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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE VT61: SANSKAR JOHNSON – Unit 2

Submitted to

UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

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Apirl-2019

Bureau of Energy Efficiency, 2019

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

ACKNOWLEDGEMENT

DESL places on record its sincere thanks to Bureau of Energy Efficiency (BEE) for vesting confidence in DESL to carry out the assignment "Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India – Morbi Ceramic Cluster". DESL is grateful to the GEF-UNIDO-BEE Project Management Unit (PMU) for their full-fledged support. Special thanks to UNIDO team for co-coordinating with cluster associations and providing support to DESL team in smooth execution of field activities.

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

DESL is indebted to M/s. Sanskar Johnson – Unit 2 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. Vasantbhai Patel, Director

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

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

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ABBREVIATIONS

Abbreviations	Expansions
APFC	Automatic Power Factor Controller
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BOP	Best operating practice
CGCRI	Central Glass and Ceramic Research Institute
CMP	Common monitor able parameters
DESL	Development Environergy Services Limited
ECM	Energy Conservation Measure
EE	Energy efficiency
FAD	Free Air Delivery
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

Particulars	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	kg
Kilo volt	kV
Kilo volt ampere	kVA
Kilo watt	kW
Kilo watt hour	kWh
Kilogram	kg
Litre	L
Meter	m
Meter Square	m^2
Metric Ton	MT
Oil Equivalent	OE
Standard Cubic Meter	scm
Ton	t
Tons of Oil Equivalent	TOE
Ton of CO_2	tCO_2
Ton per Hour	t/h
Ton per Year	t/y
Voltage	V
Watt	W
Year(s)	y

CONVERSION FACTORS

TOE Conversion	Value	UOM	Value	UOM
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.

Sanskar Johnson – Unit 2 has been selected as one of the 20 units for detailed energy audit. SanskarJhonson – Unit 2 isa 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	Sanskar Johnson – Unit 2
Year of Establishment	2014
Address	Survey No. 284/1P1, 8A, National Highway, Sartanpar Road, At. Matel, Taluka - Wakaner, District - Morbi, Gujarat
Products Manufactured	Vitrified Tiles
Name(s) of the Promoters / Directors	Mr. Vasant Bhai Patel

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

A brief description of the manufacturing process is given below. The main energy utilizing equipment is 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:

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio of 2:1:1 respectively along with water to form a plastic mass.
- **Agitator:** The plastic mass after mixing in ball mill is poured in to a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Spray Dryer and HAG:** The hot air is introduced through the top of the chamber and the ceramic slurry 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.
- **Dryer:** Biscuits are sent to dryer for pre drying after it is passed through kiln.
- **Glaze mill:** For producing glazing material used on the product.
- **Kiln:** Biscuits are baked in the roller kiln at 1100-1150°C and again baked after glazing
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The main utility equipment installed is:

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

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Insulation of HAG duct: Insulation of HAG duct connecting to cyclone separator was poor which results in increased heat loss leading to increase in coal consumption. It is recommended to insulate the HAG duct connecting cyclone separator.
- Using soft water in clay ball mill: TDS of water used in clay section was found to be 1,400 ppm against desired level of 400 ppm. It is recommended to install brackish water plant which will blend RO water with raw water.
- Temperature controller in press CT fan: The press CT fan was running continuously irrespective of the operation of the press. It is recommended to install PID based temperature controller which will ensure that CT fan will start only when oil temperature is >38°C.
- Time controller for stirrer motors: All the agitators were operating continuously throughout the day and it is recommended to install timer based control for agitators.
- Replacement of inefficient pumps: Few pumps such as bore well pump-1 & 2, Press pump-1 & 2 and Kiln pump-1 & 2 were running at lower efficiency against desired efficiency of 65%. It is recommended to replace the existing pumps with energy efficient pumps.

- Replacement of inefficient lighting systems: Conventional lights like Fluorescent Tube lights and Metal Halide were present in unit which results in higher electrical consumption. It is recommended to replace the conventional lights with energy efficient LED lamps.
- Main LT voltage optimization: The present average voltage on main LT panel was 436V against standard voltage of 415V. It is recommended to install 3 MVA servo stabilizer on main LT panel to optimize voltage.
- Installation of harmonic filter: Harmonics levels were found to be higher than the prescribed limits as per IEEE guidelines. It is recommended to install harmonic filter at main incomer.
- Energy Management System: Online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption and there were no proper fuel monitoring system installed at hot air generator and kiln. It is recommended to install online electrical energy management systems (smart energy meters) on the main incomer and on the various electricity distribution panels and fuel monitoring system.
- Cable loss minimization: In sizing section, power factor was between 0.59-0.70, whereas in press section, the power factor was 0.69-0.87 and keeps on varying as per operation of press. It is recommended to install power factor improvement capacitors for sizing and automatic power factor controller for press section.
- Voltage optimization in lighting circuits: The present voltage for lighting circuit was found to be 430V against desired voltage of 380V. It is recommended to install separate lighting transformer of 60kVA rating for lighting circuit.
- Conversion of belt drive to direct drive: Belt drives results in power transmission loss due to presence of slip. It is recommended to convert belt drives to direct drives.

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			Monetary Saving	Investment Cost	Simple Payback Period	Annual Emission reduction
		Electricity kWh	Coal MT	Total Equivt. TOE	Lakh Rs/y	Lakh Rs	Months	Tons of CO_2
1	Insulation of HAG duct		18	10	1.01	2.49	30	39
2	Using soft water in clay bill mill	90,043	1,172	652	174.81	39.60	3	2,554
3	Temperature controller in press CT fan	26,730		2	2.14	0.21	1.2	22
4	Time controller for stirrer motor	132,123		11	10.58	1.82	2	108
5	Replacement of inefficient pumps	121,321		10	2.9	4.03	17	99
6	Replacement of inefficient lighting systems	61,974		5	4.96	2.58	6	51
7	Main LT Voltage optimization	928,752		80	74.39	98.99	16	762
8	Installation of harmonic filter	50,341		4	4.03	7.13	21	41
9	Energy Management System	218,888	131	91	48.74	7.40	2	458
10	Cable loss minimization	83,291		7	6.13	3.05	6	68
11	Voltage optimization in lighting circuits	62,075		5	4.97	1.98	5	51
12	Conversion of belt drive to direct drive	25,729		2	2.06	4.75	28	21
Total		**1,801,266**	**1,322**	**882**	**336.75**	**174.03**	**6.2**	**4,274**

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

- Reduction in energy cost by 14%.
- Reduction in electricity consumption by 16%.
- Reduction in thermal energy consumption by 14%.
- Reduction in greenhouse gas emissions by 19%.

➨ FINANCIAL ANALYSIS

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

Table 2: Financial indicators

Sl. No.	Energy Conservation Measure	Investment Lakh Rs	IRR %	Discounted Payback Period Months
1	Insulation of HAG duct	2.49	20	10.74
2	Using soft water in clay ball mill	39.60	331	1.08
3	Temperature controller in press CT fan	0.21	747	0.48
4	Time controller for stirrer motor	1.82	431	0.83
5	Replacement of inefficient pumps	4.03	52	6.18
6	Replacement of inefficient lighting systems	2.58	145	2.45
7	Main LT voltage optimization	98.99	54	5.98
8	Installation of Harmonic filter	7.13	35	8.00
9	Energy Management System	7.40	487	0.73
10	Cable loss minimization	3.05	155	2.33
11	Voltage optimization in lighting circuits	1.98	189	1.89
12	Conversion of belt drive to direct drive	4.75	22	10.21

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.

1.1 About the unit

General details of the unit are given below:

Table 3: Overview of the Unit

Description	Details		
Name of the plant	Sanskar Johnson – Unit 2		
Plant Address	Survey No. 284/1P1, 8A, National Highway, Sartanpar Road, At. Matel, Taluka - Wakaner, District - Morbi, Gujarat		
Constitution	Private limited		
Name of Promoters	Vasant Bhai Patel		
Contact person	Name	Vasant Bhai Patel	
	Designation	Partner	
	Tel	7874399444	
	Fax		
	Email	sanskar.vitrified@yahoo.com	
Year of commissioning of plant	2017		
List of products manufactured	Vitrified tile, 600 x 600 mm (4 tiles/box) Vitrified tile, 800 x 800 mm (3 tiles/box)		
Installed Plant Capacity	8,000 boxes/day		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	Not provided		

Description	Details		
Net profit	Not provided		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	200	
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	Yes	Spray drier
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas (scm)	Yes	Kiln, drier (secondary firing)
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
If Yes	Year of energy audit	-	
	Conducted by	-	
	Recommendations implemented	-	
	Type of ECM	-	
Interested in DEA	Yes		
	Interested		

1.2 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.

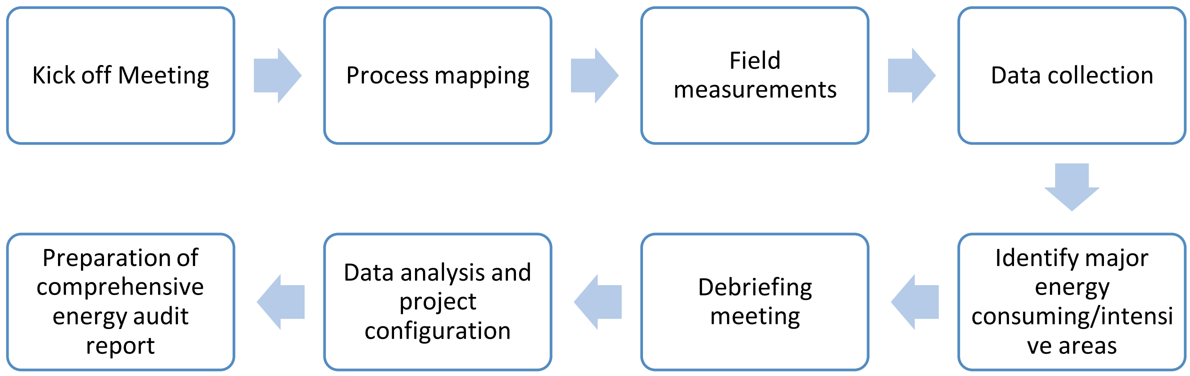

Figure 1: General methodology

The field work was carried out during 7th-10th December 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

1.3 Instruments used for the study

List of instruments used in energy audit are the following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Particulars 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	Temperature and Humidity data logging

Sl. No.	Instruments	Particulars Measured
	Logger	
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.4 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:

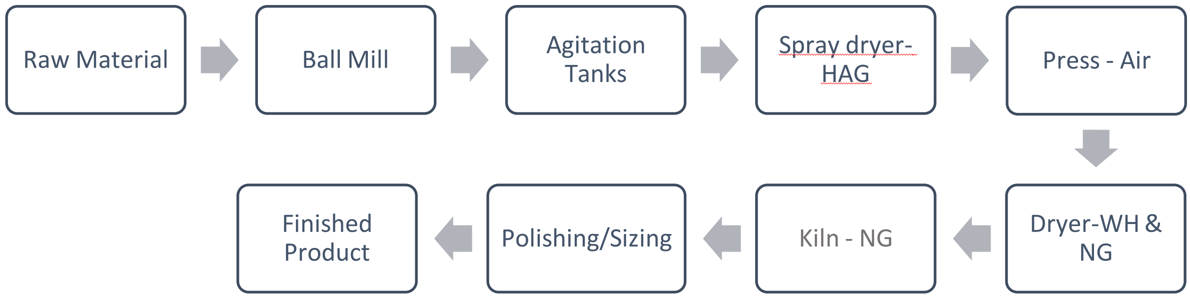

Figure 2: Process Flow Diagram

The process description is as follows:

- The raw material used is a mixture of china clay, bole clay, than clay, talc, potash, feldspar and quartz which is mixed along with water to form slurry.
- The raw materials are mixed and ground using pebbles together with water in the ball mill for a period of 7-8 hours.
- Slurry is then pumped using hydraulic piston into spray dryer where moisture content of slurry is reduced from 35-40% to about 5-6% and output of spray dryer is in powder form.
- 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.
- Biscuit is then baked initially in Five Layer Dryer.
- This is followed by the glazing process and digital printing.
- After this the glazed product makes a passage through kiln at 1,150-1,200°C for final drying and hardening.
- Output of kiln is called tiles; these tiles are then passed through cutting, sizing and polishing machines to match exact dimensions required.
- After sizing tiles are packed in boxes and then dispatched.

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

- **Ball mill:** Here the raw materials like clay, feldspar, potash, talc and quartz are mixed as per requirement along with water to form slurry.
- **Hot air generator:** Hot air generator is used to generate hot air which is used in spray dryer for evaporation of moisture present in slurry.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. instrument air, air cleaning, glazing etc.

- **Agitator:** The liquid slurry mass after mixing in ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Roller Kiln:** The kiln is the main energy consuming equipment where the product is passed twice, once in biscuit form and second time after glazing and printing. The kilns are about 150 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150^oC to 1,200^oC 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.
- **Press:** Clay in powered foam is pressed in hydraulic press and tiles are foamed.
- **Polishing and Sizing Machines:** From the Kiln machine tiles are passed to the polishing and sizing machine to match exact shape and size.

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	#
Vitrified Tiles	600 x 600	28.5	1.44	4
Vitrified Tiles	800 x 800	35	1.92	3

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

Period	Number of boxes		Corresponding Area (m²)		Corresponding Mass (MT)	
	600 x 600	800 x 800	600 x 600	800 x 800	600 x 600	800 x 800
Jun-17	117,605	-	169,351	-	3,352	-
Jul-17	194,003	-	279,364	-	5,529	-
Aug-17	182,155	-	262,303	-	5,191	-
Sep-17	180,340	-	259,690	-	5,140	-
Oct-17	163,044	22,511	234,783	32,416	4,647	788
Nov-17	146,608	22,605	211,116	32,551	4,178	791
Dec-17	97,790	39,987	140,818	57,581	2,787	1,400
Jan-18	163,796	-	235,866	-	4,668	-
Feb-18	145,589	-	209,648	-	4,149	-
Mar-18	180,685	-	260,186	-	5,150	-
Apr-18	100,412	2,231	144,593	3,213	2,862	78
May-18	25,089	-	361,28	-	715	-
Total	**1,697,116**	**87,334**	**2,443,847**	**125,761**	**48,368**	**3,057**

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 :
  - Natural Gas (NG) for roller kiln& Five layers dryer
  - Coal for HAG

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Lakh Rs	% of total	TOE	% of total
Grid – Electricity	876.61	36	941.20	11.9
Thermal-Coal	364.49	15	3,615.10	45.5
Thermal – NG	1,195.89	49	3383.80	42.6
Total	2,436.99	100	7,940.10	100

This is shown graphically in the figures below:

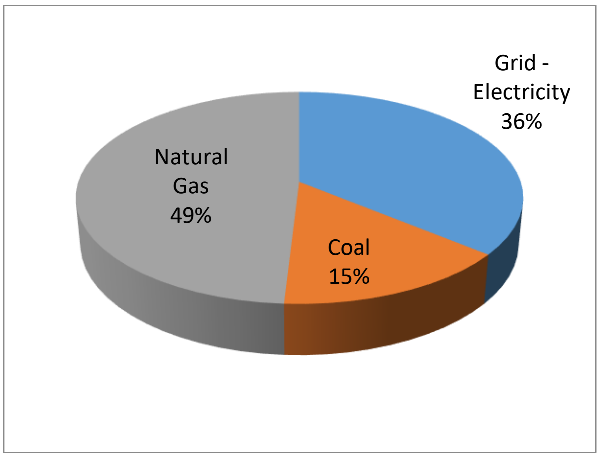

Figure 3: Energy cost share

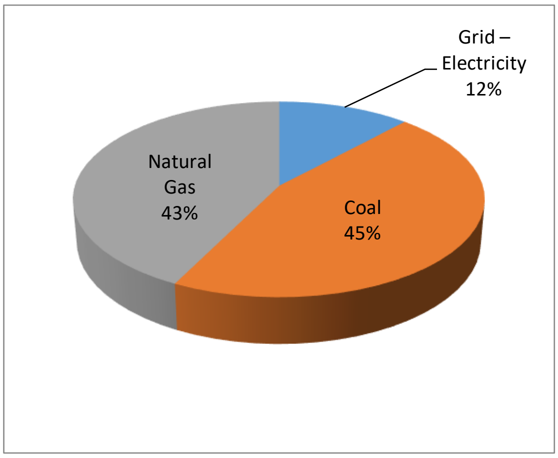

Figure 4: Energy use share

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 36% of the energy cost and 12% of the overall energy consumption.
- Source of thermal energy is from combustion of coal and by firing natural gas.

