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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE VT-68: LATIGRES VITRIFIED PVT. LTD.

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

DEVELOPMENT ENVIRONERGY SERVICES LTD
819, Antriksh Bhawan, 22 Kasturba Gandhi Marg, New Delhi -110001
Tel.: +91 11 4079 1100 Fax: +91 11 4079 1101; www.deslenergy.com

April-2019

Bureau of Energy Efficiency, 2019

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

For more information

GEF-UNIDO-BEE PMU
Bureau of Energy Efficiency
4th Floor, Sewa Bhawan, Sector-1,
R.K. Puram, New Delhi-110066

Email: gubpmu@beenet.in
Website: www.beeindia.gov.in

Disclaimer

This **Comprehensive Energy Audit Report** is an output of an exercise undertaken by **Development Environergy Services Ltd.** (DESL) under the GEF-UNIDO-BEE project's initiative for the benefit of MSME units and is primarily intended to assist and build the capability of decision making by the management of MSME units for implementation of EE & RE technologies, BOP etc. While every effort has been made to avoid any mistakes or omissions. However, GEF, UNIDO, BEE or DESL would not be in any way liable to any person or unit or other entity by reason of any mistake/omission in the document or any decision made upon relying on this document.

ACKNOWLEDGEMENT

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

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

DESL is indebted to M/s. Latigres 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. Mukeshbhai Udhreja - Director
2. Mr. Sudhirbhai Patel, Manager

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

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

DESL Team

Project Head	R Rajmohan, Chief Executive Officer
Team leader and co-coordinator	Mr. M G Dave, Senior Consultant
Team members	Ashok Kumar, Analyst Sandeep Sharma, Assistant Analyst

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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	^0C
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
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.

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

➨ INTRODUCTION OF THE UNIT

Name of the Unit	Latigres Vitrified Pvt. Ltd.
Year of Establishment	2014
Address	S/no. 135/1 8-a N/H, B/h Lalpar 132 kV power house, at: Jambudiya, Morbi
Products Manufactured	Vitrified Tiles
Name(s) of the Promoters / Directors	Mr. Mukeshbhai N Udhreja

➨ 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 coal 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 slip sprayed through the nozzle, So ID fans present outside suck the moisture.
- **Hydraulic press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Dryer:** Biscuits are sent to dryer for pre drying after it is passed through kiln.
- **Glaze ball mill:** For producing glazing material used on the product.
- **Kiln:** Biscuits 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 are:

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

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Waste heat recovery from flue gas: The flue gas (smoke) temperature at kiln outlet was found to be 260°C. It is recommended to decrease the smoke temperature from 260°C to 200°C at the outlet of recuperator, thereby increasing the heat utilization in kiln and increasing the temperature of combustion air entering in kiln.
- Insulation improvement in kiln section: It was found that the surface temperature of combustion air pipe near recuperator and near burner was 160°C against desired value of 50°C. It is recommended to insulate the mentioned area and thereby reduce fuel consumption.
- Excess air control in HAG: Coal is used as fuel in HAG and oxygen content in flue gas was found to be 14% against desired level of 8%. 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 in HAG section: 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 1,200ppm against desired level of 400ppm. It is recommended to install water softener plant which will blend RO water with raw water.
- PID Controller in CT fans: The CT fans of press and Gasifier are running continuously throughout the day. It is proposed to install PID controller in CT fans which will operate based on the temperature set point.
- Retrofit of VFD for compressor -1 & 2: 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 compressors 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 5 kg/cm^2.
- Replacement of inefficient pumps: Gasifier CT pump-1 & 2 (pump 1 - 50% & pump 2 - 58%) were running at lower efficiency against desired efficiency of 75%. It is recommended to replace the existing pumps with energy efficient pumps.
- Retrofit of VFD in Gasifier & Press CT pumps: The Gasifier & press CT pumps were operating continuously irrespective of load requirement. It is recommended to install VFD and reduce energy consumption.
- 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: The Polishing, Nano, Sizing and Calibration machines were operating at poor power factor of 0.5-0.8. It is recommended to install power factor improvement capacitors.
- Voltage optimization in lighting circuits: The present voltage for lighting circuit was found to be 455V against desired voltage of 380V. It is recommended to install separate lighting transformer of 30kVA 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.

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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	Waste heat recovery from flue gas	-		564	310	33.0	109.4	40	1,194
2	Insulation improvement in kiln section	-		47	26	2.76	1.05	5	100
3	Excess air control in HAG	-		812	447	47.5	18.5	5	1,718
4	Insulation improvement in HAG section	-		45	25	2.63	4.60	21	95
5	Using soft water in clay bal mill	31,158.04	0	540	300	70.3	39.6	7	1,169
6	PID Controller in CT fans	142,312		0	12	9.65	0.79	1	117
7	Retrofit of VFD for compressor -1 & 2	108,185		0	9	7.34	1.82	3	89
8	Compressed air pressure reduction	48,702		0	4	3.30	1.69	6	40
9	Replacement of inefficient pumps	92,413		0	8	6.3	1.2	2	76
10	Retrofit of VFD in gasifier & Press CT pumps	73,234			6	4.97	2.22	5	60
11	Installation of Harmonic filter	26,477			2	1.80	7.13	48	22
12	Cable loss minimization	42,984			4	2.83	2.53	11	35
13	Voltage optimization in lighting circuits	32,056		0	3	2.17	1.16	6	26
14	V belt to REC belt replacement	80,940			7	5.49	5	11	66
15	Energy Management system	217,805		230	145	28.25	6.13	3	666
	Total	**896,264**	**0**	**2,239**	**1,309**	**228**	**203**	**11**	**5,473**

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

- Reduction in energy cost by 12.71%.
- Reduction in electricity consumption by 7.58%.
- Reduction in thermal energy consumption by 29.93%.
- Reduction in greenhouse gas emissions by 26.74%.

FINANCIAL ANALYSIS

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

Table 2: Financial indicators

Sl No	Energy Conservation Measure	Investment Lakh Rs	IRR %	Discounted Payback Period Months
1	Waste heat recovery from flue gas	109.44	9	13.76
2	Insulation improvement in kiln section	1.05	198	1.80
3	Excess air control in HAG	18.48	193	1.85
4	Insulation improvement in HAG section	4.60	38	7.71
5	Using soft water in clay ball mill	39.60	138	1.19
6	PID Controller in CT fans	0.79	896	0.40
7	Retrofit of VFD for compressor -1 & 2	1.82	302	1.19
8	Compressed air pressure reduction	1.69	147	2.42
9	Replacement of inefficient pumps	1.19	396	0.91
10	Retrofit of VFD in gasifier & press CT pumps	2.22	168	2.11
11	Installation of harmonic filter	7.13	2	16.80
12	Cable loss minimization	2.53	85	4.11
13	Voltage optimization in lighting circuits	1.16	142	2.51
14	V belt to REC belt replacement	5.00	80	4.24
15	Energy management system	6.13	343	1.04

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	Latigres Vitrified Pvt. Ltd.			
Plant Address	S/no. 135/1 8-A N/H, B/h Lalpar 132 k.v. power house, at. Jambudiya, Morbi			
Constitution	Private Limited			
Name of Promoters	Mr. Mukeshbhai N Udhreja			
Contact person	Name	Mr. Sudhirbhai Patel		
	Designation	Manager		
	Tel	70690 66601/18, 97277 60071		
	Fax			
	Email	care@latigres.in (info@letina.in)		
Year of commissioning of plant	2014			
List of products manufactured	Twin Charge, 600 x 600 mm (4 tiles/box)			
Installed Plant Capacity	7,500 boxes/day			
Financial information (Lakh Rs)	2014-15		2015-16	2016-17
Turnover	Not provided			
Net profit				
No of operational	Days/Year		365	

Description	Details		
days in a year	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	230	
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	Yes	Spray drier
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas (scm)	Yes	Kiln
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
Interested in DEA	Yes		
	Very Interested		

1.3 Methodology and Approach

The study was conducted in 3 stages:

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

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

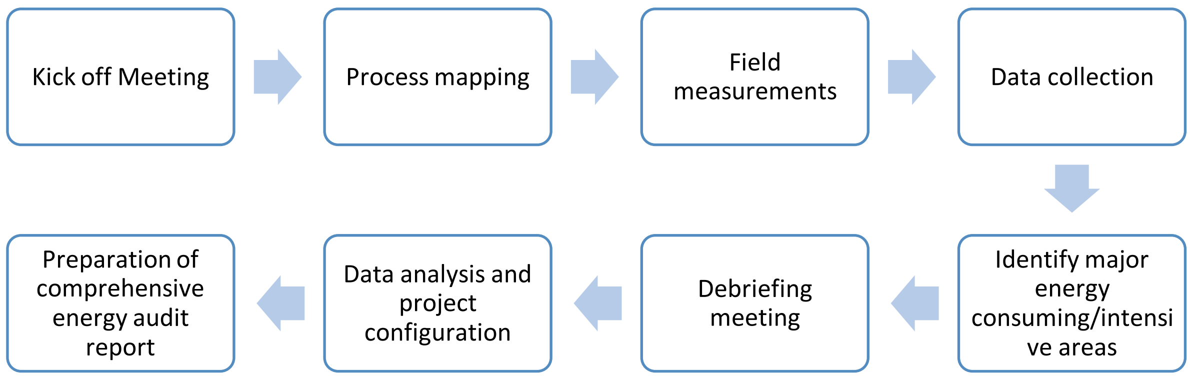


Figure 1: General methodology

The field work was carried out during 24-27th November 2018.

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

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

1.4 INSTRUMENTS USED FOR THE STUDY

List of instruments used in energy audit are the following:

Table 4: Energy audit instruments

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

Sl. No.	Instruments	Parameters Measured
15	Pressure Gauge	Water pressure 0 to 40 kg

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:

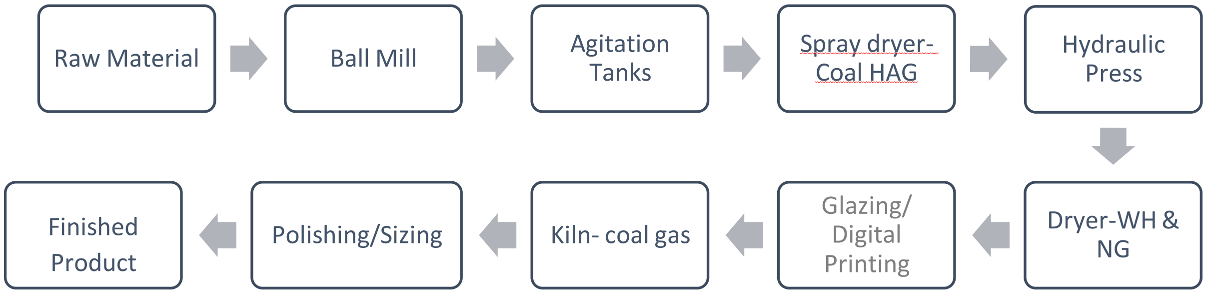


Figure 2: Process Flow Diagram

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 preheated initially in Five Layer dryer at about 140-150°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.
- **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. instrument air, air cleaning, glazing etc.

- **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.
- **Coal gasifier:** Coal gasifier is used to generate coal gas which in turn is used in kiln as fuel for baking of tiles.
- **Kiln:** The kiln is the main energy consuming equipment. The kilns are about 170 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.

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	#
Twin Charge	600 x 600	27	0.36	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

Month	Number of boxes 600 x 600	Corresponding area (m^2) 600 x 600	Corresponding mass (MT) 600 x 600
Apr-17	125,588	180,846.72	3,391
May-17	131,407	189,226.08	3,548
Jun-17	125,846	181,218.24	3,398
Jul-17	26,283	37,847.52	710
Aug-17	127,110	183,038.4	3,432
Sep-17	163,743	235,789.92	4,421
Oct-17	153,610	221,198.4	4,147
Nov-17	102,365	147,405.6	2,764
Dec-17	96,752	139,322.88	2,612
Jan-18	110,806	159,560.64	2,992
Feb-18	94,669	136,323.36	2,556
Mar-18	98,290	141,537.6	2,654
Total	1,356,469	1,953,315	36,625

2.3 Energy Scenario

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

- Electricity is supplied from two different sources:
    - From the utility, Paschim Gujarat Vij Company Ltd. (PGVCL)

- Captive backup diesel generator sets for whole plant
- Thermal energy is used for following applications :
    - Coal gas for kiln
    - Natural gas (NG) for five layers dryer

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

Table 7: Energy use and cost distribution

Particular	Energy cost Distribution		Energy distribution	
	Rs.(Lakh)	% of Total	MTOE	% of total
Grid-Electricity	799.57	44	1,017.1	15.0
Coal	294.12	16	2,799.6	41.4
Natural Gas	703.47	39	2,949.2	43.6
Total	1,797.16	100	6,766.0	100.0

This is shown graphically in the figures below:

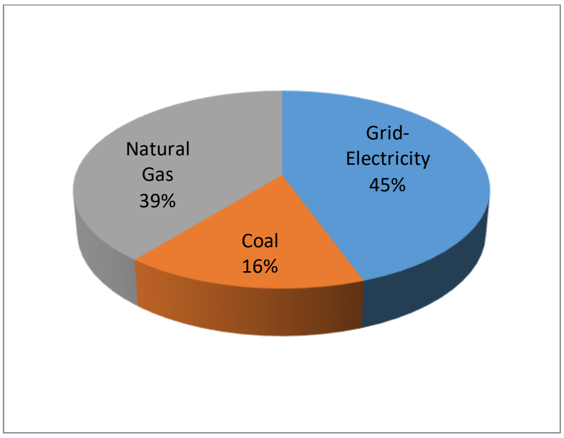


Figure 3: Energy cost share

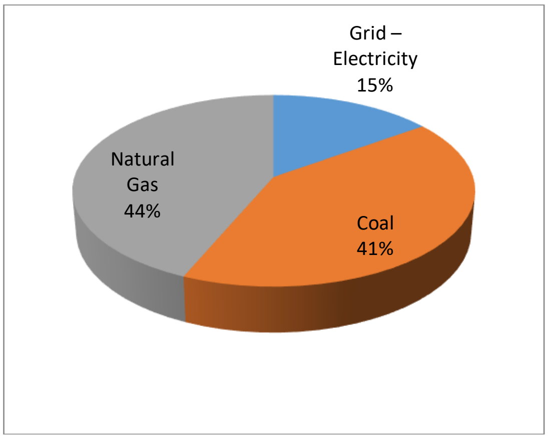


Figure 4: Energy use share

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 45% of the energy cost and 15% of the overall energy consumption.
- Coal is used in Coal gas generation and in hot air generator to generate hot air. Coal accounts for 16% of the total energy cost and 41% of overall energy consumption.
- NG used in five layers dryer accounts for 39% of the total energy cost and 44% 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
Meter Number	PG5A4492
Tariff Category	HTP-I
Contract Demand, kVA	-
Supply Voltage, kV	11

The tariff structure is as follows:

Table 9: Electric Tariff structure

Particulars	Tariff structure for Category HTP-1
Demand Charges (Rs/kVA)	
1st 500 kVA	150
2nd 500 kVA	260
Next 500	475
Energy Charges (Rs./kWh)	
Normal Hours	4.2
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 Mar-18)

2.3.1.2 Month wise Electricity Consumption and Cost

Month wise total electrical energy consumption is shown as under:

Table 10: Monthly electricity consumption & cost

Month	Units consumed kWh	Total Electricity cost Rs.	Average unit Cost Rs./kWh
Apr-17	1,085,790	7,304,373	6.73
May-17	1,097,820	7,429,388	6.77
Jun-17	1,506,177	9,799,209	6.51
Jul-17	1,085,790	7,304,373	6.73
Aug-17	758,130	5,300,560	6.99
Sep-17	898,620	6,175,382	6.87
Oct-17	879,180	6,066,729	6.90
Nov-17	820,110	5,679,670	6.93
Dec-17	873,690	6,000,085	6.87
Jan-18	1,031,760	6,923,882	6.71
Feb-18	900,240	5,955,113	6.62
Mar-18	889,290	6,017,899	6.77

2.3.1.3 Analysis of month-wise electricity consumption and cost.

Average electricity consumption is 985,550 kWh/month and cost is Rs. 66.63 Lakhs per month (April-17 to March -18). The average cost of electricity is Rs. 7 /kWh. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

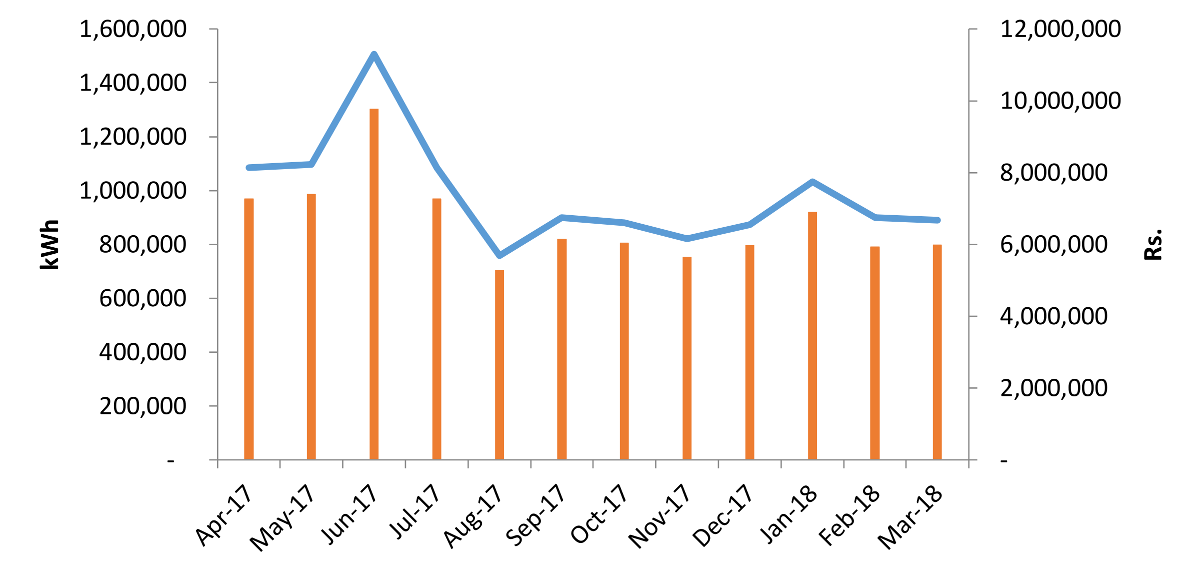


Figure 5: Month wise Variation in Electricity Consumption

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

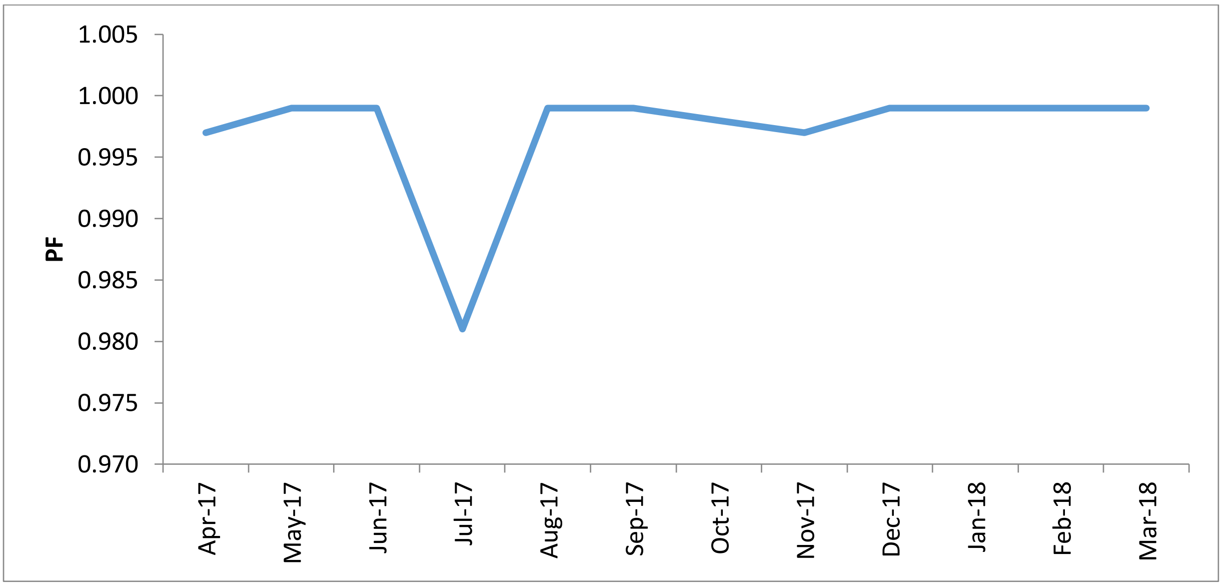


Figure 6: Month wise variation in Power Factor

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 0.997 and the maximum being 0.999.

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

Maximum Demand: Maximum demand as reflected in the utility bill is 2,238 kVA from the bill analysis.

