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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE VT-02: AMBANI VITRIFIED PVT. LTD

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

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

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

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

1. Mr. Bhavesh Bhai Ambani, Managing Director

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

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

DESL Team

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ABBREVIATIONS

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

UNITS AND MEASURES

Parameters	Unit of Measurement (UOM)
Calorific value	CV
Degree Centigrade	^{0}C
Horse power	hp
Hour(s)	h
Hours per year	h/y
Indian Rupee	INR/Rs.
Kilo Calorie	kCal
Kilo volt	kV
Kilo volt ampere	kVA

Parameters	Unit of Measurement (UOM)
Kilo watt	kW
Kilo watt hour	kWh
Kilogram	Kg
Litre	L
Meter	m
Meter Square	m^2
Metric Ton	MT
Oil Equivalent	OE
Standard Cubic Meter	scm
Ton	t
Tons of Oil Equivalent	TOE
Ton of CO_2	tCO_2
Ton per Hour	t/h
Ton per Year	t/y
Voltage	V
Watt	W
Year(s)	y

CONVERSION FACTORS

TOE Conversion	Value	Unit	Value	Unit
Electricity	1	kWh	0.000086	TOE/kWh
Coal	1	MT	0.45	TOE/MT
Natural Gas	1	scm	0.00089	TOE/scm
Emissions				
Electricity	1	kWh	0.00082	tCO_2/kWh
Coal	1	MT	2.116	tCO_2/t
Natural Gas	1	scm	0.001923	tCO_2/scm

EXECUTIVE SUMMARY

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

The assignment targets ceramic industries in four (4) major product categories viz. sanitary products, floor tiles, wall tiles and vitrified tiles. Based on walk through audit and questionnaire survey of several ceramic manufacturing industries, 20 units have been shortlisted by BEE and UNIDO in consultation and discussion with the Morbi Ceramic Association (MCA) to conduct detailed energy audits.

Ambani Vitrified Pvt. Ltd has been selected as one of the 20 units for detailed energy audit. Ambani Vitrified Pvt. Ltd. is a 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	Ambani Vitrified Pvt. Ltd.
Year of Establishment	2014
Address	Morbi - Halvad Road, At Unchi Mandal, Morbi, Gujarat - India
Products Manufactured	Vitrified Tiles
Name(s) of the Promoters / Directors	Mr. Bhavesh bhai Ambani

➨ DETAILED ENERGY AUDIT

The study was conducted in three stages:

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

➨ PRODUCTION PROCESS OF THE UNIT

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

- **Clay ball mill:** Here the raw materials like clay, feldspar and quartz are mixed along with water to form a slip.
- **Agitator:** The slip after mixing in Clay 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:** The hot air is introduced through the top of the drying chamber, and the moisture ceramic slip is sprayed through the nozzle, So ID fans present outside suck the moisture.
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit (green tile).
- **Five Layers Dryer:** In this dryer, green tiles are entered from press which is heated from 35 to 150°C.
- **Glaze ball 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. hydraulic press, Sizing, air cleaning and glazing etc.

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control in kiln: Coal gas is used as fuel in kiln and oxygen content in flue gas was found to be 4.6% against desired level of 3%. It is recommended to install two separate blowers for combustion air and cooling air along with control system to regulate the excess air for proper combustion.
- Insulation improvement: Surface Insulation of cyclone separator and 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 cyclone separator and HAG duct connecting cyclone separator.
- Using soft water in Clay ball mill: TDS of water used in clay section was found to be 1,700ppm against desired level of 400ppm. It is recommended to install water softener plant.
- Retrofit of VFD in Compressor #1: During unload condition; compressor is consuming 30% without doing work. A VFD will take care of variable air demand by changing RPM of compressor and will help to save energy upto 15% of present consumption.

- Compressed air pressure reduction: The generation pressure of compressor #1 is 6.5 kg/cm^2 and the pressure requirement at the end utilities were around 4 kg/cm^2. It is recommended to reduce operating pressure of compressor #1 from 6.5 kg/cm^2 to 4.5 kg/cm^2.
- Replacement of inefficient pumps: Press CT pump-1 & 2 (pump 1 - 53.3% & pump 2 - 52.8%) were running at lower efficiency against desired efficiency of 75%. It is recommended to replace the existing pumps with energy efficient pumps.
- 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.
- Cable loss minimization: In Polishing section, line 3 and line 4 were having poor power factor around 0.71 and 0.80 respectively against desired value of 0.99. It is recommended to install power factor improvement capacitors for polishing section.
- Voltage optimization in lighting circuits: The present voltage for lighting circuit was found to be 438.5V against desired voltage of 380V. It is recommended to install separate lighting transformer of 40kVA rating for lighting circuit.
- V belt to REC belt replacement: The existing V belts are less efficient compared to REC belts and this will reduce the power consumption by 3.6%.
- 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, five layers dryer 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.

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

Table 1: Summary of ECM

Sl. No.	Energy Conservation Measures	Annual Energy Savings Electricity	NG	Coal		Monetary savings	Investment	Payback Period	Emission Reduction
		kWh/y	scm/y	t/y	TOE/y	Lakh Rs/y	Lakh Rs	Months	tCO_2/y
1	Excess air control in kiln	26,643	37,183	0	2	12.81	9.24	9	92
2	Insulation improvement (HAG)			37	22	1.86	4.60	30	79
3	Using soft water in Clay ball mill	54,826		895	542	112.23	39.60	4	1,940
4	Retrofit of VFD in compressor #1	42,343		0	4	2.86	1.72	7	35
5	Compressed Air pressure reduction	18,152		0	2	1.76	0.00	0	15
6	Replacement of inefficient pumps	46,531		0	4	3.3	1.2	4	38
7	Installation of Harmonic filter	47,875			4	3.24	19.80	73	39
8	Cable loss minimization	12,305			1	1.15	0.53	6	10
9	Voltage optimization in lighting circuits	58,128		0	5	3.93	1.32	4	48
10	V belt to REC belt replacement	55,791			5	3.77	4.00	13	46
11	Energy management system	180,437		67	56	36.08	6.40	2	289
Total		**543,031**	**37,183**	**999**	**646**	**183**	**88**	**6**	**2,630**

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

- Reduction in energy cost by 9.7%.
- Reduction in electricity consumption by 6%.
- Reduction in thermal energy consumption by 17.5%.
- Reduction in greenhouse gas emissions by 18.2%.

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 Measures	Investment Lakh Rs	Internal Rate of Return %	Discounted Payback Period Months
1	Excess air control in kiln	9.24	107	3.36
2	Insulation improvement	4.60	20	10.63
3	Using soft water in Clay ball mill	39.60	213	1.68
4	Retrofit of VFD in Compressor #1	1.72	125	2.82
5	Compressed Air pressure reduction	-	-	-
6	Replacement of inefficient pumps	1.19	207	1.73
7	Installation of Harmonic filter	19.8	-10	24.71
8	Cable loss minimization	0.53	167	2.17
9	Voltage optimization for Lights	1.32	223	1.60
10	V belt to REC belt replacement	4	68	4.91
11	Energy Management System	6.4	418	0.85

1. CHAPTER -1 INTRODUCTION

1.1 Background and Project Objective

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

The objective of the project includes:

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

1.2 About the Unit

General details of the unit are given below:

Table 3: Overview of the Unit

Description	Details		
Name of the plant	Ambani Vitrified Pvt. Ltd.		
Plant Address	Morbi - Halvad Road, At Unchi Mandal, Morbi, Gujarat – India		
Constitution	Private limited		
Name of Promoters	Mr. Bhavesh Bhai Ambani		
Contact person	Name	Mr. Bhavesh Bhai Ambani	
	Designation	Managing Director	
	Tel	9879806713	
	Fax		
	Email	account@ambanivitrified.com	
Year of commissioning of plant	2014		
List of products manufactured	Glazed Vitrified tile, 600 x 600 mm (4 tiles/box) Glazed Vitrified tile, 1200 x 1200 mm (2 tiles/box) Glazed Vitrified tile, 300 x 600 mm (5 tiles/box) Nano tile, 600 x 600 (4 tiles/box)		
Installed Plant Capacity	9,000 boxes/day		
Financial information (Lakh Rs)	2015-16		2016-17
Turnover	1,242.28		5,270.98
Net profit	Not provided by Unit		

Description	Details		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	110	
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Area of 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?	Yes		
Interested in DEA	Yes		
	Interested		

1.3 METHODOLOGY AND APPROACH

The study was conducted in 3 stages:

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

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

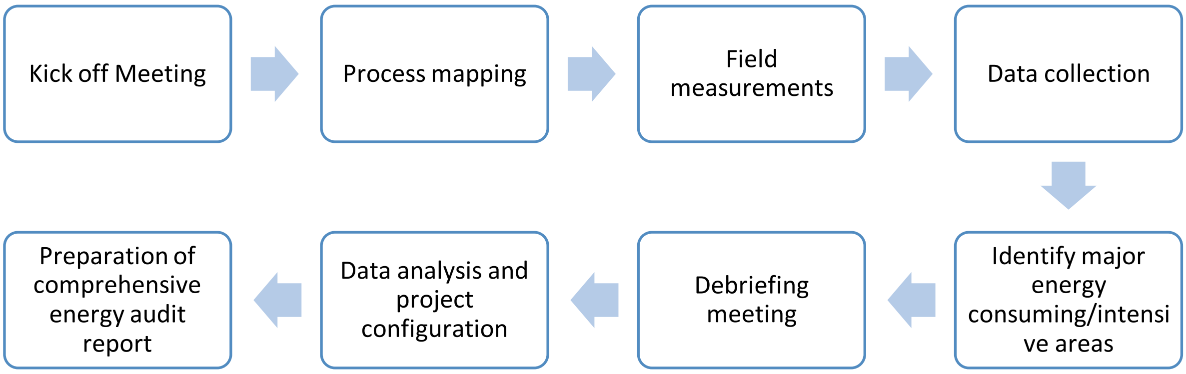


Figure 1: General methodology

The field work was carried out during 29th November-1st 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 (ECMs) normally fall under short, medium and long-term measures.

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit are the following:

Table 4: Energy audit instruments

Sl. No.	Instruments	Parameters Measured
1	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
2	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval
3	Digital Multi meter	AC Amp, AC-DC Voltage, Resistance, Capacitance
4	Digital Clamp on Power Meter – 3 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power

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

1.5 STRUCTURE OF THE REPORT

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

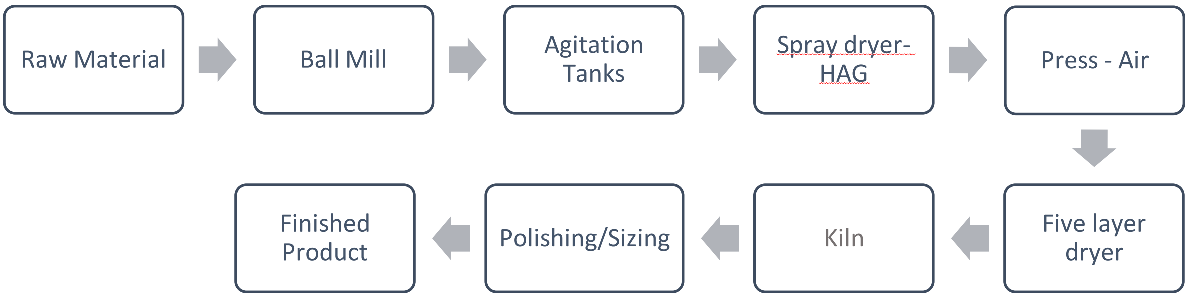


Figure 2: Process Flow Diagram

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 slip.
- The raw materials are mixed and ground using pebbles together with water in the Clay ball mill for a period of 3-6 hours.
- Slip is then pumped using hydraulic piston into spray dryer where moisture content of slip is reduced from 35-40% to about 5-6% and output of spray dryer is in powder form.
- 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 in five layers dryer for up to 115°C.
- This is followed by the glazing process and digital printing.
- After this the glazed product make 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:

- **Clay ball mill:** Here the raw materials like clay, feldspar, potash, talc and quartz are mixed along with water to form slip.
- **Agitator:** The liquid slip mass after mixing in Clay ball mill is poured into a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Hot air generator:** Hot air generator is used to generate hot air which is used in spray dryer for evaporation of moisture present in slip.
- **Glaze ball mill:** For producing glazing material used on tiles.

- **Air Compressor:** Pressurized air is used at several locations in a unit viz. hydraulic press, sizing, air cleaning, glazing etc.
- **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^{0}C to 1,200^{0}C depending upon the type of the final product. Once the tiles come out of the kiln, the materials are further gone for sizing, finishing and quality tested and packed for dispatch.
- **Press:** Clay in powered form is pressed in hydraulic press and tiles are formed**.**
- **Polishing and sizing machines:** From the Kiln, 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	#
Glazed Vitrified Tile	600X600	28	1.44	4
Glazed Vitrified Tile	600X1200	32	1.44	2
Glazed Vitrified Tile	300X600	18	0.9	5
Nano Tile	600X600	25	1.44	4

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	Nos. of boxes				Corresponding Area (m²)				Corresponding Mass (MT)			
	600X600 (GVT)	600X1200 (GVT)	600X300 (GVT)	600X600 (Nano tile)	600X600 (GVT)	600X1200 (GVT)	600X300 (GVT)	600X600 (Nano tile)	600X600 (GVT)	600X1200 (GVT)	600X300 (GVT)	600X600 (Nano tile)
Oct-17	24,002	18,091	16,514	-	176,731	-	-	32,553	672	579	297.25	-
Nov-17	107,412	-	-	55,434	173,078	35,267	-	-	3,008	-	-	1,386
Dec-17	122,730	-	-	22,606	137,903	24,849	-	-	3,436	-	-	565
Jan-18	120,193	24,491	-	-	123,404	30,050	-	25,091	3,365	784	-	-
Feb-18	95,766	17,256	-	-	216,318	35,483	14,863	79,825	2,681	552	-	-
Mar-18	85,697	20,868	-	17,424	142,880	24,872	7,441	43,584	2,400	668	-	436
Apr-18	142,115	-	-	-	204,646	-	-	-	3,979	-	-	-
May-18	143,676	-	-	-	206,893	-	-	-	4,023	-	-	-
Jun-18	139,019	-	-	-	200,187	-	-	-	3,893	-	-	-
Jul-18	124,064	-	-	-	178,652	-	-	-	3,474	-	-	-
Aug-18	150,221	-	-	-	216,318	-	-	-	4,206	-	-	-
Sep-18	84,286	-	-	-	121,372	-	-	-	2,360	-	-	-
Total	**1,339,181**	**80,706**	**16,514**	**95,464**	**2,098,382**	**150,521**	**22,303**	**181,053**	**37,497**	**2,583**	**297**	**2,387**

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 for kiln
  - Natural Gas (NG) for Five Layers dryer
  - Coal for hot air generators

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Lakh Rs	% of total	TOE	% of total
Grid – Electricity	609.83	32	776	13
Coal	166.78	9	2,001	34
Natural Gas	1,104.79	59	3,122	53
Total	1,881.40	100	5,899	100

This is shown graphically in the figures below:

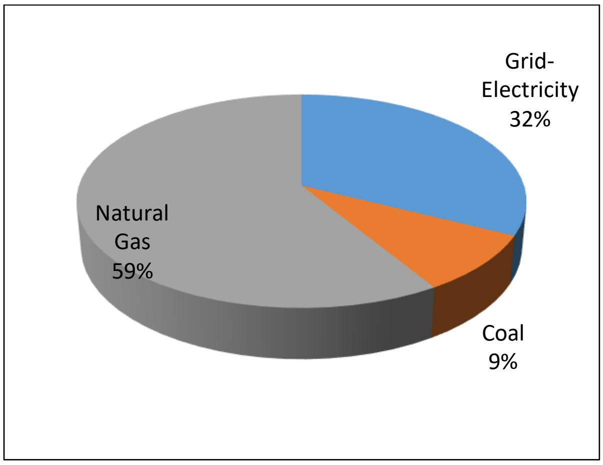


Figure 3: Energy cost share

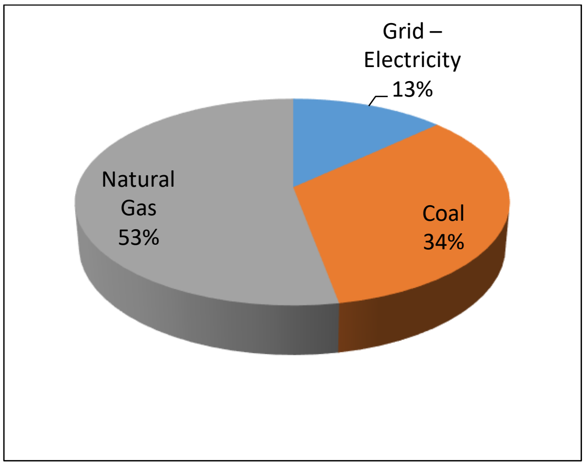


Figure 4: Energy use share

The major observations are as under:

- The unit uses both thermal and electrical energy for the manufacturing operations. Electricity is sourced from the grid as well as self-generated from DG sets when the grid power is not available. However, blackouts are infrequent, due to which the diesel consumption is minimal and records are not maintained.
- Electricity used in the utility and process accounts for the remaining 32% of the energy cost and 13% of the overall energy consumption.

