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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE WT- 42: ITACA 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. Itaca 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. Punit Patel, Managing Director
2. Mr. Rajubhai, Electrical Maintenance - Head

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

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

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.

Itaca Ceramic Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Itaca 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	Itaca Ceramic Pvt. Ltd.
Year of Establishment	2012
Address	8A National Highway, Opp 132 K.V. Lalpar Power Station, P.B. No. 306 (P.P.W), Lalpar, Morbi - 2, Gujarat - India.
Products Manufactured	Wall Tiles
Name(s) of the Promoters / Directors	Mr. Punit Patel

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

A brief description of the manufacturing process is given below: The main energy utilizing equipment is kiln in which the fuel used is natural gas. The temperature maintained in biscuits kiln is approximately 800°C – 1,150°C and glaze kiln is 700°C- 1,085°C (in heating zone).

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio as per requirement along with water to form a plastic mass.
- **Glaze mill:** For producing glazing material used on wall tiles.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.
- **Agitator:** The plastic mass after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit
- **Dryer:** Biscuits are sent to dryer for pre drying after it is passed through kiln
- **Kiln:** Biscuits are baked in Roller kiln at 1,100-1,150°C and again baked after glazing
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in kiln 1 & kiln 2: Natural gas is used as fuel in kiln 1 & kiln 2 and oxygen content in flue gas was found to be 5.2 % against desired level of 3%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation For Biscuit kiln: In kiln 1, the recuperator pipes was found to be un-insulated with surface temperature of 90 °C which should be maintain at 80 °C. Due to high surface temperature, heat losses from surface are more. It is recommended to insulate the recuperator pipes with insulation material for reducing surface heat losses.
- Insulation in Hot Air generator Duct: In HAG, the duct connecting HAG and cyclone separator was found to be un-insulated with high surface temperature of 200°C. This causes high surface heat loss. It is recommended to insulate the duct with insulation material to reduce surface temperature up to 90 °C which reduces surface heat loss.
- Use of hot air in dryer to reduce NG: Hot air leaving from both kilns is high temperature of 230 °C. This much of heat can be used in dryer to remove moisture and to reduce NG consumption.
- Optimized Resource Consumption in Clay Section: TDS of water used in clay section was found to be 1,100 ppm against desired level of 400 ppm. It is recommended to install brackish water plant which will blend RO water with raw water.

- Interlock of oil circulation pump with pump operation: Oil circulation pump is running continuously 24x7, even when press is not in operation. The pump is to interlock to reduce running hours of pump and saving in energy.
- Operational pressure optimization in compressor: The generation pressure of compressor #1 and #2 is 7.3 kg/cm^2 and the pressure requirement at the end utilities were around 4 kg/cm^2. It is recommended to reduce operating pressure of compressor #1 & 2 from 7.3 kg/cm^2 to 6 kg/cm^2.
- Retrofit of VFD in Compressor #2: During unload condition; compressor is consuming 30% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy up to 15% of present consumption.
- Replacement of inefficient lighting systems: Conventional lights like Fluorescent Tube lights and Compact fluorescent light were present in unit which results in higher electrical consumption. It is recommended to replace the conventional lights with energy efficient LED lamps.
- Main LT voltage optimization: The present average voltage on main LT panel was 436V against standard voltage of 415V. It is recommended to install 1.7 MVA servo stabilizer on main LT panel to optimize voltage.
- Cable loss minimization: In sizing section, power factor was varies in range of 0.49-0.550. It is recommended to install power factor improvement capacitors for sizing section.
- Replacement of V belt to REC belt: All of blowers used in both kilns are V belt driven. These belts were consuming more power. So it is recommended to replace V belt to raw edge cogged belt which result in 3.6 % of energy saving.
- Energy Management system: 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.
- Installation of 50kW solar PV has been recommended at the available roof space above administration building.

Table 1 : Summary of Energy Conservation Measures

Sl No	Energy Conservation Measures	Annual Energy Savings Electricity kWh/y	NG scm/y	Coal t/y	TOE/y	Monetary Savings Lakh Rs/y	Investment Lakh Rs	Payback Period Months	Emission Reduction tCO_2/y
1	Excess air control for kiln 1	8,598	35,867		33	13.23	18.48	17	77
2	Excess air control for kiln 2	32,474	204,838		187	74.34	18.48	3	423
3	Insulation For Biscuit kiln	-	1,366		1	0.48	1.06	26	3
4	Use of hot air in dryer to reduce NG consumption		105,210		95	36.96	6.0	2	202
5	Insulation in hot air carrying pipe in HAG	-		13	9	0.49	0.33	8	27
6	Optimized Resource Consumption in Clay Section	12,293		933	624	116.71	39.60	4	1,985
7	Interlocking of oil circulation pump with hydraulic press operation	12,375			1	0.91	0.20	3	11
8	Operational pressure optimization in compressor	25,651			2	1.88	Nil	Immediate	23
9	Retrofit of VFD in Compressor #2	25,355			2	1.85	1.98	13	23
10	Replacement of inefficient light with EE lights	55,690			5	4.07	2.52	7	50
11	Voltage servo stabilizer	240,909			21	17.62	19.80	13	214
12	Cable loss minimization	7,239	-		1	0.53	0.36	8	6
13	Replacement of V belt from REC (Raw edged cogged) belt	11,977			1	0.88	1.85	25	11
14	Energy Management system	117,910	87,713	276	274	49.94	6.01	1	858
	Total	**550,470**	**434,995**	**1,222**	**1,255**	**320**	**117**	**4**	**3,912**

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

1 Reduction in energy cost by 13.7%
2 Reduction in electricity consumption by 9 %
3 Reduction in natural gas consumption by 9.9%
4 Reduction in coal consumption by 8.8 %
5 Reduction in greenhouse gas emissions by 9 %

➨ FINANCIAL ANALYSIS

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

Table 2: Financial indicators

#	Energy Conservation Measure	Investment Lakh Rs	Internal Rate of Return %	Discounted Payback Period Months
1	Excess air control for kiln 1	18.48	50%	6.35
2	Excess air control for kiln 2	18.48	303%	1.19
3	Insulation For Biscuit kiln	1.06	24%	9.81
4	Use of hot air in dryer to reduce NG consumption	6.0	456%	0.78
5	Insulation in hot air carrying pipe in HAG	0.33	114%	3.12
6	Optimized Resource Consumption in Clay Section	39.60	222%	1.61
7	Interlocking of oil circulation pump with hydraulic press operation	0.20	340%	1.05
8	Operational pressure optimization in compressor	Nil	Nil	Immediate
9	Retrofit of VFD in Compressor #2	1.98	70%	4.84
10	Replacement of inefficient light with EE lights	2.52	121%	2.92
11	Voltage servo stabilizer	19.80	63%	5.20
12	Cable loss minimization	0.36	114%	3.13
13	Replacement of V belt from REC (Raw edged cogged) belt	1.85	26%	9.42
14	Energy Management system	6.01	614%	0.58
15	Installation of solar PV system	26.0	2%	16.38

1 CHAPTER – 1 INTRODUCTION

1.1 BACKGROUND AND PROJECT OBJECTIVE

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

The objective of the project includes:

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

1.2 ABOUT THE UNIT

General details of the unit are given below:

Table 3: Overview of the Unit

Description	Details		
Name of the plant	Itaca Ceramic Pvt. Ltd.		
Plant Address	8A National Highway, Opp 132 K.V. Lalpar Power Station, P.B. No. 306 (P.P.W), Lalpar, Morbi - 2, Gujarat - India.		
Constitution	Private Limited		
Name of Promoters	Mr. Punit Patel		
Contact person	Name	Mr. Punit Patel	
	Designation	Director	
	Tel	9879520834	
	Fax		
	Email	punit@itaca.in	
Year of commissioning of plant	2012		
List of products manufactured	Wall tile, 300 x 300 mm Wall tile, 300 x 600 mm Wall tile, 450 x 1200 mm		
Installed Plant Capacity	11,000 boxes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	Not Provided by Unit		

Description	Details		
Net profit	Not Provided by Unit		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
Number of employees	Staff	120	
	Worker		
	Casual labor		
Details of Energy Consumption	Source	Yes/No	Areas of Use
	Electricity (kWh)	Yes	Entire Process and Utility
	Coal (kg)	Yes	Spray Dryer through HAG
	Diesel (litres)	Yes	DG – Rarely used
	Natural Gas (scm)	Yes	Only in Kiln
	Other (specify)	No	
Have you conducted any previous energy audit?	No		

1.3 Methodology and Approach

The study was conducted in 3 stages:

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

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

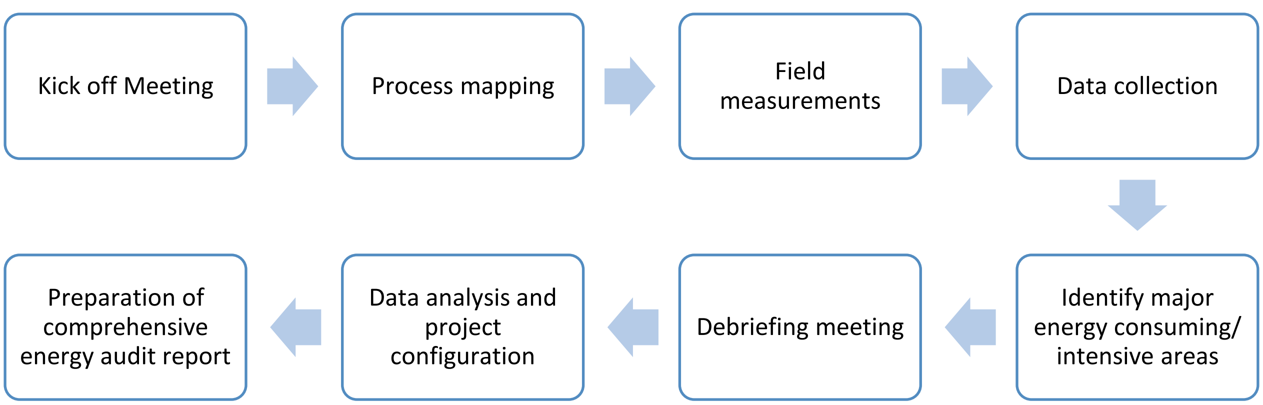


Figure 1: General methodology

The field work was carried out during 17-20th Nov 2018.

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

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

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit, are following:

Table 4: Energy audit instruments

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

1.5 Structure of the Report

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

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

2 CHAPTER – 2 PRODUCTION AND ENERGY CONSUMPTION

2.1 MANUFACTURING PROCESS WITH MAJOR EQUIPMENT INSTALLED (FLOW DIAGRAM)

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

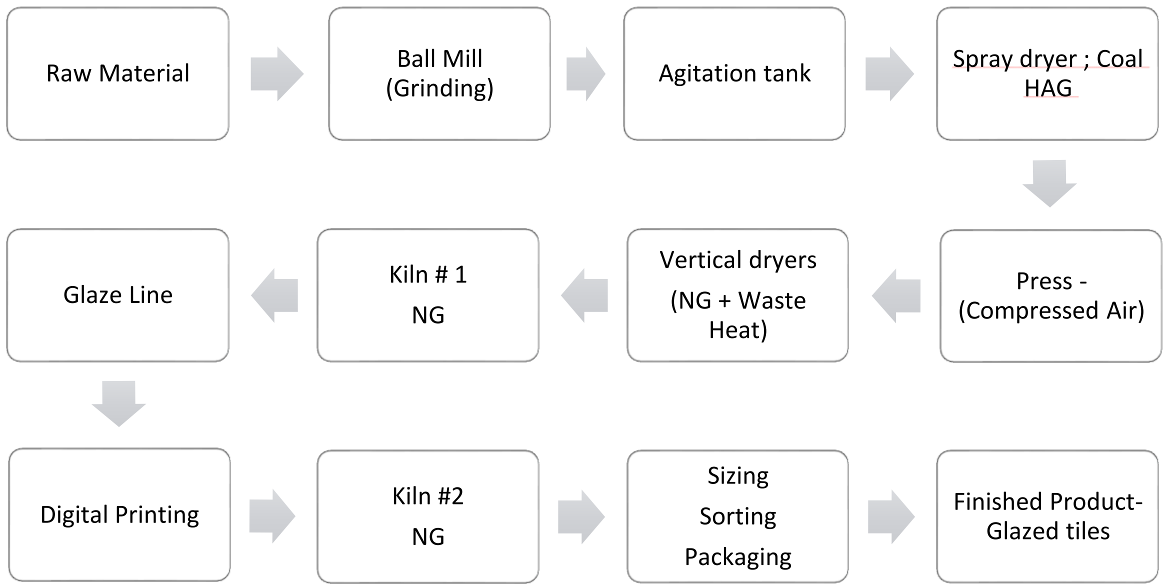


Figure 2: Process Flow Diagram

The process description is as follows:

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

- After glazing the glazed tiles are sent for final firing in the kiln. Glazed tiles are fired at a temperature of 1,050°C-1,100°C in the kiln (Kiln-2).
- Tiles coming out of kiln are sent for sizing and calibration; the tiles are cut to proper sizes so that all the tiles are of same dimension.

The major energy consuming equipment in the plant are:

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

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

2.2 Production Details

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

Table 5: Product Specifications

Product	Size /Piece	Weight/box	Area per box	Pieces per box
	mmx mm	kg	Sq m	#
Wall Tiles	300 x 300	11	0.09	9
Wall Tiles	300 x 600	14	0.18	3
Wall Tiles	450 x 1200	23	0.54	2

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

Table 6: Month wise production

Period	Number of Boxes			Corresponding Area (m^2)			Corresponding Mass (MT)		
	300 x 300	300 X 600	450 X 1200	300 x 300	300 X 600	450 X 1200	300 x 300	300 X 600	450 X 1200
Oct-17	29,721	121,580	5,030	13,374	196,960	5,432	16.05	551.49	62.47
Nov-17	29,118	119,112	4,928	13,103	192,962	5,322	15.72	540.29	61.20
Dec-17	29,648	121,281	5,017	13,342	196,475	5,419	16.01	550.13	62.32
Jan-18	29,600	121,084	5,009	13,320	196,157	5,410	15.98	549.24	62.22
Feb-18	29,106	119,063	4,926	13,098	192,881	5,320	15.72	540.07	61.18
Mar-18	30,259	123,780	5,121	13,616	200,524	5,531	16.34	561.47	63.60
Apr-18	23,402	285,690	688	18,950	304,196	743	22.74	851.75	8.54
May-18	15,729	176,450	4,076	12,732	222,704	4,402	15.28	623.57	50.62
Jun-18	25,273	209,791	7,023	20,419	243,375	7,585	24.50	681.45	87.23
Jul-18	5,637	37,427	1,780	4,564	48,852	1,922	5.48	136.79	22.11
Aug-18	18,442	193,645	7,619	14,936	246,124	8,229	17.92	689.15	94.63
Sep-18	19,494	177,792	11,678	15,784	221,647	12,612	18.94	620.61	145.04
Average	23,786	150,558	5,241	13,937	205,238	5,661	17	575	65
	59,862			74,945			219		

2.3 Energy Scenario

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

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

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	TOE	% of total
Grid – Electricity	429.45	18.3	507	3.7
Thermal-Coal	525.16	22.4	9,233	67.5
Thermal – NG	1,388.63	59.3	3,947	28.8
Total	2,343.25	100	13,687	100

This is shown graphically in the figures below:

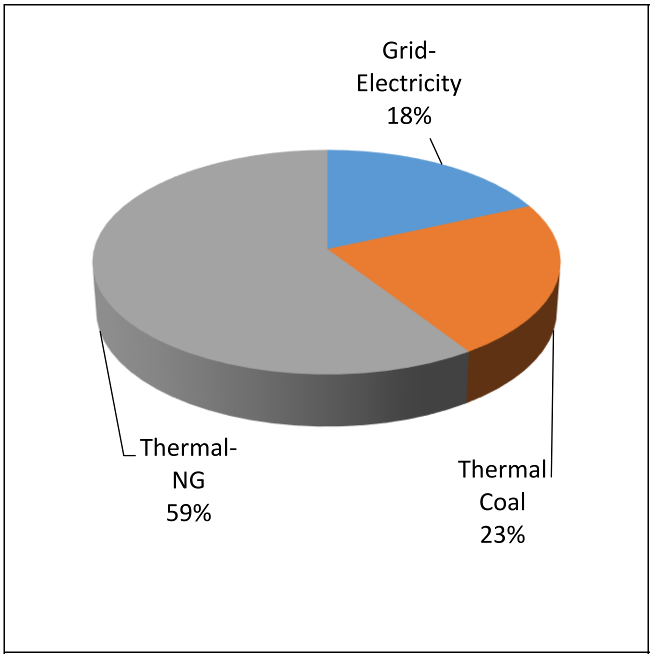


Figure 3 : Energy cost share

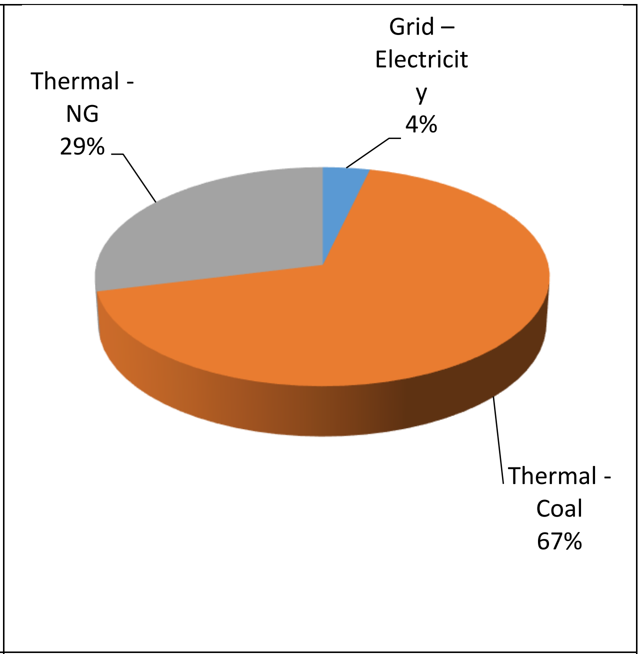


Figure 4 Energy use share

The major observations are as under

- The unit uses both thermal and electrical energy for the manufacturing operations.
- Electricity is sourced from the grid as well as self-generated in DG sets when the grid power is not available. However, blackouts are infrequent, due to which the diesel consumption is minimal and records are not maintained.
- Electricity used in the utility and process accounts for the 18.3 % of the energy cost and 3.7% of the overall energy consumption.
- Source of thermal energy is from combustion of NG, which is used for firing in the kilns, and coal for the hot air generator (HAG).
- NG used in kilns account for 59.3% of the total energy cost and 28.8% of overall energy consumption.
- Coal used in the hot air generator accounts for 22.4% of cost and 67.5% 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	26743
Tariff Category	HTP-I
Contract Demand, kVA	1,100
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Tariff structure

Particulars	Tariff structure for Category HTP-1
Demand Charges (Rs./kVA)	
1st 500 kVA	150
2nd 500 kVA	260
Next 297	475
Energy Charges (Rs./kWh)	
Normal Hours	4.2
Peak Hours	0.85
Night Time	0.4
Fuel Surcharge (Rs./kWh)	1.63
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

2.2.1.2 *Month wise Electricity Consumption and Cost*

Month wise total electrical energy consumption is shown as under:

Table 10 : Electricity consumption & cost

Month	Units Consumed kWh	Total Electricity Cost Rs	Unit Cost Rs/kWh
Oct-17	491,235	3,649,754	7.43
Nov-17	555,030	4,027,822	7.26
Dec-17	490,695	3,589,690	7.32
Jan-18	517,440	3,782,330	7.31
Feb-18	531,210	3,815,802	7.18
Mar-18	506,835	3,674,549	7.25
Apr-18	532,125	3,859,042	7.25
May-18	539,580	3,892,056	7.21
Jun-18	561,090	4,045,880	7.21
Jul-18	214,380	1,679,438	7.83
Aug-18	392,580	2,873,881	7.32
Sep-18	563,280	4,055,040	7.20

Average electricity consumption is 491,200 kWh/month and cost is Rs 35.78 Lakhs per month. The average cost of electricity is Rs. 7.31/kWh.

