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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE VT-53: METROCITY TILES PVT LTD.

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DESL

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

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Disclaimer

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

DESL is indebted to M/s Metrocity Tiles 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. Uday Gajjar, General Manager

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

Project Head	R Rajmohan, Chief Executive Officer
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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	Unit of Measurement (UOM)
Calorific value	CV
Degree Centigrade	^oC
Horse power	hp
Hour(s)	h
Hours per year	h/y
Indian Rupee	INR/Rs.
Kilo Calorie	kCal
Kilo gram	g
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.

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

➨ INTRODUCTION OF THE UNIT

Name of the Unit	Metrocity Tiles Pvt. Ltd.
Year of Establishment	2009
Address	Survey No.625/P1, Lakhdhirpur Road, 8-A N.H., Morbi - 363642
Products Manufactured	Glazed Vitrified Tiles
Name(s) of the Promoters / Directors	Mr. Dilipbhai R. Adroja Mr. Shekharbhai R. Adroja

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

- **Stage 1:** Walk through energy audit of the plant to understand process, energy drivers, assessment of the measurement system, assessment of scope, measurability, formulation of audit plan and obtaining required information
- **Stage 2:** Detailed energy audit-testing & measurement for identification of saving potential, technology assessment and understanding of project constraints

- **Stage 3**: Data analysis, initial configuration of projects, savings quantification, vendor consultation, interaction with unit and freezing of projects for implementation and preparation of comprehensive energy audit report.

➨ PRODUCTION PROCESS OF THE UNIT

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

- **Clay ball mill:** Here the raw materials like Clay, Super Kathi, Soda, Potash are mixed along with water (20-28 kl per batch) to form a slip.
- **Agitator:** The slip after mixing in Clay 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.
- **Spray Dryer:** The hot air is introduced through the top of the drying chamber, and the moisture ceramic slip sprayed through the nozzle, So ID fans present outside suck the moisture.
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit (green tile).
- **Vertical Dryer:** Biscuits (green tiles) are sent to dryer for pre drying after it is passed through kiln.
- **Glaze ball mill:** For producing glazing material used on the product.
- **Kiln:** Biscuits (green tiles) are baked in the kiln at 1100-1150°C.
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The main utility equipment installed are:

- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slip, air cleaning, glazing etc.
- **Coal gasifier:** For producing coal gas, this is used in the kiln, hot air generator.

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in Kiln: Coal gas is used as fuel in kiln and oxygen content in flue gas was found to be 8.5% against desired level of 5%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation improvement-kiln area: Surface Insulation of combustion air pipes in rapid cooling recuperator and near burner was poor which results in increased heat loss leading to increase in coal consumption. It is recommended to insulate the cyclone separator and HAG duct connecting cyclone separator.

- Insulation improvement-HAG area: Surface Insulation of cyclone separator and hot air duct connected to cyclone separator was poor which results in increased heat loss leading to increase in coal consumption. It is recommended to insulate the cyclone separator and HAG duct connecting cyclone separator.
- Using soft water in Clay ball mill: TDS of water used in clay section was found to be 800 ppm against desired level of 400ppm. It is recommended to install water softener plant.
- Use of VFD instead of soft starter in clay ball mill: It was found that the clay ball mill-2 was operating with soft starter and it is recommended to install VFD instead of soft starter which will reduce the power consumption by 10%.
- Time Controller in Agitators: All the agitators were operating continuously throughout the day and it is recommended to install timer based control for agitators to reduce the operating hours.
- Replacement of inefficient lighting systems: Conventional lights like Metal halide 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.
- Cable loss minimization: In Polishing, Nano and Final sizing section, the power factor was 0.4-0.7 against desired power factor of 0.98. It is recommended to install power factor improvement capacitors in above sections.
- Voltage optimization in lighting circuits: The present voltage for lighting circuit was found to be 418V against desired voltage of 380V. It is recommended to install separate lighting transformer of 80kVA rating for lighting circuit.
- 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, coal gasifier 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.
- VFD installation in new compressor: The new compressor having capacity 10.76 Nm^3/min and rated power is 55 kW. During study, it was observed that the compressor is operating with 30% unloading of the total running time and average unloading power consumption is 32 kW. It is recommend to installed VFD to minimize unloading power consumption.
- Compressed Leakage arresting: During study, it was observed that compressed air leakages in Nano, sizing and press section. It is suggested to attend and rectify air leakages immediately.
- Optimize pumps running time for polishing and sizing section: All pumps related to polishing and sizing section are running continuously even the machines are off. It is recommended to stop pumps during non working time to avoid unnecessary use of pumping system.
- VFD on spray dryer ID fan: ID fan is operating with damper control (80% open) and also star-delta connection. It is suggested to install VFD instead of star-delta and remove damper completely to reduce power consumption.
- Replacement of V belt to REC belt: All of blowers used in kiln and spray dryer ID fans 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.

- Replace agitator stirrer motor with IE3/IE4 motor: There are 15 stirrers and having capacity 5.6kW each. Each motor are conventional type and are rewinded more than once. It is suggested to replace these motors with energy efficient IE3 /IE4 type motor.

The following table summarizes the quantity of resource saved, monetary savings, investment and payback period of the measures.

Table 1: Summary of ECM

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 in Kiln	60,514		574	327	47.62	7.26	2	1264
2	Insulation improvement-kiln area			95	53	7.10	2.78	5	201
3	Insulation improvement-HAG area				3	2.25	1.37	7	24
4	Using soft water in Clay ball mill	24,120		20	11	1.48	2.49	20	42
5	Installation of VFD in Clay ball mill	40,200			3	2.69	2.12	9	29
6	Time Controller in Agitators	81,304		707	398	90.76	39.60	5	1517
7	Replacement of inefficient lights	39,092			3	3.1	10.2	39	33
8	Cable loss minimization	76,232			7	6.27	1.19	2	67
9	Voltage optimization for Lighting circuits	71,253			1	1.05	3.00	34	11
10	VFD on new screw compressor	43,762			1	0.68	0.50	9	7
11	Compressed air leakage arresting in Nano, Press and sizing section	21,881			4	3.37	1.50	5	36
12	Optimize pumps running time in polishing and sizing section during non working time	8,862			2	1.69	0.50	4	18
13	VFD on spray dryer ID fan	34,855			3	3.01	1.70	7	32
14	Replace V belts with REC belts in Kiln and spray dryer blowers	29,130			7	5.41	2.16	5	63
15	Replacement of existing Agitator stirrer motor with IE3/IE4 motor	13,633			6	4.90	2.64	6	58
16	Energy Management System	106,563		154	95	22.69	5.66	3	413
	Total	**651,400**	**0**	**1550**	**924**	**204.1**	**84.7**	**5**	**3814**

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

- Reduction in energy cost by 17.3%.
- Reduction in electricity consumption by 11.1%.
- Reduction in thermal energy consumption by 19.4%.
- Reduction in greenhouse gas emissions by 18.1%.

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	Kiln Excess Air Control	7.26	501	0.73
2	Insulation on combustion air pipes of Combustion & Rapid cooling zones	2.78	194	1.85
3	Replace V belts with REC belts in Kiln and spray dryer blowers	1.37	123	2.86
4	HAG Duct Insulation	2.49	38	7.61
5	VFD on spray dryer ID fan	2.12	97	3.63
6	Raw water to soft water for clay ball Mill	39.60	173	2.06
7	Soft Starter to VFD Run Ball Mill	10.19	8	14.22
8	Time Controller in Stirrer	1.19	392	0.91
9	Replacement of existing Agitator stirrer motor with IE3/IE4 motor	3.00	15	12.07
10	Optimize pumps running time in polishing and sizing section during non working time	0.50	101	3.43
11	VFD on new screw compressor	1.50	172	2.09
12	Compressed air leakage arresting in Nano, Press and sizing section	0.50	253	1.41
13	General Lights to LED Lights Replacement	1.70	133	2.66
14	Cable loss minimization	2.16	188	1.89
15	Voltage optimization for Lights	2.64	143	2.52
16	Plant Energy Monitoring	5.66	299	1.19

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	Metrocity Tiles Pvt. Ltd		
Plant Address	Survey No.625/P1, Lakhdhirpur Road, 8-A N.H., Morbi - 363642.		
Constitution	Private Limited		
Name of Promoters	Dilipbhai R. Adroja & Shekharbhai R. Adroja		
Contact person	Name	Uday Gajjar	
	Designation	General Manager	
	Tel	98988 42422	
	Fax	-	
	Email	page3metro@gmail.com	
Year of commissioning of plant	2009		
List of products manufactured	Glazed Vitrified tile, 600 x 600 mm (4 tiles/box) Glazed Vitrified tile, 600 x 1200 mm (2 tiles/box)		
Installed Plant Capacity	6,000 boxes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	5,837	5,085	5,915
Net profit	73	66	93
No of operational days in a year	Days/Year	365	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	8 am to 8 pm & 8 pm to 8 am	

Description	Details		
Number of employees	Category	Number	
	Staff	20	
	Worker	80	
	Casual Labor	170	
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	Yes	Spray dryer, Coal gasifier
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas (scm)	Yes	drier (secondary firing)
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
Interested in DEA	Yes		
	Very Interested		

1.3 METHODOLOGY AND APPROACH

The study was conducted in 3 stages:

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

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

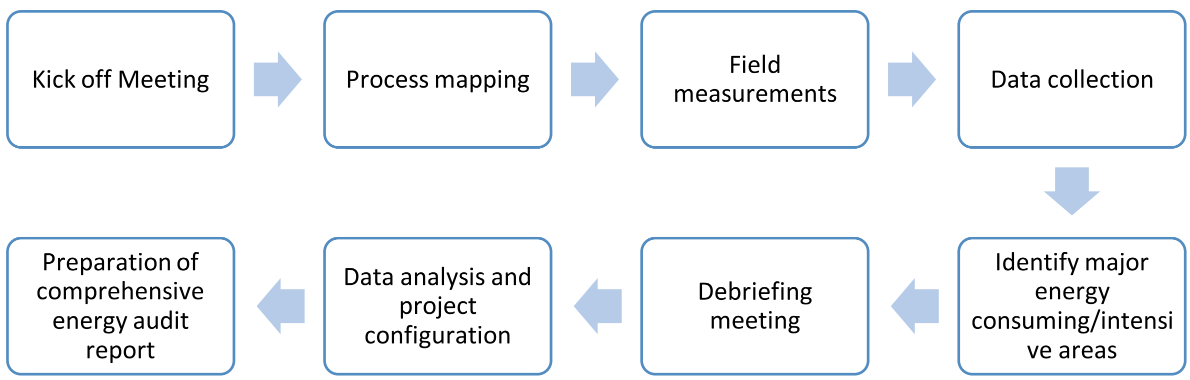


Figure 1: General methodology

The field work was carried out during 23-27th October 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 performance improvement actions (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 the 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

Sl. No.	Instruments	Parameters Measured
15	Pressure Gauge	Water pressure 0 to 40 kg
16	TDS meter	TDS of water

1.5 STRUCTURE OF THE REPORT

This detailed energy audit report has been organized and presented sequentially as follows:

- 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 covers 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

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

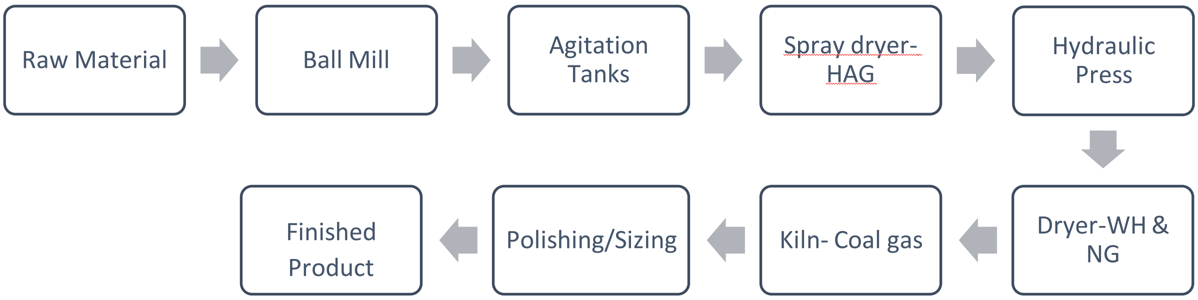


Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is a mixture of clay, Super Kathi, Soda, Potash which is mixed along with water to form slip.
- The raw materials are mixed and ground using pebbles together with water in the Clay ball mill for a period of 3-6 hours.
- Slip is then pumped using hydraulic piston into spray dryer where moisture content of slip is reduced from 35-40% to about 5-6% and output of spray dryer is in powder form. Coal is fired in a hot air generator to generate hot air.
- Clay in powdered form is stored in silos for 24 hours and then conveyed to hydraulic press machine where it is pressed and tiles is formed of required size, output of press is called biscuit (green tile).
- Biscuit is then preheated initially in vertical dryer at about 36-98°C.
- This is followed by the glazing process. The glazing prepared in the glaze is applied on the surface of the biscuits.
- After this the glazed product make a passage through kiln at 1,100-1,200°C for final drying and hardening.
- Output of kiln is called tiles; these tiles are then passed through cutting, sizing and polishing machines to match exact dimensions required.
- After sizing, tiles are packed in boxes and then dispatched.

The major energy consuming equipment's in the plants are:

- **Clay ball mill:** Here the raw materials like different clay, Soda, Potash are mixed along with water to form slip.
- **Agitator:** The liquid slip mass after mixing in Clay 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 & Spray dryer:** Hot air generator is used to generate hot air which is used in spray dryer for evaporation of moisture present in slip.
- **Vertical dryer:** It is used for preheating the biscuit and for baking before glazing process.
- **Hydraulic Press:** It is used for preparation of preparation of green tile from powdered raw material.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. instrument air, air cleaning, glazing etc.
- **Glaze ball mill:** For producing glazing material used on tiles.
- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.
- **Kiln:** The kiln is the main energy consuming equipment where the product is passed after glazing and printing. The kiln is about 155 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150°C to 1,200°C depending upon the type of the final product. Once the tiles come out of the kiln, the materials are further gone for sizing, finishing and quality tested and packed for dispatch.

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 vitrified tiles of the following specifications:

Table 5 : Product Specifications

Product	Size /Piece	Weight/box	Area per box	Pieces per box
	Mm ×mm	kg	m^2	#
Glazed Vitrified Tiles	600X600	28	1.44	4
Glazed Vitrified Tiles	600X1200	32	1.44	2

The products are mainly sold in domestic market as well as exported. The month wise production details of various products, is given below.

Table 6: Month wise production of boxes

Period	Number of Boxes		Corresponding Area (m^2)		Corresponding Mass (MT)	
	600 x 600	600 X 1200	600 x 600	600 X 1200	600 x 600	600 X 1200
Oct-17	-	-	-	-	-	-
Nov-17	-	-	-	-	-	-
Dec-17	-	29,038	-	41,814	-	1,118
Jan-18	-	126,688	-	182,430	-	4,877
Feb-18	-	69,633	-	100,271	-	2,681
Mar-18	56,232	88,465	80,974	127,389	1,799	3,406
Apr-18	49,671	44,825	71,526	64,548	1,589	1,726
May-18	-	97,924	-	141,010	-	3,770
Jun-18	74,225	26,629	106,884	38,345	2,375	1,025
Jul-18	-	144,930	-	208,699	-	5,580
Aug-18	62,127	68,049	89,462	97,990	1,988	2,620
Sep-18	20,037	49,888	28,853	71,838	641	1,921
Total	262,292	746,069	377,700	1,074,339	8,393	28,724

The production data for the month of Oct-17 & Nov-17 is not available as the plant was in shut down condition.

2.3 ENERGY SCENARIO

Both electricity and thermal energy is used in different manufacturing processes. The overall energy usage 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 diesel generator sets for whole plant
- Thermal energy is used for following applications :
    - Coal Gas for kiln and coal in hot air generator for generating hot air
    - Natural Gas (NG) for vertical dryer

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

Table 7: Energy use and cost distribution

Particular	Energy cost Distribution		Energy distribution	
	Rs.(Lakh)	% of Total	TOE	% of total
Grid - Electricity	452.64	38	505.1	10
Coal	575.51	49	4,306.8	83
Natural Gas	148.35	13	361.9	7
Total	1,176.50	100	5,173.7	100

This is shown graphically in the figures below:

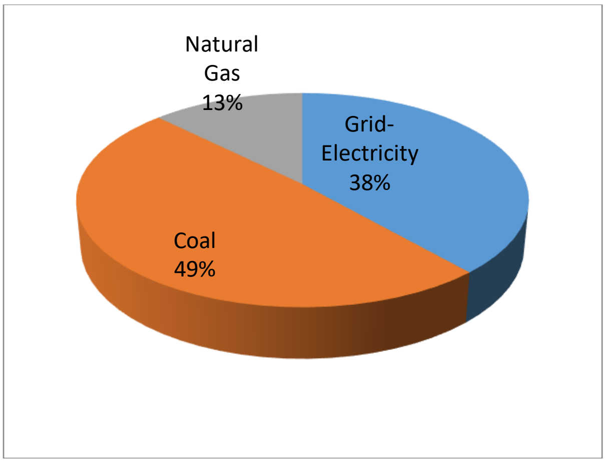


Figure 3: Energy cost share

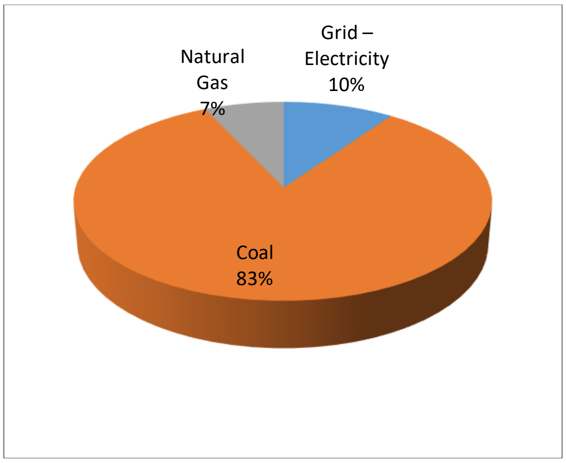


Figure 4: Energy use share

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 from 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 remaining 38% of the energy cost and 10% of the overall energy consumption.

- Coal used in the form of coal gas produced by gasifier in the kiln and as directly fired in the hot air generator accounts for 49% of the total energy cost and 83% of overall energy consumption.
- NG is used in vertical dryer accounts for 13% of the total energy cost and 7% of overall energy consumption.

2.3.1 Analysis of Electricity Consumption

2.3.1.1 Supply from Utility

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

Table 8: Details of Electricity Connection

Particulars	Description
Consumer Number	26375
Tariff Category	HTP-I
Contract Demand, kVA	1,500
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Electric Tariff structure

Particulars	Tariff structure for Category HTP-1
Demand Charges (Rs./kVA)	
1st 500 kVA	150
2nd 500 kVA	260
Next 500	475
Energy Charges (Rs./kWh)	6.88
Normal Hours	4.2
Peak Hours	0.85
Night Time	0.4
Fuel Surcharge (Rs./kVAh)	1.63
Electricity duty (% of total energy charges)	15%

(As per bill for Mar-18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units consumed kWh	Total Electricity cost Rs	Average unit Cost Rs/kWh
Oct-17	197,420	1,775,512	9.0
Nov-17	27,980	584,031	20.9
Dec-17	235,672	2,156,344	9.1
Jan-18	617,280	4,423,380	7.2
Feb-18	585,860	4,422,936	7.5
Mar-18	650,360	4,903,909	7.5
Apr-18	545,380	4,214,590	7.7
May-18	643,200	4,837,659	7.5

Month	Units consumed kWh	Total Electricity cost Rs	Average unit Cost Rs/kWh
Jun-18	649,100	4,891,221	7.5
Jul-18	651,860	4,937,805	7.6
Aug-18	632,220	4,704,951	7.4
Sep-18	436,660	3,412,036	7.8

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 489,416 kWh/month and cost is Rs 37.72 Lakhs per month (Oct-17 to Sep-18). The average cost of electricity is Rs 8.91/kWh . The average cost for the period Dec-18 to Sep-18 was Rs 7.70/kWh. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

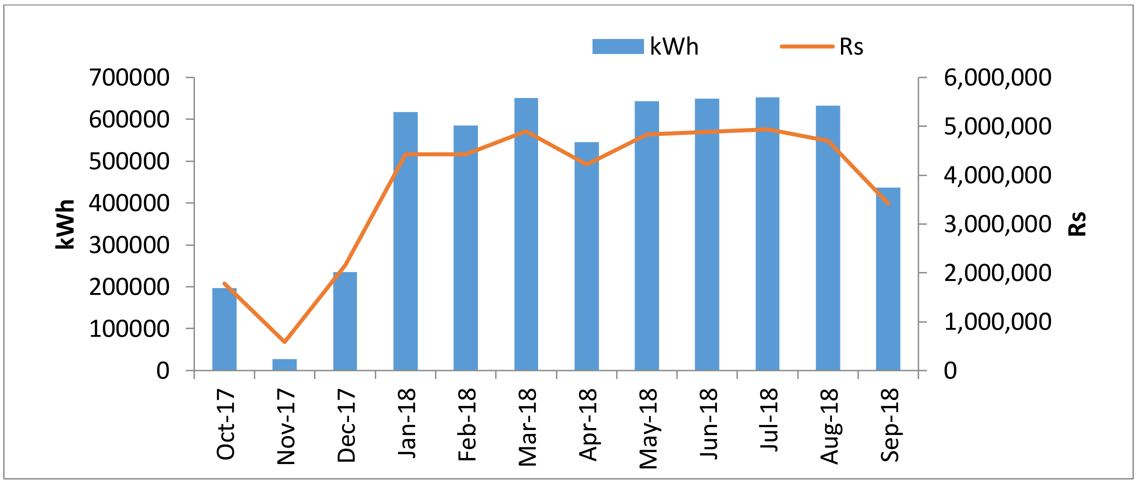


Figure 5: Month wise Variation in Electricity Consumption

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

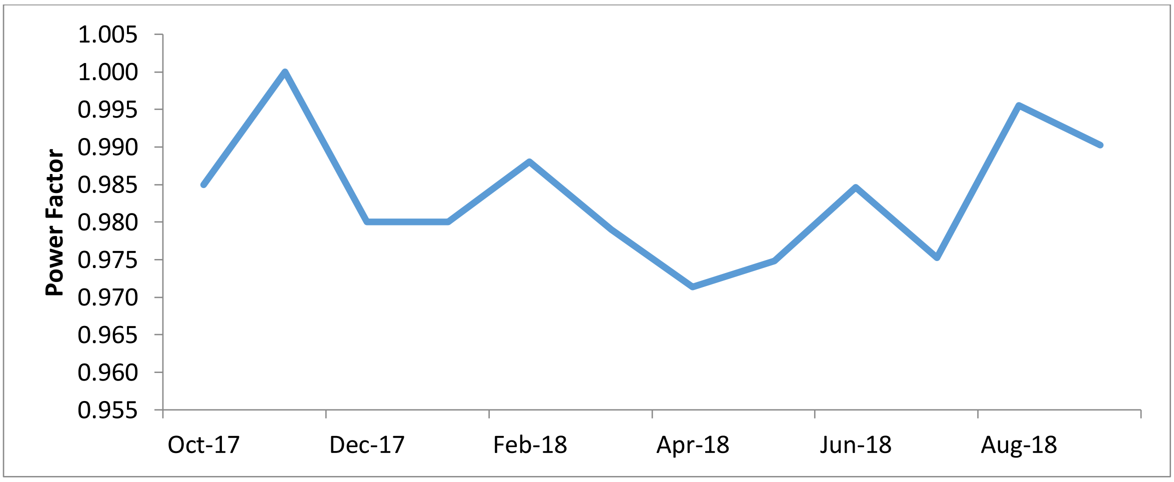


Figure 6: Month wise variation in Power Factor

The utility bills of the unit reflect the power factor. The average PF as per utility bills is 0.98. 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 0.984 and the maximum being 1.0.

Maximum Demand: Maximum demand as reflected in the utility bill is 1,271kVA from the bill analysis.

