B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar-382044	Mr. V.Jaikumar 079 2328 7180 - 81	v_jaikumar@hitachi-hirel. com

ECM-12: Conversion 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	+91 94281 01565	NA

Sl. No.	Name of Company	Address	Phone No.	E-mail
		Station,, Kalupur, Ahmedabad, Gujarat 380001		

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

ECM-14: Solar PV installation

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

ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 49: Assumptions for Financial Analysis

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