2.2.1.3 Analysis of month-wise electricity consumption and cost

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

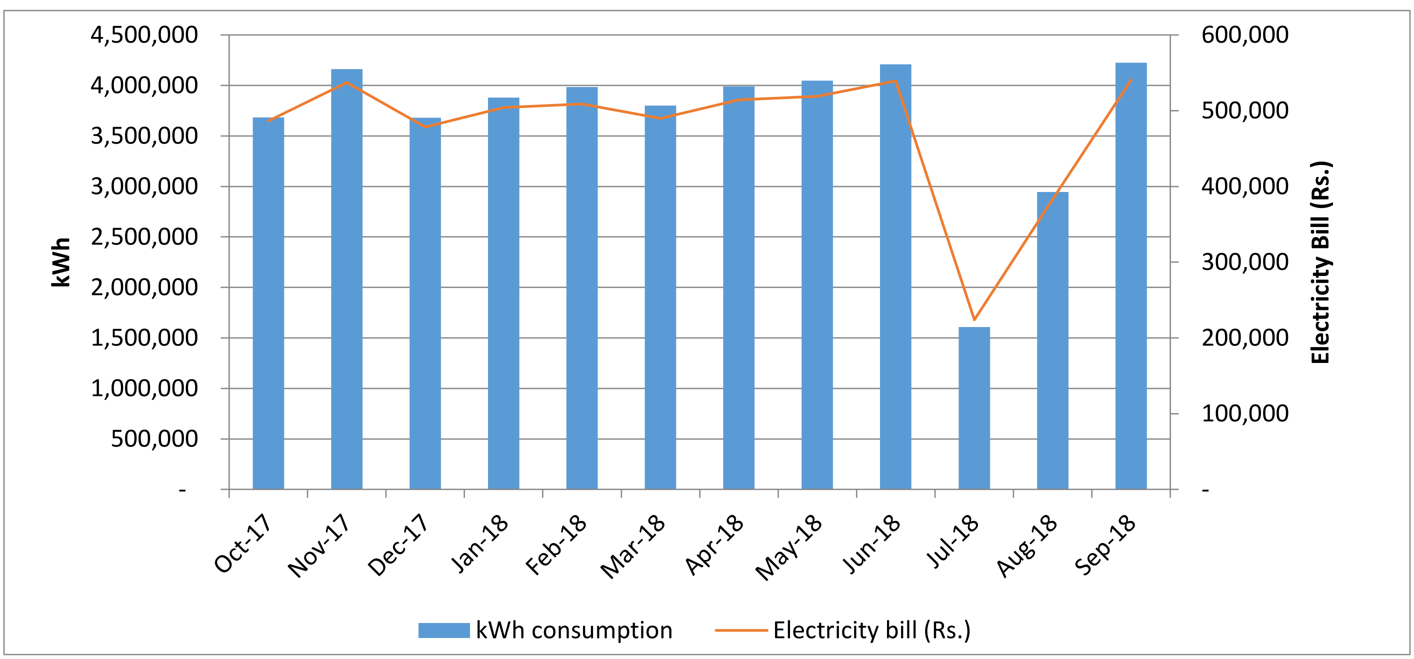


Figure 5: Month wise Variation in Electricity Consumption

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

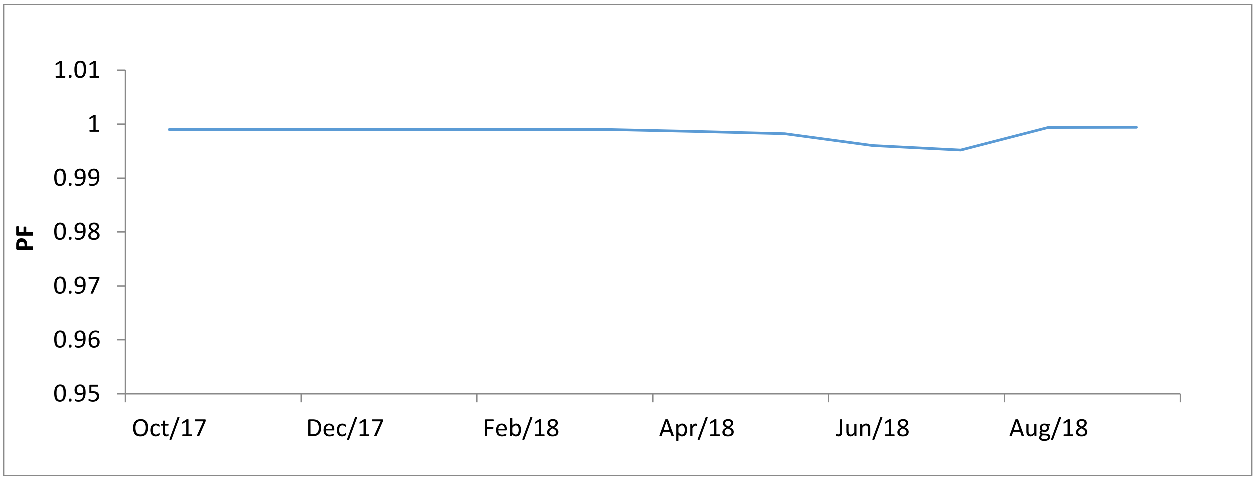


Figure 6 : Month wise variation in Power Factor

The utility bills reflect the power factor. A study was conducted by logging the electrical parameters of the main incomer using a power analyzer. The average power factor was found to be 0.99 with the minimum being 0.99 and the maximum being 1.00.

Maximum Demand: Maximum demand as reflected in the utility bill is 1,045 kVA from the bill analysis.

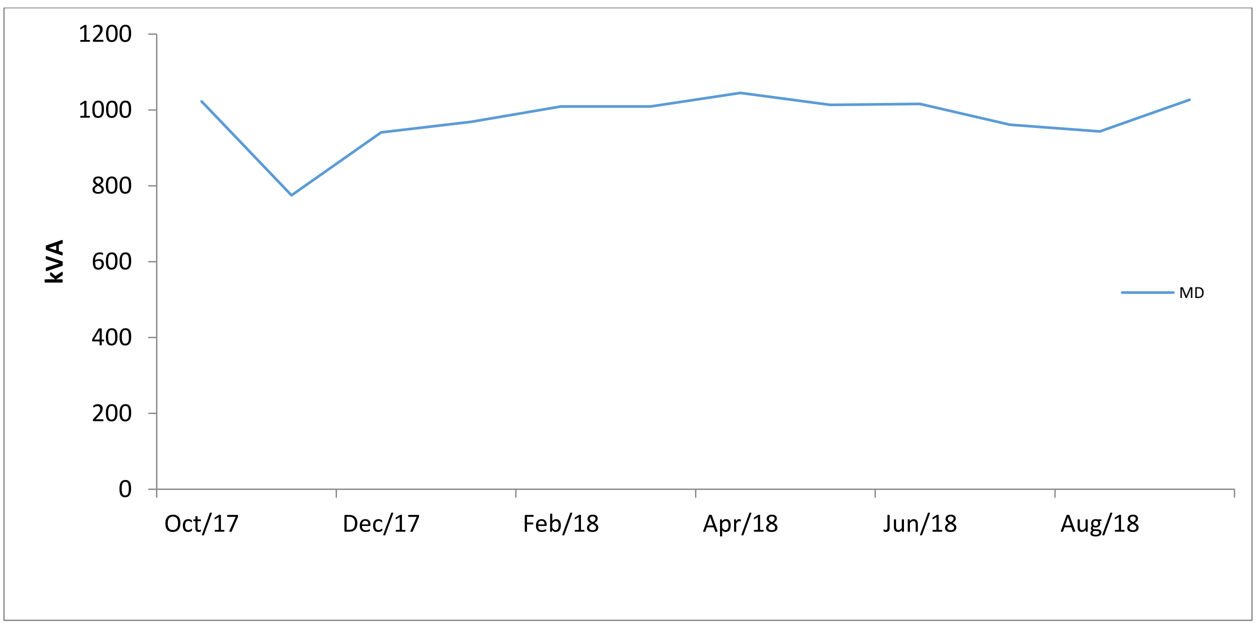


Figure 7 : Month wise variation in Maximum Demand

2.2.1.4 *Single Line Diagram*

Single line diagram of plant is shown in below figure:

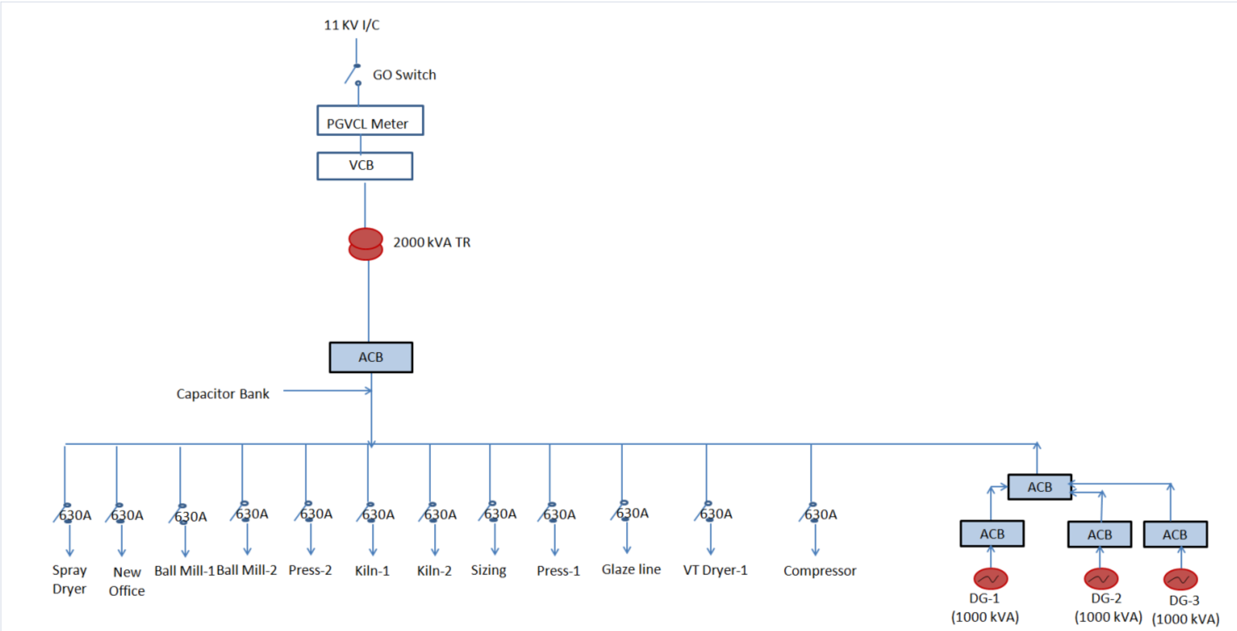


Figure 8: SLD of Electrical Load

2.2.1.5 *Electricity consumption areas*

The plant total connected load is 2,123 kW, which includes:

- The plant and machinery load is 2,032.25 kW
- The utility load (fan and lighting) is about 91.16 kW including the single phase load

Table 11 : Equipment wise connected load

Sl. No.	Equipment	Numbers	Total capacity(kW)
1	Ball Mill section	2	473
2	Hot Air Generator (HAG	1	57
3	Spray dryer	1	266
4	Hydraulic press	2	190
5	Biscuit kiln	1	231
6	Glaze kiln	1	216
7	Glaze mills	6	186
8	Vertical dryer	1	88
9	Sizing	2	313
10	Utilities	2	44
11	Lighting	1,361	47
	Total	1,380	2,123

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

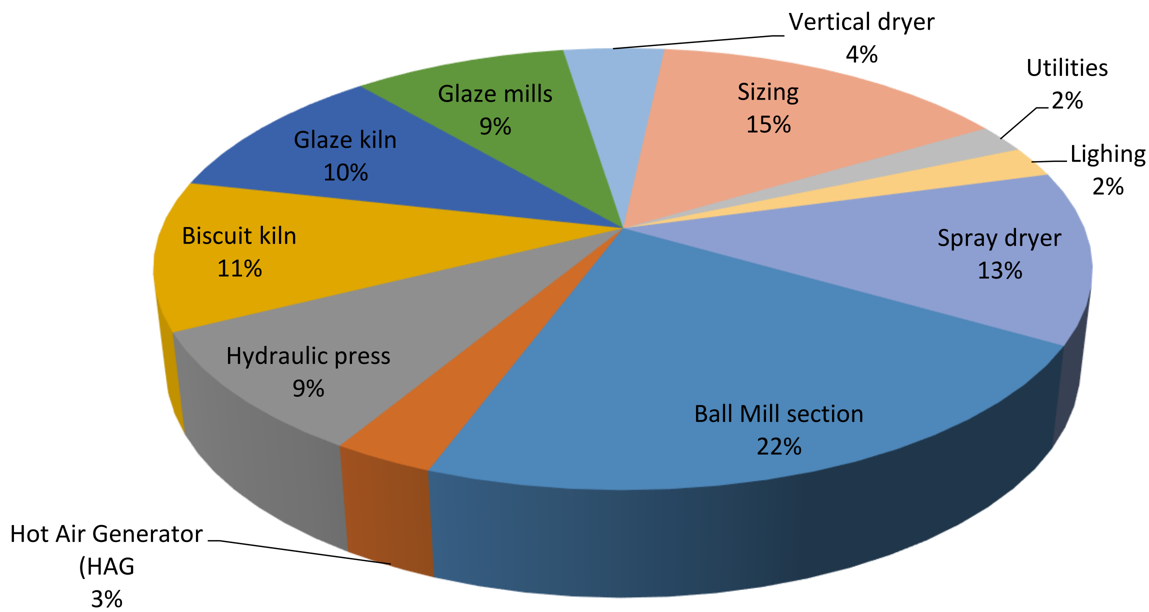


Figure 9 : Details of connected load

As shown in the figure, the maximum share of connected electrical load is for the Ball mill – 22 %, followed by kilns – 21 % , sizing – 15 %, spray dryer – 13 %, press – 9%, Glaze mills – 9% , vertical dryer – 4% .Utilities and lighting consists of 2 % 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:

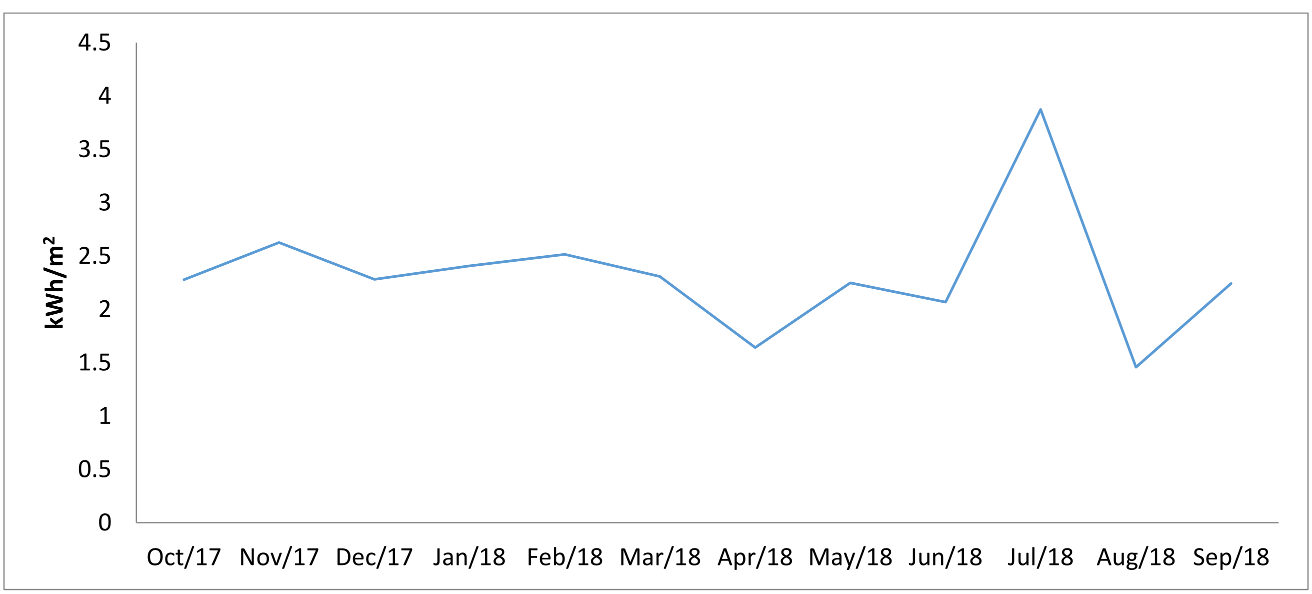


Figure 10 : Month wise variation in Specific Electricity Consumption

The month, Jul-17 is outliers. Excluding this month, the maximum and minimum values are within ±20% of the average SEC of 2.32kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in ball mill section, spray dryer section, press section, biscuits kiln, glaze kiln, utility like compressor, pumps etc.

2.2.2 Analysis of Thermal Consumption

2.2.2.1 Month wise Fuel Consumption and Cost

The thermal consumption areas are the hot air generator, vertical driers and the kilns. Coal is used as fuel for the hot air generator while NG is used as fuel for the kilns. Main source of heat for secondary dryers is waste heat from the kiln, supplemented by NG . Coal is purchased from local coal suppliers who in turn import coal from Indonesia. NG is purchased from GSPC (Gujarat State Petroleum Company). Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	Kiln-1			Kiln-2			Spray Dryer		
	NG Use	NG Cost	NG Cost	NG Use	NG Cost	NG Cost	Coal Used	Coal Cost	Coal Cost
	scm	Rs	Rs/scm	scm	Rs	Rs/scm	MT	Rs	Rs/MT
Oct-17	221,764	6,212,170	28.01	181,443	5,082,685	28.01	1,152	4,376,333	3,800
Nov-17	203,843	5,782,440	28.37	166,780	4,731,088	28.37	1,152	4,376,333	3,800
Dec-17	220,026	6,331,671	28.78	180,021	5,180,458	28.78	1,152	4,376,333	3,800
Jan-18	217,460	6,540,926	30.08	177,921	5,351,667	30.08	1,152	4,376,333	3,800
Feb-18	204,800	6,341,207	30.96	167,563	5,188,261	30.96	1,152	4,376,333	3,800
Mar-18	233,933	7,211,753	30.83	191,399	5,900,526	30.83	1,152	4,376,333	3,800
Apr-18	218,204	6,838,203	31.34	178,531	5,594,893	31.34	1,142	4,339,600	3,800
May-18	213,217	6,908,285	32.40	174,450	5,652,233	32.40	1,521	5,779,800	3,800
Jun-18	173,860	5,920,676	34.05	142,249	4,844,190	34.05	1,209	4,594,200	3,800
Jul-18	59,930	2,086,629	34.82	49,033	1,707,242	34.82	625	2,375,000	3,800
Aug-18	232,326	8,347,160	35.93	190,085	6,829,494	35.93	1,164	4,423,200	3,800
Sep-18	212,759	7,853,728	36.91	174,076	6,425,777	36.91	1,249	4,746,200	3,800

Observation:

- Kiln-1 is used for baking of biscuit tiles whereas Kiln-2 is used for baking of glazed tiles. Kiln-1 accounts for 55% of total NG used. Average monthly gas consumption in Kiln-1 is about 201,010 scm and average cost is Rs 63.65 Lakhs/month whereas monthly gas consumption in Kiln-2 is about 164,463 scm and average cost is about Rs. 52.07 Lakh/month. Cost of natural gas in Kiln-1 is Rs. 32.0/SCM whereas in Kiln-2 is Rs. 32.0 /scm
- Coal is fired in the hot air generator. Average coal consumption is 1,152 tons and average cost Rs. 43.76 Lakhs/month Cost of coal is Rs. 3,800 /ton
- There are two gas connections to the unit and out of one connection a tapping is given to vertical dryer.