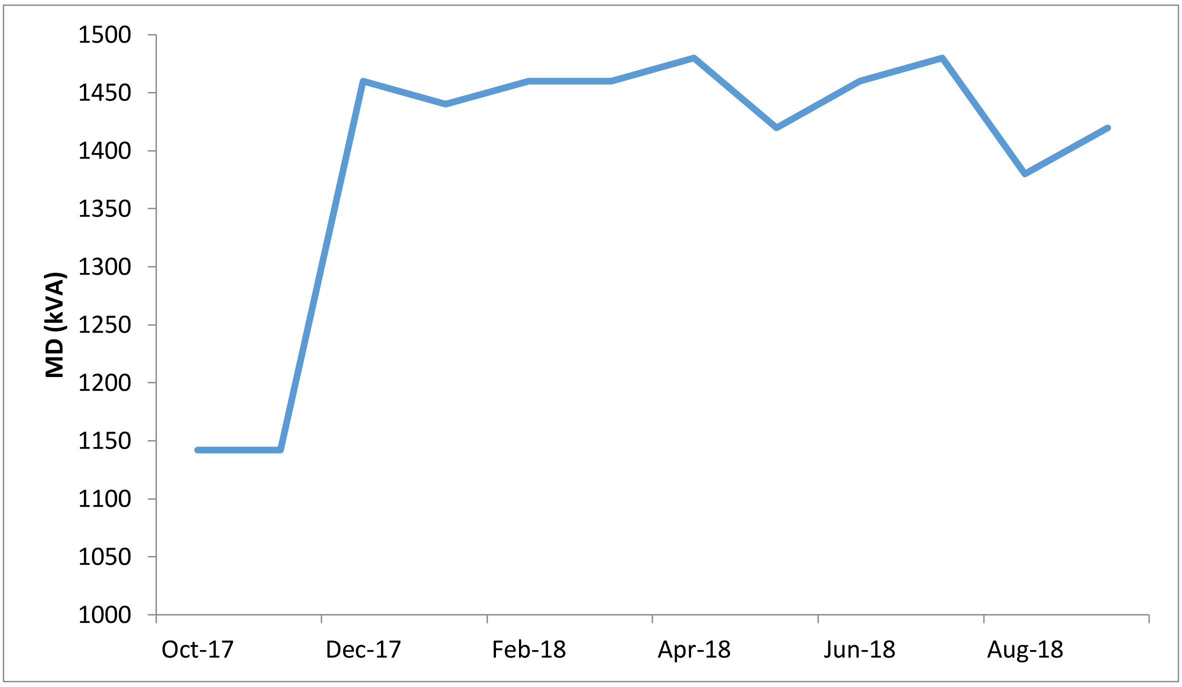


Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

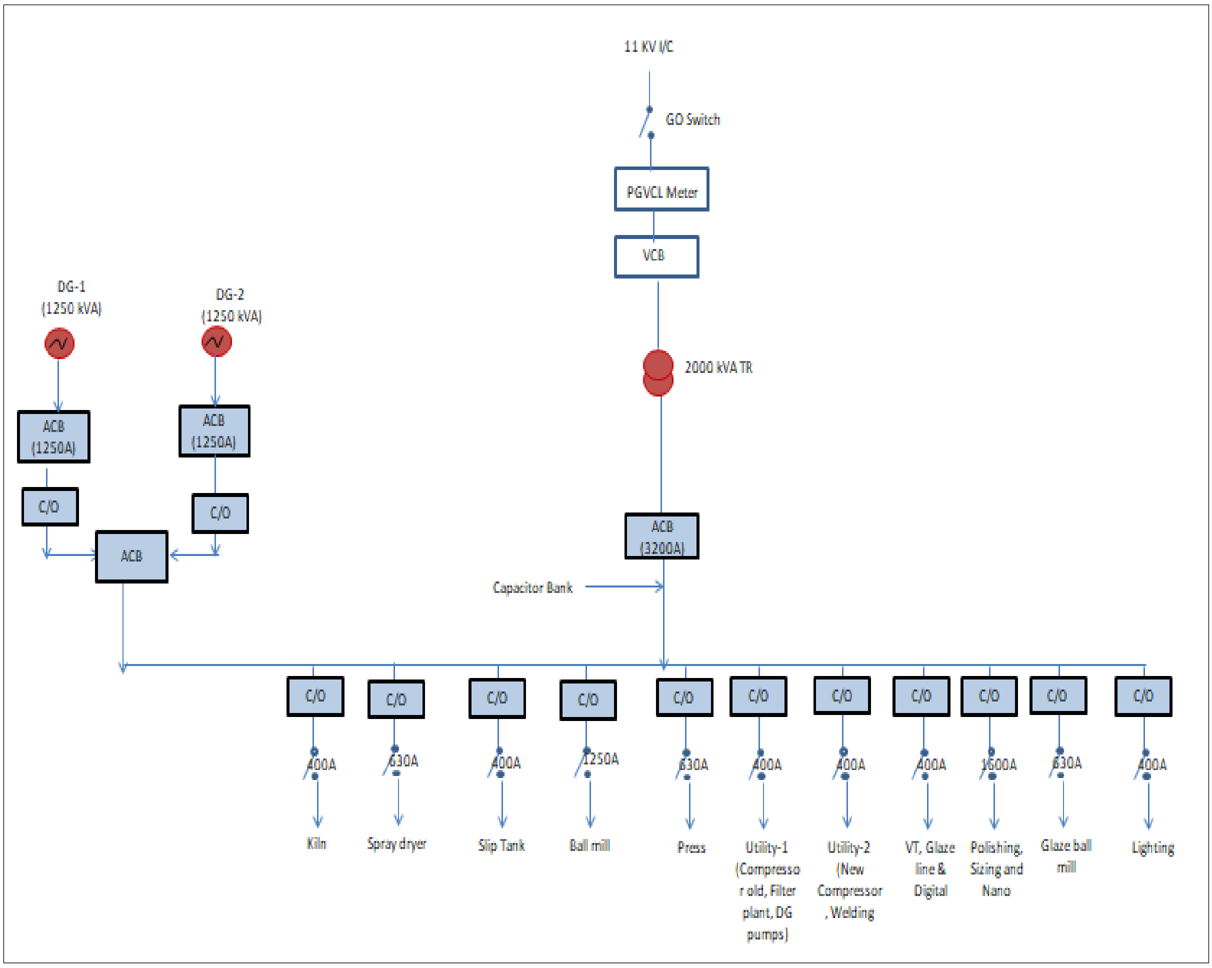


Figure 8: Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 2,634 kW, which includes:

- Plant and machinery load is 2,516 kW.
- Utility load is (lighting, air compressor and fans) about 195 kW including the single phase loads.

Table 11: Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Clay ball mill	366
2	Agitator tank	97
3	Spray dryer	151
4	Hot air generator	55
5	Press	228
6	Vertical dryer	43
7	Glaze line	101
8	Digital printing	22
9	Kiln	254
10	Sizing	136
11	Glaze ball mill	90

Sl. No.	Equipment	Capacity (kW)
12	Polishing	395
13	Nano machine	446
14	Gasifier	55
15	Compressor	62
16	Cooling tower	17
17	Pumps	39
18	Lighting & Single phase load	77
Total		**2,634**

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

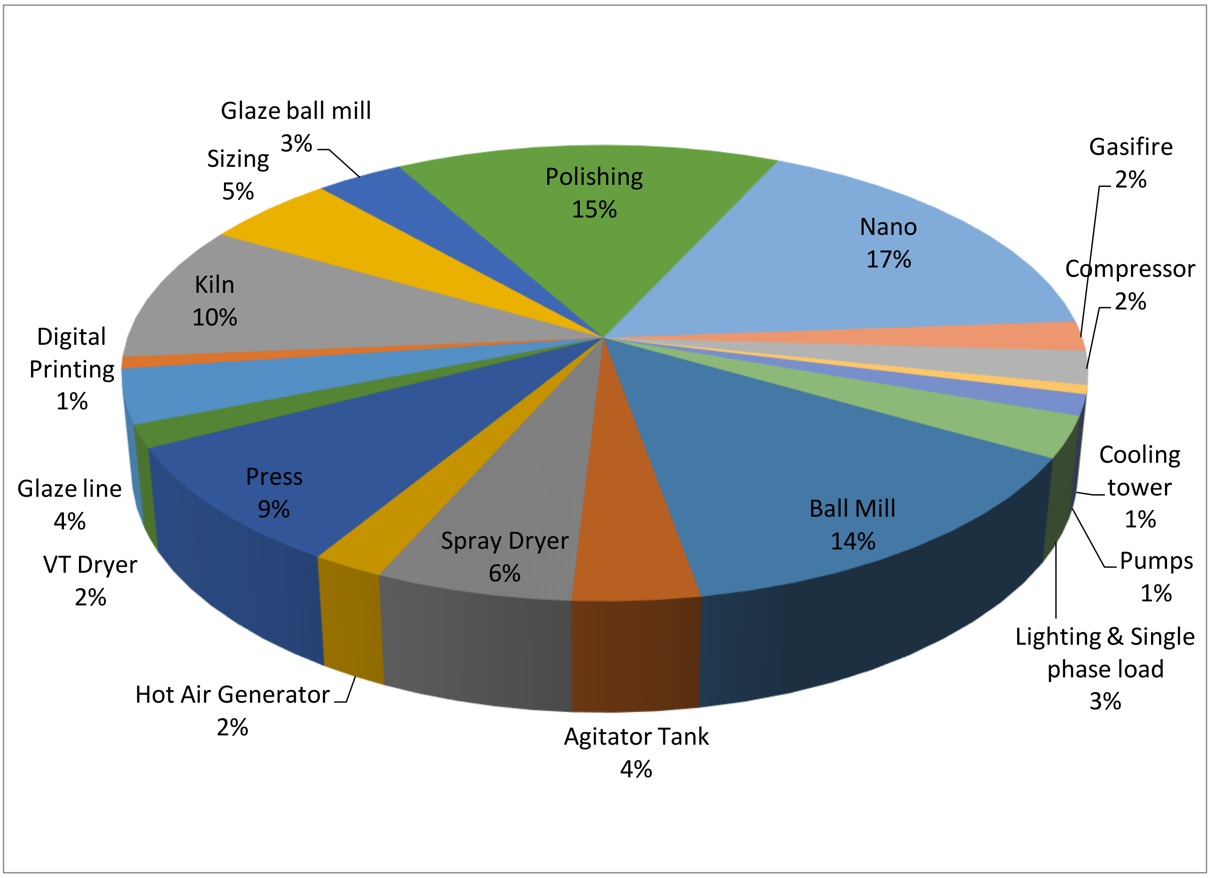


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Nano machines-17%, for Polishing machines- 15%, for Clay ball mill – 14%, for Kiln -10%, for Press-9%, for Spray dryer -6%, for Sizing machine-5%, for Agitator and Glaze -4% each, for Lighting & Single phase load-3%,for Glaze ball mill-3%, for compressor, hot air generator ,VT dryer and gasifier-2% and other loads.

2.3.1.6 Specific electricity consumption

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

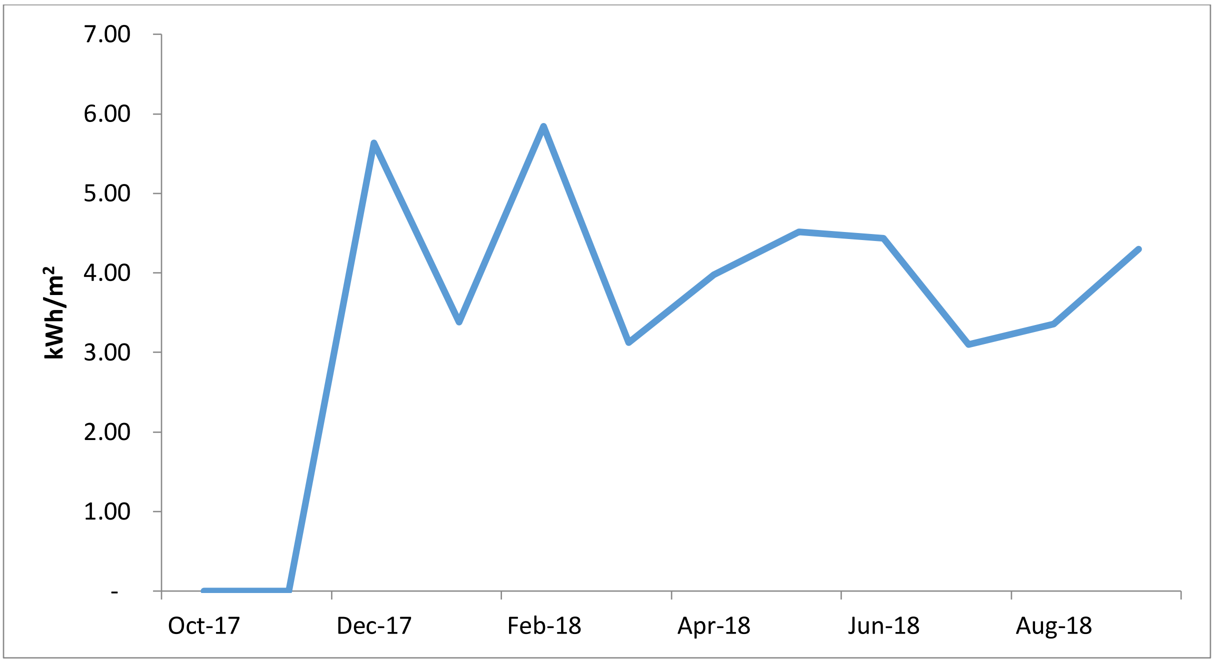


Figure 10: Month wise variation in Specific Electricity Consumption

All months except Dec-17 & Feb-18 are within ±25% of the average SEC of 4.16 kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in Clay ball mill section, spray dryer section, press section, kiln, glaze section and utility like compressor, pumps etc.

2.3.2 Analysis of Thermal Consumption

2.3.2.1 Month wise Fuel Consumption and Cost

The thermal consumption areas are the hot air generator, dryer and kiln. Coal is used as the fuel to produce coal gas from gasifier and also to generate hot air from hot air generator. Coal imported from Indonesia is being used. Natural Gas is purchased from GSPC (Gujarat State Petroleum Corporation) and is used in vertical dryer. Based on the gas bill shared for the month of Oct-17 to Sept-18, annual fuel cost has been derived as under. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	NG			Coal		
	NG Use scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs/MT
Oct-17	0	0	0	26	191,191	7,483
Nov-17	11,189	394,399	35.25	34	251,055	7,483
Dec-17	122,493	2,235,363	18.25	490	3,666,894	7,483
Jan-18	70,576	4,004,339	56.74	1,346	1,007,0247	7,483
Feb-18	40,554	2,463,294	60.74	312	2,331,478	7,483
Mar-18	23,501	875,995	37.28	528	3,953,793	7,483
Apr-18	30,448	1,134,722	37.27	301	2,254,354	7,483

Month	NG			Coal		
	NG Use scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs/MT
May-18	24,743	929,626	37.57	875	6,548,029	7,483
Jun-18	19,160	759,456	39.64	942	7,047,280	7,483
Jul-18	21,502	497,505	23.14	830	6,209,296	7,483
Aug-18	23,213	941,523	40.56	1,159	8,669,704	7,483
Sep-18	14,699	598,738	40.73	850	6,357,765	7,483

Observation (for the period Oct-17 to Sep-18)

- Average monthly coal consumption is 641 tons and average cost Rs 48 Lakh/month. The average unit cost of coal is Rs 57.10 Lakh/month for the period of Dec-17 to Sep-18.
- Average monthly gas consumption is about 33,506 scm and average cost is Rs.12.36 Lakh/month. The average unit cost of NG is Rs 39.19 per scm for the period of Dec-17 to Sep-18.

2.3.2.2 Specific Fuel Consumption.

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

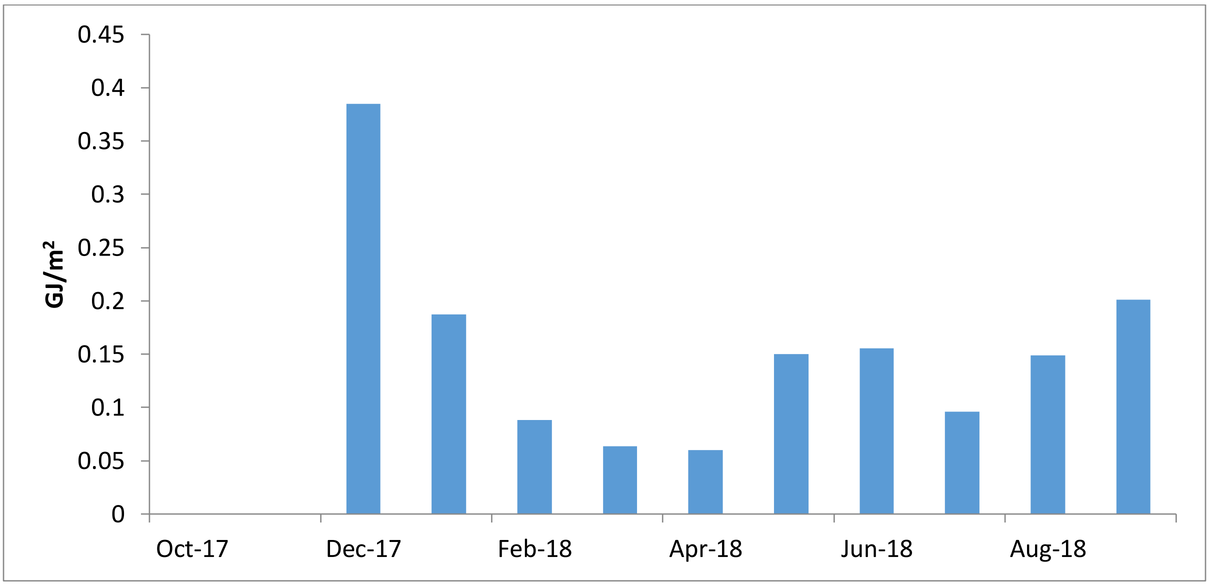


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.153GJ/m^2. SFC is high in the month of Dec-17 (production was 41,815 m^2 and thermal consumption was 16,094 GJ) and low in the month of Mar-18 & Apr-18 (production was 208,364m^2 & 137,220 m^2 respectively and thermal consumption was 13,265 GJ & 8,205 respectively). While metering for NG is recorded; the coal data is based on purchase. Actual information on coal consumption is not being maintained, and hence the SFC does not follow the production. For better quality information, sub-metering /data logging is required at kiln, hot air generator and dryers are required.

2.3.3 Specific energy consumption

2.3.3.1 Based on data collected during EA.

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

Table 13: Specific energy consumption

Particulars	UOM	Value
Average production	m^2/h	169
Power consumption	kW	679.7
Coal consumption	kg/h	890.2
NG consumption	scm/h	25
Energy consumption	TOE/h	0.60
SEC of plant	**TOE/m^2**	**0.004**

2.3.3.2 Section wise specific 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	SEC		
	NG (scm/t)	Coal (kg/t)	Electricity (kWh/t)
Clay ball mill			7.72
HAG & spray dryer		153	7.8
Press			28.78
Kilns		183.7	16.92
Vertical Dryer	4.38		
Glaze Ball Mill			43.5
Sizing Machines			12.46
Polishing Machines			22.5
Nano Machines			38.75

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

2.3.3.3 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

Particulars	UOM	Value
Annual Grid Electricity Consumption	kWh/y	5,872,992
Annual DG Generation Unit	kWh/y	-
Annual Total Electricity Consumption	kWh/y	5,872,992
Annual Thermal Energy Consumption (Coal)	MT/y	7,691
Annual Thermal Energy Consumption (NG)	scm/y	402,077
Annual Total Energy Consumption	TOE/y	5,174
Annual water Consumption	kl/y	38,880
Annual Water Cost	Lakh Rs/y	1.6

Particulars	UOM	Value
Annual Energy Cost	Lakh Rs/y	1,177
Annual Production	m^2/y	1,459,505
	t/y	37367
SEC; Electrical	kWh/m^2	4.02
	kWh/t	157.17
SEC; Thermal	GJ/m^2	0.13
	GJ/t	5.23
SEC: Water	kL/m^2	0.03
	kL/t	1.04
SEC; Overall	TOE/m^2	0.0035
	TOE/t	0.14
SEC; Cost Based	Rs/m^2	80.61
	Rs/t	3,148.52

(Annual data based on the period Oct-17 to Sep-18)

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 : 9,000kCal/scm
- GCV of Imported Coal : 5,600 kCal/kg
- CO_2 Conversion factor
    - Grid : 0.82 kg/kWh
    - Imported Coal : 2.116 t/t of coal
    - NG : 0.001923 tCO_2/scm

2.3.3.4 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

Particulars	UOM	Value
Cost of Electricity	Rs/kWh (Sept-18)	7.81
Cost of Coal	Rs/kg (Oct-17 to Sep-18)	7.48
Cost of NG	Rs/scm (Oct-17 to Sep-18)	36.9
Operating Hours per day	h/d	24
Annual Operating Days per year	d/y	365
Annual production	m^2/y	1,459,505

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using bore well pump which lifts water from ground and which is collected in overhead tank. From this raw water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 150-200m^3/day as reported by the unit and verified during DEA. There is no metering available to monitor the exact water consumption.

Water distribution diagram is shown below.

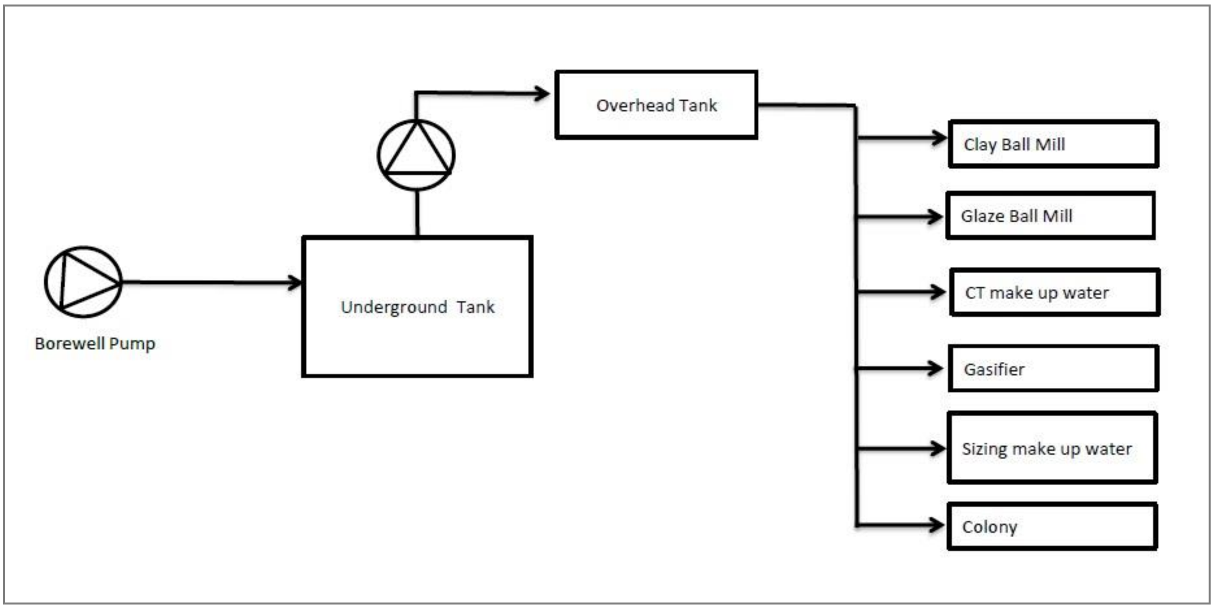


Figure 12: Water Distribution Diagram

One bore well pump is installed to meet the water requirements of process (clay ball mills, Glaze ball mills, CT make up water, Gasifier, Sizing make up water, Colony). Installation details of the pump are tabulated here under.

Table 17: Bore well pump details

Particulars	UOM	Value
Make	-	-
Motor rating	kW	7.46
RPM	rpm	-
Quantity	Number	1

Factory has water treatment plant of small capacity for sizing section. It is recommended to install meters to monitor and control water consumption.