- Source of thermal energy is from combustion of coal and firing of Natural gas.
- Coal is used in hot air generator to generate hot air and accounts for 9% of total energy cost and 34% of overall energy consumption.
- NG is used in Kiln and Five layers dryer accounts for 59% of total energy cost and 53% 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	33017
Tariff Category	HTP-I
Contract Demand, kVA	2,200
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 1,1100	475
Energy Charges (Rs./kWh)	
Normal Hours	4.2
Peak Hours	0.85
Night Time	0.4
Fuel Surcharge (Rs./kVAh)	1.63
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill for March-18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units Consumed kWh	Total Electricity Cost Rs	Average Unit Cost Rs/kWh
Oct-17	761,520	5,177,313	6.80
Nov-17	681,360	4,677,689	6.87
Dec-17	729,840	4,987,062	6.83
Jan-18	727,680	4,977,694	6.84
Feb-18	829,500	5,530,904	6.67
Mar-18	781,200	5,222,813	6.69
Apr-18	907,830	6,077,316	6.69
May-18	774,540	5,187,721	6.70
Jun-18	717,510	4,845,824	6.75
Jul-18	701,100	4,733,676	6.75
Aug-18	803,610	5,339,591	6.64
Sep-18	606,150	4,225,500	6.97
Total	9,021,840	60,983,104	6.76

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 751,820 kWh/month and cost is Rs.50.81 Lakhs per month (Oct-17 to Sep-18). The average cost of electricity is Rs 6.76/kWh. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

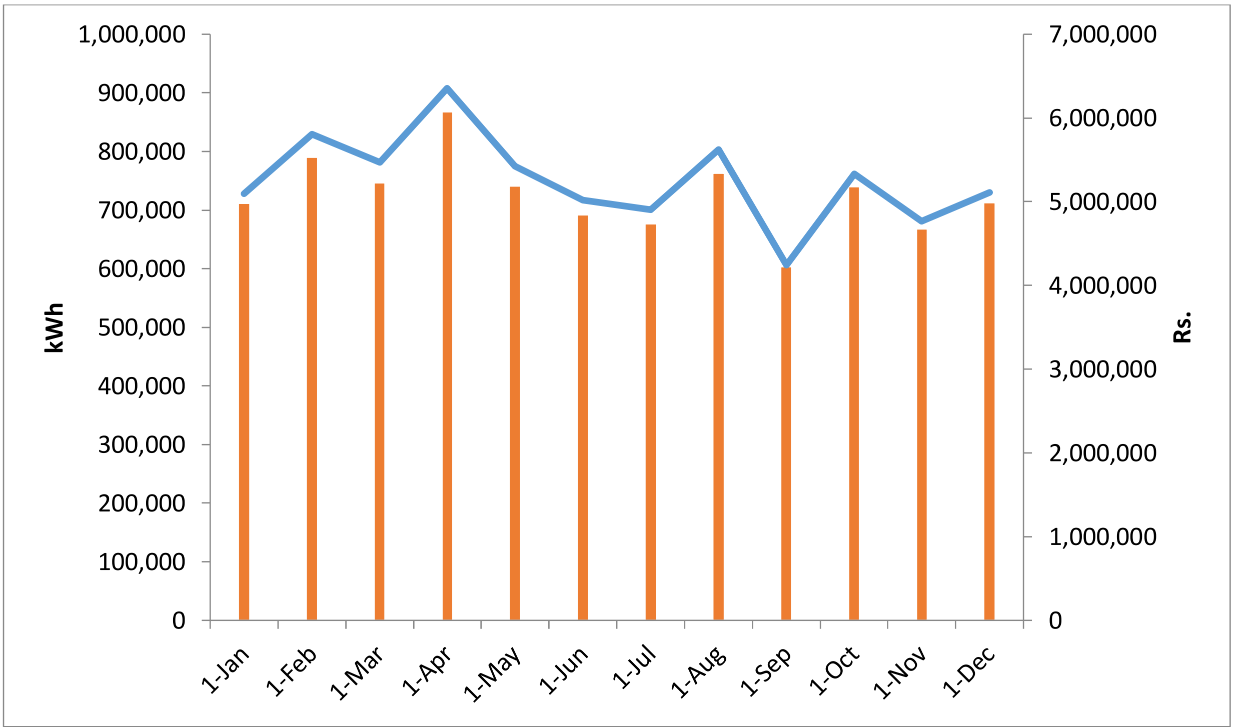


Figure 5: Month wise Variation in Electricity Consumption

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

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

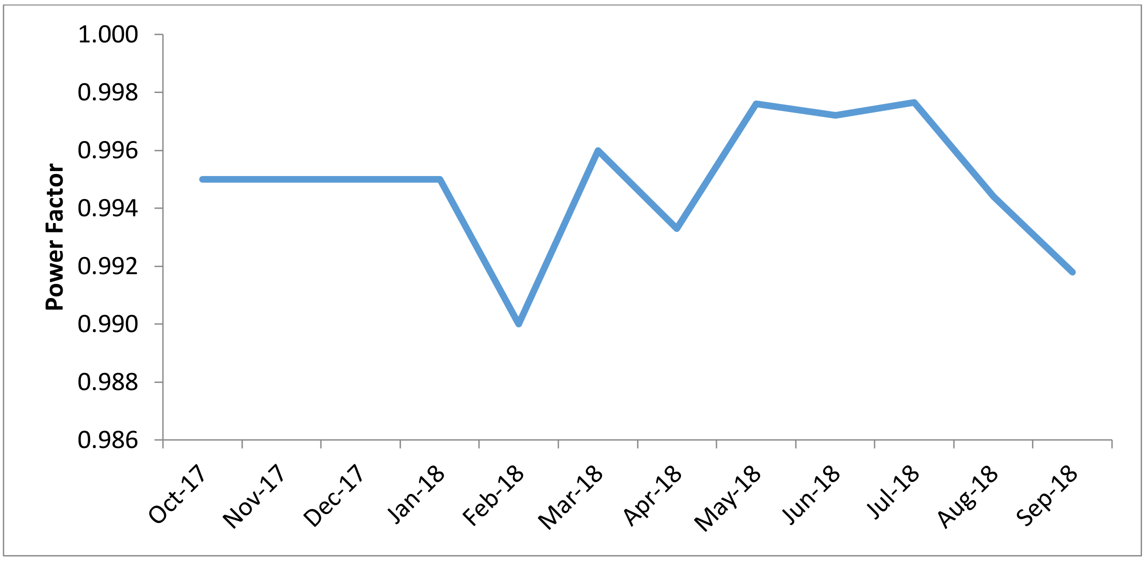


Figure 6: Month wise variation in Power Factor

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 0.994 and the maximum being 0.99.

Maximum Demand: Maximum demand as reflected in the utility bill is 1807.5kVA from the bill analysis[1].

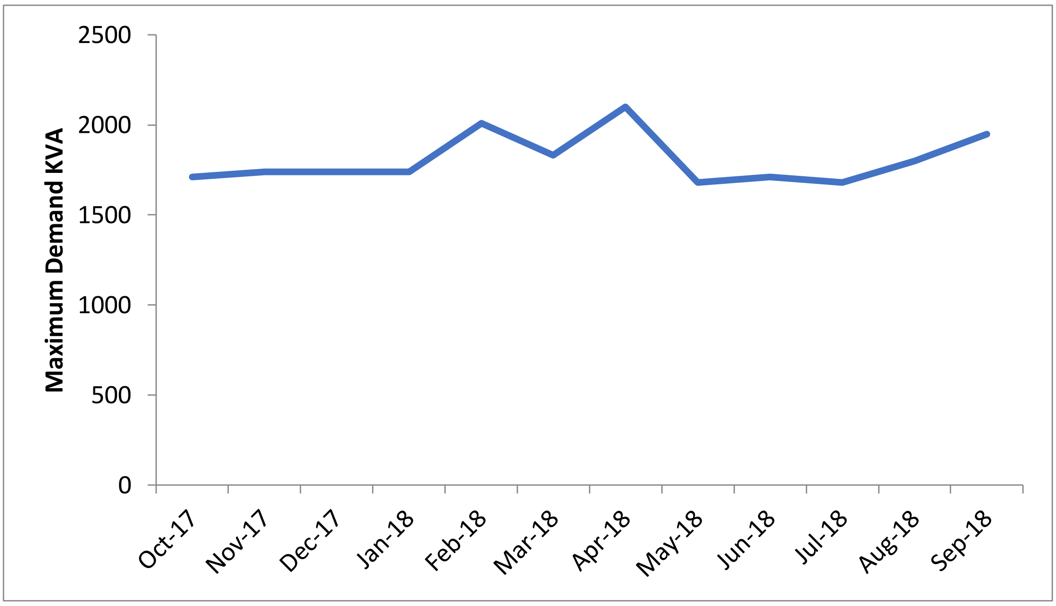


Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

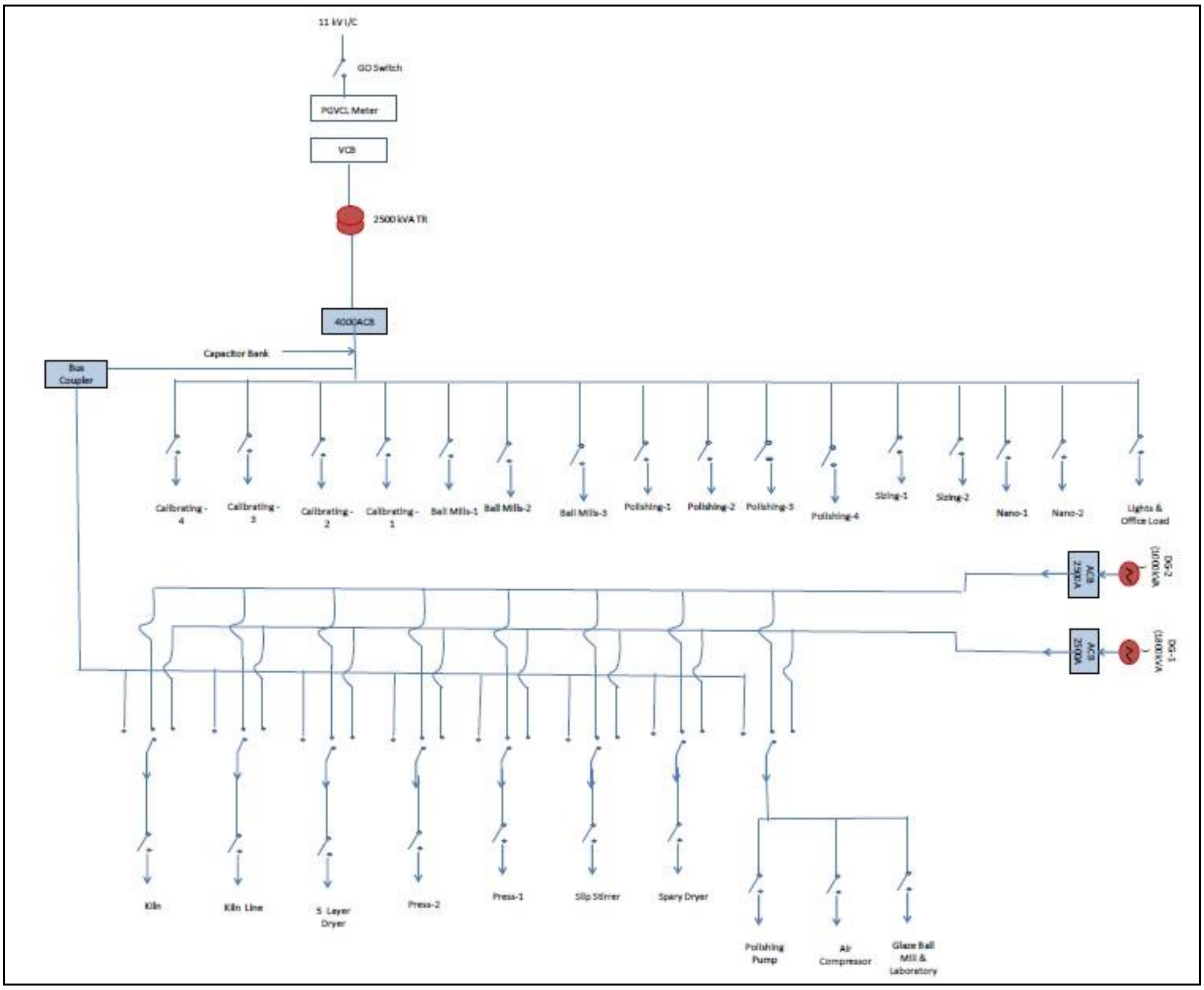


Figure 8: Single Line Diagram of Electrical load (SLD)

2.3.1.5 *Electricity consumption areas*

The plant total connected load is 3,655 kW, which includes:

- Plant and machinery load is 3,472kW.
- Utility load is (lighting, air compressor and fans) about 183 kW including the single phase loads.

Table 11 : Equipment wise connected load (Estimated)

Sl. No.	Equipment Name	Electrical Load (kW)
1	Compressor	135
2	HAG & spray dryer	269.2
3	Press-1	139.5
4	Press-2	139.5
5	Five layers dryer	220
6	Kiln	444
7	Final Sizing machine-1	85.6
8	Final Sizing machine -2	85.6
9	Nano machine -1	117.5
10	Nano machine -2	117.5
11	Polishing machine -1	165
12	Polishing machine -2	165

Sl. No.	Equipment Name	Electrical Load (kW)
13	Polishing machine -3	165
14	Polishing machine -4	165
15	Calibrating machine -1	165
16	Calibrating machine -2	165
17	Glaze ball mills	66
18	Stirrer Motors	137.5
19	Final Motor	15
20	RO Plant	8
21	Lights & Office connected Load	40
22	Clay ball mill	645
	Total	**3,655**

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

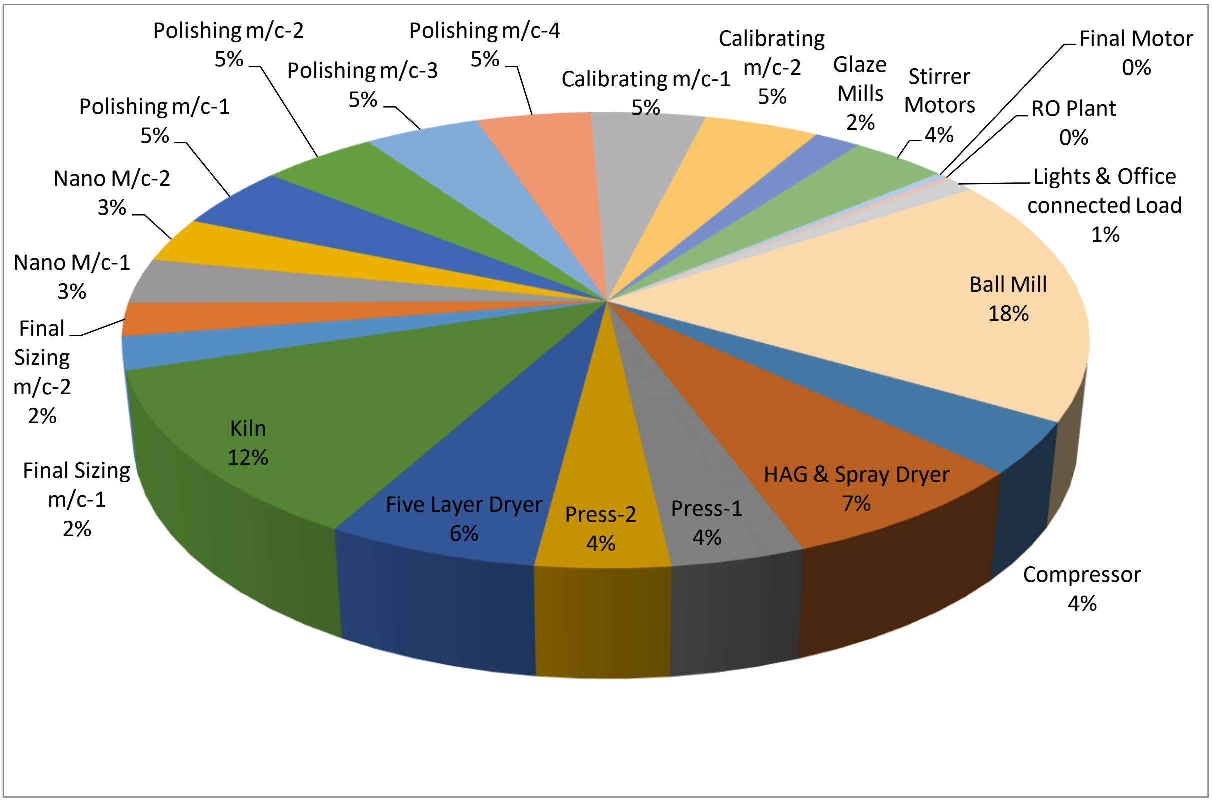


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Clay ball mill 18%, for Kiln 12%, for HAG and Spray Dryer 7%, for Five Layers dryer 6% , for Polishing Machine 1,2,3 & 4 is 5% each, for Calibrating machine 1 & 2 is 5% each , for Stirrer Motors is 4% ,for Press 1 & 2 is 4% each, for Nano machines 1 & 2 is 3% each, for compressor is 4 %, for final sizing machine 1 & 2 is 2% each 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:

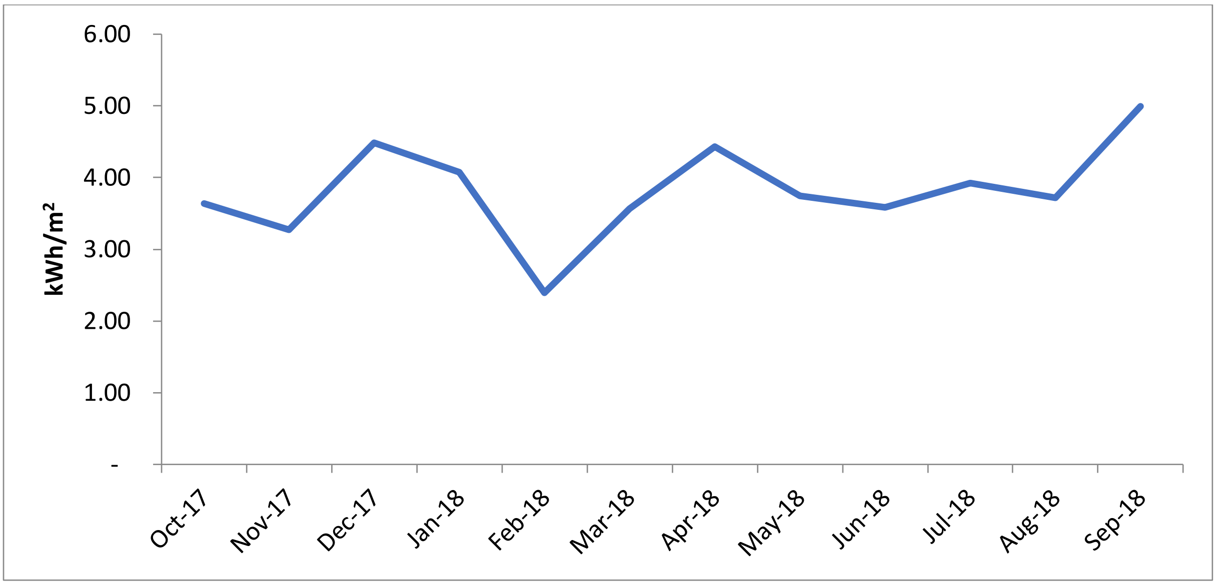


Figure 10: Month wise variation in Specific Electricity Consumption

The maximum and minimum SEC values for all months are within ±25% of the average SEC of 4 kWh/m^2 indicating that electricity consumption follows the production. Sub-metering is not available in the plant; and the only metering available is for PGVCL supply. Implementation of sub-metering will help establish section wise SEC. Sub-metering and monitoring is required in Clay ball mill section, spray dryer section, press section, biscuits kiln, glaze ball mill, 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 dryers and the kiln. Coal is used to generate hot air from hot air generator. Coal imported from Indonesia is being used. Natural Gas is purchased from GSPC (Gujarat State Petroleum Corporation) and is used in the five layers dryer as well as kiln. Based on the gas bill shared for the month of Oct-17 to Sept-18 annual fuel cost has been derived as under. Annual fuel consumption and cost are summarized below:

Table 12: Month Wise Fuel Consumption and Cost

Month	NG			Coal		
	NG Used scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs./MT
Oct-17	300,990	8,379,694	27.8	202.1	1,010,550	5,000
Nov-17	288,939	8,196,834	28.4	345.6	1,728,000	5,000
Dec-17	315,215	9,107,288	28.9	436.7	2,183,700	5,000
Jan-18	315,941	9,531,656	30.2	251.9	1,259,600	5,000
Feb-18	303,902	9,499,289	31.3	63.7	3,18,450	5,000
Mar-18	320,432	9,833,914	30.7	128.1	6,40,450	5,000
Apr-18	317,662	10,041,263	31.6	299.3	1,496,700	5,000
May-18	300,740	9,754,615	32.4	312.4	1,561,750	5,000
Jun-18	268,757	9,187,667	34.2	293.1	1,465,500	5,000
Jul-18	261,398	9,124,001	34.9	239.5	1,197,650	5,000
Aug-18	280,097	10,059,319	35.9	532.6	2,663,050	5,000
Sep-18	194,267	7,763,862	40.0	230.5	1,152,450	5,000

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

- Average monthly coal consumption is 278 MT and average cost Rs 13.89Lakhs/month
- Average monthly gas consumption is about 289,028 scm and average cost is Rs 92 Lakh/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:

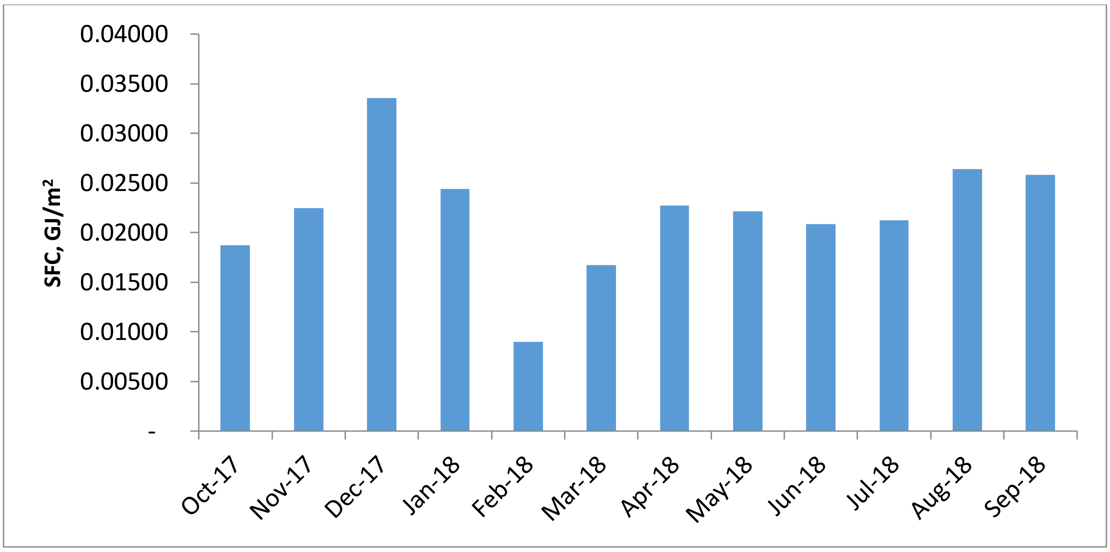


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.02 GJ/m^2. SFC is high in the month of Dec-18 (production was 162,752 m^2 and thermal consumption was 5457.38 GJ) and low in the month of Feb-18(production was 346,489 m^2 and thermal consumption was 3117.26 GJ).While metering for NG is recorded; the coal data is based on purchase. Actual information on coal consumption is not being maintained, and hence the SFC does not follow the production. For better quality information, sub-metering/data logging is required at kiln, hot air generator and dryers are required.

2.3.3 Specific energy consumption

2.3.3.1 Based on data collected during EA.

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

Table 13: Specific energy consumption

Particulars	Units	Value
Daily production	m^2/h	284
Power consumption	kW	1,044
Coal consumption	kg/h	386
NG consumption	scm/h	401
Energy consumption	TOE/h	0.682
SEC of plant	TOE/m^2	0.0012

2.3.3.2 Section wise specific energy consumption

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

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

Particulars	SEC		
	NG scm/t	Coal Kg/t	Electricity kWh/t
Clay ball mill			14.2
Agitators			5.7
HAG & Spray Dryer		90.9	11.9
Presses			15.2
Five Layers Dryer	1.9		2.72
Glaze ball mills			4.5
Kiln	58.12		10.5
Polishing Machines			69.69
Nano Machines			22.40
Final Sizing Machines			24.8
Calibrating Machines			47.8

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	9,021,840
Annual DG Generation Unit	kWh	-
Annual Total Electricity Consumption	kWh	9,021,840
Annual Thermal Energy Consumption (Coal)	MT	3,336
Annual Thermal Energy Consumption (NG)	scm	3,468,338
Annual Energy Consumption	TOE	5,899
Annual water Consumption	kL	39,600
Annual Water Cost	Lakh Rs	1.3
Annual Energy Cost	Lakh Rs	1,881
Annual Production	m^2	2,452,259
	t	42,764
SEC; Electrical	kWh/m^2	3.68
	kWh/t	211
SEC; Thermal	TOE/m^2	0.00021
	TOE/t	0.12
SEC: Water	kL/m^2	0.018
	kL/t	0.988
SEC; Overall	TOE/m^2	0.0024
	TOE/t	0.14
SEC; Cost Based	Rs/m^2	77

Particulars	UOM	Value
	Rs/t	4,400

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

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

- Conversion Factors
  - Electricity from the Grid : 860 kCal/kWh
- GCV of NG : 9,000 kCal/scm
- GCV of Imported Coal : 6,000 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	6.76
Cost of NG	Rs/scm	29.6
Cost of Coal	Rs/t	6,000
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	22,48,903

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using two pumps, submersible pump (5 kW) and Bore well Pump (7.5 kW). Bore well water is being used for Clay ball mill and make up water for cooling tower.

Submersible pump is used to supply water to RO Plant which is being used for drinking purpose and for Glaze ball mill.

Water distribution diagram is shown below.

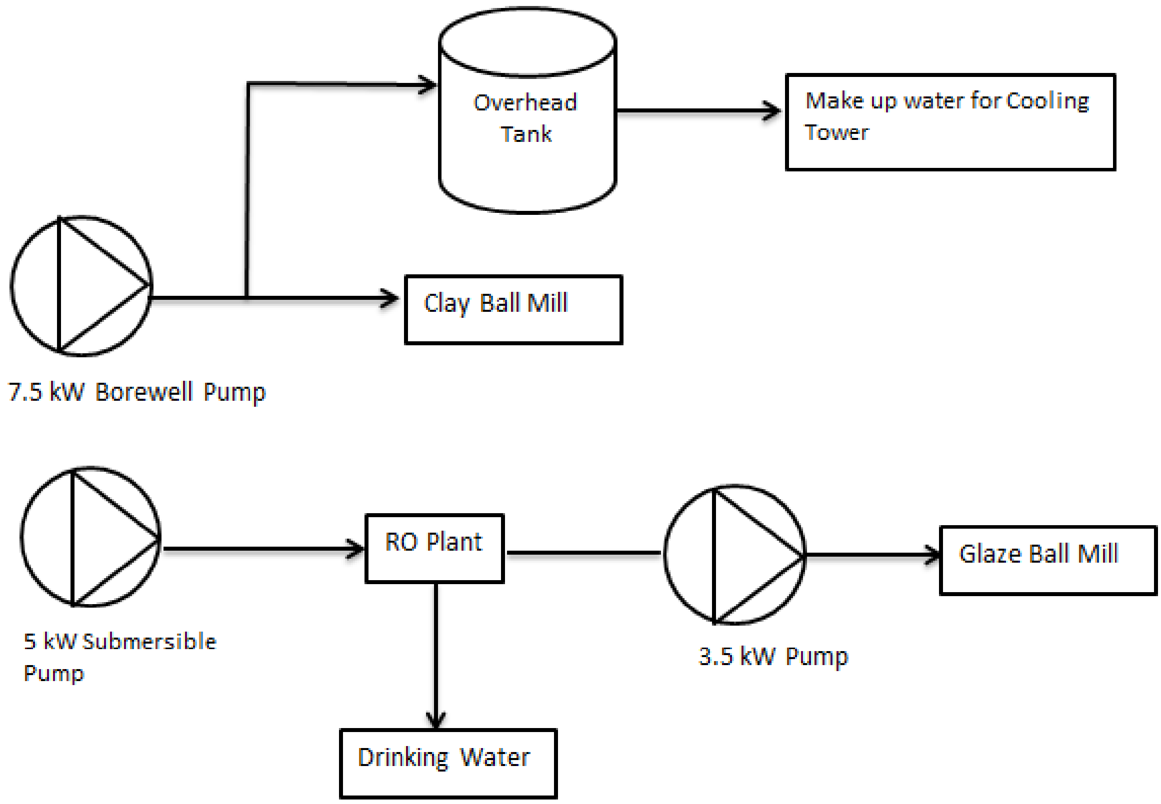


Figure 12: Water Distribution Diagram

Table 17: Submersible pump details

Particulars	UOM	Submersible Pump	Bore well Pump
Make	-	-	-
Motor rating	kW	5	7.5
RPM	rpm	-	-
Quantity	Number	1	1

The plant is having its own water treatment plant of small capacity.

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 595 HP electrical load of which 147 HP for smoke blowers, 147 HP for combustion blowers, 50 HP for rapid cooling, 121 HP for Hot air blower, 60 HP for cooling section, 50 HP for R.L.W. blower & remaining electrical load of kiln roller motors.

Table 18: Kiln Details

Parameter	UOM	Value
Make		-
Kiln operating time	h	24
Fuel consumption	scm/h	401.43
Number of burner to left	-	110
Number of burner to right	-	110
Cycle Time	Minutes	60-65
Pressure in firing zone	mmWC	40-50
Maximum temperature	°C	1,200
Waste Heat recovery option		Yes
Kiln Dimensions (Length X Width X Height)		
Preheating Zone	m	63.59 x 1.5 x 1
Firing Zone	m	49.06 x 1.5 x 1
Rapid Cooling Zone	m	14.53 x 1.5 x 1
Indirect cooling Zone	m	14.53 x 1.5 x 1
Final cooling zone	m	19.9 x 1.5x 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 in the five layers dryer and kiln. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 19: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	4.64 %
Ambient Air Temperature	38°C
Exhaust Temperature of Flue Gas	230°C

From the above table, it is clear that the oxygen level measured in flue gas was high. The inlet temperature of raw material in kiln was in the range of 42-45°C and Surface temperature throughout the zone of kiln was around 50°C 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:

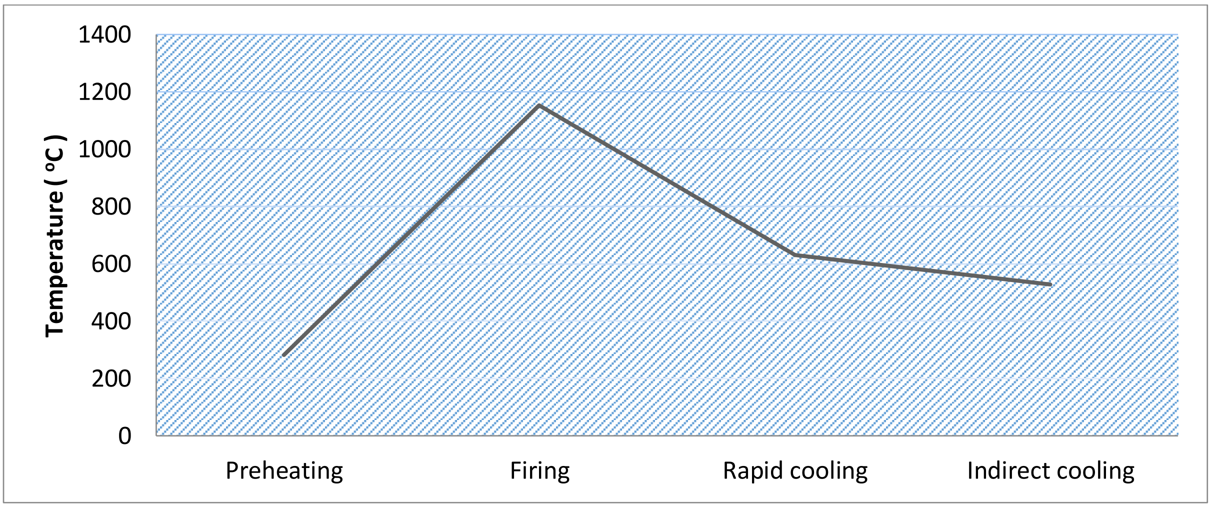


Figure 13: Temperature Profile of Kiln

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

Table 21: Power measurements of all blowers

Equipment	Average Power (kW)	Power factor
Combustion blower	13.5	0.99
Smoke Blower	5.79	0.99
Hot air blower	8.02	0.99
Cooling blower	27.2	1
Rapid cooling blower	3.48	0.98
R.L.W. blower	3.56	0.98

3.1.3 Observations and performance assessment

Kiln efficiency has been calculated based on the flue gas analysis study conducted during visit. Summary of all losses and Heat mass balance is shown in below figure:

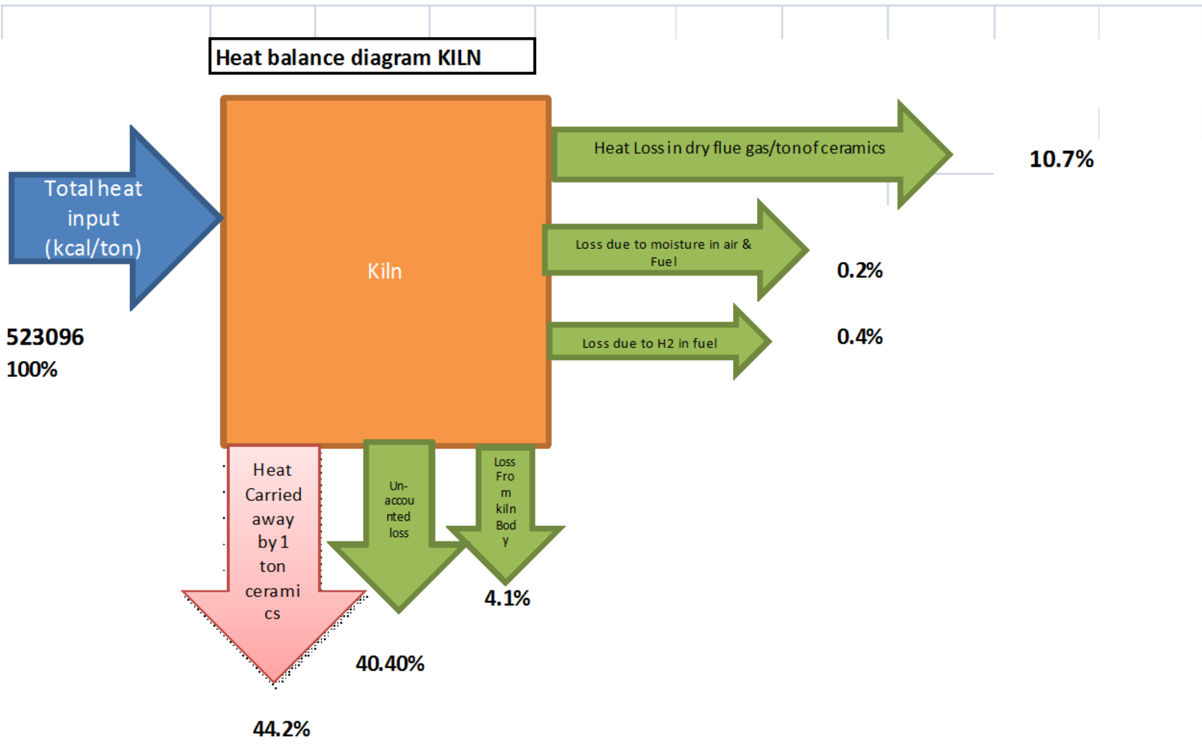


Figure 14: Heat balance diagram of Kiln

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

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln - Excess Air Control

Technology description

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

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

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

Study and investigation

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

Flue gas analysis of kiln is given in below table:

Table 22: Flue gas analysis

Particulars	UOM	Value
O_2 in flue gas	%	4.64
CO_2 in flue gas	%	15.6
CO in flue gas	ppm	10.3

Recommended action

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

Table 23: Savings and cost benefit analysis for Excess air control in kiln [ECM-1]

Particulars	UOM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	4.6	3.0
Excess air percentage in flue gas	%	28.4	16.7
Dry flue gas loss	%	11%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	scm/t	58	57
Average production in Kiln	t/h	6.9	6.9
Saving in specific fuel consumption	scm/h		4.69
Operating hours per day	h/d		330
Annual operating days	d/y		24
Annual fuel saving	scm/y		37183
Fuel cost	Rs/scm		30
Annual fuel cost saving	Lakh Rs/y		11.0
Power saving in combustion blower			
Mass flow rate of air	t/h	8.88	8.07
Density of air	kg/m3	1.23	1.23
Mass flow rate of air	m^3/s	2.0	1.8
Total pressure rise	Pa	2,412	2,412
Measured power of blower	kW	13.50	10.14
Total power saving	kW		3.36
Operating days per year	d/y		330
Operating hours per day	h/d		24
Annual energy saving	kWh/y		26,643

Particulars	UOM	Present	Proposed
Electricity cost	Rs/kWh	6.76	6.76
Annual energy cost saving	Lakh Rs/y		1.80
Overall energy cost saving	Lakh Rs/y		12.81
Estimated investment	Lakh Rs		9.24
Payback period	Months		8.65
Project IRR	%		107
Discounted payback period	Months		3.36

3.2 Five Layers Dryer

3.2.1 Specifications

There is one five layers dryer present in plant. Biscuits (green tiles) are entered from press into the five layer dryer which are heated from 35 to 115°C. There are seven hot air blowers & two smoke blowers connected. Waste heat from kiln and firing of NG in auxiliary burners is used as a heat source in five layer dryers. The specifications of dryer are given below table:

Table 24: Specifications of Five layer dryer

Particular	UOM	Value
Capacity	Nos. of tiles/h	1,000
Fuel type		NG
Rated fuel consumption	scm/h	40
Exit temperature of tiles	°C	115
Hot Air Blower	kW	7 x 19
Smoke Blower	kW	2x37

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 25: Field measurement at site

Particular	UOM	Five layers dryer
Tiles Passed through dryer	Nos/h	987
Mass of each tile at entry	g	7,400
Mass of each tile at exit	g	7,100
Temperature of tile at exit	° C	115
Gas consumption	scm/h	39 (NG)

Hot air blower discharge duct from kiln is utilized in only in five layers dryer which helps in fuel savings. All blowers are being operated with VFDs.

3.2.3 Observation and Performance assessment

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

Therefore energy balance has been determined by energy balance.