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:

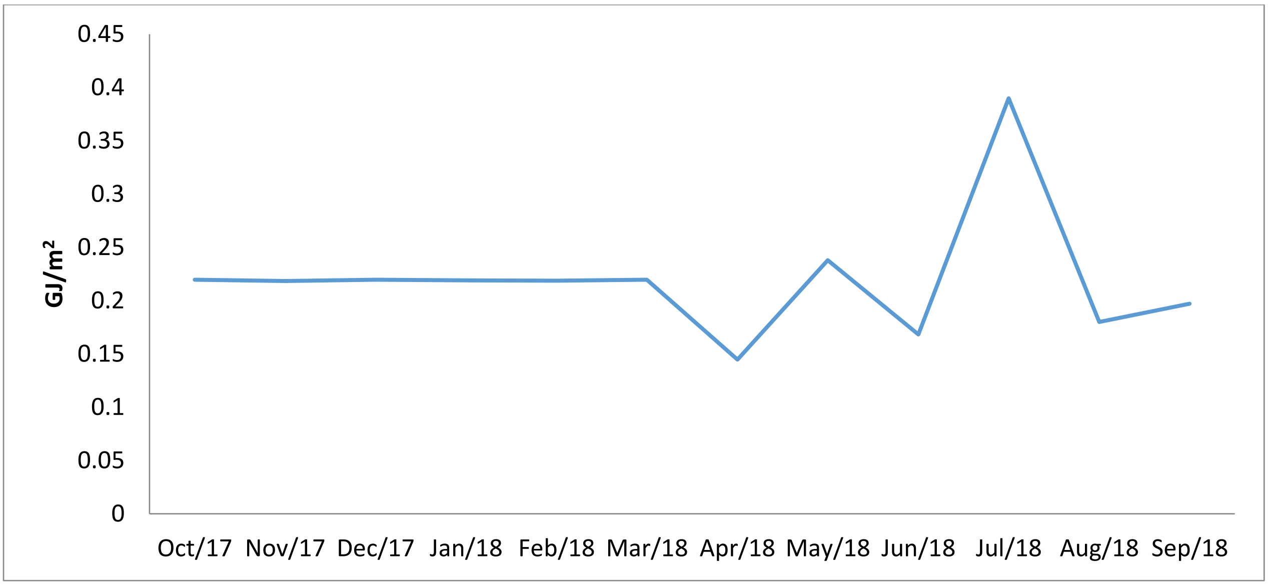


Figure 11 : Month wise variation in Specific Fuel Consumption

The average SFC is 0.219 GJ/m^2, i.e. 0.063 GJ/m^2 for the kilns and 0.156 GJ/m^2 for the hot air generator. Excluding the month of Jul-18, the NG consumption varied between 0.04-0.072 GJ/m^2 and was within ±10% of the average value. The SFC for coal varied between 0.098 and 0.315 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	369.7
Power consumption	kW	875.02
Coal consumption	kg/h	1600
NG consumption	scm/h	512.17
Energy consumption	TOE/h	5.64
SEC of plant	TOE/m^2	0.015

2.2.3.2 *Section wise energy consumption*

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

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

Particulars	NG	Coal	Electricity
	scm/t	kg/t	kW/t
Ball mill 1			2.14
Ball mill 2			2.39
Agitator			0.489
HAG		260.1	8.50
& Spray Dryer			6.62
Hydraulic Press- 2			8.48
Vertical dryer			4.85
Biscuit kiln	43.11		4.46
Glaze kiln	38.42		4.95
Sizing Section 1			2.30
Sizing Section 2			3.00
Sizing Section 3			2.92
Sizing Section 4			2.55

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	5,895,480
Self-Generation from DG Set	kWh/y	0
Annual Total Electricity Consumption	kWh/y	5,895,480
Annual Thermal Energy Consumption (Imported Coal)	t/y	13,820
Annual Thermal Energy Consumption (NG)	scm/y	4,385,672
Annual Energy Consumption	TOE	13,687
Annual Energy Cost	Rs. Lakh	2,384
Annual production	m^2	2,699,267
	t	7,904

Parameters	Units	Value
SEC; Electrical	kWh/m^2	2.18
	kWh/t	746
SEC; Thermal	GJ/m^2	0.204
	GJ/t	69.82
SEC; Overall	TOE/ m^2	0.0051
	TOE/t	1.73
SEC; Cost Based	$Rs./m^2$	86.8
	Rs./t	29,647

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

- Conversion Factors
  - Electricity from the Grid : 860 kcal/kWh
- GCV of NG : 9,000 kcal/scm
- GCV of Imported Coal : 6,681 kcal/kg
- CO_2 Conversion factor
  - Grid : 0.82 kg/kWh
  - Imported Coal : 2.116 t/t
  - NG : 0.001923 tCO_2/SCM

2.2.3.4 *Baseline Parameters*

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

Table 16: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs./ kWh	7.20
Cost of NG	Rs./scm	35.13
Cost of Coal	Rs./MT	3,800
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	2,699,267

2.4 Water Usage & Distribution

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

Water requirement is met by own bore-well from where it is extracted and stored in storage tank. From this storage water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 150-200 m^3/day as informed by unit.

Water distribution diagram is shown below.

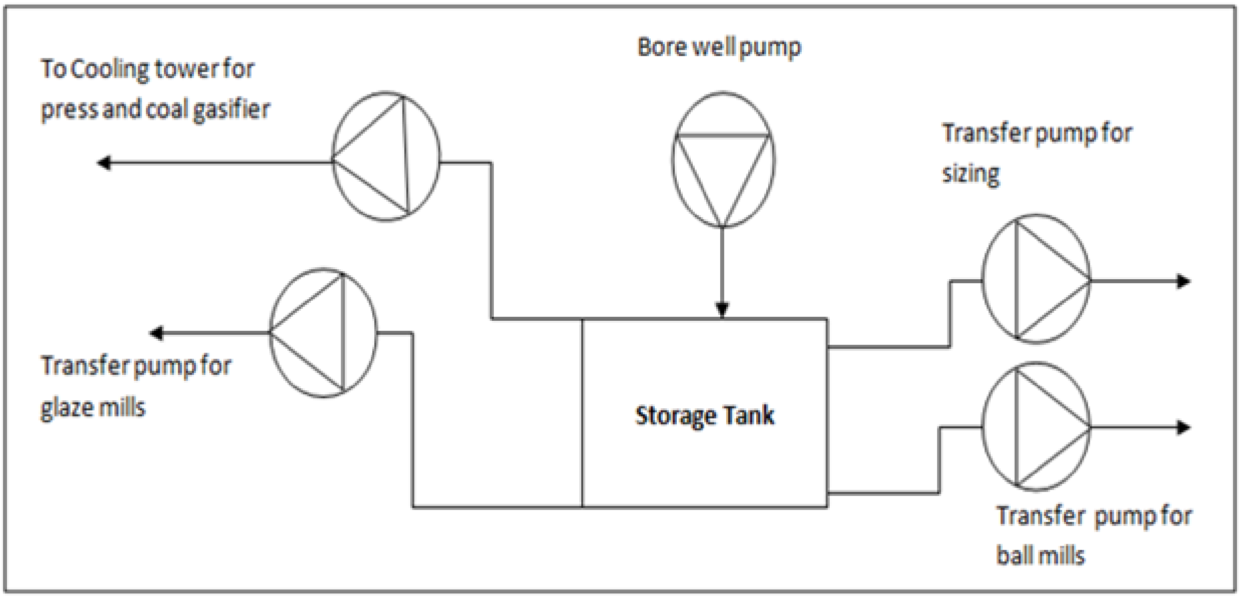


Figure 12: Water Distribution Diagram

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

Table 17: Press cooling water circulation pump details

Parameters	Unit	Cooling Water Pumps
Make	-	-
Motor rating	kW	5.6
RPM	rpm	2,900
Quantity	number	3

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

3 CHAPTER – 3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Natural gas is used as a fuel in both the kilns to heat the ceramic tiles to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan). Cooling blower and rapid cooling blowers are used for cooling the tiles after combustion zone to get required tile quality and at the starting point, a smoke blower is installed which preheats the tiles before combustion zone of kiln. Kiln-1 consists of 231 kW electrical loads whereas Kiln-2 has 216 kW of electrical load. Kiln - 1 includes 60 HP smoke blower, 50 HP combustion blowers, 25 HP for rapid cooling, 60 HP for Hot air blower, 15 HP for intermediate cooling blower, 40 HP for final cooling blowers. Kiln - 2 includes 50 HP smoke blower, 60 HP combustion blowers, 30 HP for rapid cooling, 60 HP for Hot air blower, 20 HP for cooling section,& 10 HP final exhaust blower and remaining electrical load of kiln roller motors.

Table 18: Kiln Details

Sl. No	Parameter	Unit	Kiln-1	Kiln-2
	Make		Local	Local
1	Kiln operating time	h	24	24
2	Fuel Consumption	scm/h	282	230
3	Number of burner to left	-	116	96
4	Number of burner to right	-	116	96
5	Cycle Time	Minutes	54	49
6	Pressure in firing zone	mmWC	60	60
7	Maximum temperature	°C	1,132	1,088
8	Waste Heat recovery option		Yes	Yes
9	Kiln Dimensions (Length X Width X Height)			
	Preheating Zone	m	39.9 x 0.8 x 3.6	46.2 x 0.8 x 3.6
	Firing Zone	m	52.5 x 0.8 x 3.6	44.1 x 0.8 x 3.6
	Rapid Cooling Zone	m	10.5 x 0.8 x 3.6	9.3 x 0.8 x 3.6
	Indirect cooling Zone	m	22.4 x 0.8 x 3.6	21.6 x 0.8 x 3.6
	Final cooling zone	m	36.8 x 0.8 x 3.6	35.5 x 0.8 x 3.6

3.1.2 FIELD MEASUREMENT AND ANALYSIS

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

Table 19: FGA study of kilns

Parameter	Kiln-1	Kiln-2
Oxygen Level measured in Flue Gas	5.18%	11.8%
Ambient Air Temperature	41°C	41°C
Exhaust Temperature of Flue Gas	135 °C	130 °C

From the above table, it is clear that the oxygen level measured in flue gas was high in Kiln-2. The inlet temperature of raw material in Kiln-1 was in the range of 42 °C whereas in Kiln-2 it was in the range of 42 °C.

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

Table 20: Surface temperature of kilns

Kiln Surface Temperatures (°C)	Kiln-1	Kiln-2
Ambient Temperature	41.0	41.0
Pre-heating zone average surface temperature	42.1	44.2
Heating zone average surface temperature	58.9	56.0
Rapid cooling zone average surface temperature	73.2	65.4
Indirect cooling zone average surface temperature	77.9	78.6
Final cooling zone average surface temperature	55.8	58.9

The temperature profile of the kilns is shown below:

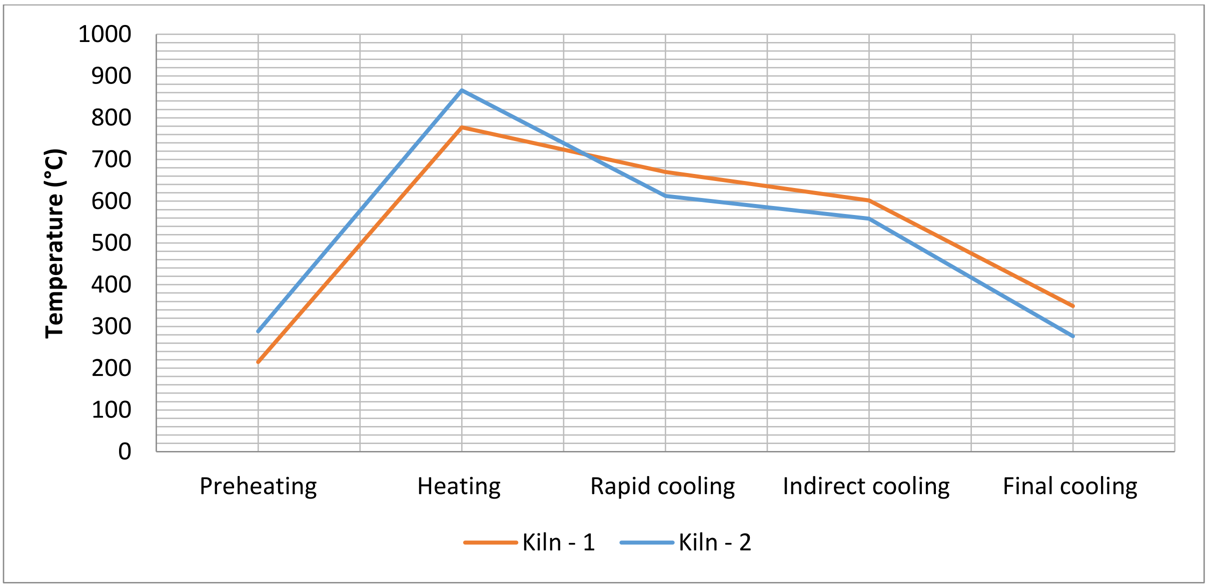


Figure 13: Temperature Profile of Kilns

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

Table 21: Power measurements of all blowers

Equipment	Kiln 1 Average Power (kW)	PF	Kiln 2 Average Power (kW)	PF
Final Cooling Blower	3.23	0.994	5.18	0.997
hot air Blower	2.42	0.989	5.29	0.991
Rapid Cooling Blower	1.46	0.994	1.86	0.996
Smoke Blower	3.63	0.996	3.66	0.990
Combustion Blower	3.38	0.995	4.72	0.998

3.1.3 Observations and Performance Assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln-1 is 61.8% and kiln-2 66.5%. Summary of all losses is shown in below figure:

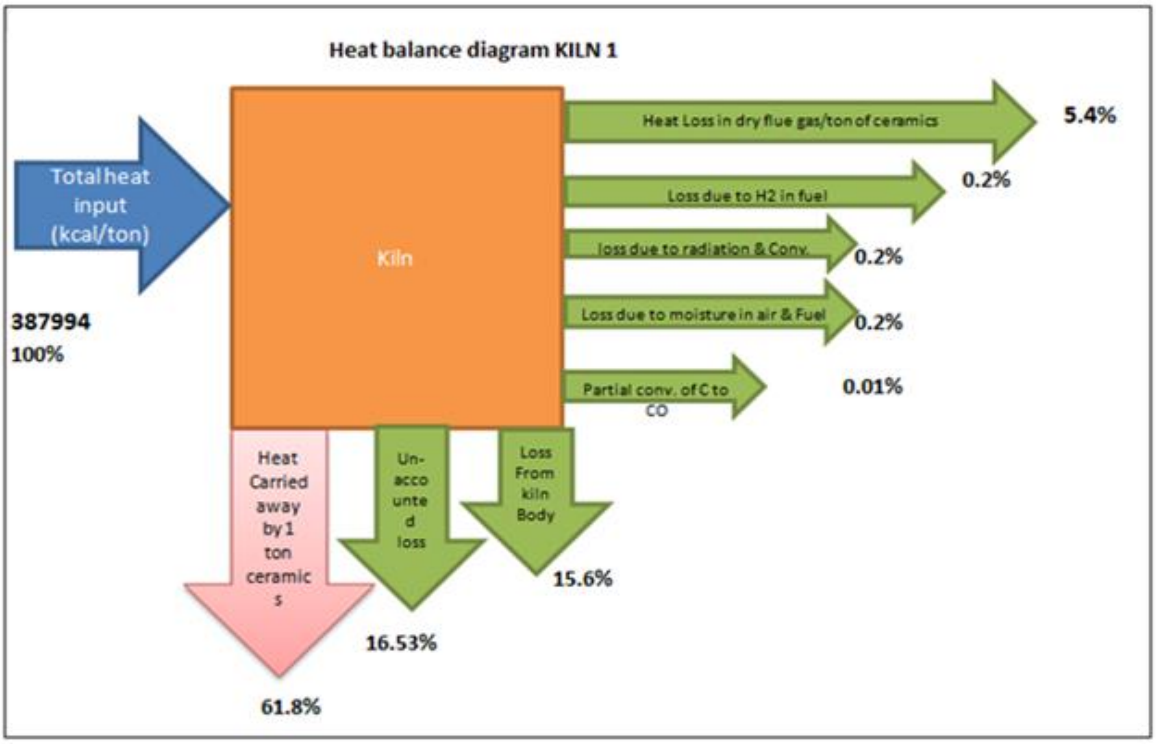


Figure 14: Heat Balance Diagram of Kiln-1

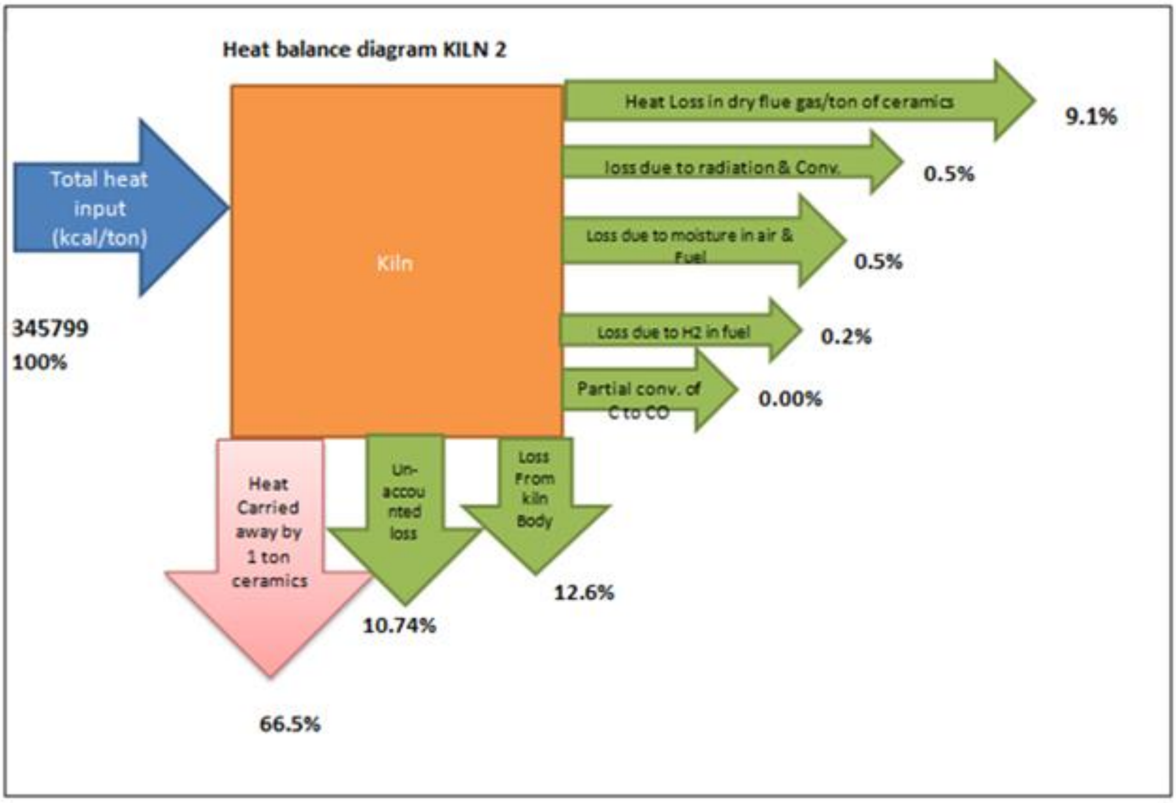


Figure 15: Heat Balance Diagram of Kiln-2

Detailed calculation is included in Annexure-5.

3.1.4 Energy Conservation Measures (ECM)

Energy conservation measures are described below:

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

Technology description

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

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

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

Study and investigation

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

Recommended action

Separate blowers for Kiln-1 and Kiln-2 have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. For **Kiln 1** oxygen level is 5.2% which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

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

Parameters	Unit	Present	Proposed
Oxygen level in flue gas just before firing zone	%	5.2	3.0
Excess air percentage in flue gas	%	32.7	16.7
Dry flue gas loss	%	5%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	43	42
Average production in Kiln	t/h	6.5	6.5
Saving in specific fuel consumption	scm/h		4.53
Operating hours per day	h/d		330
Annual operating days	d/y		24

Parameters	Unit	Present	Proposed
Annual fuel saving	scm/y		35,867
Fuel cost	Rs/scm		35
Annual fuel cost saving	Lakh Rs/y		12.6
Power saving in combustion blower			
Mass flow rate of air	t/h	4.70	4.13
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	1.1	0.9
Measured power of blower	kW	3.38	2.30
Total power saving	kW		1.09
Operating days per year	d/y		24
Operating hours per day	h/d		330
Annual energy saving	kWh/y	8,598	
Weighted electricity cost	Rs/kWh	7.31	
Annual energy cost saving	Lakh Rs/y	0.63	
Overall energy cost saving	Lakh Rs/y	13.23	
Estimated investment	Lakh Rs	18.48	
Payback period	Months	17	
IRR	%	50%	
Discounted Payback period	Months	6	

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

Technology description

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

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

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

Study and investigation

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

Recommended action

Separate blowers for Kiln-1 and Kiln-2 have been recommended for supplying combustion air and cooling air. It is proposed to install control system to regulate the supply of excess air for proper combustion. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. For **Kiln 2** oxygen level is 11.8% which is to be controlled. The cost benefit analysis of the energy conservation measure is given below:

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

Parameters	Unit	Present	Proposed
Oxygen level in flue gas just before firing zone	%	11.8	3.0
Excess air percentage in flue gas	%	128.9	16.7
Dry flue gas loss	%	9%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	38	34
Average production in Kiln	t/h	6.0	6.0
Saving in specific fuel consumption	scm/h		25.86
Operating hours per day	h/d		330
Annual operating days	d/y		24
Annual fuel saving	scm /y		204,838
Fuel cost	Rs/scm		35
Annual fuel cost saving	Lakh Rs/y		72.0
Power saving in combustion blower			
Mass flow rate of air	t/h	6.63	3.38
Density of air	kg/m3	1.23	1.23
Mass flow rate of air	m^3/s	1.5	0.8
Total pressure rise	Pa	2,412	2,412
Measured power of blower	kW	4.73	0.63
Total power saving	kW		4.10
Operating days per year	d/y		24
Operating hours per day	h/d		330
Annual energy saving	kWh/y	32,474	
Weighted electricity cost	Rs/kWh	7.31	
Annual energy cost saving	Lakh Rs/y	2.38	
Overall energy cost saving	Lakh Rs/y	74.34	
Estimated investment	Lakh Rs	18.48	
Payback period	Months	3	
IRR	%	303%	
Discounted Payback period	Months	1	

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

Technology description

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

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

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

Study and investigation

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

Recommended action

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

Table 24: Cost benefit analysis for hot face insulation in kiln 1 (ECM-3)

Parameter	Unit	Present	Proposed
No of un-insulated pipe in recuperator	#	24	24
Recuperator pipe size	m	0.08	0.08
Pipe length	m	1.2	1.2
Total surface area	m^2	6.79	6.79
Average surface temperature	°C	95	80
Ambient air temperature	°C	35	35
Heat loss	$kcal/h.m^2$	780	551
Total heat loss	kcal/h	5,294	3,741
GCV of fuel	kcal/scm	9,000	9,000
Heat loss in terms of fuel	scm/h	0.6	0.4
Fuel saving	scm/h		0.2
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	scm/y	1,366	
Fuel cost	Rs/scm	35.1	
Annual fuel cost saving	Rs Lakh/y	0.48	
Estimated investment	Rs Lakh	1.06	

Parameter	Unit	Present	Proposed
Payback period	Months	26	
IRR	%	24%	
Discounted Payback period	Months	10	

3.2 Dryers

3.2.1 Specifications

There is one vertical dryer which is in operation. Vertical dryer is being run with hot air from Kiln and NG as supplement. Preheating of biscuit is done in dryers before entering into kilns. The specifications of dryers are given below table:

Table 25: Specifications of vertical dryer

Particular	Units	Vertical dryer
Capacity	No of tiles/h	2,400
Fuel type		NG + Waste heat
Exit temperature of tiles	°C	135
FD Blower	kW	18.5
Hot Air Circulation blower	kW	5.5

3.2.2 Field measurement and analysis

During DEA, the following measurements were done:

a) Mass flow study (table below)
b) Temperature of each tile at exit (table below)

Data measured during study is tabulated below:

Table 26: Field measurement at site

Particular	Units	Vertical dryer
Tiles passed though dryer		2,400
Mass of each tile	g	1,500
Average surface temperature	°C	57
Gas consumption	scm/h	198

Hot air from both kilns is collected in an accumulator from where air is distributed to the dryer. All blowers are operating with VFDs.