3. CHAPTER -3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 Roller Kiln

3.1.1 Specifications

Coal gas is used as a fuel in the kiln 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 consists 329 HP electrical load of which 60HP is for smoke blower, 75 HP for combustion blowers, 20 HP for rapid cooling, 40 HP for Hot air blower (blower to dryer), 29 HP for Hot air Blower-2, 50 HP for final cooling blowers, 29 HP for final exhaust blower, 29 HP for RLW blower & remaining electrical load of kiln roller motors. The specifications of the kiln is given below:

Table 18: Kiln Details

Sr. No	Parameter	UOM	Value
	Make		Modena
1	Kiln operating time	h	24
2	Fuel consumption	scm/h	3,727
3	Number of burner to left	-	90
4	Number of burner to right	-	90
5	Cycle Time	Minutes	88
6	Pressure in firing zone	mmWC	50
7	Maximum temperature	°C	1,200
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	m	35.7 x 2.1 x 1
	Firing Zone	m	65.1 x 2.1 x 1
	Rapid Cooling Zone	m	10.5 x 2.1 x 1
	Indirect cooling Zone	m	23.1 x 2.1 x 1
	Final cooling zone	m	21 x 2.1 x 1

3.1.2 Field measurement and analysis

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

Table 19: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	8.5%
Ambient Air Temperature	42 °C
Exhaust Temperature of Flue Gas	250 °C

From the above table, it is clear that the oxygen level measured in flue gas was high. The inlet temperature of raw material in kiln was in the range of 39 – 42°C which was the ambient air temperature. Surface temperature of kiln as shown in the table below:

Table 20: Surface temperature of kiln

Zone	Temperature (°C)
Ambient Temperature	40.20
Pre-heating zone Average Surface Temperature	50
Heating zone Average Surface Temperature	77
Rapid cooling zone Average Surface Temperature	60
Indirect cooling zone Average Surface Temperature	50
Final cooling zone Average Surface Temperature	50

From the above table, it is seen that the surface temperature of heating zone and rapid cooling zone is high.

The temperature profile of the kiln is shown below:

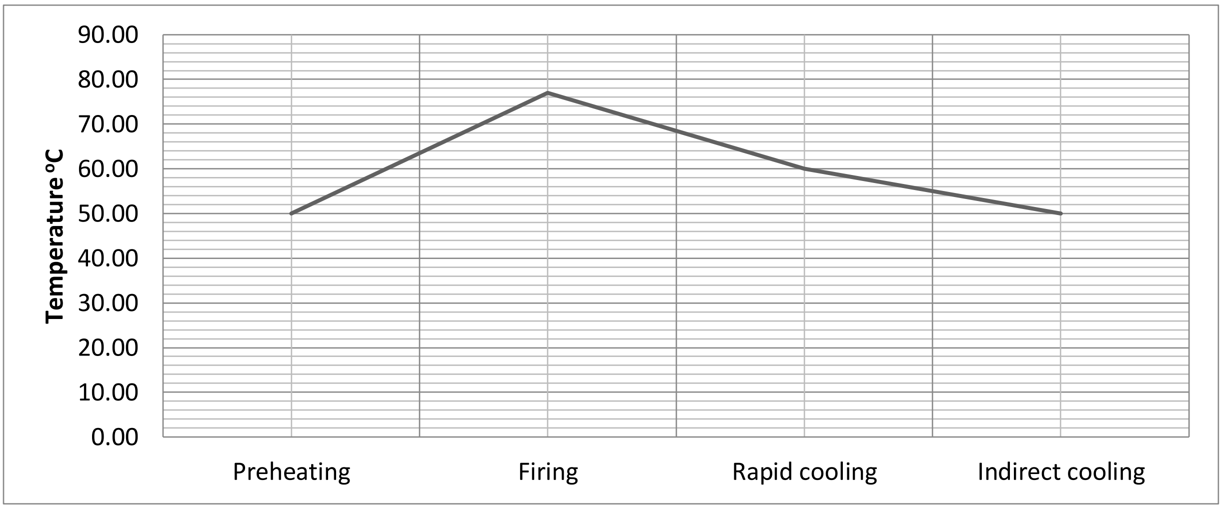


Figure 13: Temperature Profile of Kiln

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

Table 21: Power measurements of all blowers

Equipment	Average Power (kW)	Power factor
Final Cooling Blower	13.27	0.99
Rapid Cooling Blower	9.28	0.99
Intermediate Cooling Blower	5.36	0.99
Combustion Blower	13.2	0.99
Smoke Blower	10.37	0.99

The air flow in final cooling and rapid cooling blower was 1,034 m^3/h and 24,478 m^3/h.

3.1.3 Observations and performance assessment

Kiln heat utilization has been calculated based on the flue gas analysis study conducted during visit. Heat utilization by the kiln is 34.8%. Summary of all losses is shown in below figure:

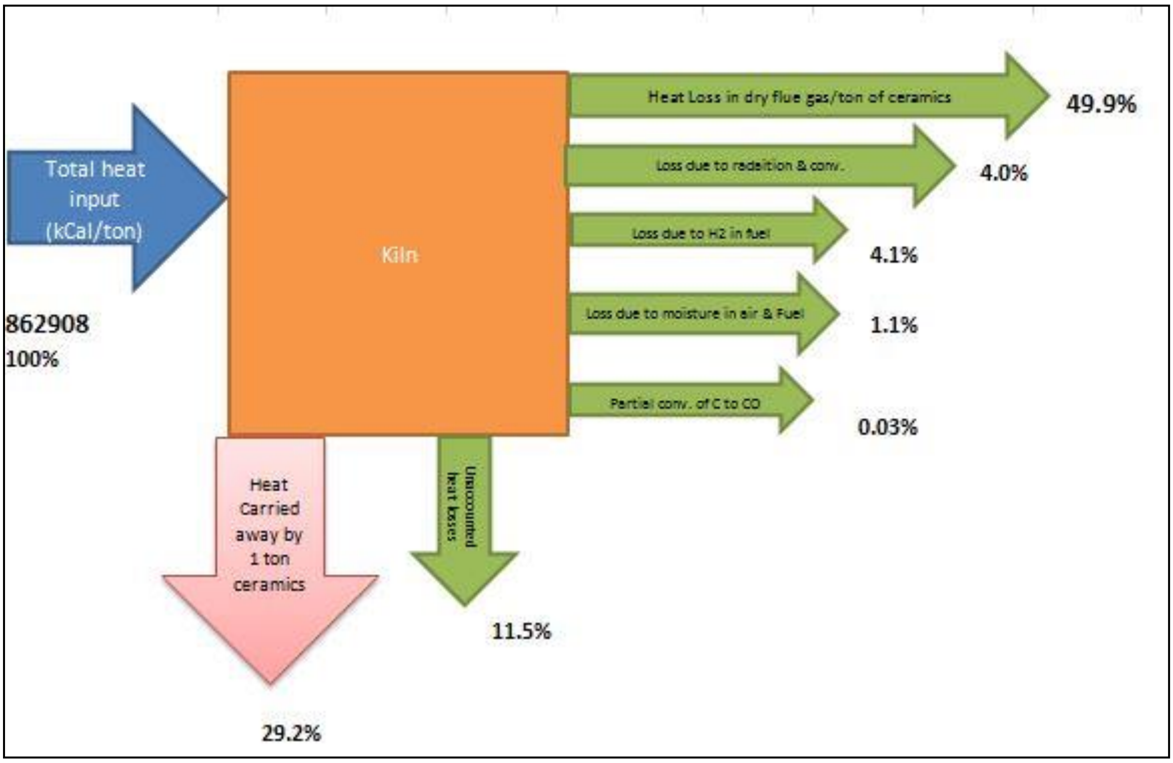


Figure 14: Heat balance diagram of Kiln

Causes of unaccounted losses arising due to following reasons:

1. Kiln leakage observed in kiln.
2. Rollers are getting heated itself by kiln heat.
3. Inspection holes are closed by aluminum dart which increases radiation loss.
4. Hot air fans body are un-insulated.
5. Atmospheric air dilution in kiln.

Detailed calculation is included in **Annexure-5**.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln: Excess Air Control

Technology description

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of the 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 processes require a 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 of excess air results in excessive heat loss through the flue gases. On the other hand, too little excess air results in incomplete 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 of excess air. This results in formation of excess flue gases, taking away the heat produced from the combustion and increasing the fuel consumption.

A PID controller, if installed, can measure 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) will be regulated. Subsequently, proper temperature and optimum excess air for combustion can be attained in the kiln.

Study and investigation

At the time of DEA, it was observed that there was 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 the practice of supplying both combustion and cooling air from one common FD fan is not a good practice.

Flue gas analysis of kiln is given in Table 19.

Recommended action

Two separate blowers are recommended for supplying combustion air and cooling air. It is recommended to install control system to regulate the supply of excess air for proper combustion. Every reduction in every 10% of excess air will save 1% in specific fuel consumption. The cost benefit analysis of the energy conservation measure is given below:

Table 22: Kiln Excess Air Control [ECM-1]

Particulars	UOM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	8.5	5.0
Excess air percentage in flue gas	%	68.0	31.3
Dry flue gas loss	%	50%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	kg of fuel/ton of tile	671	647
Average production in Kiln	t/h	5.8	5.8
Saving in specific fuel consumption	kg/h		143.14
Operating hours per day	h/d		24
Annual operating days	d/y		365
Annual fuel saving	t/y		1254
Coal gas to coal ratio	kg/kg	2	2
Coal saving in gasifier	t/y		627
Fuel cost	Rs/t		7,483
Annual fuel cost saving	Lakh Rs/y		46.9
Power saving in combustion blower			
Mass flow rate of air	t/h	50.52	39.47
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	11.5	8.9

Particulars	UOM	Present	Proposed
Total pressure rise	Pa	2,412	2,412
Measured power of blower	kW	13.20	6.30
Total power saving	kW	13.20	6.91
Operating days per year	d/y		24
Operating hours per day	h/d		365
Annual energy saving	kWh/y	60,514	
Cost of electricity	Rs/kWh	7.71	7.71
Annual energy cost saving	Lakh Rs/y		4.66
Overall energy cost saving	Lakh Rs/y		51.58
Estimated investment	Lakh Rs		18.48
Payback period	Months		4.30
Project IRR	%		212
Discounted Payback Period	Months		1.86

3.1.4.2 ECM #2: Insulation improvement - kiln area

Technology description

Proper Insulation helps reduce the heat loss to the surroundings and thereby reducing the fuel consumption.

Study and investigation

During field measurements, it was found that the surface temperatures of combustion air pipes of combustion zone & rapid cooling zone was very high due to poor insulation. Due to this, the heat loss to the surrounding increases and thereby increasing the fuel consumption.

Recommended action

It is recommended to insulate the combustion air pipes of combustion and rapid cooling zones. The cost benefit analysis for insulation of combustion air pipes is as follows:

Table 23: Insulation on combustion pipes [ECM-2]

Parameter	UOM	Present	Proposed
No of uninsulated pipe in recuperator	#	40	40
No of uninsulated pipe in firing zone	#	208	208
Recuperator pipe size	mm	75	75
Pipe length	m	1	1
Pipe size in firing zone	mm	50	50
Pipe length	m	0.30	0.30
Total surface area	m^2	42.10	42.10
Average surface temperature	°C	140	80
Ambient air temperature	°C	35	35
Heat loss	$kCal/h/m^2$	1,601	551
Total heat loss	kCal/h	67,408	23,206
GCV of coal gas	kCal/scm	1,231	1,231

Parameter	UOM	Present	Proposed
Heat loss in terms of fuel (coal gas) in Kiln	scm/h	54.8	18.9
Gas to coal ratio of Gasifier	scm/kg	2.52	2.52
Heat loss in terms of coal in gasifier	kg/h	21.7	7.5
Fuel saving	kg/h		14.2
Operating hours per day	h/d	24	24
Annual operating days	d/y	300	300
Annual fuel saving	t/y		103
Fuel cost	Rs/t		6000
Annual fuel cost saving	Lakh Rs/y		6.16
Estimated investment	Lakh Rs		2.80
Payback period	Months		5.45

The cost benefit analysis for insulation of Rapid cooling zone is as follows:

Table 24: Insulation on Rapid Cooling Zone [ECM-2]

Parameter	UOM	Present	Proposed
No of uninsulated pipe in rapid cooling Zone	#	40	40
No of uninsulated pipe in firing zone	#	208	208
Recuperator pipe size	mm	75	75
Pipe length	m	1	1
Pipe size in firing zone	mm	50	50
Pipe length	m	0.30	0.30
Total surface area	m^2	42.10	42.10
Average surface temperature	°C	140	50
Ambient air temperature	°C	35	35
Heat loss	$kCal/h/m^2$	1,601	161
Total heat loss	kCal/h	67,408	6,788
GCV of fuel	kCal/kg	5,600	5,600
Heat loss in terms of fuel	kg/h	12.0	1.2
Fuel saving	kg/h		10.8
Operating hours per day	h/d	24	24
Annual operating days	d/y	365	365
Annual fuel saving	kg/y		94,827
Fuel cost	Rs/kg		7.5
Annual fuel cost saving	Lakh Rs/y		7.10
Estimated investment	Lakh Rs		2.78
Payback period	Months		4.70
Combined Project IRR	%		192
Combined Discounted payback period	Months		1.86

3.1.4.3 ECM #3: Replace V belts with REC belts in Kiln and Spray dryer blower - kiln area

Technology description

Replace V belts with REC belts in kiln blower.

Study and investigation

During field measurements, it was found that the all most all blower in kiln are belt drive. All the belts are V type. These belts were consuming more power.

Recommended action

It is recommended to replace V belt to raw edge cogged belt which result in 3.6 % of energy saving:

Table 25: Install REC belts in place of V belts in Kiln blowers [ECM-3]

Parameters	UoM	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Name of the belt driven blower	#	HAG ID Fan		Kiln Smoke blower		Kiln Combustion blower		Kiln Rapid cooling blower		Kiln Final cooling blower		Kiln Hot air blower-1		Kiln Hot air blower-2	
Rated power of blower	kW	74.6	74.6	45	45	56	56	15	15	37	37	30	30	22	22
Measured power the blower	kW	52	50	11	10	13	13	9	9	13	13	8	8	9	8
Running hours of blower per day	h/d	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Annual operating days	d/y	250	250	330	330	330	330	330	330	330	330	330	330	330	330
Annual energy consumption	kWh/y	313,694	302,401	83,160	80,166	104,578	100,813	72,621	70,006	105,155	101,370	61,730	59,508	68,218	65,762
Annual energy saving	kWh/y		11293		2,994		3,765		2,614		3,786		2,222		2,456
Weighted electricity cost	Rs/kWh	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71	7.71
Annual energy cost saving	Rs Lakh		0.87		0.23		0.29		0.20		0.29		0.17		0.19
Net cost saving	Rs Lakh	2.25													
Estimated investment	Rs Lakh	1.4													
Simple payback period	months	7													
Combined Project IRR	%	123													
Combined Discounted payback period	Months	2.86													

3.2 COAL GASIFIER

3.2.1 Specifications

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

Table 26: Specifications of coal gasifier

Particulars	UOM	Value
Make		Radhey
Coal consumption	kg/h	950
Water consumption	l/d	250
FD Blower	hp	2 x 20
Cooling water pump	hp	2 x 7.5

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Power measurement of FD & ID fan
- Amount of coal gas produced

Coal consumption is recorded by the plant in terms of lifts as per kiln cycle time.

FD blower and ID blower was operating with VFDs. Average power consumption of ID & FD blower is 25.77kW (PF 0.99) & 4.4kW (PF 0.99) respectively. Air flow is 2,937 m^3/h at FD fan suction.

3.2.3 Observations and performance assessment

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, the specific energy consumption of coal gasifier was 0.26 kg/scm. Specific electricity consumption will be considered as how much power is required for 1 scm coal in plant which is 0.006 kWh/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed.

3.3 VERTICAL DRYER

3.3.1 Specifications

There is one vertical dryer. It is used for pre drying of tiles before entering into kiln. The specifications of dryers are given below table:

Table 27: Specifications of vertical dryer

Particulars	UOM	Value
Capacity	Nos. of tiles/h	1,500
Fuel type		NG
Rated fuel consumption	scm/h	50
Exit temperature of tiles	°C	98
FD Blower	hp	2 x15
Combustion Blower	hp	1 x 7.46

3.3.2 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)
c) Power consumption of blowers
d) Gas consumption data

Data measured during study is tabulated below:

Table 28: Field measurement at site

Particular	UOM	Value
Tiles passed through dryer	Nos./h	363
Mass of each tile at entry	g	17,000
Mass of each tile at exit	g	16,690
Temperature of tile at exit	°C	98
Gas consumption	scm/h	16.9 (NG)

Hot air blower discharge duct from kiln is utilized in vertical dryer which helps in fuel savings and NG is used for firing auxiliary burners. All blowers are operating with VFDs.

The power profile and PF profile of blowers installed in vertical dryer are given in **Annexure-4**.

3.3.3 Observation and Performance assessment

Mass and energy balance of vertical dryer determined based on DEA is as follows:

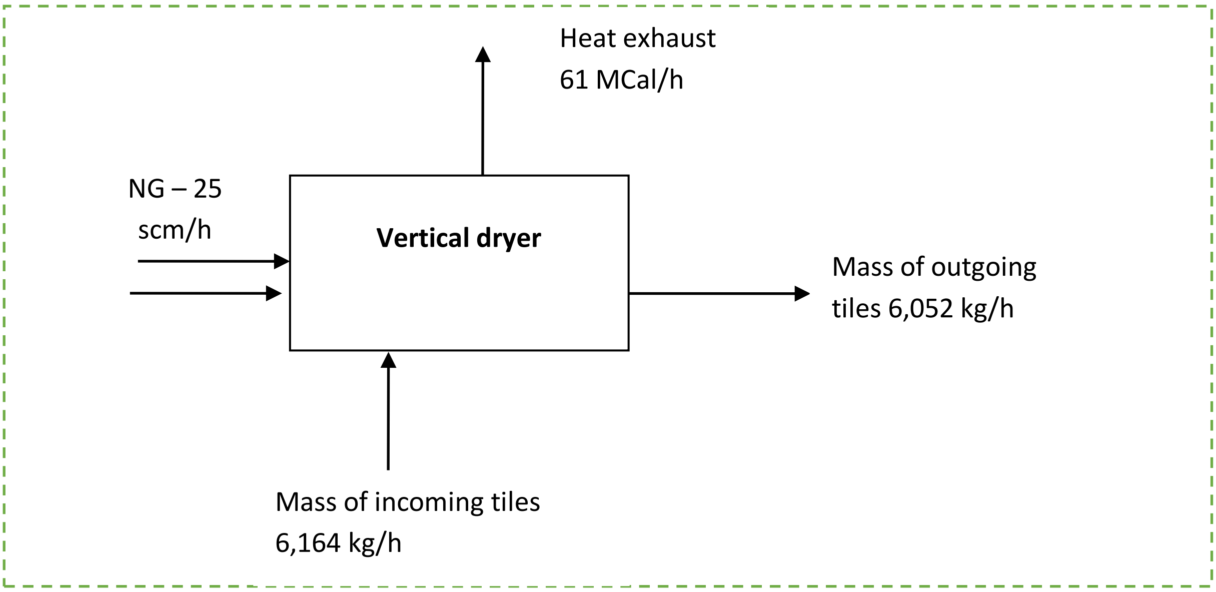


Figure 15: Mass and energy balance of vertical dryer

The energy balance for the Vertical dryer has been determined by waste heat and NG.

Based on observations during DEA, the specific thermal energy is 4.38 scm/ton of tile.

Since blowers are VFD controlled, hot air is utilized and operation is optimized. No energy conservation measure is proposed.

3.4 Hot Air Generators& Spray Dryers

3.4.1 Specifications

There is one hot air generator (HAG) of bubbling bed type is used for evaporating water from slip which is coming from Clay ball mill. There is one spray dryer installed which is taking heat from HAG. Spray dryer is the heat exchanging unit for power generation from slip. Specifications of HAG are given below:

Table 29: Specifications of Hot air generator (HAG)

Particular	UOM	Value
Air handling capacity	m^3/h	-
Fuel type		Coal
Rated fuel consumption	kg/h	-
Exhaust air temperature	°C	750
FD Blower	hp	1 x 54
ID Blower	hp	1 x 100
PA Blower	hp	1 x 10

The specifications of spray dryers is given below:

Table 30: Specifications of spray dryer

Particular	UOM	Value
Powder generation capacity	kg/h	12,500
Inlet slip moisture	%	40
Outlet powder moisture	%	6
Slip pump	kW	30

3.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Hot air generators
  - Power consumption of FD, PA and ID fan
  - Air flow measurement of FD fan
  - Exhaust air temperature
  - Surface temperature
- Spray dryer
  - Inlet and outlet moisture data
  - Power consumption of slip pump
  - Powder generation

Details of measurements on HAG are given below:

Table 31: Field measurement at site

Particulars	UOM	Value
Air velocity at FD fan suction	m/s	13.96
Suction area	m^2	0.14
Exit temperature of air	° C	730
Surface temperature	° C	70
Average power consumption-FD Blower	kW	25.99 (PF=1)
Average power consumption -ID Blower	kW	58.09 (PF=0.87)
Average power consumption of PA blower	kW	4.25 (PF=1)

HAG FD and PA blowers are occupied with VFDs.

The power consumption of slip pump in the spray dryer was 14.45 kW (PF 0.70).

3.4.3 Observations and performance assessment

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

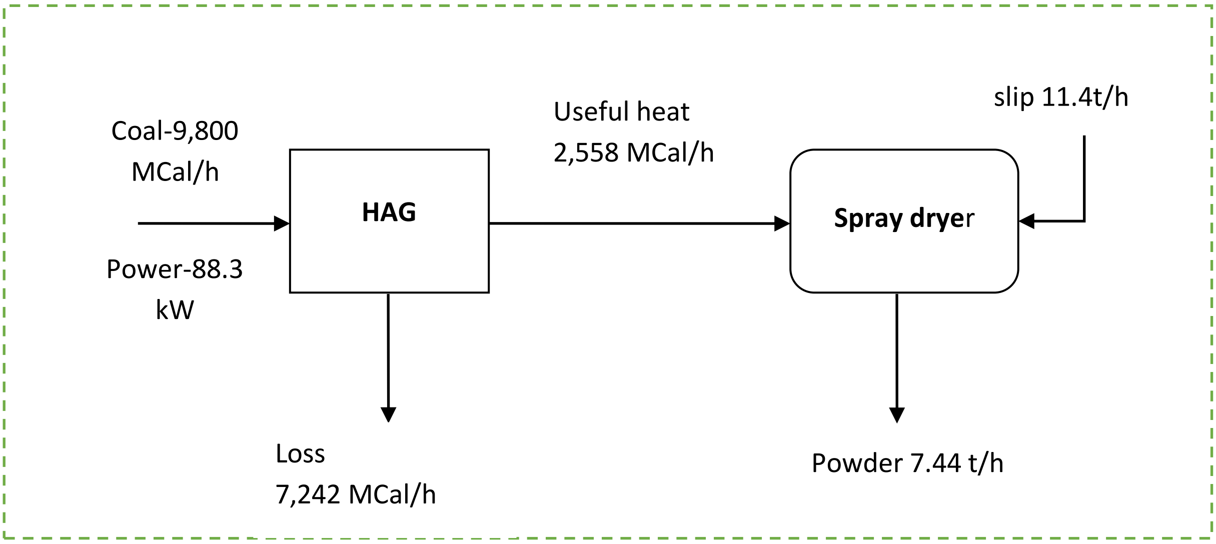


Figure 16: Energy and mass balance of Chain Stoker HAG and spray dryer

Performance of HAG & spray dryer measures in terms of specific energy consumption (electrical energy used for delivering one kg of slip). Based on observations during DEA, the specific energy consumption of HAG & spray dryer was 7.8 kW/ton and specific thermal consumption is 0.153 ton of coal/ton of slip.

3.4.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.4.4.1 ECM # 4: Insulation improvement – HAG Are

Technology description

Proper Insulation helps reduce the heat loss to the surroundings and thereby reducing the fuel consumption.

Study and investigation

During field measurements, it was found that the surface temperature of duct connecting HAG and cyclone separator was very high due to poor insulation. Due to this, the heat loss to the surrounding increases and thereby increasing the fuel consumption.