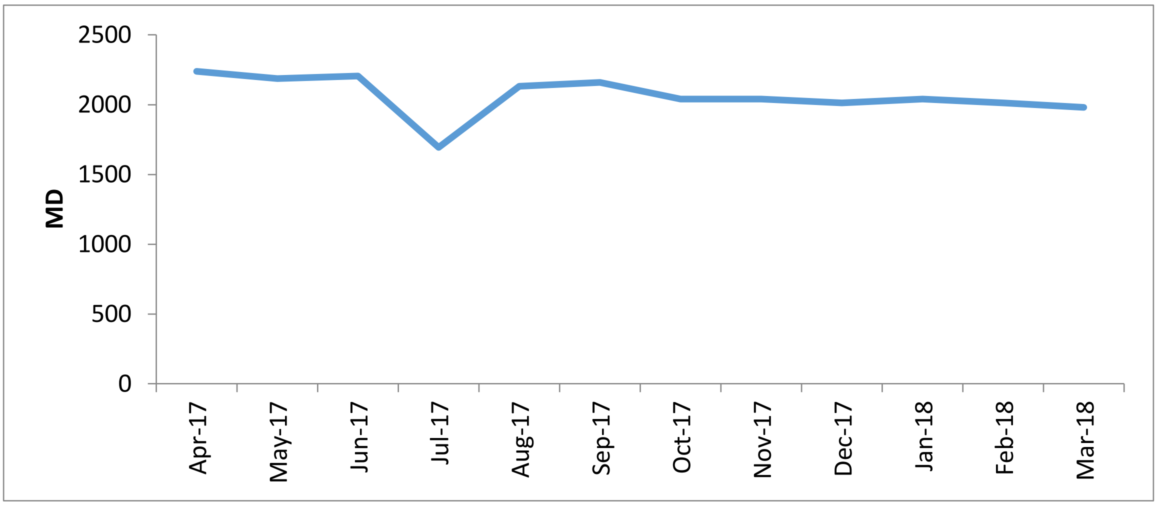


Figure 7: Month wise variation in Maximum Demand

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

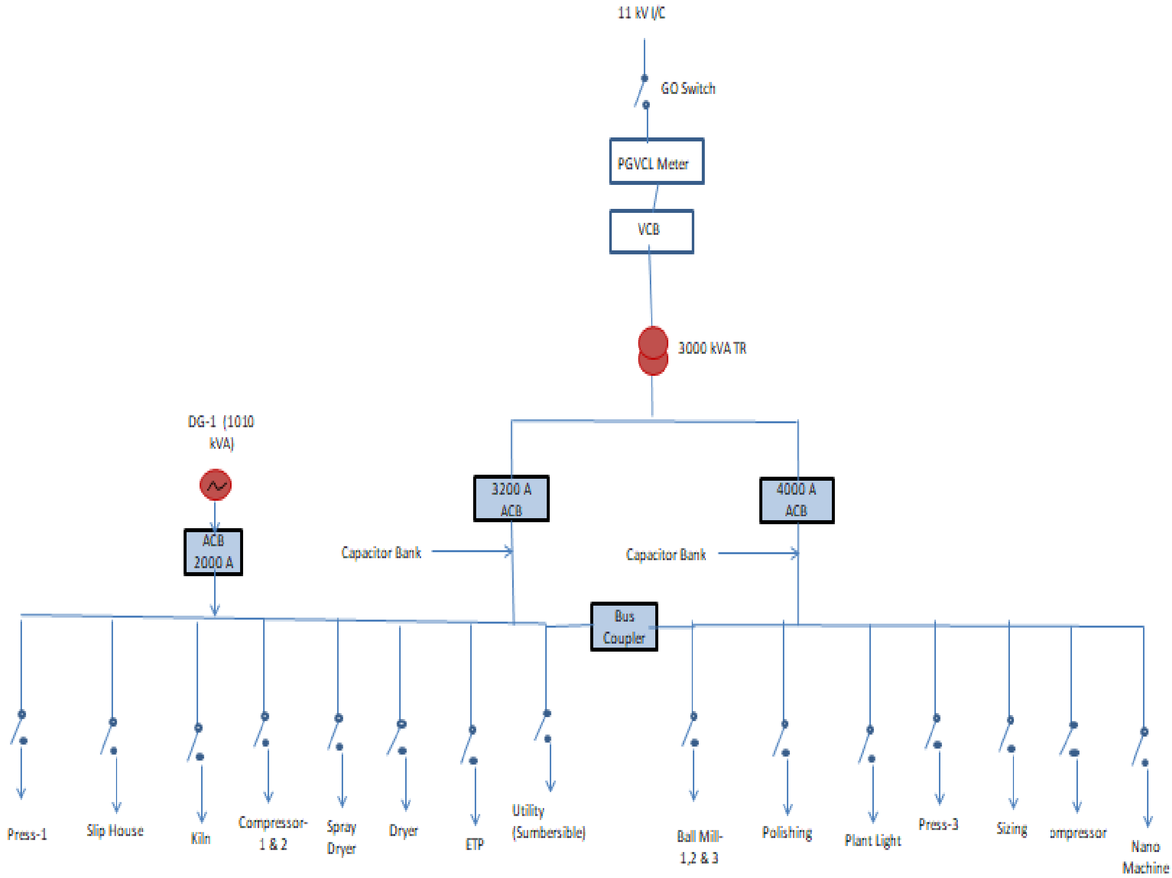


Figure 8: Single Line Diagram (SLD)

2.3.1.5 Electricity consumption areas

The plant total connected load is 4,111.8 kW, which includes:

- Plant and machinery load is 4,002 kW.
- Utility load is (lighting, air compressor and fans) about 144 kW including the single phase loads.

Table 11 : Equipment wise connected load (Estimated)

Equipment	UOM	Value
Five layers Dryer	kW	254
Presses	kW	422
Kiln	kW	342
HAG	kW	224
Piston Pump	kW	60
Compressor	kW	74
Stirrer Motor	kW	225
Clay Ball Mill	kW	435
Coal Gasifier	kW	104
Initial Sizing Machines	kW	186
Final Sizing Machines	kW	186
Calibrating Machines	kW	480
Polishing Machines	kW	676
Nano Machines	kW	408
Lights & Office Load	kW	35
Glaze ball mills	kW	120
Total	kW	4232

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

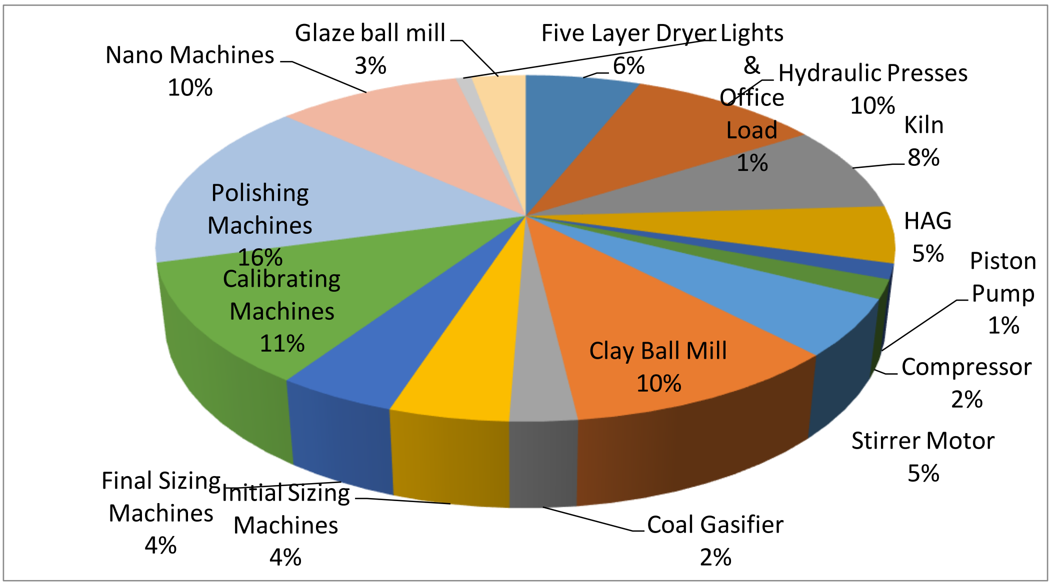


Figure 9: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Polishing machine-16%, for the Calibrating Machines– 12%, for Clay Ball Mill– 11%, for Nano machines & Presses - 10% each, for Kiln - 8%, for five layer dryer– 6%, for Initial and Final Sizing Machine- 5% each, for stirrer motor & Hot Air Gasifier -5% each, Coal Gasifier-3%, Glaze ball mill-3%, Compressor-2% and other loads.

2.3.1.6 Specific electricity consumption

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

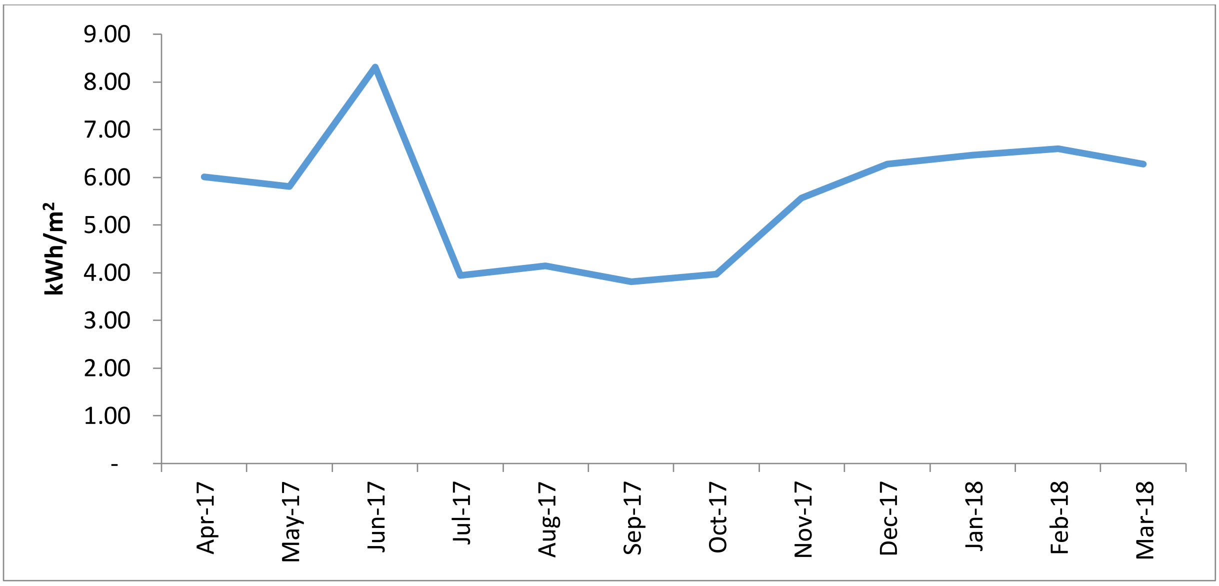


Figure 10: Month wise variation in Specific Electricity Consumption

Three months, Jul-17, Aug-17, Sep-17 and Oct-17 are outliers. Excluding these months, the maximum and minimum values are within ±25% of the average SEC of 6 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 kiln, 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, secondary dryers and the kilns. Coal is used as the fuel for to produce coal gas for firing in the kiln and to generate hot air from hot air generator. Coal gas is produced at plant level by a coal gasifier. Coal imported from Indonesia is being used. Natural Gas is purchased from GSPC (Gujarat State Petroleum Corporation) and used in the five layers dryer only. Based on the gas bill shared for the month of April-17 to Mar-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 Used in Drier			Coal used in Gasifier		
	NG Use scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs/MT
Apr-17	341,508	10,278,267	30.10	0	0	0
May-17	337,446	10,141,839	30.05	251	1,382,041	5,500.004
Jun-17	313,141	9,522,834	30.41	0	0	0
Jul-17	28,746	2,126,270	73.97	0	0	0
Aug-17	261,812	7,963,111	30.42	555	2,889,787	5,209.358
Sep-17	291,065	8,245,845	28.33	707	3,705,846	5,243.874

Month	NG Used in Drier			Coal used in Gasifier		
	NG Use scm	NG Cost Rs	NG Cost Rs/scm	Coal Used MT	Coal Cost Rs	Coal cost Rs/MT
Oct-17	288,351	6,962,478	24.15	620	3,170,048	5,111.085
Nov-17	270,282	7,666,329	28.36	472	2,315,959	4,908.877
Dec-17	208,589	8,774,346	42.07	679	4,333,528	6,383.537
Jan-18	336,695	10,154,016	30.16	680	4,373,358	6,434.437
Feb-18	296,077	9,149,287	30.90	616	3,923,804	6,370.329
Mar-18	303,229	9,305,649	30.69	511	3,317,793	6,492.491

Observation (for the period April-17 to March-18)

- Average monthly coal consumption is 424 tons and average cost Rs. 24.51 Lakhs/month.
- Average monthly gas consumption is about 273,078 scm and average cost is Rs 83.57 Lakhs/month.

2.3.2.2 Specific Fuel Consumption.

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

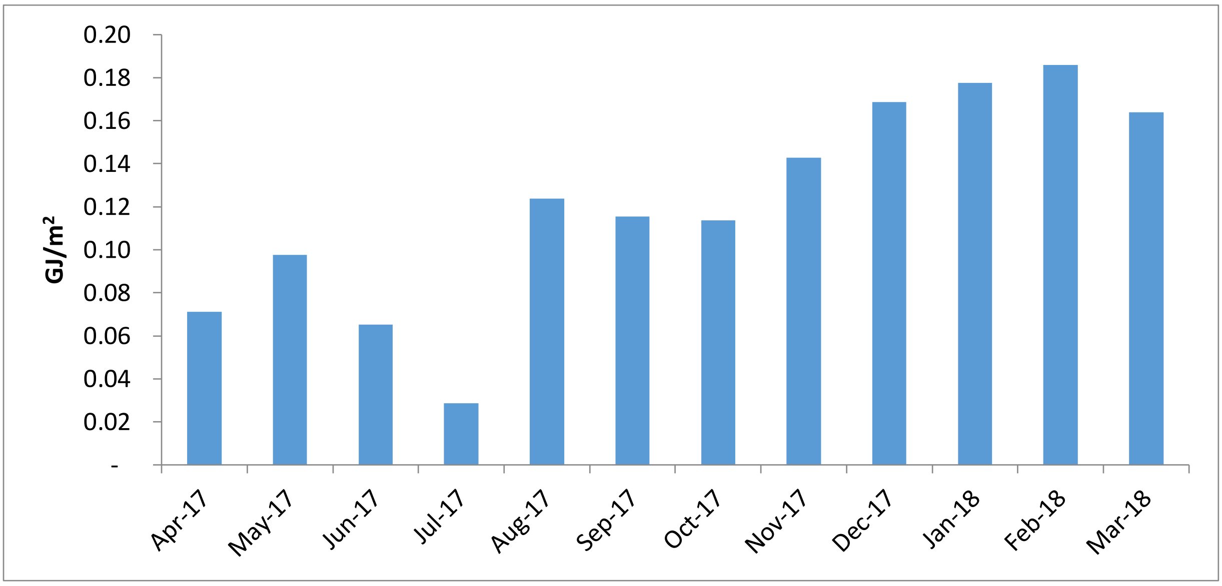


Figure 11: Month wise variation in Specific Fuel Consumption

The average SFC is 0.12 GJ/m^2. SFC is high in the month of Feb-18 (production was 136,323 m^2 and thermal consumption was 25,335.4 GJ) and low in the month of Jul-17(production was 37,848 m^2 and thermal consumption was 1,083 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	UOM	Value
Average production	m^2/h	226.08
Power consumption	kW	1,260.45
Coal consumption	kg/h	589.15
NG consumption	scm/h	379.27
Energy consumption	TOE/h	0.32
SEC of plant	TOE/m^2	0.00346

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	
	Coal (kg/t)	Electricity (kWh/t)
Five Layer Dryer	10,286.247	10.4
Presses		10.73
Kiln	0.4	17.7
HAG & Spray dryer	119	7.8
Slip piston Pump		2.2
Stirrer Motor		3.23
Clay Ball Mill		11.11
Glaze ball mill		- (Not in operation)
Initial Sizing Machines		24.0
Final Sizing Machines		13.7
Calibrating Machines		21.2
Polishing Machines		81.0
Nano Machines		47.3

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

Parameters	Unit	UOM
Annual Grid Electricity Consumption	kWh/y	11,826,597
Annual DG Generation Unit	kWh/y	-
Annual Total Electricity Consumption	kWh/y	11,826,597
Annual Thermal Energy Consumption (Coal)	t/y	5,090
Annual Thermal Energy Consumption (NG)	scm/y	3,276,941
Annual Total Energy Consumption	TOE/y	6,766
Annual water Consumption	Kl/y	30,600
Annual Water Cost	Lakh Rs/y	1.3
Annual Energy Cost	Lakh Rs/y	1,797
Annual Production	m^2/y	1,953,315

Parameters	Unit	UOM
	t/y	36,624.7
SEC; Electrical	kWh/m^2	6.055
	kWh/t	322.91
SEC; Thermal	GJ/m^2	0.12
	GJ/t	6.57
SEC; Water	kl/m^2	0.02
	kl/t	0.84
SEC; Overall	TOE/ m^2	0.00
	TOE/t	0.18
SEC; Cost Based	Rs/m^2	92.01
	Rs/t	4,906.97

(Annual data based on the period April-17 to March-18)

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

- Conversion Factors
  - Electricity from the Grid : 860 kCal/kWh
- GCV of NG : 9,000kCal/scm
- GCV of Imported Coal : 5,500kCal/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

Particular	Unit	Value
Cost of Electricity	Rs/kWh (March-18)	6.8
Cost of NG	Rs/scm	30.6
Cost of Coal	Rs/t	5,852
Operating Hours per day	h/d	24
Annual Operating Days per year	d/y	365
Annual production	m^2/y	1,953,315

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using bore well pumps (2 numbers). These pumps lift water from ground and which is collected in storage tank. From this tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 150 m^3/day as reported by the unit and verified during DEA. There is no metering available to monitor the exact water consumption.

Water distribution diagram is shown below.

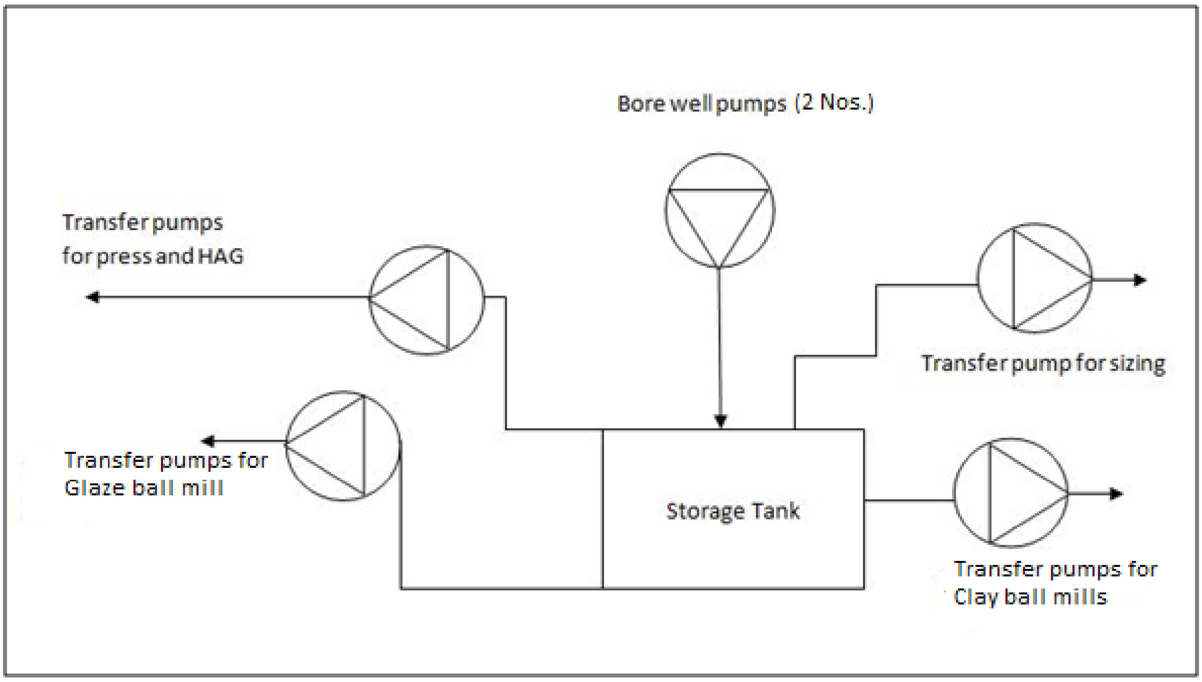


Figure 12: Water Distribution Diagram

Two submersible pumps (only one is in working condition) are installed to meet the water requirements of process (cooling towers for press and coal gasifier, clay ball mills, sizing and cutting section, chain stoker HAG and domestic use).

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

3. CHAPTER -3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILN

3.1.1 Specifications

Coal gas is used as a fuel in the roller 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 is having 458.64 hp electrical load, out of which 59 hp is for RV blower, 100.5 hp for combustion blowers, 40 hp for rapid cooling fan, 73.75 hp for Smoke blower, 30 hp for suction fan, 45 hp for final cooling blowers & remaining electrical load of kiln roller motors.