3.2.3 Observation and Performance assessment

Mass and energy balance of vertical dryer could not be done since it was not feasible to measure volume of hot air being supplied to vertical dryer. Design data of vertical dryer was also not available with unit.

Based on observations during DEA, Specific thermal energy is 24.91 scm/ton of tile for vertical dryer. This is based on input of tiles from press to Vertical Dryer and gas consumption data (scm/h) is provided by unit.

Since all blowers are VFD controlled, hot air is utilized and operation is optimized.

3.2.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

3.2.4.1 Energy conservation measures (ECM) - ECM # 4– Use of hot air in dryer to reduce NG

Technology description

Dryer is used to preheat and remove moisture from the biscuit tile coming from press. It contains around 30% moisture which is to be reduced before entering to kiln. NG is used as a fuel in dryer.

Study and investigation

During field measurements, it was found that hot air coming out from both kilns leaving at temperature of 230°C, when NG is used as a fuel in dryer.

Recommended action

It is recommended to use of hot air in dryer to reduce NG consumption and reduce the temperature of hot air up to 180 °C. So heat content by hot air/flue gas will utilize to remove moisture.

Estimated cost benefit is given in the table below:

Table 27: Cost benefit analysis for use of hot air in dryer (ECM – 4)

Parameters	UOM	Present	Proposed
Mass of flue gas exiting from kiln	kg/h	10,868.8	10,868.8
Temperature of flue gas	°C	230.0	230.0
Temperature of flue gas after dryer	°C		180.0
Specific heat of flue gas	kcal/kg °C		0.22
Heat supplied by flue gas	kcal/h		119,557
Flow rate of NG in dryer	scm/h	198.0	184.7
GCV of NG	kcal/scm	9,000	9,000
Heat supplied by NG	kcal/h	1,782,000	1,662,443
Saving in fuel	scm/h		13.3
Operating hours per day	h/d	24.0	24.0
Annual operating days	d/y	330	330
Annual fuel saving	SCM/y		105,210
Fuel cost	Rs/SCM		35.1
Annual fuel cost saving	Rs Lakh/y		37.0
Estimated investment	Rs Lakh		6.0
Payback period	Months		1.9
IRR	%		456%
Discounted Payback period	Months		0.78

3.3 Hot Air Generator& Spray Dryer

3.3.1 Specifications

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

Table 28: Specifications of Hot air generator (HAG)

Particular	Units	Bubbling bed
Fuel type		Coal
Air handling capacity	m^3/h	-
Fuel consumption	kg/h	1445.0
Flue gas temperature	°C	740.0
FD Blower	kW	1 x 45
PA Fan	kW	2 x 5.5

The specification of spray dryer is given below:

Table 29: Specifications of spray dryer

Particular	Units	Value
Powder generation capacity	MT	-
Inlet slurry moisture	%	40
Outlet powder moisture	%	6
Hydraulic pump	kW	2x22

3.3.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

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

Details of measurements on HAG are given below:

Table 30: Field measurement at site

Particular	Units	Bubbling bed
Air velocity at FD fan suction	m/s	12.6
Suction area	m^2	0.25
Exit temperature of air	°C	750
Surface temperature	°C	97.3
Average power consumption-FD Blower	kW	44 (PF=0.99)
Average power consumption-ID Fan	kW	115 (PF=0.94)
Average power consumption-HAG PA fan	kW	7.7 (PF=0.99)

All blowers are operating with VFDs.

3.3.3 OBSERVATIONS AND PERFORMANCE ASSESSMENT

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

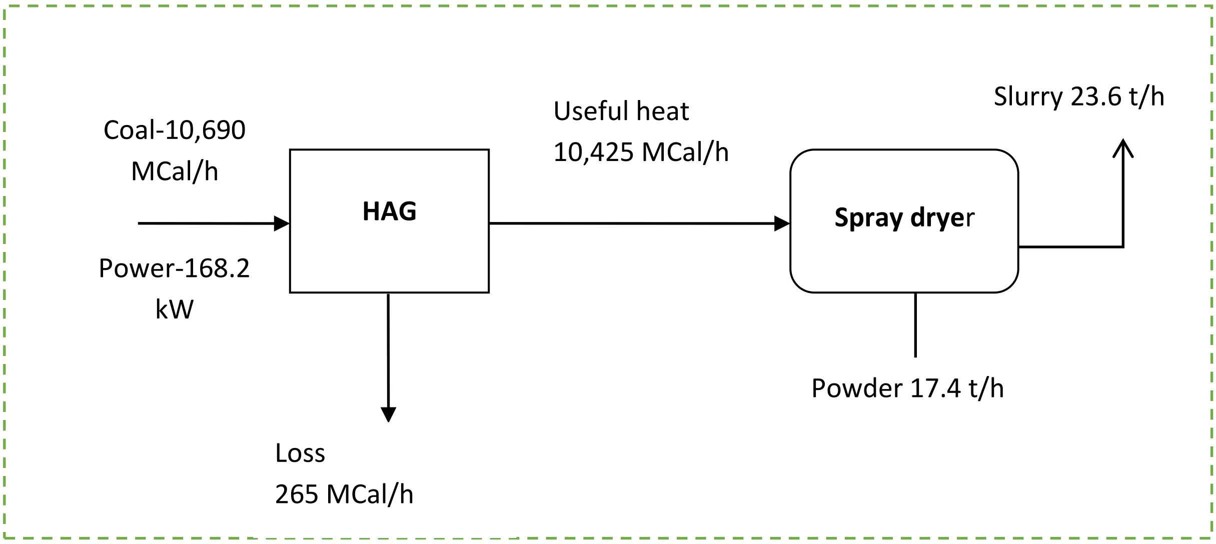


Figure 16: Energy and mass balance of Chain Stoker HAG and New spray dryer

Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for evaporating one kg water from slurry) and specific thermal energy measure (fuel used for evaporating 1 kg of water in slurry). Based on observations during DEA, the bubbling bed HAG corresponding values are 8.50 kW/ton and 260 kg of coal/ton.

Performance of spray dryer measures in terms of specific electricity consumption (electrical energy used for delivering one kg of powder). Based on observations during DEA, the specific electricity consumption of spray dryer was 6.62kW/ton. Since blowers are VFD controlled and operation is optimized.

3.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

3.3.4.1 Energy conservation measures (ECM) - ECM # 5– Insulation of HAG duct

Technology description

The HAG is used to generate the hot gas using coal as input fuel. The hot air produced is passed to cyclone separator and then used in spray dryer.

Study and investigation

During field measurements, it was found that the insulation of HAG duct connecting to cyclone separator was poor which results in increased heat loss leading to increase in coal consumption.

Recommended action

It is recommended to insulate the HAG duct connecting cyclone separator.

Estimated cost benefit is given in the table below:

Table 31: Saving and cost benefit by Insulating HAG duct (ECM-5)

Particulars	Unit	Present	Proposed
Location of HAG		Connecting duct to Cyclone separator	
Total surface area	m^2	4.71	4.71
Average surface temperature	°C	200	90

Ambient air temperature	°C	35	35
Heat loss	kcal/h/m^2	3,011	701
Total heat loss	kcal/h	14,190	3,305
GCV of coal	kcal/kg	6,681	6,681
Heat loss in terms of coal	kg/h	2.1	0.5
Fuel saving	kg/h		1.6
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	t/y	13	
Fuel cost	Rs/t	3,800	
Annual fuel cost saving	Rs Lakh/y	0.49	
Estimated investment	Rs Lakh	0.33	
Payback period	Months	8	
IRR	%	111%	
Discounted Payback period	Months	3	

4 CHAPTER – 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 BALL MILLS

4.1.1 Specifications

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

Table 32: Specifications of ball mills

Particular	Units	Value
Numbers of ball mills	#	2
Capacity of each ball mill	t/batch	40
Water consumption in each ball mill	t/batch	14.5
SMS (chemical consumption)	kg/batch	50
Soda (chemical consumption)	kg/batch	100
Silicate	kg/batch	100
Agar	kg/batch	1000
Water TDS	ppm	1100
Nos. of batch per day		11
Power consumption	kW	160

4.1.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done: Power consumption of all ball mills and mass consumption as per Table 32. Average power consumption and power factor are given in below table:

Table 33: Average power consumption and PF of ball mills

Equipment	Average Power (kW)	PF
Ball Mill#1	103.47	0.93
Ball Mill#2	115.4	0.94

4.1.3 OBSERVATIONS AND PERFORMANCE ASSESSMENT

Mass balance of Ball mills based on measurements for Ball Mill#1 and Ball Mill#2 is given below:

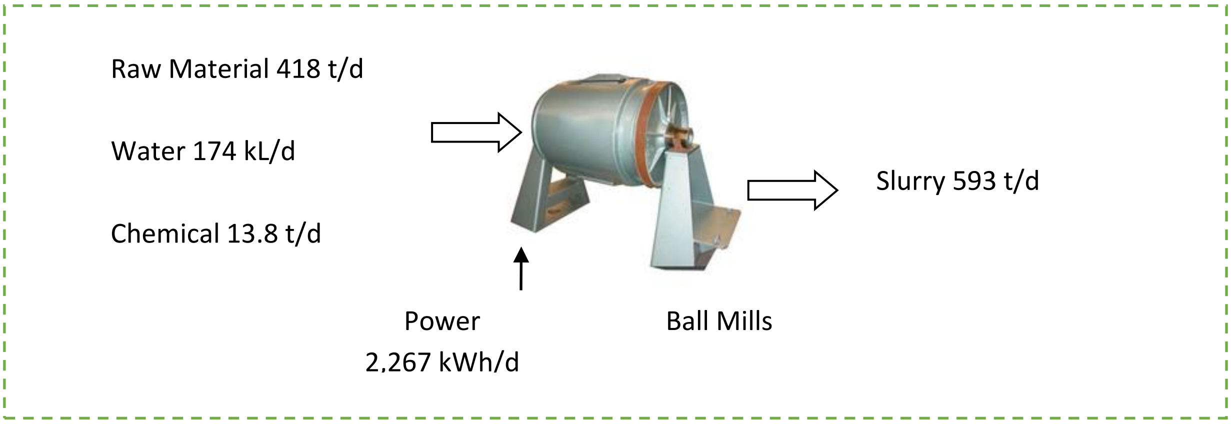


Figure 17: Energy and mass balance of Ball Mills

Performance of ball mills measure in terms of specific energy consumption (power consumed for preparation of 1 ton of slurry). Based on observations during DEA, the specific energy consumption of ball mills was 4.42kW/ton. TDS of bore well water is very high; this should be controlled by installing softener plant, which will enable resource savings.

4.1.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.1.4.1 Energy conservation measures (ECM) - ECM # 6 –Optimized Resource Consumption in Clay Section

Technology description

It was observed that the TDS of water used in clay section is 1,100 ppm, which results in higher consumption of water, chemicals and electricity per batch of slurry preparation and later higher coal consumption for spray dryer.

Study and investigation

All the details of the composition of raw materials per batch, water consumption per batch and electricity consumption per batch were collected for analysis and proposed solution for resource conservation.

Recommended action

It is recommended to install brackish water plant which will blend RO water with raw water to get desired TDS of water(less than 400ppm) to be used in ball mill. Resource saving has been considered for water, chemicals, coal and power consumption to arrive at techno economics of the proposed energy conservation measure. Coal consumption will be reduced due to reduced quantity of water to be evaporated in spray dryer.

Estimated cost benefit is given in the table below:

Table 34: Saving and cost benefit by using improved water quality [ECM-6]

Particulars	Unit	Present	Proposed
TDS of Water	ppm	1100	400
Assumption : Water Saving			15%
Assumption : Electricity Saving			3%
Assumption : Fuel Saving			30%
Assumption : Chemical Saving			30%
Water used per batch	m^3	14.50	12.33
Water saving	m^3		2.18
Electricity used per batch	kWh	103.47	100.37
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kcal/kg	6,681	6,681
Eff. Of HAG	%	85%	85%
Coal saving per batch	kg		236
Chemical saving per batch			
SMS	kg	150	105
STPP		50	35
Per Unit Cost			
Water	Rs./m^3	5.00	5.00
Electricity	Rs/kWh	7.31	7.31

Particulars	Unit	Present	Proposed
Coal	Rs/kg	3.80	3.80
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		3,194
Total batches per day	#	12	12
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		8,613.0
Electricity	kWh/y		12,293
Coal	t/y		932.76
Chemical	kg/y		237,600.00
Annual cost savings	Lakh Rs/y		126.47
Operating cost- Water Treatment	Rs/m^3		20.00
	Lakh Rs/y		9.76
Net monetary savings	Lakh Rs/y		116.71
Estimated investment	Lakh Rs		39.60
Payback period	Months		4
IRR	%	225%	
Discounted Payback period	Months	2	

4.2 HYDRAULIC PRESSES

4.2.1 Specifications

There are 2 hydraulic presses. Hydraulic presses give shape for powder that is coming from spray dryer in tiles form by pressing powder with high pressure (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 35: Specifications of hydraulic press

Particular	Units	Press 2
Cycle (stock) per minute	N/m	10
Nos. of tiles per stock		4
Tile size	mm × mm	300 × 600
Tile thickness	mm	9
Tiles weight	kg	1.5
Power rating	kW	77.2
Water Circulation Pump	#	1

Press -1 was not in operating during DEA and specifications are not available.

4.2.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

- Power consumption of presses and water circulation pumps
- Count of tiles processed

Average power consumption of press 2 was 75.5 kW (PF 0.83) and Press 1 was not in operation during DEA. Water circulation pumps were consuming power as 6.25 kW.

4.2.3 Observation and performance assessment

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

Performances of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press was 8.48kW/ton.

4.2.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.2.4.1 Energy conservation measures (ECM) - ECM # 7 – Interlocking oil circulation pump with press operation

Technology description

Oil is used as a lubricant for proper functioning of hydraulic press. Oil gets heated due to continuous operation of press. Oil is cooled in a heat exchanger using cold water. For circulation of oil, circulating pumps are used

Study and investigation

During field measurements, it was found that oil circulation pump are in continuous operation instead of hydraulic press was not in operation.

Recommended action

It is recommended to interlock oil circulation pump with hydraulic press operation, so that pump will work only when press will in operation. This will reduce in oil circulation operating time and saves in energy. The cost benefit analysis is given below:

Table 36 : Cost benefit analysis of interlocking of pump with press operation (ECM- 7)

Parameters	UOM	Present	Proposed
Rated power of pump	kW	5.5	5.5
Measured power of pump	kW	6.25	6.25
Running hours of pump	h/d	24	18
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	49,500	37,125
Annual energy saving	kWh/y		12,375
Weighted electricity cost	Rs/kWh	7.31	7.31
Annual energy cost saving	Rs Lakh		0.91
Estimated investment	Rs Lakh		0.20
Simple payback period	months		3
IRR	%		340%
Discounted Payback period	Months		1.05

4.3 AGITATOR

4.3.1 Specifications

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

Table 37: Specifications of agitators

Particular	Units	Value
Numbers of agitators in tank	#	20
Capacity of each agitator motor	kW	5.5
Number of motors	#	20

4.3.2 FIELD MEASUREMENT AND ANALYSIS

During DEA, the following measurements were done:

- Power consumption of all agitator motors

Power consumption and P.F. of all agitator motors (stirrer) are given in below table:

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

Equipment	kW	PF
Agitator Stirrer motor-6	3.65	0.75
Agitator Stirrer motor-8	3.5	0.72
Agitator Stirrer motor-9	3.52	0.74
Agitator Stirrer motor-11	2.52	0.61
Agitator Stirrer motor-12	2.96	0.68
Agitator Stirrer motor-13	3.15	0.61
Agitator Stirrer motor-14	1.15	0.78
Agitator Stirrer motor-15	3.59	0.52

The other agitator stirrer motors (12 nos.) are not in operation during DEA.

4.3.3 OBSERVATIONS AND PERFORMANCE ASSESSMENT

Based on measurement it can be seen that power factor of agitator motor is in the range of 0.52-0.78. There is timer controller installed for each motor having time interval of 40 minutes.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry). Based on observations during DEA, the specific energy consumption of agitator motors were 0.48kW/ton.

4.4 GLAZING

4.4.1 Specifications

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

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

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

The specifications of glazing mills are given below:

Table 39: Specifications of glazing machine

Particular	Units	Glaze mill
Numbers of glazing mills	Nos.	6
Capacity of glaze mill 1	Ton/batch	3
Capacity of glaze mill 2	Ton/batch	3
Capacity of glaze mill 3	Ton/batch	3
Capacity of glaze mill 4	Ton/batch	1.5
Capacity of glaze mill 5	Ton/batch	0.5
Capacity of glaze mill 6	Ton/batch	0.1
Power consumption of mill 1	kW	22
Power consumption of mill 2	kW	22
Power consumption of mill 3	kW	30
Power consumption of mill 4	kW	22
Power consumption of mill 5	kW	5.5
Power consumption of mill 6	kW	2.2

4.4.2 Field Measurement and Analysis

During DEA, the following measurements were done:

- Power consumption of four glaze mills which were in operation.
- Mass consumption (t/batch) is as per Table 39.

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

Table 40: Power consumption and P.F. of glaze mills

Equipment	kW	PF
Glaze mill 2	25.15	0.8
Glaze mill 3	20.7	0.8
Glaze mill 4	10.3	0.57
Glaze mill 5	4.21	0.58

4.4.3 Observations and Performance Assessment

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 11.6kW/ton.

4.5 Sizing

4.5.1 Specifications

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

Table 41: Specifications of sizing machine

Particular	Units	New sizing
Numbers of sizing machines	Nos.	4
Sizing Machine 1	kW	90.6
Sizing Machine 2	kW	70
Sizing Machine 3	kW	70
Sizing Machine 4	kW	70
Sizing line 1 – Conveyors	kW	6
Sizing line 2 – Conveyors	kW	6

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

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

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

Table 42 : Measured Parameters of sizing machine

Equipment	Unit	Value	PF
Average Power (M/c#1)	kW	13.8	0.92
Average Power (M/c#2)	kW	17.9	0.51
Average Power (M/c#3)	kW	17.5	0.55
Average Power (M/c#4)	kW	15.3	0.49

4.5.3 Observation and performance assessment

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

Table 43 : SEC of sizing machine

Equipment	Unit	Value
Sizing Machine # 1	kW/t	2.30
Sizing Machine # 2	kW/t	3.00
Sizing Machine # 3	kW/t	2.92
Sizing Machine # 4	kW/t	2.55

4.6 Air Compressors

4.6.1 Specifications

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

Table 44: Specifications of compressors

Particular	Units	Air compressor 1	Air compressor 2
Power rating	kW	22	22
Maximum pressure	Bar (a)	7	7

Particular	Units	Air compressor 1	Air compressor 2
Rated Capacity	m^3/min	3.85	3.85

All compressors have a common receiver.