Recommended action

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

Estimated cost benefit is given in the table below:

Table 32: Saving and cost benefit by insulation improvement near HAG [ECM-4]

Particulars	UOM	Present	Proposed
Area needing insulation		Connecting duct to Cyclone separator	
Total surface area	m^2	37.7	37.7
Average surface temperature	°C	115	70
Estimated heat loss	kcal/h	28,219	7,958
GCV of coal	kcal/kg	5600	5600
Estimated coal loss	kg/h	5.0	1.4
Average coal saving	kg/h		3.6
Annual Operating Hours	h/y	5,475	5,475
Annual coal saving	t/y		20
Fuel cost	Rs/t	7483	7483
Annual fuel cost saving	Lakh Rs/y		1.48
Total Savings	Lakh Rs/y		1.48
Estimated insulation cost	Lakh Rs		2.49
Payback period	Month		20.13
Project IRR	%		38
Discounted Payback Period	Months		7.61

3.4.4.2 ECM # 5: Installed VFD in spray dryer ID fan– HAG Are

Technology description

Install VFD instead of dampening control and star-delta operation for spray dryer ID blower which result energy saving.

Study and investigation

During field measurements, it was found that the ID fan is operating with damper control (80% open) and also star-delta connection. It is suggested to install VFD instead of star-delta and remove damper completely to reduce power consumption.

Recommended action

It is recommended to install VFD instead of star-delta operation.

Estimated cost benefit is given in the table below:

Table 33: Saving and cost benefit by installing VFD in spray dryer ID blower [ECM-5]

Parameters	UoM	Present	Proposed
Rated power of ID fan motor	kW	74.6	74.6
Connection type		Star-Delta	VFD
Damper control system		80% damper open	100% open
Average running power	kW	58.1	52.3
Average running hours per day	h/d	24	24
Annual operating days	d/y	250	250
Annual energy consumption	kWh/y	348,548	313,694
Annual energy saving	kWh/y	34,855	
Weighted average electricity cost	Rs/kWh	7.71	
Annual monetary savings	Rs Lakh/y	2.69	
Estimate of Investment	Rs Lakh	2.12	
Simple Payback period	Months	9	
Project IRR	%	94	
Discounted Payback Period	Months	3.7	

4. CHAPTER - 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 CLAY BALL MILLS

4.1.1 Specifications

Clay ball mills produce slip by mixing clay, water and chemicals SMS and STPP. Clay ball mills take 3 to 6 hours for slip preparation. The specifications of Clay ball mills and its accessories are given below:

Table 34: Specifications of Clay ball mills

Particulars	UOM	Value
Numbers of Clay ball mills	#	2
Capacity of each Clay ball mill	tons	45
Water consumption in each Clay ball mill	l	25,000
SMS (chemical consumption)	kg/batch	300
STPP (chemical consumption)	kg/batch	35
Water TDS	ppm	800
Nos. of batch per day	#	2

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all Clay ball mills
- Mass of raw material fed in the clay ball mill
- Water hardness

All power profiles are included in **Annexure-4**.

Average power consumption and power factor are given in below table:

Table 35: Average power consumption and PF of Clay ball mills

Equipment	Average Power (kW)	PF
Clay ball mill#1	88.5	0.93
Clay ball mill#2	91.7	0.85

4.1.3 Observations and performance assessment

Mass balance of Clay ball mill #1 Based on measurements is given below:

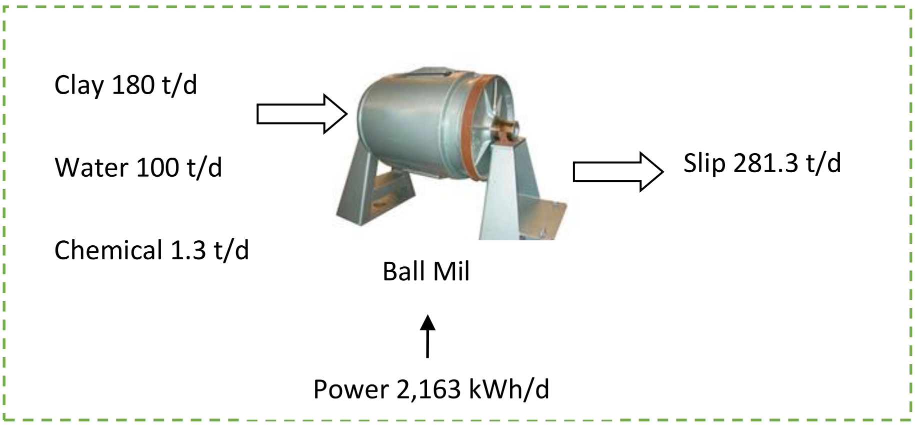


Figure 17: Energy and mass balance of Clay ball mill

Performance of Clay ball mill is measured in terms of specific energy consumption (power consumed for preparation of 1 ton of slip). Based on observations during DEA, the specific electricity consumption was 7.68 kW/ton. TDS of bore well water is very high; this should be controlled by installing softener plant, which will enable resource savings.

Detailed calculation is included in **Annexure-5**.

4.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.1.4.1 ECM # 6: Using soft water in clay ball mill

Technology description

It was observed that the TDS of water used in clay section is 800 ppm, which results in higher consumption of water, chemicals and electricity per batch of slip 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 400 ppm) to be used in Clay 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 HAG.

Estimated cost benefit is given in the table below:

Table 36: Saving and cost benefit by using soft water in clay ball mill [ECM-6]

Particulars	UOM	Present	Proposed
TDS of Water	ppm	800	400
Assumption : Water Saving			15%
Assumption : Electricity Saving			3%
Assumption : Fuel Saving			30%
Assumption : Chemical Saving			30%
Water used per batch	m^3	25.00	21.25
Water saving	m^3		3.75
Electricity used per batch	kWh	550.7	534.2
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kcal/kg	5,600	5,600

Particulars	UOM	Present	Proposed
Eff. Of HAG	%	85	85
Coal saving per batch	kg		485
Chemical saving per batch			
SMS	kg	300	210
STPP	kg	35	24.5
Per Unit Cost			
Water	Rs./m^3	4.20	4.20
Electricity	Rs/kWh	7.71	7.71
Coal	Rs/kg	7.48	7.48
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		6,641
Total batches per day	#	4	4
Annual operating days	d/y	365	365
Annual resource savings			
Water	m^3/y		5,475
Electricity	kWh/y		24,120
Coal	t/y		707.38
Chemical	kg/y		146,730
Annual cost savings	Lakh Rs/y		96.96
Operating cost- Water Treatment	Rs/m^3		20.00
	Lakh Rs/y		6.21
Net monetary savings	Lakh Rs/y		90.76
Estimated investment	Lakh Rs		39.60
Payback period	Months		5.24
Project IRR	%		179
Discounted payback period	Months		2

4.1.4.2 ECM # 7: Use of VFD instead of soft starter in Clay ball mill

Technology description

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

Study and investigation

During field measurement, it was found that the clay ball mill-2 was operating with soft starter.

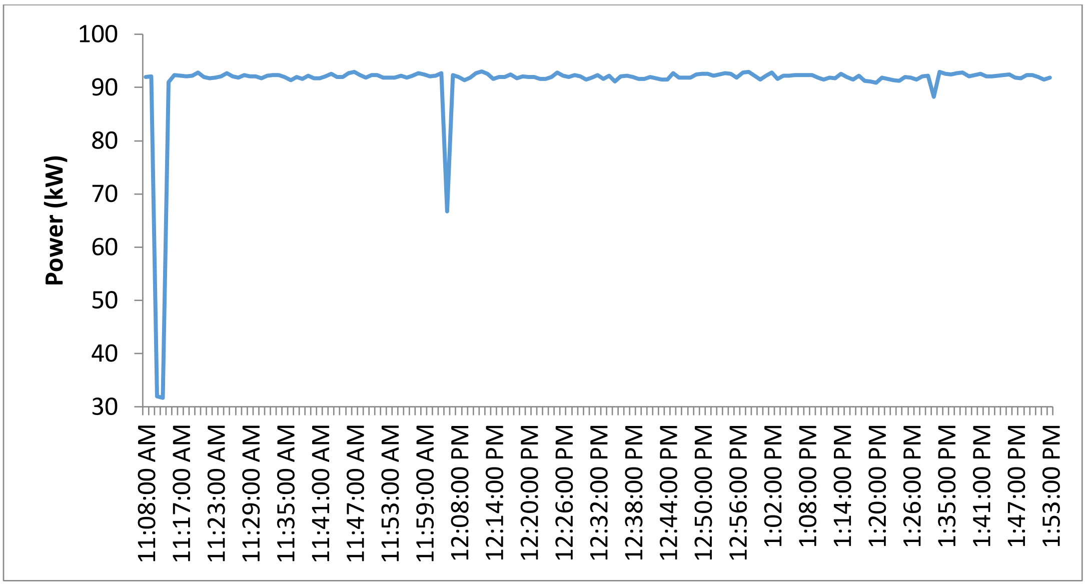


Figure 18: Power profile of clay ball mill-2

Recommended action

It is recommended to replace the soft starter by VFD which will reduce the power consumption by 10%.

Table 37: Savings and cost benefit analysis for using VFD instead of soft starter in clay ball mill [ECM-7]

Particulars	UOM	Present	Proposed
Clay ball mill Motor Capacity	kW	171.58	171.58
Measured Motor Power	kW	91.78	82.60273
Batch time	h	6	6
Nos. of Batch per day	#	2	2
Annual Working Days	#	365	365
VFD saving	%		10
Annual Energy Consumption	kWh/y	402,000	361,800
Energy Saving	kWh/y		40,200
Unit Cost	Rs/kWh	7.71	7.71
Cost Saving	Lakh Rs/y		3.10
Estimate Investment	Lakh Rs.		10.19
Payback period	Months		39.5
Project IRR	%		9
Discounted payback period	Months		13.96

4.2 Hydraulic Presses

4.2.1 Specifications

Hydraulic presses give shape for powder that is coming from spray dryer in tiles form by pressing powder with high pressure (20.5MPa). 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 38: Specifications of hydraulic press

Particular	UOM	Value
Cycle (stroke) per mins	N/min	8
Nos. of tiles per stroke	#	1
Water Circulation Pump	#	1

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of presses
- Number of tiles produced

Tiles produced from the press is 363 per hour.

4.2.3 Observation and performance assessment

Performance of hydraulic presses can measures 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 28.8kW/ton.

4.3 AGITATOR

4.3.1 Specifications

Slip is stored in agitation tank after preparation in clay ball mills where agitator motors (stirrer) are rotating continuously. Stirrer avoids settling of slip. The specifications of agitator motors are given below:

Table 39: Specifications of agitators

Particular	UOM	Value
Numbers of agitators in tank	#	15
Capacity of each agitator motor	kW	5.6
Number of motors	#	15

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all working agitator motors
- Mass of slip fed to agitators

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

Table 40: Power consumption and P.F. of agitator motors

Equipment	kW	PF
Agitator#6	1.7	0.5
Agitator#7	3.2	0.41
Agitator#8	1.8	0.41
Agitator#9	1.5	0.23
Agitator#11	2.0	0.4
Agitator#12	1.0	0.23

Equipment	kW	PF
Agitator#14	0.9	0.29
Agitator#15	1.2	0.32

The mass of slip fed to agitators were 280t/d.

4.3.3 Observations and performance assessment

During DEA, it is observed that only 8 agitators were running and all motors operate same time. All agitators were having poor power factor. It is suggested that all motor should operate by timer control.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slip). Based on observations during DEA, the specific energy consumption of agitator motors were 0.57kW/ton.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 ECM #8: Timer Controller for stirrer motor

Technology description

A number of agitators are running only to maintain homogenous of the slip. A timer-based control can help save energy. A number of units have implemented timer based control where two agitators in same tank are made to operate 30-45 minutes each based on time control.

Study and investigation

It was observed that all the agitators are not equipped with VFD and all agitators are in continuous operation throughout the day.

Recommended action

It is recommended to install timer based control for agitators to save energy. Timing of agitators can be decided based on requirement and configuration of agitators. The cost benefit analysis for this project is given below:

Table 41: Stirrer Time Controller [ECM-8]

Particulars	UOM	Present	Proposed
No of agitator stirrer	#	15	15
No of agitator stirrer running	#	15	15
Rated power of agitator stirrer motor	kW	84	84
Daily running of each stirrer motor	h/d	24	15
Operating days per year	d/y	365	365
Measured power of agitator stirrer motor	kW	1.65	1.7
Annual energy consumption	kWh/y	216,810	135,506

Particulars	UOM	Present	Proposed
Annual energy saving	kWh/y		81,304
cost of electricity	Rs/kWh		7.71
Annual monetary savings	Lakh Rs/y		6.27
Estimated Investment	Lakh Rs		1.19
Payback Period	Months		2.28
Project IRR	%		396
Discounted payback period	Months		0.91

4.3.4.2 ECM #9: Replacement of existing agitator stirrer motor with IE3/IE4 motor

Technology description

IE3/IE4 energy efficiency motor inplace of conventional motor.

Study and investigation

There are 15 stirrers and having capacity 5.6kW each. Each motor are conventional type and are rewinded more than once. It is suggested to replace these motors with energy efficient IE3 /IE4 type motor.

Recommended action

It is recommended to replace existing all agitator conventional motor with energy efficiency IE3/IE4 motor to reduce energy consumption:

Table 42: Energy efficiency IE3/IE4 stirrer motor [ECM-9]

Particular	UoM	Present	Proposed
Facility name		Stirrer section	
Quantity of motors	#	15	15
Rated power of existing each motor	kW	1.66	1.66
Existing efficiency of motor	%	86.0	90
Average operating power	kW	1.66	1.49
Energy loss in motor	kW	0.23	0.07
Possible energy saving	kW	0.17	
Annual operating days	d/y	365	365
Operation hours per day	h/d	15	15
Oveall annual energy consumption	kWh/y	136,328	122,695
Annual energy savings	kWh	13,633	
Weighted avg. electricity cost	Rs/kWh	7.71	
Annual cost saving	Rs Lakh/y	1.1	
Estimated investment	Rs Lakh	3.0	
Simple payback period	months	34	
Project IRR	%	13	
Discounted payback period	Months	1.19	

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 glaze ball mills are given below:

Table 43: Specifications of glaze ball mills

Particular	UOM	Value
Numbers of glaze ball mills	Nos.	4
Capacity of glaze ball mills-1,2,3,4	HP	3 x 25, 1 x 40

4.4.2 Field measurement and analysis

During DEA, glaze ball mill -1 was in operation and the following measurements were done:

- Power consumption of glaze ball mill-1
- Mass of material fed to glaze ball mill-1

The power consumption of glaze ball mill-1 was 5.58 kW and mass of material fed to glaze ball mill was 128 kg/h.

4.4.3 Observations and performance assessment

Performance of glaze ball mill can be measured in terms of specific energy consumption (power consumed for holding 1 ton of material). Based on observations during DEA, the specific energy consumption of glaze ball mill was 43.5 kW/ton.

4.5 SIZING, POLISHING & NANO MACHINES

4.5.1 Specifications

There were two sizing, three polishing and two nano machines present in the unit. The specifications of machines are given below:

Table 44: Specifications of sizing, polishing and Nano machines

Particular	UOM	Sizing	Polishing	Nano
Numbers of machines	Nos.	2	3	2
Capacity of machines	hp	2 x 90	3 x 265	2 x 300

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of sizing machines, Polishing machines-1,2,3 & Nano machines-1,2
- Mass of slip fed to sizing machine, Polishing & Nano machines

The average power consumption of sizing machines were 72.29 kW, Polishing machines were 130 kW and Nano machines were 225 kW.

Mass of slip fed to sizing, Polishing and Nano machines was 5.8t/h.

4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption of sizing machine, Polishing machines and Nano machines was 12.46, 22.5 and 38.75 kW/ton of slip respectively.

4.5.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.5.4.1 ECM #9: Optimize pumps running time in polishing and sizing section

Technology description

Stop pumping system during non working time.

Study and investigation

During study, it was observed that all pumps related to polishing and sizing section are running continuously even the machines are off..

Recommended action

It is recommended to stop pumps during non working time to avoid unnecessary use of pumping system.

Table 45: Stop pumping system during non working time [ECM-10]

Parameters	UoM	Present	Proposed
Number of pumps	#	2	2
Rated power of pumps	kW	7.5	7.5
Average operating powers	kW	6.7	6.7
Average running time per day	h	24	22
Average non working time of polishing and sizing section	h	2	2
Annual operating days	d/y	330	300
Annual energy consumption	kWh/y	53,175	44,312

Parameters	UoM	Present	Proposed
Annual energy saving	kWh/y	8,862	
Weighted average electricity cost	Rs/kWh	7.71	
Annual monetary savings	Rs Lakh/y	0.68	
Estimate of Investment	Rs Lakh	0.50	
Simple Payback period	Months	9	
Project IRR	%	104	
Discounted payback period	Months	3.39	

4.6 Air Compressors

4.6.1 Specifications

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

Table 46: Specifications of compressors

Particular	UOM	Air compressor-1	Air compressor-2
Power rating	kW	55	22
Maximum pressure	Bar (a)	7	-
Air handling capacity	m^3/min	10.76	-

4.6.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of compressor-1

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

Table 47: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF
Compressor-1	54.81	0.78

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

4.6.3 Observation and performance assessment .

During DEA, it is observed that only one compressor is dedicated for whole process. Power was logged for the compressor and is given below:

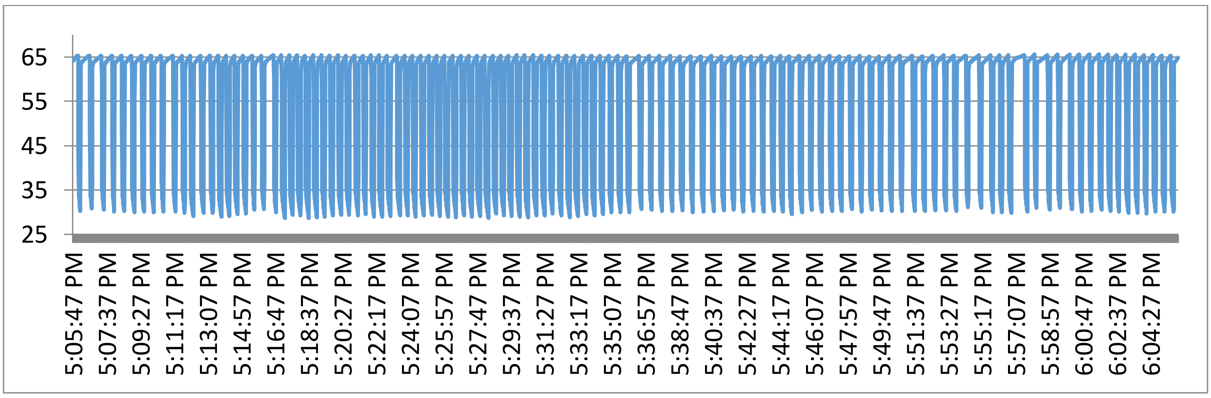


Figure 19: Power (kW) profile of new compressor

As per the above power profile of the compressor, unloading percentage 30% of the total operating time. It is suggested that install VFD to reduce unloading power consumption.

4.6.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.6.4.1 ECM #11: VFD on new screw compressor

Technology description

One new screw compressor is operating more than 30% unloading time of the total operating time. VFD is suitable to reduce unloading power consumption and will deliver pressure at desired pressure.

Study and investigation

The new compressor having capacity 10.76 Nm^3/min and rated power is 55 kW. During study, it was observed that the compressor is operating with 30% unloading of the total running time and average unloading power consumption is 32 kW.

Recommended action

It is recommend to installed VFD to minimize unloading power consumption.

Table 48: VFD on screw compressor [ECM-11]

Parameters	UoM	Present	Proposed
Compressor motor rating	kW	55	55
Average power consumption during loading	kW	64.5	-
Average power consumption during unloading	kW	34	-
On load time in percentage	%	69.91%	-
Off load time in percentage	%	30.09%	-
Average power consumption	kW	55.25	49.73
Compressor operating hours	h/d	24	24
Compressor annual operating days	d/y	330	330
Annual energy consumption	kWh/y	437,619	393,857
Annual energy saving	kWh/y	43,762	
Weighted average electricity cost	Rs/kWh	7.71	
Annual monetary savings	Rs Lakh/y	3.37	
Estimate of Investment	Rs Lakh	1.50	
Payback period	Months	5	
Project IRR	%	173	
Discounted payback period	Months	2.09	

4.6.4.3 ECM #12: Compressed air leakage arresting

Technology description

Compressed air leakage arresting at press section, Nano section and sizing section.

Study and investigation

During field study, it was observed that some of the points at sizing section, Nono section and hydraulic press section compressed air leaking out.

Recommended action

It is recommend to attain and repair the leakage point on the spot to avoid loss of energy.

Table 49: Compressed air leakage arresting [ECM-12]

Parameter	UoM	Present	Proposed
Rated capacity of compressor	Nm^3/Min	10.76	10.76
Rated power of compressor	kW	55	55
Average operating power	kW	55.3	55.3
Free air discharge	Nm^3/Min	9.68	9.68
Specific energy Consumption	kW/Nm3	0.10	0.10
Leakage quantity	Nm3/min	0.97	0.484
Operating requirements	h/d	24	24
Operating requirements	d/y	330	330
Annual energy consumption	kWh/y	43,762	21,881
Energy savings	kWh/y	-	21,881
Weighted average cost of electricity	Rs/kWh	7.7	7.7
Monetary savings	Rs Lakh/y	-	1.69
Estimated Investment	Rs Lakh	-	0.50
Payback Period	Months	-	4
Project IRR	%		253
Discounted payback period	Months		1.41

4.7 LIGHTING SYSTEM

4.7.1 Specifications

The plant lighting system includes:

Table 50: Specifications of lighting load

Particular	UOM	MH Lights	CFL	MH lights	CFL	CFL	CFL	GLS
Power consumption of each fixture	W	270	18	450	24	36	65	60
Numbers of fixtures	#	2	75	2	7	5	103	50

4.7.2 Field measurement and analysis

- Recording Inventory
- Recording Lux Levels

Table 51: Lux measurement at site

Particular	UOM	Value
Office	Lumen/m^2	168
Gasifier	Lumen/m^2	96
Clay ball mill	Lumen/m^2	70
HAG & Spray Dryer	Lumen/m^2	67
Kiln	Lumen/m^2	76
Inventory	Lumen/m^2	79
Glaze Line	Lumen/m^2	84
Press	Lumen/m^2	105
Vertical Dryer	Lumen/m^2	78
Polishing Area	Lumen/m^2	90

4.7.3 Observations and performance assessment

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

4.7.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.7.4.1 ECM #13: Replacement of inefficient light

Technology description

Replacing conventional lights like CFL & MH lights with LED lights helps reduce the power consumption and also results in higher illumination (lux) levels for the same power consumption.

Study and investigation

The unit is having 190 CFL, 50 GLS and 4 MH lights.

Recommended action

It is recommended to replace the above mentioned light fixtures with energy efficient LED lamps & flood lights, which will result in reduction of present lighting energy consumption. The cost benefit analysis for the ECM is given below:

Table 52: Replacement of inefficient lights [ECM-13]

Parameter	UOM	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Type of fixture		MH Lights	Flood Light	CFL	LED	MH Lights	Flood LED	CFL	LED	CFL	LED	CFL	LED	GLS	LED
Type of choke if applicable		Driver	Driver	Driver	Driver	NA	Driver	Driver	Driver	Driver	Driver	Driver	Driver	NA	Driver
Number of fixtures	#	2	2	75	75	2	2	7	7	5	5	103	103	50	50
Rated power of fixture	W/Unit	270	150	18	7	430	250	24	10	36	10	65	36	60	10
Operating power	W/fixture	270	150	18	7	430	250	24	10	36	10	65	36	60	10
Operating hours per day	h/d	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Operating days per year	d/y	365	365	365	365	365	365	365	365	365	365	365	365	365	365
Annual energy consumption	kWh/y	2,957	1,643	7,391	2,874	4,709	2,738	920	383	986	274	36,655	20,301	16,425	2,738
Annual energy saving	kWh/y		1,314		4,517		1,971		537		712		16,354		13,688
Unit cost of electricity	Rs/kWh		7.71		7.71		7.71		7.71		7.71		7.71		7.71
Annual monetary savings	Lakh Rs/y		0.10		0.35		0.15		0.04		0.05		1.26		1.05
Estimated Investment	Lakh Rs		0.04		0.38		0.07		0.04		0.04		0.88		0.26
Payback Period	Months		5		13		5		11		8		8		3
Total estimated investment	Lakh Rs	1.70													
Total payback period	Months	6.78													
Total Project IRR	%	133													
Total Discounted payback period	Months	2.67													

4.8 ELECTRICAL DISTRIBUTION SYSTEM

4.8.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (433V) by step down transformer (2000KVA). Capacitor bank is installed in parallel to main supply. There were two DGs (capacity of 1250 KVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeder which is shown in Figure 8.