- Coal is used in hot air generator accounts for 15% of the total energy cost and 45% of overall energy consumption.
- NG used in Kiln and Five Layer Dryer accounts for 49% of the total energy cost and 43% 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	33264
Tariff Category	HTP-I
Contract Demand, kVA	2,700
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)	
Normal Hours	4.20
Peak Hours	0.85
Night Time	0.40
Fuel Surcharge (Rs./kVAh)	1.63
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(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
Jun-17	340,830	4,127,130	12.11
Jul-17	1,113,870	8,767,870	7.87
Aug-17	1,141,740	8,977,225	7.86
Sep-17	1,108,710	8,518,724	7.68
Oct-17	984,990	7,938,340	8.06
Nov-17	1,116,060	8,859,364	7.94
Dec-17	990,330	8,040,341	8.12

Month	Units consumed kWh	Total Electricity cost Rs	Average unit Cost Rs/kWh
Jan-18	836,370	6,730,907	8.05
Feb-18	875,730	6,898,722	7.88
Mar-18	817,290	6,525,734	7.98
Apr-18	951,390	7,496,406	7.88
May-18	667,080	4,780,335	7.17

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 912,033 kWh/month and cost is Rs. 73.05 Lakhs per month (Jun-17 to May-18). The average cost of electricity is Rs. 8.01/kWh, for the duration Jun-17 to May-18. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

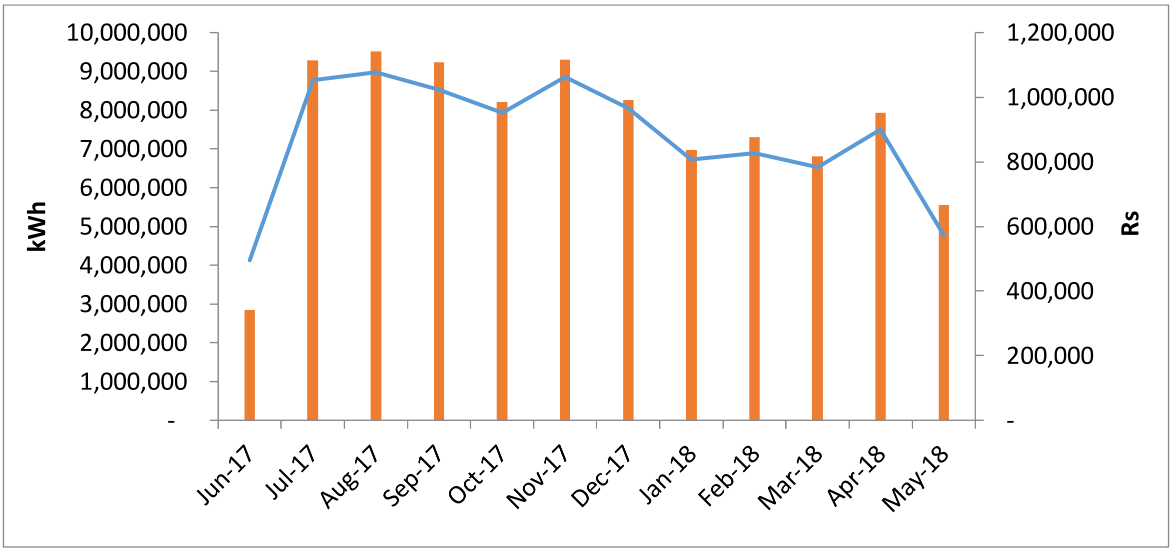

Figure 5: Month wise Variation in Electricity Consumption

Power Factor: Power factor as per electricity bills is shown below[1]:

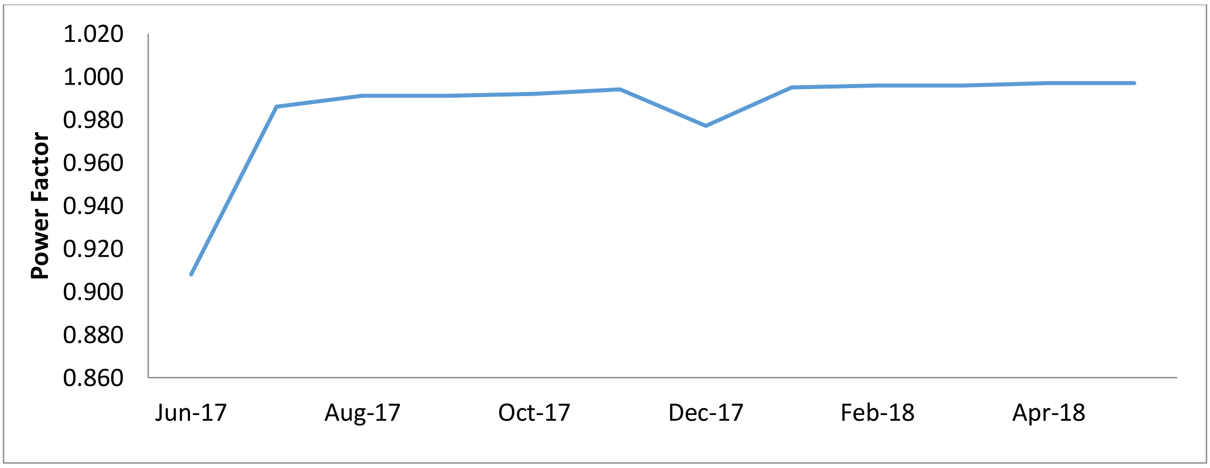

Figure 6: Month wise variation in Power Factor

[1] PF and KVA details are available in duration of Jun-17 to May-18

The utility bills of the unit reflect the power factor. A study was conducted by logging the electrical parameters of the main incomer using a power analyzer. The average power factor was found to be 0.985 and the maximum being 0.997.

Maximum Demand: Maximum demand as reflected in the utility bill is 2,643 kVA from the bill analysis.

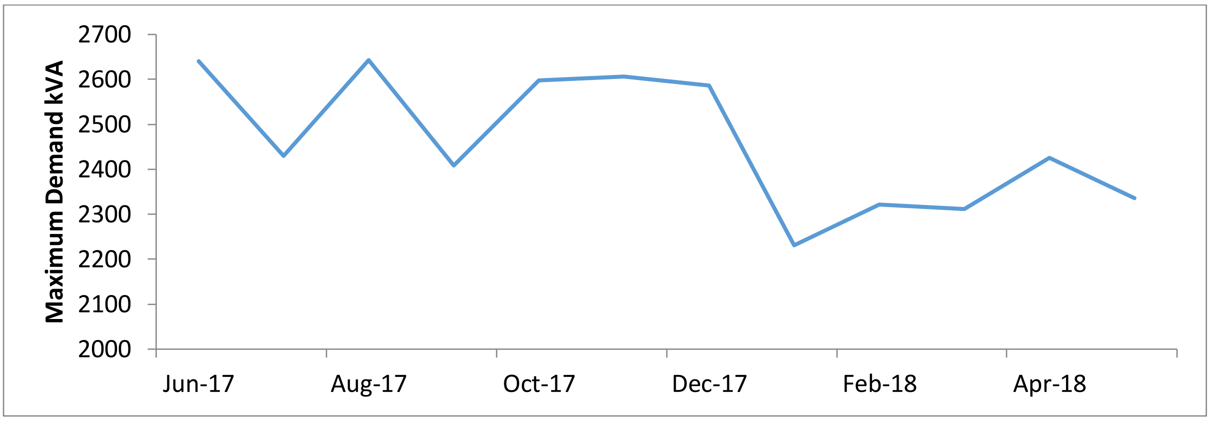

Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

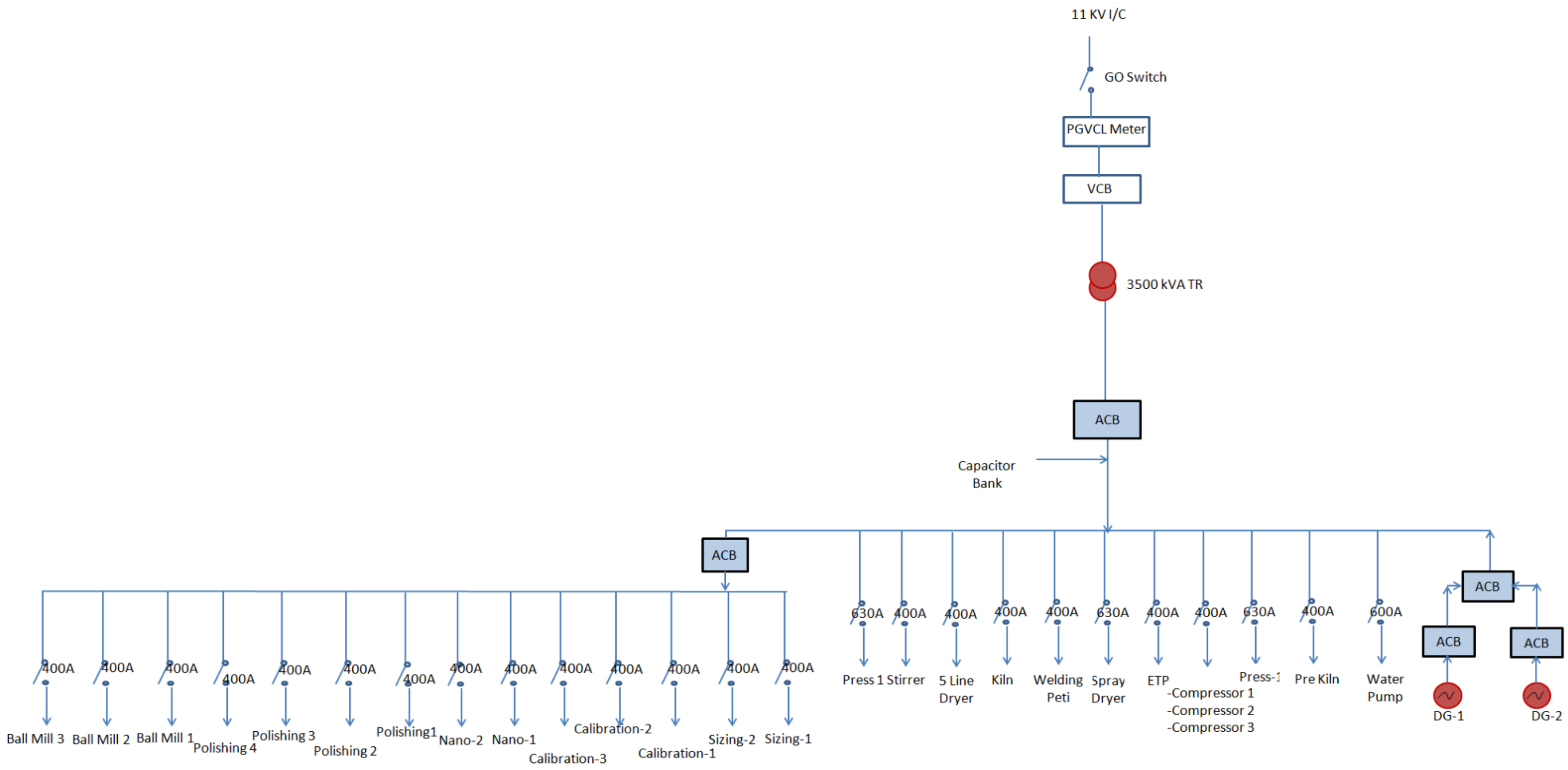

Figure 8: Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 5,024 kW, which includes:

- Plant and machinery load is 4,899 kW.
- Utility load is (lighting, air compressor and fans) about 151 kW including the single phase loads.

Table 11 : Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Ball Mill	1011
2	Clay Section	170
3	Agitator	92
4	Spray Dryer	255
5	Hot Air Generator	51
6	Press	379
7	Cooling tower	25
8	Pre Kiln	102
9	Kiln	605
10	Polishing Area	1965
11	Lighting	26
12	Compressor	74
13	Five Layer Dryer	270
Total Connected Load		5,024

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

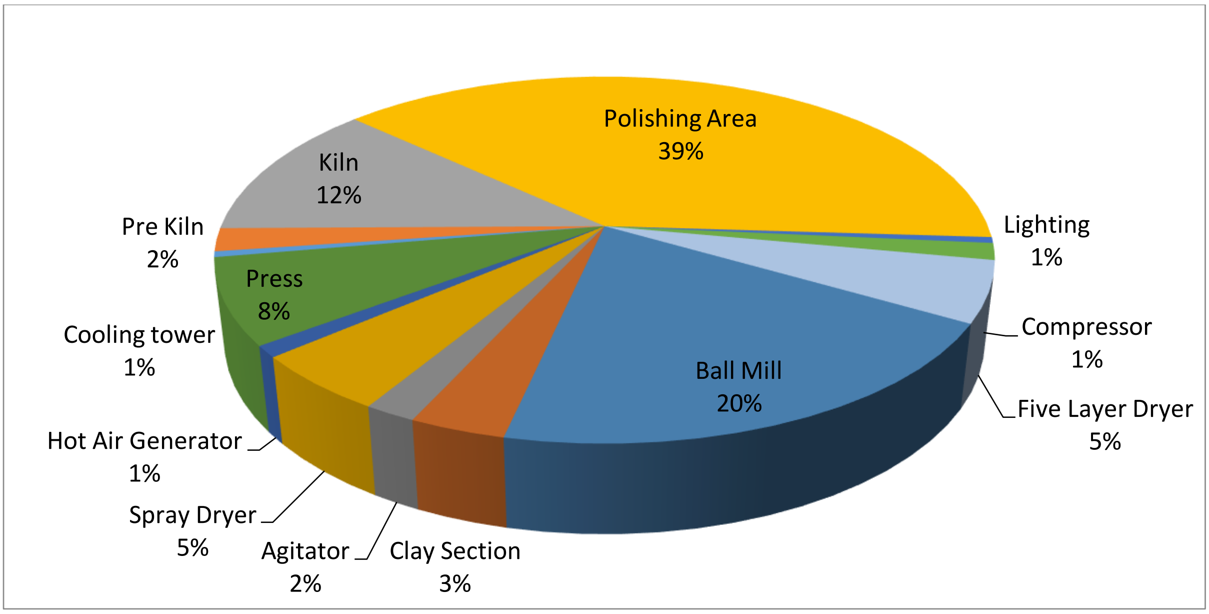

Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Polishing area – 39%, for Ball mill – 20%, for Kiln – 12%, for Press – 8%, for Spray dryer – 5%, for Five Layer Dryer – 5% 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:

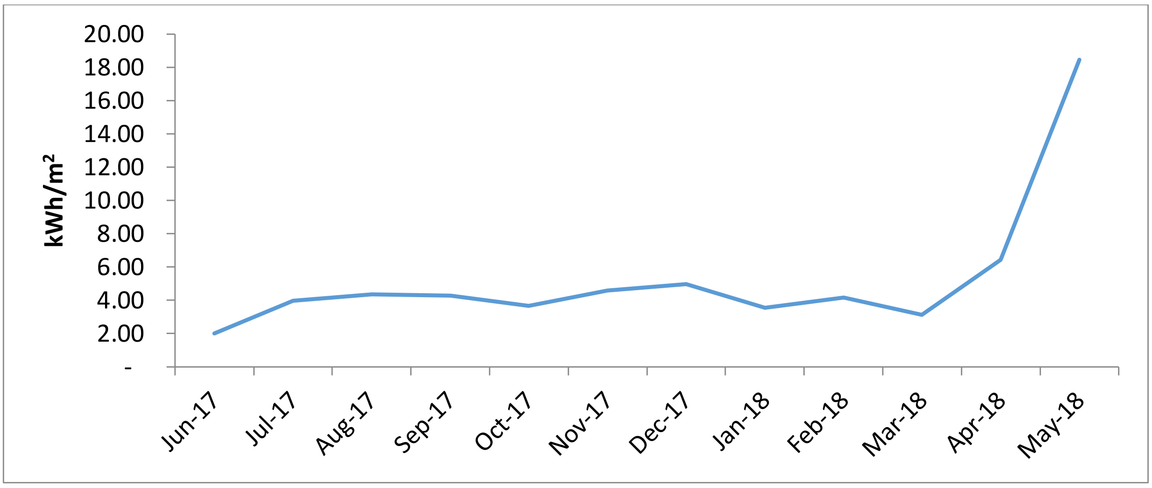

Figure 10: Month wise variation in Specific Electricity Consumption

May-18 is outliers. Excluding this month, the maximum and minimum values are within ±25% of the average SEC of 5kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is available in the plant but there is no historical record of the consumption in various sections; apart from the metering available for PGVCL supply. Monitoring of sub-metering along with recording will help establish section wise SEC on daily basis, this will be useful in ball mill section, spray dryer section, press section, kiln and polishing machines 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, five layers dryer and the kilns. Natural gas is used as the fuel for firing in the kiln and Coal is used as the fuel for hot air generator. Coal imported from Indonesia is being used. Natural Gas is purchased from GSPC (Gujarat State Petroleum Corporation) and used in the kiln and five layers dryer. Based on the gas bills shared for the month of Jun-17 to May-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 Used scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs/MT
Jun-17	322,974	10,878,656	33.68	496	2,576,000	5,196
Jul-17	396,270	11,956,240	30.17	377	2,940,000	7,805
Aug-17	394,658	11,810,608	29.93	536	2,727,000	5,092
Sep-17	339,453	9,611,037	28.31	666	3,427,000	5,150
Oct-17	353,868	9,907,704	28.00	846	4,397,000	5,195
Nov-17	331,823	9,409,298	28.36	767	4,009,000	5,227
Dec-17	319,777	9,258,703	28.95	655	3,534,000	5,398
Jan-18	337,851	10,091,883	29.87	619	3,422,000	5,527

Month	NG			Coal		
	NG Used scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs/MT
Feb-18	312,809	9,664,626	30.90	543	3,037,000	5,593
Mar-18	354,530	10,880,366	30.69	610	3,454,000	5,663
Apr-18	219,747	7,415,791	33.75	326	2,074,000	6,363
May-18	76,042	8,703,764	114.46	133	852,000	6,397

Observation (for the period Jun-17 to May-18)

- Average monthly coal consumption is 548 tons and average cost Rs. 30.37 Lakhs/month.
- Average monthly gas consumption is about 313,317 scm and average cost is Rs.99.66 Lakhs/month.

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:

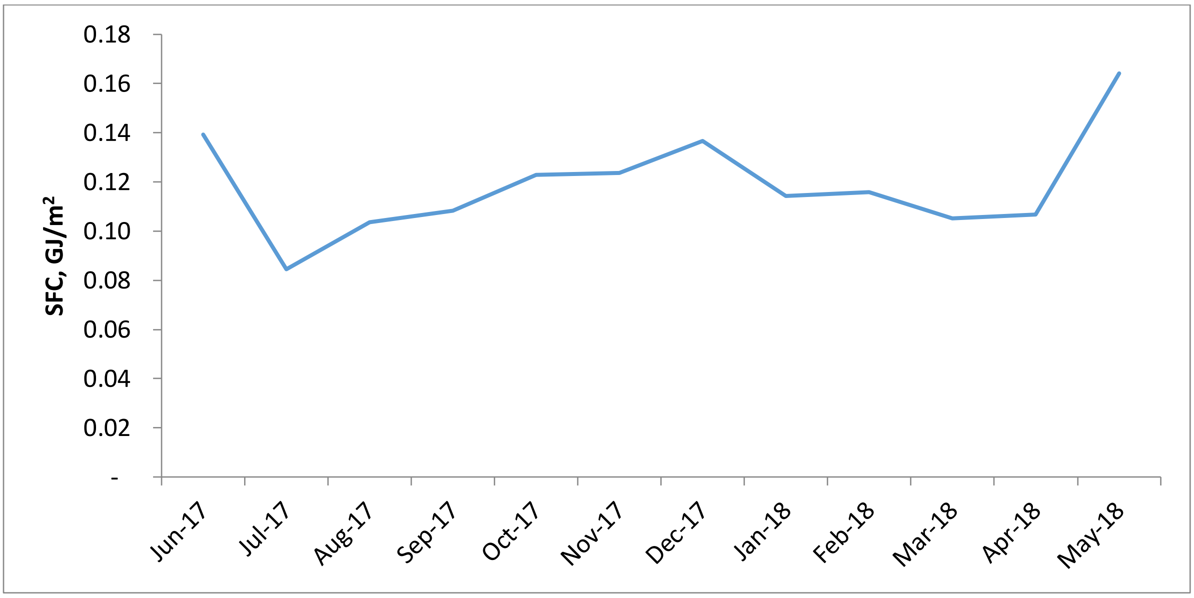

Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.12GJ/m^2. SFC is high in the month of May-18 (production was 36,128 m^2 and thermal consumption was 5,931 GJ) and low in the month of Jul-17(production was 279,364 m^2 and thermal consumption was 23,602 GJ).While metering for NG is recorded; the coal data is also maintained in the log books. For better quality information, sub-metering/data logging is required at kiln 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	297

Particulars	UOM	Value
Power consumption	kW	1267
Coal consumption	kg/h	761
NG consumption	scm/h	435.2
SEC of Plant	TOE/m^2	0.0018

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)
Ball Mill			16.8
Agitator			6.0
Spray Dryer			4.0
Hot Air Generator		95.1	6.3
Press			7.4
Kiln	55.4		11.4
Polishing & Sizing			74.0
Five Layer Dryer	2.29		8.5

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	10,944,390
Annual DG Generation Unit	kWh	-
Annual Total Electricity Consumption	kWh	10,944,390
Diesel Consumption for Electricity Generation	l	-
Annual Thermal Energy Consumption (Coal)	MT	6,573
Annual Thermal Energy Consumption (NG)	scm	3,759,801
Annual Total Energy Consumption	TOE	7,940
Annual water Consumption	Kl	23,364
Annual Water Cost	Lakh Rs	1.0
Annual Energy Cost	Lakh Rs	2,437
Annual Production	m^2	2569608
	MT	51424
SEC; Electrical	kWh/m^2	4.259
	kWh/MT	212.824
SEC; Thermal	GJ/m^2	0.1140
	GJ/MT	5.6972
SEC: Water	kl/m^2	0.009
	kl/t	0.4543

Particulars	UOM	Value
SEC; Overall	TOE/m^2	0.0018
	TOE/t	0.0886
SEC; Cost Based	Rs/m^2	94.8
	Rs/t	4739.0

(Annual data based on the period Jun-17 to May-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 : 9,000 kCal/scm
- GCV of Coal : 5,500 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 (Jun-17 to May-18)	8.01
Cost of Coal	Rs/MT	5,545
Cost of NG	Rs/scm	31.8
Operating Hours per day	h/d	24
Annual Operating Days per year	d/y	330

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using Bore well pumps (2 numbers). The water from these pumps is collected in ground water tank. From this ground water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is around 65 m^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.