Table 17: Kiln Details

Sr. No	Parameter	Unit	Value
	Make		Modena
1	Kiln operating time	h	24
2	Average Fuel consumption	sm^3/d	400
3	Number of burner to left	-	124
4	Number of burner to right	-	124
5	Cycle Time	Minutes	86
6	Pressure in firing zone	mmWC	36
7	Maximum temperature	°C	1,200
8	Waste Heat recovery option		Yes
9	Kiln Dimensions (Length X Width X Height)		
	Preheating Zone	m	63 x1 x 2.1
	Firing Zone	m	37.8 x 1 x 2.1
	Rapid Cooling Zone	m	14.7 x 1 x 2.1
	Indirect cooling Zone	m	27.3 x 1 x 2.1
	Final cooling zone	m	27.3 x 1 x 2.1

3.1.2 Field measurement and analysis

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

Table 18: FGA Study of Kiln

Parameter	Value
Oxygen Level measured in Flue Gas	6.3%
Ambient Air Temperature	38°C
Exhaust Temperature of Flue Gas	260 °C

From the above table, it is clear that the oxygen level measured in flue gas was not high. The inlet temperature of raw material in kiln was in the range of 35 – 42°C which was the ambient air temperature. Surface temperature was low throughout the surface of the kiln as shown in the table below:

Table 19: Surface temperature of kiln

Zone	Temperature (°C)
Ambient Temperature	40.2
Pre-heating zone Average Surface Temperature	48
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	45

The temperature profile of the kiln is shown below:

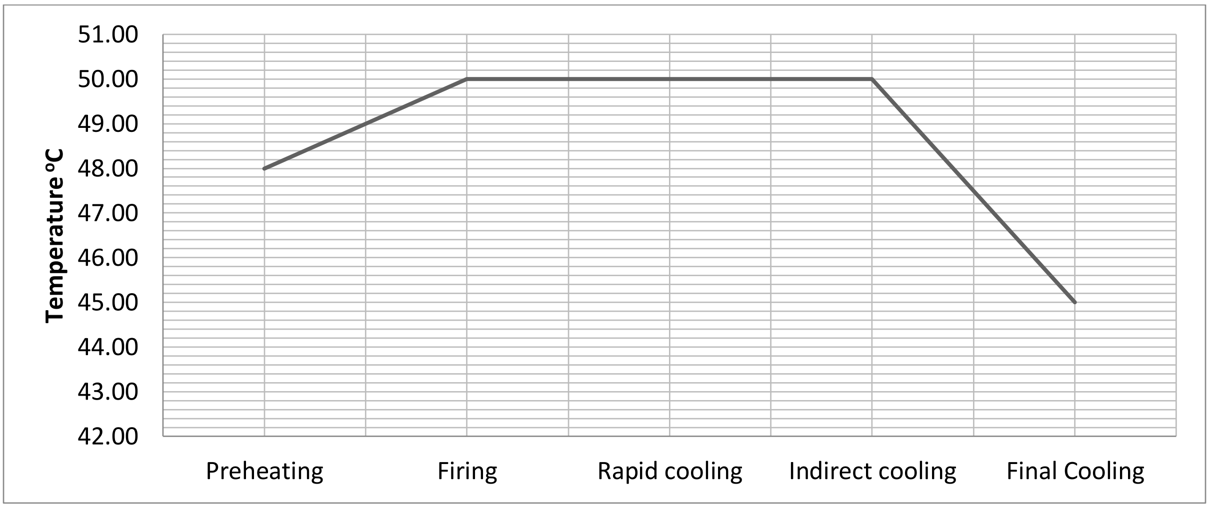


Figure 13 : Temperature Profile of Kiln

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

Table 20: Power measurements of all blowers

Equipment	Average Power (kW)	Power factor
Final Cooling Blower	10.5	1
Suction Blower	3.88	0.98
Heat Exchanger Blower	15.5	1
Rapid Cooling Blower	3.28	0.95
Smoke Blower	3.38	0.98
Combustion Blower	15.8	1
RV Blower	17.5	1

3.1.3 Observations and performance assessment

Heat utilization in kiln has been calculated based on the flue gas analysis study conducted during visit. Heat utilization of the kiln is 32.5%. Summary of all losses is shown in below figure:

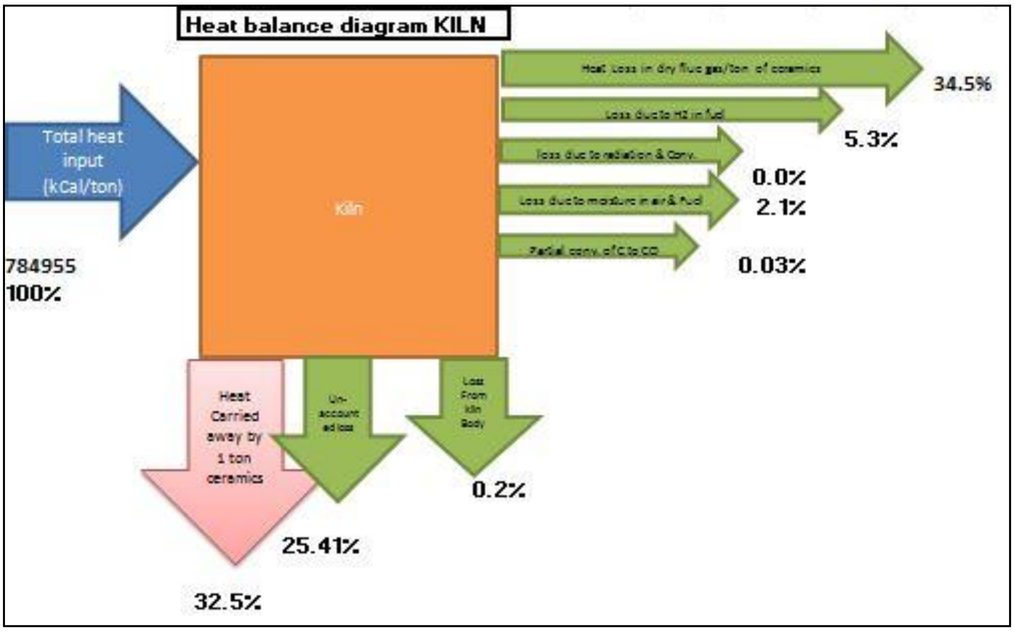


Figure 14: Heat balance diagram of Kiln

Causes of unaccounted losses arising due to following reasons:

i. Kiln leakage observed in kiln from roller periphery gaps
ii. Rollers are having hot air leakage from kiln heat.
iii. Burner inspection holes are closed by aluminum covers which increases radiation loss.
iv. Hot air fans body are un-insulated.
v. Atmospheric air dilution in kiln.

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

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Waste heat recovery from flue gas of kiln

Technology description

Utilization of waste heat content available in smoke (flue gas and vapors).

Study and investigation

It was observed during the field visit that the flue gas (smoke) temperature at kiln outlet was 260°C. So, to improve efficiency levels of kiln and to save fuel, it is suggested to utilize this additional heat content in the flue gases (that is presently being wasted) to marginally increase the temperature of air at the FD blower of hot air generator (HAG), thereby also bringing down the flue gas temperatures at stack by further 60°C.

Recommended action

It is recommended to decrease the smoke temperature at kiln so that the outlet temperature could be decreased from 260°C to 200°C, thereby increasing the more heat utilization in kiln and increasing the temperature of fresh air entering in HAG. This would help to reduce amount of fuel consumption.

Table 21: Savings and cost benefit analysis for waste heat recovery from flue gas of kiln [ECM-1]

Particulars	UOM	Value
Smoke temperature at smog blower	°C	260.0
Smog flow rate	t/h	24.60
Waste gas flow	t/h	24.6
Specific heat of waste gas	kcal/kg K	0.24
Smog temperature after recuperator	°C	200.0
Heat available in smoke	kcal/h	354300
Heat utilization	%	100
Specific heat of FD blower air	kcal/kg K	0.24
Thermic fluid temperature at ambient	°C	35.0
Combustion air flow	m^3/h	20085.1
Density of combustion air	kg/m^3	1.2
Mass flow rate of Combustion blower air	kg/h	24604.2
Effectiveness of HE	%	90.0
FD blower air temperature after recuperator	°C	89.0
Heat saving	kcal/h	354300.5
GCV of coal	kcal/kg	5500
Fuel savings	kg/h	64.4
Operating hours per day	h/d	24
Operating days per year	d/y	365
Coal Price	Rs./kg	5.9
Annual running hours	h/y	8760
Annual coal saving	kg/y	564304
Monetary saving	Lakh Rs/y	33.0
Net monetary saving	Lakh Rs/y	33.0
Estimate investment	Lakhs Rs	109
Payback Period	months	40
Project IRR	%	9
Discounted Payback Period	Months	13.76

3.1.4.2 ECM#2: Insulation improvement

Technology description

Proper insulation helps to reduce the heat loss to surrounding and thereby reduces fuel consumption.

Study and investigation

During DEA, it was found that the combustion air pipes in rapid cooling recuperator and near burner were poor which resulted in increased fuel consumption.

Recommended action

It is recommended to insulate the combustion air pipes in rapid cooling recuperator and near burner so that heat loss to the surroundings will be reduced which will result in reduced fuel consumption.

Table 22: Savings and Cost benefit analysis for insulation improvement [ECM-2]

Parameter	UOM	Present	Proposed
No of uninsulated pipe in Recuperator	#	36	36
No of uninsulated pipe in firing zone	#	204	204
Recuperator pipe size	mm	50	50
Pipe length	m	1	1
Pipe size in firing zone	mm	50	50
Pipe length	m	0.30	0.30
Total surface area	m^2	15.83	15.83
Average surface temperature	°C	160	50
Ambient air temperature	°C	35	35
Heat loss	$kCal/h/m^2$	2,031	161
Total heat loss	kCal/h	32,162	2,553
GCV of fuel	kCal/kg	5,500	5,500
Heat loss in terms of fuel	kg/h	5.8	0.5
Fuel saving	kg/h		5.4
Operating hours per day	h/d	24	24
Annual operating days	d/y	365	365
Annual fuel saving	kg/y		47,159
Fuel cost	Rs/kg		5.9
Annual fuel cost saving	Rs Lakh/y		2.76
Estimated investment	Rs Lakh		1.05
Simple Payback period	Months		4.5
Project IRR	%		198
Discounted payback period	Months		1.80

3.2 Coal Gasifier

3.2.1 Specifications

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

Table 23: Specifications of coal gasifier

Particular	UOM	Value
Make		Radhey
Coal consumption	t/d	24
Water consumption	l/d	2,000
FD Blower	hp	2 x 30
Cooling water pump	hp	2 x 15

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Coal input to gasifier
- Volume of gas produced by gasifier
- Power measurement of ID & FD blower
- Power measurement of CT fans and pumps

The coal input to the gasifier was 733 kg/h. The power consumption for ID & FD blower was 0.06 kW & 2.36 kW, for CT pump-1 & 2 was 10.8 & 12.6 kW and for CT fan-1 & 2 was 8.5 & 9.33 kW.

The coal consumption of gasifier was measured by lifts per day and the coal per lift is 600 kg and no. of lifts per day is 40 and the volume of gas produced is 3044 sm^3/h.

The performance of gasifier is attached in **Annexure-5**.

3.2.3 Observations and performance assessment

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, the specific energy consumption of coal gasifier was 0.24 kg/scm. Specific electricity consumption will be considered as how much power consumes for 1 scm coal in plant which is 0.014 kW/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed.

3.3 Dryers

3.3.1 Specifications

There is a one five layers dryer installed in the unit. This is used for pre drying of tiles before entering into kiln. The specifications of five dryers are given below table:

Table 24: Specifications of five layer dryer

Particular	UOM	Values
Capacity	Nos. of tiles/h	633
Fuel type		NG
Rated fuel consumption	scm/h	-
Exit temperature of tiles	°C	120
Heat Supply Fan	kW	12 x 15
Suction Fan	kW	2 x 15
Burner Fan	kW	12 x 0.37

3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

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

Data measured during study is tabulated below:

Table 25: Field measurement at site

Particular	UOM	Five Layer dryer
Tiles passed through dryer		633

Particular	UOM	Five Layer dryer
Mass of each tile at entry	g	7,800
Mass of each tile at exit	g	7,300
Temperature of tile at exit	° C	120
Gas consumption	scm/h	16.67 (NG)

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

The zone wise temperatures of five layer dryer are:

- Zone - 1: 118 °C
- Zone -2 : 121°C
- Zone-3: 125°C
- Zone-4: 134°C
- Zone-5: 170°C
- Zone-6: 170 °C
- Zone-7: 130 °C
- Zone-8: 131 °C
- Zone-9: 131 °C
- Zone-10: 131 °C
- Zone-11: 116 °C
- Zone-12: 116°C

The power profile and PF profile of blowers are attached in **Annexure-4**.

Average power consumption of blowers is given below:

Table 26: Five layer dryer blower measurements

Blower name	Power (kW)	PF
Suction Fan-1	3.93	0.98
Suction Fan-2	4.11	0.99
Heat Supply Fan-1	3.95	0.98
Heat Supply Fan-2	3.11	0.99
Heat Supply Fan-3	3.5	0.99
Heat Supply Fan-4	3.22	0.99
Heat Supply Fan-5	3.25	0.99
Heat Supply Fan-6	2.74	0.84
Heat Supply Fan-7	2.33	0.99
Heat Supply Fan-8	3.19	0.98
Heat Supply Fan-9	3.48	0.99
Heat Supply Fan-10	3.32	0.99
Burner Blower-5	0.385	0.72
Burner Blower-6	0.427	0.76

3.3.3 Observation and Performance assessment

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

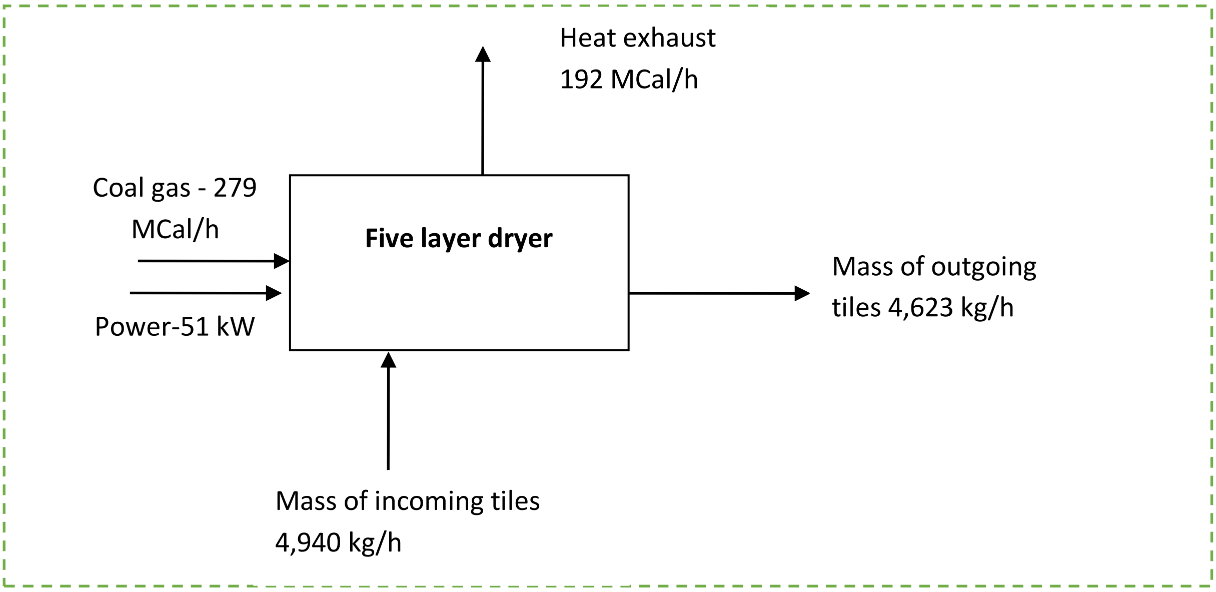


Figure 15: Mass and energy balance of five layer dryer

Based on observations during DEA, the specific energy consumption of vertical dryer is 10.32 kW/ton of tile and specific thermal energy is 56.47 MCal/ton of tile.

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

3.4 Hot Air Generators& Spray Dryers

3.4.1 Specifications

There is one hot air generator (HAG) of chain stoker type from slip which is coming from clay ball mill. There is one spray dryer which is taking heat from chain stoker HAG. Spray dryer is the heat exchanging unit for body clay powder generation from slip. Specifications of HAG are given below:

Table 27: Specifications of Hot air generator (HAG)

Particular	UOM	Chain stoker
Air handling capacity	m^3/h	-
Fuel type		Coal
Rated fuel consumption	t/d	15
Exhaust air temperature	°C	-
FD Blower	kW	2 x 22
ID blower	kW	1 x 180

The specifications of spray dryers are given below:

Table 28: Specifications of spray dryer

Particular	UOM	Value
Powder generation capacity	t/h	11.5
Inlet slip moisture	%	35
Outlet powder moisture	%	6
piston pump	kW	2 x 30

3.4.2 Field measurement and analysis

During DEA, the following measurements were done:

- Hot air generators
  - Power consumption of FD and ID fan
  - Air flow measurement of FD fan
  - Surface temperature
- Spray drier
  - Inlet and outlet moisture data
  - Power consumption of piston pump

Details of measurements on HAG are given below:

Table 29: Field measurement at site

Particular	UOM	FD Blower-1	FD Blower-2
Air velocity at FD fan suction	m/s	11.6	12.6
Suction area	m^2	0.196	0.196
Average power consumption	kW	3.72 (PF=0.99)	3.58 (PF=0.99)

The average power consumption of Auxiliary FD blower-1 & 2 and ID fan is 0.39 kW (PF 0.93) & 0.60 kW (PF 0.99) and 29.3 kW (PF 0.99). All blowers are operating with VFDs.
In spray dryer, the piston pump was operated with VFD. Average power consumption of piston pump is 10.7 kW (PF 1.00).

3.4.3 Observations and performance assessment

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

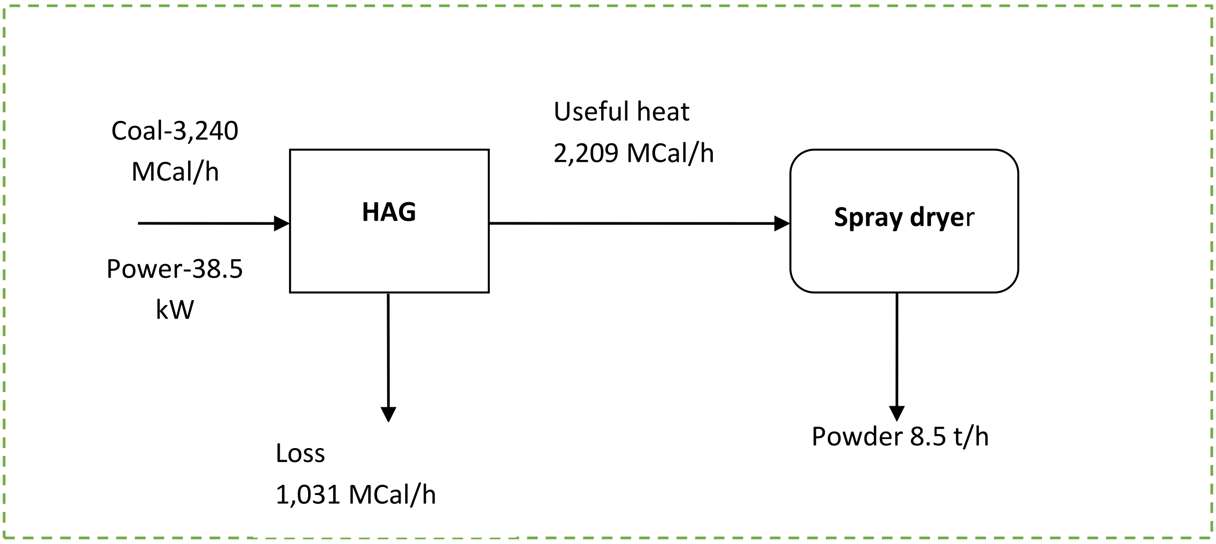


Figure 16: Energy and mass balance of Chain Stoker HAG and Spray dryer

Performance of HAG & spray dryer is measured in terms of specific electricity consumption (electrical energy used for delivering one kg of slip). Based on observations during DEA, the specific electricity consumption of HAG & spray dryer was 7.8 kW/ton and specific thermal consumption is 119 kW/ton.

3.4.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.4.4.1 ECM#3: Excess air control in HAG

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.

If 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 HAG 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 HAG.

Study and investigation

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

Recommended action

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 30: Savings and cost benefit analysis for Excess Air Control in HAG [ECM-3]

Parameters	UOM	Present	Proposed
Oxygen level in flue gas just before firing zone	%	14.0	8.0
Excess air percentage in flue gas	%	200.0	61.5
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	kg/t	85	73
Average production in HAG	t/h	11.5	11.5
Coal consumption	kg/h	977.5	842.2
Saving in specific fuel consumption	t/h		0.14

Parameters	UOM	Present	Proposed
Operating hours per day	h/d		300
Annual operating days	d/y		20
Annual fuel saving	t/y		812
Fuel cost	Rs/t		5,852
Annual fuel cost saving	Lakh Rs/y		47.5
Estimated investment	Lakh Rs		18.48
Payback period	Months		4.7
Project IRR	%		193
Discounted payback period	Months		1.85

3.4.4.2 ECM#4: Insulation improvement

Technology description

Poor surface insulation results in heat loss to surroundings and thereby increasing fuel consumption.

Study and investigation

During DEA, it was found that the surface insulation of cyclone separator and duct connecting Hot air generator & cyclone separator was poor.

Recommended action

It is recommended to insulate the duct connecting hot air generator and cyclone separator and thereby achieve reduction in fuel reduction.

Table 31: Savings and cost benefit analysis for Insulation improvement [ECM-4]

Parameters	Unit	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	4.7	1.8	3.6	1.4
Average coal saving	kg/h		2.9		2.2
Annual operating hour	h/y	8,760	8,760	8,760	8,760
Annual coal saving	t/y		26		19
Fuel cost	Rs/t	5,852	5,852	5,852.3	5,852.3
Annual fuel cost saving	Lakh Rs/y		1.49		1.14
Net saving	Lakh Rs/y	2.63			
Estimated insulation cost	Lakh Rs	4.60			
Payback period	Months	21			
Project IRR	%	38			
Discounted Payback period	Months	8			

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 ISMS and STPP. Clay ball mills take 3 to 6 hours for slip preparation. The specifications of clay ball mills and its accessories are given below:

Table 32: Specifications of clay ball mills

Particulars	UOM	Value
Numbers of clay ball mills	#	3
Capacity of each clay ball mill	t/batch	60
Water consumption in each clay ball mill	t/batch	25
SMS (chemical consumption)	Kg/batch	350
STPP (chemical consumption)	Kg/batch	40
Water TDS	ppm	1,200
Nos. of batch per day		1

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all clay ball mill-1

FD blower and 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 33: Average power consumption and PF of clay ball mills

Equipment	Average Power (kW)	PF
Clay ball mill-1	25.5	0.94

4.1.3 Observations and performance assessment

Mass balance of Clay ball mill- 1 based on measurements is given below:

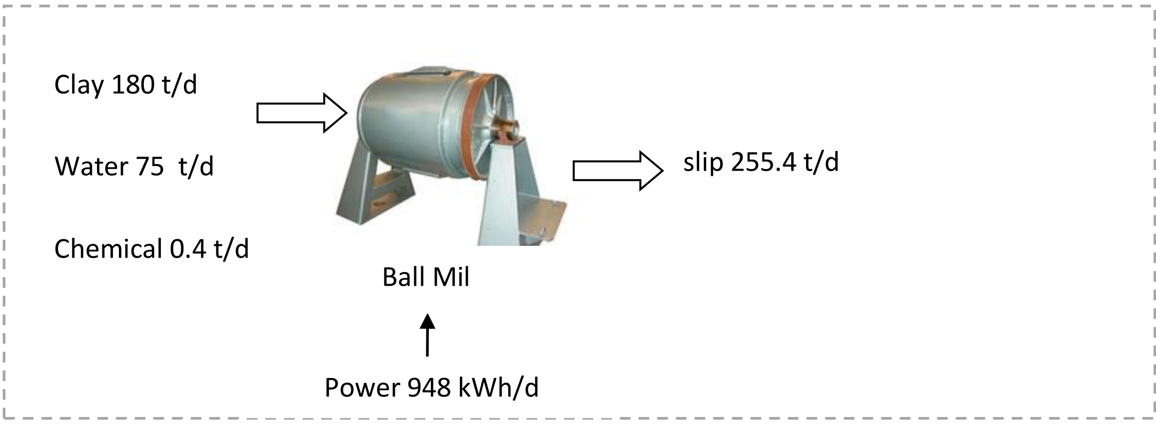


Figure 17: Energy and mass balance of Clay ball mill

Performance of clay ball mill is measured in terms of specific energy consumption (power consumed for preparation of 1 ton of slip). Based on observations during DEA, the specific energy consumption of coal was 11.11 kW/ton. TDS of bore well water is very high; this should be controlled by installing water softener plant which will enable resource savings.