4.8.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.8.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **1307kVA**.

The voltage profile of the unit is satisfactory and average voltage measured was **428.5 V.** Maximum voltage was **438.9 V** and minimum was **419.5 V**.

Average total voltage and current Harmonics distortion found **9.8%** & **19.9%** respectively during power profile recording.

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

It is observed that some of the outgoing feeders to sizing and press section has very poor power factor. Poor power factor leads to cable losses (I^2R) in the electrical distribution system.

4.8.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.8.4.1 ECM #14: Cable loss minimization

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted in polishing section power factor was between 0.4-0.5, whereas in Nano machines & Sizing section the power factor was 0.7.

Particulars	PF
Polishing machine-1	0.40
Polishing machine-2	0.50
Polishing machine-3	0.43
Nano machine-1	0.70

Particulars	PF
Nano machine-2	0.70
Sizing machine	0.70

Recommended action

It is recommended to install power factor improvement capacitors for polishing, Sizing and in Nano section automatic power factor controller is recommended.

The cost benefit analysis for this project is given below:

Table 53: Cable Loss minimization [ECM-14]

Particulars	UOM	Polishing machine-3 Value	Polishing machine-2 Value	Polishing machine-1 Value	Nano machine-1 Value	Nano machine-2 Value	Sizing machine Value
Existing Power Factor	PF	0.43	0.5	0.4	0.7	0.7	0.7
Proposed Power Factor	PF	0.98	0.98	0.98	0.98	0.98	0.98
Existing load	kW	41.0	40.6	48.6	107.1	117.7	72.3
Cable Losses	Watts	1550	1336	2157	3948.7	4664.9	1738.9
Capacitor Required	kVAr	79	72	88	81.45	86.28	60.62
Annual Energy Saving	kWh/y	10765	8927	14924	16,052	18,764	6,800
Savings Estimated	Rs. Lakh/y	0.37	0.69	1.15	1.24	1.45	0.52
Total Energy Saving	kWh/y	76232					
Total Savings	Rs. Lakh/y	5.41					
Investment	Rs. Lakh	2.16					
Payback Period	Months	5					
Project IRR	%	193					
Discounted payback period	Months	2					

4.8.4.2 ECM #15: Voltage Optimization in lighting circuits

Technology description

In most of the industries, lighting load varies between 2-10%. Most of the problems faced by lighting equipment and the gears are due to the voltage fluctuations. Hence, the lighting circuit should be isolated from the power feeders. This provided a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lighting system. In many industries, night time grid voltages are higher than normal; hence reduction in voltage can save energy and also provide the rated light output.

A large number of industries have used these devices and have saved to the tune of 5-15%. Industries having a problem of higher night time voltage can get an additional benefit of reduced premature failure of lamps.

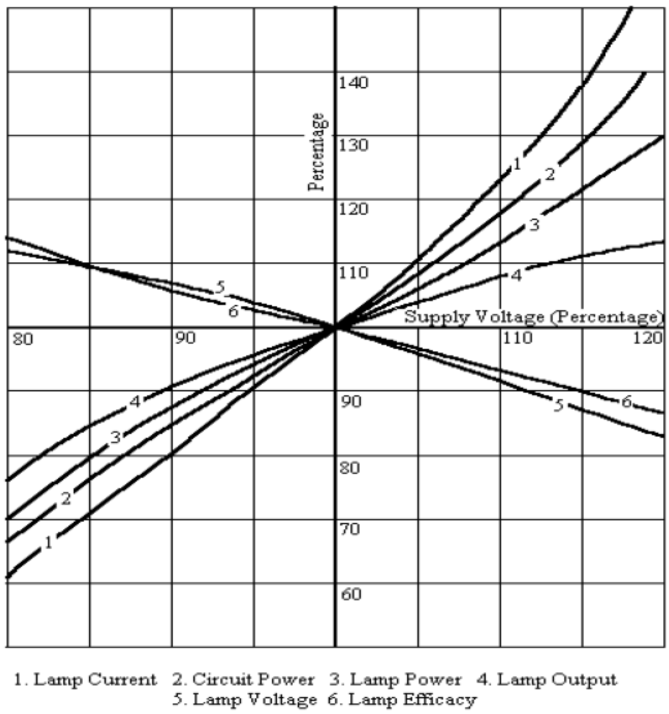


Figure 20: Effect of supply voltage on lamp parameters

Study and investigation

Lighting feeder measurements were carried out to estimate existing lighting load and the voltage level in the lighting circuit. Present lighting energy consumption is 488,808kW/y and measured average voltage level is 239V.

Recommended action

It is recommended to install separate servo stabilizer of 80 kVA rating for lighting circuit to save energy, optimize voltage and also reduce premature failure of lamps. The cost benefit analysis for this project is given below:

Table 54: Voltage Optimization in lighting circuit [ECM-15]

Parameter	UOM	Present	Proposed
Maximum load	kW	62	62
Maximum load	KVA	63	63
Maximum Line Voltage	V	434	380
Maximum Phase voltage	V	248	219
Average Line Voltage	V	418	380
Average voltage	V	239	220
% reduction in voltage	%	8.0	
% reduction in energy consumption	%	15.34	
Average power factor		0.90	0.9
Annual lighting energy consumption	kWh/y	488,808	
Savings estimate from lighting EPIAs	kWh/y		0
Actual energy considered for voltage regulation	kWh/y		488,808
Actual energy consumption after voltage regulation	kWh/y		413,805
Efficiency of Servo Stabilizer	%		95%
Assumption : Period for which voltage regulation is required	Months/y		12
Net saving from voltage regulation	kWh/y		71,253
Electricity tariff from grid only	Rs/kWh	6.88	
Annual monetary saving	Lakh Rs	4.9	
Sizing of servo stabilizer	kVA	73	
Rating of servo stabilizer	kVA	80	
Estimate investment	Lakh Rs	2.64	
Payback period	Months	6	
Project IRR	%	140	
Discounted payback period	Month	2.54	

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 management system has been proposed for the unit and is given below.

5.1.1 ECM #16: Energy management system

Technology description

Installation of energy management system at unit level will monitor the energy consumed by various machines. From this, the benchmark energy consumption 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 done on the main incomer as well as at various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed at coal gasifier, hot air generator and kiln like on-line flow-meters.

Recommended action

It is recommended to install online electrical energy management system (smart energy meters) on the main incomer and on the various electricity distribution panels and fuel monitoring system. This measure will help in reduction in energy consumption by approximately 2% from its present levels. The recommended locations for the energy meter are:

- Kiln
- Clay ball mills
- Agitator motors
- Sizing machines
- Polishing machine
- Calibrating machine
- Compressor
- Spray dryer – ID fan
- Spray pump
- HAG – FD & PA fan
- Glaze & Kiln line
- CT pumps
- Vertical dryer

The cost benefit analysis for this project is given below:

Table 55: Cost benefit analysis [ECM-16]

Particulars	UOM	Present	Proposed
Energy management saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	5,328,155	5,221,592
Annual electricity saving per year	kWh/y	0	106,563
Average Electricity Tariff	Rs/kWh	7.71	7.71
Annual monetary savings	lakh Rs/y	0	8.21
Number of Electrical equipment's	#	30	30
No. of energy meters	#	0	30
Estimate of Investment	Lakh Rs		2.99
Thermal energy monitoring system	%	2.00	
Current coal consumption	kg/y	7,690,690	7,536,876
Annual coal saving per year	kg/y		153,814
Cost of Coal	Rs/kg		7
Annual NG consumption	scm/y	402,077	394,035
Annual fuel saving	scm/y		8,042
Average NG cost	Rs/scm	36.9	36.90
Total annual monetary savings	Lakh Rs/y		14.48
Number of equipment or system	#	1	1
Number of coal weighing machines			2
Number of NG Meters			1
Estimated investment	Lakh Rs		2.67
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		22.69
Total Estimated investment (Electrical + Thermal)	Lakh Rs		5.66
Payback period	Months		3
Project IRR	%		303
Discounted payback period	Month		1.19

5.2 Best Operating Practices

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

Sl. No.	Equipment/System	Best Operating Practices
1	Transformer	PF well maintained
2	Clay ball mill	VFD & Soft starter for energy saving
3	Agitation tank	None
4	Spray Dryer and HAG	Cyclone and Wet scrubber for reducing pollution
5	Press	Auto control system for operating CT. Oil filter cleaning once in a month
6	Vertical Dryer	Waste heat from kiln is used in VT dryer
7	Glaze ball mill	Timer control in each ball mill.
8	Glaze line	None
9	Kiln	VFD in each blower, waste heat used in preheating section, VT dryer and as combustion air. PID control system for controlling chamber temperature in firing zone.
10	Gasifier	VFD in ID and FD fan. Waste water converted into steam through boiler used in gasifier. Coal tar produce in gasifier supplied to cement industries.
11	Polishing machine	Fully automatic system.

Sl. No.	Equipment/System	Best Operating Practices
12	Sizing machine	Fully automatic system. Dust collected system installed.
13	Nano machine	Fully automatic system.
14	Printing machine	Automated digital printing with fully auto control system
15	Lighting system	LED lights

5.3 New/Emerging Technologies

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

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

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

Table 56 : 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).

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

- Further, the grinding process optimizes the ball media grading of the ball mill, so as to increase contact of ball media and materials and increase grinding efficiency. Since this process features very small grain sizes of materials, it can directly enter fine grinding stage, without the need of rough grinding of large-size ball media.

Case Study New Pearl Ceramics and Beisite Ceramics Co., Ltd[2]:

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

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

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

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

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

[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

Figure 21 : Heat recovery system for combustion air

The estimated benefits of double heat recovery include[3]:

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

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

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

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.

[3] SACMI Kiln Revamping catalogue for roller kilns

[4] SACMI Kiln Revamping catalogue for roller kilns

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 22: NG consumption monitoring kit

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

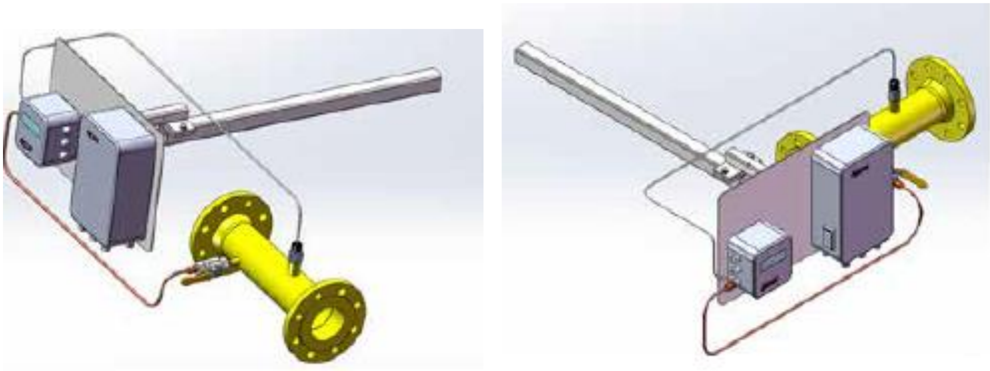


Figure 23: Combustion air control for burner

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 24: 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

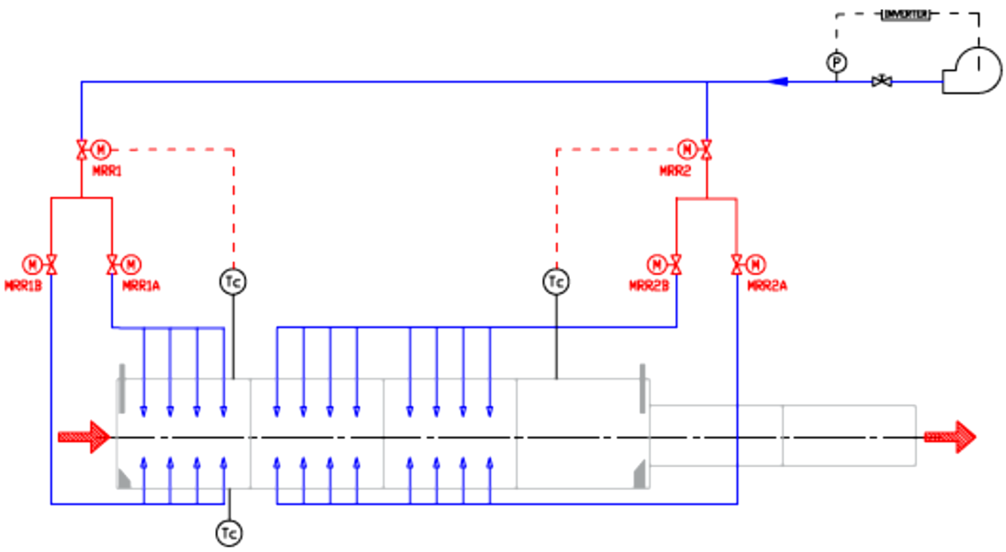


Figure 25: Fast cooling air management

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 26: 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 27: - High Alumina pebbles for Ball mill

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

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

d. Replacement of pebbles is a coniferous process as this is consumable. Only a few units in Morbi cluster are already following this practice, there is a scope for wider adaption of the recommended practice.

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

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

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

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

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

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

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

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

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

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

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

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

5.3.7 USE OF DIRECT BLOWER FANS INSTEAD OF BELT DRIVE:

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

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

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

Figure 28: Direct drive blower fan

6. Chapter-6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA. A rooftop area of 800 m^2 is available in the unit. The feasibility of installing solar PV in this area was evaluated. The corresponding solar energy generation potential is shown below.

Table 57: Solar PV installation

Particulars	UOM	Value
Available area on roof	m^2	800
Estimated total solar PV panel area	m^2	480
Number of panels (1m x 2m) of 320 Wp	#	240
Estimated installed capacity of solar panel	kW	77
Estimated Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	323
Solar radiation days per year	d/y	365
Average electricity generation per year	kWh/y	117,734
Cost of electricity	Rs/kWh	7.81
Annual monetary savings	Lakh Rs/y	9.20
Estimated investment	Lakh Rs	42
Payback period	Months	55
Project IRR	%	-1%
Discounted payback period	Months	18

The project IRR is negative and hence the project is not considered feasible. The reasons are as follows:

a) Increase in capital expenditure on account of
   a. Requirement for strengthening the structure for accommodating the solar panels.
   b. Requirement for construction of walkways for cleaning of solar panels.

b) Degradation of generation considered on account of heavy dust accumulation on the panels.

c) Increase in operating costs on account of
   a. Increased cleaning frequency.
   b. Requirement of DM water for cleaning the panels twice a day.

7. ANNEXES

7.1 Annex-1: Process Flow Diagram

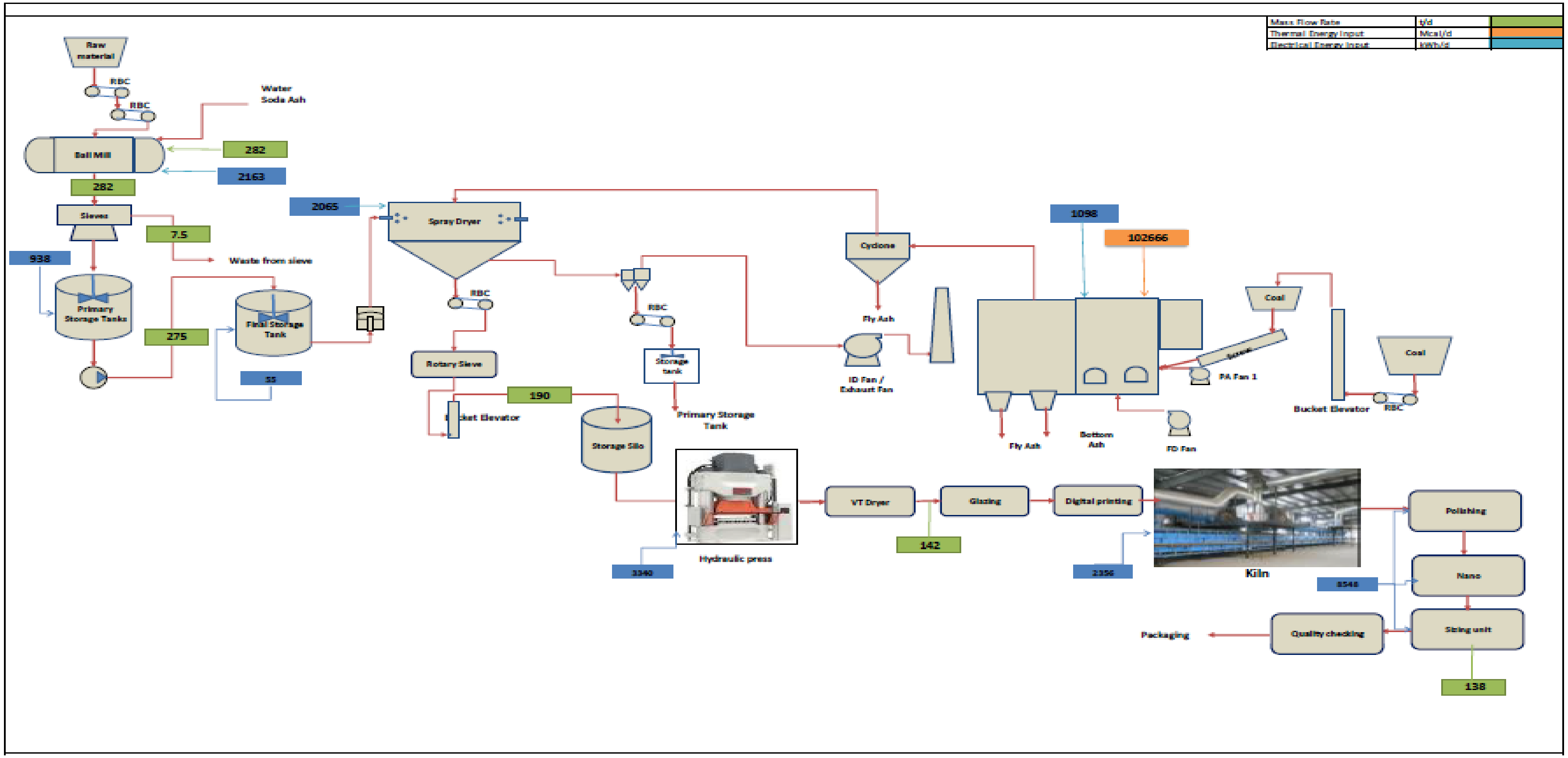


Figure 29: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 58: Detailed Inventory list

Particulars	UOM	Value
Clay ball mill	kW	366
Agitator Tank	kW	97
Spray Dryer	kW	151
Hot Air Generator	kW	55
Press	kW	228
Vertical Dryer	kW	43
Glaze line	kW	101
Digital Printing	kW	22
Kiln	kW	254
Sizing	kW	136
Glaze ball mill	kW	90
Polishing	kW	395
Nano machine	kW	446
Gasifier	kW	55
Compressor	kW	62
Cooling tower	kW	17
Pumps	kW	39
Lighting & Single phase load	kW	77
Total	kW	2,634

7.3 Annex-3: Single Line Diagram

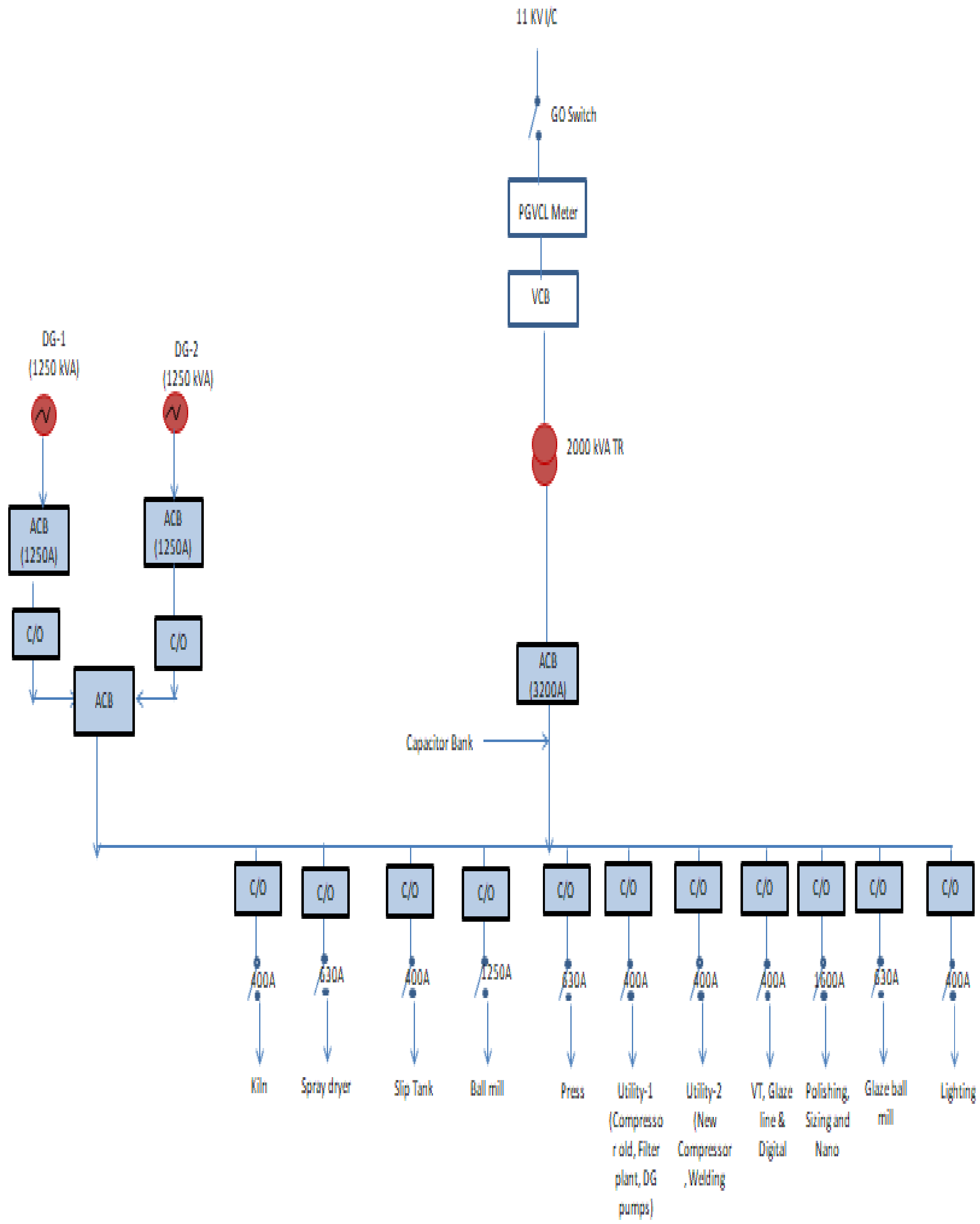


Figure 30: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

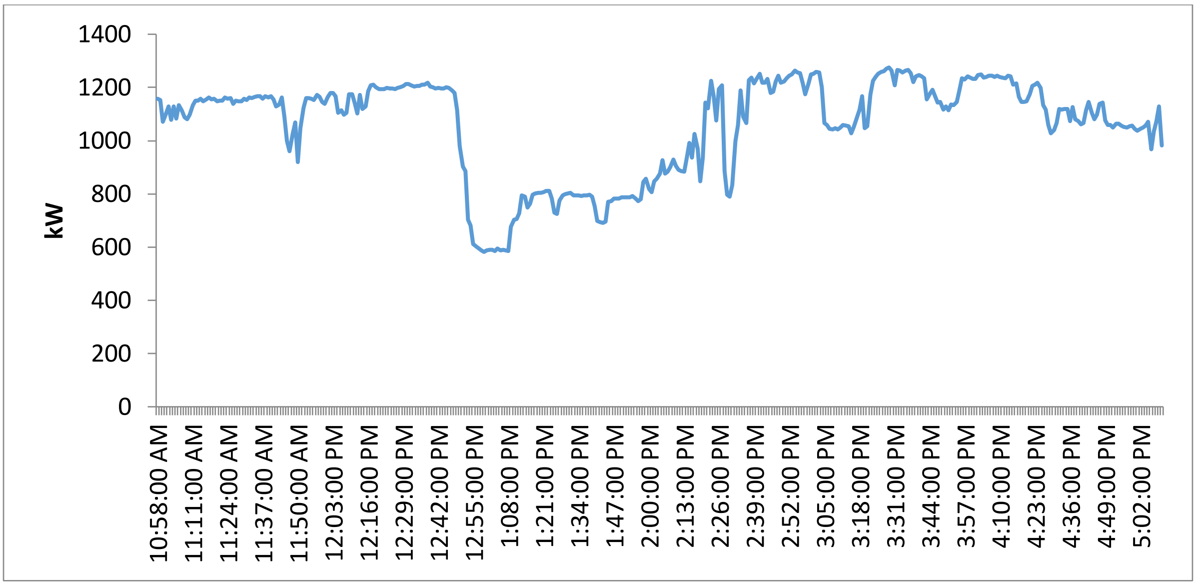
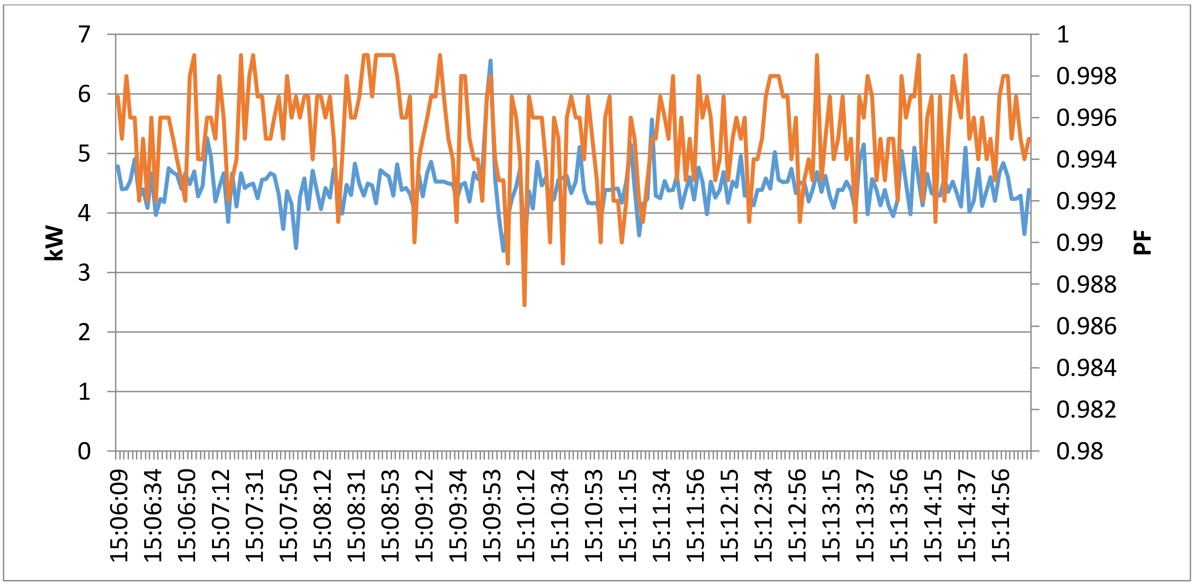