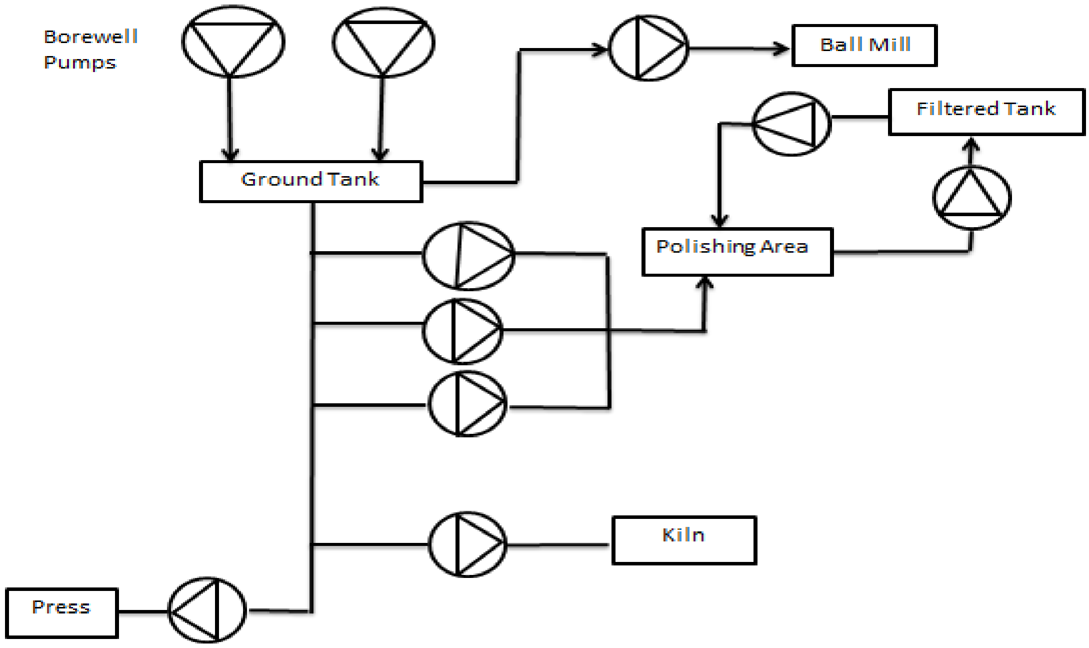

Figure 12: Water Distribution Diagram

Two Bore well pumps are installed to meet the water requirements of process (cooling towers for press, ball mills, Kiln, chain stoker HAG and domestic use). Installation details of Bore well pumps are tabulated hereunder.

Table 17: Bore well pump details

Particulars	UOM	Bore well Pump
Make	-	-
Motor rating	kW	11.2
RPM	rpm	2,900
Quantity	Number	2

Factory does not have any water treatment plant. It is recommended to install meters, to monitor and control water consumption.

3. CHAPTER -3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Natural 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 811HP electrical load of which 241HP is for 2 smoke blowers, 201HP for combustion blower, 74 HP for rapid cooling, 74 HP for Hot air blower, 74 HP for final cooling section, 74 HP for dryer blowers& 74 HP for roller motor.

Table 18: Kiln Details

Sl. No	Particulars	UOM	Value
	Make		-
1	Kiln operating time	h	24
2	Fuel consumption	scm/h	460.9
3	Number of burner to left	-	180
4	Number of burner to right	-	180
5	Cycle Time	Minutes	80
6	Pressure in firing zone	mmWC	45
7	Maximum temperature	°C	1,200
8	Waste Heat recovery option		Yes(double heat recovery)
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	m	84 x 2.1 x 1
	Firing Zone	m	65 x 2.1 x 1
	Rapid Cooling Zone	m	18 x 2.1 x 1
	Indirect cooling Zone	m	19 x 2.1 x 1
	Final cooling zone	m	26 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. Natural gas is used at both kiln and the five layers drier; therefore, the consumption in kiln has been calculated based on heat load of the kiln during DEA. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 19: FGA Study of Kiln

Particulars	Value
Oxygen Level measured in Flue Gas	1.2%
Ambient Air Temperature	38°C
Exhaust Temperature of Flue Gas	110°C
Burner combustion air temperature	250°C

It is observed herein this kiln is having double heat recovery from recupertor is done from rapid cooling and final cooling air which is filtered and filtered and sent to the combustion air fan before being heated further via an exchanger in the fast cooling zone, reaching a temperature between 150°C and 250°C depending upon different working cycle.

It is also observed that the oxygen level measured in flue gas was low and hence no ECM has been proposed. Exhaust temperature of flue gas was 110°C which is less so no ECM has been proposed for any further recovery. Average surface temperature was around 50 °C which is within the permissible range, so no ECM has been proposed as shown in the table below:

Table 20: Surface temperature of kiln

Zone	Temperature (°C)
Ambient Temperature	40.2
Pre-heating zone Average Surface Temperature	50
Heating zone Average Surface Temperature	50
Rapid cooling zone Average Surface Temperature	50
Indirect cooling zone Average Surface Temperature	50
Final cooling zone Average Surface Temperature	50

The temperature profile of the kiln is shown below:

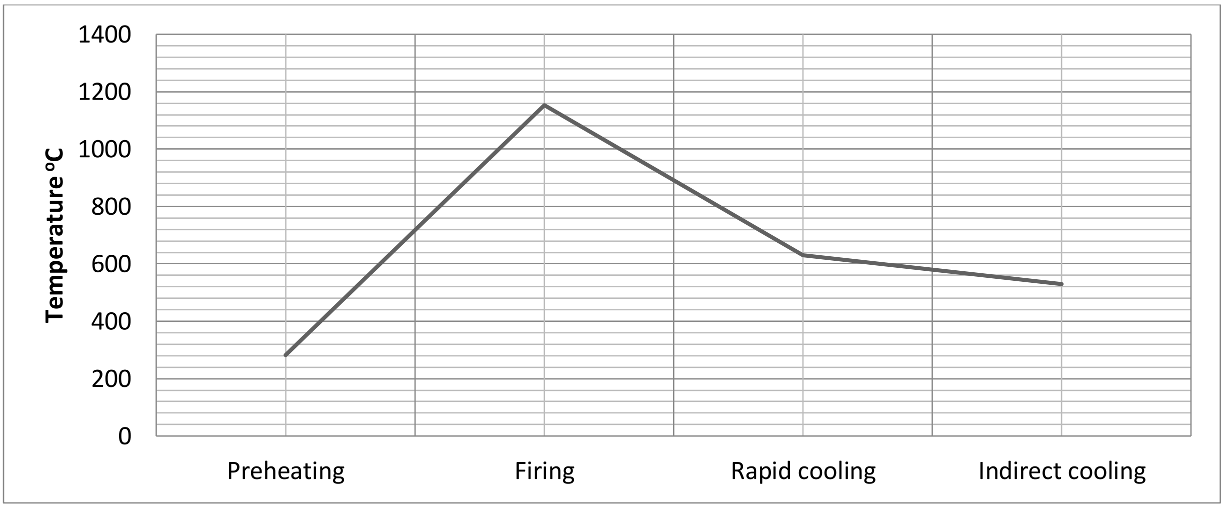

Figure 13: Temperature Profile of Kiln

Measured data of power for all blowers is given in below table, details are provided in<u>Annexure-4</u>:

Table 21: Power measurements of all blowers

Equipment	Average Power (kW)	Power factor
Hot air blower	25.2	0.99
Heat Recovery Blower	3.6	0.99
Rapid Cooling Blower	6.2	0.99
Smoke Blower	12.2	0.99
Combustion Blower	27.0	0.99

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Overall efficiency of the kiln is 73.3%. Summary of all losses is shown in below figure:

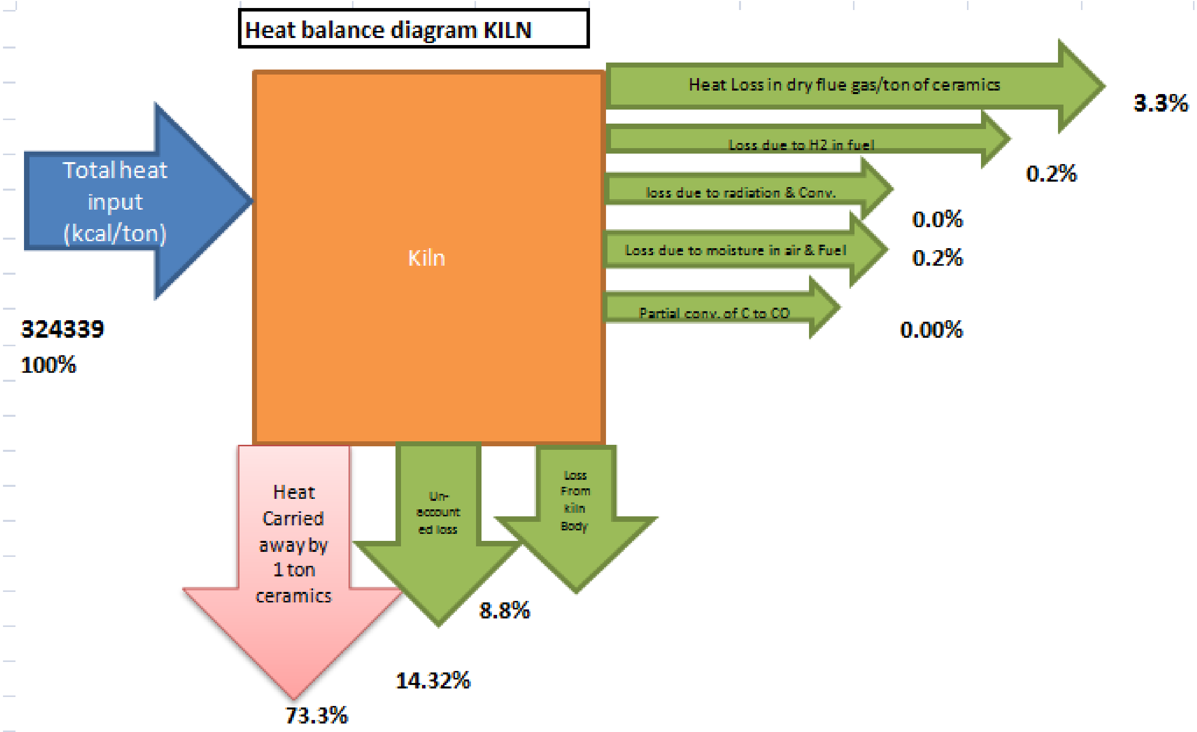

Figure 14: Heat balance diagram of Kiln

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

3.2 Five Layers Dryer

3.2.1 Specifications

There is one five layer dryer installed in plant. In this dryer, biscuits (green tiles) are entered from press which are heated from 35 to 115°C. There are fifteen hot air blowers &three smoke blowers connected. Heat is being supplied from kiln and some auxiliary burners. The specifications of five layer dryers are given below table:

Table 22: Specifications of Five layer dryer

Particulars	UOM	Value
Capacity	Nos. of tiles/h	1,167
Fuel type		NG
Estimated fuel consumption	scm/h	19
Exit temperature of tiles	°C	120
Smoke Blower	kW	3 x 15
Hot air Blower	kW	15 x 15

3.2.2 Field measurement and analysis

During DEA, the following measurements were done:

a) Mass flow study (table below)
b) Temperature of each tile at exit(table below)
c) Power consumption of blowers
d) Gas consumption data

Data measured during study is tabulated below:

Table 23: Field measurement at site

Particular	UOM	Value
Tiles counter reading at start		1,167
Tiles counter reading at end		2,334
Mass of each tile at entry	g	7,125
Mass of each tile at exit	g	7,100
Temperature of tile at exit	°C	120
Energy consumption	kCal/h	1,71,383

The power profile and PF profile of five layer dryer are given below:

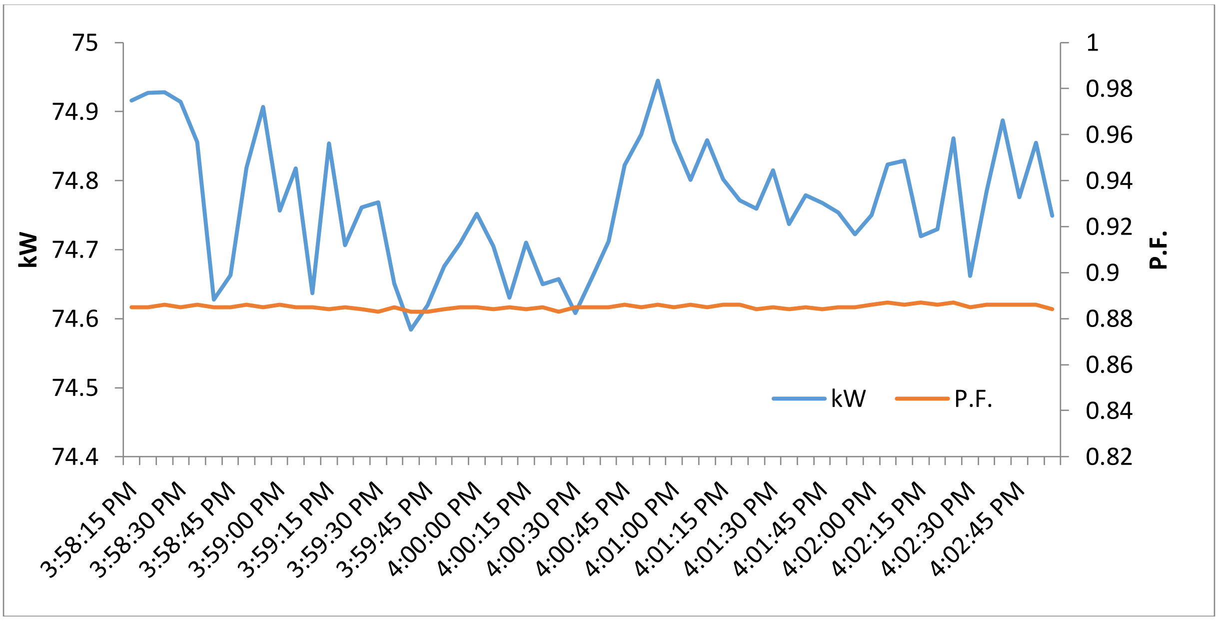

Figure 15: Power and PF profile of Five Layer Dryer

Average power consumption of dryer is 74.766 kW (PF 0.89)

3.2.3 Observation and Performance assessment

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

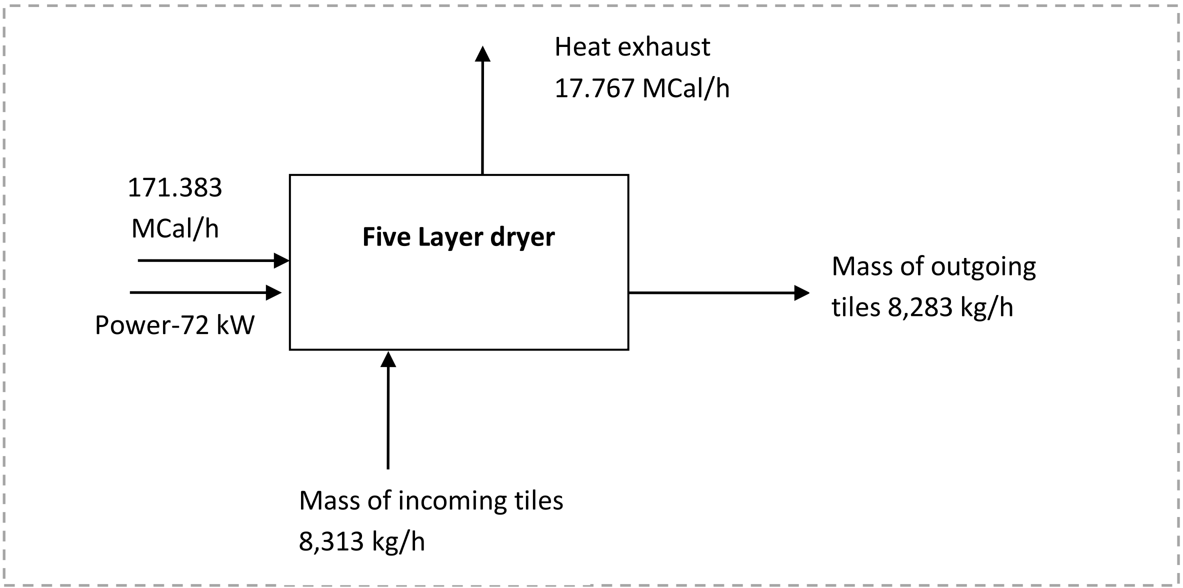

Figure 16: Mass and energy balance of five layer dryer

Based on observations during DEA, the specific electricity consumption of five layer dryer is 8.6 kW/t of tile and specific thermal energy is 2.3 scm/t of tile. Since blowers are VFD controlled, hot air is utilized and operation is optimized. No energy conservation measure is proposed.

3.3 HOT AIR GENERATORS& SPRAY DRYERS

3.3.1 Specifications

There is one hot air generators (HAG) of chain stoker type and is used for evaporating water from slurry which is coming from ball mill. There is one spray dryers installed, which is taking heat from chain stoker HAG. Spray dryer is the heat exchanging unit for powder generation from slurry.Specifications of HAG are given below:

Table 24: Specifications of Hot air generator (HAG)

Particular	UOM	Chain stoker
Air handling capacity	m^3/h	-
Fuel type		Coal
Rated fuel consumption	tonnes	-
Hot air temperature	°C	750
FD blower	hp	1 x 60
SFD blower	hp	1 x 3

The specification of spray dryers is given below:

Table 25: Specifications of spray dryer

Particular	UOM	Value
Powder generation capacity		-
Inlet slurry moisture	%	40
Outlet powder moisture	%	6
Hydraulic pump	hp	2 x 75

3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

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

Details of measurements on HAG are given below:

Table 26: Field measurement at site

Particular	UOM	Chain stoker
Air velocity at FD fan suction	m/s	21
Suction area	m^2	0.17
Exit temperature of air	° C	750
Surface temperature	° C	135
Average power consumption-FD Blower	kW	44
Average power consumption-ID Blower	kW	48
Average power consumption – PA fan-1	kW	5.04
Average power consumption – PA fan-2	kW	4.88

ID blower and FD blowers were operating with VFDs.