4.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.1.4.1 ECM # 5: Using treated water in clay ball mill

Technology description

It was observed that the TDS of water used in clay section is 1,200 ppm, which results in higher consumption of water, chemicals and electricity per batch of slip preparation and later higher coal consumption for spray dryer.

Study and investigation

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

Recommended action

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

Estimated cost benefit is given in the table below:

Table 34: Saving and cost benefit by using improved water quality [ECM-5]

Parameters	Unit	Present	Proposed	Saving
TDS of Water	ppm	1,200	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	3.75
Water saving	m^3		3.75	
Electricity used per batch	kWh	948.5	920.03	28.45
Temperature of water	°C	25	25	
Boiling temp. of water	°C	100	100	
GCV of coal	kcal/kg	5,500	5,500	
Eff. Of HAG	%	85%	85%	
Coal saving per batch	kg		493	493.32
Chemical saving per batch				
SMS	kg	350	245	105.00
STPP	kg	40	28	12.00
Per Unit Cost				
Water	Rs./m^3	3.50	3.50	
Electricity	Rs/kWh	6.78	6.78	
Coal	Rs/kg	5.85	5.85	

Parameters	Unit	Present	Proposed	Saving
Chemical				
SMS	Rs/kg	22.00	22.00	
STPP	Rs/kg	85.00	85.00	
Cost Savings per batch	Rs		6,423	
Total batches per day	#	3	3	
Annual operating days	d/y	365	365	
Annual resource savings				
Water	m^3/y		4,106.3	
Electricity	kWh/y		31,158.04	
Coal	t/y		540.18	
Chemical	kg/y		128,115	
Annual cost savings	Lakh Rs/y		70.33	
Operating cost- Water Treatment	Rs/m^3		20.00	
	Lakh Rs/y		4.65	
Net monetary savings	Lakh Rs/y		65.68	
Estimated investment	Lakh Rs		39.60	
Payback period	Months		7.24	
Project IRR	%		138	
Discounted payback period	Months		2.64	

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 35: Specifications of hydraulic press

Particular	UOM	Value
Cycle (stroke) per min	N/m	8
Nos. of tiles per stroke	#	2
Number of presses	#	3

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of presses
- Count of tiles processed
- Power consumption of CT pumps & fans of Gasifier and Press

The power consumption of press-1 & 3 were 87.4 kW (PF 0.63) & 73.34 kW (PF 0.64).

Tiles producing from both presses are 480 tiles per hour.

4.2.3 Observation and performance assessment

Performance of hydraulic presses can be measured in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption of press section was 10.73 kW/ton of tile.

The power consumption of the CT press fans and pumps were 3.24 & 3.39 kW and 8.25, 7.2 & 2.95 kW respectively.

The power consumption of the CT gasifier pumps and fans were 10.8 & 12.6 kW and fans were 8.5 & 9.33 kW respectively.

4.2.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.2.4.1 ECM #6: PID Controller in CT fans

Technology description

Cooling tower is used to cool the water returning from heat exchanger of press machine for oil cooling and also from gasifier for cooling of coal gas produced by gasifier. A PID controller for cooling tower fan will ensure operation of fan only when it is required based on temperature set point.

Study and investigation

It was observed that cooling tower fans were running continuously irrespective of the operation of the Coal gasifier and press and the CT fans were drawing 2 kW each respectively. It was also observed that even when press and gasifier are not in operation, CT fans are running.

Recommended action

It is recommended to install PID based controller which will ensure that CT fans will start only when the temperature of oil and water reaches above set point and once this temperature is maintained, CT fans will stop automatically. The cost benefit analysis for this project is given below:

Table 36: Savings and cost benefit analysis for PID Controller in CT fans [ECM-6]

Parameters	UOM	Press CT Fans		Coal Gasifier CT Fans	
		Present	Proposed	Present	Proposed
No. of cooling tower	#	2	2	2	2
No. of cooling tower Fan	#	2	2	2	2
Rated power of Fan	kW	5.6	5.6	11.2	11.2
Operating power	kW	3.3	3.3	8.5	8.5
Operating hours per day	h/d	24	15	24	15
Operating days per year	d/y	365	365	365	365
Annual energy consumption	kWh/y	58,079	18,150	148,920	46,538
Annual electricity saving	kWh/y		39,929		102,383
Unit cost of electricity	Rs/kWh		6.78		6.78
Annual monetary savings	Lakh Rs/y		2.71		6.94
Estimated Investment	Lakh Rs		0.40		0.40
Payback Period	Months		1.75		0.68
Total estimated investment	Lakh Rs		0.80		
Total payback period	Months		2.43		
Total Project IRR	%		896		
Total Discounted Payback period	Months		0.40		

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 37: Specifications of agitators

Particular	UOM	Value
Numbers of agitators in tank	#	30
Capacity of each agitator motor	kW	7.5
Number of motors	#	30

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

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

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

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

Equipment	kW	PF
Stirrer Motor T1	0.696	0.93
Stirrer Motor B1	1.1	0.99
Stirrer Motor B9	2.15	1

Mass of slip fed to agitators was 12.2 t/h.

4.3.3 Observations and performance assessment

During DEA, the agitator motors were running with VFD and power factor of these motors were good. Performance of agitator motors can be measured 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 3.23 kW/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 39: Specifications of glaze ball mill

Particular	UOM	Value
Numbers of glaze ball mill	Nos.	4
Capacity of glaze ball mill	kW	30

4.4.2 Field measurement and analysis

During DEA, the glaze ball mills were not in operation.

4.5 SIZING

4.5.1 Specifications

There were two sizing machines .The specifications of sizing machines are given below:

Table 40: Specifications of sizing machine

Particular	UOM	Head motors	Main belt motors	Inclining belt motor
Initial sizing machine	#	44	1	2
Final sizing machine	#	44	1	2
Capacity of each motor	kW	4	5.5	2.4

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of initial sizing machine and final sizing machine
- Mass of tiles entering the sizing machines

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

Table 41: Measured Parameters of sizing machine

Equipment	Average Power (kW)	PF
Initial sizing machine	63.2	0.79
Final sizing machine	111	0.84

Mass of tiles entering the initial and final sizing machines are 4.6t/h respectively.

4.5.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption were 24 kW/t for initial sizing machine and 13.7 kW/t for final sizing machine.

4.6 AIR COMPRESSORS

4.6.1 Specifications

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

Table 42: Specifications of compressors

Particular	UOM	Air compressor 1	Air compressor 2
Power rating	kW	37	37
Maximum pressure	Bar (a)	7	7
Air handling capacity	m^3/min	7.14	7.14

4.6.2 Field measurement and analysis

During DEA, 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 43: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)	% of time on load
Compressor-1	46.1	0.87	5.54	60
Compressor-2	30.6	0.99	2.8	100

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

4.6.3 Observation and performance assessment

Based on observations during DEA, the specific energy consumption are 0.235 kW/CFM & 0.31 kW/CFM for the compressor 1 & 2 respectively.

4.6.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.6.4.1 ECM #7: Retrofit of VFD for compressor 1 & 2

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 three compressors were captured to understand unload/load pattern of air compressor it was found that two of compressor 1 is getting unloaded for 40% of the time. There was only one receiver and it was not possible to conduct FAD test for compressor. The compressor 2 was already running with VFD but there was not feedback of pressure to VFD.

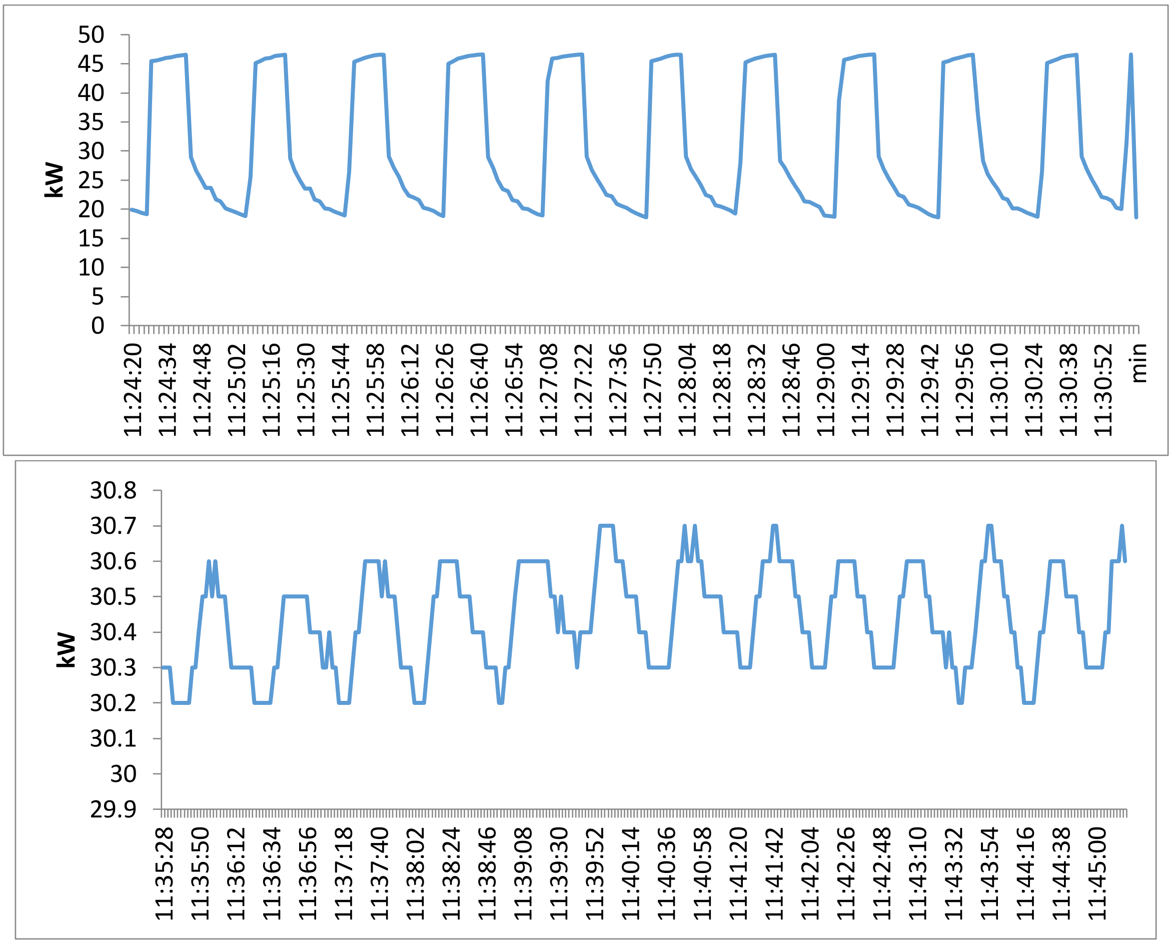


Figure 18: Load/Unload pattern of Compressor#1 and Compressor#2

Recommended action

It is recommended to install VFD on compressor 1 which will cater to the variable air demand of the plant and in compressor 2 is recommended to give pressure feedback to the VFD. The cost benefit analysis for this project is given below:

Table 44: Savings and cost benefit analysis for retrofit of VFD for compressor 1 & 2 [ECM-7]

Parameters	UOM	Compressor-1 Present	Compressor-1 Proposed	Compressor-2 Present	Compressor-2 Proposed
Compressor motor rating	kW	37	37	37	37
Average power consumption	kW	31.32	25.05	30.43	24.34
Operating hours/day	h/d	24	24	24	24
Operating days/year	d/y	365	365	365	365
Annual energy consumption	kWh/y	274,351	219,481	266,571	213,257

Parameters	UOM	Compressor-1 Present	 Proposed	Compressor-2 Present	 Proposed
Annual energy saving	kWh/y		54,870		53,314
Unit cost of electricity	Rs/kWh	6.78	6.78	6.78	6.78
Annual monetary savings	Lakh Rs/y		3.72		3.62
Estimated Investment	Lakh Rs	1.69		0.13	
Payback period	Months		5	0.4	
Total Project IRR	%	**302**			
Total Discounted payback period	Months	**1.19**			

4.6.5 ECM # 8: 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 & 2 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 45: Savings and cost benefit analysis compressed air pressure reduction [ECM-8]

Parameter	UOM	Compressor-1 Present	 Proposed	Compressor-2 Present	 Proposed
Operating pressure required	kg/cm²	6.5	5	6.5	5
Reduction in pressure	kg/cm²	-	1.5	-	1.5
% of energy saving	%	-	9	-	9
Average load	kW	31.3	28.50	30.5	27.71
Operating hours per day	h/d	24	24	24	24
Operating days per year	d/y	365	365	365	365
Annual energy consumption	kWh/y	274,351	249,660	266,779	242,769
Annual energy savings	kWh/y		24,692		24,010
Unit cost of electricity	Rs/kWh		6.78		6.78
Annual monetary saving	Lakh Rs/y		1.67		1.63
Estimated Investment	Lakh Rs			1.69	
Payback period	Months			6	
Project IRR	%	**147**			
Discounted payback period	Months	**2.42**			

4.7 Water Pumping System

4.7.1 Specifications

Pumping system comprises two bore well pumps and transfer pumps for supplying water to various sections.

4.7.2 Field measurement and analysis

During DEA, the following measurements were done for the bore well pump:

- Power consumption of gasifier pumps (other pumps are having smaller size and internal corrosion problems)
- Flow measurements for same pumps

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

Table 46: Operating details of pump

Particulars	Unit	Gasifier CT Pump-1	Gasifier CT Pump-2
Measured flow	m^3/h	42.2	38
Total head	m	40	44
Actual power consumption	kW	12.6	10.8

4.7.3 Observation and performance assessment

Based on observations during DEA, the Gasifier CT Pump-1 & 2 efficiency is determined as 50.5% & 58.4% respectively.

4.7.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

4.7.5 ECM #9: Replacement of inefficient pumps

Technology description

Presently, There are energy efficient pumps present having pump efficiency of 75%.

Study and investigation

During DEA, Gasifier CT pumps were operating at lower efficiency.

Recommended action

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

Table 47: Replace bore-well pump by energy efficient pump [ECM-9]

Parameters	UOM	Gasifier CT Pump-1		Gasifier CT Pump-2	
		Present	Proposed	Present	Proposed
Flow	m^3/h				

Parameters	UOM	Gasifier CT Pump-1 Present	Gasifier CT Pump-1 Proposed	Gasifier CT Pump-2 Present	Gasifier CT Pump-2 Proposed
Head	m				
Pump I/P Power	kW	11.19	6.5	11.2	6.4
Pump Efficiency	%	50.53	75.00	58.39	75.00
Motor Rated Power	kW	11.19	6.5	11.19	6.4
Motor Efficiency	%	85.00	95.00	85.00	95.00
Overall Efficiency	%				
VFD	Y/N	N		N	
VFD Frequency	Hz	50.0	50.0	50.0	50.0
Measured Parameters	**Unit**	**Present**	**Proposed**	**Present**	**Proposed**
Flow rate Q	m^3/h	42.2	42.2	38.0	25.2
Suction Pressure	kg/cm^2	-1.8	-1.8	-1.8	-1.8
Discharge Pressure	kg/cm^2	2.20	2.20	2.60	2.60
Motor Input Power	kW	12.6	6.5	10.8	6.4
Temperature In	°C				
Temperature Out	°C				
Calculation	**Unit**	**Value**		**Value**	
Flow rate Q	m^3/s	0.01172	0.01172	0.01056	0.01056
Total Head/head developed	m	40.0	40.0	44.0	44.0
Liquid Horse Power	kW	4.6	4.6	4.6	4.6
Motor Shaft Power	kW	10.7	6.1	9.2	6.1
Motor Loading	%	95.7	95	82.0	95%
Overall system efficiency	%	43	75	50	75
Pump Efficiency	%	**50.5**	**75.0**	**58.4**	**75.0**
Operating hour per day	h/d		24		24
Annual operating days	d/y		365		365
Annual power savings	kWh/y		53,822.7		38,590.7
Electricity tariff	Rs/kWh		6.78		6.78
Monetary savings	Lakh Rs /y		3.6		2.6
Estimated investment	Lakh Rs		0.6		0.6
Simple payback period	months		2.0		2.0
Total Monetary savings	Lakh Rs /y			6.3	
Total Estimated investment	Lakh Rs			1.19	
Total Payback period	months			2	
Project IRR	%			396	
Discounted payback period	Months			0.91	

4.7.6 ECM# 10: Retrofit of VFD in Gasifier & Press CT pumps

Technology description

VFD is a type of adjustable-speed drive used in electro-mechanical drive systems to control motor speed by varying motor input frequency and voltage to cater the variable demand.

Study and investigation

During field measurement, it was found that the Gasifier & press CT pumps were running continuously irrespective of load requirement.

Recommended action

It is recommended to install VFD on Gasifier and Press CT pumps and thereby reduce energy consumption.

Table 48: Savings and cost benefit analysis for retrofit of VFD in Gasifier and Press CT pumps(ECM-10)

		Coal Gasifier CT Pump-1		Coal Gasifier CT Pump-2		Press CT Pump-1		Press CT Pump-2		Press CT Pump-3	
Particulars	**UOM**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**	**Present**	**Proposed**
Motor Capacity	kW	11.19	11.19	11.19	11.19	5.595	5.595	5.595	5.595	3.73	3.73
Measured Motor Power	kW	10.80	8.64	12.60	10.08	8.25	6.6	7.20	5.76	2.95	2.36
Operating hours per day	h/d	24	24	24	24	24	24	24	24	24	24
Annual Working Days	d/y	365	365	365	365	365	365	365	365	365	365
VFD saving	%		20		20		20		20		20
Annual Energy Consumption	kWh/y	94608	75686.4	110376	88300.8	72270	57816	63072	50457.6	25842	20673.6
Energy Saving	kWh/y		18921.6		22075.2		14454		12614.4		5168.4
Unit Cost	Rs/kWh	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78
Cost Saving	Lakh Rs/y		1.28		1.50		0.98		0.86		0.35
Investment	Lakh Rs.		0.66		0.66		0.33		0.33		0.22
Payback period	Months		6.2		5.3		4.1		4.7		7.6
Project IRR	%	168									
Discounted payback period	Months	2.11									

4.8 Lighting System

4.8.1 Specifications

The plant lighting system includes:

Table 49: Specifications of lighting load

Particular	UOM	LED	LED
Power consumption of each fixture	W	85	36
Numbers of fixtures	#	250	50

4.8.2 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	157
Kiln control room	Lumen/m^2	115
Kiln area	Lumen/m^2	63
Press	Lumen/m^2	76
Clay ball mill and agitators	Lumen/m^2	71
HAG and spray dryer	Lumen/m^2	73
Vertical dryer	Lumen/m^2	66

4.8.3 Observations and performance assessment

Adequate day lighting is used wherever possible and energy efficient lamps are also installed in this unit. Hence, no ECM has been proposed.

4.9 Electrical Distribution System

4.9.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (433V) by step down transformer (3 MVA). There was single DGs (capacity of 1.010 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeders which are shown in Figure 8.

4.9.2 Field measurement and analysis

During DEA, the following measurements were done:

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

4.9.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **1190kVA**.

The voltage profile of the unit is satisfactory and average voltage measured was **423.8 V.** Maximum voltage was **454.9 V** and minimum was **402.3 V**.

Average total voltage and current Harmonics distortion found **5.4%** & **15.79%** respectively during power profile recording.

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

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

4.9.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.9.4.1 ECM #11: Install active harmonics Filter

Technology description

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

Some of the effects of harmonics are mentioned hereunder.

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

Study and investigation

During the field measurement, it was found that the harmonics levels are higher than the prescribed limits at the main incomer. Estimated losses due to harmonics are about 3 kW.

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	423	776	5.38	15.4	2.05	12.8	5.5	0.38	3.8
		Minimum	424	66	4.40	3.8	0.00	2.8	0.9	0.00	0.3
		Maximum	402	1618	6.60	30.6	8.70	26.9	12.2	2.50	10.4
	Y	Average	426	791	5.36	16.5	1.52	13.5	6.3	0.40	4.2
		Minimum	416	68	4.50	3.1	0.20	2.2	1.4	0.00	0.2
		Maximum	456	1674	6.40	31.4	5.90	27.6	14.8	2.50	10.3
	B	Average	424	772	5.37	15.5	1.09	12.6	5.9	3.97	3.97
		Minimum	405	65	4.50	2.8	0.20	1.8	0.8	0.60	0.60
		Maximum	455	1618	6.30	32.0	4.90	28.2	13.9	10.20	10.20

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

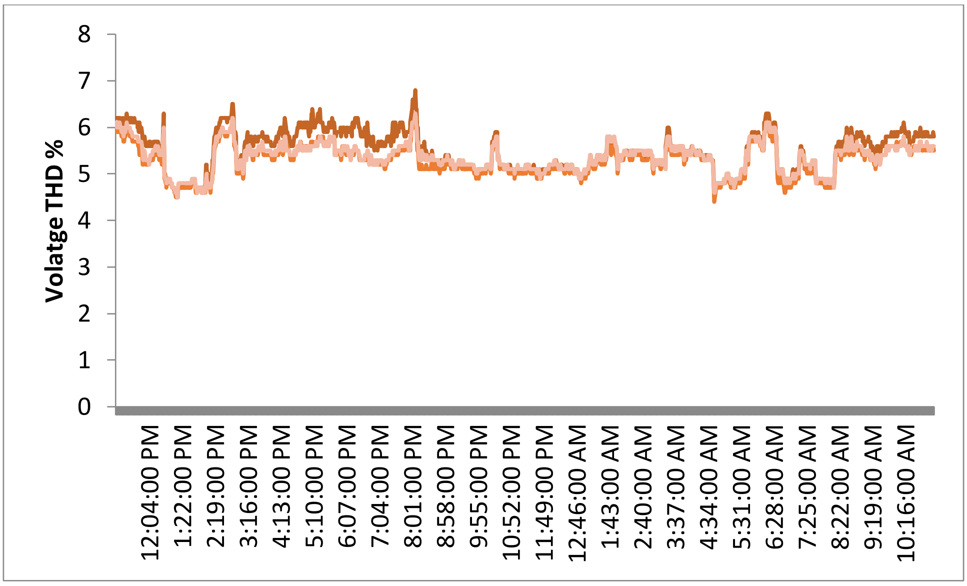


Figure 19: Voltage THD profile

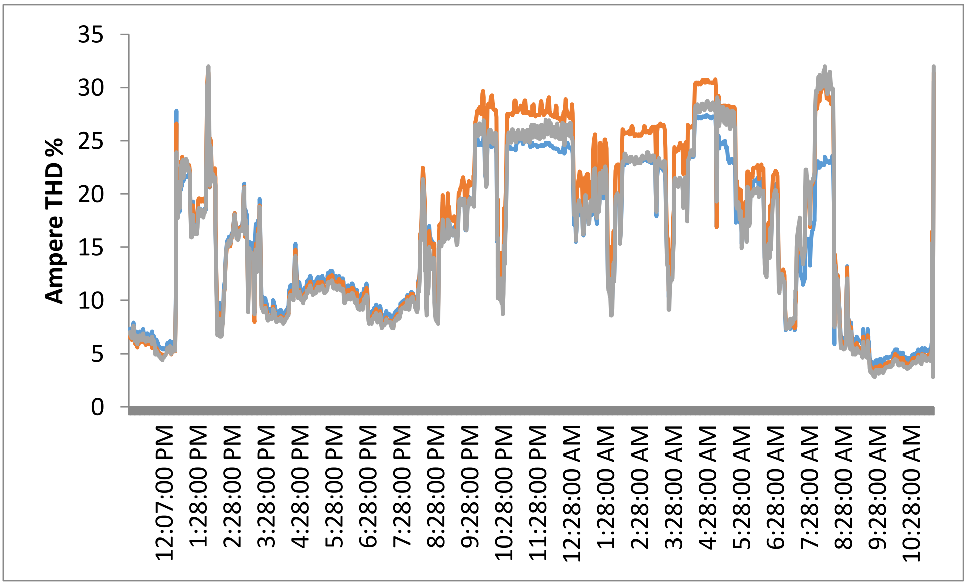


Figure 20: Ampere THD profile

Recommended action

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

- It is a known fact that if harmonics are present in any system, then power factor improvement capacitors will further amplify the existing harmonics.
- It is strongly recommended to install active harmonic filter at locations where THD is exceeding the prescribed limits.
- The active harmonic filter will take care of harmonics in the system and maintain the desired power factor as per requirement.