Figure 31: Power profile (kW) of Main Incomer



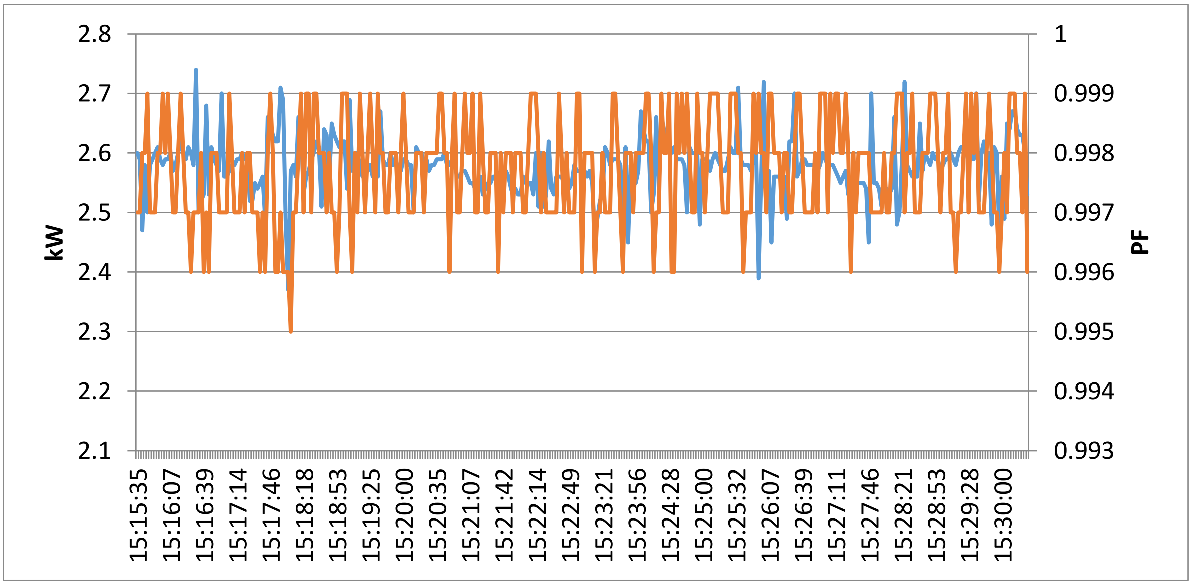


Figure 32 Power and PF profile of Gasifier ID and FD Fan

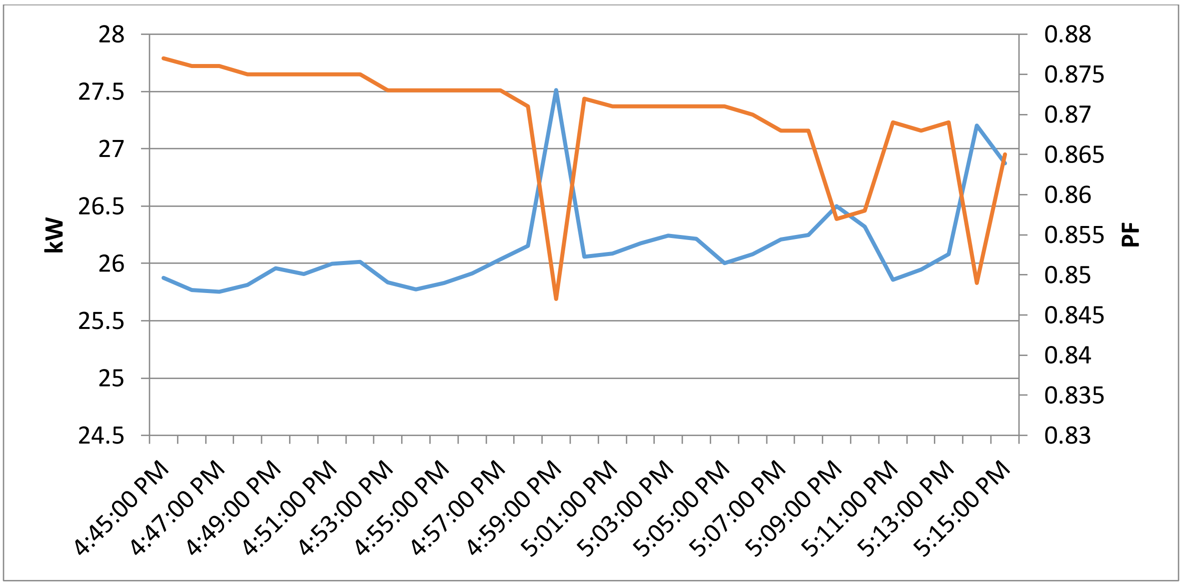
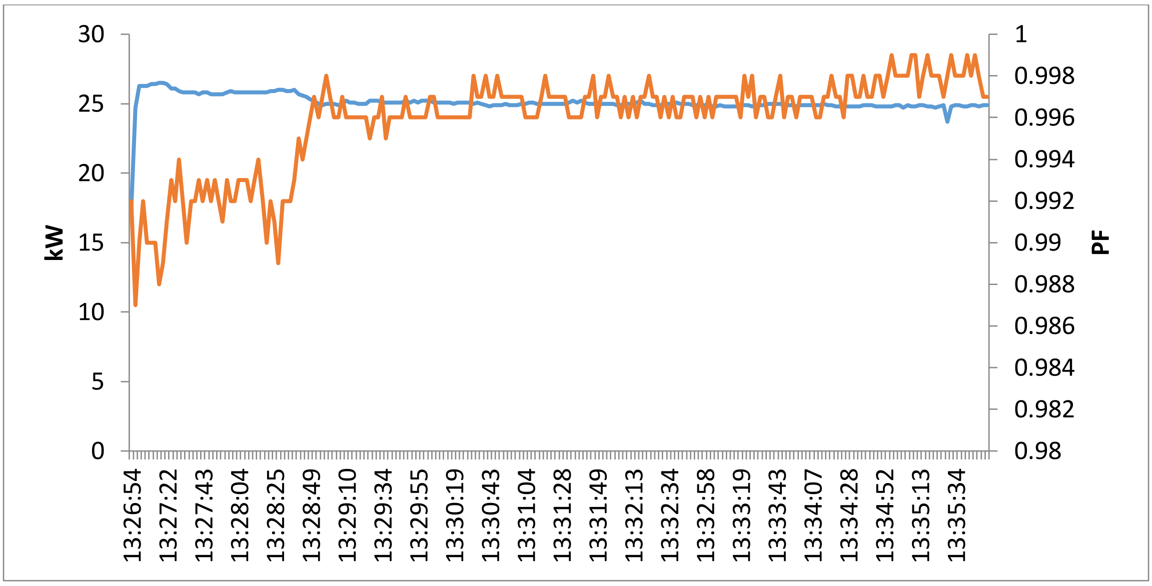
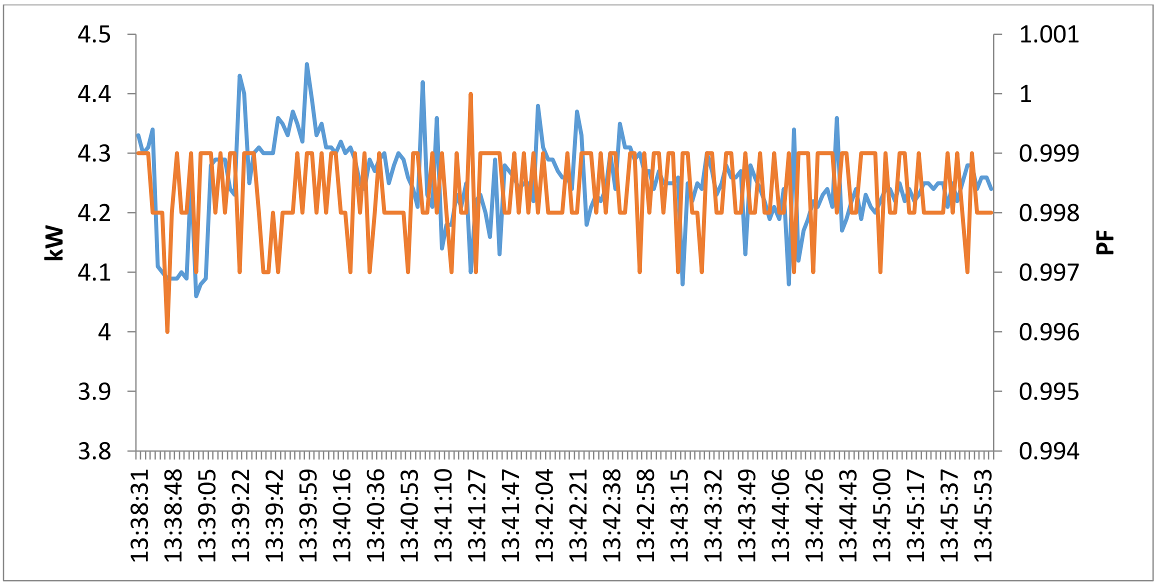


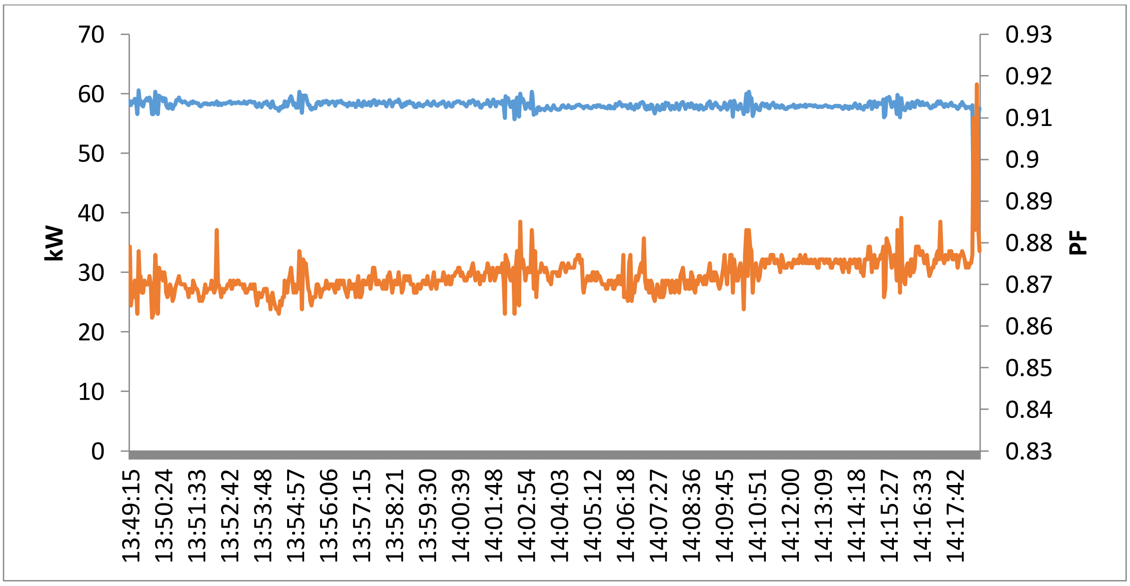
Figure 33: Power and PF Profile of Gasifier main Incomer



kW
PF
30
25
20
15
10
5
0
1
0.998
0.996
0.994
0.992
0.99
0.988
0.986
0.984
0.982
0.98
13:26:54
13:27:22
13:27:43
13:28:04
13:28:25
13:28:49
13:29:10
13:29:34
13:29:55
13:30:19
13:30:43
13:31:04
13:31:28
13:31:49
13:32:13
13:32:34
13:32:58
13:33:19
13:33:43
13:34:07
13:34:28
13:34:52
13:35:13
13:35:34



kW
PF
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
1.001
1
0.999
0.998
0.997
0.996
0.995
0.994
13:38:31
13:38:48
13:39:05
13:39:22
13:39:42
13:39:59
13:40:16
13:40:36
13:40:53
13:41:10
13:41:27
13:41:47
13:42:04
13:42:21
13:42:38
13:42:58
13:43:15
13:43:32
13:43:49
13:44:06
13:44:26
13:44:43
13:45:00
13:45:17
13:45:37
13:45:53



kW
PF
70
60
50
40
30
20
10
0
0.93
0.92
0.91
0.9
0.89
0.88
0.87
0.86
0.85
0.84
0.83
13:49:15
13:50:24
13:51:33
13:52:42
13:53:48
13:54:57
13:56:06
13:57:15
13:58:21
13:59:30
14:00:39
14:01:48
14:02:54
14:04:03
14:05:12
14:06:18
14:07:27
14:08:36
14:09:45
14:10:51
14:12:00
14:13:09
14:14:18
14:15:27
14:16:33
14:17:42

Figure 34 Power and PF profile of Fans of HAG

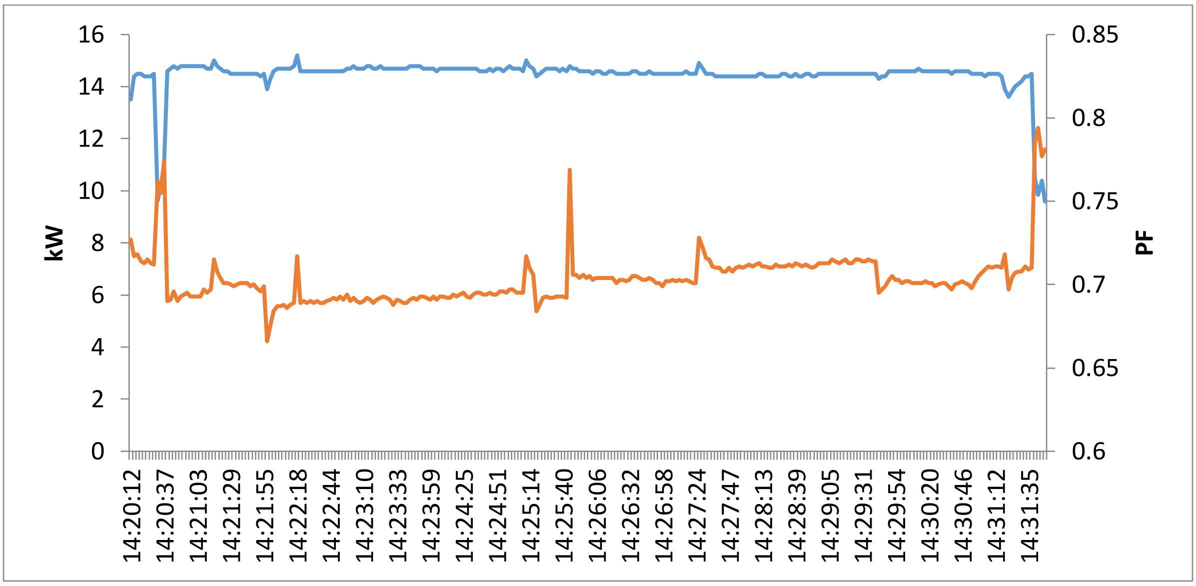
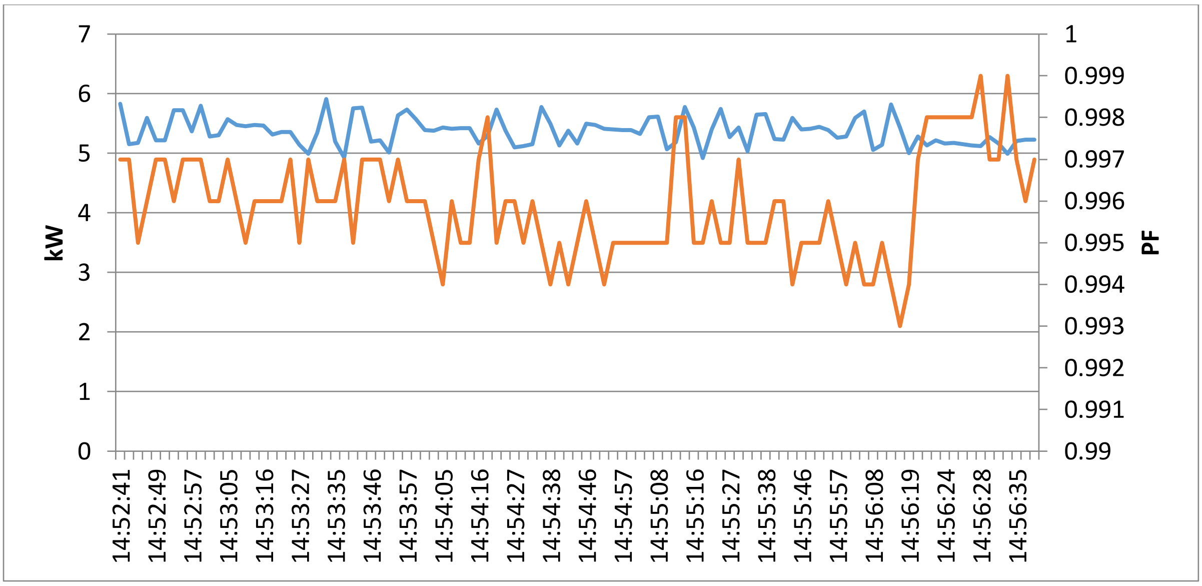
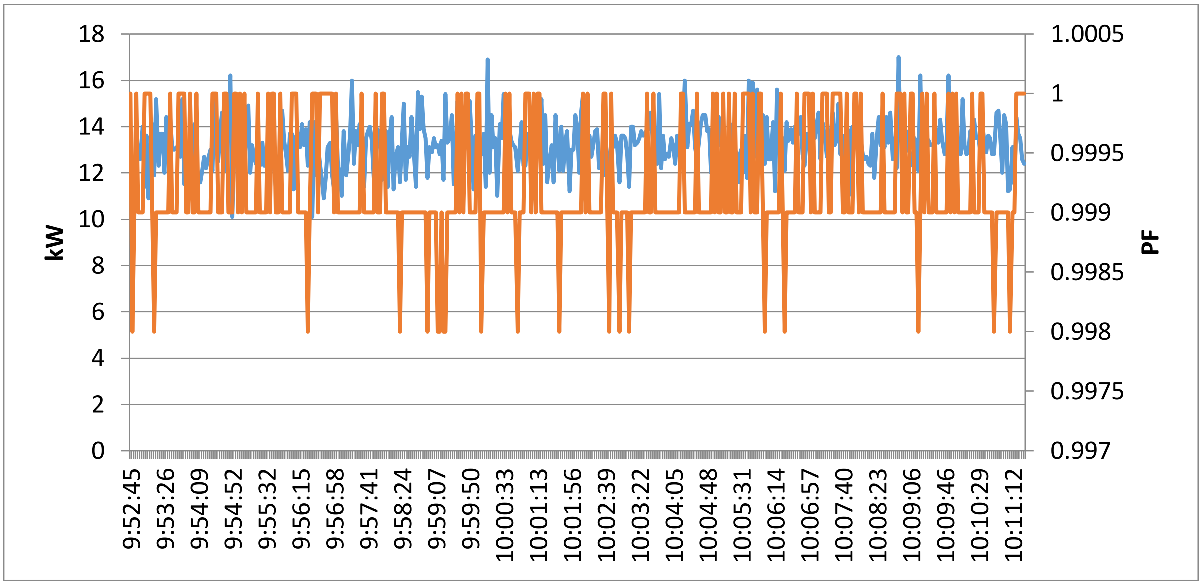
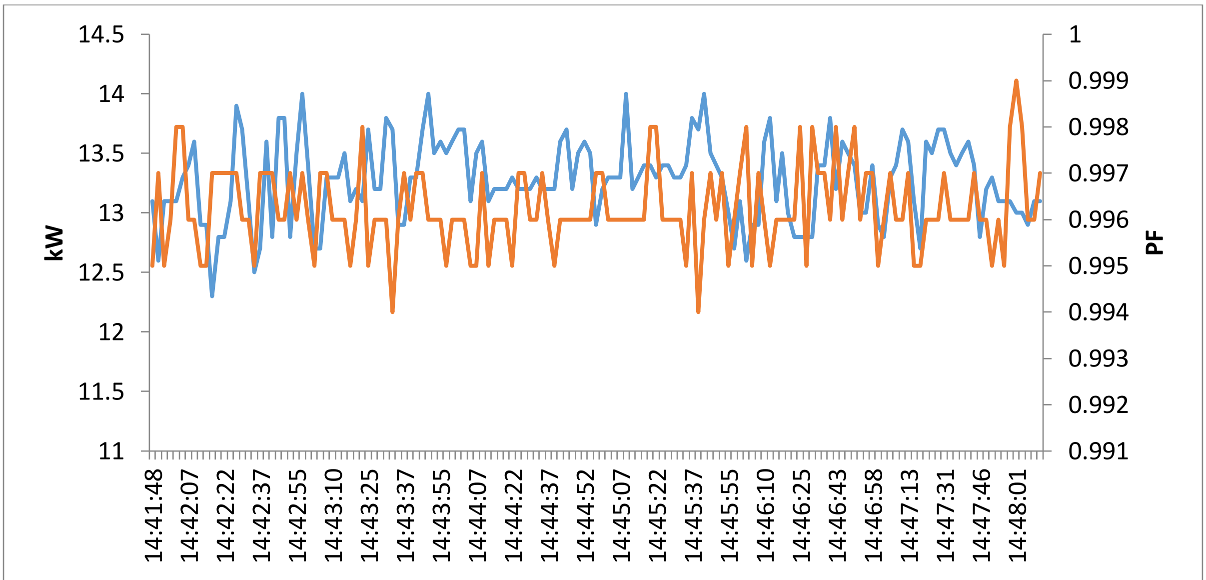