3.3.3 Observations and performance assessment

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

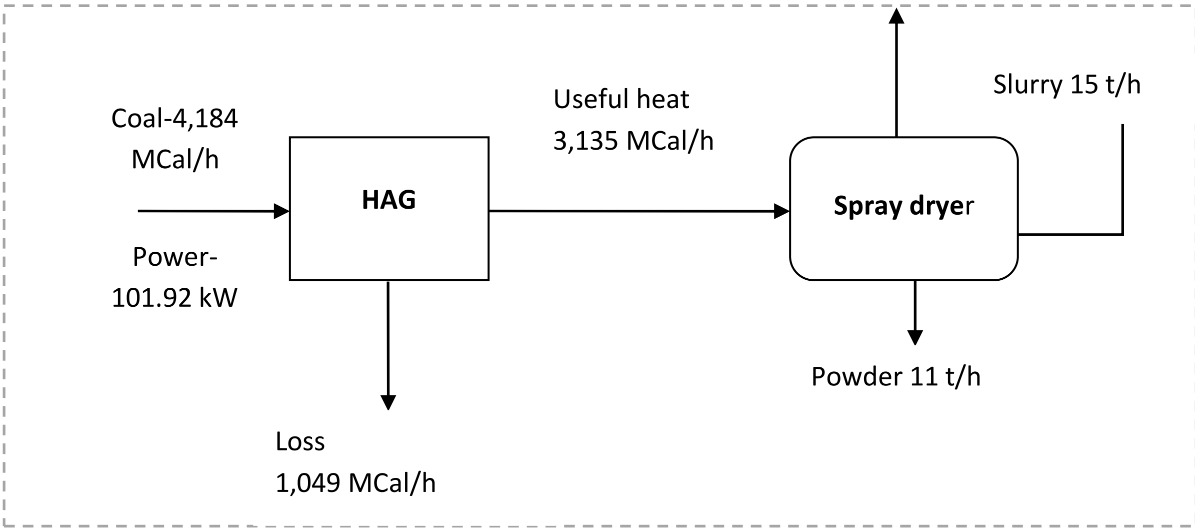

Figure 17: Energy and mass balance of Chain Stoker HAG and Spray dryer

Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for evaporating one kg water from slurry) and specific thermal energy (heat used for evaporating 1 kg of water in slurry). Based on observations during DEA, the specific electricity consumption of HAG is 6.3 kW/t and Specific thermal consumption is 95.1 kg/t. The specific electricity consumption of Spray dryer is 0.5 kW/t.

3.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

3.3.4.1 ECM # 1: Insulation of HAG duct

Technology description

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

Study and investigation

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

Recommended action

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

Estimated cost benefit is given in the table below:

Table 27: Saving and cost benefit analysis by Insulating HAG duct [ECM-1]

Particulars	UOM	Present	Proposed
Location of HAG		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	5,500	5,500
Estimated coal loss	kg/h	5.1	1.4
Average coal saving	kg/h		3.7
Annual Operating Hours	h/y	4,950	4,950
Annual coal saving	t/y		18
Fuel cost	Rs/t	5,545	5,545
Annual fuel cost saving	Lakh Rs/y		1.01
Total Savings	Lakh Rs/y		1.01
Estimated insulation cost	Lakh Rs		2.49
Simple Payback period	Month		30
Project IRR	%		20
Discounted payback period	Months		10.74

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 BALL MILLS

4.1.1 Specifications

Ball mills produce slurry by mixing clay, water and chemicals SMS and STPP. Ball mills take 5 to 6 hours for slurry preparation. The specifications of ball mills and its accessories are given below:

Table 28: Specifications of ball mills

Particular	UOM	Value
Numbers of ball mills	#	3
Capacity of each ball mill	t/batch	60
Water consumption in each ball mill	t/batch	30
SMS (chemical consumption)	kg/batch	280
STPP (chemical consumption)	kg/batch	150
Water TDS	ppm	1,400
Nos. of batch per day		2

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all ball mills

All power profiles are included in **Annexure-4**. Average power consumption and power factor are given in below table:

Table 29: Average power consumption and PF of ball mills

Equipment	Average Power (kW)	PF
Ball Mill#1	202	0.89
Ball Mill#2	212	0.86

Average Ball mill#1 is 202 kW (PF 0.89) and Ball Mill#2 is 212 kW (PF0.86).

4.1.3 Observations and performance assessment

Mass balance of Ball mill #1 based on measurements is given below:

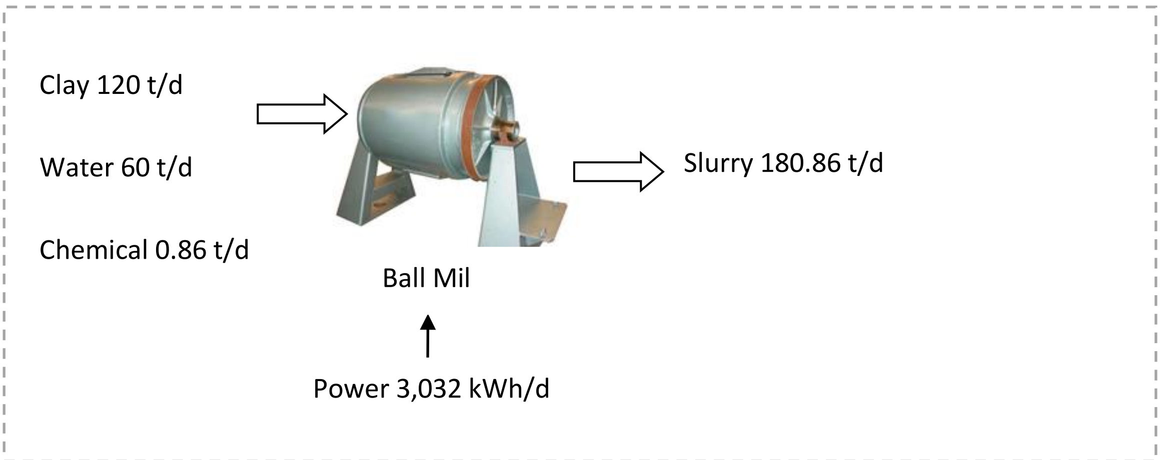

Figure 18: Energy and mass balance of Ball Mill

Performance of ball mills measure in terms of specific energy consumption (power consumed for preparation of 1 ton of slurry). Based on observations during DEA, the specific energy consumption of ball mill was 16.8 kW/t. TDS of bore well water is very high; this should be controlled by installing softener plant, which will enable resource savings.

4.1.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.1.4.1 ECM # 2: Using soft water in Clay Ball mill

Technology description

It was observed that the TDS of water used in clay section is 1,400 ppm, which results in higher consumption of water, chemicals and electricity per batch of slurry preparation and later higher coal consumption for spray dryer.

Study and investigation

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

Recommended action

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

Estimated cost benefit is given in the table below:

Table 30: Saving and cost benefit analysis by using soft water in clay ball mill [ECM-2]

Particulars	UOM	Present	Proposed
TDS of Water	ppm	1,400	400
Assumption : Water Saving	%		15
Assumption : Electricity Saving	%		3
Assumption : Fuel Saving	%		30
Assumption : Chemical Saving	%		30
Water used per batch	m^3	30.00	25.50
Water saving	m^3		4.50
Electricity used per batch	kWh	1515.9	1470.4
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kCal/kg	5,500	5,500
Eff. Of HAG	%	85	85
Coal saving per batch	Kg		592
Chemical saving per batch			
SMS	Kg	280	196

Particulars	UOM	Present	Proposed
STPP	Kg	150	105
Per Unit Cost			
Water	Rs/m^3	4.20	4.20
Electricity	Rs/kWh	8.01	8.01
Coal	Rs/kg	5.55	5.55
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		9,339
Total batches per day	#	6	6
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		8,910
Electricity	kWh/y		90,043
Coal	t/y		1,172
Chemical	kg/y		255,420
Annual cost savings	Lakh Rs/y		184.91
Operating cost- Water Treatment	Rs/m^3		20.00
	Lakh Rs/y		10.10
Net monetary savings	Lakh Rs/y		174.81
Estimated investment	Lakh Rs		39.60
Simple Payback period	Months		3
Project IRR	%		331
Discounted payback period	Months		1.08

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 (15.5MPa). Hydraulic oil gets heated when pressed so that it is required to be cooled in heat exchanger where water circulates as cold media. The specifications of presses and its accessories are given below:

Table 31: Specifications of hydraulic press

Particular	UOM	Press-1	Press-2
Cycle (stroke) per minute	N/m	5.1	5.1
Number of tiles per stroke		2	2
Water Circulation Pump	#s	1	1

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all water circulation pumps
- Count of tiles processed

Average power consumption of water circulation pump 1 is 8.2 kW, water circulation pump 2 is 6.3 kW.

Tiles are producing from press-1 & press-2 were 612 per hour each.

4.2.3 Observation and performance assessment

Both circulation pumps operates 24 hours in a day while press has frequent shut down. So it is suggested that pump operation must be controlled by sensing return oil temperature from press.

Performance of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press was 7.4 kW/t.

4.2.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.2.4.1 ECM #3: Temperature Controller in press CT fan

Technology description

Cooling water is circulated in heat exchanger of press machine for oil cooling. A PID controller for cooling water fan will ensure operation of CT fan only when it is required based on temperature set point.

Study and investigation

It was observed that cooling water fan is running continuously irrespective of the operation of the press this CT fan is drawing 4.5 kW. It was also observed that even when press is not in operation pump and CT fan are in operation.

Recommended action

It is recommended to install PID based controller which will ensure that CT fan will start only when oil temperature is >38°C; and once this temperature is maintained, pump will stop automatically. The cost benefit analysis for this project is given below:

Table 32:Saving and cost benefit analysis by Temperature Controller in press CT fan[ECM-3]

Particulars	UOM	Present	Proposed
No. of cooling tower	#	2	2
No. of cooling tower fan	#	1	1
Rated power of fan	kW	5.0	5.0
Operating power	kW	4.5	4.5
Operating hours per day	h/d	24	15
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	71,280	44,550
Annual electricity saving	kWh/y		26,730
Unit cost of electricity	Rs/kWh		8.01
Annual monetary savings	Rs Lakh/y		2.14
Estimated Investment	Rs Lakh		0.21
Simple Payback Period	Months		1
Project IRR	%		747
Discounted payback period	Months		0.48

4.3 Agitator

4.3.1 Specifications

Slurry stored in agitation tank after preparation in ball millswhere agitator motors (stirrer) were rotating continuously. Stirrer avoids settling of slurry. The specifications of agitator motors are given below:

Table 33: Specifications of agitators

Particular	UOM	Value
Numbers of agitators in tank	#	23
Capacity of each agitator motor	kW	3
Number of motors	#	23

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

Power consumption of all agitator motors (stirrer) are given in below table:

Table 34: Power consumption of agitator motors

Equipment	kW
Stirrer-1	0.88
Stirrer-1A	0.86
Stirrer-4	1.3
Stirrer-4A	2.3
Stirrer-4B	2.39
Stirrer-4C	2.29
Stirrer-5	1.27
Stirrer-5A	1.3
Stirrer-5B	2
Stirrer-5C	1.68
Stirrer-5D	1.9
Stirrer-5E	2.42
Stirrer-6	1.1
Stirrer-6A	1.08
Stirrer-6B	1.03
Stirrer-6C	1.2
Stirrer-6D	1.15
Stirrer-6E	1.52
Stirrer-7	2.7
Stirrer-7A	3.22
Stirrer-7B	4.57
Stirrer-7C	3.17
Stirrer-7D	2.56
Stirrer-7E	2.53

4.3.3 Observations and performance assessment

During DEA it is observed that all motors operate same time. It is suggested that all motor should be operated by timer control.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry). Based on observations during DEA, the specific energy consumption of agitator motors were 6kW/t.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 ECM #4: Timer Controller for stirrer motor

Technology description

A number of agitators are running only to maintain homogenous of the slurry. 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 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 35: Saving and cost benefit analysis by time Controller for stirrer motor [ECM-4]

Particulars	UOM	Present	Proposed
Number of agitator stirrer	#	23	23
Number of agitator stirrer running	#	23	23
Rated power of agitator stirrer motor	kW	3	3
Daily running of each stirrer motor	h/d	24	15
Operating days per year	d/y	330	330
Measured power of agitator stirrer motor	kW	1.93	1.9
Annual energy consumption	kWh/y	352,328	220,205
Annual energy saving	kWh/y		132,123
Unit cost of electricity	Rs/kWh		8.01
Annual monetary savings	Lakh Rs/y		10.58
Estimated Investment	Lakh Rs		1.82
Simple Payback Period	Months		2
Project IRR	%		431
Discounted payback period	Months		0.83

4.4 Polishing Area

4.4.1 Specifications

There were four squaring and chamfering line, two FM coating machine, four Polishing machines, & three calibrating machines present in the polishing area. The specifications of all machines are given below:

Table 36: Specifications of all machines in Polishing area

Particular	UOM	Value
Squaring & Chamfering line	kW	4 x 75
FM coating machines	kW	2 x 158.5
Polishing machines	kW	4 x 195
Calibrating machines	kW	4 x 174.6

4.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of Squaring & Chamfering lines, FM coating machines, Polishing machines and Calibrating machines.

Average power consumption and PF of all machines are tabulated below:

Table 37: Measured Parameters of sizing machine

Equipment	Average Power (kW)	PF
Calibrating machine-1	50.05	0.54
Calibrating machine-2	71.60	0.69
Calibrating machine-3	70.68	0.69
Nano machine-1	133.18	0.77
Polishing machine-1	92.67	0.63
Polishing machine-2	108.84	0.68
Polishing machine-3	75.95	0.57
Polishing machine-4	104.98	0.71

4.4.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were 74 kW/t for polishing area.

4.5 Air Compressors

4.5.1 Specifications

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

Table 38: Specifications of compressors

Particular	UOM	Air compressor 1	Air compressor 2
Power rating	HP	50	50
Maximum pressure	Bar (a)	7	7
Air handling capacity	m^3/min	6.63	6.63

- Receiver

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all compressor

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

Table 39: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF
Compressor-1	22.8	0.98
Compressor-2	27.4	0.99

4.5.3 Observation and performance assessment

Free air delivery(FAD) of compressors could not be conducted as there was only one receiver for whole plant, the specific energy consumption of the compressors cannot be evaluated. No ECM has been proposed as both the compressors were operated with VFD.

4.6 Water Pumping System

4.6.1 Specifications

Pumping system comprises two bore well pumps, two Press Pumps and two Kiln Pumps.

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

- Power consumption of pump
- Flow measurements for same pump

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

Table 40: Operating details of pump

Particulars	UOM	Press Pump-1	Press Pump-2	Kiln Pump-1	Kiln Pump-2	Bore-well Pump-1	Bore-well Pump-2
Measured flow	m^3/h	42	72.4	23	38.5	22	27
Total head	m	24	13.8	18.8	23.5	70	70
Actual power consumption	kW	2.7	2.7	1.2	2.5	4.2	5.2

4.6.2 Observation and performance assessment

Based on observations during DEA, the pump efficiency of different pumps was ranging from 38.9 – 52%.

4.6.3 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.6.3.1 ECM #5: Replacement of inefficient pumps

Technology description

Presently, there are energy efficient pumps available having pump efficiency of 65% which leads to reduced energy consumption.

Study and investigation

During Field measurements, bore well pump-1 & 2, Press pump-1 & 2 and Kiln pump-1 & 2 were running at lower efficiency.

Recommended action

Recommendations have been given to replace low efficiency pumps with energy efficient pumps. Additional water meters have also been recommended. Measured parameters and the derived efficiency of the pumps are mentioned hereunder.

Table 41:Saving and cost benefit analysis by replacing inefficient pumps [ECM-5]

Design	UOM	Press Pump-1		Press Pump-2		Kiln Pump-1		Kiln Pump-2		Bore Well Pump-1		Bore Well Pump-2	
Particulars		Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
Flow	m^3/h	-		-		-		-		-		-	
Head	m	-		-		-		-		-		-	
Pump I/P Power	kW	7.5		8		5.0		5.0		11.2		11.2	
Pump Efficiency	%		65.00		65.00		65.00		65.00		65.00		65.00
Motor Rated Power	kW	7.5	6.1	7.5	5.1	5.0	2.3	5	4.6	11.2	8.1	11.2	9.7
Motor Efficiency	%	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00	85.00
VFD	Y/N	N		N		N		N		N		N	
VFD Frequency	Hz	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Measured Parameters	**UOM**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**
Flow rate Q	m^3/h	42.0	42.0	72.4	72.4	23.0	23.0	38.5	38.5	22.2	22.2	27.0	27.0
Suction Pressure	kg/cm^2	0.10	0.1	0.02	0.0	0.02	0.0	-0.2	-0.2	0.0	0.0	0.0	0.0
Discharge Pressure	kg/cm^2	2.50	2.5	1.4	1.4	1.9	1.9	2.2	2.2	7.0	7.0	7.0	7.0
Motor Input Power	kW	8.2	5.0	6.3	4.9	3.37	2.1	5.44	4.5	12.80	7.7	12.70	9.3
Calculation	UOM	Value		Value		Value		Value		Value		Value	
Flow rate Q	m^3/s	0.011	0.011	0.020	0.020	0.006	0.006	0.010	0.010	0.006	0.006	0.007	0.007
Total Head/head developed	m	24.0	24.0	13.8	13.8	18.8	18.8	23.5	23.5	70.0	70.0	70.0	70.0
Liquid Horse Power	kW	2.7	2.7	2.7	2.7	1.2	1.2	2.5	2.5	4.2	4.2	5.2	5.2
Motor Shaft Power	kW	7.0	4.2	5.3	4.2	2.9	1.8	4.6	3.8	10.9	6.5	10.8	7.9
Motor Loading	%	92.9	70	71.3	82%	57.3	78%	92.5	83%	97.1	81%	96.4	82%
Overall system efficiency	%	33	55	43	55	35	55	45	55	33	55	41	55
Pump Efficiency	%	39.4	65.0	50.9	65.0	41.1	65.0	53.3	65.0	38.9	65.0	47.7	65.0
Operating hour per day	h/d		24		24		24		24		24		24
Annual operating	d/y		330		330		330		330		330		330

Design Particulars	UOM	Press Pump-1		Press Pump-2		Kiln Pump-1		Kiln Pump-2		Bore Well Pump-1		Bore Well Pump-2	
		Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed	Present	Proposed
days													
Annual power savings	kWh/y		25,569		10,789		9,800		7,735		40,673		26,756
Electricity tariff	Rs/kWh		8.01		8.01		8.01		8.01		8.01		8.01
Monetary savings	Lakh Rs /y		2.0		0.9		0.8		0.6		3.3		2.1
Estimated investment	Lakh Rs		0.6		0.6		0.3		0.5		0.9		1.1
Simple payback period	Months		3		3		3		3		3		3.5
Total Monetary savings	Lakh Rs /y		2.9										
Total Estimated investment	Lakh Rs		4.03										
Simple payback period	Months		17										
Project IRR	%		52										
Discounted payback period	Months		6.18										

4.7 Lighting System

4.7.1 Specifications

The plant lighting system includes:

Table 42: Specifications of lighting load

Particular	UOM	Fluorescent tube light	Metal Halide
Power consumption of each fixture	W	48	150
Numbers of fixtures	#	415	10

4.7.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 43: Lux measurement at site

Particular	UOM	Value
Office	Lumen/m^2	155
Kiln control room	Lumen/m^2	106
Kiln area	Lumen/m^2	55
Press area	Lumen/m^2	67
Ball mill and agitators	Lumen/m^2	73
HAG and spray dryer	Lumen/m^2	77
Five layer dryer	Lumen/m^2	61

4.7.3 Observations and performance assessment

Adequate day lighting is used wherever possible. There is scope to replace existing luminaries with more energy efficient types.