4.6.2 Field Measurement and Analysis

During DEA, the following measurements were done:

- Power consumption of all compressor
- Loading and unloading time

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

Table 45: Measured parameters of Compressors

Equipment	Average Power (kW)	PF	% of time on load	Air flow rate (m^3/min)
Compressor-1	15.6	0.73	87	Not possible to measure
Compressor-2	25.92	0.87	69	

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

4.6.3 Observation and Performance Assessment

Based on observations during DEA, it was observed that operating pressure was higher in both the compressors which can be reduced as per requirement. VFD installation is recommended for compressor 2 to avoid power consumption during unloading.

4.6.4 Energy Conservation Measures (ECM)

The energy conservation measures recommended are:

4.6.4.1 Energy conservation measures (ECM) - ECM #8 Operational pressure optimization in compressor

Technology description

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

Study and investigation

It was observed during the energy audit that the cut-in pressure was 6.3 kg/cm^2 and cut-out pressure was 7.3 kg/cm^2. Both compressors were running in unload/load condition.

Recommended action

As very high pressure compressed air is not necessary in the process area. it is recommended that the existing cut-out pressure setting of 7.3 kg/cm^2 be lowered to 6 kg/cm2 which will reduce the energy consumption by 6% (approx).

The cost benefit analysis is given in the table below:

Table 46: Cost benefit analysis for pressure reduction in compressor 1 & 2 (ECM-8)

Parameter	Unit	Present	Proposed	Present	Proposed
		For compressor 1		For compressor 2	
Operating pressure required	kg/cm²	4	4	4	4
Compressor loading pressure	kg/cm²	6.3	5	6.3	5
Compressor unloading pressure	kg/cm²	7.3	6	7.3	6
Reduction in pressure	kg/cm²	-	1.3	-	1.3
% of energy saving	%	-	8%	-	8%
Average load	kW	15.6	14.3	25.92	23.90
Operating hours/day	h/d	24	24	24	24
Operating days/year	d/y	330	330	330	330
Annual energy consumption	kWh/y	123,564	113,926	205,296	189,283
Annual energy savings	kWh/y		9,638		16,013
Unit cost of electricity	Rs/kWh		7.31		7.31
Annual monetary saving	Lakh Rs/y		0.70		1.17
Estimated Investment	Lakh Rs		Nil		Nil
Payback period	Months		Immediate		Immediate
IRR	%		Nil		Nil
Discounted Payback period	Months		Nil		Nil

4.6.4.2 Energy conservation measures (ECM) - ECM #9: Retrofit 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 1/4th 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 31% 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 47: Cost benefit analysis for retrofit of VFD on compressor - 2 (ECM-9)

Parameters	Unit	Present	Proposed
Compressor motor rating	kW	22	22
Average power consumption during loading	kW	26.3	-
Average power consumption during unloading	kW	10.0	-
Total running hours	h	9,018	
Total loading hours	h	6,260	
Total unloading hours	h	2,758	
On load time in percentage	%	69.42%	-
Off load time in percentage	%	30.58%	-
Average power consumption	kW	21.34	18.14
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	169,034	143,679
Annual energy saving	kWh/y		25,355
Unit cost of electricity	Rs/kWh		7.31
Annual monetary savings	Lakh Rs/y		1.85
Estimated Investment	Lakh Rs		1.98
Payback period	Months		13
IRR	%		67%
Discounted Payback period	Months		5

4.7 Water Pumping System

4.7.1 Specifications

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

4.7.2 Field measurement and analysis

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

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

Power measured for pump 1 is given in below table:

Table 48: Operating details of pump

Particulars	Unit	Pump 1
Actual power consumption	kW	6.25
Power factor		0.8

4.8 Lighting System

4.8.1 Specifications

The plant's lighting system includes:

Table 49: Specifications of lighting load

Particular	Units	T-8	T-12	CFL	CFL	CFL	MH	MH
Power consumption per fixture	W	36	40	65	85	36	250	400
Numbers of fixtures	#	148	11	34	9	83	2	3

4.8.2 Field measurement and analysis

During DEA, the following measurements were done by recording inventory and lux levels. Measured values are summarized below:

Table 50: Lux measurement at site

Particular	Measured Value Lumen/m^2	Particular	Measured Value Lumen/m^2
Office	180	Ball mill and agitators	83
Kiln control room	110	HAG and spray dryer new	80
Kiln area	90	Glaze line	112
Press	110	Sizing Machine	90
Inventory	90	Glaze ball mill	85

4.8.3 Observations and performance assessment

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

4.8.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.8.4.1 Energy conservation measures (ECM) - ECM #10: Energy Efficient Lighting

Technology description

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

Study and investigation

Most of the installed luminaries are of conventional type.

Recommended action

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

Table 51 : Cost benefit analysis for lighting replacement (ECM 10)

Parameter	Unit	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
fixture		T8	20 W LED	T12	20 W LED	65 W CFL	36 W LED	85 W CFL	36 W LED	36 W CFL	18 W LED	250 W MH	100 W LED	400 W MH	200 W LED
Type of choke		Magnetic	Driver	Magnetic	Driver							Magnetic	Driver	Magnetic	Driver
Number of fixtures	#	148	148	11	11	34	34	9	9	83	83	2	2	3	3
Rated power of fixture	W/ Unit	36	20	40	20	65	36	85	36	36	18	250	100	400	200
Consumption of choke	W	12	0	12	0	0	0	0	0	0	0	30	0	35	0
Operating power	W/ fixture	48	20	52	20	65	36	85	36	36	18	280	100	435	200
Operating hours/day	h/d	20	20	20	20	20	20	18	18	20	20	20	20	20	20
Operating days/year	d/y	330	330	330	330	330	330	330	330	330	330	330	330	330	330
Annual energy consumption	kWh/y	46,886	19,536	3,775	1,452	14,586	8,078	4,544	1,925	19,721	9,860	3,696	1,320	8,613	3,960
Annual energy saving	kWh/y		27,350		2,323		6,508		2,620		9,860		2,376		4,653
Total annual energy saving	kWh/y	55,690													
Unit cost of electricity	Rs/ kWh	7.31													
Annual monetary savings	Lakh Rs/y	4.07													
Estimated Investment	Lakh Rs	2.52													
Pay back period	Months	7													
IRR	%	121%													
Discounted Payback period	Months	3													

4.9 Electrical Distribution System

4.9.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415 V) by step down transformer (2.00 MVA). Automatic power factor correction system is installed in parallel to main supply. There were three DGs (capacity of 1 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeders which are shown in single line diagram in Figure 20.

4.9.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.9.3 Observations and performance assessment

After analyzing feeder power profiling, it was observed that the maximum kVA recorded during study period was **1,193 kVA** at main incomer.

The voltage profile of the unit was satisfactory and average voltage measured was **424 V.** Maximum voltage was **436.7 V** and minimum was **411 V**.

Average total voltage and current harmonics distortion found **6.9%** & **12.82%** respectively during power profile recording.

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

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

4.9.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.9.4.1 Energy conservation measures (ECM) - ECM #11: Main LT Voltage Optimization

Technology description

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

Study and investigation

During field measurements, it was found that the present voltage was higher than the standard voltage which is 415V. According to the main LT Power Profiling, maximum voltage was 436.7 V & average voltage is 411 V found.

Recommended action

A 1.7 MVA servo stabilizer is suggested to install on main LT panel to optimize voltage. Servo stabilizer rating is suggested according to Electricity monthly billing demand. The cost benefit analysis for this project is given below:

Table 52: Cost Benefit analysis of main LT Optimization [ECM-11]

Particulars	Unit	Present	Proposed
Maximum load (Measured)	kW	1,183	1,183
	kVA	1,194	1,194
Maximum demand as per electricity bill	kVA	1,100	1,100
Maximum voltage		437	415
Average voltage	V	425	410
Reduction in Voltage	%		3.5%
% reduction in energy consumption	%		6.79%
Average power factor of system	PF	0.98	0.98
Annual electricity consumption	kWh/y	5,895,480	5,895,480
Savings Estimate from other EPIAs	kWh/y		297,557
Actual energy considered for voltage regulation	kWh/y		5,597,923
Actual energy consumption after voltage regulation	kWh/y		5,217,566
Efficiency of servo stabilizer	%		95%
Period for which voltage regulation is required	Months/y		8
Net saving from voltage regulation	kWh/y		240,893
Unit cost of electricity	Rs/kWh		7.31
Annual monetary saving	Lakh Rs/y		17.62
Sizing of servo stabilizer	kVA		1,288
Rating of servo stablizer	kVA		1,700
Estimated investment	Lakh Rs		19.8
Payback period	Months		13
IRR	%		63%
Discounted Payback period	Months		**5**

4.9.4.2 Energy conservation measures (ECM) - ECM #12: Cable loss minimization

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted that in sizing section power factor was between 0.59-0.70.

Recommended action

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

Table 53 : Cost benefit analysis of cable loss minimization (ECM -12)

Particulars	Unit	Sizing Machine 1 (Section 2)	Sizing Machine 2 (Section 1)	Sizing Machine 2 (Section 2)
Existing Power Factor	PF	0.51	0.55	0.49
Proposed Power Factor	PF	0.99	0.99	0.99
Existing load	kW	18.0	17.5	15.3
Cable Losses	W	361.5	267	285.4
Capacitor Required	kVAr	28	24	25
Annual Energy Saving	kWh/y	2,863	2,115	2,261
Savings Estimated	Rs Lakh/y	0.20	0.14	0.15
Total Savings	Rs Lakh/y	0.53		
Investment	Rs Lakh	0.36		
Simple Payback Period	Months	8		
IRR	%	115%		
Discounted Payback period	Months	3		

4.10 Belt Operated Drives

4.10.1 Specifications

There are 14 drives operated with V Belt of total capacity of 447 kW. Locations include

- Kiln 1 have 7 blowers
- Kiln 2 have 7 blowers

4.10.2 Field measurement and analysis

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

4.10.3 Observations and performance assessment

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

4.10.4 Energy conservation measures (ECM)

The energy conservation measures recommended are:

4.10.4.1 Energy conservation measures (ECM) - ECM #13: V Belt replacement with REC belt

Technology description

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

Benefits of Cogged belts & Pulley over V belts:

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

Study and investigation

The unit is having about 14 belt driven blowers in plant

Recommended action

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

Table 54: Cost benefit analysis of replacement of conventional belt with REC belt [ECM-13]

Parameters	Unit	Present	Proposed
Measured power of all belt driven blowers	kW	42	40
Running hours of blowers	h/d	24	24
Average power of blowers	kWh/d	1,008.1	971.8
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	332,685	320,709
Annual energy saving	kWh/y		11,977
Weighted electricity cost	Rs/kWh	7.31	7.31
Annual energy cost saving	Rs Lakh		0.88
Estimated investment	Rs Lakh		1.85
Simple payback period	months		25
IRR	%		28%
Discounted Payback period	Months		9

5 CHAPTER – 5 ENERGY CONSUMPTION MONITORING

5.1 Energy Consumption Monitoring

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

5.1.1 Energy conservation measures (ECM) - ECM#14: Energy Monitoring System

Technology description

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

Study and investigation

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

Recommended action

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

Table 55: Cost benefit analysis for energy monitoring system (ECM-14)

Parameters	Unit	Present	Proposed
Energy monitoring saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	5,895,480	5,777,570
Annual electricity saving per year	kWh/y		117,910
Cost of Electricity	Rs/kWh		7.31
Annual monetary savings	Lakh Rs/y		8.62
Number of equipments/system	#	46	46
No. of energy meters	#	0	46
Estimated investment	Lakh Rs		4.59
Thermal energy monitoring system	%	2.00	
Current coal consumption in HAG	kg/y	13,820,000	13,543,600
Annual coal saving per year	kg/y		276,400
Cost of Coal	Rs/kg		3.80
Annual NG consumption in kiln	SCM/y	4,385,672	4,297,959
Annual fuel saving	SCM/y		87,713
Average NG cost	Rs/SCM		35.13
Total annual monetary savings	Lakh Rs/y		41.32

Parameters	Unit	Present	Proposed
Number of equipments/system	#	3	3
Number of coal weighing machines			1
Number of NG Meters			3
Estimated investment	Lakh Rs		1.42
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		49.94
Estimated (Electrical + Thermal)	Lakh Rs		6.01
Payback period	Months		1
IRR	%		614%
Discounted Payback period	Months		1

5.2 Best Operating Practices

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

Table 56: Unique Operating practices

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Ball mill	VFD for energy saving. Timer control system. Alumina balls are used in ball mills
3	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing pollution
3	Press	PRV installed for usage of compressed air
5	VT Dryer	Waste heat from kiln is used in VT dryer.
6	Glaze ball mill	Timer control in each ball mill. Alumina balls are used in glaze ball mills
7	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
8	Sizing	Fully automatic system. Dust collected system installed.
9	Printing	Automated digital printing with fully auto control system
10	Lighting	LED lights in a few locations

5.3 New/Emerging Technologies

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

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

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

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

Table 57 : Specifications of dry clay grinding technology

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

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

The working principle is as follows:

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

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

[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

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 120ºC to 250 ºC (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 250ºC. Final cooling air is also retrieved for use as combustion air, where the air is filtered and sent to combustion air fan before being heated via a heat exchanger in the fast cooling zone reaching temperature up to 250 ºC depending upon the product and kiln temperature.

Figure 18 : 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 ºC 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

[3] SACMI Kiln Revamping catalogue for roller kilns

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

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

Figure 19: NG consumption monitoring kit

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

[4] SACMI Kiln Revamping catalogue for roller kilns

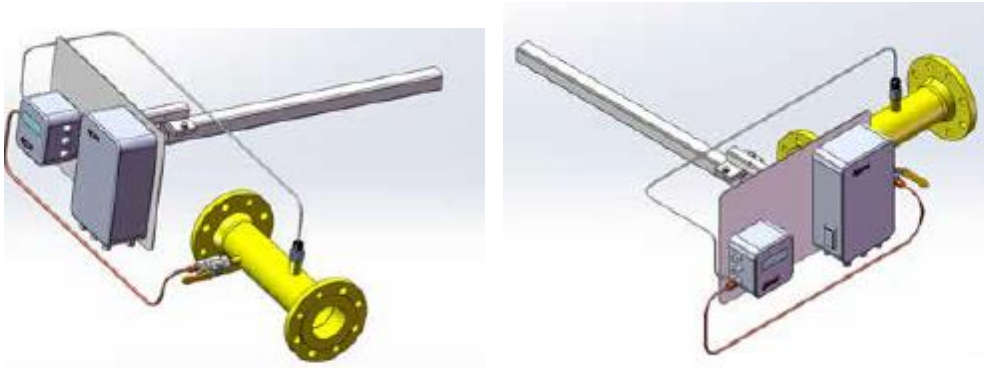


Figure 20: Combustion air control for burner

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

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

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

Figure 21: Heat recovery from kiln to dryer

6. **Fast Cooling Management:** This retrofit intervention involves modification of the fast cooling duct by separating the upper and lower circuit with motorized control valve which can be controlled from operator panel. Further modification to the duct can allow the creation of two separate fast cooling zones. Each zone has a general motorized valve which is controlled by a thermocouple; it also has a motorized valve with position control for both upper and lower channel separately. To complete the system, an inverter is fitted on fan drive motor and a pressure transducer is fitted on the main duct. All regulators and valves are controlled via operator panel. The advantages of the system include:
    - Complete control
    - Parameters can be changed / set as per RM recipe
    - Volume control in case of gap in production
    - Flow control via fan inverter
    - Adjustment flexibility in upper and lower roller bed

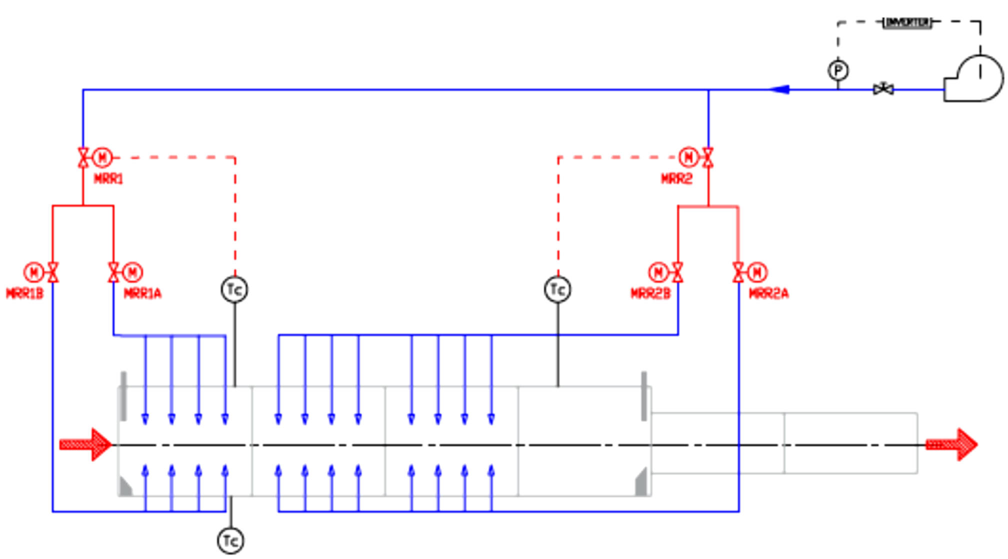


Figure 22: Fast cooling air management

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

Figure 23: Real time information system 4.0

The advantages of the system are:
- Production and consumption data can be shared with company management system
- Coordinated automation to plan production
- Remote/Tele-assistance system
- Productivity and plant problem analysis

5.3.4 High Alumina Pebbles for Ball Mills:

Ball mills performance is greatly affected by quantity and quality of grinding balls / Pebbles used. There are different qualities of pebbles used in Morbi cluster:

a. Local pebbles from river
b. Imported pebbles from China
c. High Alumina Pebbles from EU

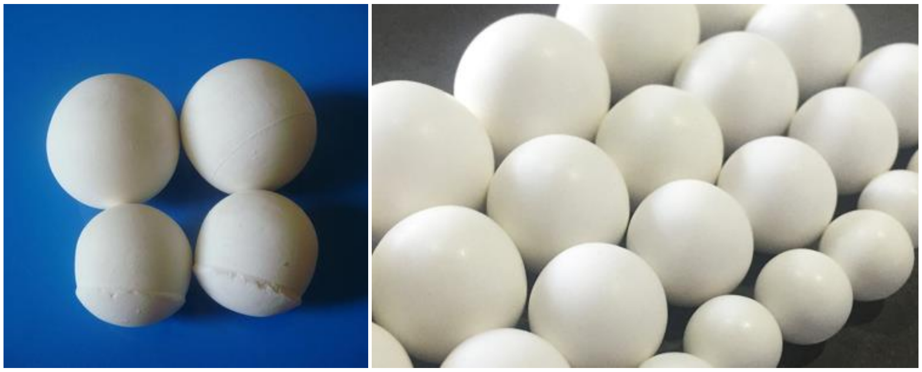


Figure 24: - High Alumina pebbles for Ball mill

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

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

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

In the tile manufacturing process different raw materials which include one or more clays are mixed in specific Ratio (Clay Body). Clay body is subjected to wet grinding in a ball mill to get required density and viscosity. For efficient grinding, inorganic dispersants like STPP, SHMP or sodium silicate are used. These can be replaced either partially or fully by organic deflocculant (Brand name FLOSPERSE[5]) to save fuel cost during spray drying. Slip is stored in tanks which will be sieved for sending to spray drying.

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

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

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

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

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

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

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

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

- 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.

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

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

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

5.3.7 Use of Direct blower fans instead of belt drive:

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

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

Figure 25: Direct drive blower fan

6 CHAPTER – 6 RENEWABLE ENERGY APPLICATIONS

The roof top PV potential is estimated as 50 kW. Cost benefit analysis is given below:

6.1 ENERGY CONSERVATION MEASURES (ECM) - ECM#15: 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 500 m^2 of area is available on the roof top for installation of solar PV panels.