- Active harmonic filters can also take care of unbalanced load problems
- It is further recommended that all VFDs, UPS should be procured only with 12-pulse or 18-pulse rectifier circuit.
- All electronic ballasts to be procured in future shall be specified for less than 10% THD (Current).

The cost benefit analysis for this project is given below:

Table 52: Savings and cost benefit analysis for installing active harmonics Filter [ECM-11]

Parameters	Unit	Present	Proposed
Estimated losses due to Harmonics	kW	3.0	0
Saving potential by installation of active harmonics filter	kW		3.0
Operating hours per day	h/d		24
Operating days per year	d/y		365
Annual electricity savings	kWh/y		26,477
Cost of electricity	Rs/kWh		6.78
Annual electricity cost saving	Lakh Rs /y		1.80
Estimated rating of active harmonics filter (Ampere)	A		90
Estimated investment	Lakh Rs		7.13
Payback period	Months		47.64
Project IRR	%		2
Discounted payback period	Months		16.80

4.9.4.2 ECM #12: Cable loss minimization

Technology description

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

Study and investigation

Electrical parameters were logged in these feeders and it was noted in sizing section power factor was between 0.8,in polishing section the power factor was 0.7-0.9,in Nano machines-0.8-0.9 and in calibrating -0.5-0.8 .

Recommended action

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

The cost benefit analysis for this project is given below:

Table 53: Savings and cost benefit analysis for cable loss minimization [ECM-12]

Particulars	UOM	Polishing Machine-4 Present	Polishing Machine-3 Proposed	Polishing Machine-2 Present	Polishing Machine-1 Proposed	Nano Machine-1 Present	Nano Machine-2 Proposed	Calibrating Machine-2 Present	Calibrating Machine-3 Proposed	Sizing Machine-1 Present	Sizing Machine-2 Proposed
Existing Power Factor	pf	0.78	0.9	0.8	0.9	0.9	0.8	0.5	0.8	0.8	0.8
Proposed Power Factor	pf	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Existing load	kW	88.4	97.0	76.1	110.1	127.3	91.4	34.2	63.8	66.1	110.7
Cable Losses	W	1815	1603	1160	2073.4	2691.3	1465.6	572.1	825.5	883.6	2163.5
Capacitor Required	kVAr	65	49	52	56.72	63.66	51.64	56.07	44.23	45.62	64.58
Annual Energy Saving	kWh/y	7100	3441	3695	4,568	5,727	3,665	3,693	2,645	2,824	5,626
Savings Estimated	Lakh Rs/y	0.40	0.23	0.25	0.31	0.39	0.25	0.25	0.18	0.19	0.38
Total Energy Saving	kWh/y	42,983.85									
Total Savings	Lakh Rs/y	2.83									
Estimate Investment	Lakh Rs	2.53									
Payback Period	Months	11									
Project IRR	%	85									
Discounted payback period	Months	4.11									

4.9.4.3 ECM #13: Voltage Optimization in lighting circuit

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.

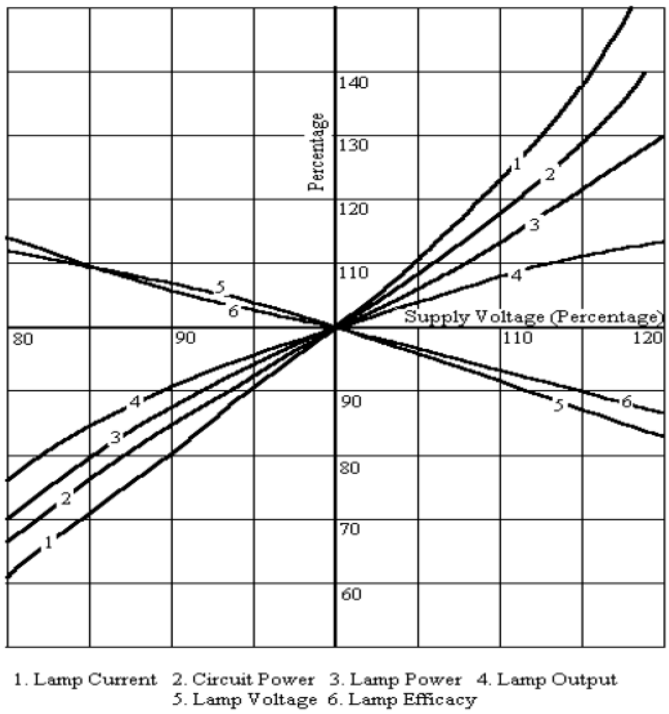


Figure 21: Effect of supply voltage on lamp parameters

Study and investigation

Lighting feeder measurements were carried out to estimate existing lighting load and the voltage level in the lighting circuit. Present maximum load is 28 kW and measured voltage level is 455V.

Recommended action

It is recommended to install separate servo stabilizer of 35 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 for Voltage Optimization in lighting circuit [ECM-13]

Parameter	UOM	Present	Proposed
Maximum load	kW	28	28
Maximum load	KVA	29.26	29.26
Maximum Line Voltage	V	455	380
Maximum Phase voltage	V	262	219
Average Line Voltage	V	416	380
Average Phase voltage	V	242	220
% reduction in voltage	%	9.2	
% reduction in energy consumption	%	17.51	
Average power factor		0.90	0.9
Annual lighting energy consumption	kWh/y	192,720	
Savings estimate from lighting EPIAs	kWh/y		0
Actual energy considered for voltage regulation	kWh/y		192,720
Actual energy consumption after voltage regulation	kWh/y		158,977
Efficiency of Servo Stabilizer	%		95
Assumption : Period for which voltage regulation is required	Months/y		12
Net saving from voltage regulation	kWh/y		32,056
Electricity tariff from grid only	Rs/kWh	6.78	
Annual monetary saving	Lakh Rs	2.2	
Sizing of servo stabilizer	kVA	32	
Rating of servo stabilizer	kVA	35	
Estimate investment	Lakh Rs	1.16	
Payback period	Months	6	
Project IRR	%	142	
Discounted payback period	Months	2.51	

4.10 Belt Operated Drives

4.10.1 Specifications

There are 27 drives operated with V Belt of total capacity of 1,375 kW. Locations include

- Kiln (7)
- HAG & Spray dryer (3)
- Five layer dryer(14)
- Clay ball mill (3)

4.10.2 Field measurement and analysis

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

4.10.3 Observations and performance assessment

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

4.10.4 Energy conservation measures (ECM) - ECM #14: 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 27 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-14]

Parameters	UOM	Present	Proposed
Total rated power of belt drives	kW	1,375	1,375
Energy Saving	%		3.60%
Measured total power of belt drives	kW	284	274
Operating hours per day	h/d	24	24
Operating Days per year	d/y	330	330
Annual energy consumption	kWh/y	2,248,331	2,167,391
Annual energy saving	kWh/y		80,940
Unit cost of electricity	Rs/kWh		6.78
Annual monetary savings	Lakh Rs/y		5.49
Estimated Investment	Lakh Rs		5
Payback Period	Months		10.93
Project IRR	%		80
Discounted payback	Months		4.24

5. Chapter-5 Energy consumption monitoring

5.1 Energy Consumption Monitoring

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

5.1.1.1 ECM #15: Energy management system

Technology description

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

Study and investigation

It was observed during the audit that online data measurement is not done on the main incomer as well as at various electrical panels for the energy consumption. It was also noticed that there were no proper fuel monitoring system installed at coal Gasifier and hot air generator and kiln like on-line flow-meters.

Recommended action

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

- Kiln
- Five Layer dryer
- Clay ball mills
- Agitator motors
- Sizing machine
- Compressor
- Spray dryer ID fan
- Slip piston pump
- Glaze ball mill
- HAG – FD & PA fan
- CT pumps
- Press
- Polishing machine
- Calibrating machine
- Nano machines

The cost benefit analysis for this project is given below:

Table 56: Cost benefit analysis [ECM-15]

Parameters	UOM	Present	Proposed
Energy management saving for electrical system	%	2.00	
Energy consumption of major machines per year	kWh/y	10,890,252	10,672,447
Annual electricity saving per year	kWh/y	0	217,805
Average Electricity Tariff	Rs/kWh	6.78	6.78
Annual monetary savings	lakh Rs/y	0	14.77
Number of Electrical equipments	#	40	40
No. of energy meters	#	0	35
Estimate of Investment	Lakh Rs		3.49
Thermal energy monitoring system	%	2.00	
Current coal consumption	kg/y	11,514,240	11,283,955
Annual coal saving per year	kg/y		230,285
Cost of Coal	Rs/kg		5.85
Annual NG consumption	scm/y	-	-
Annual fuel saving	scm/y		-
Average NG cost	Rs/scm		-
Total annual monetary savings	Lakh Rs/y		13.48
Number of equipments or system	#	2	2
Number of coal weighing machines			2
Number of NG Meters			0
Estimated investment	Lakh Rs		2.64
Annual monetary savings (Electrical + Thermal)	Lakh Rs/y		28.25
Total Estimated investment (Electrical + Thermal)	Lakh Rs		6.13
Simple Payback period	Months		2.60
Project IRR	%		343
Discounted payback	Months		1.04

5.2 Best Operating Practices

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

Sl No	Equipment/System	
1	Transformer	APFC installed to maintain power factor
2	Clay ball mill	VFD for energy saving. Timer control system.
3	Agitation tank	None
4	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing emission
5	Press	None
6	Vertical Dryer	Waste heat from kiln is used in VD with supplementary firing.
8	Glaze line	None
9	Kiln	VFD in each blower, waste heat used in preheating section and VT dryer. PID control system for controlling chamber temperature in firing zone.
10	Sizing	Fully automatic system. Dust collected system installed.
11	Printing	Automated digital printing with fully auto control system
12	Lighting	LED lights

5.3 NEW/EMERGING TECHNOLOGIES

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

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

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

[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

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

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

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

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

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

[4] SACMI Kiln Revamping catalogue for roller kilns

- Easy installation

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

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

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

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

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

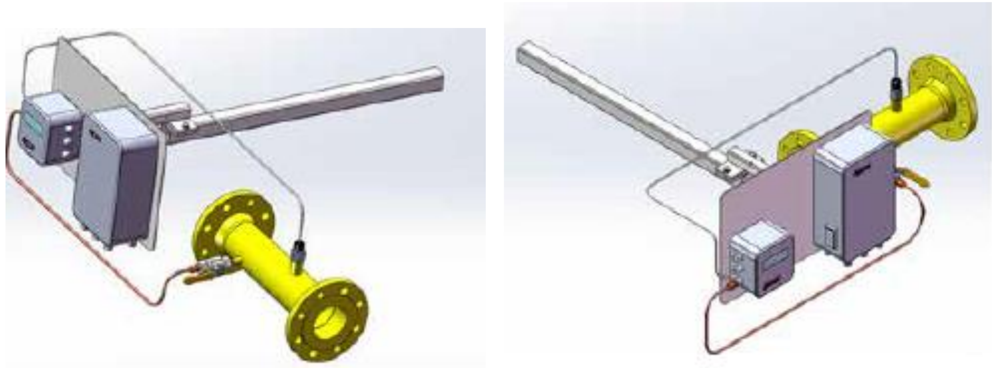


Figure 24: Combustion air control for burner

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

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

Figure 25: Heat recovery from kiln to dryer

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

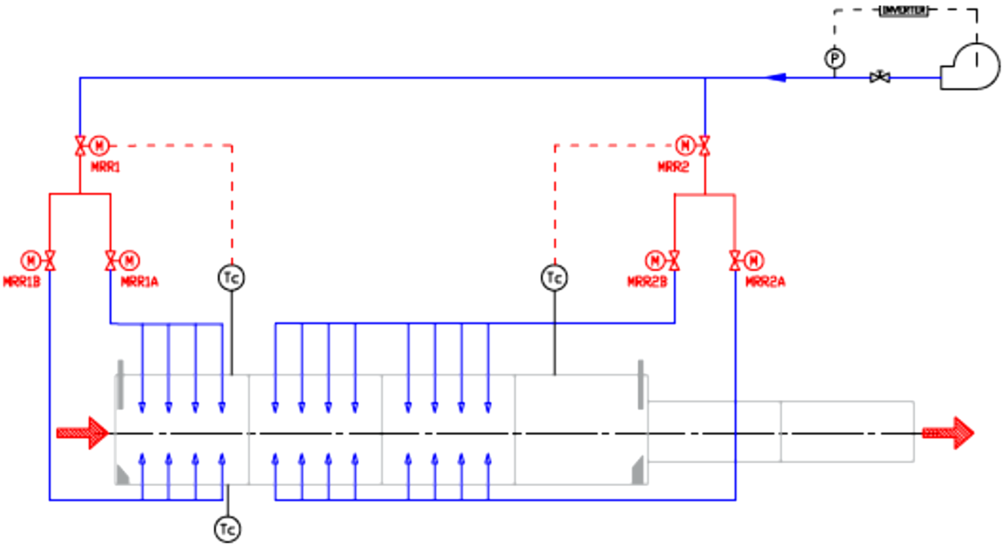


Figure 26: Fast cooling air management

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

Figure 27: Real time information system 4.0

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

5.3.4 High Alumina Pebbles for Ball Mills:

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

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

Figure 28: - High Alumina pebbles for Ball mill

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

a. Local pebbles: The local river pebbles are used mainly for economic reasons as they are cheap but its sizes vary irregularly and wears out very fast resulting in longer grinding time which increases the energy consumption.
b. Imported Pebbles: Chinese pebbles are available in different quality and variable working life span. These quality is also widely used by ceramic units which give 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 are 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.

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

- Minimum or no adverse effect on the rheological properties of slip (The rheological behavior of non-Newtonian fluids such as cement paste, mortar, or concrete is often characterized by two parameters, yield stress, τ_0, and plastic viscosity, μ, as defined by the Bingham equation Eq. (1) If observed, can be easily corrected by a small dosage of deflocculant.
- The use of organic binder could reduce the addition of expensive clays in the clay body which impact higher resistance and reduce the cost

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

5.3.7 Use of Direct blower fans instead of belt drive:

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

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

Figure 29: Direct drive blower fan

6. Chapter-6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA. A rooftop area of 400 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	400
Estimated total solar PV panel area	m^2	240
Number of panels (1m x 2m) of 320 Wp	#	120
Estimated installed capacity of solar panel	kW	38.4
Electricity generation per kW of panel	kWh/d	4.2
Energy generation from solar panel	kWh/d	161
Solar radiation days per year	d/y	365
Average electricity generation per year	kWh/y	58,867
Cost of Electricity	Rs/kWh	6.76
Annual monetary savings	Lakh Rs/y	3.98
Estimated Investment	Lakh Rs	21.12
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

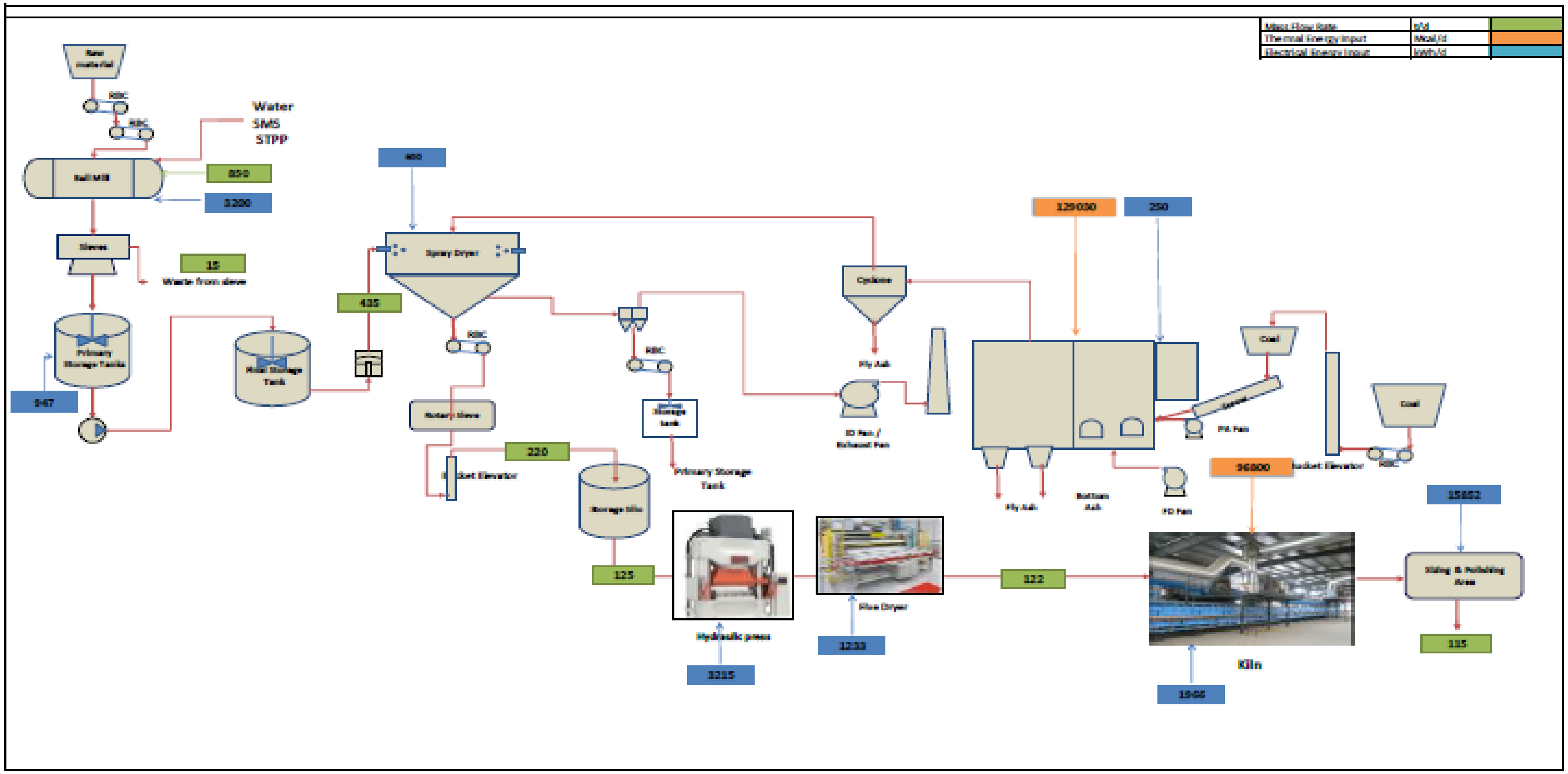


Figure 30: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 59: Detailed Inventory list

Equipment Name	Electrical Load (kW)
Five Layer Dryer	254
Hydraulic Presses	422
Kiln	342
HAG	224
Piston Pump	60
Compressor	74
Stirrer Motor	225
Clay Ball Mill	435
Coal Gasifier	104
Initial Sizing Machines	186
Final Sizing Machines	186
Calibrating Machines	480
Polishing Machines	676
Nano Machines	408
Lights & Office Load	35
Glaze ball mill	120
Total	**4232**