Figure 35:Power and PF profile of Fans of Clay feed to spray dryer




kW
PF
18
16
14
12
10
8
6
4
2
0
1.0005
1
0.9995
0.999
0.9985
0.998
0.9975
0.997
9:52:45
9:53:26
9:54:09
9:54:52
9:55:32
9:56:15
9:56:58
9:57:41
9:58:24
9:59:07
9:59:50
10:00:33
10:01:13
10:01:56
10:02:39
10:03:22
10:04:05
10:04:48
10:05:31
10:06:14
10:06:57
10:07:40
10:08:23
10:09:06
10:09:46
10:10:29
10:11:12


kW
PF
14.5
14
13.5
13
12.5
12
11.5
11
1
0.999
0.998
0.997
0.996
0.995
0.994
0.993
0.992
0.991
14:41:48
14:42:07
14:42:22
14:42:37
14:42:55
14:43:10
14:43:25
14:43:37
14:43:55
14:44:07
14:44:22
14:44:37
14:44:52
14:45:07
14:45:22
14:45:37
14:45:55
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14:47:46
14:48:01

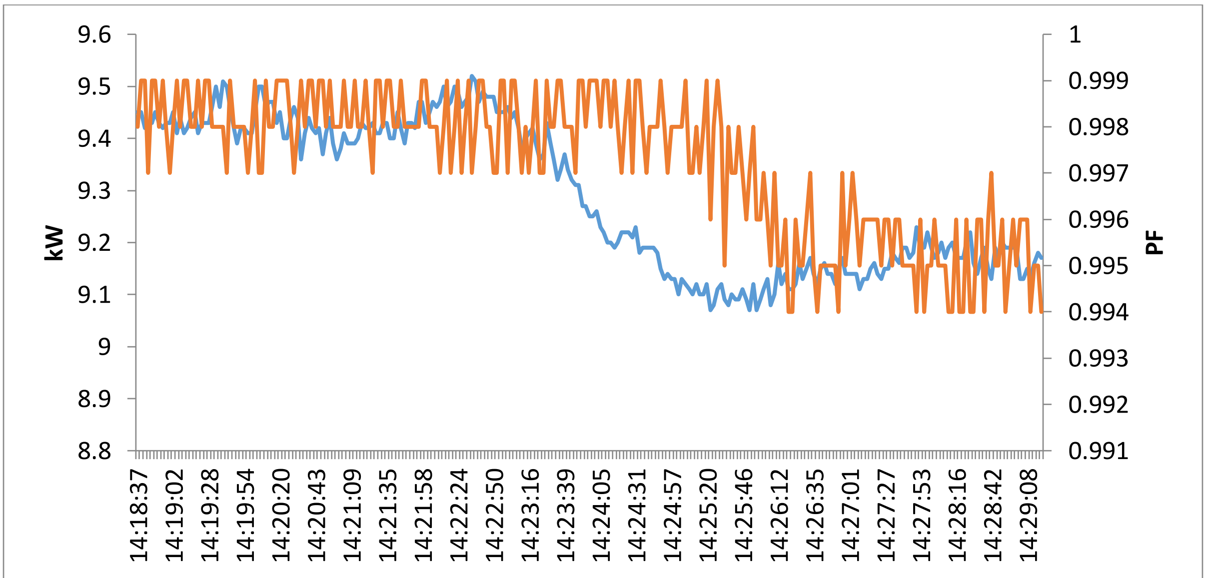

kW
PF
9.6
9.5
9.4
9.3
9.2
9.1
9
8.9
8.8
1
0.999
0.998
0.997
0.996
0.995
0.994
0.993
0.992
0.991
14:18:37
14:19:02
14:19:28
14:19:54
14:20:20
14:20:43
14:21:09
14:21:35
14:21:58
14:22:24
14:22:50
14:23:16
14:23:39
14:24:05
14:24:31
14:24:57
14:25:20
14:25:46
14:26:12
14:26:35
14:27:01
14:27:27
14:27:53
14:28:16
14:28:42
14:29:08

Figure 36: Power and PF Profile of Blowers of Kiln (Intermediate, combustion ,Final, Rapid cooling)

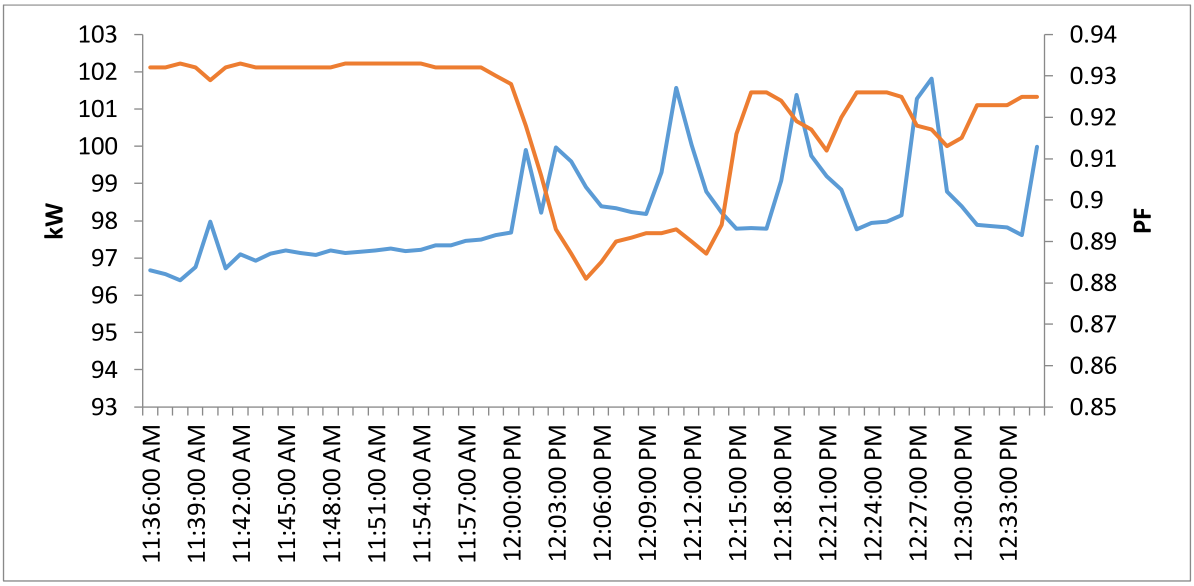
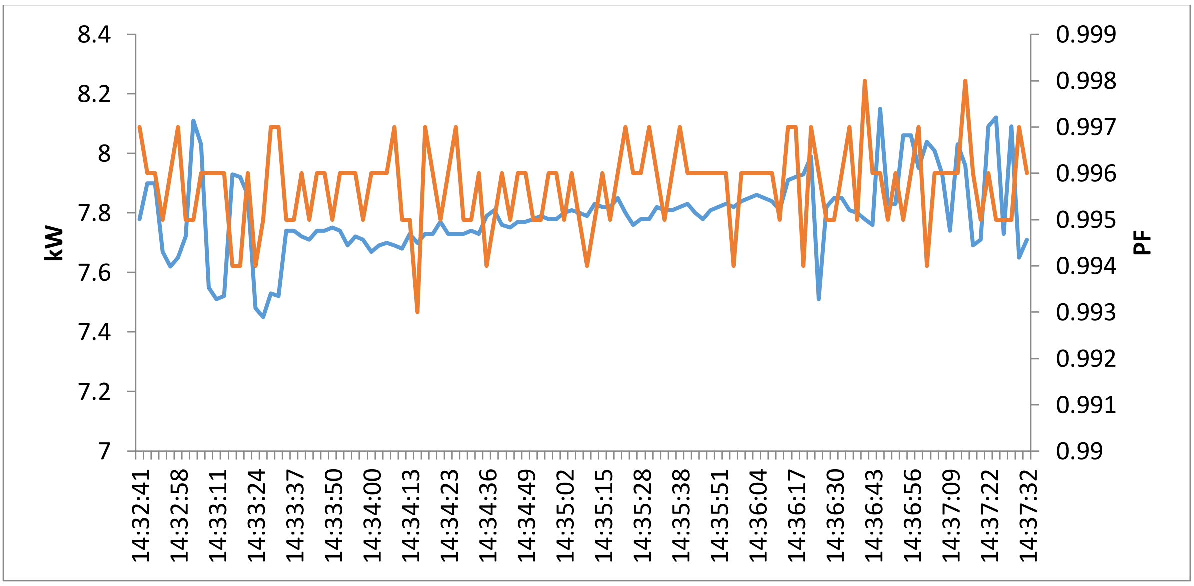


Figure 37: Power and PF profile of Kiln main feeder



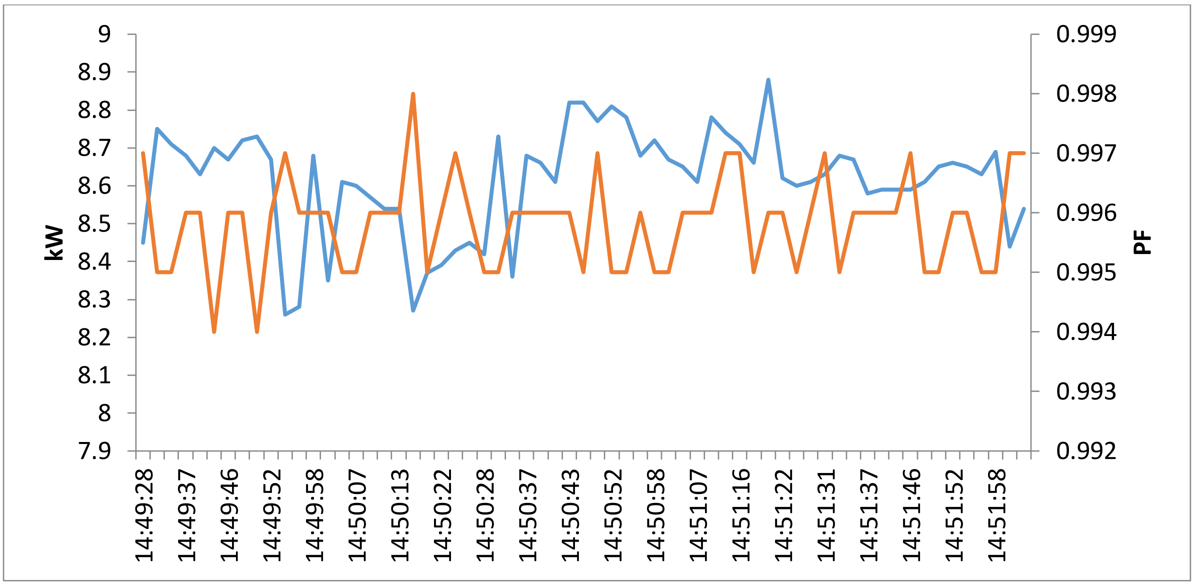


Figure 38: Power and PF profile of Blower to dryer

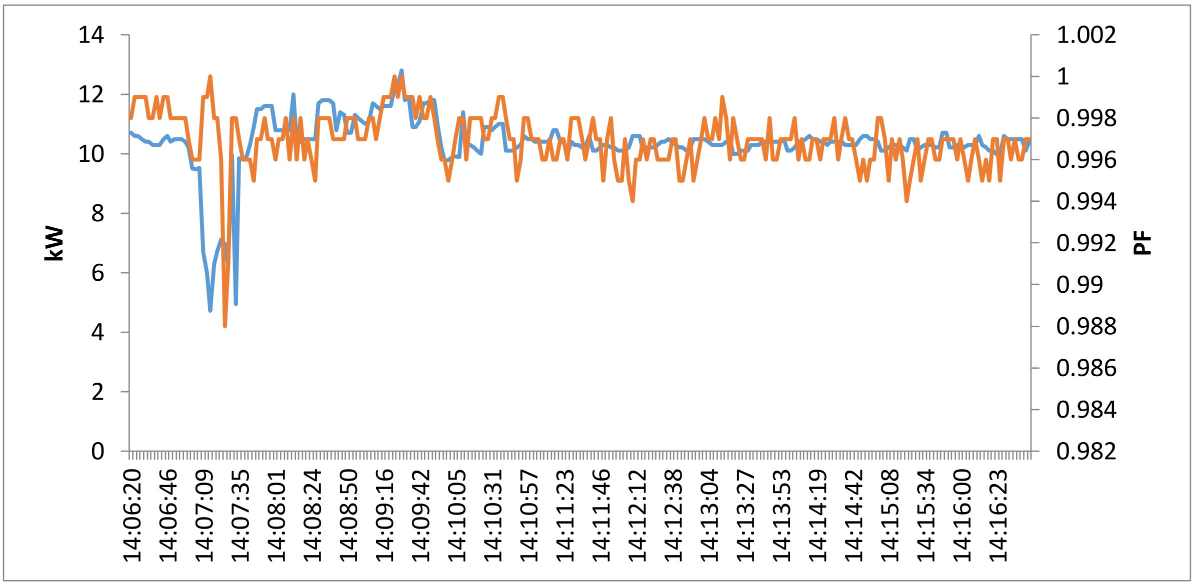


Figure 39: Power and PF Profile of Smoke ID blower

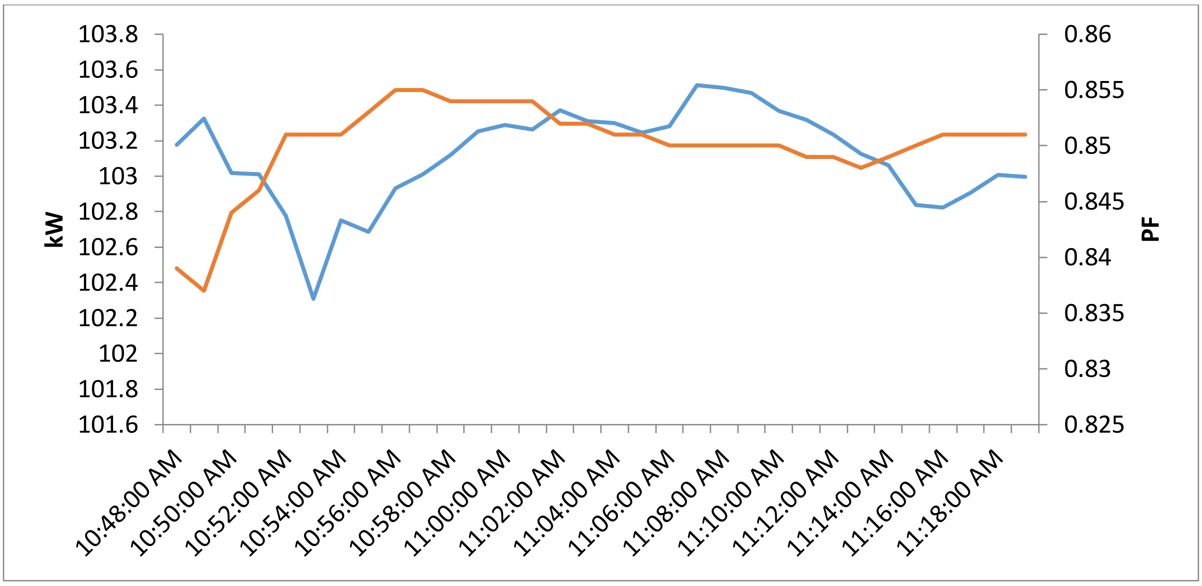


Figure 40: Power and PF profile of Spray feeder

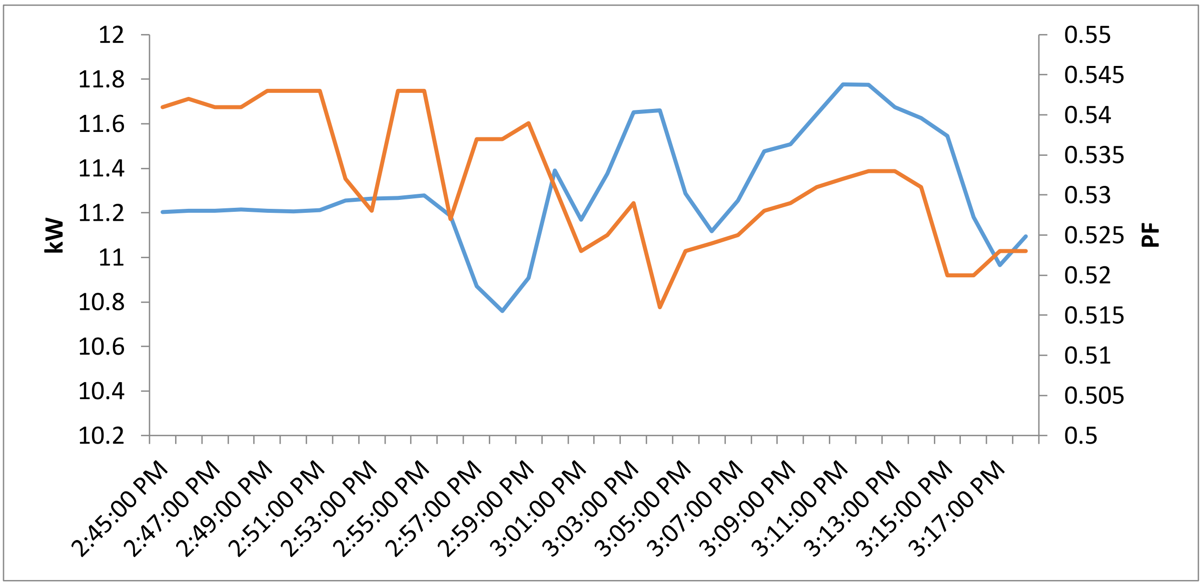


Figure 41: Power and PF profile of Glaze line feeder

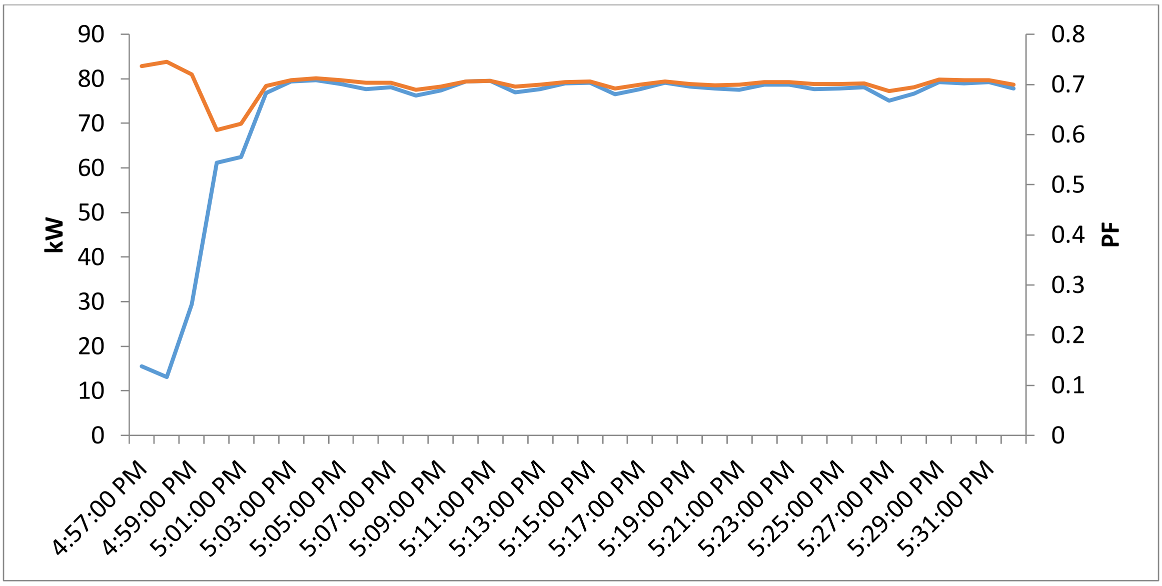


Figure 42: Power and PF Profile of Sizing main incomer

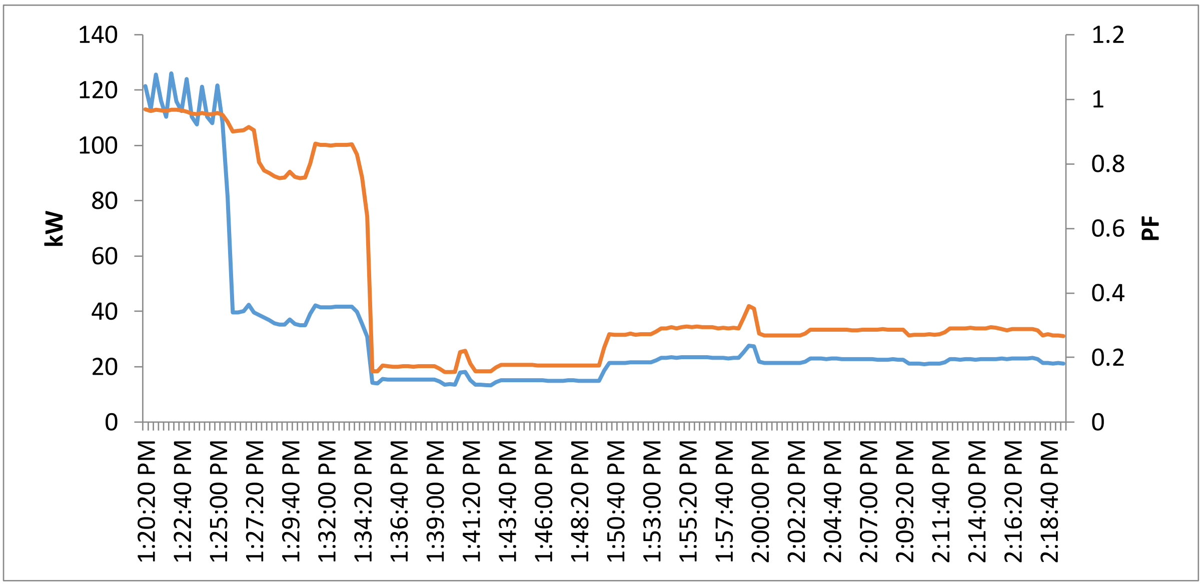
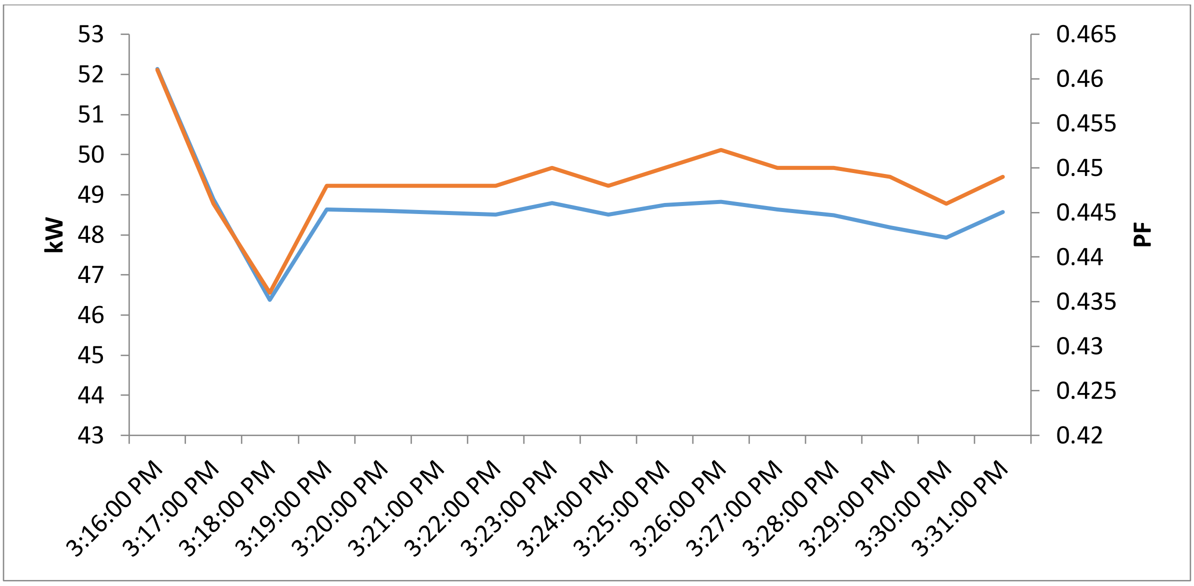