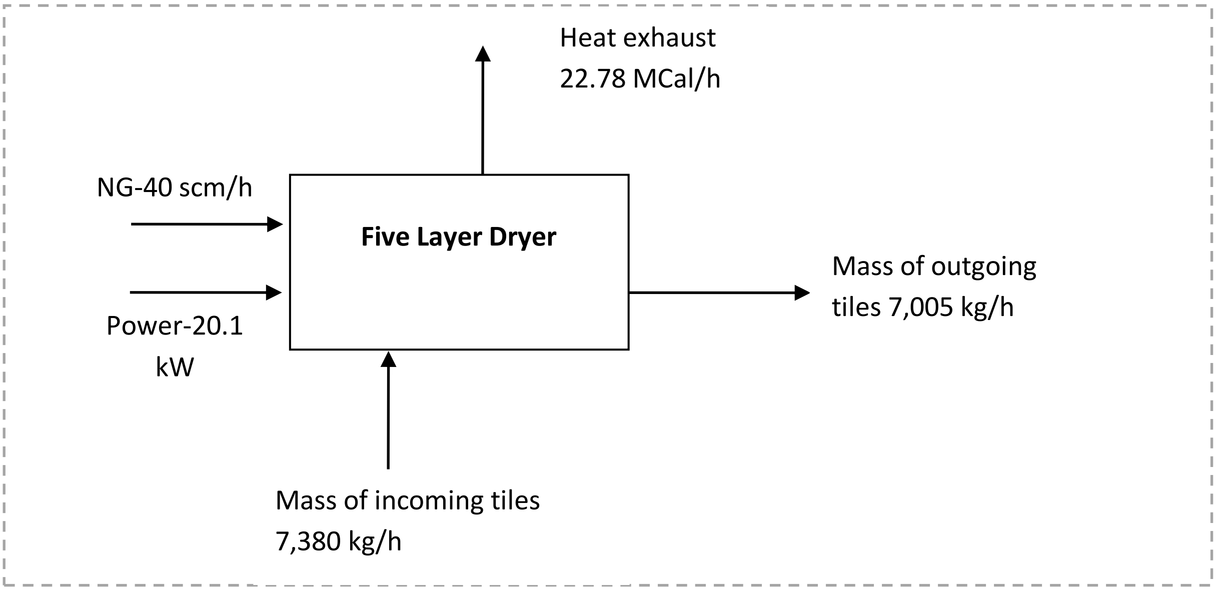


Figure 15: Mass and energy balance of Five layers dryer

Based on observations during DEA, the specific electricity consumption of five layers dryer is 2.7 kW/ton of tile and specific thermal energy is 1.9 scm/ton of tile.

Since blowers are VFD controlled, hot air is utilization 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 used for evaporating water from slip which is coming from Clay ball mill. There is one spray dryer installed which is taking heat from chain stoker HAG. Spray dryer is the heat exchanging unit for clay powder generation from slip. Specifications of HAG are given below:

Table 26: Specifications of Hot air generator (HAG)

Particular	UOM	Value
Air handling capacity	m^3/h	-
Fuel type		Coal
Rated fuel consumption	kg/h	550
Exhaust air temperature	°C	-
FD Blower	hp	1 x 60
ID Blower	hp	1 x 177

The specifications of spray dryer are given below:

Table 27: Specifications of spray dryer

Particulars	UOM	Value
Powder generation capacity	t/d	350
Inlet slip moisture	%	40
Outlet powder moisture	%	6

Particulars	UOM	Value
Slip house pump	kW	90

3.3.2 Field measurement and analysis

During DEA, the surface temperatures of HAG duct and cyclone separator was measured on first day and was found to be on higher side. On second day, the plant was installing Bubbling type in the Hot air generator.

3.3.3 Observations and performance assessment

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

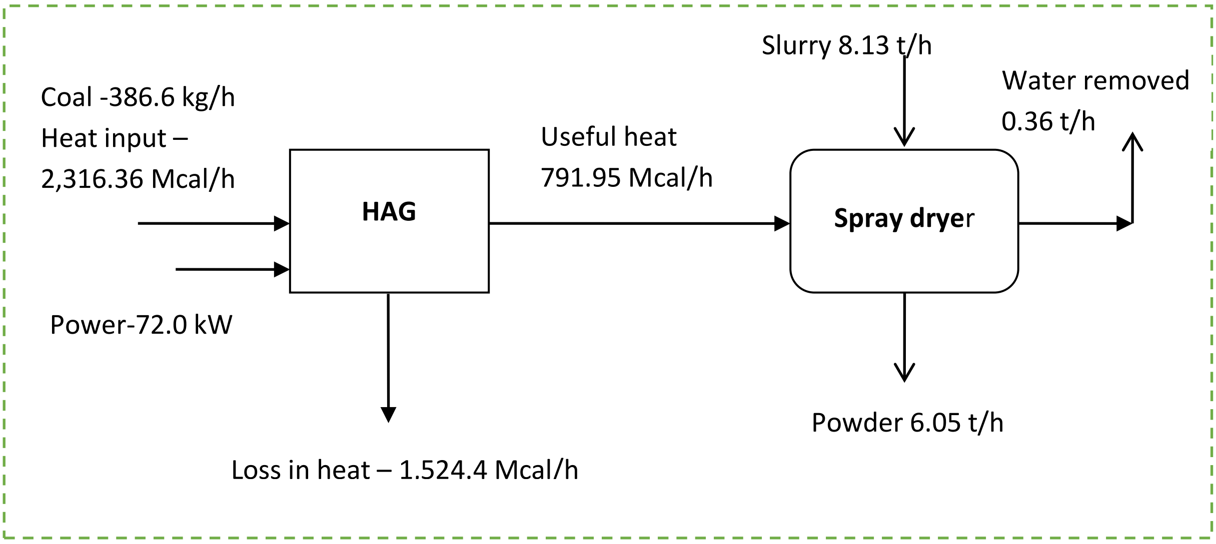


Figure 16 : Energy and mass balance of Chain Stoker HAG and spray dryer

Performance of HAG & spray dryer measures in terms of specific energy consumption (electrical energy used for delivering one kg of powder generation). Based on observations during DEA, the specific energy consumption of HAG & spray dryer was 11.9 kW/ton of powder generation and specific thermal consumption is 90.90 kg of coal/ton of powder generation.

3.3.4 Energy conservation measures (ECM)

The energy conservation measures are described in section below:

3.3.4.1 ECM # 2: Insulation improvement

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 surface insulation of cyclone separator and 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 surface of cyclone separator and HAG duct connecting cyclone separator.

Estimated cost benefit is given in the table below:

Table 28: Saving and cost benefit analysis for insulation improvement [ECM-2]

Parameters	UOM	Present	Proposed	Present	Proposed
Location of HAG		Cyclone separator		Connecting dust to Cyclone separator	
Diameter of cyclone separator	m	3		2	
Length of cyclone separator	m	3.5		4	
Total surface area	m^2	33.0	33.0	25.1	25.1
Average surface temperature	°C	110	70	110	70
Average coal loss due to high skin temperature	kg/h	4.3	1.7	3.3	1.3
Average coal saving per hour	kg/h		2.7		2.0
Annual operating hours	h/y	7,920	7,920	7,920	7,920
Annual coal saving	t/y		21		16
Fuel cost	Rs/t	5000	5000	5000.0	5000.0
Annual fuel cost saving	Rs Lakh/y		1.06		0.81
Annual monetary saving	Rs Lakh/y	1.86			
Estimated investment	Rs Lakh	4.60			
Payback period	Months	30			
Project IRR	%	20			
Discounted payback period	Months	10.63			

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 CLAY BALL MILLS

4.1.1 Specifications

Clay ball mills produce slip by mixing clay, water and chemicals SMS and STPP. Clay ball mills take 6-8 hours for slip preparation. The specifications of Clay ball mills and its accessories are given below:

Table 29: Specifications of Clay ball mills

Particular	UOM	Value
Numbers of Clay ball mills	#	3
Capacity of each Clay ball mill	t/batch	40
Water consumption in each Clay ball mill	t/batch	25
SMS (chemical consumption)	Kg/batch	280
STPP (chemical consumption)	Kg/batch	70
Water TDS	ppm	1,700
Nos. of batch per day		2

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of Clay ball mill#1
- Capacity of Clay ball mill and batches per day

Cooling water pumps was operating with VFDs. All power profiles are included in **Annexure-4**. Average power consumption and power factor are given in below table:

Table 30: Average power consumption and PF of Clay ball mills

Equipment	Average Power (kW)	PF
Clay ball mill#1	105.65	0.93

Average power consumption of Clay ball mill#1 is 105.65 kW (PF-0.93)

4.1.3 Observations and performance assessment

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

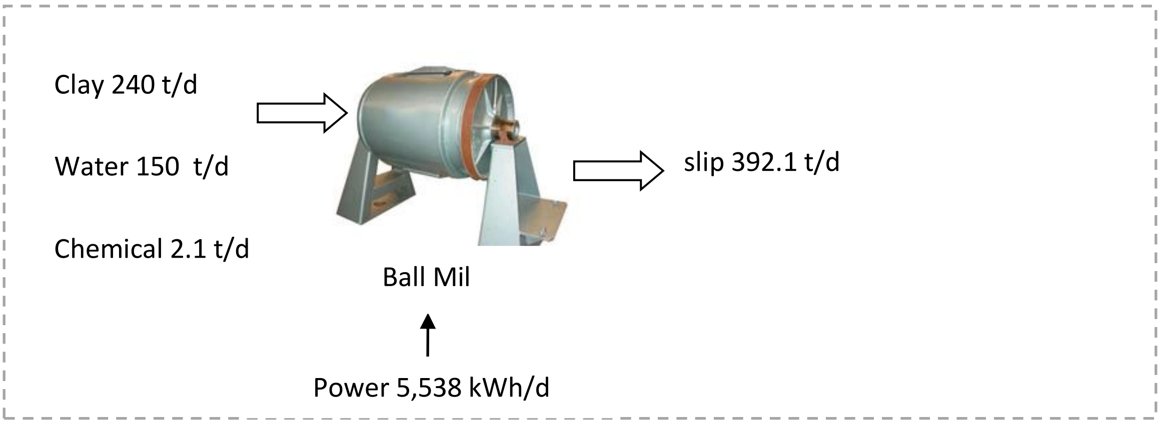


Figure 17: Energy and mass balance of Clay ball mill

Performance of Clay ball mills is measured in terms of specific energy consumption (power consumed for preparation of 1 ton of slip). Based on observations during DEA, the specific energy consumption of Clay ball mill was 14.2kW/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)

The energy conservation measures are described in section below:

4.1.4.1 ECM # 3: Using treated water in Clay ball mill

Technology description

It was observed that the TDS of water used in clay section is 1,700ppm, which results in higher consumption of water, chemicals and electricity per batch of slip preparation and later higher coal consumption for spray dryer.

Study and investigation

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

Recommended action

It is recommended to use water treatment plant which will reduce TDS from 1,700 ppm less than 400 ppm which can be used in Clay ball mill. Resource saving has been considered for water, chemicals, coal and power consumption to arrive at techno economics of the proposed energy conservation measure. Coal consumption will also be reduced due to reduced quantity of water to be evaporated in spray dryer.

Estimated cost benefit is given in the table below:

Table 31: Savings and cost benefit analysis by using Soft water in Clay ball mill [ECM-3]

Particulars	UOM	Present	Proposed
TDS of Water	ppm	1,700	400
Assumption : Water Saving		%	15
Assumption : Electricity Saving		%	3
Assumption : Fuel Saving		%	30
Assumption : Chemical Saving		%	30
Water used per batch	m^3	25.00	21.25
Water saving	m^3		3.75
Electricity used per batch	kWh	923	895.3
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kCal/kg	6000	6000
Eff. Of HAG	%	85%	85%
Coal saving per batch	Kg		452
Chemical saving per batch			

Particulars	UOM	Present	Proposed
SMS	Kg	280	196
STPP	Kg	70	49
Per Unit Cost			
Water	Rs/m^3	3.18	3.18
Electricity	Rs/kWh	6.76	6.76
Coal	Rs/kg	5.00	5.00
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		6,093
Total batches per day	#	6	6
Annual operating days	d/y	330	330
Annual Water Saving	m^3/y		7,425.0
Annual Electricity Saving	kWh/y		54,826.19
Annual Coal Saving	t/y		895.37
Annual Chemical Saving	kg/y		207,900.00
Annual cost savings	Lakh Rs/y		120.64
Operating cost - Water Treatment	Rs/m^3		20.00
Annual operating cost for RO	Lakh Rs/y		8.42
Net monetary savings	Lakh Rs/y		112.23
Estimated investment	Lakh Rs		39.60
Payback period	Months		4.23
Project IRR	%		213
Discounted payback period	Months		1.68

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 32: Specifications of hydraulic press

Particular	UOM	Press-1	Press-2
Cycle (stock) per minutes	Nos./min	11	10
Nos. of tiles (600X600) per stock		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 presses
- Count of tiles processed

Average power consumption of water circulation pump 1 is 9.61kW (PF 0.8), water circulation pump 2 is 9.5kW (PF 0.0.82).

Tiles are producing from Press-1 were 1,320 per hour and Press-2 is producing 1,200 per hour.

4.2.3 Observation and performance assessment

During DEA, it was observed that both cooling towers pumps of press are being operated based on temperature feedback. This feedback is being taken from press heat exchanger therefore pumps are being operated automatically. The specific energy consumption of presses was found to be 15.2kW/t.

4.3 AGITATOR

4.3.1 Specifications

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

Table 33: Specifications of agitators

Particular	UOM	Value
Numbers of agitator tanks	#	5
Capacity of each agitator motor	kW	5.5
Number of motors	#	25

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

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

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

Table 34: Power consumption and P.F. of agitator motors

Equipment	Power (kW)	PF
Motor#1 (Tank 3)	3.13	0.59
Motor#1 (Tank 3)	1.19	0.29
Motor#1 (Tank 3)	2.48	0.45
Motor#1 (Tank 4)	2.21	0.51
Motor#1 (Tank 4)	1.23	0.51
Motor#1 (Tank 4)	1.39	0.41
Motor#1 (Tank 5)	1.55	0.38
Motor#1 (Tank 5)	1.62	0.44
Motor#1 (Tank 5)	1.74	0.40

The mass of slip input to the agitators was 8.125 t/h.

4.3.3 Observations and performance assessment

During DEA, All the Agitator motors were running with VFDs. Hence, no ECM is proposed for the same. Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slip). Based on observations during DEA, the specific energy consumption of agitator motors were 5.7kW/t.

4.4 GLAZING

4.4.1 Specifications

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

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

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

The specifications of glazing ball mills are given below:

Table 35: Specifications of glazing machine

Particular	UOM	Value
Numbers of glazing ball mills	Nos.	3
Capacity of glazing ball mills	kW	1 x 18.6, 1 x 15, 1 x 3.7

4.4.2 Field measurement and analysis

During DEA, one glaze ball mill of 15 kW was working while other two were not in operation and the following measurements were done:

- Power consumption of Glaze ball mill (15kW)
- Mass of material fed in glaze ball mill

Average power consumption of Glaze ball mill is tabulated below:

Table 36: Measured Parameters of Glaze ball mill

Equipment	Average Power (kW)	PF
Glaze ball mill (15kW)	10.8	0.81

The mass of material entering the glaze ball mill was found to be 2.4 t/h.

4.4.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption was 4.5 kW/t for Glaze ball mill.

4.5 SIZING

4.5.1 Specifications

There were two sizing units which comprising many head and Conveyor motors. The specifications of sizing machines are given below:

Table 37: Specifications of sizing machine

Particular	UOM	Sizing-1	Sizing-2
Capacity of Head motor	kW	20 x 4	20 x 4
Capacity of Conveyor motor	KW	1 x 5.6	1 x 5.6

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of Sizing machines
- Number of Boxes produced per day

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

Table 38: Measured Parameters of sizing machine

Equipment	Average Power (kW)	No. of Boxes produced per day
Final Sizing machine	186	4,058

4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were 24.8 kW/t for Final sizing machine.

4.6 NANO FINISHING MACHINES

4.6.1 Specifications

There were two Nano finishing machines which comprising many head and main motors. The specifications of Nano finishing machines are given below:

Table 39: Specifications of Nano machine

Particular	UOM	Nano machine-1	Nano machine-2
Capacity of Head motor	kW	10 x 11	10 x 11
Capacity of Main motor	KW	1 x 7.5	1 x 7.5

4.6.2 **Field measurement and analysis**

During DEA, the following measurements were done:

- Power consumption of Nano machines
- Mass of tiles entering Nano machines

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

Table 40: Measured Parameters of Nano machine

Equipment	Average Power (kW)	P.F.
Nano machine – 1	78.83	0.91
Nano machine – 2	77.34	0.90

The mass of tiles entering the Nano machines were 6,907 kg/h.

4.6.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were 22.40 kW/t for Nano machines.

4.7 POLISHING

4.7.1 Specifications

There were four polishing machines which comprising many head and main motors. The specifications of Polishing machines are given below:

Table 41: Specifications of polishing machine

Particular	UOM	Polishing-1,2,3 & 4
Capacity of Head motor	kW	14 x 11
Capacity of main motor	KW	1 x 11

4.7.2 Field measurement and analysis

During DEA, Polishing machine-3 & 4 were running while other two were not running due to less production. The following measurements were done:

- Power consumption of Polishing machines
- Mass of tiles entering polishing machines

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

Table 42: Measured Parameters of Polishing machine

Equipment	Average Power (kW)	P.F.
Polishing machine – 3	78.83	0.81
Polishing machine – 4	72.72	0.70

The mass of tiles entering polishing machines-3 & 4 were 6,907 kg/h.

4.7.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were 69.69 kW/t for polishing machine.

4.8 AIR COMPRESSORS

4.8.1 Specifications

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

Table 43: Specifications of compressors

Particular	UOM	Air compressor 1	Air compressor 2	Air compressor 3
Power rating	hp	60	60	60
Maximum pressure	Bar (a)	6.5	6.5	6.5
Air handling capacity	cfm	254	254	254

4.8.2 Field measurement and analysis

During DEA, Compressor-1 & 2 were running and compressor-3 was standby. The following measurements were done:

- Power consumption of all compressor

- Air flow measurement of all compressor

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

Table 44: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (cfm)	% of time on load
Compressor-1	52	0.71	207	77
Compressor-2	46.1	0.87	233	100

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

4.8.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption are 0.25 kW/CFM and 0.20 kW/CFM for compressor-1 and compressor-2 respectively.