4.7.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.7.4.1 ECM #6: Replacement of inefficient lighting systems

Technology description

Replacing conventional lights like Fluorescent Tube lights and Metal Halide 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 415 Fluorescent tube lights and 10 Metal halide lamps.

Recommended action

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

Table 44: Saving and cost benefit analysis by replacing inefficient lighting systems[ECM-6]

Particulars	UOM	Present	Proposed	Present	Proposed
Type of fixture		FTL T8	LED T8	MH Lights	Flood LED
Type of choke if applicable		Magnetic	Driver	NA	Driver
Number of fixtures	#	415	415	10	10
Rated power of fixture	W/Unit	36	20	150	60
Consumption of choke	W	12	0	0	0
Operating power	W/fixture	48	20	150	60
Operating hours per day	h/d	15	15	15	15
Operating day per year	d/y	330	330	330	330
Annual energy consumption	kWh/y	98,604	41,085	7,425	2,970
Annual energy saving	kWh/y		57,519		4,455
Unit cost of electricity	Rs/kWh		8.01		8.01
Annual monetary savings	Lakh Rs/y		4.61		0.36
Estimated Investment	Lakh Rs		2.38		0.20
Simple Payback Period	Months		6		7
Project IRR	%			145	
Discounted payback period	Months			2.45	

4.8 Electrical Distribution System

4.8.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (415) by step down transformer (3500kVA). There were two DGs (capacity of 1.05 MVA) 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

4.8.3 Observations and performance assessment

After analyzing feeder's power profiling, it is observed that the maximum kVA recorded during study period was **745 kVA**.

The voltage profile of the unit is satisfactory and average voltage measured was **434 V.** Maximum voltage was **444 V** and minimum was **422 V**.

Average total voltage and current Harmonics distortion found **5%&15%** respectively during power profile recording.

There is only one electricity meter in the plant at the main incomer, sub meters are installed at each outgoing feeder at LT panel however there is no monitoring or record of electricity consumption from these feeders.

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 #7: Main LT Voltage Optimization

Technology description

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

Study and investigation

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

Recommended action

A 3 MVA servo stabilizer is suggested to install on main LT panel to optimize voltage. Servo stabilizer rating is suggested according to Electricity monthly billing demand. The cost benefit analysis for this project is given below:

Table 45: Saving and cost benefit analysis by Main LT Optimization [ECM-7]

Particulars	UOM	Present	Proposed
Maximum load (Measured)	kW	731	731
	kVA	745	745
Maximum demand as per electricity bill	kVA	2,425	2,425
Maximum voltage	V	446	415
Average voltage	V	436	410
Reduction in Voltage	%		5.9%
% reduction in energy consumption	%		11.46%
Average power factor of system	PF	0.98	0.98
Annual electricity consumption	kWh/y	10,944,390	8,995,457
Efficiency of servo stabilizer	%		95%
Net saving from voltage regulation	kWh/y		1,851,486
Unit cost of electricity	Rs/kWh		8.01
Annual monetary saving	Lakh Rs/y		148.2
Sizing of servo stabilizer	kVA		798
Rating of servo stabilizer	kVA		3,000
Estimated investment	Lakh Rs		98.99
Simple Payback period	Months		8

Particulars	UOM	Present	Proposed
Project IRR	%		115
Discounted payback period	Months		3.10

4.8.4.2 ECM #8: Install harmonics Filter

Technology description

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

Some of the effects of harmonics are mentioned hereunder.

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

Study and investigation

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 6.7kW.

Table 46: Measured Harmonics Level at Main Incomer

Name & Sl. No.	Phase		Voltage	Amp.	THD V (%)	THD I (%)	Individual Current Harmonics				
							A3%	A5%	A7%	A9%	A11%
Main Incomer	R	Average	434	851	4.66	14.6	1.41	12.5	5.03	0.46	2.24
		Maximum	444	972	7.80	32.6	2.50	31.6	9.10	1.20	5.30
		Minimum	422	600	2.70	5.7	0.20	0.4	1.00	0.00	0.40
	Y	Average	437	853	4.53	14.7	1.77	12.3	5.43	0.21	2.24
		Maximum	447	972	7.50	30.7	4.50	29.8	9.80	0.70	5.00
		Minimum	422	632	2.50	6.8	0.60	0.7	1.20	0.00	0.40
	B	Average	436	878	4.4	14.6	1.76	12.6	4.92	2.27	2.27
		Maximum	447	1007	7.3	31.3	3.10	30.4	9.30	4.70	4.70
		Minimum	420	625	2.5	6.5	0.60	1.2	0.80	0.30	0.30

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

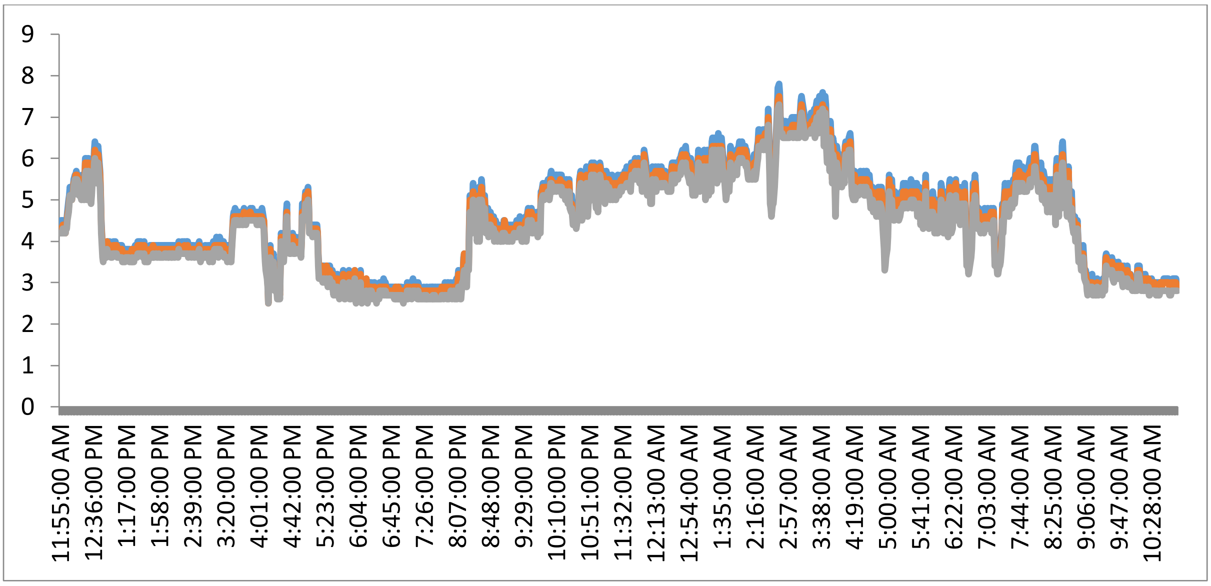

Figure 19: Voltage THD profile

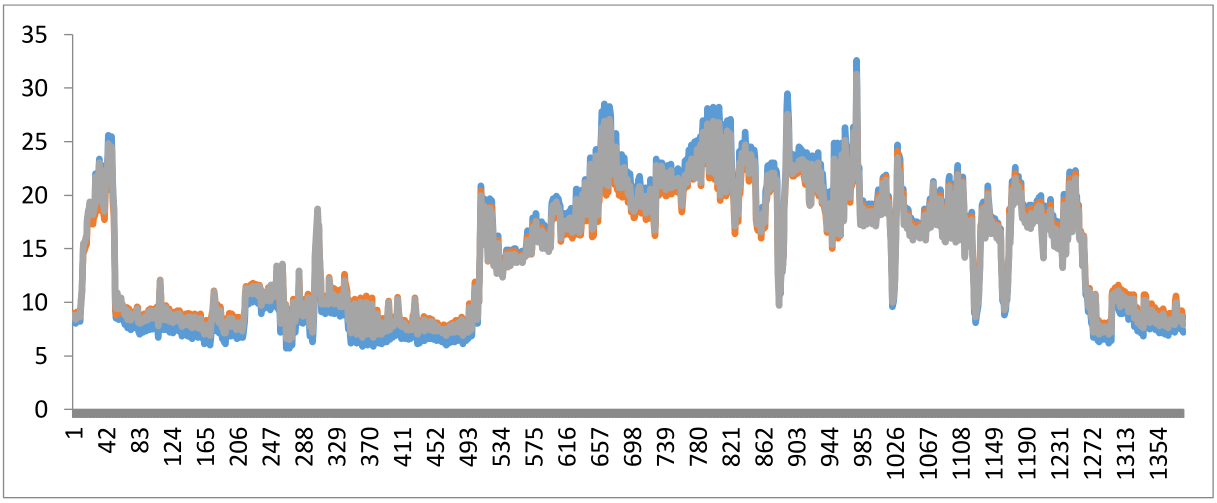

Figure 20: Ampere THD profile

Recommended action

It is recommended to install active harmonics filters (AHF) at main incomer; further study can be conducted to find out exact source of harmonics generation. **Ampere ratings of harmonics filters to be installed are 90A**. Estimation of ratings for AHF is done on the basis of power cycles captured during field visit.

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

- All electronic ballasts to be procured in future shall be specified for less than 10% THD (Current).

The cost benefit analysis for this project is given below:

Table 47:Saving and cost benefit analysis byinstalling harmonic filter [ECM-8]

Particulars	UOM	Present	Proposed
Estimated losses due to Harmonics	kW	6.36	0
Saving potential by installation of harmonic filter	kW	6.4	
Operating days per year	d/y	330	
Operating hours per day	h/d	24	
Saving potential	kWh/y	50,341	
Unit Cost	Rs/kWh	8.01	
Saving Potential	Lakh Rs/y	4.0	
Estimated rating of active harmonics filter	Ampere	90	
Estimated cost of active harmonics filter	Lakh Rs	7	
Simple Payback Period	Months	21	
Project IRR	%	35	
Discounted payback period	Months	8	

4.8.4.3 ECM #9: 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 hot air generator and kiln like on-line flow-meters.

Recommended action

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. 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
- Dryer
- HAG

The cost benefit analysis for this project is given below:

Table 48: Saving and cost benefit analysis by energy management system[ECM-9]

Particulars	UOM	Present	Proposed
Energy management saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	10,944,390	10,725,502
Annual electricity saving per year	kWh/y	0	218,888
Average Electricity Tariff	Rs/kWh	8.01	8.01
Annual monetary savings	Lakh Rs/y	0	17.53
Number of Electrical equipments	#	60	60
Number of energy meters	#	0	60
Estimate of Investment	Lakh Rs		5.98
Thermal energy monitoring system	%	2.00	
Current coal consumption in HAG	kg/y	6,572,850	6,441,393
Annual coal saving per year	kg/y		131,457
Cost of Coal	Rs/kg		6
Annual NG consumption	scm/y	3,759,801	3,684,605
Annual fuel saving	scm/y		75,196
Average NG cost	Rs/scm	31.8	31.81
Total annual monetary savings	Lakh Rs/y		31.21
Number of equipments or system	#	1	1
Number of coal weighing machines			1
Number of NG Meters			3
Estimated investment	Lakh Rs		1.42
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		48.74
Total Estimated investment (Electrical + Thermal)	Lakh Rs		7.40
Simple Payback period	Months		1.82
Project IRR	%		487
Discounted payback period	Months		0.73

4.8.4.4 ECM #10: Cable loss minimization

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted that in sizing section power factor was between 0.59-0.70, whereas in press section the power factor was 0.69-0.87 and keeps on varying as per the operation of the press.

Recommended action

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

The cost benefit analysis for this project is given below:

Table 49: Saving and cost benefit analysis by Cable Loss minimization [ECM-10]

Particulars	UOM	Polishing Machine-4	Polishing Machine-3	Polishing Machine-2	Polishing Machine-1	Nano Machine-1	Calibrating Machine-3	Calibrating Machine-2	Calibrating Machine-1
Existing Power Factor	PF	0.71	0.57	0.68	0.63	0.77	0.69	0.69	0.54
Proposed Power Factor	PF	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Existing load	kW	105.0	75.9	108.8	92.7	133.2	70.7	71.6	50.1
Cable Losses	W	3,379	2,658	3,795	3,191.7	4,412.5	1,562.5	1,560.0	1,229.8
Capacitor Required	kVAr	87	97	97	98	87	62	63	69
Annual Energy Saving	kWh/y	11,788	13,310	14,490	13,829	11,794	5,879	5,738	6,524
Savings Estimated	Lakh Rs/y	0.40	1.07	1.16	1.11	0.94	0.47	0.46	0.52
Total Energy Saving	kWh/y	83,291							
Total Savings	Lakh Rs/y	6.13							
Investment	Lakh Rs	3.05							
Simple Payback Period	Months	6							
Project IRR	%	155							
Discounted payback period	Months	2.33							

4.8.4.5 ECM #11: 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.

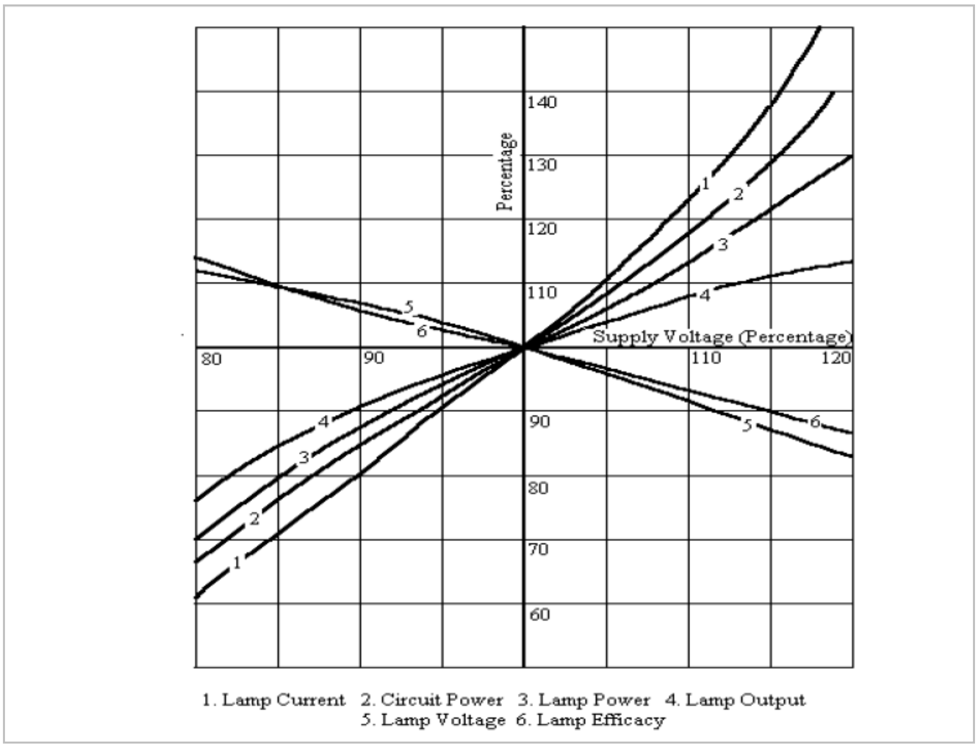

Figure 21: Effect of supply voltage on lamp parameters

Study and investigation

Lighting feeder measurements were carried out to estimate existing lighting load and the voltage level in the lighting circuit. Present Power Consumption in Lighting is 858.8 kWh/d and measured voltage level is 430V.

Recommended action

It is recommended to install separate lighting transformer of 60kVA 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 50: Saving and cost benefit analysis by Voltage Optimization in lighting circuit [ECM-11]

Particulars	UOM	Values
Present Power Consumption in Lighting	kWh/d	858.8
Present Voltage Level in Lighting Circuit	V	430
Proposed Voltage Level in Lighting Circuit	V	380
Saving Potential (%)	%	21.9
Saving Potential	kWh/d	188
Operating days per year	d	330
Saving Potential	kWh/y	62,075
Cost of Electricity	Rs/kWh	8.01
Estimated Savings	Lakh Rs/y	4.97
Lighting voltage transformer rating	kVA	60
Estimated Investment	Lakh Rs	1.98
Simple Payback Period	months	5
Project IRR	%	189
Discounted payback period	Months	1.89

4.9 Belt Operated Drives

4.9.1 Specifications

There are 30 Belt drives operated with total capacity of 270 kW.

- Five Layer dryer (30)

4.9.2 Field measurement and analysis

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

4.9.3 Observations and performance assessment

Maximum belts in plant are V-belt which are not energy efficient

4.9.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.9.4.1 ECM #12: Conversion of belt drive with direct drive

Technology description

Convert belt drive with direct drive.

Benefits of Direct drive over belt drive:

- Higher power transmission due to absence of slip.
- Less space is required.
- Less maintenance costs.

Study and investigation

The unit is having about 30 belt drives in plant.

Recommended action

It is recommended to replace the existing belt drive to direct drive for energy savings. Cost benefit is given below:

Table 51: Saving and cost benefit analysis of conversion of belt drive to direct drive [ECM-12]

Particular	UOM	Present	Proposed
Rated power of motor/blower	kW	270	270
Existing power consumption	kW	72.19	69
Assumed: Energy loss in transmission	%	6	1.5
Power loss in transmission	kW	4	1.1
Operating hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	571,745	546,016
Annual energy savings	kWh/y		25,729
Unit cost of electricity	Rs/kWh		8.01
Annual monetary savings	Rs Lakh/y		2.06
Estimated Investment	Rs Lakh		4.75
Simple Payback Period	Months		28
Project IRR	%		22
Discounted payback period	Months		10.21

5. Chapter-5 Energy consumption monitoring

5.1 Energy Consumption Monitoring

In order to monitor the overall energy performance, the installation of a basic energy monitoring system has been proposed for the unit (ECM #9).

5.2 Best Operating Practices

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

Table 52: Unique operating practices in the unit

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

5.3 New/Emerging Technologies

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

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

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

Table 53 : 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.

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

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

The working principle is as follows:

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

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

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

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

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

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

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

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

Figure 22: Heat recovery system for combustion air

The estimated benefits of double heat recovery include[4]:

- Fuel savings upto 10%
- Combustion air temperature up to 250 °C at burner
- Easy installation

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

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

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

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[4] SACMI Kiln Revamping catalogue for roller kilns

[5] SACMI Kiln Revamping catalogue for roller kilns

b. Real-time gas consumption monitoring on operator panel
c. Instantaneous pressure and temperature readings
d. Easy calibration

Figure 23: 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.