7.3 Annex-3: Single Line Diagram

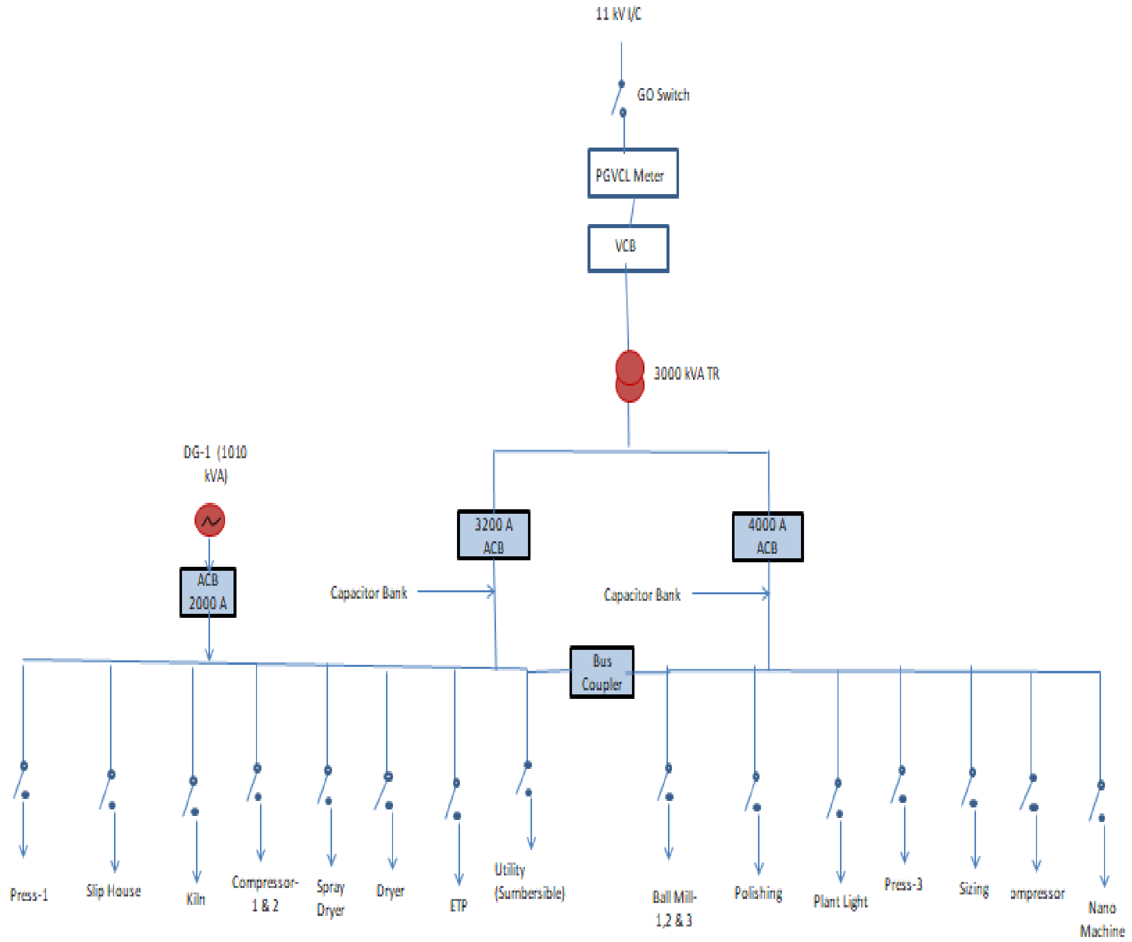


Figure 31: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

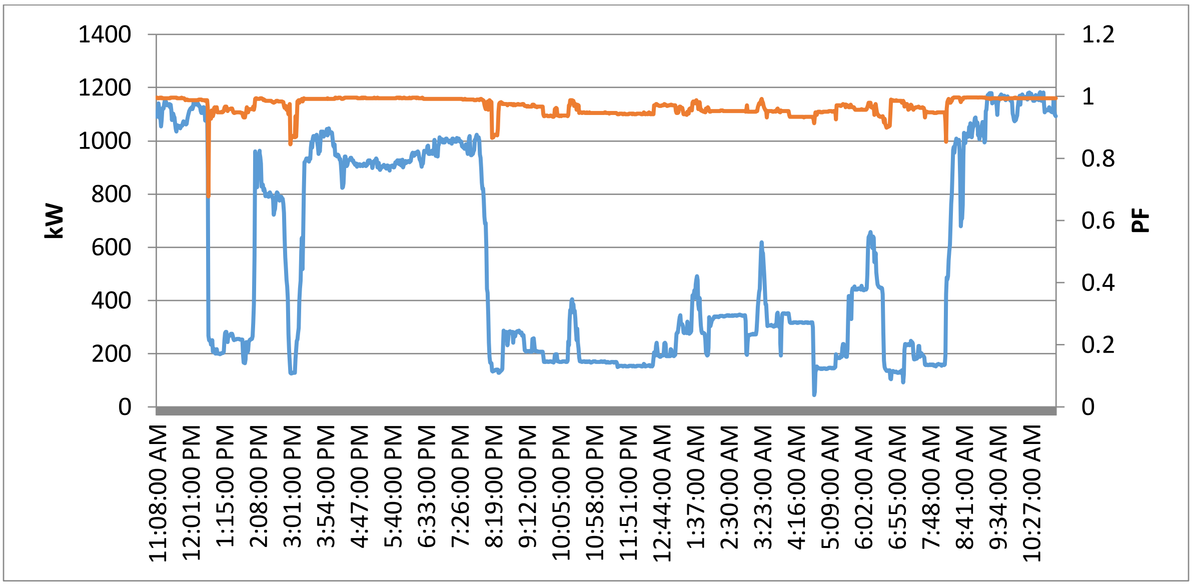


Figure 32: Power and PF Profile of GEB-1

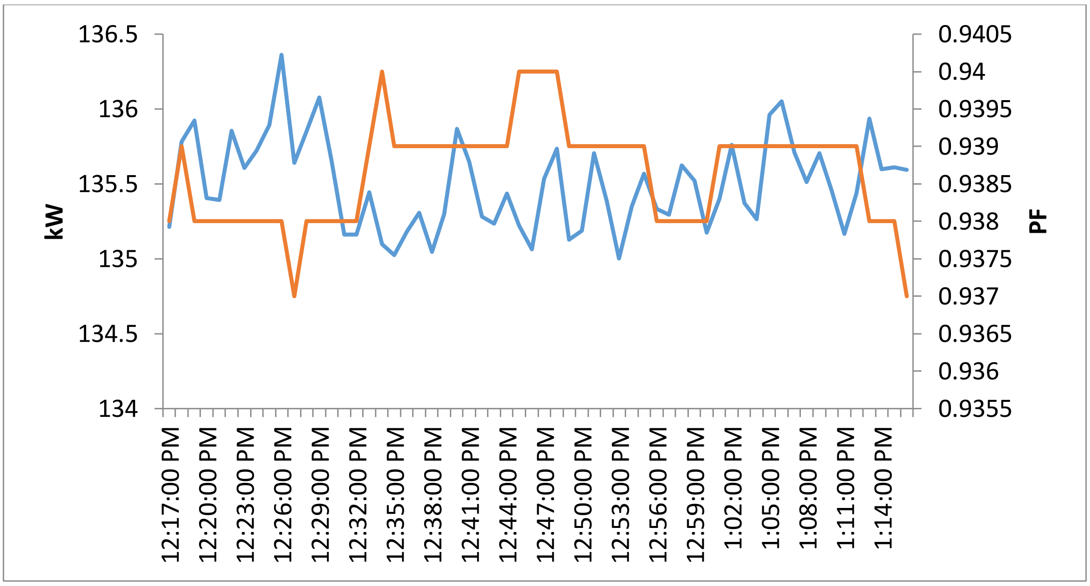


Figure 33: Power and PF Profile of Clay ball mill-1

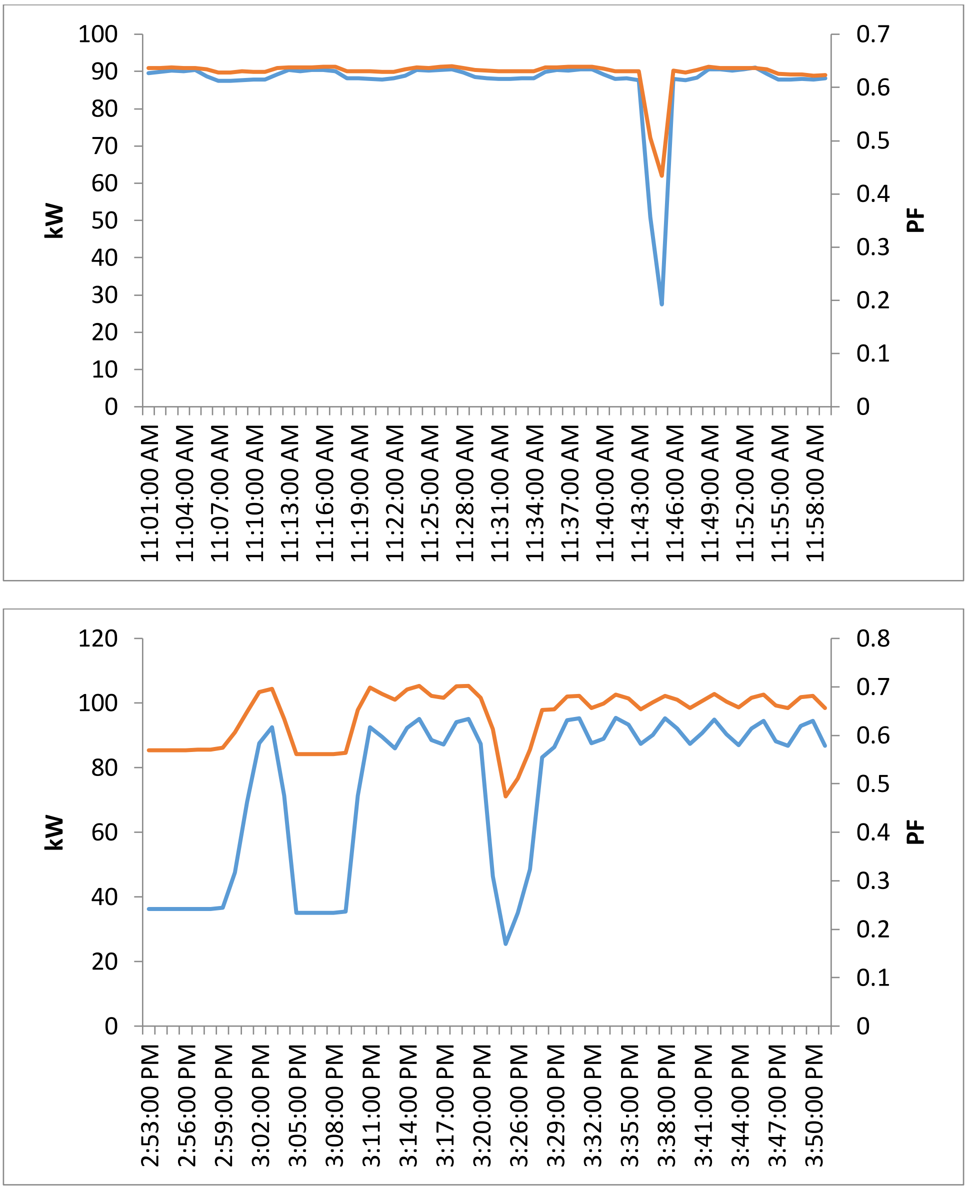


Figure 34: Power and PF Profile of Press1 & Press 3

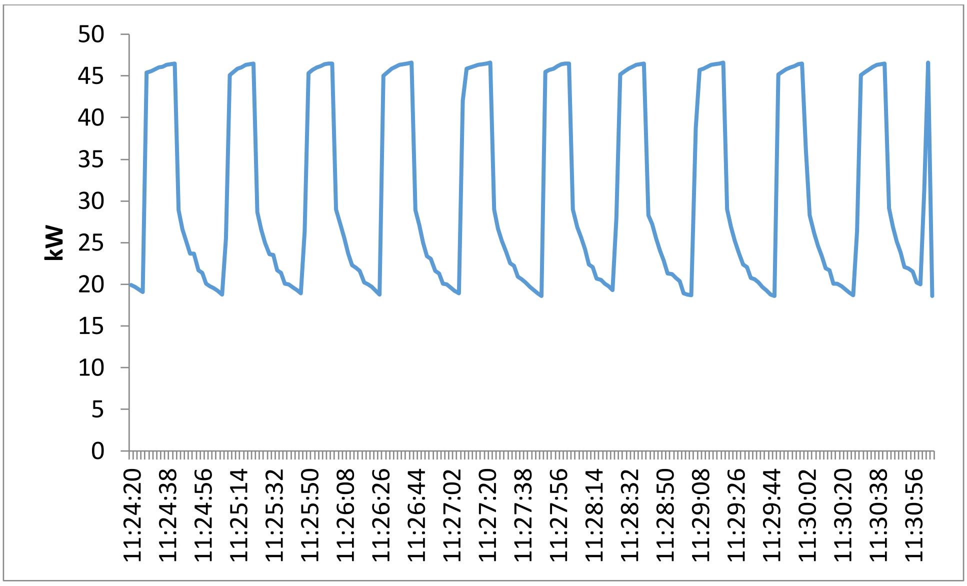


Figure 35: Power Profile of Compressor-1

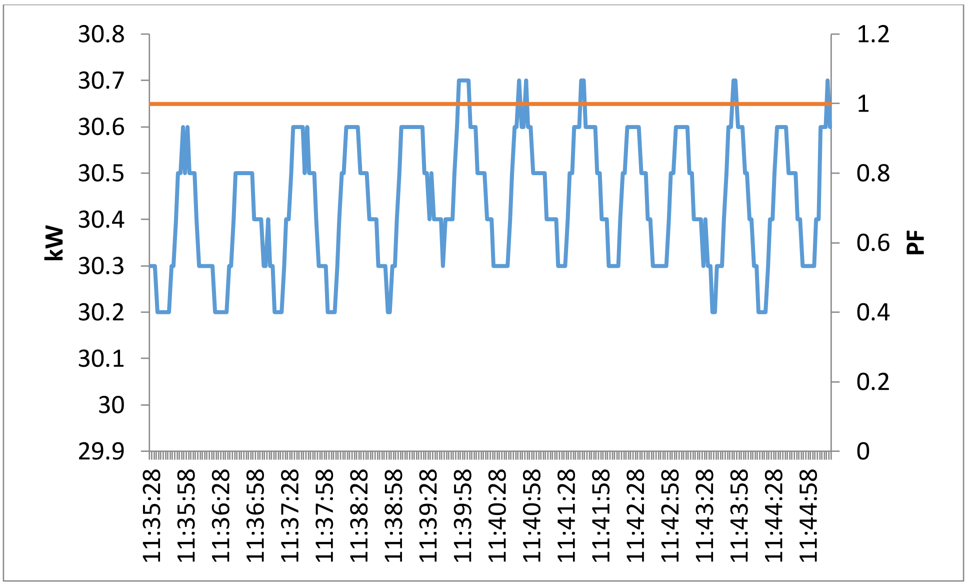


Figure 36: Power and PF Profile of Compressor-2

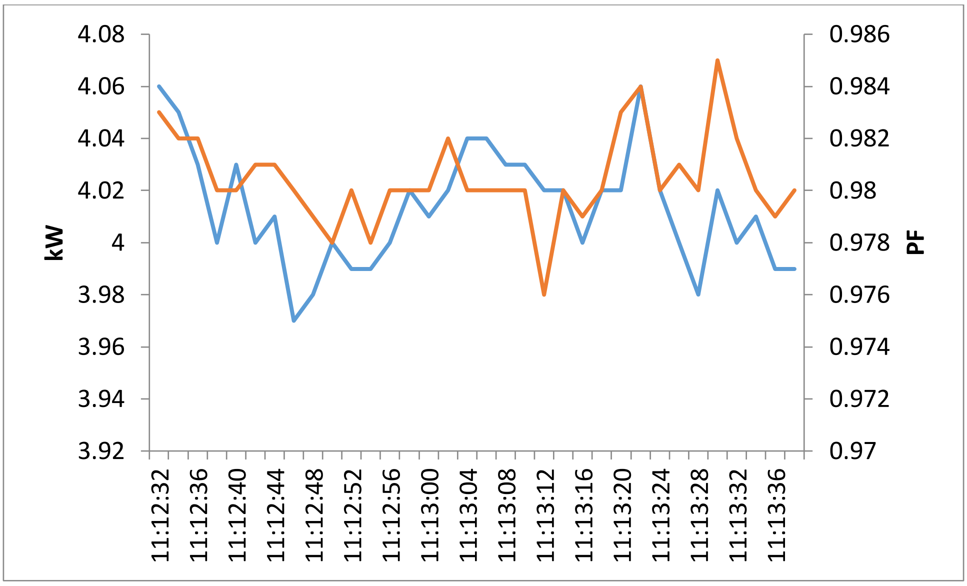
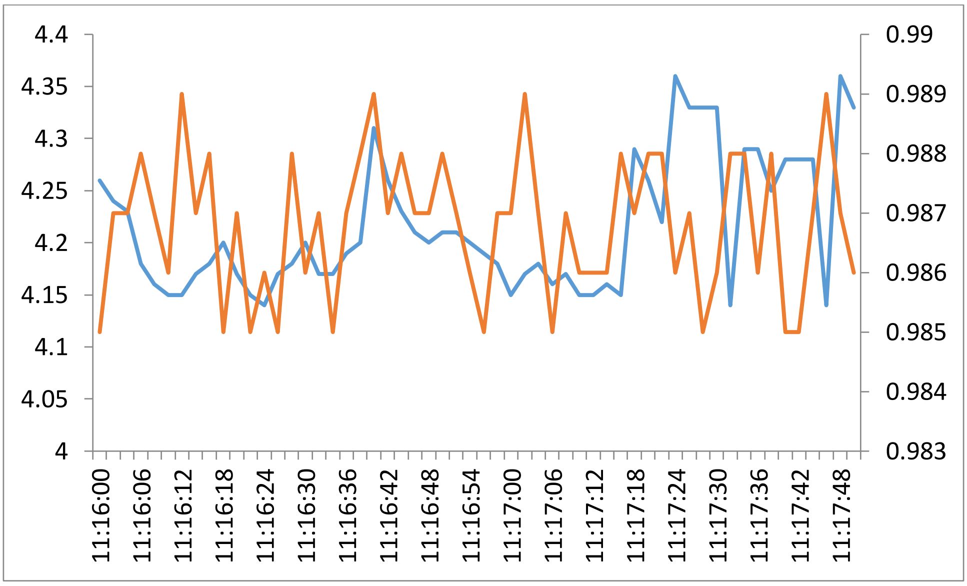
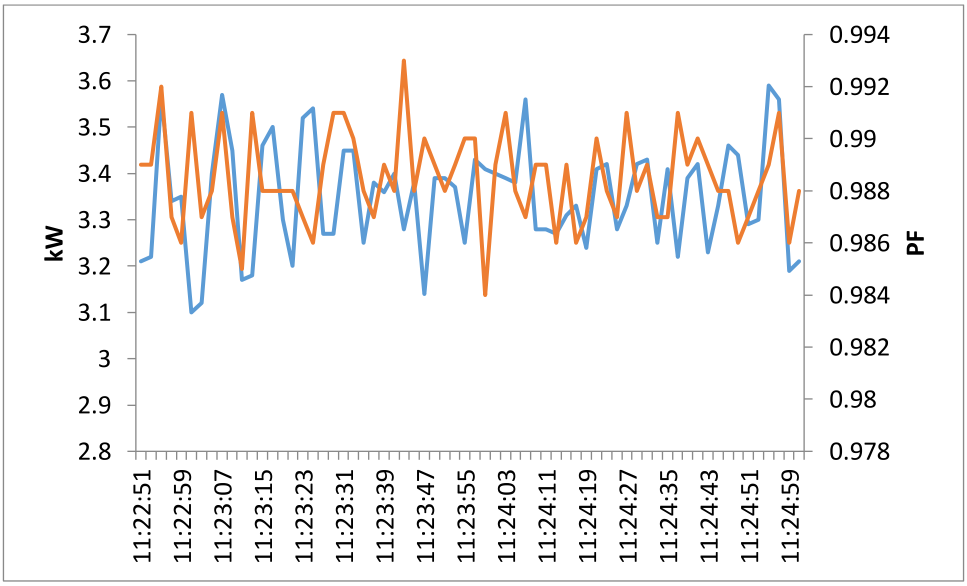
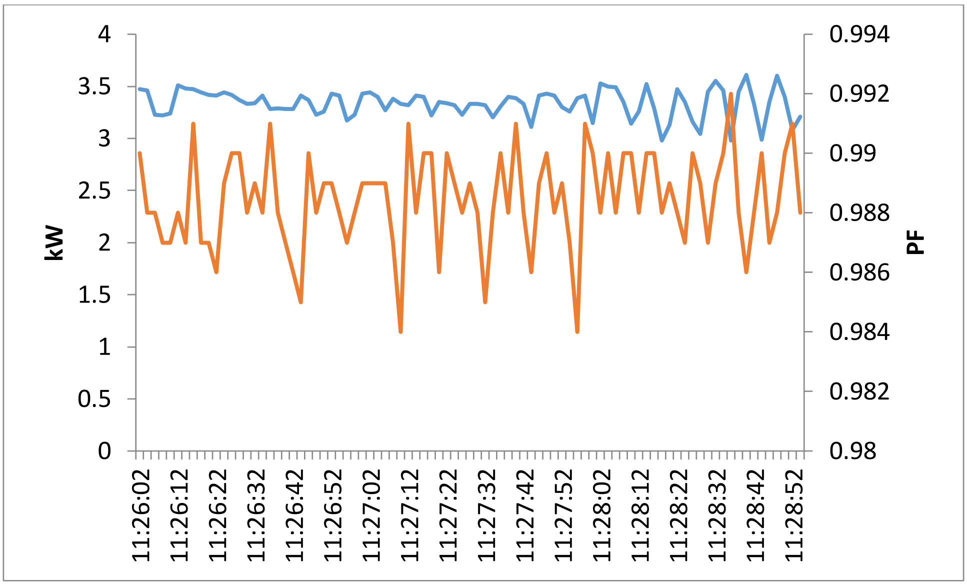