Recommended action

It is recommended to install 50 kW solar panel capacities. The average electricity generation is estimated at 87,600kWh/y. The cost benefit analysis is given below:

Table 58: Cost benefit analysis for installing solar PV system (ECM 15)

Parameters	Unit	Present	Proposed
Available area on roof	m^2	500	
Capacity of solar panel	kW		50
Energy generation from solar panel	kWh/day		240
Solar radiation day per year	d/y		365
Average electricity generation per year	kWh/y		87,600
Electricity Cost	Rs/kWh		7.31
Annual monetary savings	lakh Rs/Y		6.41
Estimate of Investment	Lakh Rs		26.0
Payback Period	Months		49
IRR	%		1%
Discounted payback period	Months		17.14

6 CHAPTER – 7 ANNEXES

ANNEX-1: PROCESS FLOW DIAGRAM

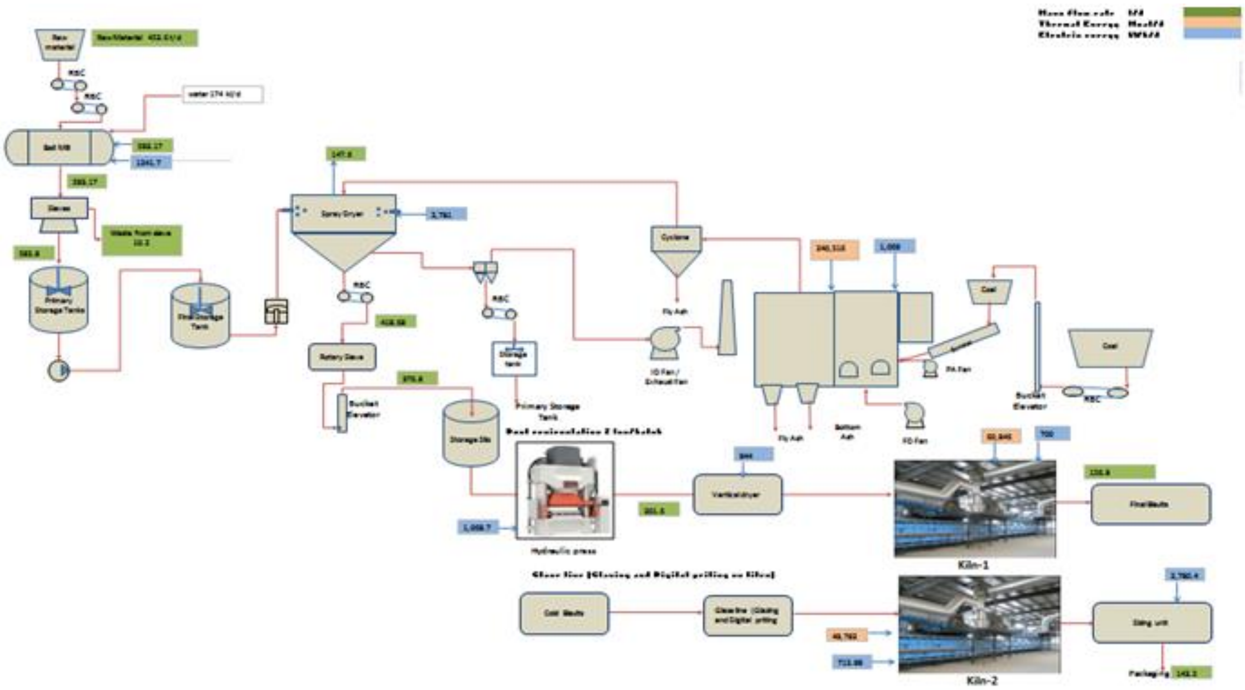


Figure 26: Process Flow Diagram of Plant

ANNEX-2: DETAILED INVENTORY

Equipment	Connected Load	Rating (kW)
Ball Mill	Ball mill 1	168
	Ball mill 2	168
	Weighting machine	7.5
	Conveyer	6
	Mud Pump	7.6
Agitator Tank	Stirrer-1	5.5
	Stirrer-2	5.5
	Stirrer-3	5.5
	Stirrer-4	5.5
	Stirrer-5	5.5
	Stirrer-6	5.5
	Stirrer-7	5.5
	Stirrer-8	5.5
	Stirrer-9	5.5
	Stirrer-10	5.5
	Stirrer-11	5.5
	Stirrer-12	5.5
	Stirrer-13	5.5
	Stirrer-14	5.5
	Stirrer-15	5.5
	Stirrer-16	5.5
	Stirrer-17	5.5
	Stirrer-18	5.5
Final Tank	Stirrer-1	5.5
	Stirrer-2	5.5
Spray Dryer	Hydraulic pump-1	22.0
	Hydraulic pump-1 (S/B)	22.0
	ID fan	140.0
	Cyclone	0.7
	Conveyer	81.7
Hot Air Generator	PA Fan	11.0
	FD Fan	45.0
	Varam	3.7
	Coal Conveyer	1.5
	Coal elevator	1.5
Press	Press-1	98
	Press-2	77.2
Cooling Tower	Pump	11.18
VT Dryer/HZ dryer	Blower-1	37
	Blower-2	3.5
	Blower-3	5.5
	Conveyer	39.52
Printing	Printing	18.74
Kiln	Kiln-1	231.1

Equipment	Connected Load	Rating (kW)
	Kiln-2	261.19
Sizing line	sizing machine 1	90.6
	sizing machine 2	70
	sizing machine 3	70
	sizing machine 4	70
	sizing line 1	5.99
	sizing line 2	5.99
Glaze line	Stirrer	22.753
	Vibrator	8.952
	Ball mill 3 ton	149.2
Glaze ball mill	Ball mill 2 ton	22.38
	Ball mill 1 ton	14.92
	Ball mill 100kg	2.238
	china clay tank	7.46
	Storage Tanks	11.19
	Lighting	180.0011

ANNEX-3: SINGLE LINE DIAGRAM

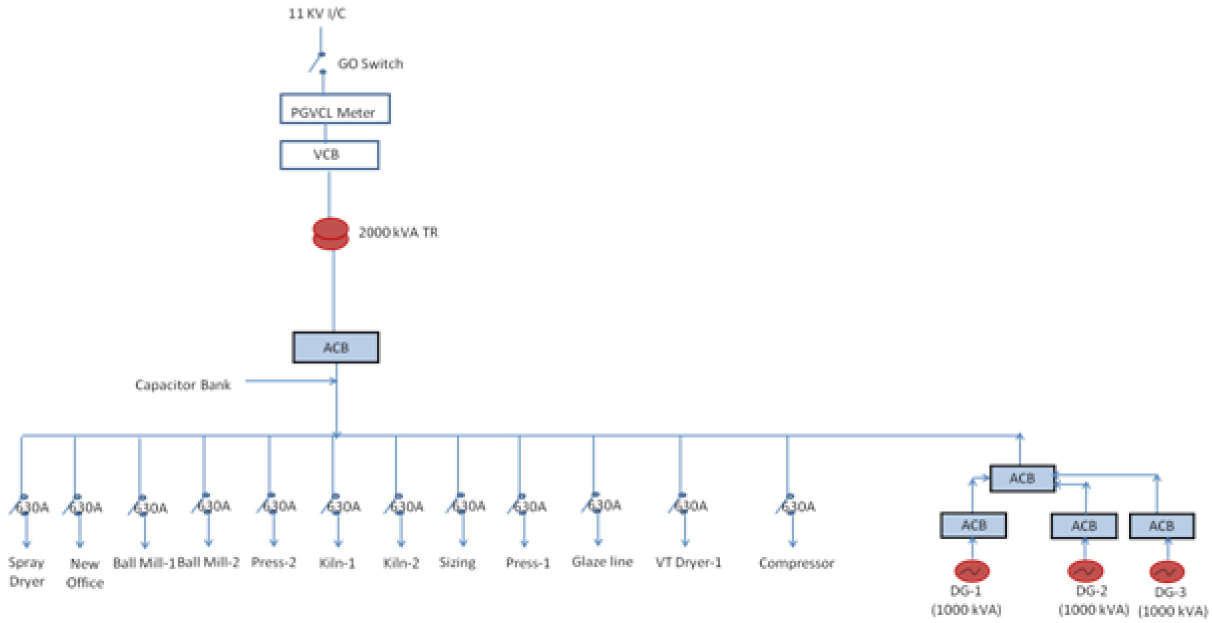
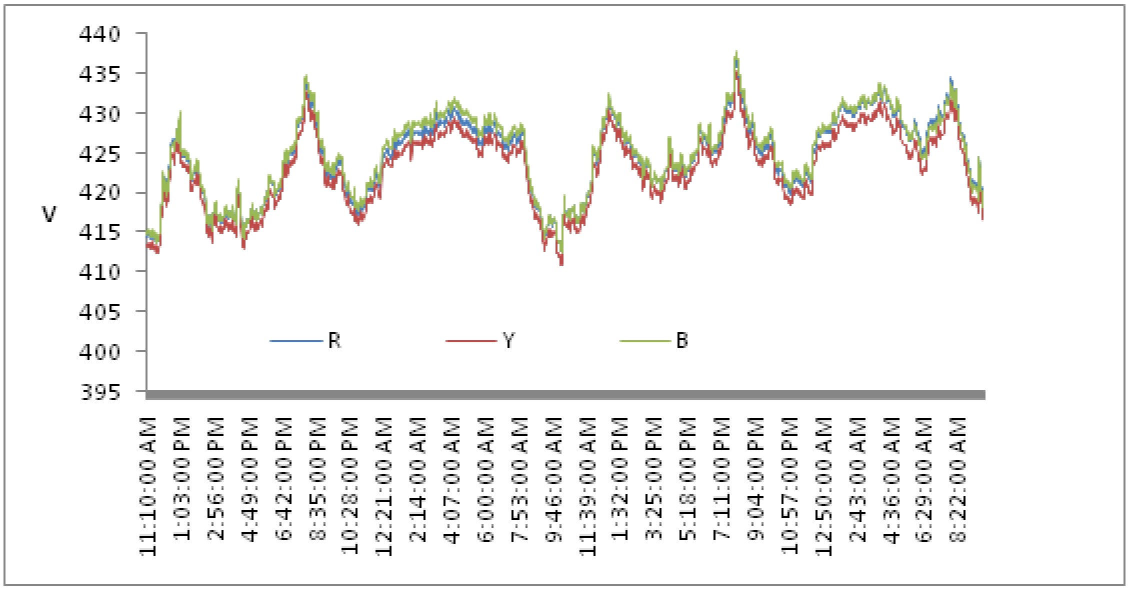


Figure 27: Single Line Diagram (SLD)

ANNEX-4: ELECTRICAL MEASUREMENTS



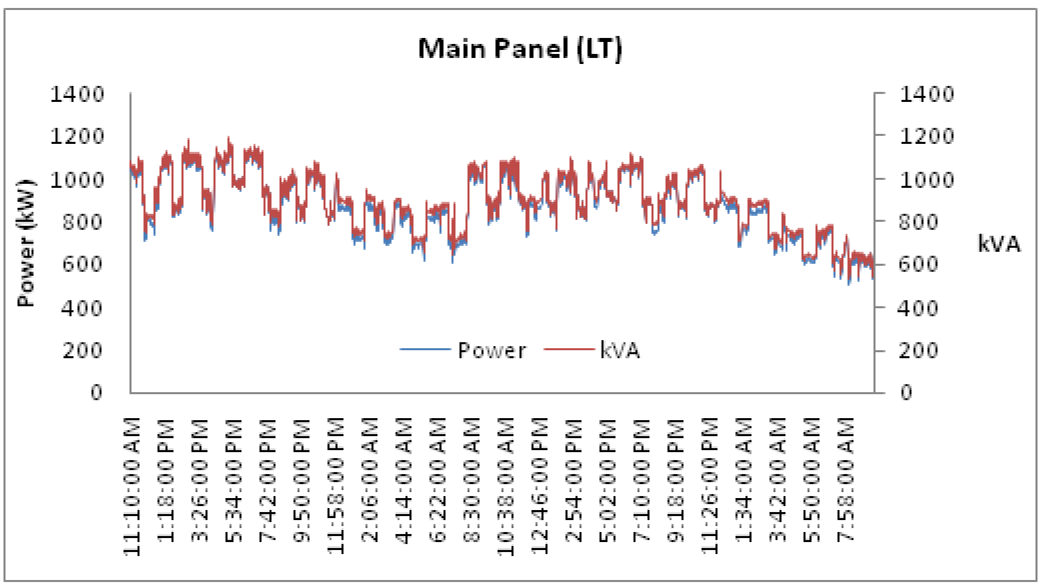
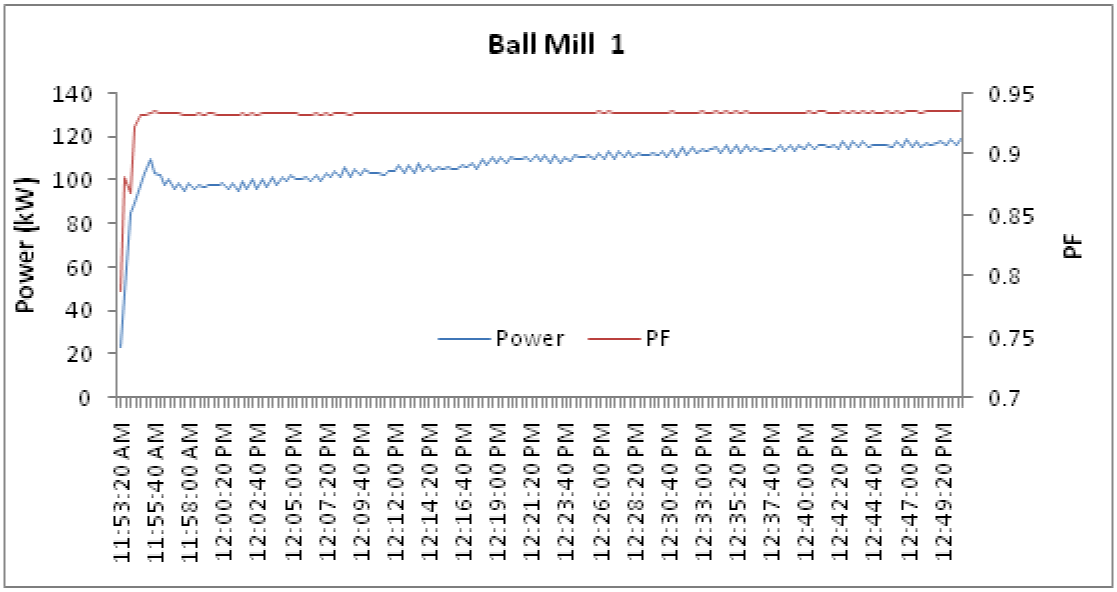


Figure 28: Power and voltage profile of Main Incomer



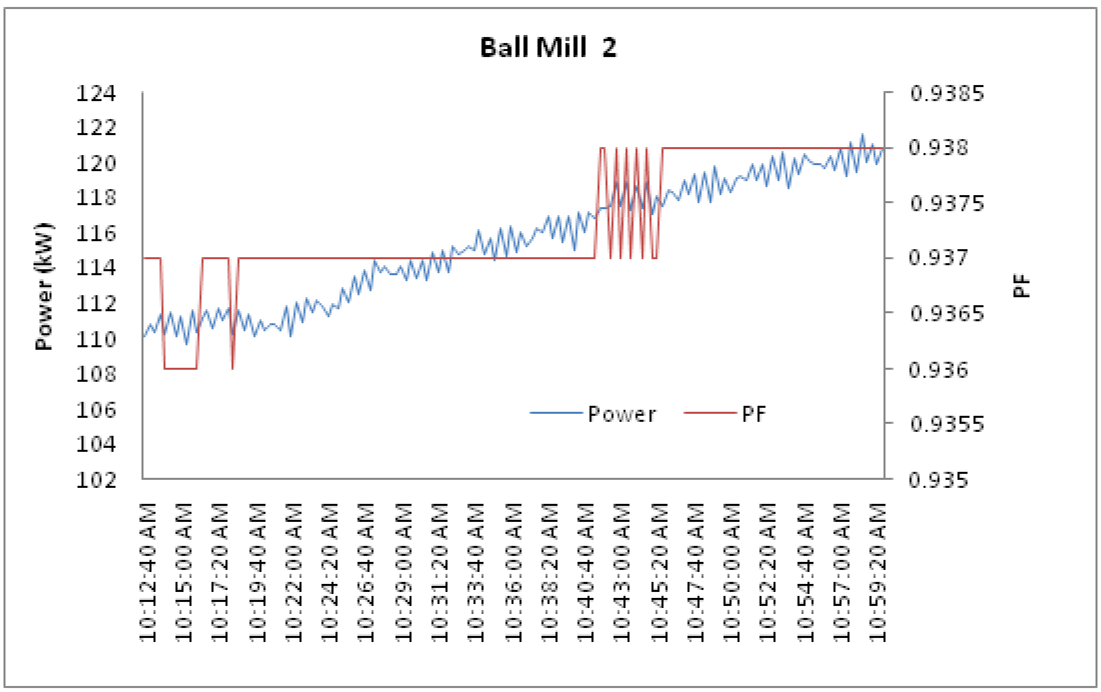
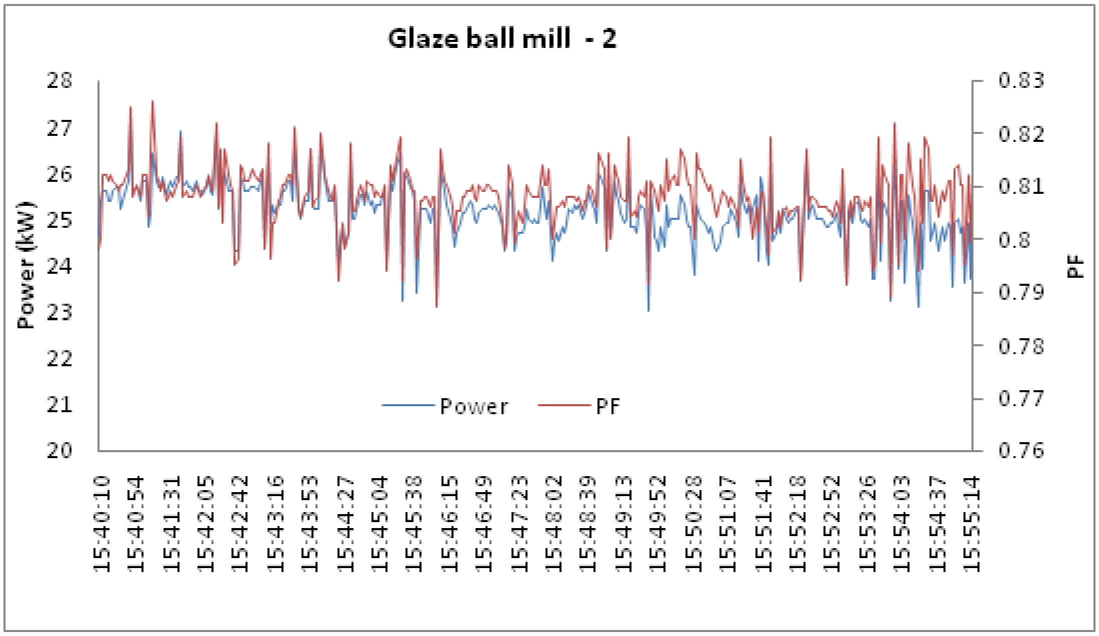
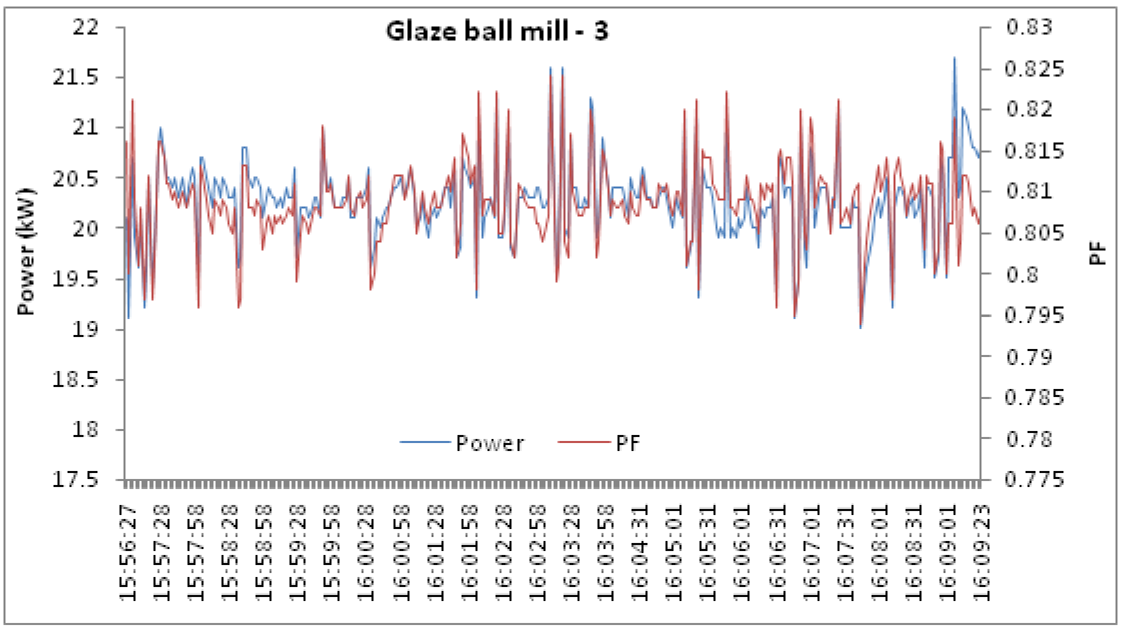
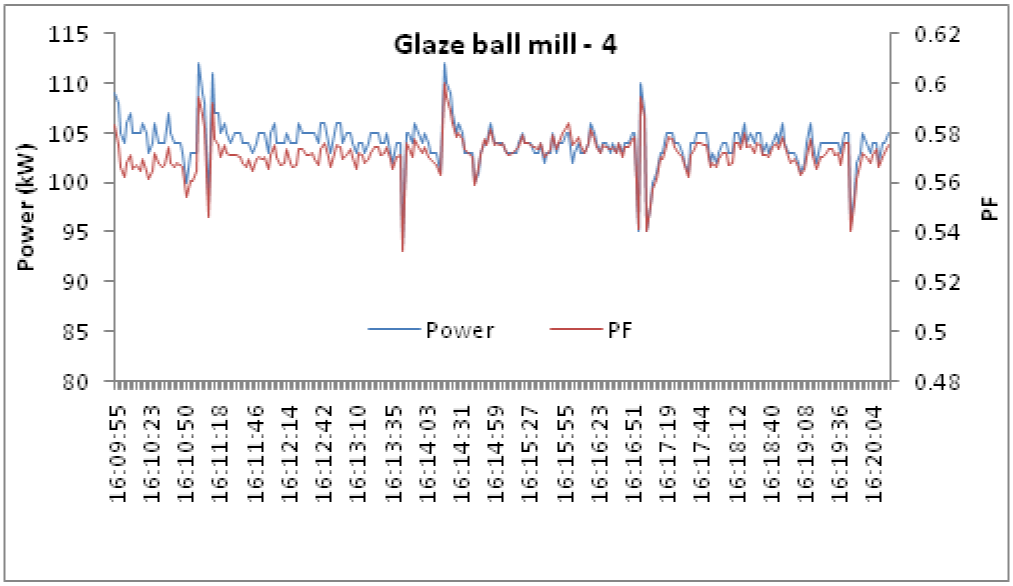