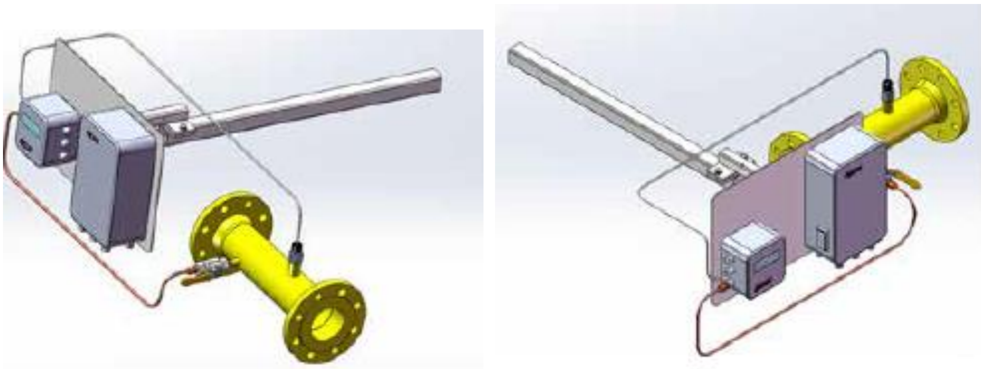

Figure 24: Combustion air control for burner

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

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

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

Figure 25: 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

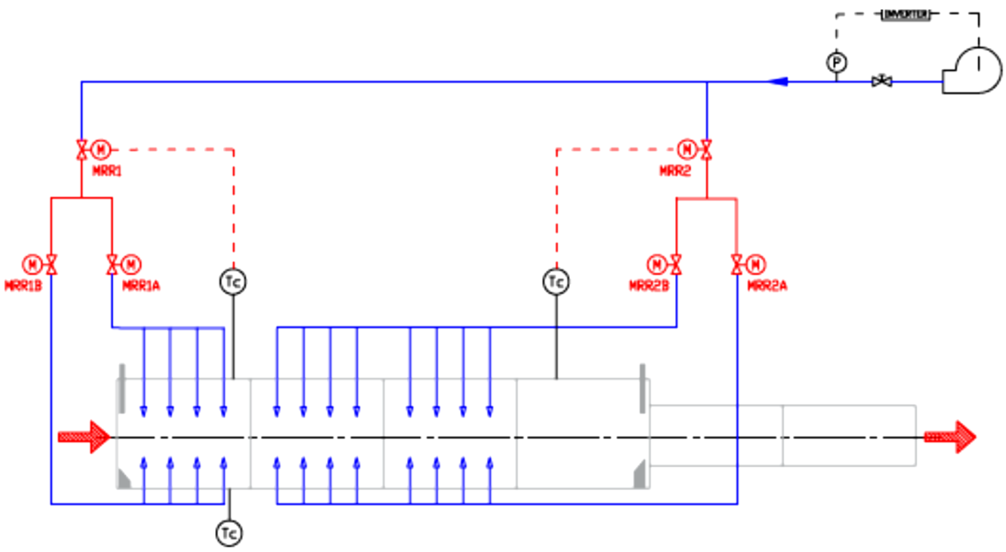

Figure 26: Fast cooling air management

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 27: 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 28: - High Alumina pebbles for Ball mill

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

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

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

In the tile manufacturing process different raw materials which include one or more clays are mixed in specific Ratio (Clay Body). Clay body is subjected to wet grinding in a ball mill to get required density and viscosity. For efficient grinding, inorganic dispersants like STPP, SHMP or sodium silicate are used. These can be replaced either partially or fully by organic deflocculant (Brand name FLOSPERSE[6]) to save fuel cost during spray drying. Slip is stored in tanks which will be sieved for sending to spray drying.

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

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

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

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

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

5.3.6 Use of Organic Binder in Porcelain/Granite Tiles Manufacture

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

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

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

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

Advantages of using Binder for Vitrified tiles include:

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

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

5.3.7 Use of Direct blower fans instead of belt drive

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

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

Figure 29: Direct drive blower fan

6. Chapter-6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA.

The total space available is 600 $m^2$and corresponding solar power potential is 60kW.

Therefore Solar PV installation is recommended and details is given in the below table.

Table 54: Saving and cost benefit analysis for solar PV installation

Parameters	UOM	Present	Proposed
Available area on roof	m^2	600	600
Capacity of solar panel	kW		60
Energy generation from solar panel	kWh/d		288
Solar radiation day per year	d/y		365
Average electricity generation per year	kWh/y		105,120
Cost of Electricity	Rs/kWh		6.88
Annual monetary savings	Lakh Rs/y		7.23
Estimated Investment	Lakh Rs		31.20
Payback Period	Months		51.79
Project IRR	%		-1
Discounted payback period	Months		18.10

7. ANNEXES

7.1 ANNEX-1: PROCESS FLOW DIAGRAM

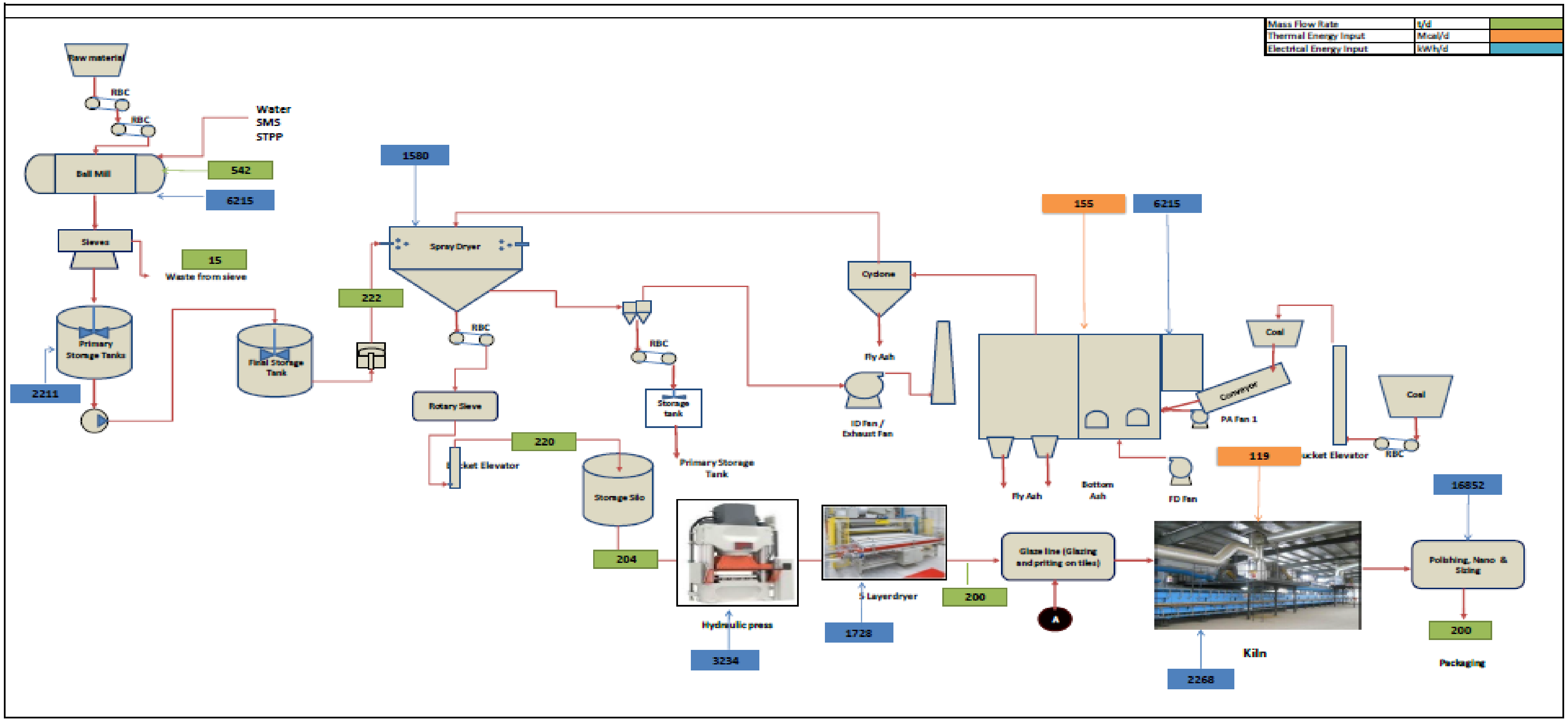

Figure 30: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 55: Detailed Inventory list

Equipment Name	Electrical Load (kW)
Ball Mill	1,011
Clay Section	170
Agitator	92
Spray Dryer	255
Hot Air Generator	51
Press	379
Cooling tower	25
Pre Kiln	102
Kiln	605
Polishing Area	1,965
Lighting	26
Compressor	74
Five Layer Dryer	270
Total Connected Load	**5,024**

7.3 ANNEX-3: SINGLE LINE DIAGRAM

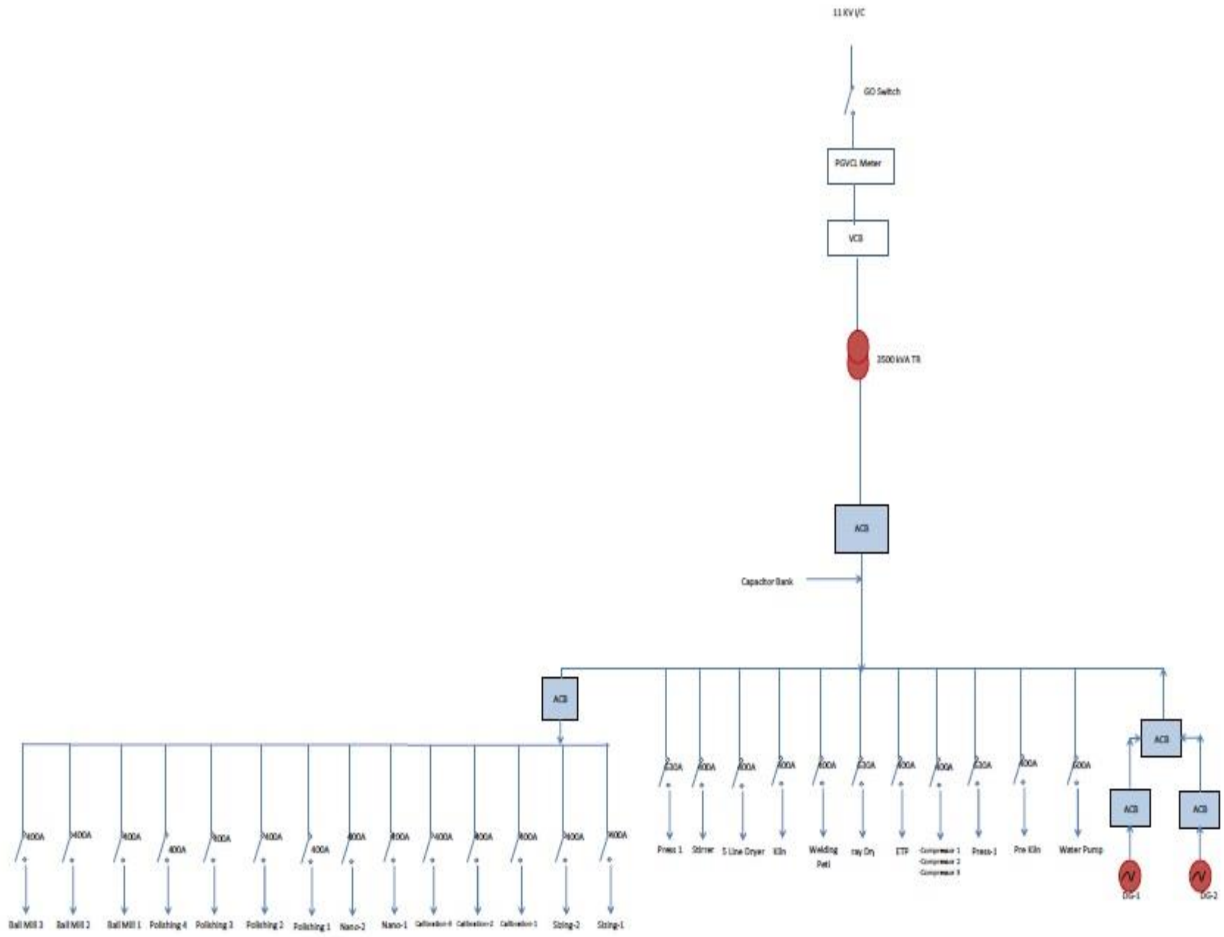

Figure 31: Single Line Diagram (SLD)