4.8.4 Energy conservation measures (ECM)

The energy conservation measures are described in section below:

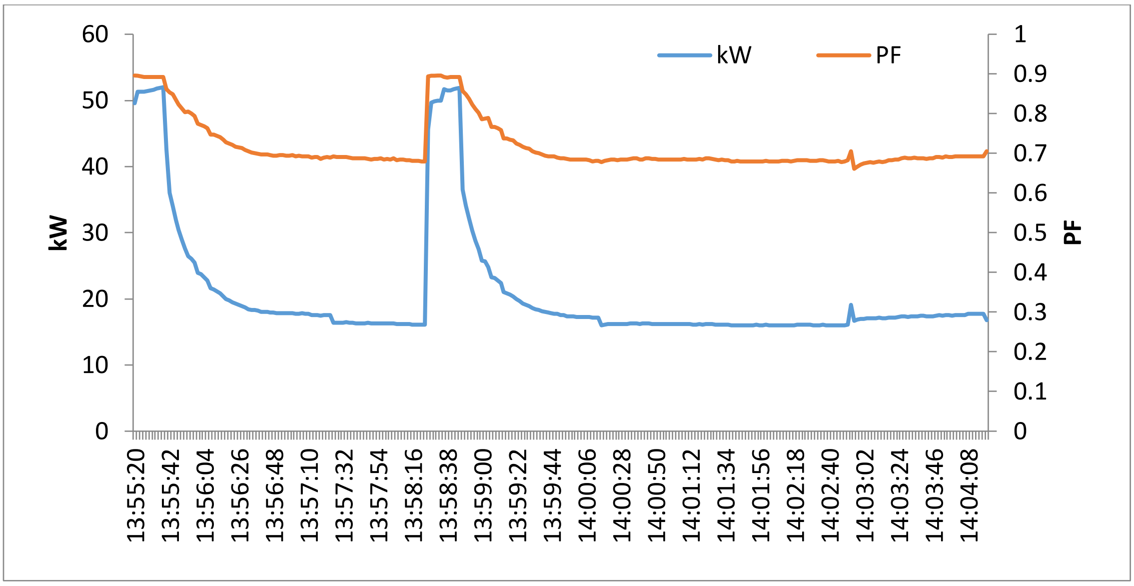
4.8.4.1 ECM #4: Retrofit of VFD in compressor #1

Technology description

In any industry, compressor requirement keeps on varying based on the production demand and hence air compressor will run in load/unload sequence as per demand. During the unload condition air compressor will consume about 30% power without doing any work. A VFD can take care of this variable air demand by changing the RPM of compressor motor based on pressure feedback received from pressure sensor. As the demand reduces, pressure will increase, hence compressor RPM will reduce. Similarly, when there is high demand pressure will reduce during this period VFD will raise the RPM of motor to meet the demand.

Study and investigation

Power cycles of all two compressors were captured to understand unload/load pattern of air compressor it was found that two of compressor 1 is getting unloaded for 23% of the time. There was only one receiver and it was not possible to conduct FAD test for compressor.



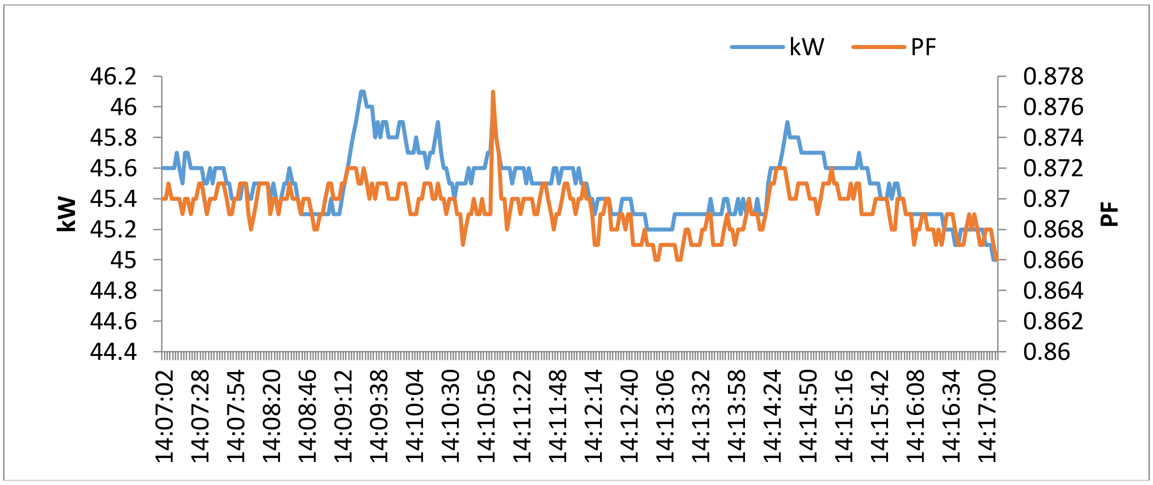


Figure 18: Load/Unload pattern of Compressor#1 and Compressor#2

Recommended action

It is recommended to install VFD on compressor 1 which will cater to the variable air demand of the plant whereas other two compressors will run to meet the base load. The cost benefit analysis for this project is given below:

Table 45: Savings and cost benefit analysis for retrofit of VFD in compressor #1 [ECM - 4]

Particulars	UOM	Present	Proposed
Compressor motor rating	kW	45	45
Average power consumption during loading	kW	38.9	-
Average power consumption during unloading	kW	24.6	-
On load time in percentage	%	77.22	-
Off load time in percentage	%	22.78	-
Average power consumption	kW	35.64	30.30
Operating hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	282,286	239,943

Particulars	UOM	Present	Proposed
Annual energy saving	kWh/y		42,343
Unit cost of electricity	Rs/kWh		6.76
Annual monetary savings	Lakh Rs/y		2.86
Estimated Investment	Lakh Rs		1.72
Payback period	Months		7.19
Project IRR	%		125
Discounted payback period	Months		2.82

4.8.4.2 ECM #5: Compressed air pressure reduction

Technology description

When the generation pressure of compressed air is reduced by 1 kg/cm^2, there is reduction in energy consumption of compressor by 6% as per BEE.

Study and investigation

During DEA, it was found that the compressor #1 was generating compressed air at 6.5 kg/cm^2 and the pressure requirement at the end utilities were around 4 kg/cm^2.

Recommended action

It is recommended to reduce the generation pressure of compressed air and thereby achieve energy savings. The cost benefit analysis for this project is given below:

Table 46: Savings and cost benefit analysis for compressed air pressure reduction [ECM-5]

Parameter	UOM	Present	Proposed
Operating pressure required	kg/cm^2	6.5	4.5
Compressor loading pressure	kg/cm^2	6.3	5
Compressor unloading pressure	kg/cm^2	7	6
Reduction in pressure	kg/cm^2	-	1
% of energy saving	%	-	6
Average load	kW	38	35.91
Operating hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual energy consumption	kWh/y	302,541	284,389
Annual energy savings	kWh/y		18,152
Unit cost of electricity	Rs/kWh		9.70
Annual monetary saving	Lakh Rs/y		1.76
Estimated Investment	Lakh Rs		-
Payback period	Months		-
Project IRR	%		-
Discounted payback period	Months		-

4.9 WATER PUMPING SYSTEM

4.9.1 Specifications

Pumping system comprises one bore well pump, one submersible pumps and few transfer pumps.

4.9.2 Field measurement and analysis

During DEA, the following measurements were done for the Press CT pump:

- Power consumption of Press CT pumps
- Flow measurements for same pumps

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

Table 47: Operating details of CT Press pumps

Particulars	UOM	Press CT Pump-1	Press CT Pump-2
Measured flow	m^3/h	49.3	55.3
Total head	m	17	18
Actual power consumption	kW	5.9	7.1

4.9.3 Observation and performance assessment

Based on observations during DEA, the pump efficiency is determined as 53.3% & 52.8%.

4.9.4 Energy conservation measures (ECM)

The energy conservation measures are described in section below:

4.9.4.1 ECM #6: Replacement of inefficient pumps

Technology description

Presently, there are energy efficient pumps available having pump efficiency of 75% which leads to reduced energy consumption.

Study and investigation

The Press CT pump-1 & 2 were running at lower efficiency and is recommended to be replaced with new high efficiency pumps and the press CT pumps are running throughout the day as per requirement. Pump is operating for about 24 hours per day.

Recommended action

Recommendations have been given to refurbish/replace Press CT pumps with energy efficient pumps. Additional water meters have also been recommended. Measured parameters and the derived efficiency of the pumps are mentioned here under.

Table 48: Savings and cost benefit analysis by replacing inefficient pumps [ECM-6]

Parameters		Press CT Pump-1		Press CT Pump-2	
	UOM	Present	Proposed	Present	Proposed
Pump Efficiency	%	53.31	75.00	52.80	75.00
Motor Rated Power	kW	5.595	3.7	7.46	3.7
Motor Efficiency	%	85.00	85.00	85.00	85.00
VFD	Y/N	N		N	
VFD Frequency	Hz	50.0	50.0	50.0	50.0

Parameters		Press CT Pump-1		Press CT Pump-2	
	UOM	Present	Proposed	Present	Proposed
Measured Parameters					
Flow rate Q	m^3/h	49.3	49.3	55.3	55.3
Suction Pressure	kg/cm^2	-0.2	-0.2	-0.2	-0.2
Discharge Pressure	kg/cm^2	1.50	1.50	1.60	1.60
Motor Input Power	kW	5.9	3.6	7.1	3.6
Calculation					
Flow rate Q	m^3/s	0.01369	0.01369	0.01536	0.01536
Total Head/head developed	m	17.0	17.0	18.0	18.0
Liquid Horse Power	kW	2.3	2.3	2.7	2.3
Motor Shaft Power	kW	5.0	3.0	6.0	3.0
Motor Loading	%	90.1	82	81.0	82%
Overall system efficiency	%	45	75	45	75
Pump Efficiency	%	**53.3**	**75.0**	**52.8**	**75.0**
Operating hour per day	h/d		24		24
Annual operating days	d/y		330		330
Annual power savings	kWh/y		18,592.5		27,938.1
Electricity tariff	Rs/kWh		7		7
Annual Monetary savings	Lakh Rs/y		1.3		2.0
Estimated investment	Lakh Rs		0.6		0.6
Simple payback period	months		5.5		5.5
Annual Monetary savings	Lakh Rs /y		3.3		
Estimated investment	Lakh Rs		1.19		
Payback period	Months		4		
Project IRR	%		207		
Discounted payback period	Months		1.73		

4.10 Lighting System

4.10.1 Specifications

The plant lighting system includes:

Table 49: Specifications of lighting load

Particular	UOM	CFL	Fluorescent tube light
Power consumption of each fixture	W	85	36
Numbers of fixtures	#	205	50

4.10.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 50: Lux measurement at site

Particular	UOM	Value
Office	$Lumen/m^2$	155
Kiln control room	$Lumen/m^2$	113

Particular	UOM	Value
Kiln area	Lumen/m^2	69
Press section	Lumen/m^2	71
Clay ball mill and agitators	Lumen/m^2	65
HAG and spray dryer	Lumen/m^2	62
Five layers dryer	Lumen/m^2	69

4.10.3 Observations and performance assessment

Adequate day lighting is used wherever possible. As the plant has already installed energy efficient lightings, hence no ECM has been proposed.

4.11 Electrical Distribution System

4.11.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (433V) by step down transformer (2.5 MVA). Capacitor bank is installed in parallel to main supply. There were two DGs (capacity of 1 MVA & 1.8 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.

4.11.2 Field measurement and analysis

During DEA, the following measurements were done:

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

The power profile of the main incomer feeder is attached in the **Annexure-4**.

4.11.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **1950 kVA** at plant main feeder.

The voltage profile of the unit is satisfactory and average voltage measured was **426.3 V.** Maximum voltage was **439.9 V** and minimum was **407.2 V**.

Average total voltage and current Harmonics distortion found **8.6%**&**19.2%** respectively during power profile recording.

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

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

4.11.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.11.4.1 ECM #7: Installation of 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 6.04kW.

Table 51: Measured Harmonics Level at Main Incomer

Name & Sr. No.	Phase		Voltage	Amp.	THD V (%)	THD I (%)	Individual Current Harmonics				
							A3%	A5%	A7%	A9%	A11%
Main Incomer	R	Average	245	1548	8.69	19.2	1.87	16.1	9.02	0.78	3.77
		Maximum	253	2221	10.90	27.9	3.80	24.1	14.60	1.80	7.10
		Minimum	234	820	5.90	11.5	0.90	9.1	4.10	0.10	1.70
	Y	Average	247	1610	8.77	19.9	0.99	16.3	10.35	0.26	3.44
		Maximum	254	2312	11.10	29.9	2.20	24.4	16.70	0.90	6.40
		Minimum	236	863	5.80	12.1	0.40	9.7	4.90	0.00	1.70
	B	Average	245	1527	8.8	20.4	1.96	17.1	9.67	0.84	4.03
		Maximum	252	2180	10.9	29.8	3.40	25.4	14.90	1.80	7.80
		Minimum	234	814	6.0	12.4	0.90	10.1	4.80	0.30	1.90

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

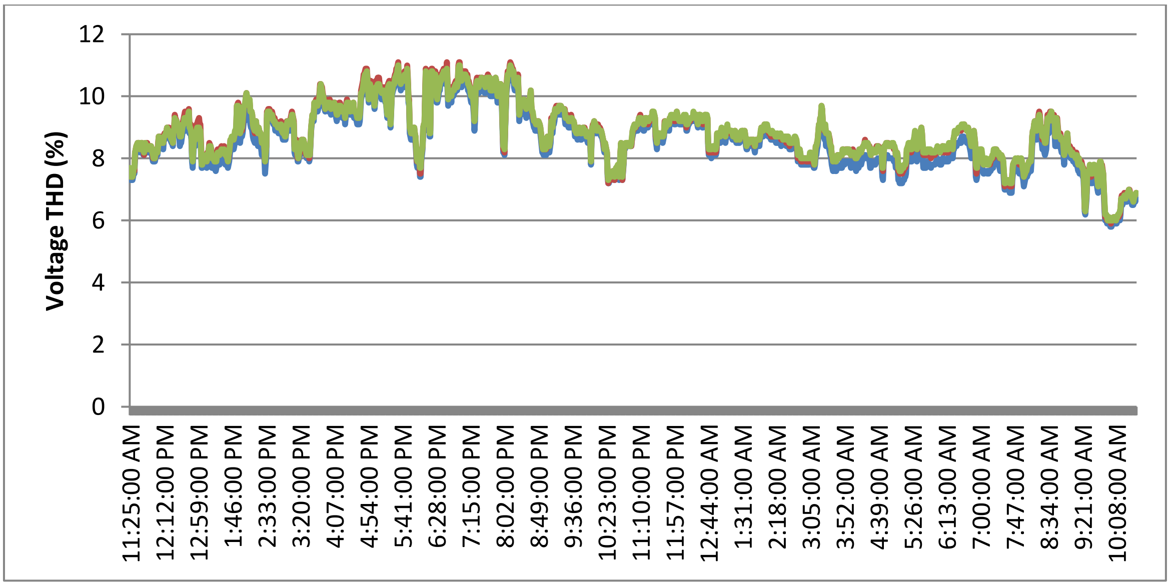


Figure 19: Voltage THD profile

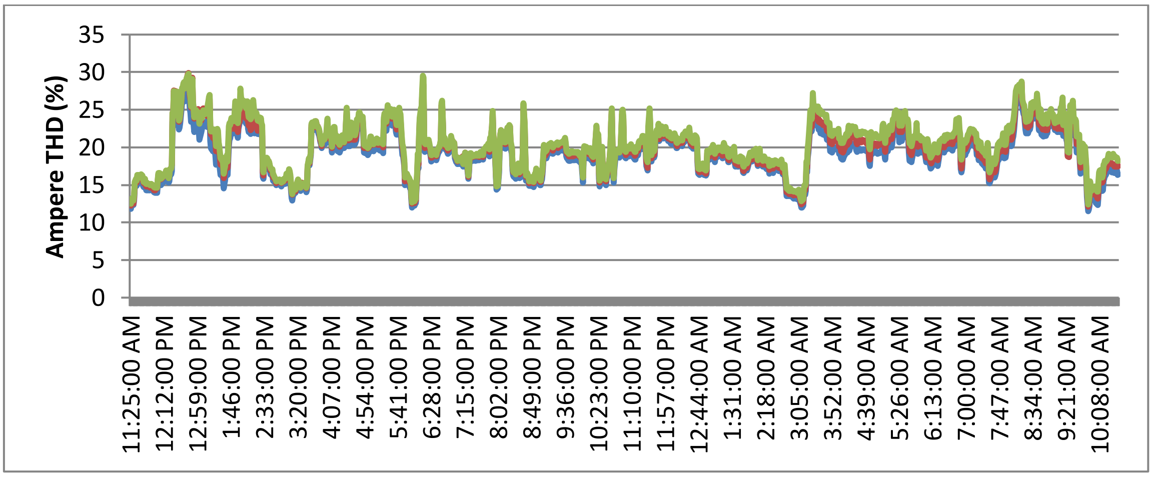


Figure 20: Ampere THD profile

Recommended action

It is recommended to install 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 310A**. 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.
- 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 52: Savings and cost benefit analysis for Installation of harmonics Filter [ECM-7]

Particulars	UOM	Present	Proposed
Estimated losses due to Harmonics	kW	6.04	0
Saving potential by installation of harmonics filter	kW	6.0	
Operating days per year	d/y	330	
Operating hours per day	h/d	24	
Saving potential	kWh/y	47875	
Unit Cost	Rs/kWh	6.76	
Saving Potential	Lakh/y	3.2	
Estimated rating of harmonics filter	Ampere	250	
Estimated investment	Lakh Rs	20	
Payback period	Months	73	
Project IRR	%	-10	
Discounted payback period	Months	24.71	

4.11.4.2 ECM #8: 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 found that power factor in polishing Line-3 and Line-4 was 0.71 and 0.80.

Recommended action

It is recommended to install power factor improvement capacitors for polishing line-3 and line-4.