Figure 29: Power and PF profile of Ball Mill 1 and 2


Glaze ball mill - 2
Power (kW)
PF
Power
PF
28
27
26
25
24
23
22
21
20
0.83
0.82
0.81
0.8
0.79
0.78
0.77
0.76
15:40:10
15:40:54
15:41:31
15:42:05
15:42:42
15:43:16
15:43:53
15:44:27
15:45:04
15:45:38
15:46:15
15:46:49
15:47:23
15:48:02
15:48:39
15:49:13
15:49:52
15:50:28
15:51:07
15:51:41
15:52:18
15:52:52
15:53:26
15:54:03
15:54:37
15:55:14


Glaze ball mill - 3
Power (kW)
PF
Power
PF
22
21.5
21
20.5
20
19.5
19
18.5
18
17.5
0.83
0.825
0.82
0.815
0.81
0.805
0.8
0.795
0.79
0.785
0.78
0.775
15:56:27
15:57:28
15:57:58
15:58:28
15:58:58
15:59:28
15:59:58
16:00:28
16:00:58
16:01:28
16:01:58
16:02:28
16:02:58
16:03:28
16:03:58
16:04:31
16:05:01
16:05:31
16:06:01
16:06:31
16:07:01
16:07:31
16:08:01
16:08:31
16:09:01
16:09:23



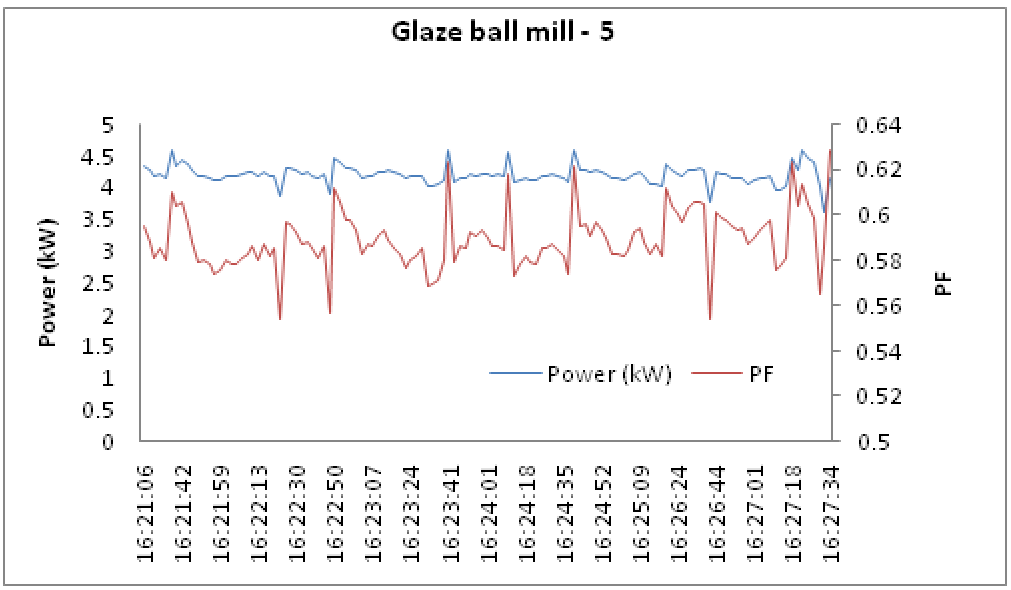


Figure 30: Power and PF profile of Glaze ball mill - 2, 3,4 & 5

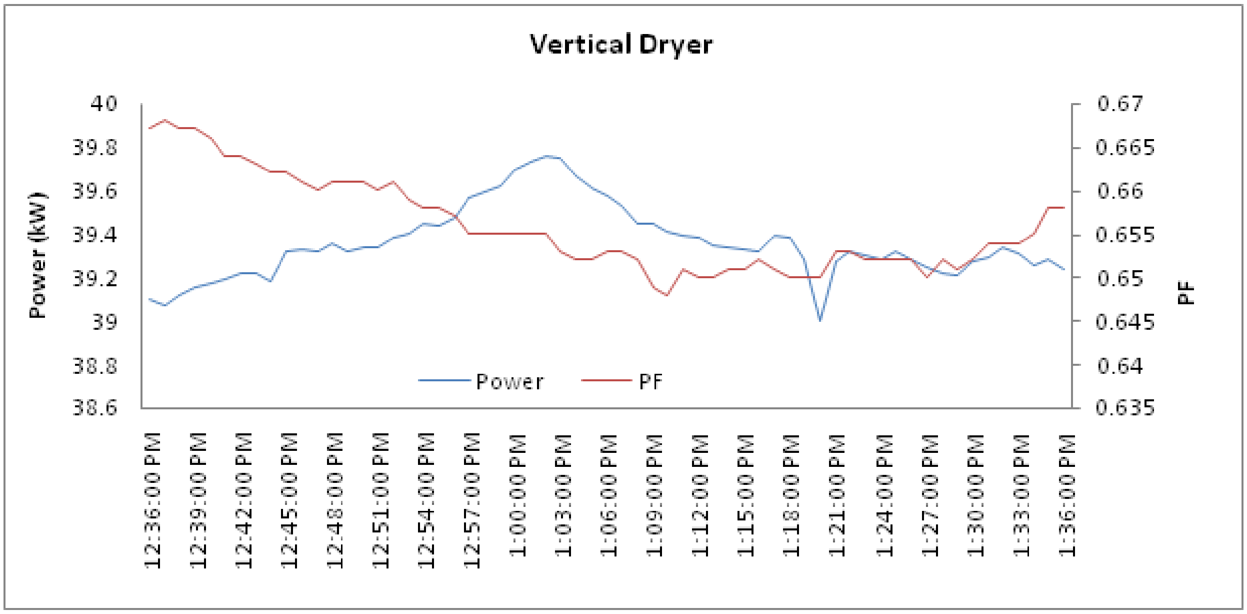


Figure 31 : Power and PF profile of Vertical dryer

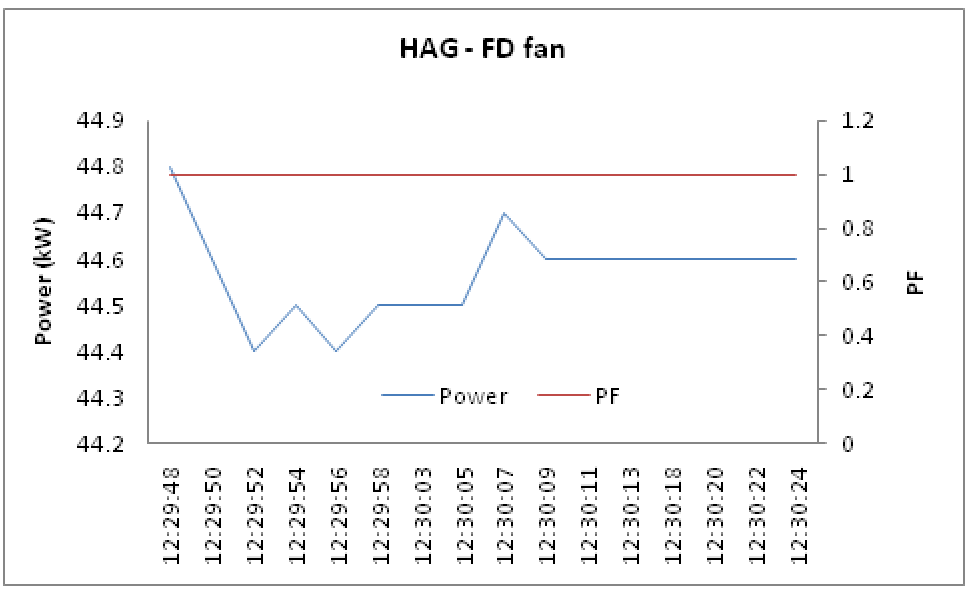


Figure 32 : Power and PF profile of HAG - FD fan

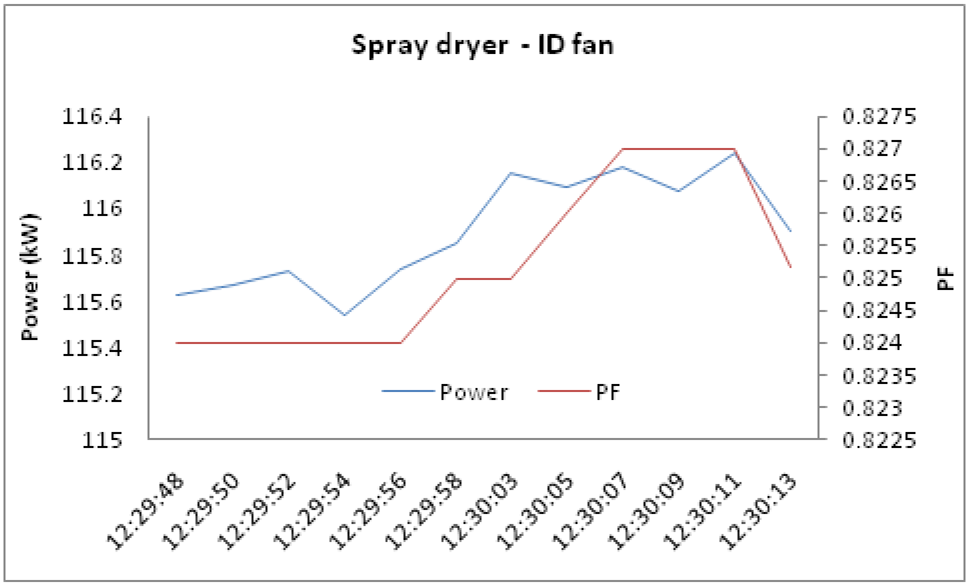
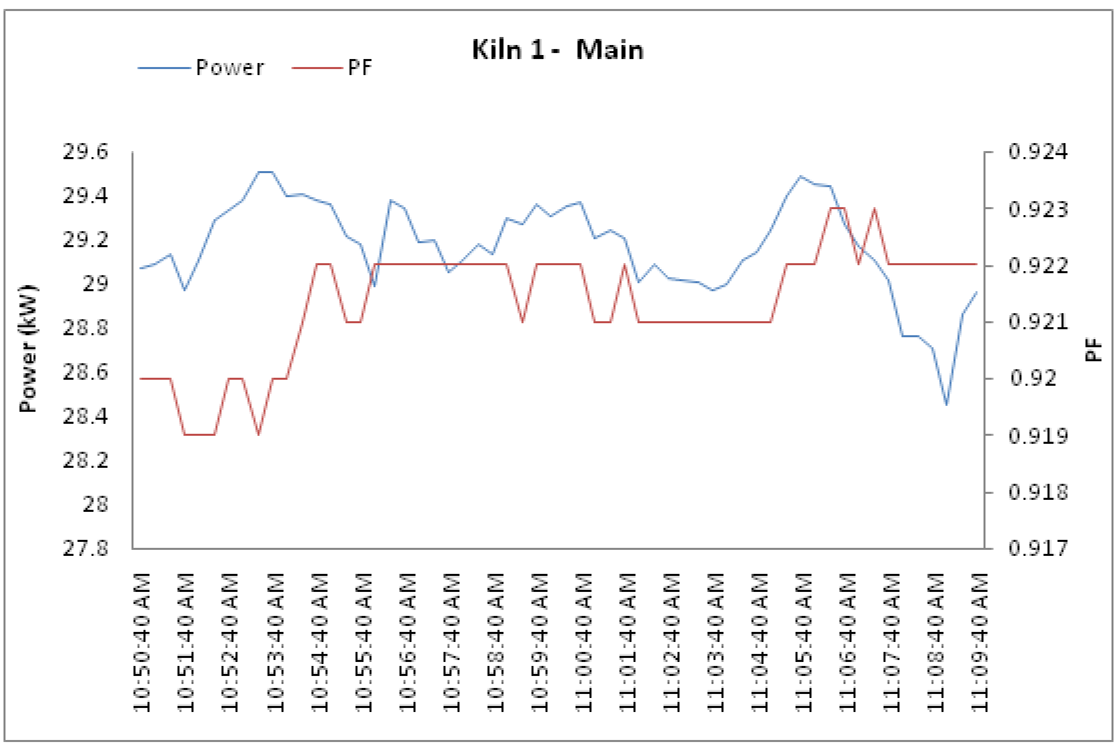
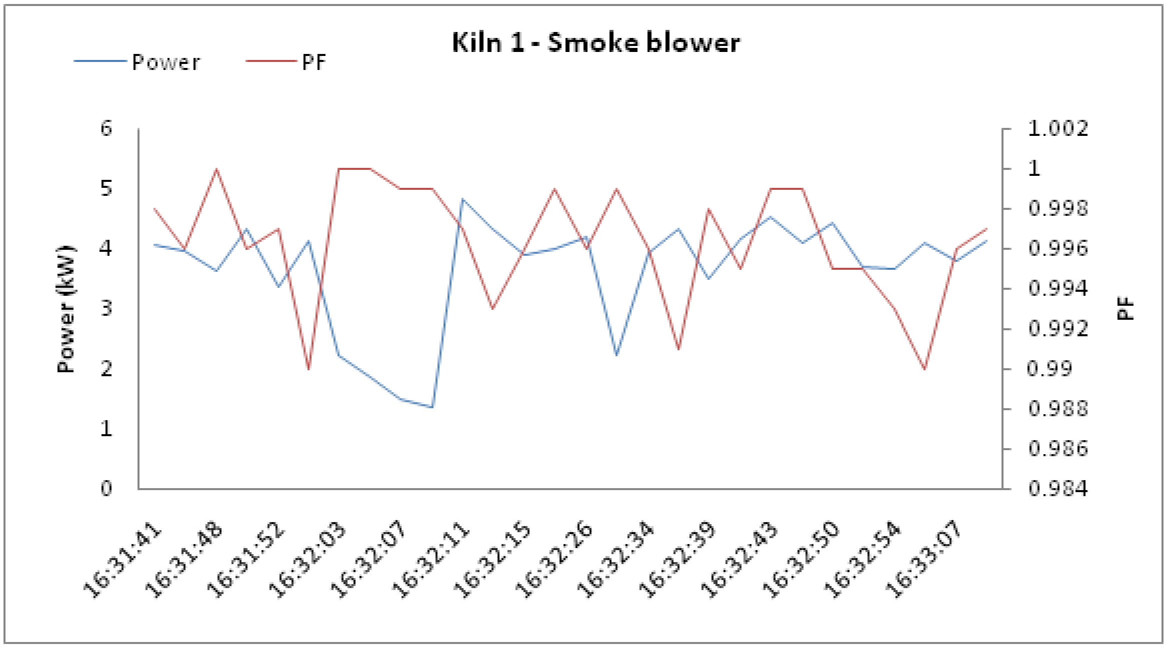
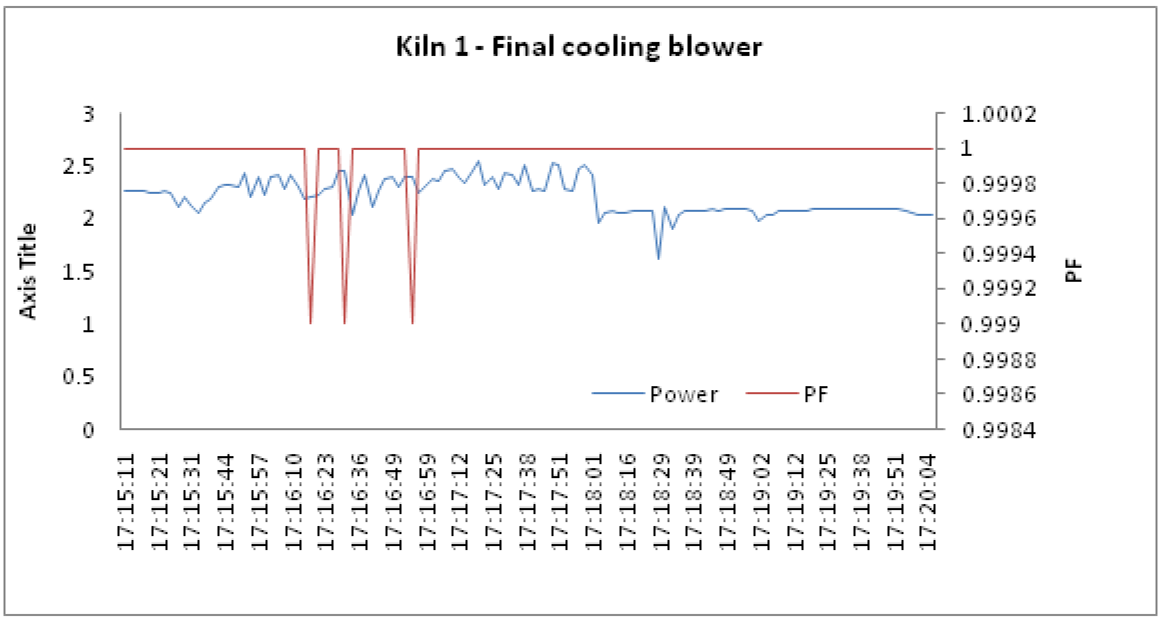