7.4 ANNEX-4: ELECTRICAL MEASUREMENTS

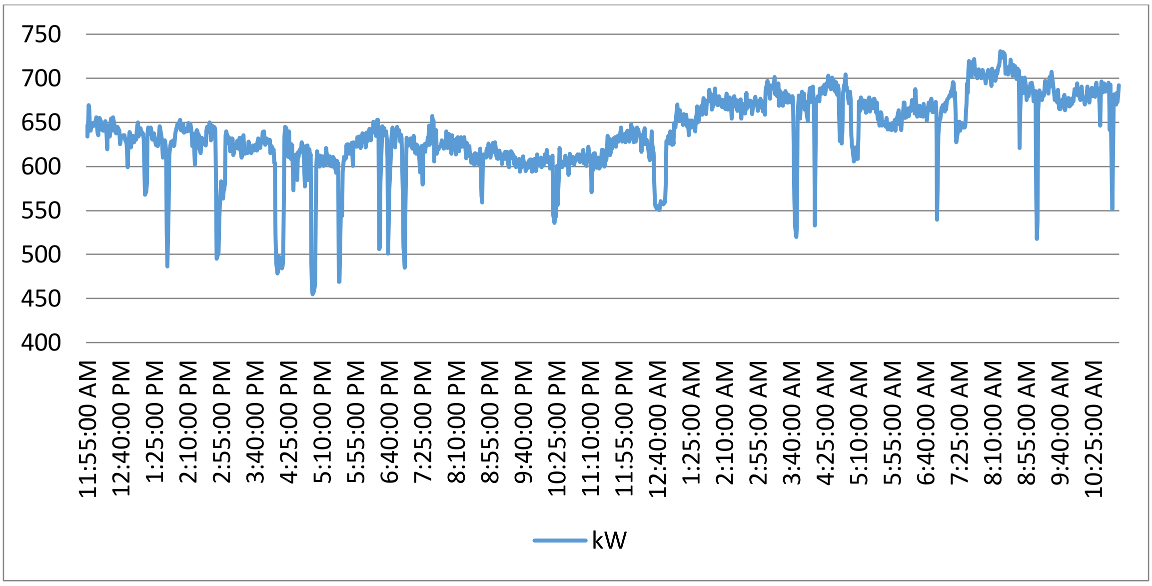

Figure 32: Power profile (kW) of Main Incomer

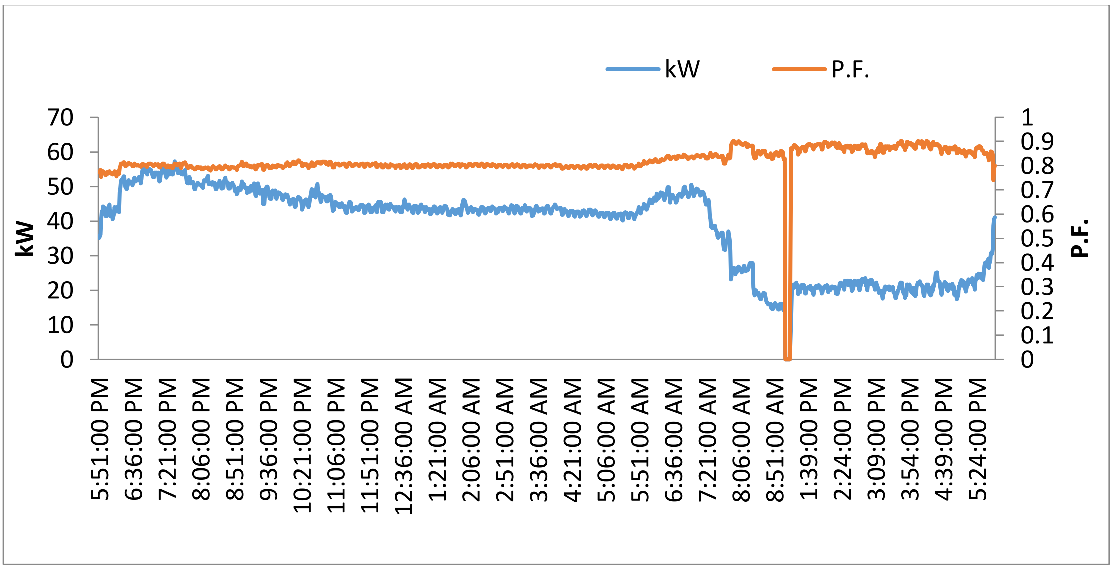

Figure 33: Power and PF profile of Light feeder

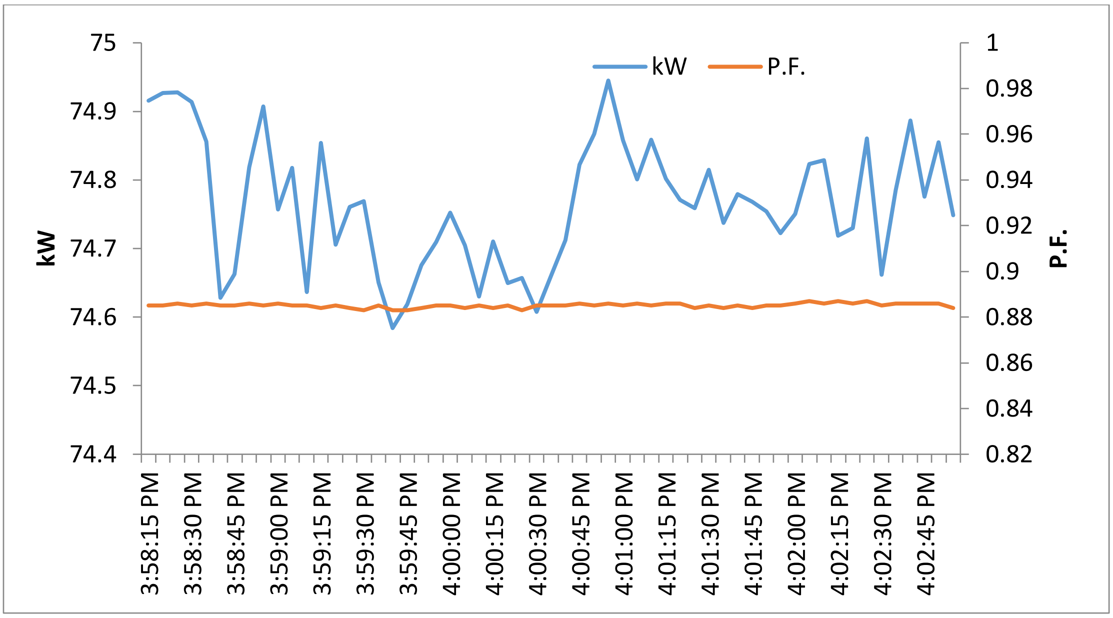

Figure 34: Power and PF profile of Five layer Dryer

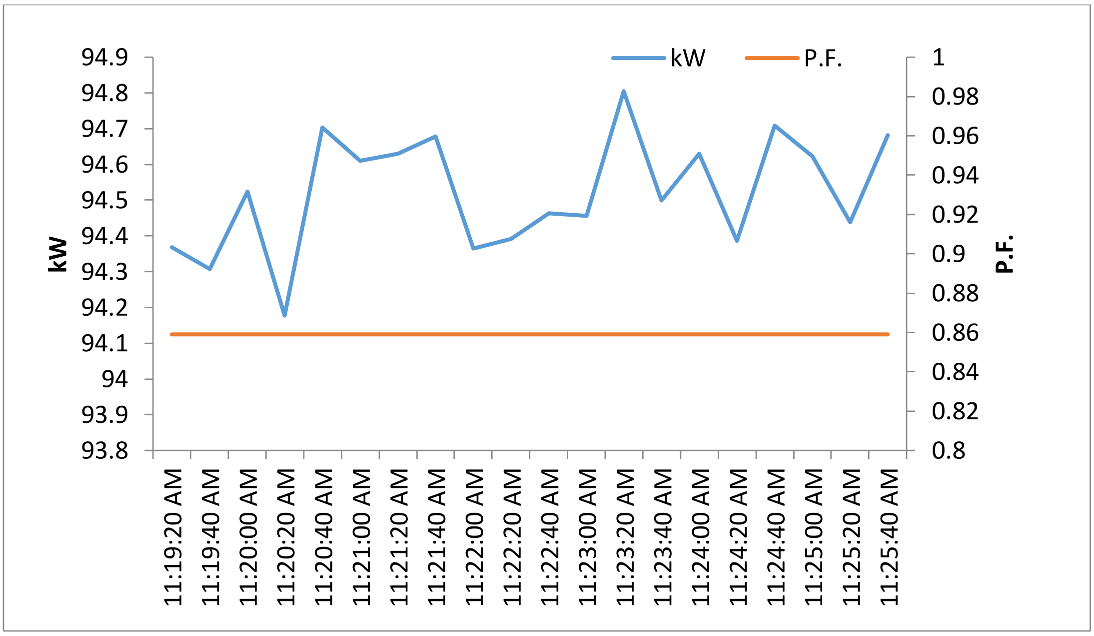

Figure 35: Power and PF profile of Kiln

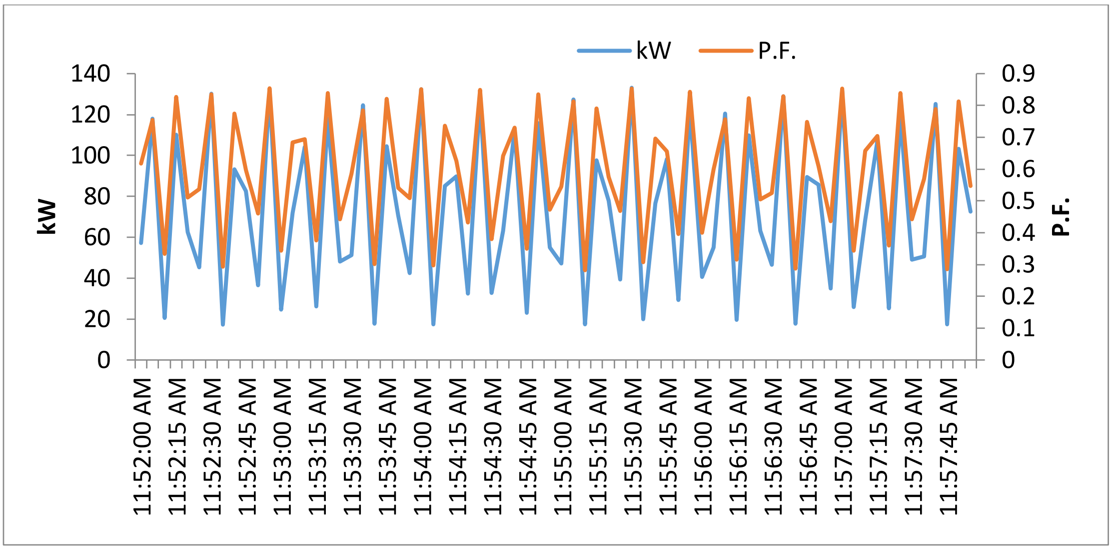

Figure 36: Power and PF profile of Press – 1

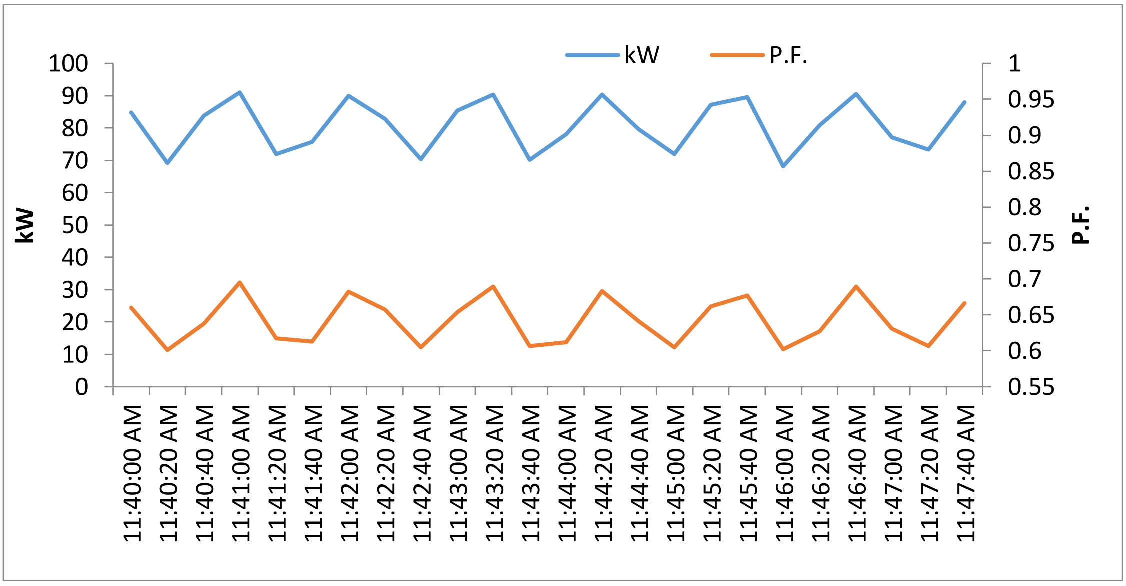

Figure 37: Power and PF profile of Press – 2

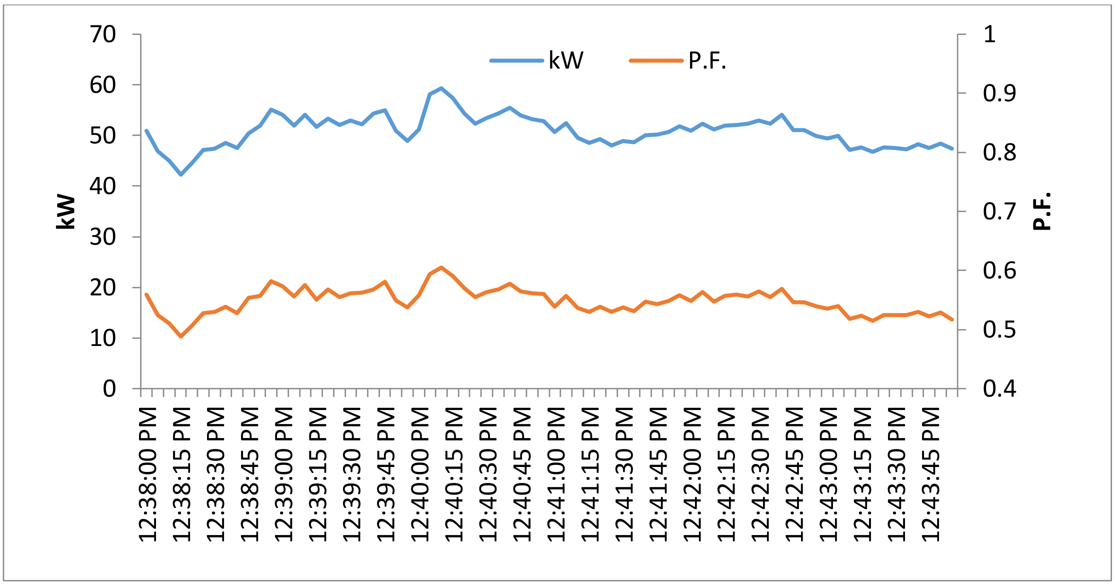

Figure 38: Power and PF profile of calibrating machine – 1

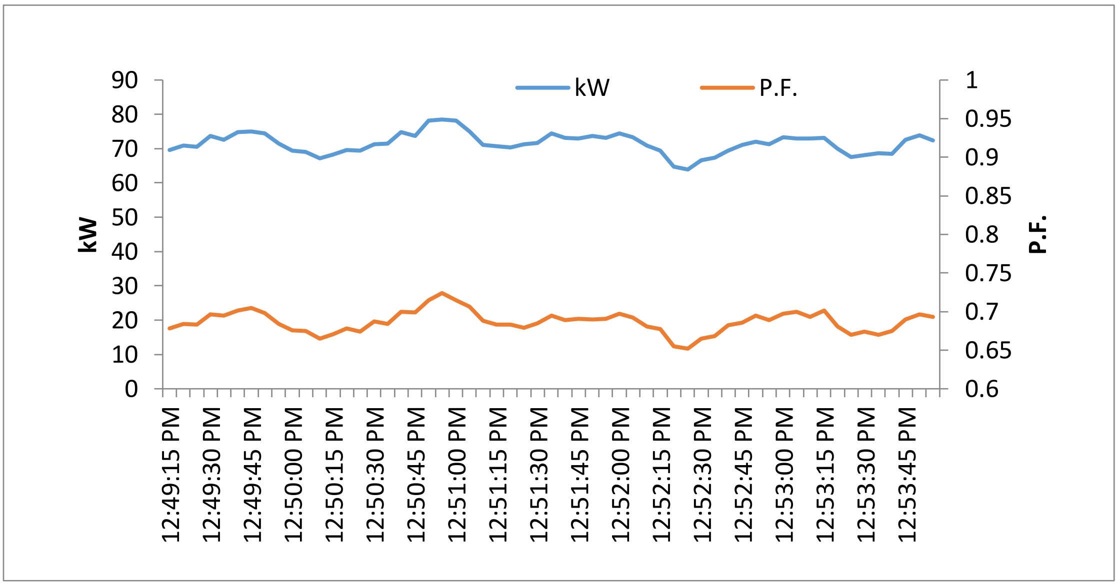

Figure 39: Power and PF profile of calibrating machine – 2

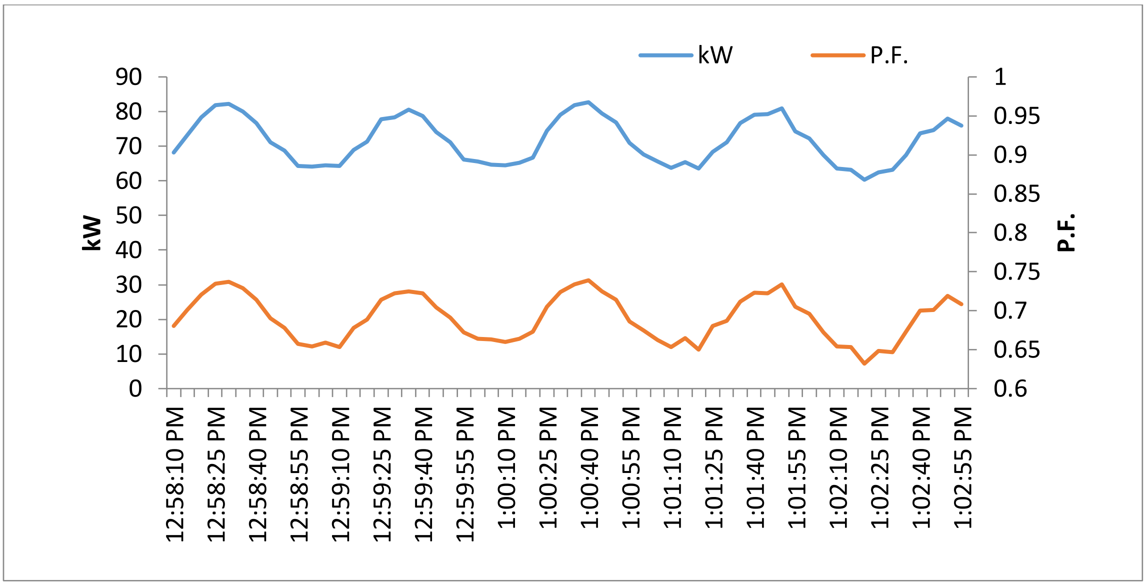

Figure 40: Power and PF profile of calibrating machine – 3

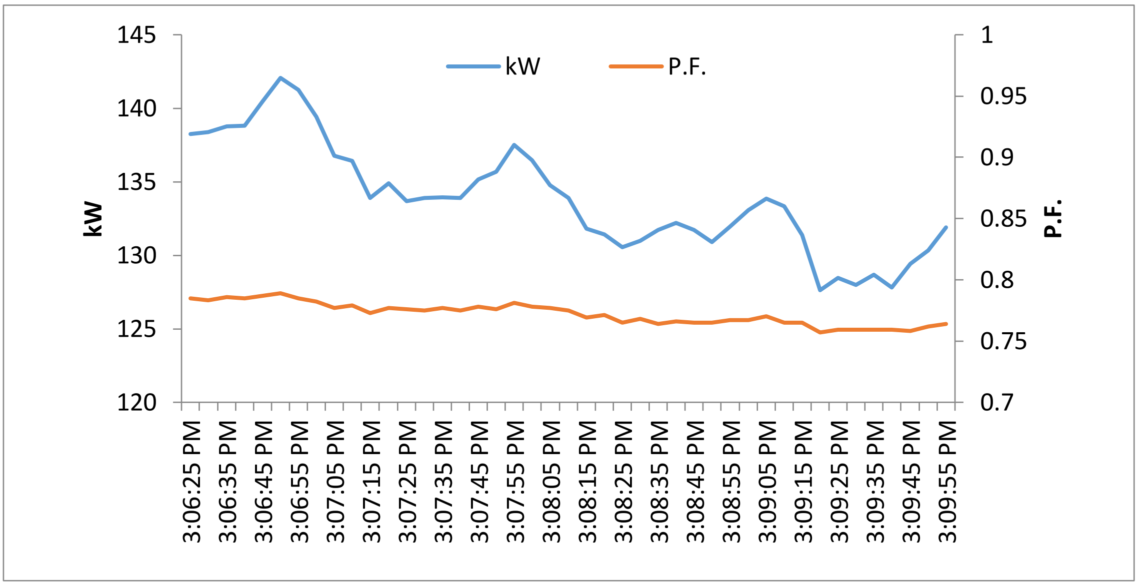

Figure 41: Power and PF profile of Nano machine – 1

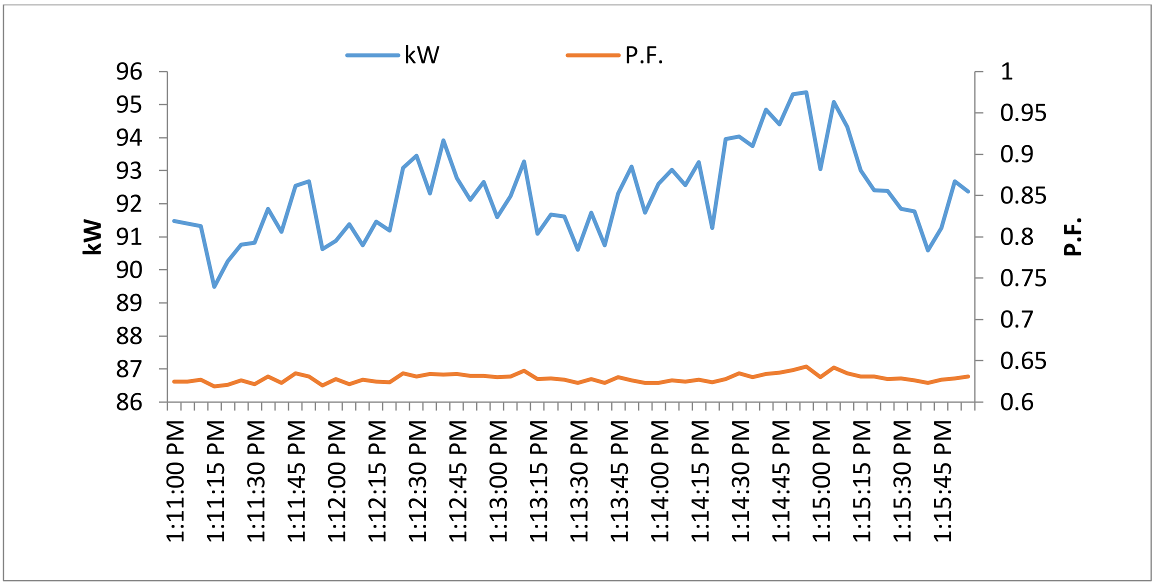

Figure 42: Power and PF profile of Polishing machine – 1

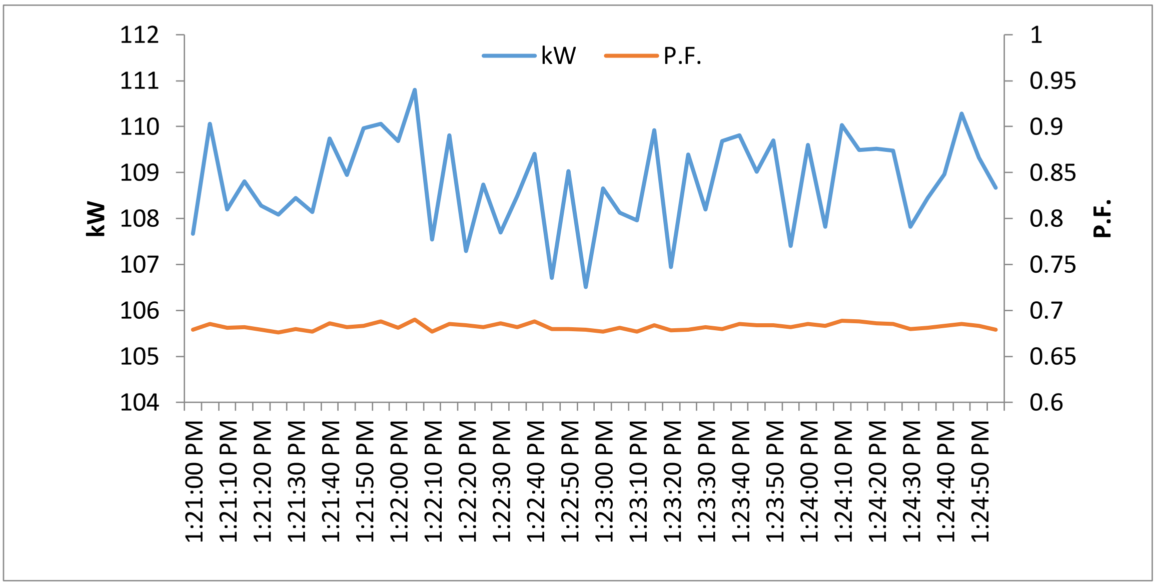

Figure 43: Power and PF profile of Polishing machine – 2

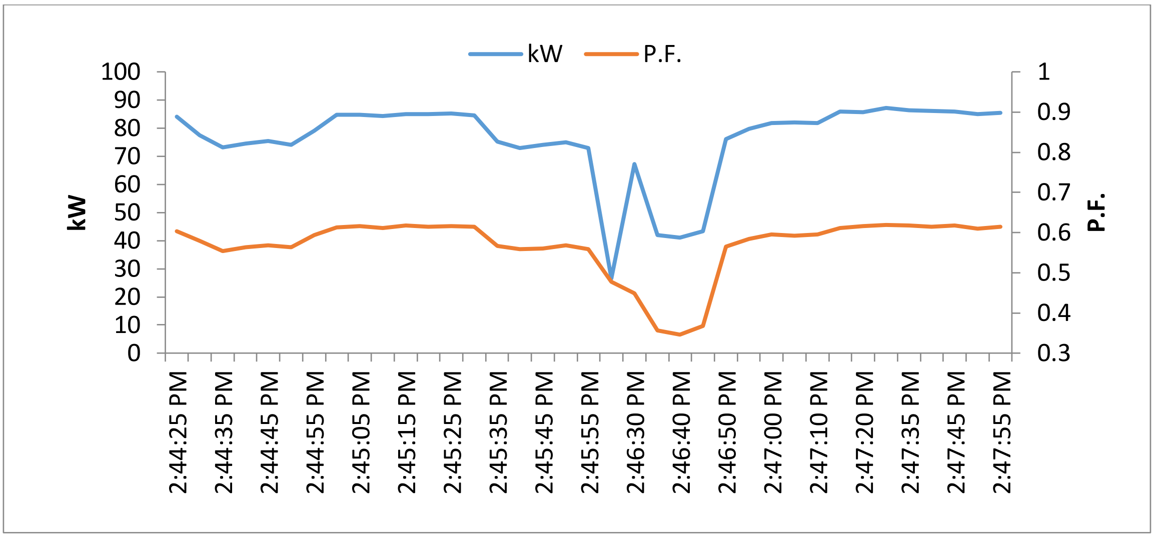

Figure 44: Power and PF profile of Polishing machine – 3

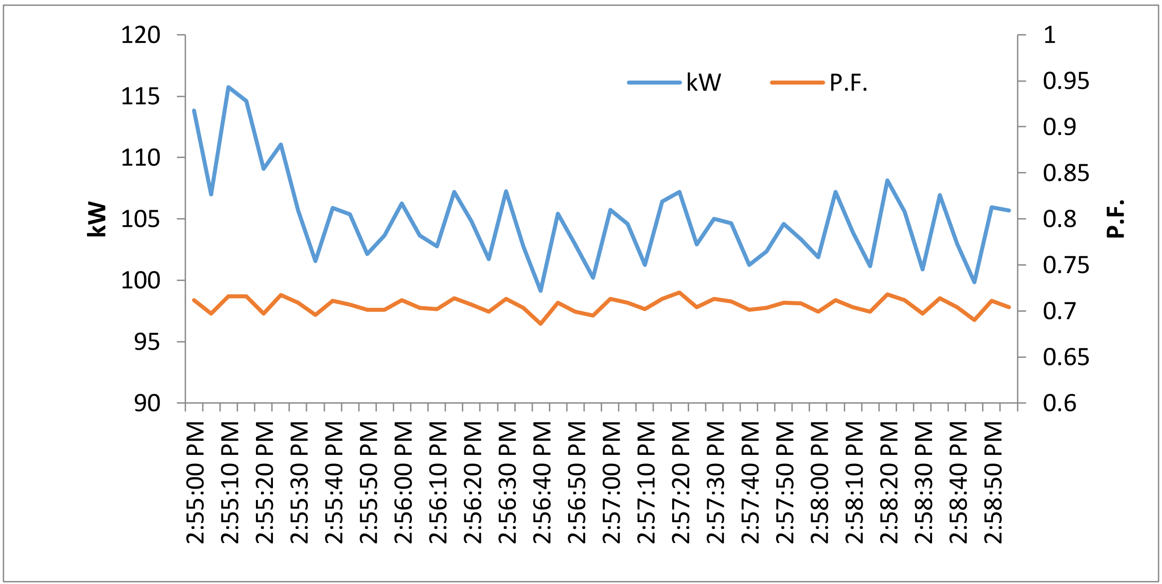

Figure 45: Power and PF profile of Polishing Machine - 4

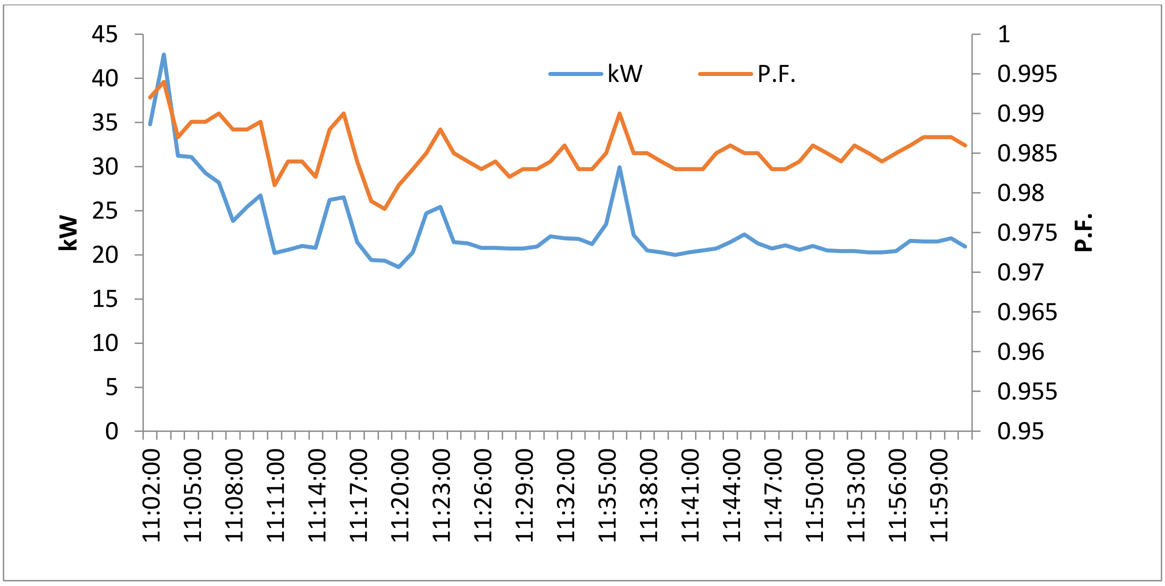

Figure 46: Power and PF profile of Compressor – 1

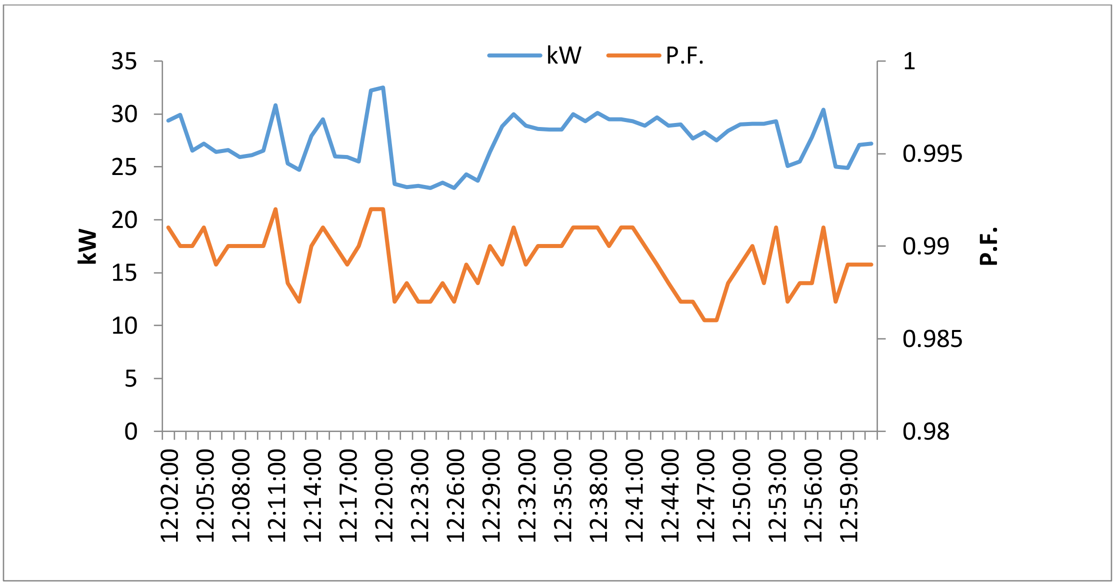

Figure 47: Power and PF profile of Compressor – 2

7.5 Annex-5: Thermal Measurements

1. *Kiln efficiency calculations*

Input parameters

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujarat gas	
Particulars	**Value**	**UOM**
Kiln Operating temperature (Heating Zone)	1,145	*°C*
Initial temperature of kiln tiles	65	*°C*
Average fuel Consumption	460.9	*scm/h*
Flue gas temp at smog blower	110	*°C*
O2 in flue gas	1.20	*%*
CO2 in flue gas	7.7	*%*
CO in flue gas	7.8	*ppm*
Ambient Temp.	38	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
C	*73.80*	%
H	*24.90*	%
N	*1.30*	%
O	*0.00*	%
S	*0.00*	%
Moisture	*0.00*	%
Ash	*0.00*	%
GCV of fuel	9000	*kCal/scm*
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
Weight of Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	8,313	*kg/h*
Weight of Stock	8,313	*kg/h*
Specific heat of clay material	0.22	*kCal/kg °C*
Avg. specific heat of fuel		*kCal/kg °C*
fuel temp	38	*°C*
Specific heat of flue gas	0.24	*kCal/kg °C*

Input Data Sheet		
Specific heat of superheated vapour	0.45	*kCal/kg°C*
Radiation and convection from preheating zone surface	16,108	*kCal/h*
Radiation and convection from heating zone surface	12,464	*kCal/h*
Heat loss from all zones	**28,572**	*kCal/h*
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	1.33	*h*
Area of entry opening	1.2	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*K*

Efficiency calculations

Calculations	Kiln	UOM
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	6.06	*%*
Actual Mass of Supplied Air	18.27	*kg/kg of fuel*
Mass of dry flue gas	17.03	*kg/kg of fuel*
Amount of Wet flue gas	19.27	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*Kg of H_2O/kg of fuel*
Amount of dry flue gas	17.03	*kg/kg of fuel*
Specific Fuel consumption	36.04	*scm of fuel/ton of tile*
Combustion heat of fuel	324,339	*kCal/ton of tiles*
Total heat input	324,339	*kCal/ton of tile*
Heat carried away by 1 ton of tile	237,600	*kCal/ton of tile*
Heat loss in dry flue gas	10,604	*kCal/ton of tile*
Loss due to H_2 in fuel	494	*kCal/ton of tile*
Loss due to moisture in combustion air	591.95	*kCal/ton of tile*
Loss due to partial conversion of C to CO	15.15	*kCal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	29.50	*kCal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	-	*kCal/ton of tile*
Total heat loss from kiln (surface) body	28,572	*kCal/ton of tile*
Heat loss due to un-burnt in Fly ash	-	*kCal/ton of tile*
Heat loss due to un-burnt in bottom ash	-	*kCal/ton of tile*
Heat loss due to kiln car	-	*kCal/ton of tile*
Unaccounted heat losses	46,431	*kCal/ton of tile*
Total heat loss from kiln	28,572	*kCal/t*
Kiln Efficiency	73.26	*%*

2. Heat Balance Diagram

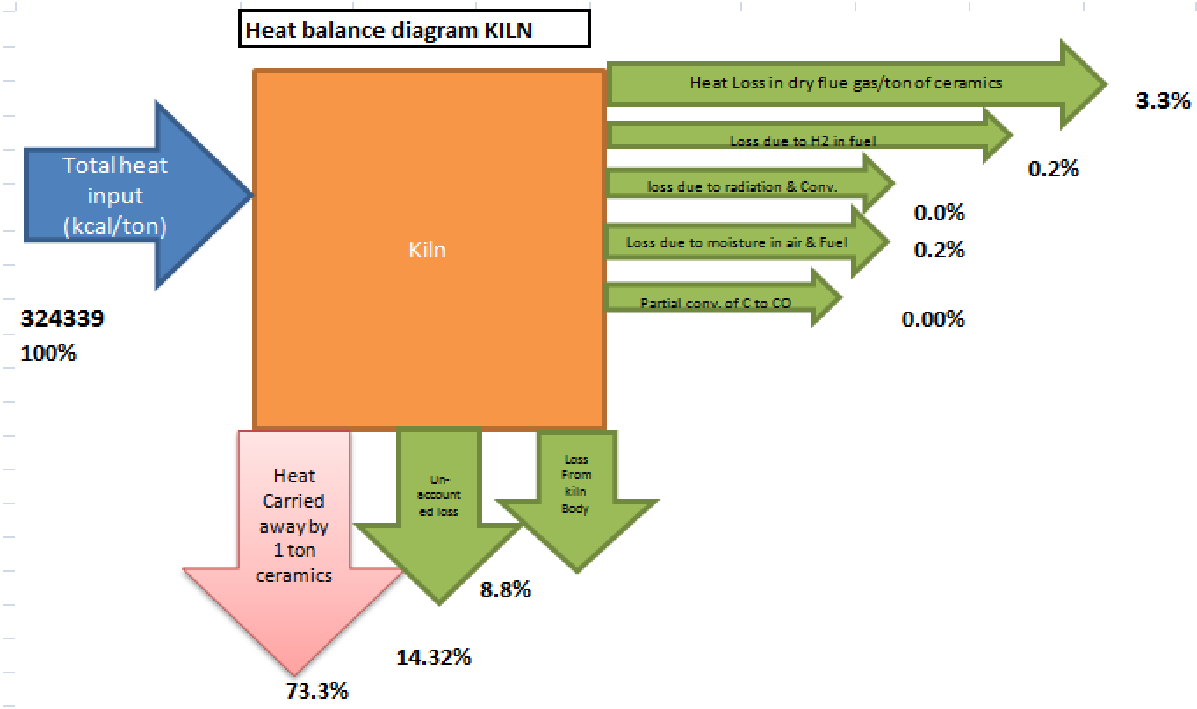

Figure 48: - Direct drive blower fan

7.6 ANNEX-6: LIST OF VENDORS

ECM-1: Insulation of HAG duct