The cost benefit analysis for this project is given below:

Table 53: Savings and cost benefit analysis for Cable Loss minimization [ECM-8]

Particulars	UOM	Polishing Line-3 Value	Polishing Line-4 Value
Existing Power Factor	PF	0.71	0.80
Proposed Power Factor	PF	0.99	0.99
Existing load	kW	72.7	78.6
Cable Losses	W	1,949	1,727
Capacitor Required	kVAr	66	49
Annual Energy Saving	kWh/y	7,669	4,636
Annual Monetary Savings	Lakh Rs/y	0.62	0.53
Annual Energy Saving	kWh/y	12,304.92	

Particulars	UOM	Polishing Line-3 Value	Polishing Line-4 Value
Annual monetary savings	Lakh Rs/y	1.15	
Estimated Investment	Lakh Rs	0.53	
Payback Period	Months	6	
Project IRR	%	167	
Discounted payback period	Months	2.17	

4.11.4.3 ECM #9: 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.

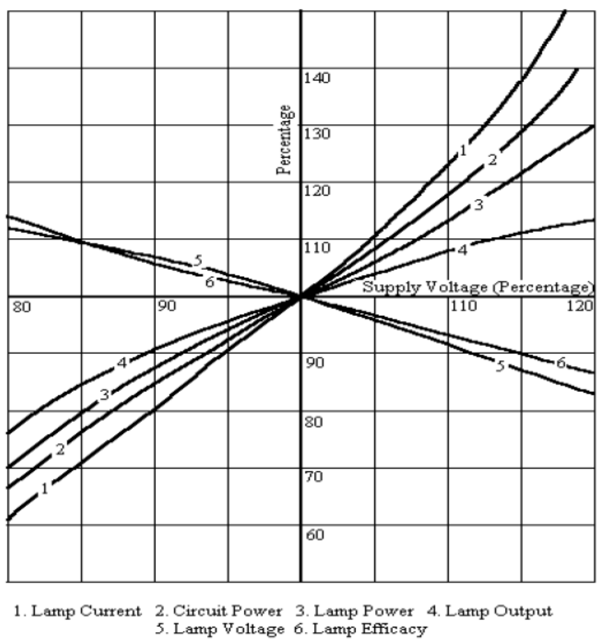


Figure 21: Effect of supply voltage on lamp parameters

Study and investigation

Lighting feeder measurements were carried out to estimate existing lighting load and the voltage level in the lighting circuit. Present lighting load in the plant is 29.5 kW and measured voltage level is 438.5 V.

Recommended action

It is recommended to install separate lighting transformer of 40 kVA rating for lighting circuit to save energy, optimize voltage and also reduce premature failure of lamps. The cost benefit analysis for this project is given below:

Table 54: Savings and cost benefit analysis by Voltage Optimization in lighting circuit [ECM-9]

Particulars	UOM	Values
Present Power Consumption in Lighting	kWh/d	707.7
Present Voltage Level in Lighting Circuit	V	438.5
Proposed Voltage Level in Lighting Circuit	V	380
Saving Potential	%	24.9
Saving Potential	kWh/d	176
Operating days per year	d	330
Saving Potential	kWh/y	58,128
Cost of Electricity	Rs/kWh	6.76
Estimated Savings	Lakh Rs/y	3.93
Lighting voltage transformer rating	kVA	40
Estimated Investment	Lakh Rs	1.32
Payback period	Months	4.03
Project IRR	%	223
Discounted payback period	Months	1.60

4.12 Belt Operated Drives

4.12.1 Specifications

There are 22 drives operated with V Belt of total capacity of 1,644 kW. Locations include

- Kiln (6)
- HAG & Spray dryer (2)
- Five layer dryer(9)
- Clay ball mill (2)
- Glaze ball mill (3)

4.12.2 Field measurement and analysis

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

4.12.3 Observations and performance assessment

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

4.12.4 Energy conservation measures (ECM) - ECM #10: V Belt replacement with REC belt

Technology description

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

Benefits of Cogged belts & Pulley over V belts:

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

Study and investigation

The unit is having about 22 belt drives in plant.

Recommended action

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

Table 55: Replacement of conventional belt with REC belt [ECM-10]

Parameters	UOM	Present	Proposed
Total Rated power of belt drives	kW	1,644	1,644
Energy Saving	%		3.60
Total measured power of belt drives	kW	196	189
Operating hours per day	h/d	24	24
Operating Days per year	d/y	330	330
Annual energy consumption	kWh/y	1,549,746	1,493,955
Annual energy saving	kWh/y		55,791
Unit cost of electricity	Rs/kWh		6.76
Annual monetary savings	Lakh Rs/y		3.77
Estimated Investment	Lakh Rs		4.00
Payback Period	Months		13
Project IRR	%		68
Discounted payback	Months		4.91

5. Chapter-5 Energy consumption monitoring

5.1 Energy Consumption Monitoring

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

5.1.1 ECM #11: 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.

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:

- Hot air generator - FD & PA fan
- Kiln
- Five layers dryer
- Clay ball mills
- Agitator motors
- Glaze ball mills
- Sizing machines
- Air Compressors
- Spray dryer - ID fan & pump
- Glaze line & kiln line
- CT pumps

The cost benefit analysis for this project is given below:

Table 56: Savings and cost benefit analysis for Energy management system [ECM-11]

Particulars	UOM	Present	Proposed
Energy management saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	9,021,840	8,841,403
Annual electricity saving per year	kWh/y	0	180,437

Particulars	UOM	Present	Proposed
Average Electricity Tariff	Rs/kWh	6.76	6.76
Annual monetary savings	lakh Rs/y	0	12.20
Number of Electrical equipments	#	50	50
No. of energy meters	#	0	50
Estimate of Investment	Lakh Rs		4.98
Thermal energy monitoring system	%	2.00	
Current coal consumption in HAG	kg/y	3,335,570	3,268,859
Annual coal saving per year	kg/y		66,711
Cost of Coal	Rs/kg		5
Annual NG consumption	scm/y	3,468,338	3,398,971
Annual fuel saving	scm/y		69,367
Average NG cost	Rs/scm	29.6	29.62
Total annual monetary savings	Lakh Rs/y		23.88
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		36.08
Total Estimated investment (Electrical + Thermal)	Lakh Rs		6.40
Payback period	Months		2.13
Project IRR	%		418
Discounted payback period	Months		0.85

5.2 Best Operating Practices

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

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Clay ball mill	VFD for energy saving.
3	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing pollution
4	Press	PRV installed for regulating usage of compressed air
5	Five layers Dryer	Waste heat from kiln is used in Five layers 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 collected 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 57 : Specifications of dry clay grinding technology

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

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

The working principle is as follows:

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

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

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

[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

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

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

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

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

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.

[4] SACMI Kiln Revamping catalogue for roller kilns

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

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

Figure 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.

[5] SACMI Kiln Revamping catalogue for roller kilns

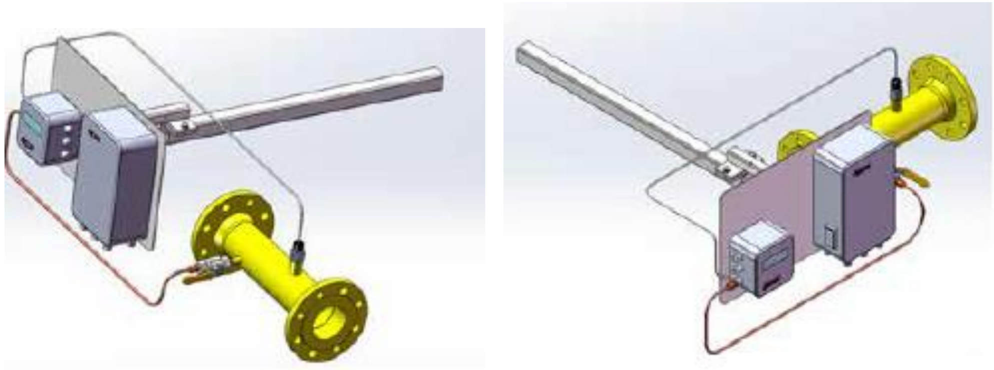


Figure 24: Combustion air control for burner

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

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

Figure 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

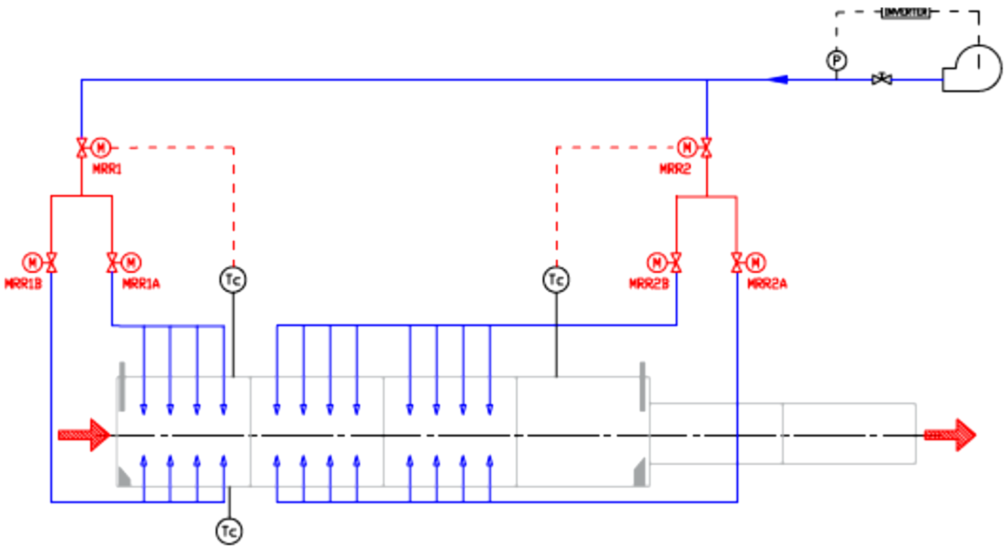


Figure 26: Fast cooling air management

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

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

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

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

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

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

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

5.3.6 Use of Organic Binder in Porcelain/Granite Tiles Manufacture

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

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

Advantages of using Binder for Vitrified tiles include:

- Lower dosage or effective binder cost.
- 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

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

two parameters, yield stress, τ0, and plastic viscosity, μ, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.

- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost

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

5.3.7 Use of Direct blower fans instead of belt drive

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

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

Figure 29: Direct drive blower fan

6. Chapter-6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA. A rooftop area of 10,000 m^2 is available in the unit. The feasibility of installing solar PV in this area was evaluated. The corresponding solar energy generation potential is shown below.

Table 58: Solar PV installation

Parameters	UOM	Value
Available area on roof	m^2	10,000
Estimated total solar PV panel area	m^2	6,000
Number of panels (1m x 2m) of 320 Wp	#	3,000
Estimated installed capacity of solar panel	kW	960
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	4,032
Solar radiation days per year	d/y	365
Average electricity generation per year	kWh/y	1,471,680
Cost of Electricity	Rs/kWh	6.76
Annual monetary savings	Lakh Rs/y	99.48
Estimated Investment	Lakh Rs	528
Payback Period	Months	64
Project IRR	%	-6%
Discounted payback period	Months	20.78

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

a) Increase in capital expenditure on account of
    a. Requirement for strengthening the structure for accommodating the solar panels.
    b. Requirement for construction of walkways for cleaning of solar panels.
b) Degradation of generation considered on account of heavy dust accumulation on the panels.
c) Increase in operating costs on account of
    a. Increased cleaning frequency.
    b. Requirement of DM water for cleaning the panels twice a day.

7. ANNEXES

7.1 Annex-1: Process Flow Diagram

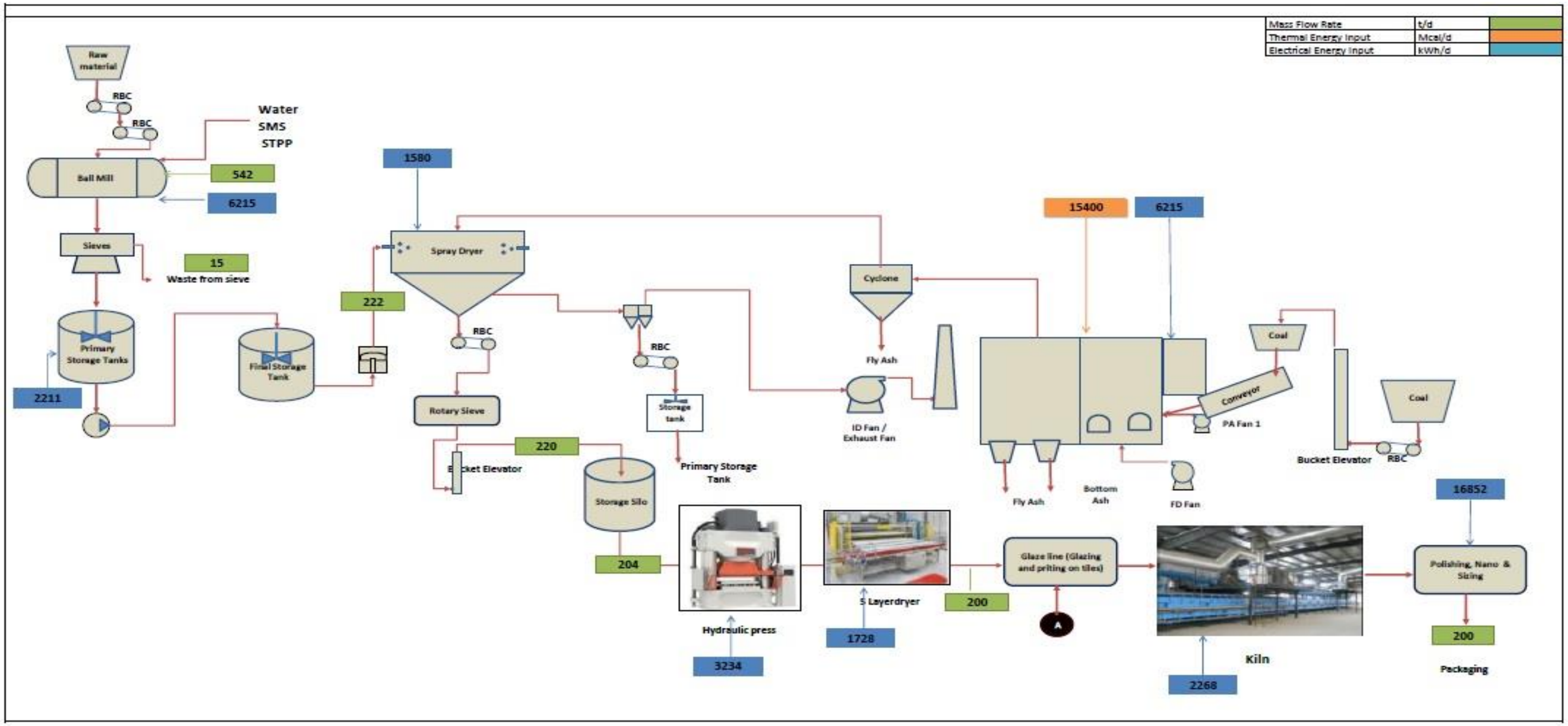


Figure 30: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 59: Detailed Inventory list

Equipment Name	UOM	Value
Compressor	kW	135
HAG & Spray Dryer	kW	269.2
Press-1	kW	139.5
Press-2	kW	139.5
Five Layers Dryer	kW	220.0675
Kiln	kW	444
Final Sizing m/c-1	kW	85.6
Final Sizing m/c-2	kW	85.6
Nano M/c-1	kW	117.5
Nano M/c-2	kW	117.5
Polishing m/c-1	kW	165
Polishing m/c-2	kW	165
Polishing m/c-3	kW	165
Polishing m/c-4	kW	165
Calibrating m/c-1	kW	165
Calibrating m/c-2	kW	165
Glaze ball mills	kW	66
Stirrer Motors	kW	137.5
Final Motor	kW	15
RO Plant	kW	8
Lights & Office connected Load	kW	40
Clay ball mill	kW	645
Total Connected Load	**kW**	**3654.96**