Figure 33 : Power and PF profile of spray dryer - ID fan

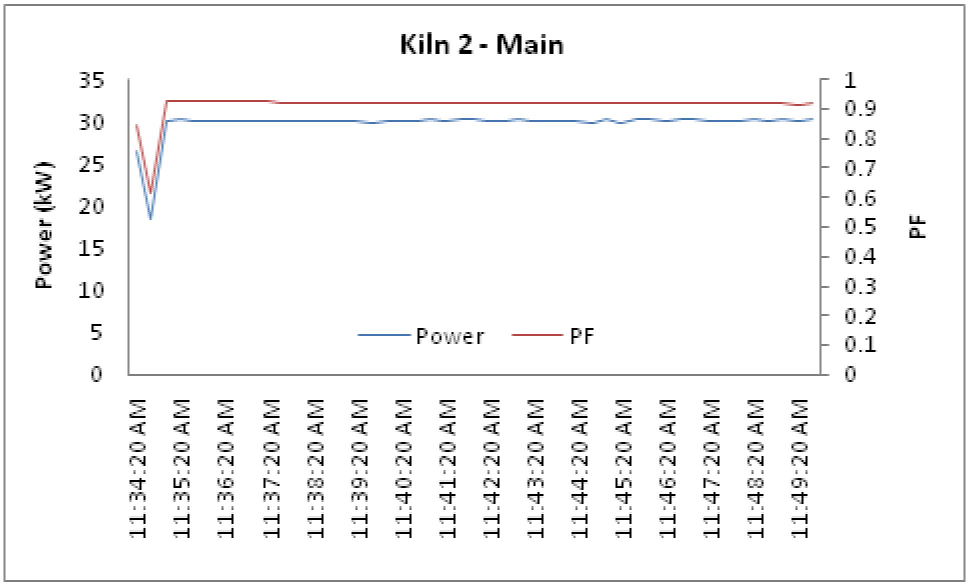


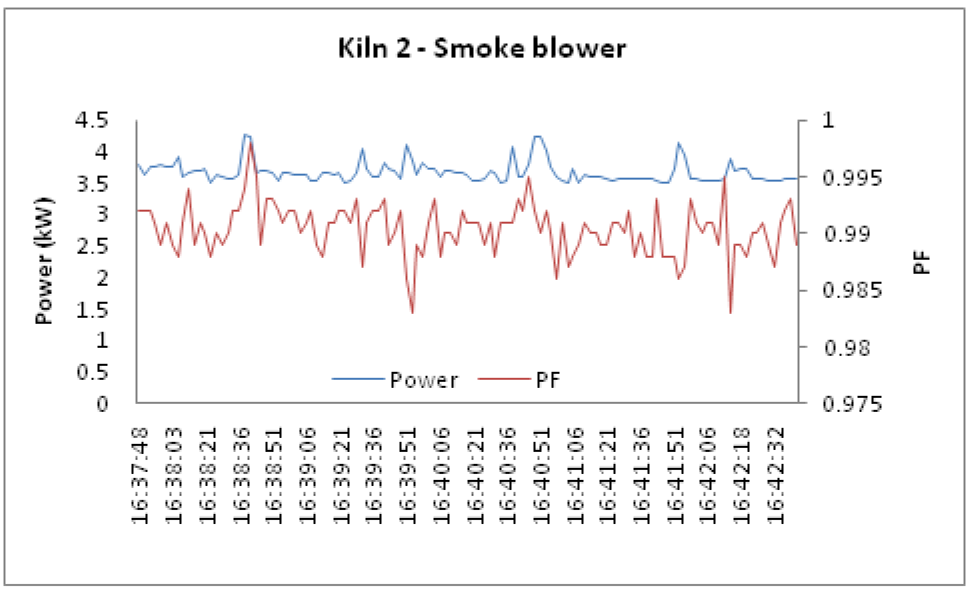


Kiln 1 - Smoke blower
Power
PF
Power (kW)
PF
6
5
4
3
2
1
0
1.002
1
0.998
0.996
0.994
0.992
0.99
0.988
0.986
0.984
16:31:41
16:31:48
16:31:52
16:32:03
16:32:07
16:32:11
16:32:15
16:32:26
16:32:34
16:32:39
16:32:43
16:32:50
16:32:54
16:33:07



Kiln 1 - Final cooling blower
Axis Title
PF
Power
PF
3
2.5
2
1.5
1
0.5
0
1.0002
1
0.9998
0.9996
0.9994
0.9992
0.999
0.9988
0.9986
0.9984
17:15:11
17:15:21
17:15:31
17:15:44
17:15:57
17:16:10
17:16:23
17:16:36
17:16:49
17:16:59
17:17:12
17:17:25
17:17:38
17:17:51
17:18:01
17:18:16
17:18:29
17:18:39
17:18:49
17:19:02
17:19:12
17:19:25
17:19:38
17:19:51
17:20:04


Kiln 2 - Main
Power (kW)
PF
Power
PF
35
30
25
20
15
10
5
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
11:34:20 AM
11:35:20 AM
11:36:20 AM
11:37:20 AM
11:38:20 AM
11:39:20 AM
11:40:20 AM
11:41:20 AM
11:42:20 AM
11:43:20 AM
11:44:20 AM
11:45:20 AM
11:46:20 AM
11:47:20 AM
11:48:20 AM
11:49:20 AM


Kiln 2 - Smoke blower
Power (kW)
PF
Power
PF
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1
0.995
0.99
0.985
0.98
0.975
16:37:48
16:38:03
16:38:21
16:38:36
16:38:51
16:39:06
16:39:21
16:39:36
16:39:51
16:40:06
16:40:21
16:40:36
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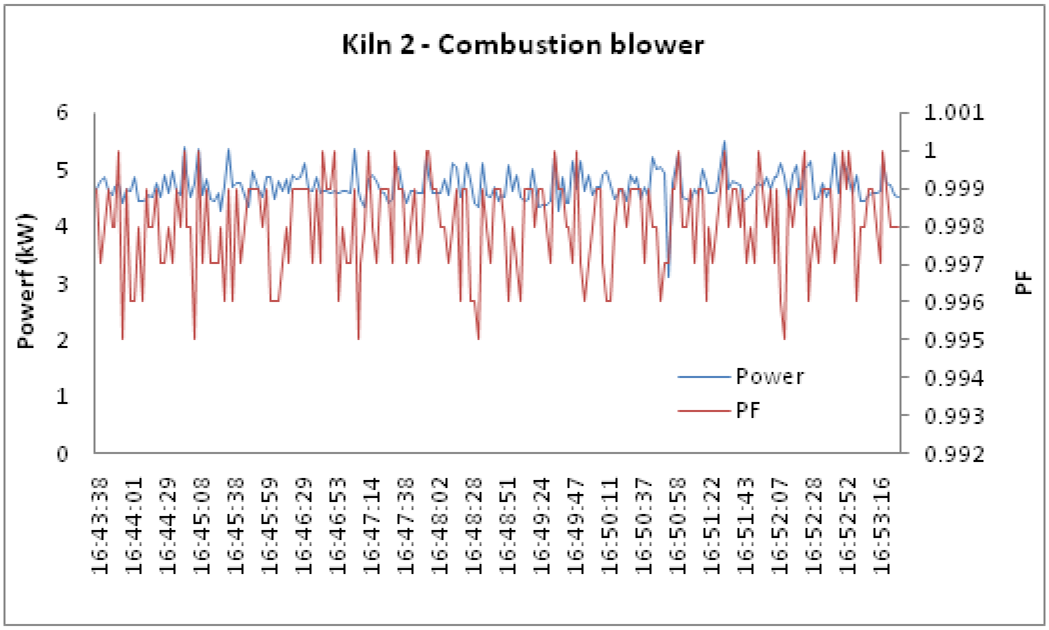
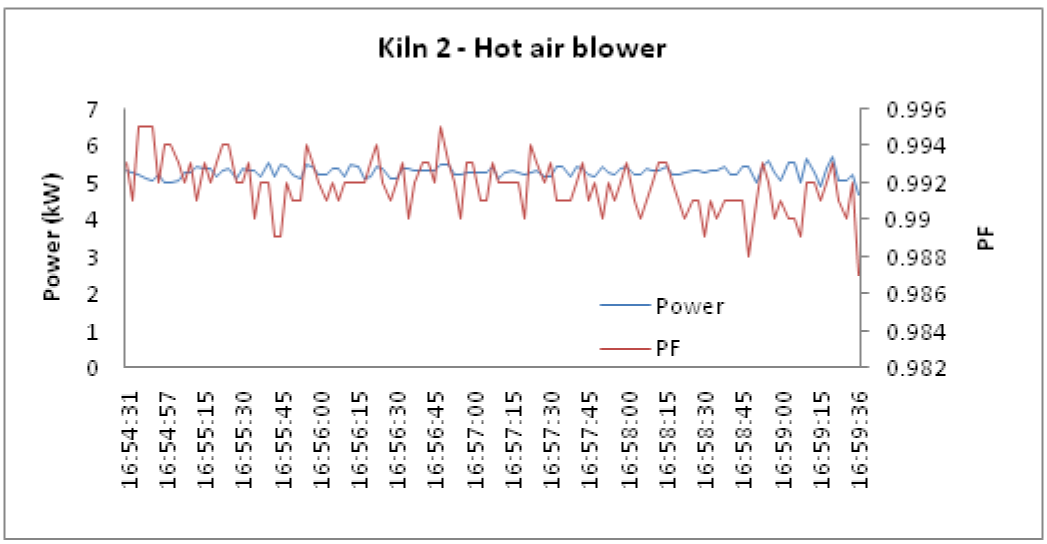
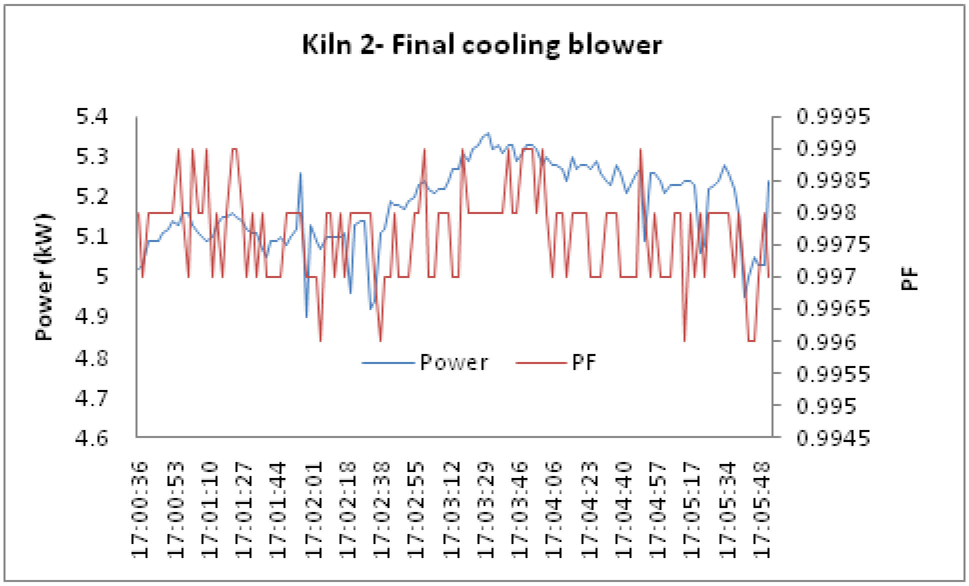
16:41:06
16:41:21
16:41:36
16:41:51
16:42:06
16:42:18
16:42:32



Kiln 2 - Combustion blower
Powerf (kW)
PF
Power
PF
0
1
2
3
4
5
6
0.992
0.993
0.994
0.995
0.996
0.997
0.998
0.999
1
1.001
16:43:38
16:44:01
16:44:29
16:45:08
16:45:38
16:45:59
16:46:29
16:46:53
16:47:14
16:47:38
16:48:02
16:48:28
16:48:51
16:49:24
16:49:47
16:50:11
16:50:37
16:50:58
16:51:22
16:51:43
16:52:07
16:52:28
16:52:52
16:53:16



Kiln 2 - Hot air blower
Power (kW)
PF
Power
PF
0
1
2
3
4
5
6
7
0.982
0.984
0.986
0.988
0.99
0.992
0.994
0.996
16:54:31
16:54:57
16:55:15
16:55:30
16:55:45
16:56:00
16:56:15
16:56:30
16:56:45
16:57:00
16:57:15
16:57:30
16:57:45
16:58:00
16:58:15
16:58:30
16:58:45
16:59:00
16:59:15
16:59:36



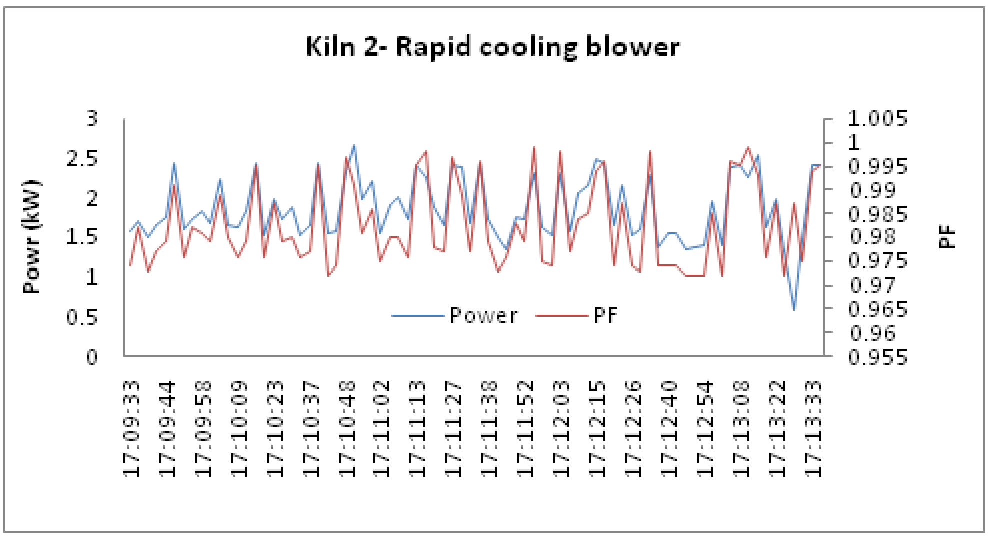


Figure 34: Power and PF profile of all blowers of Kiln 2

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

1. Kiln-1 efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujrat Gas	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1132	*°C*
Initial temperature of kiln tiles	42	*°C*
Avg. fuel Consumption	282	*scm/h*
Density of Natural gas	0.7298	*kg/scm*
Avg. fuel Consumption	205.5810	*kg/h*
Flue Gas Details		
Flue gas temp at smog blower	135	*°C*
Preheated air temp./Ambient	170	*°C*
O_2 in flue gas	5.18	*%*
CO_2 in flue gas	8.45	*%*
CO in flue gas	13	*ppm*
Atmospheric Air		
Ambient Temp.	41	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
Fuel Analysis		
C	*73.80*	%
H	*24.90*	%
N	*1.30*	%
O	*0.00*	%
S	*0.00*	%
Moisture	*0.00*	%
Ash	*0.00*	%
GCV of fuel	9,000	*kcal/scm*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	%
Un-burnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	*kcal* l/kg
GCV of fly ash	*0*	*kcal* /kg

Material and flue gas data		
Weight of Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	6,534	*kg/h*
Weight of Stock	6,534	*kg/h*
Specific heat of clay material	0.22	*kcal /kg- °C*
Avg. specific heat of fuel		*kcal /kg-°C*
fuel temp	30	*°C*
Specific heat of flue gas	0.24	*kcal /kg-°C*
Specific heat of superheated vapour	0.45	*kcal/kg-oC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	5,500	*kcal/h*
Radiation and convection from heating zone surface	55,206	*kcal/h*
Heat loss from all zones	60,706	*kcal/h*
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.90	*h*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	611	*deg K*

Efficiency calculations

Calculations	Kiln	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	32.74	*%*
Actual Mass of Supplied Air	22.87	*kg/kg of fuel*
Mass of dry flue gas	21.62	*kg/kg of fuel*
Amount of Wet flue gas	23.87	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*Kg of H_2O/kg of fuel*
Amount of dry flue gas	21.63	*kg/kg of fuel*
Specific Fuel consumption	43.11	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	387,994	*kcal/ton of tiles*
Total heat input	387,994	*kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	239,800	*kcal /ton of tile*
Heat loss in dry flue gas	21,032	*kcal /ton of tile*
Loss due to H_2 in fuel	604	*kcal/ton of tile*
Loss due to moisture in combustion air	967.25	*kcal/ton of tile*
Loss due to partial conversion of C to CO	27.66	*kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	738.38	*kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	-	*kcal/ton of tile*
Total heat loss from kiln (surface) body	60,706	*kcal/ton of tile*

Heat loss due to un-burnt in Fly ash	-	*kcal/ton of tile*
Heat loss due to un-burnt in bottom ash	-	*kcal/ton of tile*
Heat loss due to kiln car	-	*kcal/ton of tile*
Unaccounted heat losses	64,119	*kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	60,706	*Kcal/ton*
Kiln Efficiency	61.81	*%*

Kiln-2 efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujarat gas	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1088	*°C*
Initial temperature of kiln tiles	42	*°C*
Avg. fuel Consumption	230	*scm/h*
Density of Natural gas	0.73	*kg/scm*
Avg. fuel Consumption	168.2	*kg/h*
Flue Gas Details		
Flue gas temp at smog blower	130	*° C*
Preheated air temp./Ambient	90	*°C*
O_2 in flue gas	11.8	*%*
CO_2 in flue gas	6.22	*%*
CO in flue gas	0	*ppm*
Atmospheric Air		
Ambient Temperature	41	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg of dry air*
Fuel Analysis		
C	*73.80*	*%*
H	*24.90*	*%*
N	*1.30*	*%*
O	*0.00*	*%*
S	*0.00*	*%*
Moisture	*0.00*	*%*
Ash	*0.00*	*%*
GCV of fuel	9000	*kcal/scm*
Ash Analysis		
Un-burnt in bottom ash	*0.00*	*%*
Un-burnt in fly ash	*0.00*	*%*
GCV of bottom ash	*0*	*kcal/kg*
GCV of fly ash	*0*	*kcal/kg*
Material and flue gas data		
Weight of Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	5,999	*kg/h*
Weight of Stock	5,999	*kg/h*

Specific heat of clay material	0.22	*kcal/kg-°C*
Avg. specific heat of fuel		*kcal/kg-°C*
fuel temp	30	*°C*
Specific heat of flue gas	0.24	*kcal/kg-°C*
Specific heat of superheated vapour	0.45	*kcal/kg-°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	10,232	*kcal/h*
Radiation and convection from heating zone surface	33,222	*kcal/h*
Heat loss from all zones	43,454	*kcal/h*
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	1.00	*h*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	706	*K*

Efficiency Calculation

Calculations	Kiln	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	128.88	*%*
Actual Mass of Supplied Air	39.43	*kg/kg of fuel*
Mass of dry flue gas	38.18	*kg/kg of fuel*
Amount of Wet flue gas	40.43	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*Kg of H_2O/kg of fuel*
Amount of dry flue gas	38.19	*kg/kg of fuel*
Specific Fuel consumption	38.42	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	345,799	*kcal/ton of tiles*
Total heat input	345,799	*kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	230,120	*kcal/ton of tile*
Heat loss in dry flue gas	31,339	*kcal/ton of tile*
Loss due to H_2 in fuel	537	*kcal/ton of tile*
Loss due to moisture in combustion air	1,579.07	*kcal/ton of tile*
Loss due to partial conversion of C to CO	-	*kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	1,643.79	*kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	-	*kcal/ton of tile*
Total heat loss from kiln (surface) body	43,454	*kcal/ton of tile*
Heat loss due to un-burnt in Fly ash	-	*kcal/ton of tile*
Heat loss due to un-burnt in bottom ash	-	*kcal/ton of tile*
Heat loss due to kiln car	-	*kcal/ton of tile*
Unaccounted heat losses	37,126	*kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	43,454	*kcal/ton*
Kiln Efficiency	66.5	*%*

ANNEX-6: VENDORS

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

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

ECM 3: Radiation and convection loss reduction from surface of kiln

.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA	T 91 44 2530 6888 F 91 44 2534 5985 M 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com
2	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 7**5** 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: Insulation of HAG duct

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

ECM-6: Optimized Resource Consumption in Clay Section

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

ECM-9: 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: Replacement of inefficient lighting systems

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

ECM-11: Main LT Voltage optimization

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Dynamic Energy Solutions	Plot Number 6, Nangla Industrial Area, Nangla Gazipur Road, Faridabad-121004	9873565940	dynamicenergysolutions@gmail.com
2	Recons Power Equipment Pvt. Ltd	Plot Number 38, Sector-25, Faridabad-121004	0129-4062114-116 9811095526	mail@reconsindia.com
3	SERVOMAX INDUSTRIES LIMITED (Manufacturer)	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033	+91 9111234567	customercare@servomax.in www.wervomax.in

ECM-12: Cable loss minimization

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

ECM-13: 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 (4^{th} Floor), Kolkata - 700 053,India.	Mr. Tarun Roy Mob: +91 94330 32474	tr@reitzindia.com
2.	Mangal singh Bros. Pvt Ltd	24-B, Raju Gardens, Near Krishnasamy nagar, Sowripalayamp Post, Coimbatore-641028	Ramiz Parker +91 77381 86851	mangalsinghcbe@gmail.com
3	Shreeji Traders	Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001	+91 94281 01565	NA

ECM-14: 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 15: Solar PV system

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	GREEN EARTH INFRACON & SOLAR	348, Avadh Viceroy, Sarthana Jakatnaka, Varachha Road, Surat, Gujarat, 395006, India	Mr. Dhaval Patel 7210113608	NA
2	CITIZEN Solar Pvt. Ltd	711, Sakar-2 Ellisbridge corner, Ahmedabad-380006	Girishsinh Rav Jadeja 9376760033	www.citizensolar.com sales@citizensolar.com
3	Sun gold Enterprise	D-134, Udhna Sangh Commercial Complex, Near Divya Bhaskar press, Central Road, Udhna Udhyog nagar, Surat-394010	Mr. Pravin Patel 98251 94488	sungoldindia@gmail.com

ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 59: Assumptions for Financial Analysis

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