Figure 37: Power and PF Profile of heat suction fan of dryer



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3
2.5
2
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0.5
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0.992
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0.988
0.986
0.984
0.982
0.98
11:26:02
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11:26:22
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11:26:42
11:26:52
11:27:02
11:27:12
11:27:22
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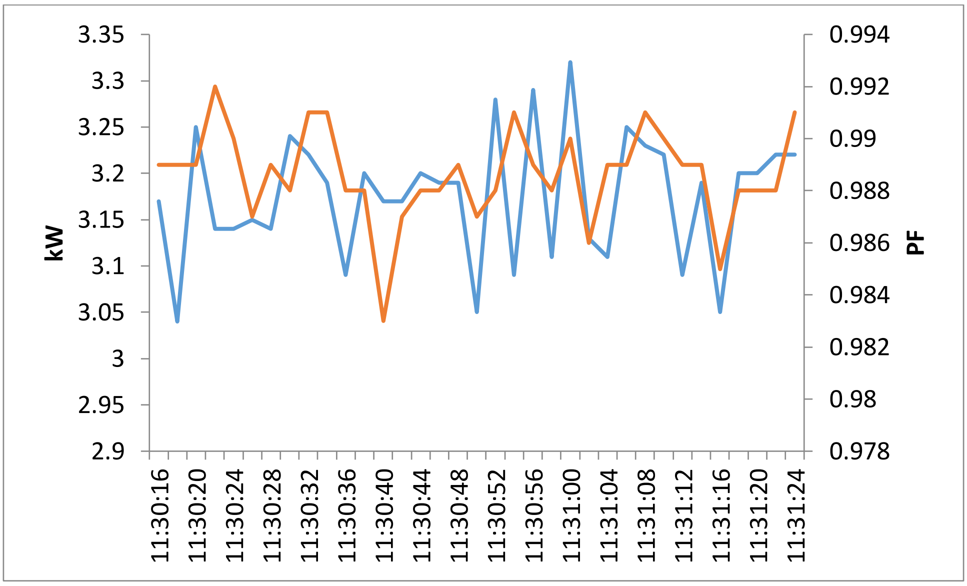
11:28:52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3.15
3.1
3.05
3
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2.9
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0.992
0.99
0.988
0.986
0.984
0.982
0.98
0.978
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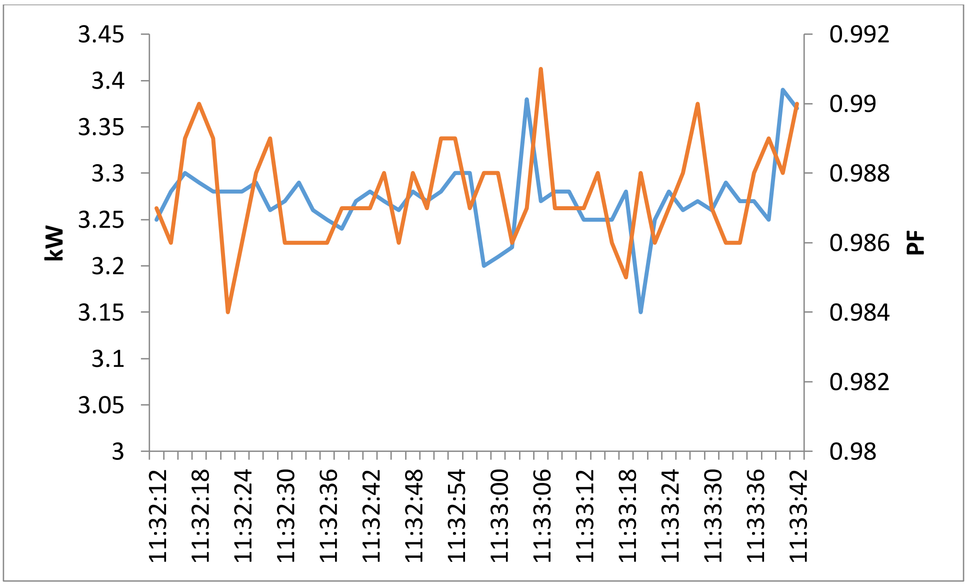
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3.1
3.05
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0.99
0.988
0.986
0.984
0.982
0.98
11:32:12
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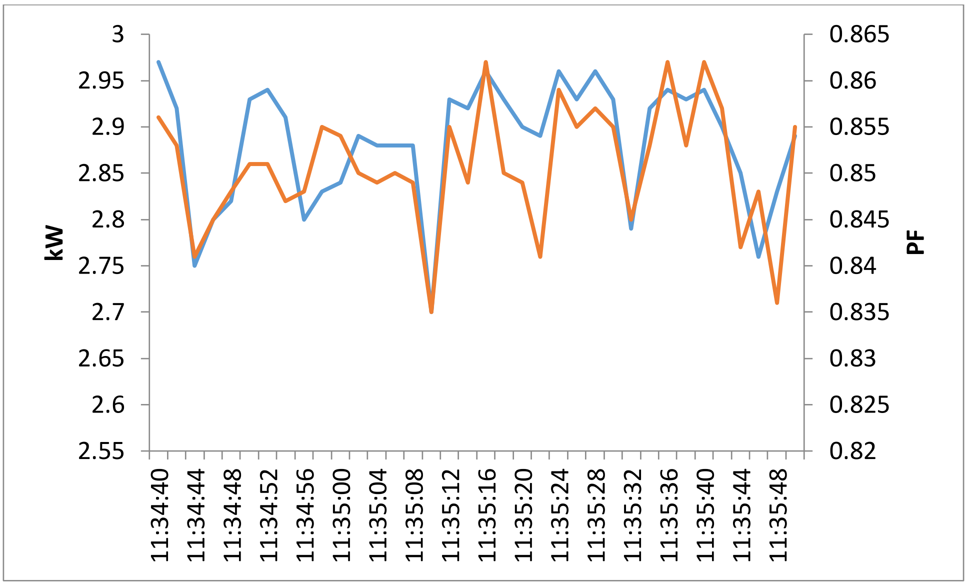
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0.855
0.85
0.845
0.84
0.835
0.83
0.825
0.82
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11:35:04
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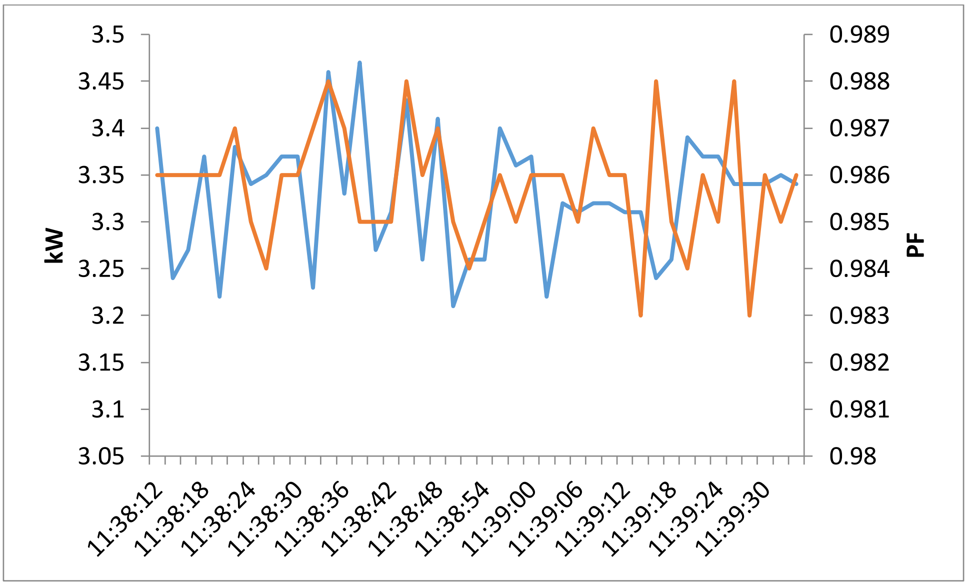
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3.1
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0.988
0.987
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0.985
0.984
0.983
0.982
0.981
0.98
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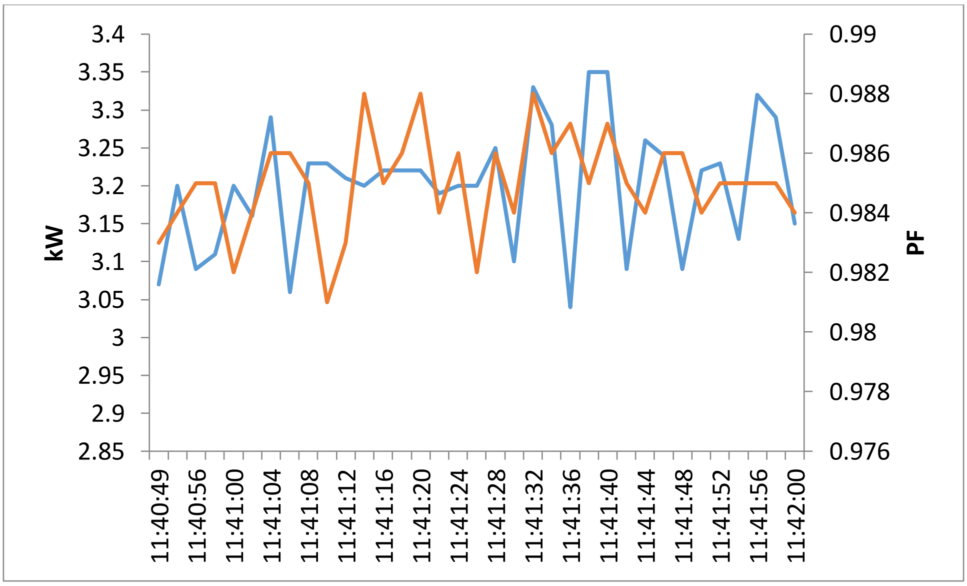
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0.986
0.984
0.982
0.98
0.978
0.976
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11:41:08
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11:42:00

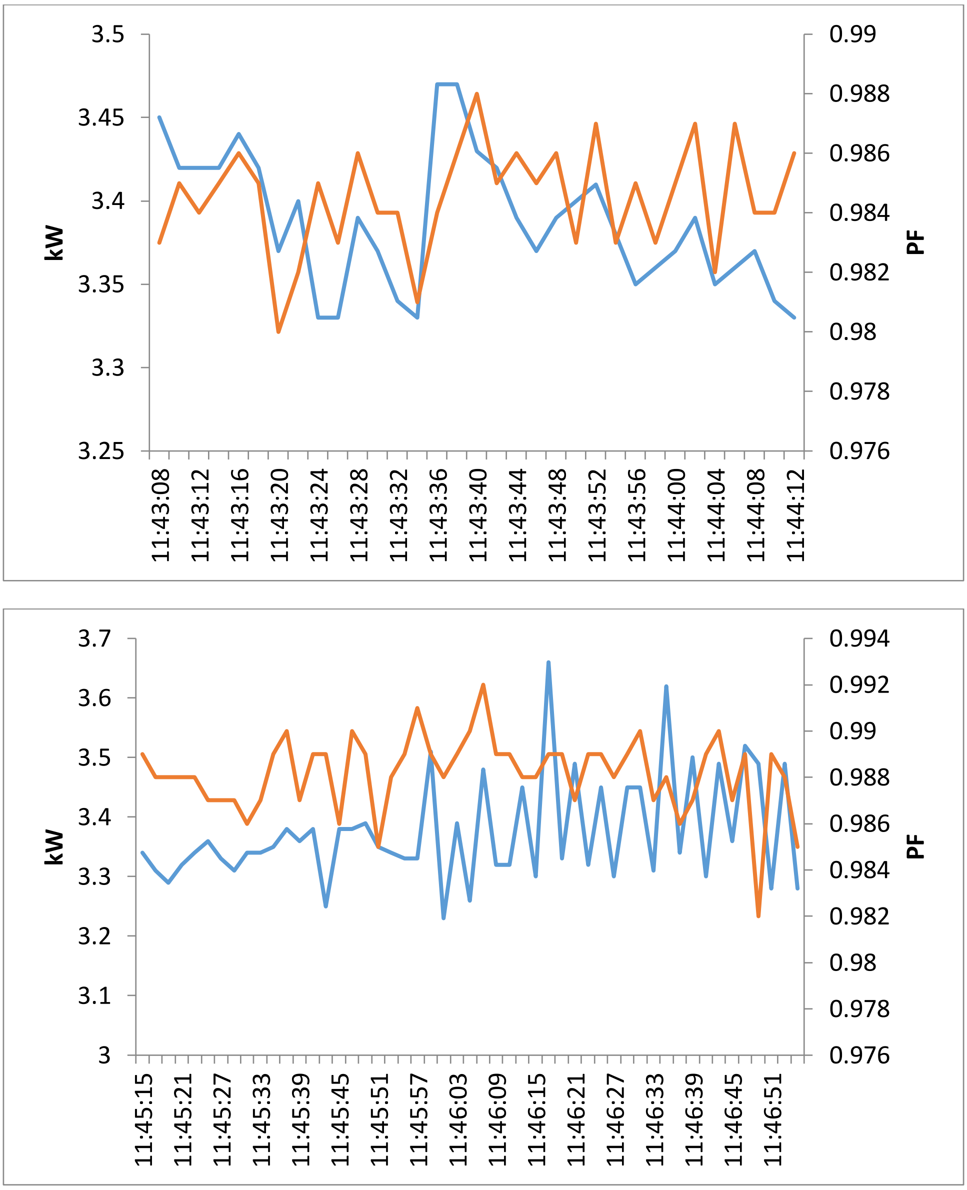
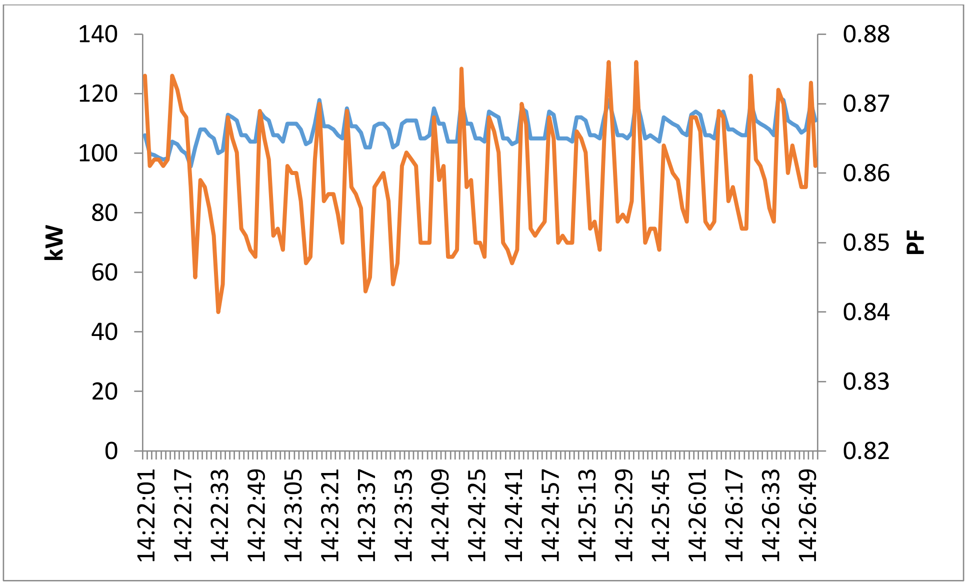


Figure 38: Power and PF Profile of all heat supply fans of Dryers



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PF
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100
80
60
40
20
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0.87
0.86
0.85
0.84
0.83
0.82
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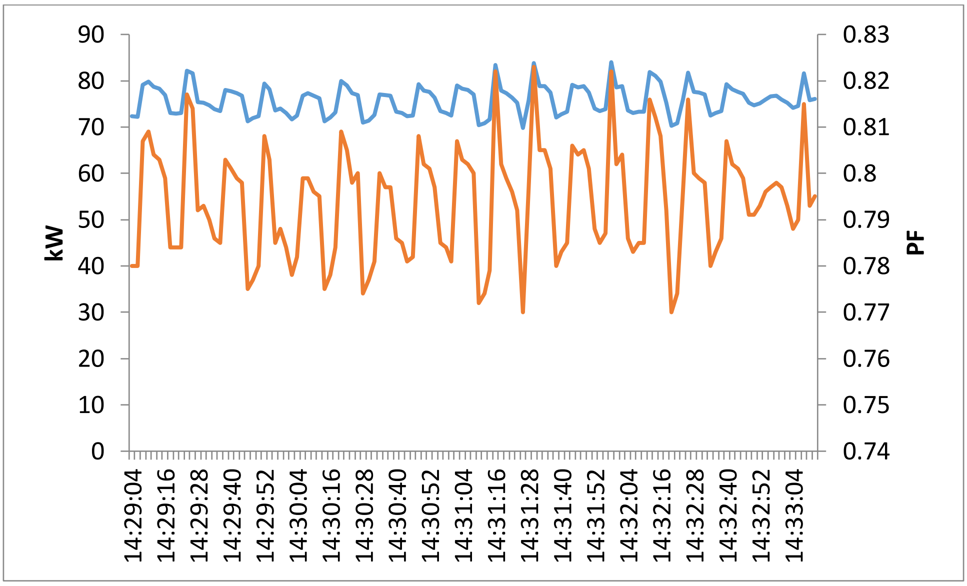

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0.77
0.76
0.75
0.74
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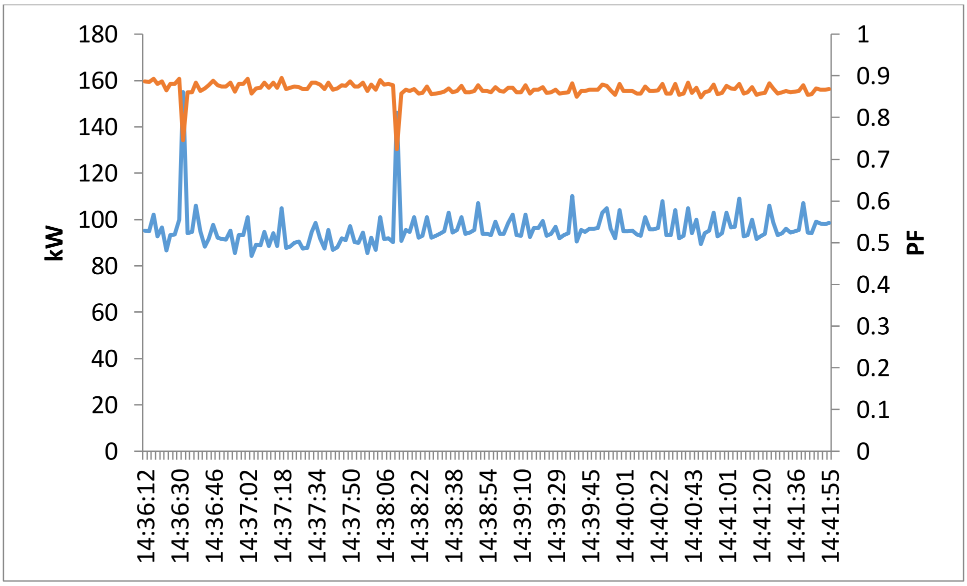

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140
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100
80
60
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0.5
0.4
0.3
0.2
0.1
0
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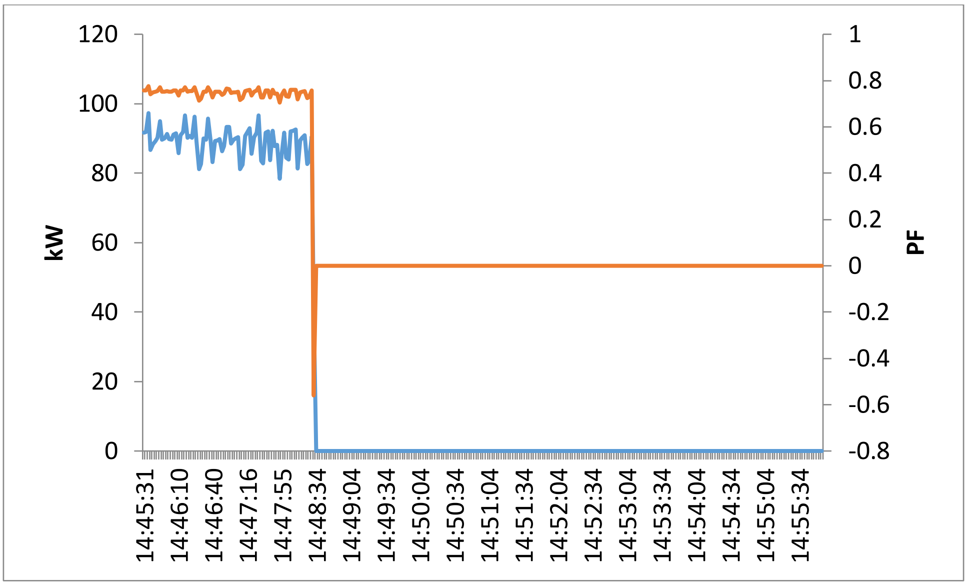
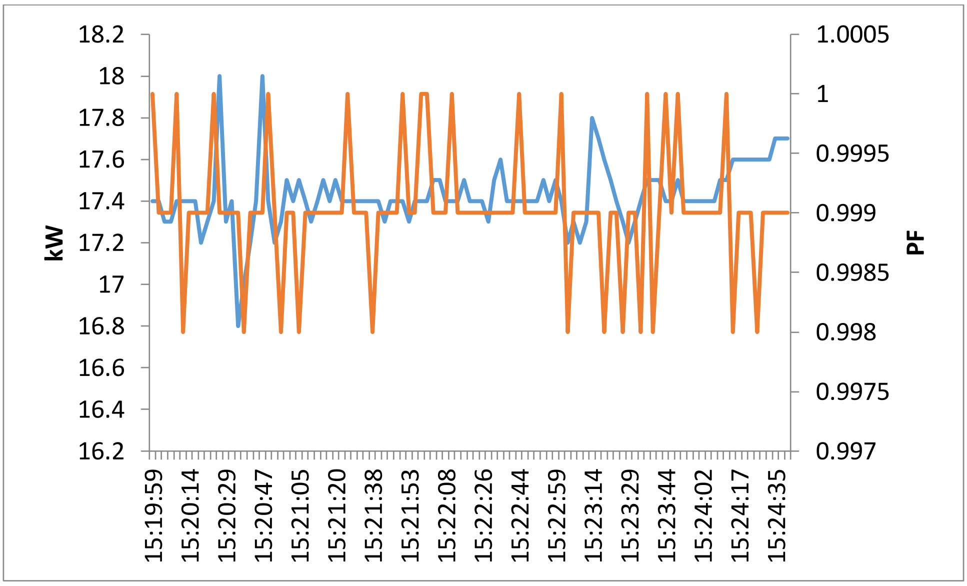
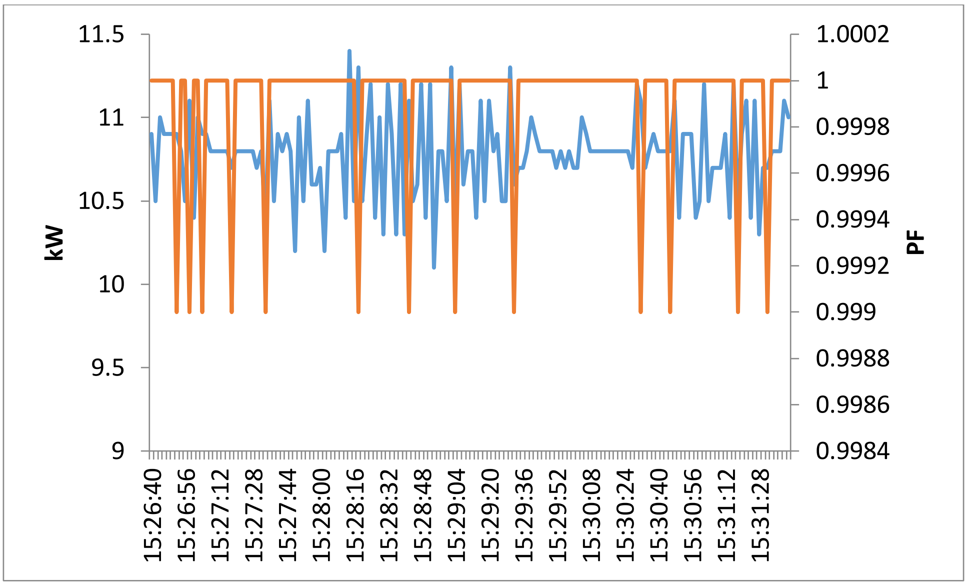