7.3 Annex-3: Single Line Diagram

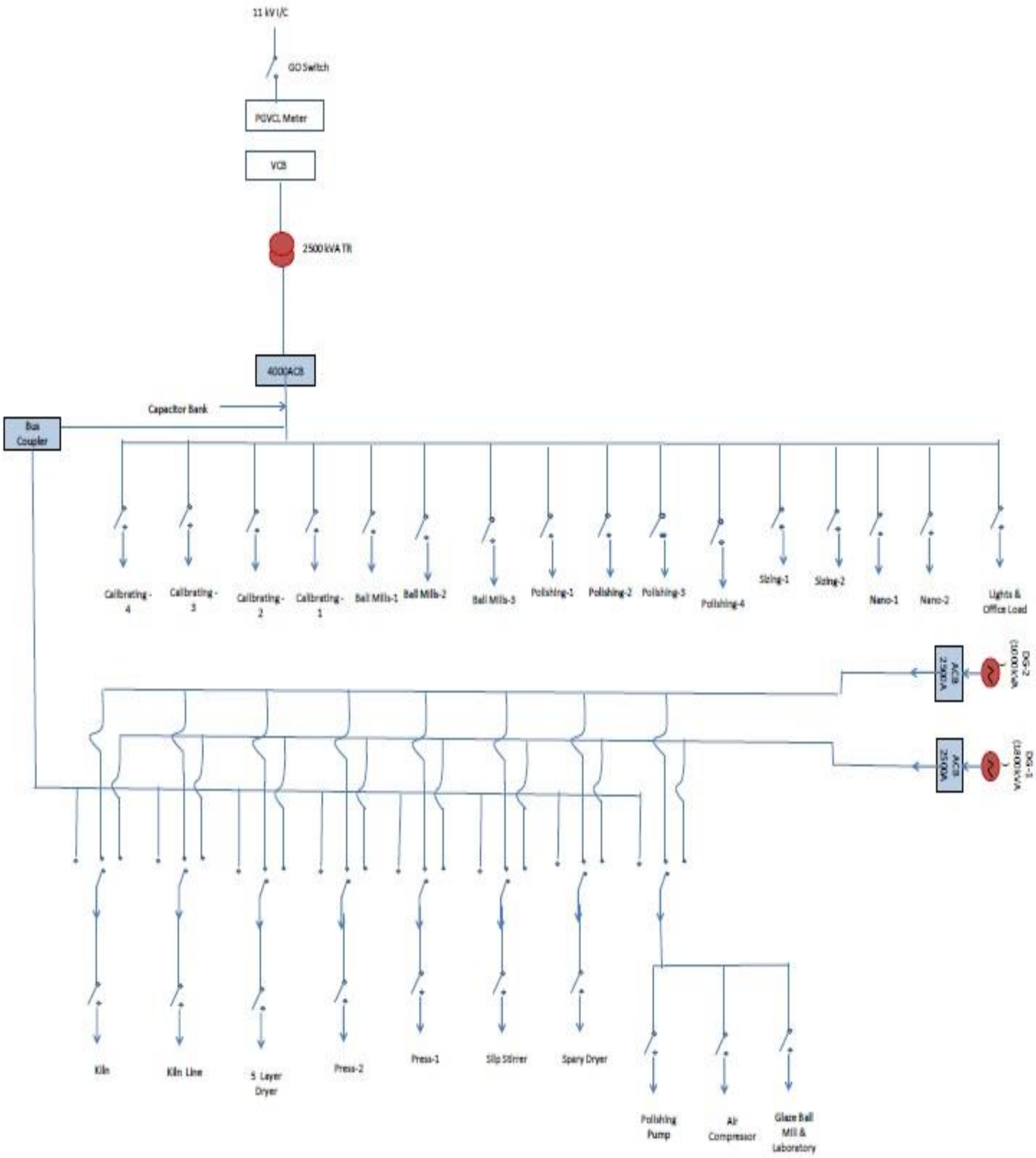


Figure 31: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

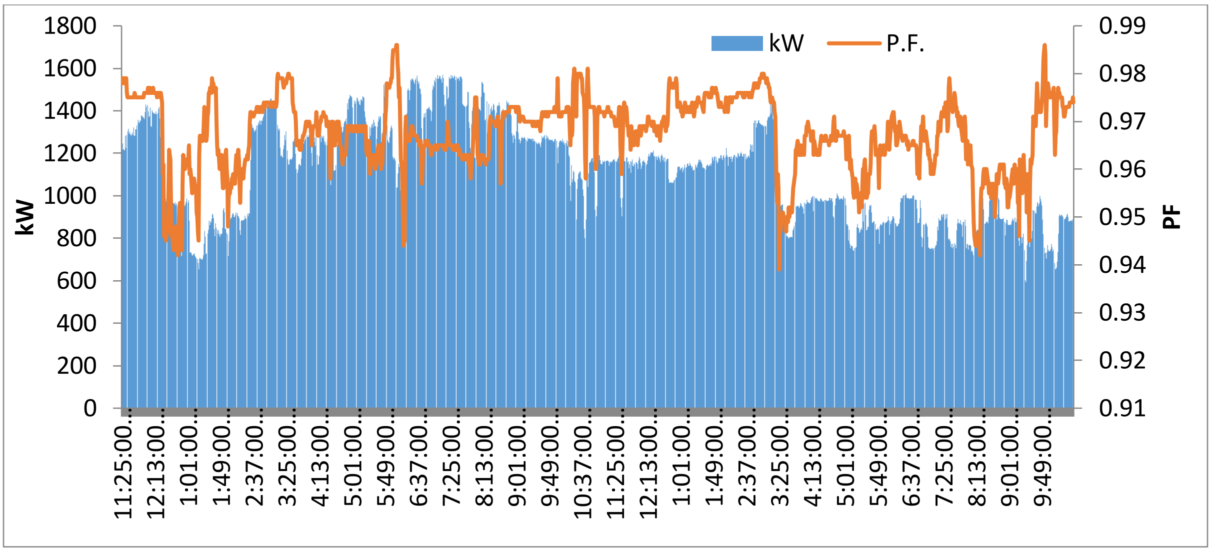
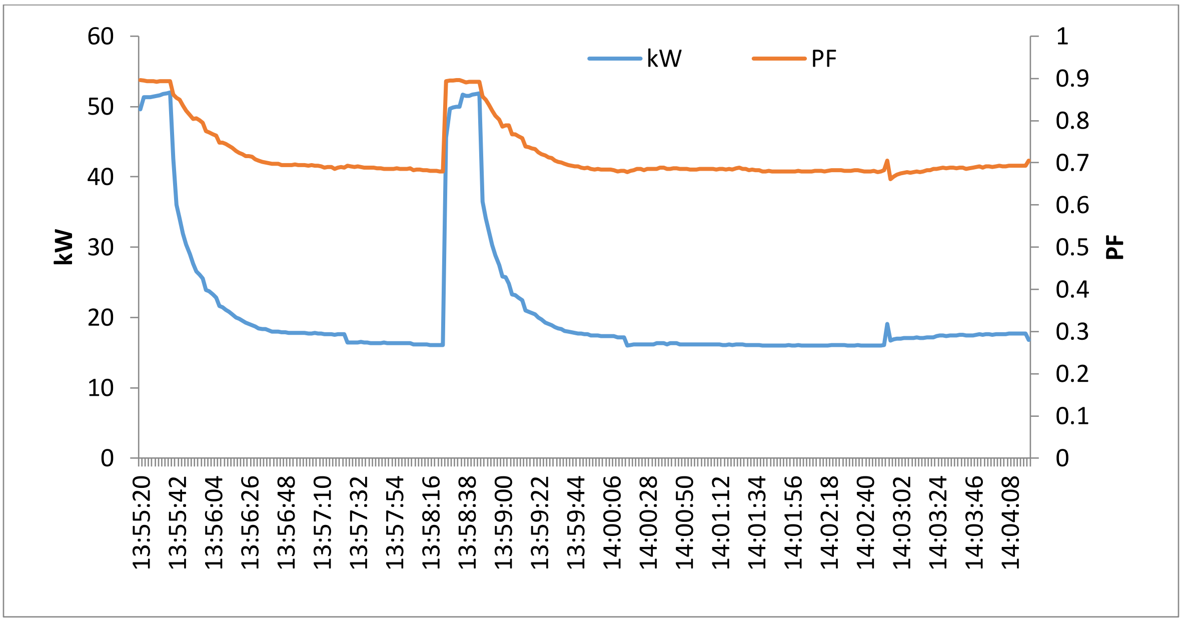


Figure 32: Power profile of Main incomer feeder



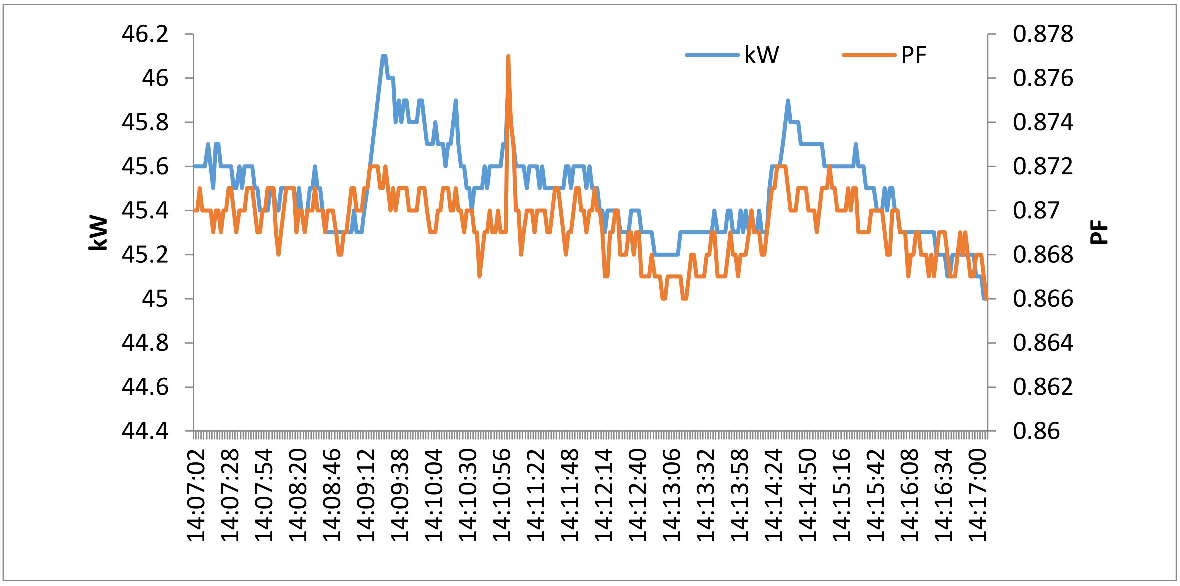
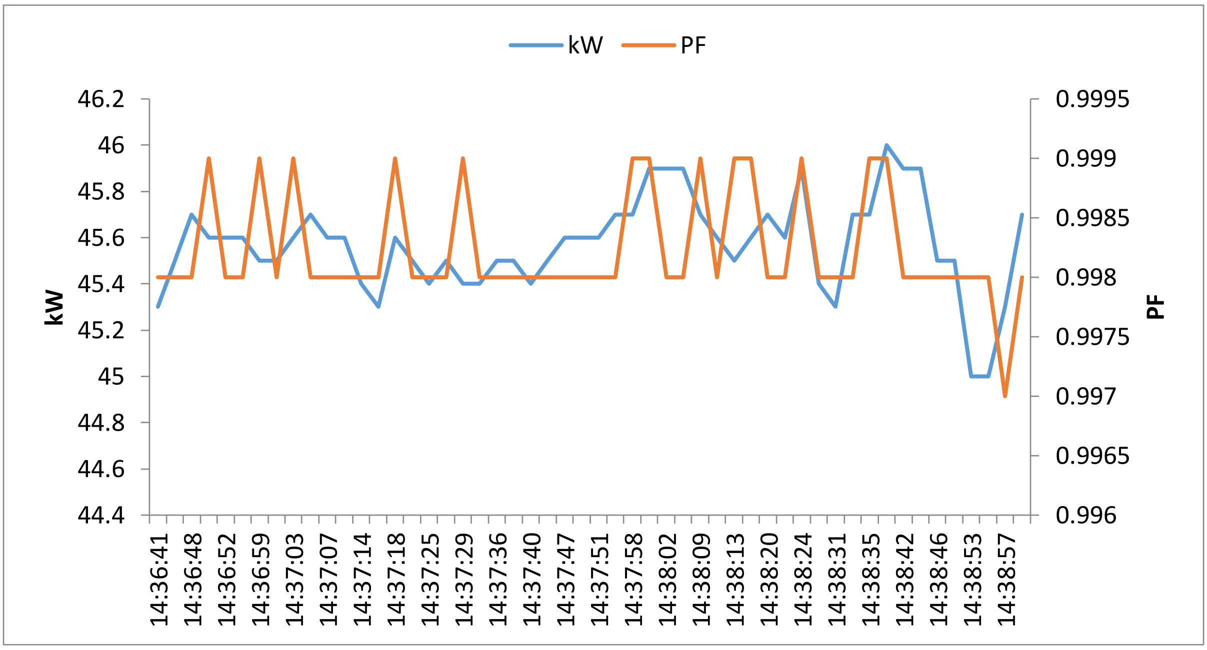


Figure 33: Power and PF profile of blowers of Compressor 1 & Compressor 2



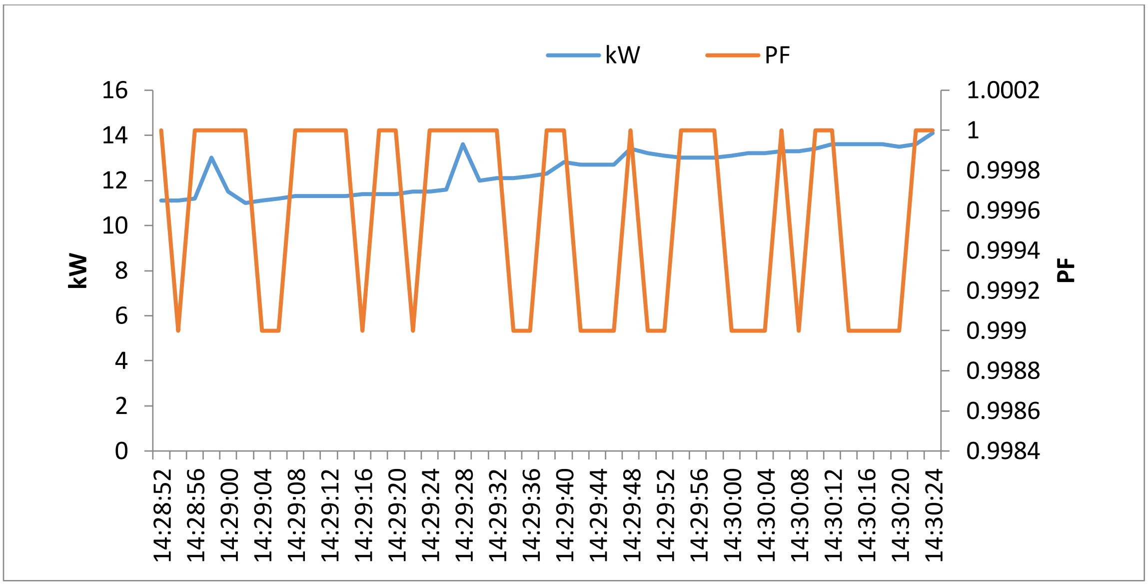


Figure 34: Power and PF profile of blowers of Spray dryer – ID fan & FD fan

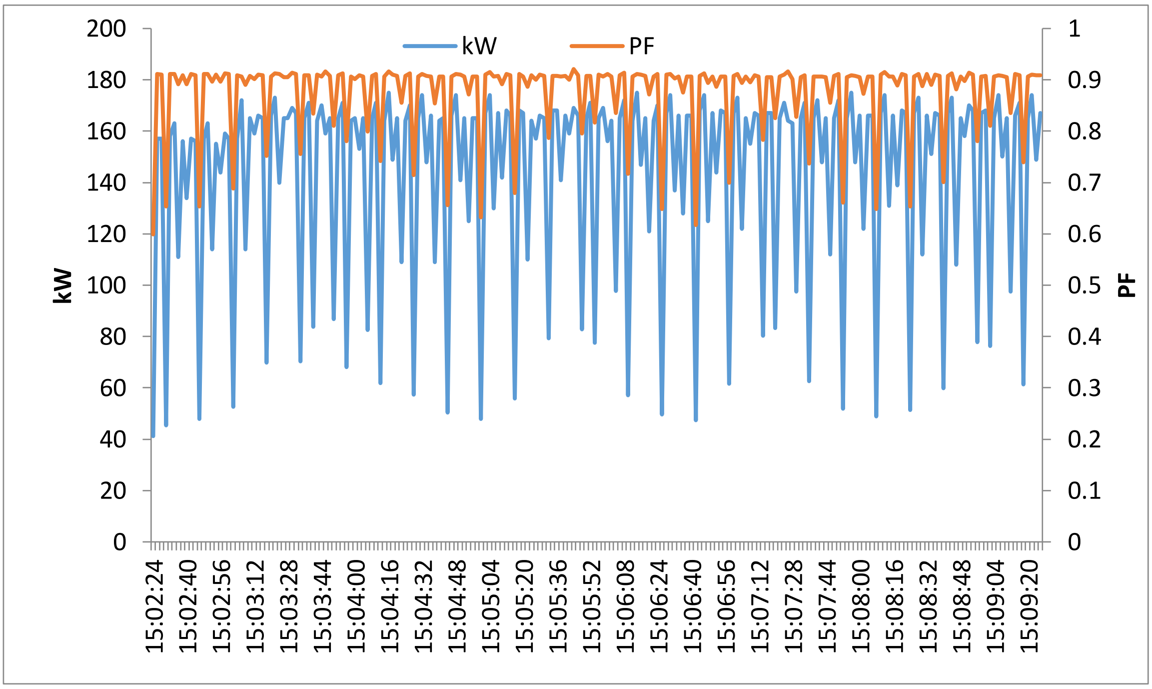


Figure 35: Power and PF profile of Press motor – 1

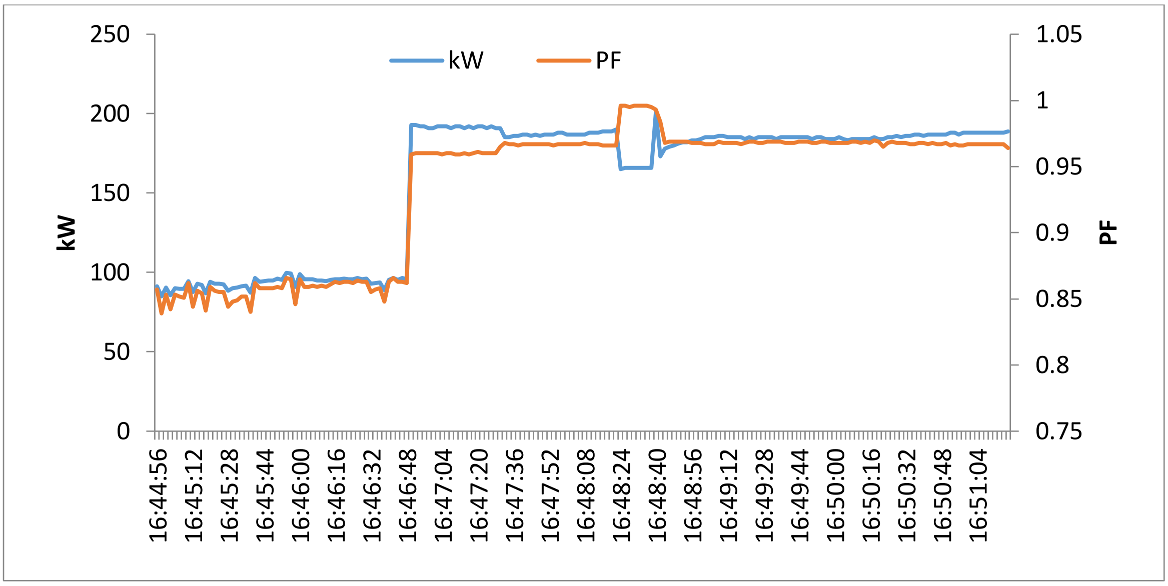
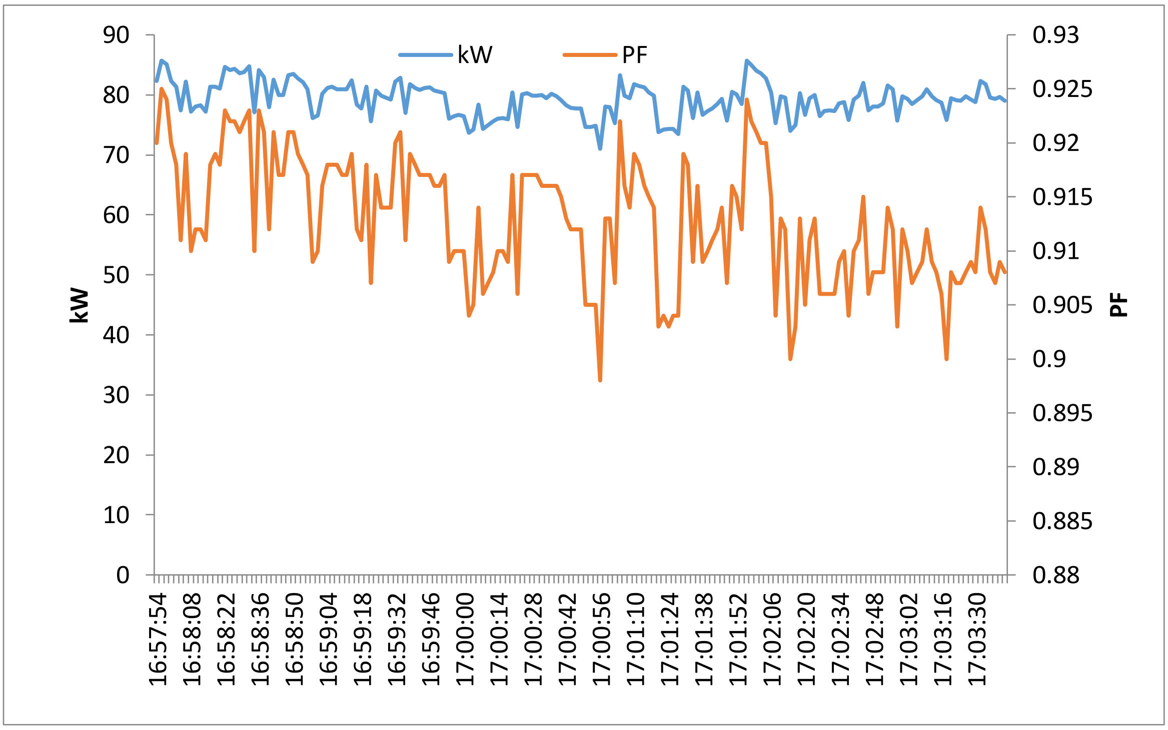