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001	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-2: 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. Ltd.	Shree Khodiyar Park, behind Ruda Transportnagar,Rajkot-Amdavad Highway, Rajkot-363670	Mr. Bhavesh Dabhi 9512301122	www.aquatechro.com bhavesh@aquatechro.com
3	Raj Water Technology (Gujarat) Pvt Ltd	Plot-27, Survey-47, Jivraj Industrial Area Near Falcon Pump, Gondal Rd, Vavdi, Rajkot, Gujarat 360004	70439 55777	marketing@rajwater.com www.rajwater.com

ECM-3: Temperature Controller in press CT fan

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Cogent Controls	205, Vinay Industrial Estate, Chincholi Bunder Link Road, Malad – West, Mumbai - 400064	Tel: 022-28750421 Mob: 9820032946	COGENT CONTROLS [enquiry@cogentcontrols.com]
2	SHIWKON controls	33-34-35, First Floor,	93750 50704	morbi@shiwkon.com

Sl.No.	Name of Company	Address	Phone No.	E-mail
		Shakti Chamber - 1, N. H. 8A, Opposite Adarsh Hotel, Morbi-363642		
3	Happy Instruments	20, Prafullit Society, Near Navo Vas Rakhial Gam Ahmedabad- 380021,	8048707581	https://www.happyinstrument.co.in/

ECM-4: Timer controller for stirrer motor

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Swastik Automation & Control	D-60, Vivekanand Estate, Vivekanand Mill Compound, Near Rakhial Cross Road, Rakhial, Ahmedabad – 380023	Mob: 8048763940	
2	Jagdish Electro Automation	41,Sreenath complex, National Highway 8-A, Trajpar, Morbi-363641	Mr. Paresh Patel 9909458699	www.jagdishautomation.com
3	Shivson Instruments & Sensors	No-27, Shakti Chamber, 1st Floor, 8-A N.H., Morbi- 363642	Mr. Pragnesh Bhai Ramavat	https://www.tradeindia.com/Seller-2748902-Shivson-Instrument-Sensor/

ECM-5: Replacement of inefficient pumps

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

ECM-6: Replacement of inefficient lighting systems

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

ECM-7: Main LT Voltage optimization

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Dynamic Energy Solutions	Plot Number 6, Nangla Industrial Area, Nangla Gazipur Road, Faridabad-121004	9873565940	dynamicenergysolutions@gmail.com
2	Recons Power Equipment Pvt. Ltd	Plot Number 38, Sector-25, Faridabad-121004	0129-4062114-116 9811095526	mail@reconsindia.com
3	SERVOMAX INDUSTRIES LIMITED (Manufacturer)	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033 BRANCH: #166A, 2nd Floor,Pratap Nagar, Mayur Vihar,Phase-I, New Delhi- 110092	+91 9111234567	customercare@servomax.in www.wervomax.in

ECM-8: Install Harmonics filter

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Infinity Enterprise Private Limited	13, Crystal Avenue & Industrial Park, near Odhav Ring road circle, Odhav, Ahmedabad – 382415, Gujarat, India.	Mob: +91 8048412433	info@infinityenterprise.net

Sl. No.	Name of Company	Address	Phone No.	E-mail
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-9: 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-10: Cable loss minimization

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

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
		Palace Hotel Odhav, Ahmedabad-382415, Gujarat, India		

ECM-11: 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	Protek Enterprises	Protek House, Opp Swaminarayan mandir, On I.O.C. road, Chandkela, Ahmedabad-382424, Gujarat, India.	Mob: +91 7965216521	info@protekg.com
3	SERVOKON System ltd.	Servokon House,C-13,Radhu palace road, opp.scope minar,Laxmi Nagar, Delhi-110092	75330088 Toll free:18002001786	http://www.servokonstabilizer.com/contact-us.html

ECM-12: Conversion of belt drive with direct drive

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Reitz India Limited	New Alipore Market Complex, Block - M; Phase - I, Room No. 414 (Fourth Floor), Kolkata - 700 053, India.	Mr. Tarun Roy Mob: +91 94330 32474	tr@reitzindia.com
2	Chicago Blower India Pvt. Ltd.	No.3702, Phase-4, Gidc Industrial Are, Vatva, Behind- New Nirma, Near-Sabar Pump, Ahmedabad, Gujarat, 382445, India	079-25842499	http://www.chicagoblower.in info@chicagoblower.in
3	Hexagon Engineering	1&2, Anupam Ind Estate, Near Zaveri Estate, Kathwada GIDC estate,, Ahmedabad-382430	8042972891	https://www.hexagonblower.in

ECM-13: Solar PV installation

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

7.7 ANNEX-7: FINANCIAL ANALYSIS OF PROJECT

Table 56: 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%