Figure 43: Power and PF of Press main feeder



kW
53
52
51
50
49
48
47
46
45
44
43
PF
0.465
0.46
0.455
0.45
0.445
0.44
0.435
0.43
0.425
0.42
3:16:00 PM
3:17:00 PM
3:18:00 PM
3:19:00 PM
3:20:00 PM
3:21:00 PM
3:22:00 PM
3:23:00 PM
3:24:00 PM
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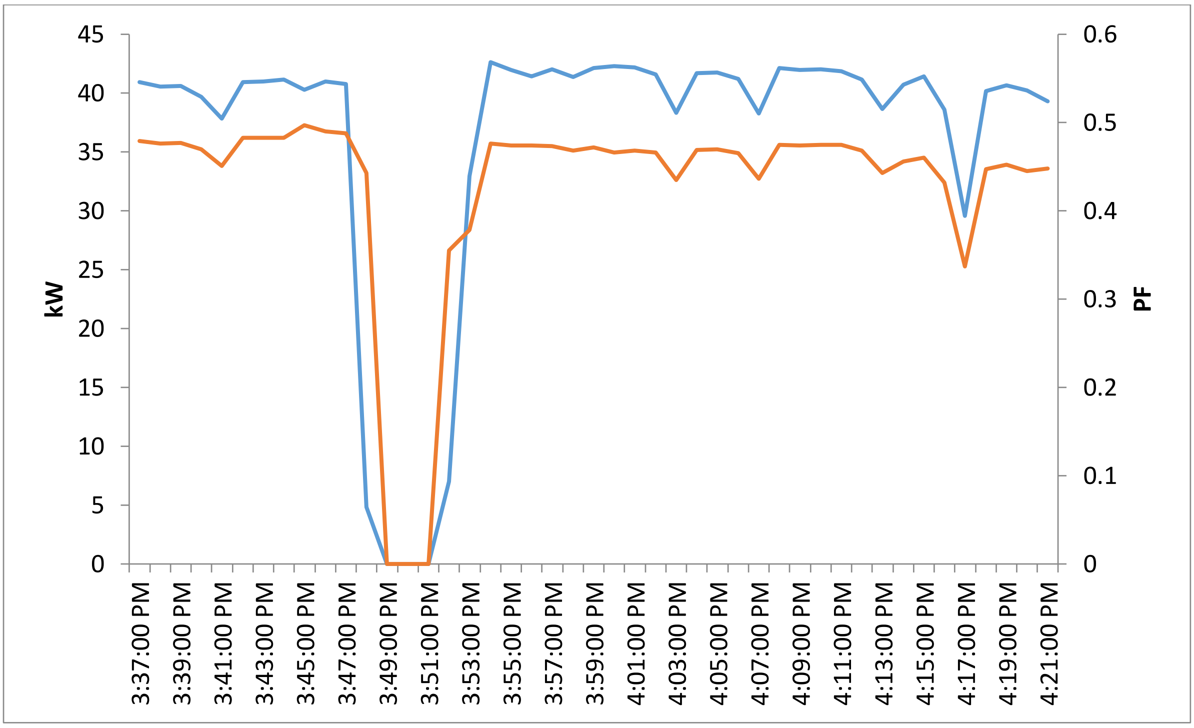
3:30:00 PM
3:31:00 PM



kW
45
40
35
30
25
20
15
10
5
0
PF
0.6
0.5
0.4
0.3
0.2
0.1
0
3:37:00 PM
3:39:00 PM
3:41:00 PM
3:43:00 PM
3:45:00 PM
3:47:00 PM
3:49:00 PM
3:51:00 PM
3:53:00 PM
3:55:00 PM
3:57:00 PM
3:59:00 PM
4:01:00 PM
4:03:00 PM
4:05:00 PM
4:07:00 PM
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4:19:00 PM
4:21:00 PM

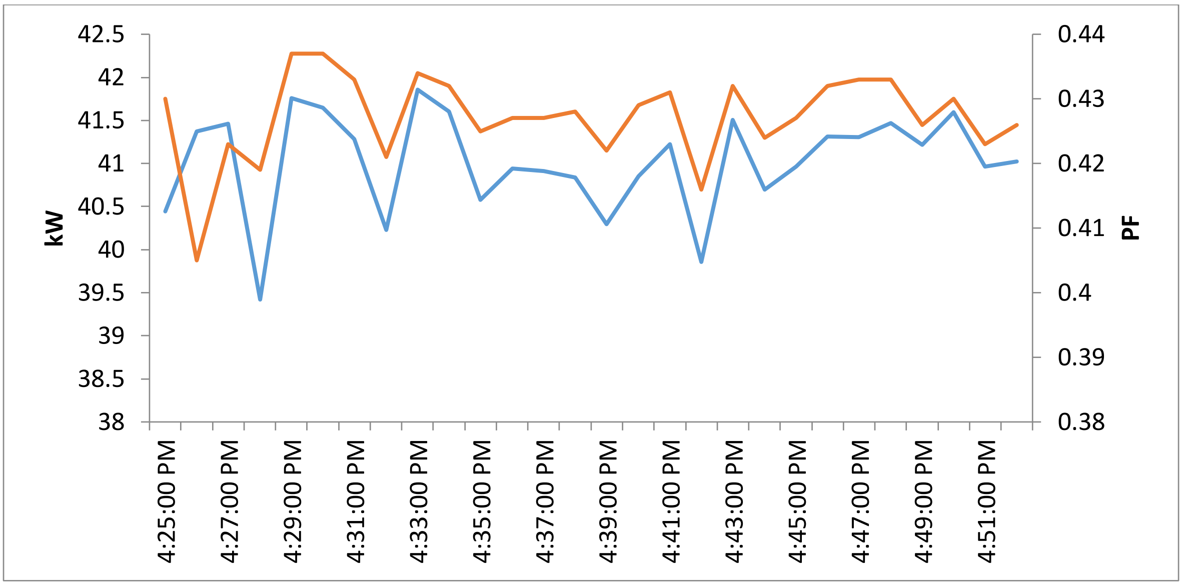

Figure 44: Power and PF Profile of polishing machines -1,2 & 3

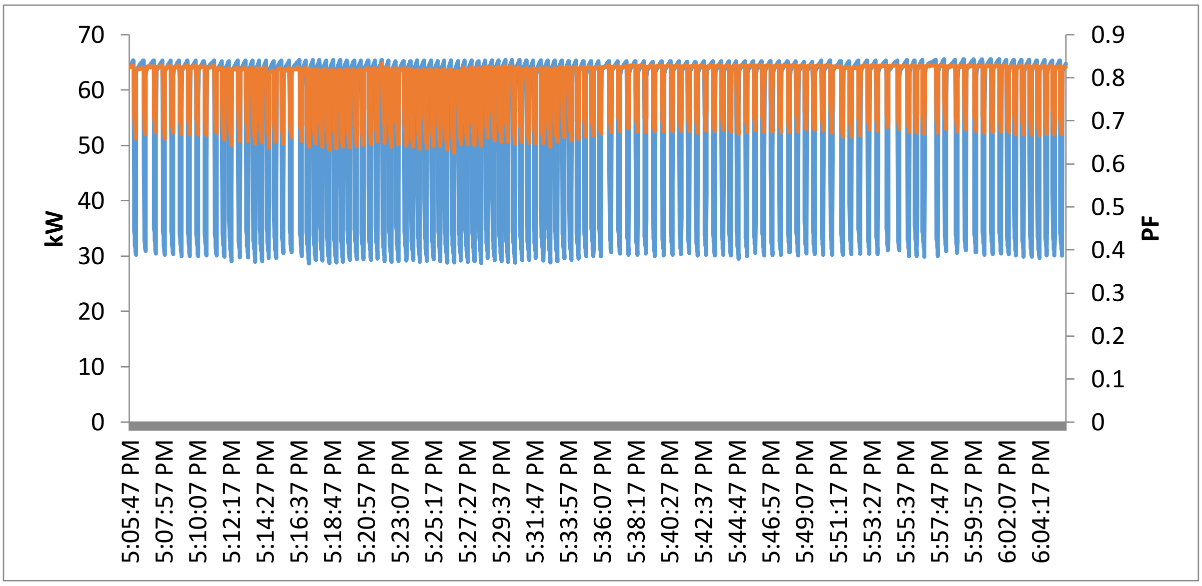

Figure 45: Power and PF Profile of compressor-1

Figure 46: Power and PF profile of Nano machine-1 & 2

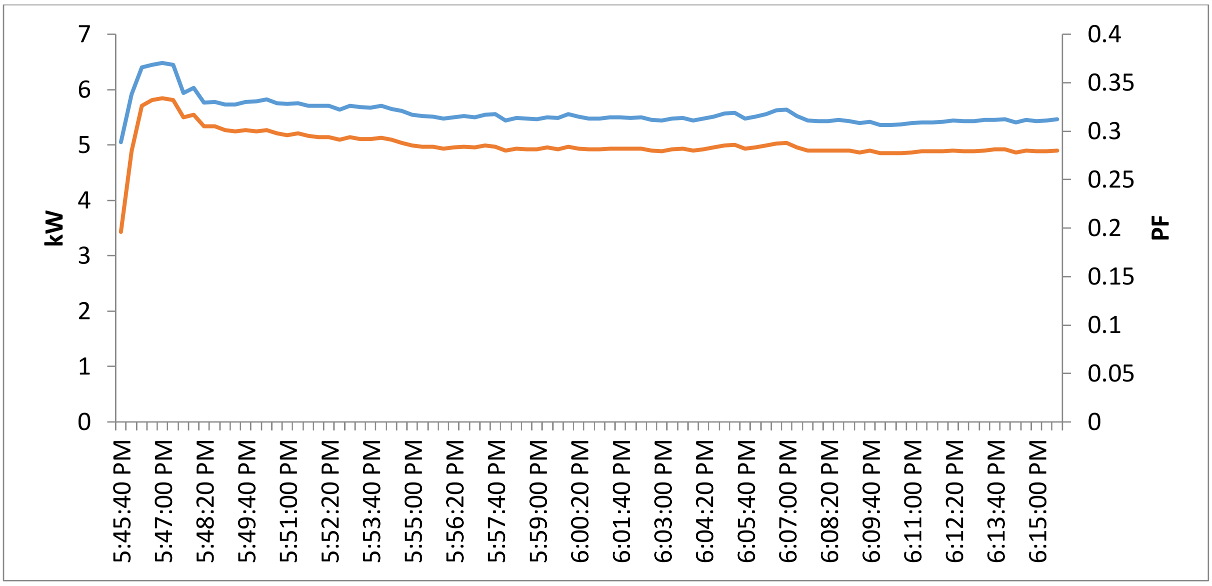

Figure 47: Power and PF profile of Glaze ball Mill-1

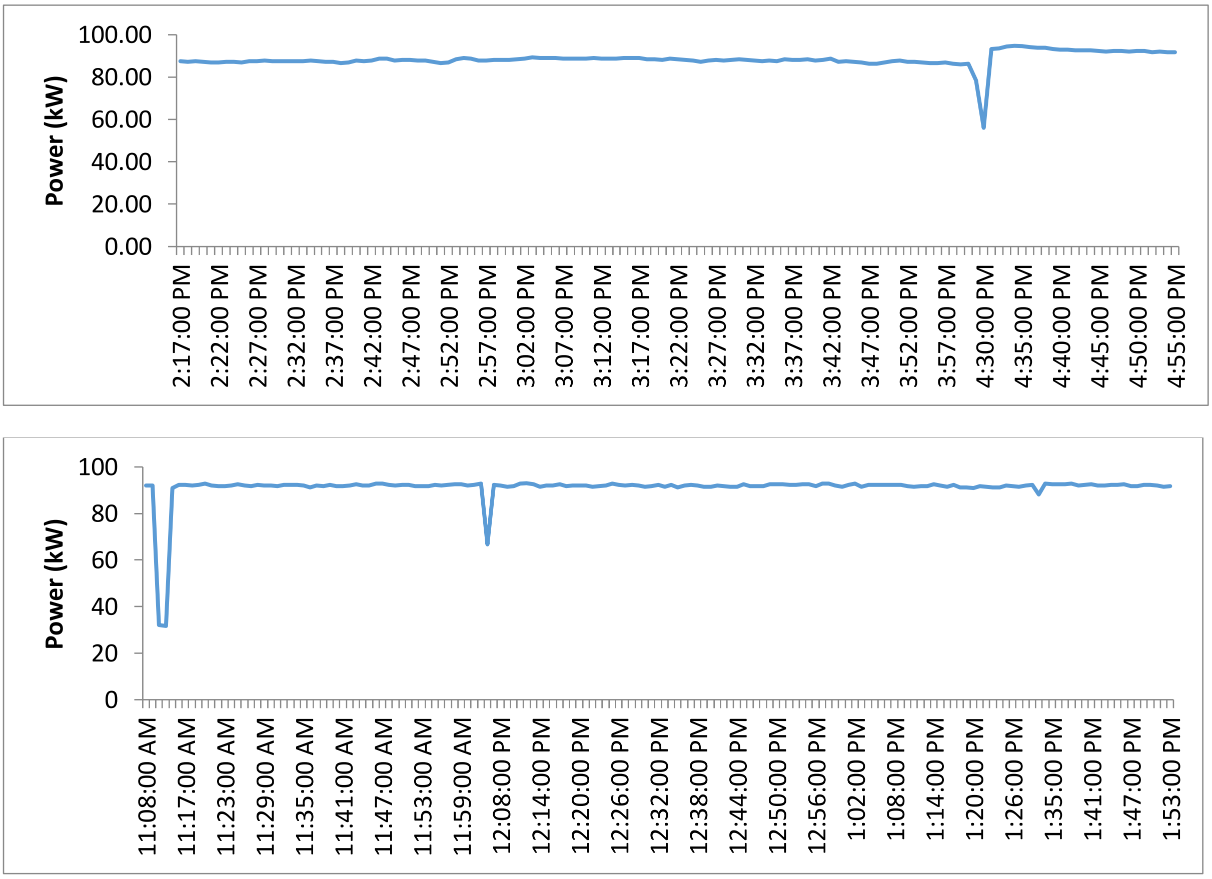

Figure 48: Power profile of Clay ball mill-1& 2

7.5 Annex-5: Thermal Measurements

1. Kiln heat utilization calculations

Input parameters

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Coal Gasifier	
Particulars	**Value**	**UOM**
Roller Kiln Operating temperature (Heating Zone)	1182.5	*Deg C*
Initial temperature of kiln tiles	39	*Deg C*
Avg. fuel Consumption	3,727	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	250	*deg C*
Preheated air temp./Ambient	180	*deg C*
O2 in flue gas	8.5	*%*
CO2 in flue gas	7.3	*%*
CO in flue gas	20	*ppm*
Atmospheric Air		
Ambient Temp.	42	*Deg C*
Relative Humidity	45	*%*
Humidity in ambient air	0.0213	*kg/kgdry air*
Fuel (coal gas) Analysis		
C	*24.34*	%
H	*12.17*	%
N	*46.09*	%
S	*0.00*	%
O	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	1230	*kcal/scm*
Ash Analysis		
Unburnt in bottom ash	*0.00*	%
Unburnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kcal/kg
GCV of fly ash	*0*	kcal/kg
Material and flue gas data		
Weight of Kiln car material	0	*Kg/Hr*
Weight of ceramic material being heated in Kiln	5802	*Kg/Hr*
Weight of Stock	0	*kg/hr*
Specific heat of clay material	0.22	*Kcal/kgdegC*
Avg. specific heat of fuel	0.51	*Kcal/kgdegC*
fuel temp	39	*deg C*
Specific heat of flue gas	0.24	*Kcal/kgdegC*
Specific heat of superheated vapour	0.45	*Kcal/kgdegC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	3260	*kcal/hr*
Radiation and convection from heating zone surface	31161	*kcal/hr*
Heat loss from all zones	34421	*kcal/hr*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits	0.75	*Hr*

Input Data Sheet		
through cooling zone of kiln		
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*K*

Efficiency calculations

Calculations	Kiln	UOM
Theoretical Air Required	7.72	*kg/kg of fuel*
Excess Air supplied	68.00	*%*
Actual Mass of Supplied Air	12.97	*kg/kg of fuel*
Mass of dry flue gas	12.85	*kg/kg of fuel*
Amount of Wet flue gas	13.97	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*Kg of H2O/kg of fuel*
Amount of dry flue gas	12.85	*kg/kg of fuel*
Specific Fuel consumption	671.31	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	862908	*Kcal/ton of tiles*
Sensible heat of fuel	0	*Kcal/ton of tile*
Total heat input	862908	*Kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	251570	*Kcal/ton of tile*
Heat loss in dry flue gas	430754	*Kcal/ton of tile*
Loss due to H2 in fuel	35265	*Kcal/ton of tile*
Loss due to moisture in combustion air	1214	*Kcal/ton of tile*
Loss due to partial conversion of C to CO	253	*Kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	9871	*Kcal/ton of tile*
Loss due to convection and radiation	34421	*Kcal/ton of tile*
Heat loss due to unburnts in Fly ash	0	*Kcal/ton of tile*
Heat loss due to unburnts in bottom ash	0	*Kcal/ton of tile*
Heat loss due to kiln car	0	*Kcal/ton of tile*
Unaccounted heat losses	99559	*Kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln		
Kiln heat utilization	29.2	*%*

2. Heat Balance Diagram

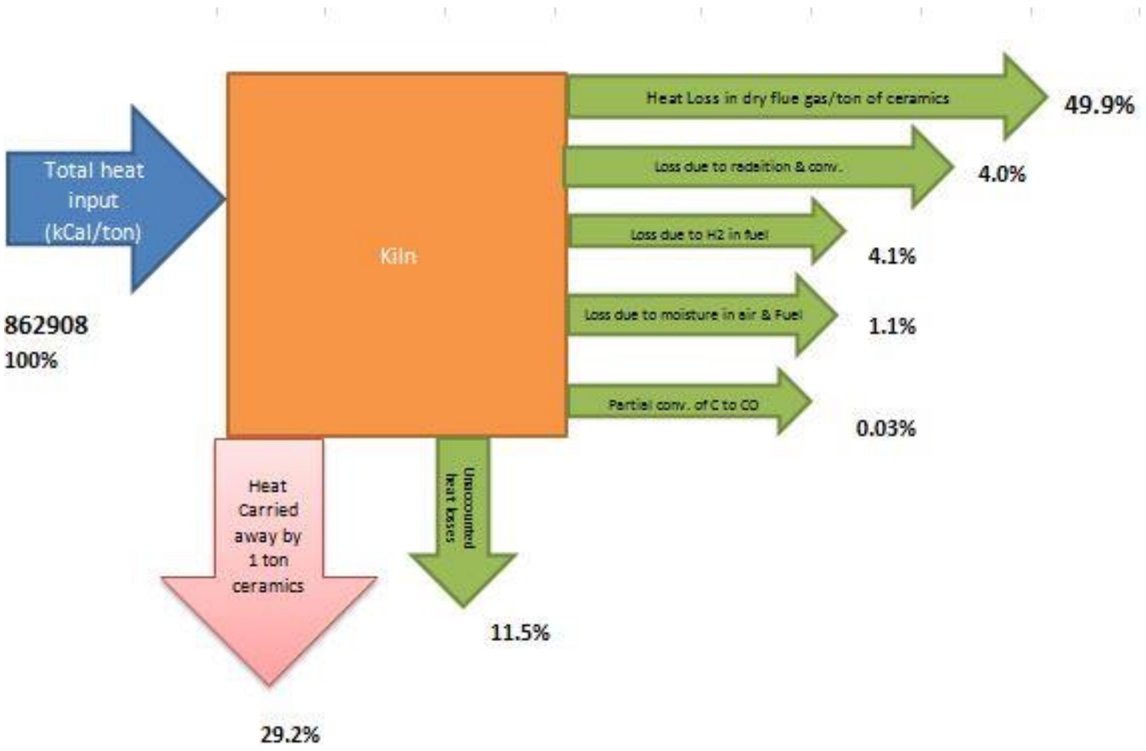

Figure 49: Heat Balance of Kiln

3. Gasifier Performance

Performance analysis	UOM	Values
Fuel fired		Coal
Fuel through put	kg/h	1066.00
Fuel composition		
Carbon	%	0.59
Hydrogen	%	0.04
Oxygen	%	0.12
Nitrogen	%	0.01
Moisture	%	0.09
Ash	%	0.14
GCV of fuel fired	kcal/kg	5495
Atmospheric conditions		
Nitrogen	%	77
Oxygen	%	20
Water vapour	%	3
Coal Gas analysis		
Carbon dioxide	%	7
Carbon monoxide	%	21
Methane	%	3
Hydrogen	%	14
Nitrogen	%	53
Water vapour	%	3

Performance analysis	UOM	Values
Ashes generated	%	9
Calculations		
Amount of gas produced	kg mole	186.26
Volume of the gas produced	sm^3/h	4123.95
Density of coal gas	kg/scm	1.045
Mass flow of coal gas	kg/h	4309.70
Coal gas fed to horizontal dryer	kg/h	414.74
Coal gas fed to kiln	kg/h	3894.96
Volume of air required	kg mole	128.08
Volume of air required	sm^3/h	2870.84
Density of air	kg/sm^3	1.29
Amount of air required	kg/h	3711.99
HHV of gas produced	$kcal/sm^3$	1231
HHV of gas produced	kcal/kg	1178

7.6 Annex-6: List of Vendors

ECM-1: Excess air control in kiln

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

ECM-2 & 3: Insulation improvement near kiln and HAG

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	T 91 44 2530 6888 F 91 44 2534 5985 M 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com
2	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 Mr. Rajneesh Phone : 0161-2819388 Mobile : 9417004025	Email: kk.mitra@lloydinsulation.com
3	Shivay Insulation	20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009	Mobile- 9712030444	shivayinsulation@gmail.com

ECM-4: Using soft water in clay ball mill

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

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

ECM-5: Use of VFD instead of soft starter in clay ball mill

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

ECM-6: Time controller for stirrer motor

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Jagdish Electro Automation	41,Sreenath complex, National Highway 8-A, Trajpar, Morbi-363641	Mr. Paresh Patel 9909458699	www.jagdishautomation.com
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com
3	Hitachi Hi-Rel Power Electronics Pvt. Ltd	B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044	Mr. V.Jaikumar 079 2328 7180 - 81	v_jaikumar@hitachi-hirel. com

ECM-7: Replacement of inefficient lighting systems

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Osram Electricals Contact Person: Mr. Vinay Bharti	OSRAM India Private Limited,Signature Towers, 11th Floor,Tower B, South City - 1,122001 Gurgaon, Haryana	Phone: 011-30416390 Mob: 9560215888	vinay.bharti@osram.com

Sl. No.	Name of Company	Address	Phone No.	E-mail
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-8: 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-9: Voltage optimization in lighting circuits

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

Sl. No.	Name of Company	Address	Phone No.	E-mail
		Telangana - 500033		

ECM-10: VFD on new Screw compressor

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

ECM-11: Energy Management system

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

ECM-13: VFD on Spray dryer ID Fan motor

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Samhita Technologies Pvt. Ltd	309, Vardhman Grand Plaza, Distt Center, Mangalam Place, Plot No. 7, Outer ring road, Sec 3, Rohini, Delhi – 110085	Mob: +91 9711320759 Tel: +91 11 45565088	sales@samhitatech.com
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com

Sl.No.	Name of Company	Address	Phone No.	E-mail
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-14: V Belt with REC belt replacement

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Shree Ram Marketing Co.	67, Sharhanand Marg, G.B. Road, Shardanand Marg, Delhi – 110006	08048022651	NA
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 15: Replacement of Agitator motors by EE motor

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	The General Electric Agency	Crompton House, Ganesh Shopping Centre, Opp. Dr. Beck & Co. GIDC, Ankleshwar	Mr. Nimesh Patel 9925152416	generalagenc@sify.com
2	Siemens Limited	3rd floor, Prerna Arbour, Girish Cold Drinks Cross Road, Off. C.G.Road, Ahmedabad	Mr. Paresh Prajapati 079-40207600	paresh.prajapati@siemens.com
3	Crompton Greaves	909-916, Sakar-II, Near Ellisbridge, Ahmedabad	079-40012000 079-40012201 079-40012222	sagar.mohbe@cgglobal. com

ECM 16: Energy Monitoring 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,	Office: 011-30810229, Mobile: +91-981817181	manjulpandey@aimil.com

Sl. No.	Name of Company	Address	Phone No.	E-mail
		New Delhi - 110 044		
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

7.7 Annex-7: Financial analysis of project

Table 59: Assumptions for Financial Analysis

Particulars	UOM	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%