Figure 36: Power and PF profile of Final Sizing machine



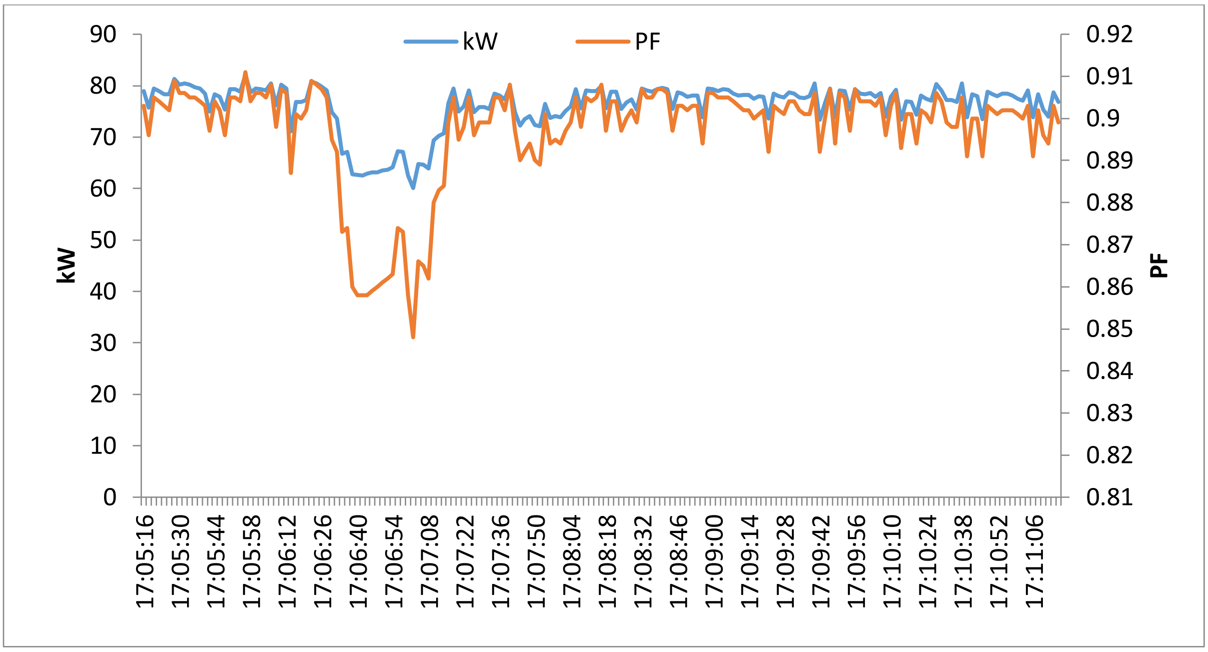
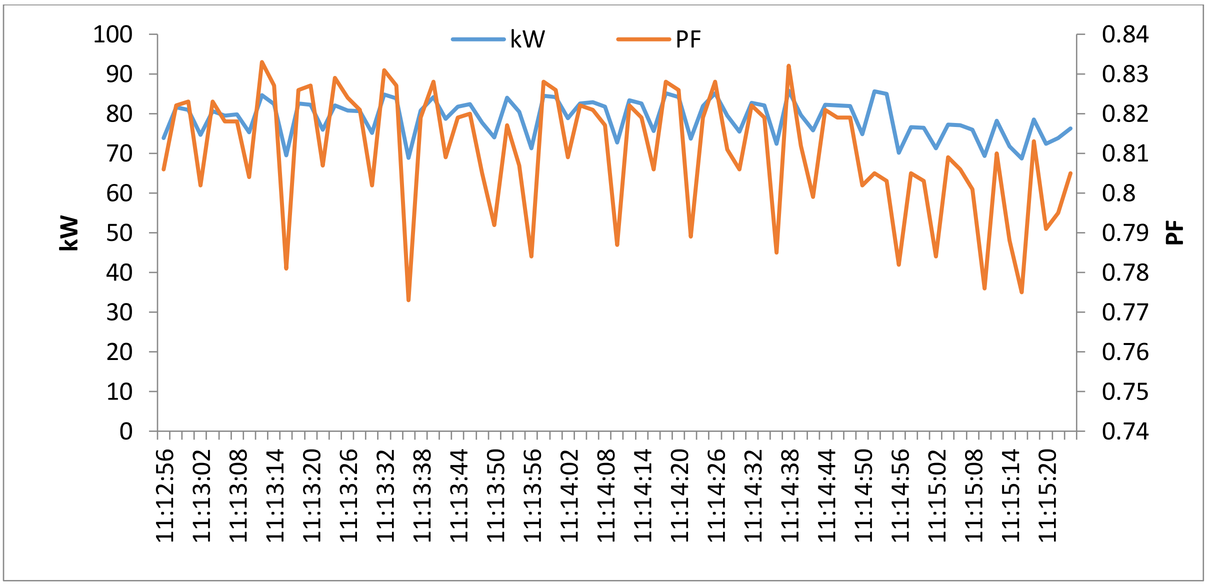


Figure 37: Power and PF profile of Nano machine 1 & 2



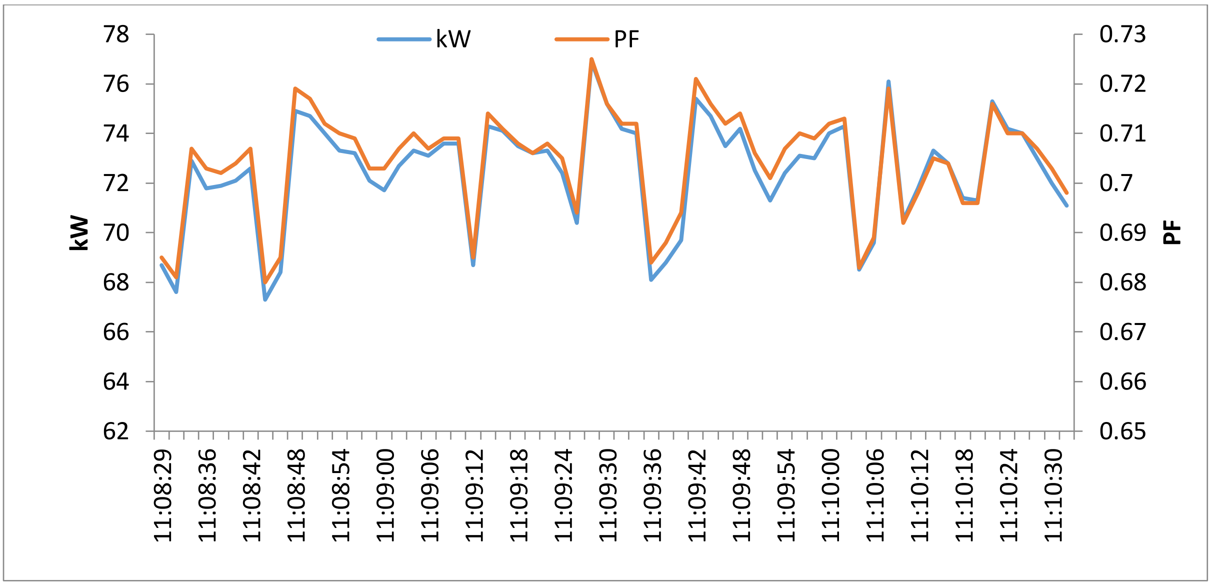


Figure 38: Power and PF profile of Polishing machine 3 & 4

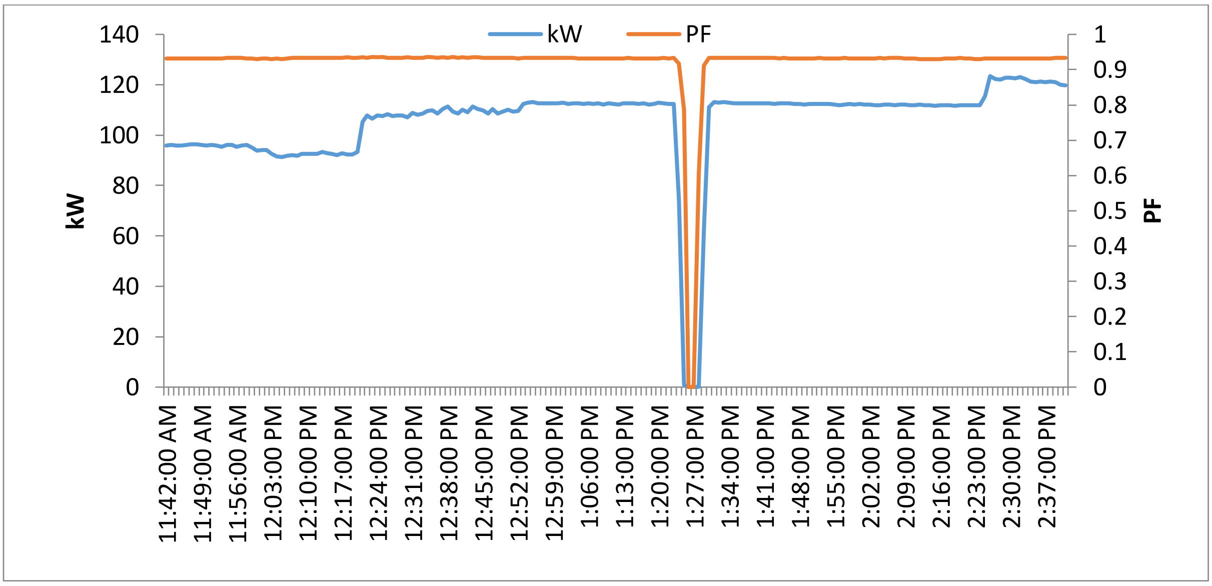


Figure 39: Power and PF profile of Clay ball mill – 1

7.5 Annex-5: Thermal Measurements

1. *Heat utilization calculations*

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujarat gas	
Kiln Operating temperature (Heating Zone)	1097	*°C*
Initial temperature of kiln tiles	45	*°C*
Avg. fuel Consumption	401.43	*scm/h*
Flue gas temp at smog blower	230	*°C*
O_2 in flue gas	4.64	*%*
CO_2 in flue gas	15.6	*%*
CO in flue gas	10.3	*ppm*
Ambient Temp.	38	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry 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	6,907	*kg/h*
Weight of Stock	6,907	*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*
Specific heat of superheated vapour	0.45	*kCal/kg °C*
Radiation and convection from preheating zone surface	5,807	*kCal/h*
Radiation and convection from heating zone surface	4,480	*kCal/h*
Heat loss from all zones	**10,287**	*kCal/h*
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	1.08	*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*

Heat utilization calculations

Calculations	Kiln	UOM
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	28.36	*%*
Actual Mass of Supplied Air	22.11	*kg/kg of fuel*
Mass of dry flue gas	20.87	*kg/kg of fuel*
Amount of Wet flue gas	23.11	*Kg of flue gas/kg of fuel*
Amount of water vapor in flue gas	2.24	*Kg of H_2O/kg of fuel*
Amount of dry flue gas	20.87	*kg/kg of fuel*
Specific Fuel consumption	58.12	*scm of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	523,096	*kCal/ton of tiles*
Total heat input	523,096	*kCal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	231,440	*kCal/ton of tile*
Heat loss in dry flue gas	55,897	*kCal/ton of tile*
Loss due to H2 in fuel	846	*kCal/ton of tile*
Loss due to moisture in combustion air	1,910.44	*kCal/ton of tile*
Loss due to partial conversion of C to CO	16.01	*kCal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	28.85	*kCal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	-	*kCal/ton of tile*
Total heat loss from kiln (surface) body	21,602	*kCal/ton of tile*
Heat loss due to unburnts in Fly ash	-	*kCal/ton of tile*
Heat loss due to unburnts in bottom ash	-	*kCal/ton of tile*
Heat loss due to kiln car	-	*kCal/ton of tile*
Unaccounted heat losses	211,357	*kCal/ton of tile*
Heat loss from kiln body and		
Total heat loss from kiln	21,602	*Kcal/ton*
Kiln heat utilization	**44.24**	*%*

2. *Heat Balance Diagram*

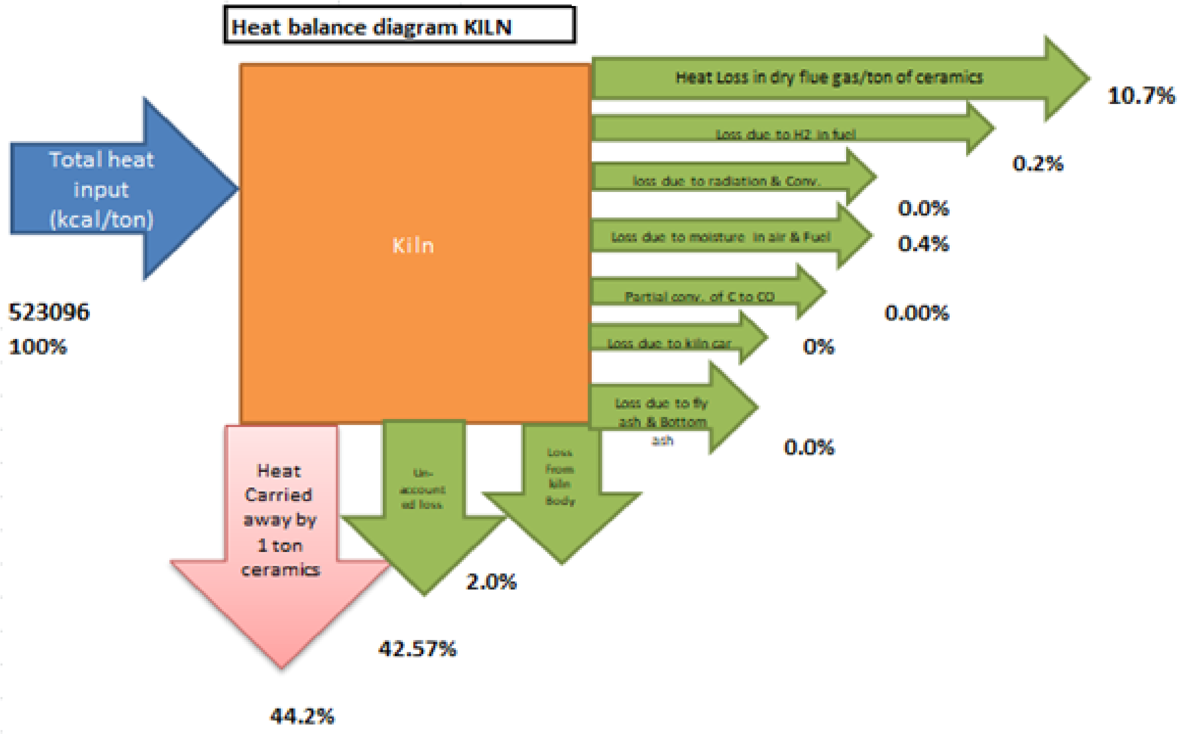


Figure 40: Heat Balance diagram of kiln

7.6 Annex-6: List of Vendors

ECM - 1: Excess air control in kiln

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

ECM - 2: Insulation improvement

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA	Tel:+ 91 44 2530 6888 Fax: 91 44 2534 5985 Mob: 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com ramaswamy.pondian@morganplc.com
2.	Divine Cera Wool India LLP	Survey 397, Nr. Bhalpura, Village - Khavad, Kadi to Sachana Road, Taluka - Kadi, District - Mahesana, Gujarat, India - 382 165	+91 9824655778	www.divinecerallp.com sales@divinecerallp.com
3.	Ravani Ceramic	Jadeshwar Chamber – 1 Shop No. 101 / 102 First Floor, N.H.8/A Near Zanjar Cinema Wankaner – 363621 Dist – Morbi, Gujarat	Dipak Patel: +91 93280 42126 General Manager Aliasgar Ghiyawadwala: +91 99242 47069	ravanicera@yahoo.com

ECM - 3: 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 - 5: VFD in compressor

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

ECM - 6: Pumps replacement with Efficient pumps

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

Sl.No.	Name of Company	Address	Phone No.	E-mail
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 - 7 : Installation of Harmonics filter

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

ECM - 8 : Cable loss minimization

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	NIFA Electronics Pvt. Ltd.	64, Shankheswar Indl park; 20/2, Ph-1, GIDC, Vatva; Nr. Railway Bridge, Ahmedabad – 382 445, Gujarat, India.	Mob: +91 7929707399	sales@nifaelectronics.com
2	Next Gen-Power Control Centre	19, Satsang Ind Estate,Opp. Malhar Estate,, B/h. Safari Restaurant,S.P. Ring Road,, Odhav,, Ahmedabad, Gujarat 382415	Mr. Sanjay Patel 91730 18114, 9173018114 +91-8487070735	www.nextgencontrols.net nextgen.panels@gmail.com
3	Yesha Electricals Pvt. Ltd	C-2/18, Industrial Estate, Gorwa Road Vadodara	Mr. M.R.Patel 0265-2282271	NA

ECM - 9 : Voltage optimization for lights

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Protek Enterprises	Protek House, Opp Swaminarayan mandir, On I.O.C. road, Chandkela, Ahmedabad-382424, Gujarat, India.	Mob: +91 7965216521	info@protekg.com
2	SERVOKON System ltd.	Servokon House,C-13,Radhu palace road, opp.scope minar,Laxmi Nagar, Delhi-110092	75330088 Toll free:18002001786	http://www.servokonstabilizer.com/contact-us.html
3	SERVOMAX INDUSTRIES LIMITED (Manufacturer)	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033 BRANCH: #166A, 2nd Floor,Pratap Nagar, Mayur Vihar,Phase-I, New Delhi-110092	+91 9111234567	customercare@servomax.in www.wervomax.in

ECM-10: V Belt with REC belt replacement

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Shree Ram Marketing Co.	67, Sharhanand Marg, G.B. Road, Shardanand Marg, Delhi – 110006	08048022651	NA
2.	Mangal singh Bros. Pvt Ltd	24-B, Raju Gardens, Near Krishnasamy nagar, Sowripalayamp Post, Coimbatore-641028	Ramiz Parker +91 77381 86851	mangalsinghcbe@gmail.com
3	Shreeji Traders	Mahavir Cloth Market, B/H, Kapasiya Bazar, Old Railway Station,, Kalupur, Ahmedabad, Gujarat 380001	+91 94281 01565	NA

ECM - 11: Energy Management system

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

7.7 Annex-7: Financial analysis of project

Table 60: 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 (WDV)	%	15.00%
Effective Tax Rate	%	26.750%
Effective MAT Rate	%	21.000%
Discount factor	%	15.000%