Figure 39: Power and PF profile of all Polishing machines

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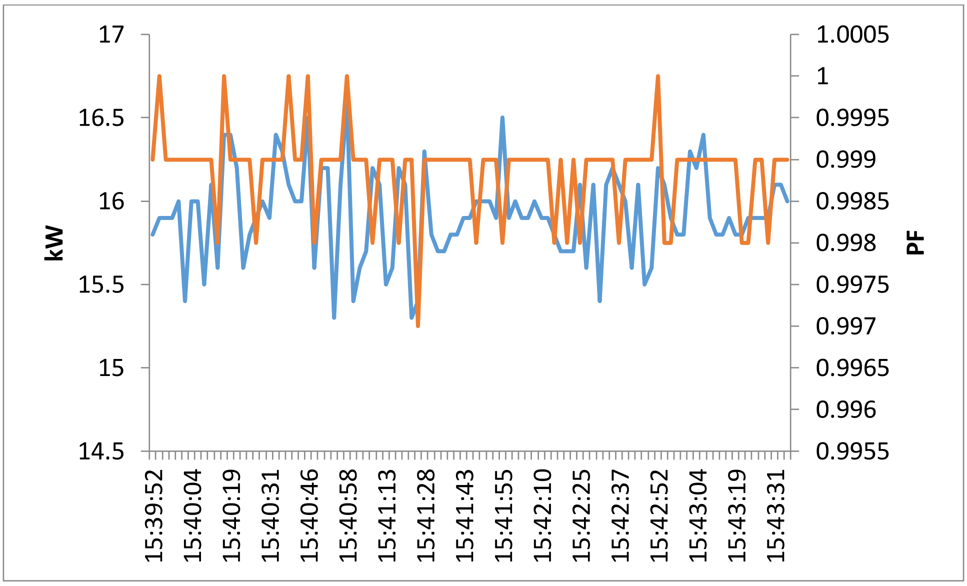
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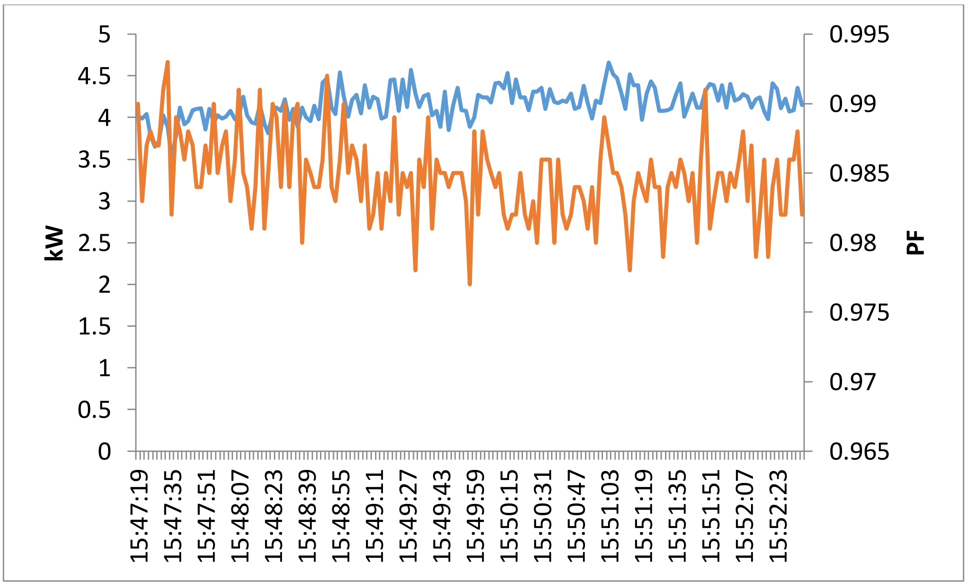
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PF
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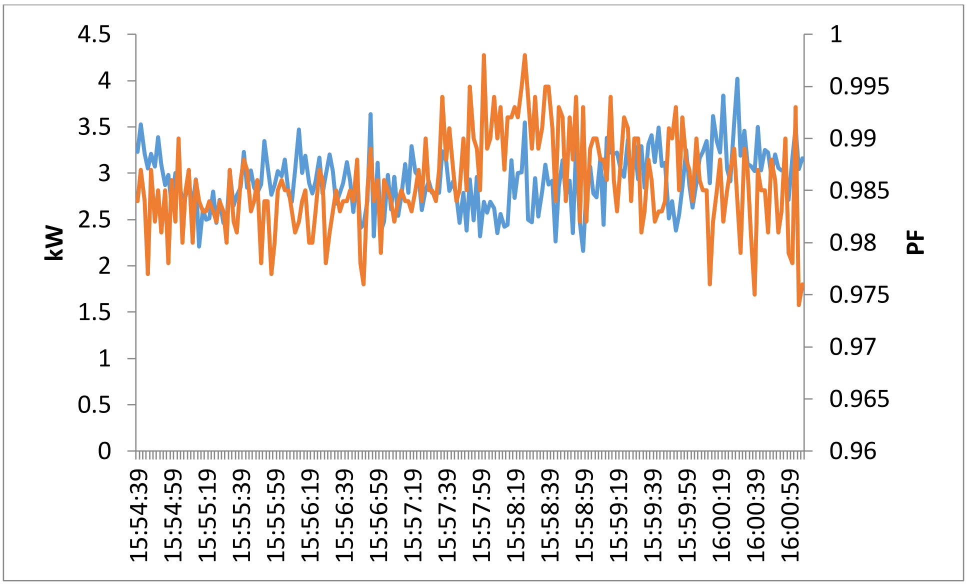
15:52:23



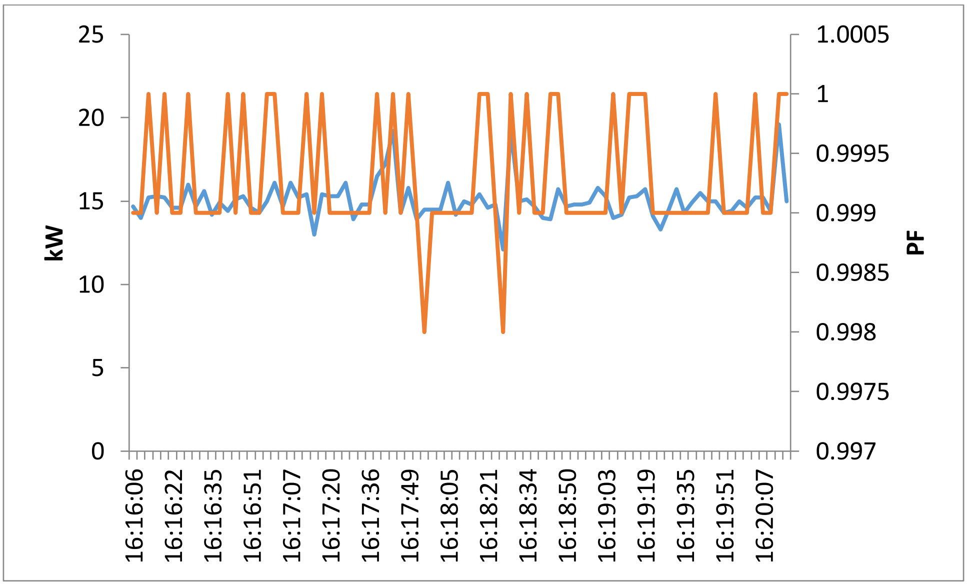


Figure 40: Power and PF Profile of all blowers of Kiln

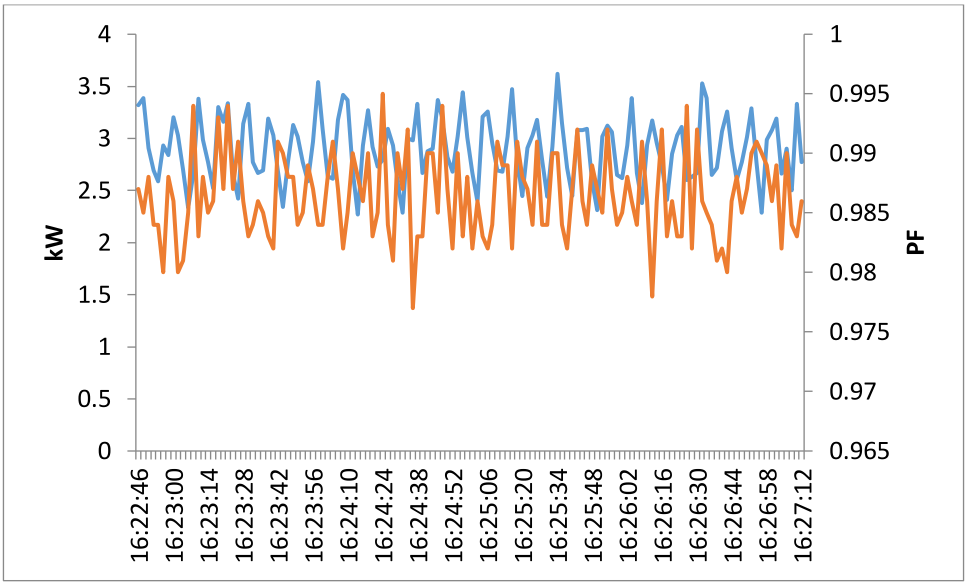
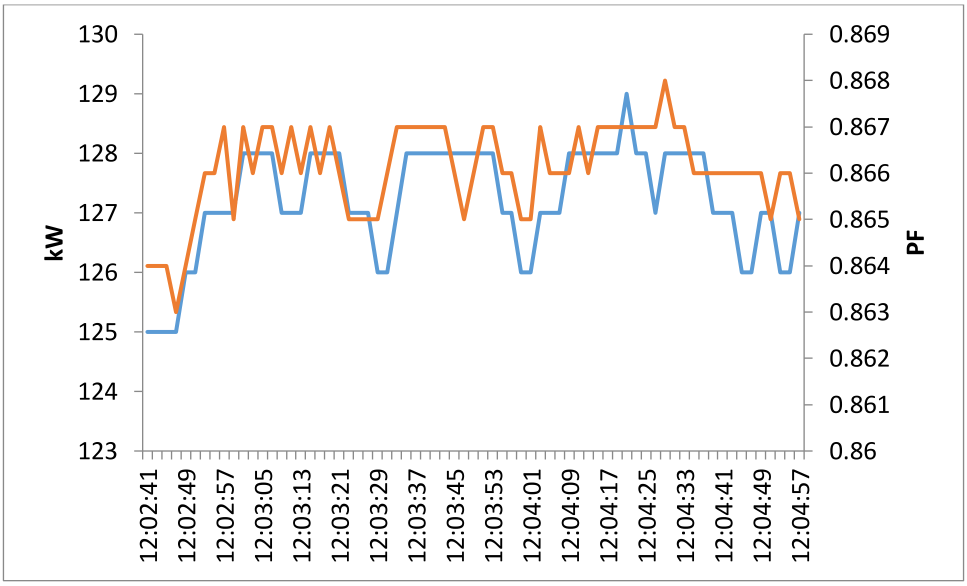


Figure 41: Power and PF Profile of Smoke combustion blower



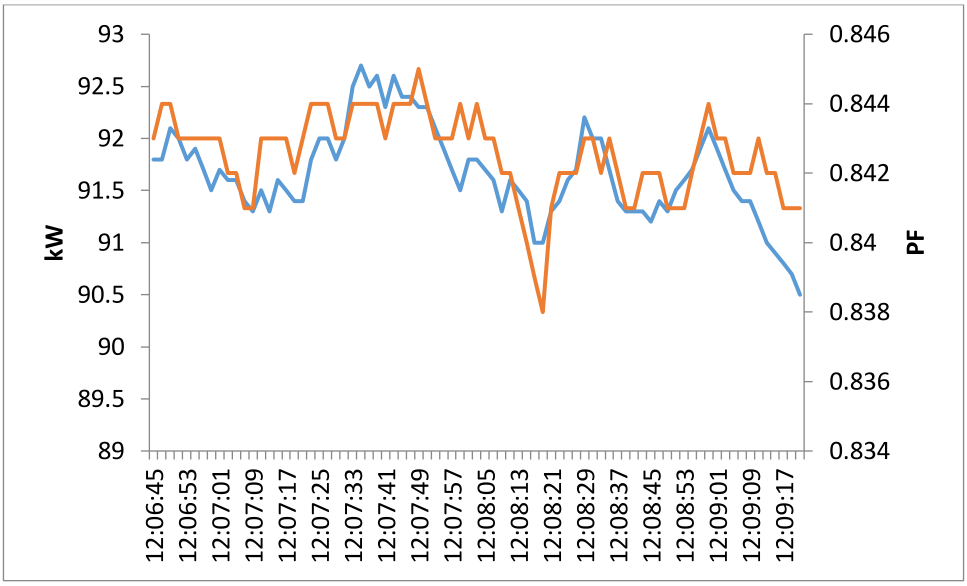
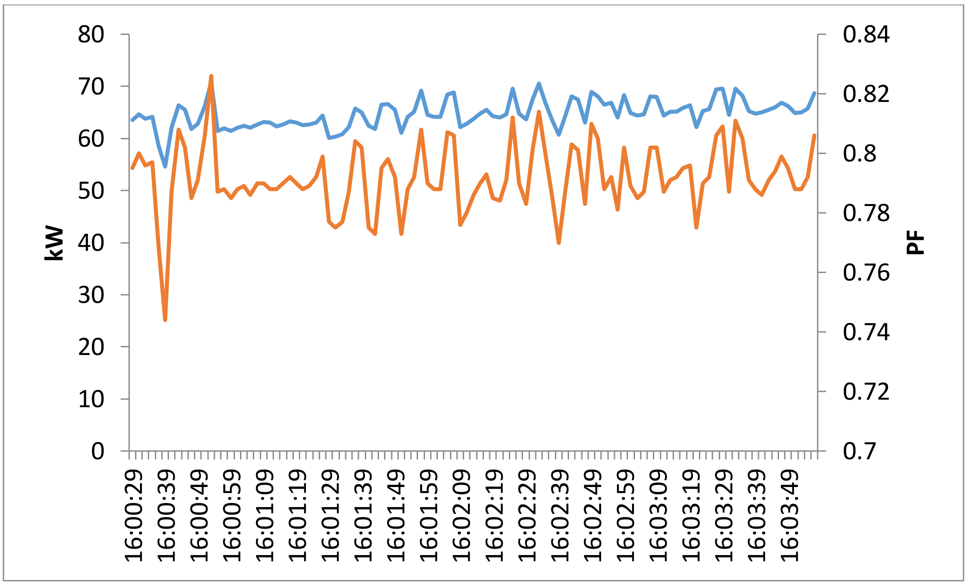


Figure 42: Power and PF Profile of Nano machines 1 &2



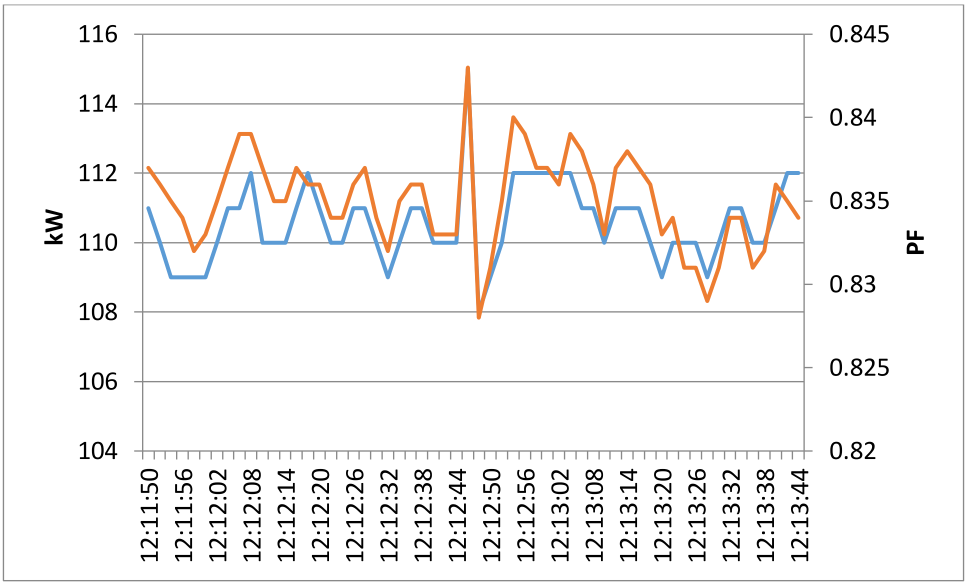
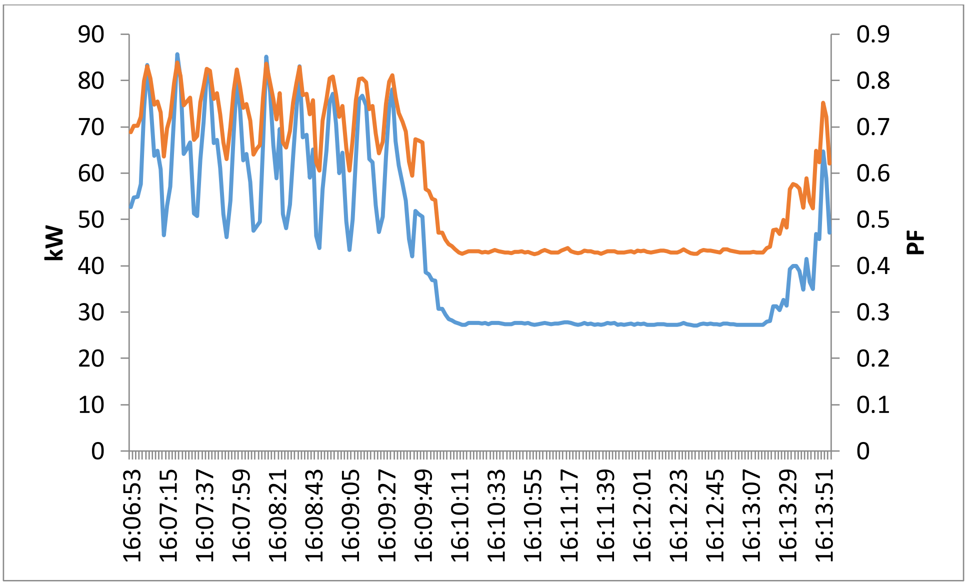


Figure 43: Power and PF profile of Sizing Machine 1&2



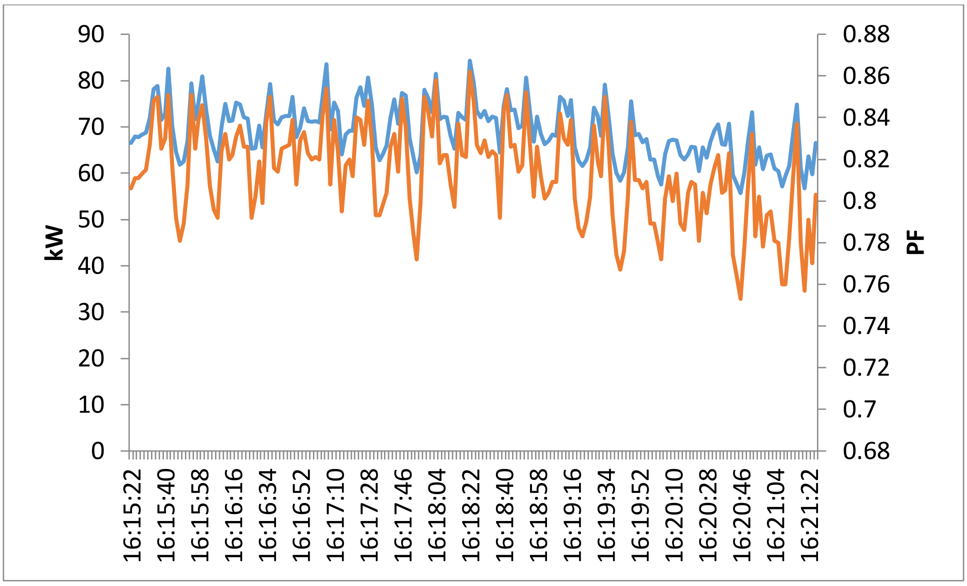


Figure 44: Power and PF profile of Calibration Machines 2&3

7.5 Annex-5: Thermal Measurements - Kiln heat utilization & Gasifier Performance

1. Kiln heat utilization calculations

Input parameters

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Local Vendor	
Particulars	**Value**	**UOM**
Roller Kiln Operating temperature (Heating Zone)	1200	*Deg C*
Initial temperature of kiln tiles	40.2	*Deg C*
Avg. fuel consumption	2,821	*sm3/hr*
Flue Gas Details		
Flue gas temp at smog blower	260	*deg C*
O2 in flue gas	6.3	*%*
CO2 in flue gas	8.2	*%*
CO in flue gas	42	*ppm*
Atmospheric Air		
Ambient Temp.	38	*Deg C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Coal Gas Analysis		
C	*12.78*	%
H	*14.90*	%
N	*52.97*	%
O	*19.31*	%
S	*0.33*	%
Moisture	*3.50*	%
Ash	*0.00*	%
GCV of fuel	1231	*kcal/kg*
Material and flue gas data		
Weight of ceramic material being heated in Kiln	4623	*Kg/Hr*
Specific heat of clay material	0.22	*Kcal/kgdegC*
Avg. specific heat of fuel	0.51	*Kcal/kgdegC*
fuel temp	40.2	*deg C*
Specific heat of flue gas	0.24	*Kcal/kgdegC*
Specific heat of superheated vapour	0.45	*Kcal/kgdegC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	4325	*kcal/hr*
Radiation and convection from heating zone surface	3452	*kcal/hr*
Heat loss from all zones	**7776**	*kcal/hr*
For radiation loss in furnace(through entry and exit of kiln car		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	1.43	*Hr*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
average operating temp. of kiln	343	*deg K*

Efficiency calculations

Calculations	Kiln	Unit
Theoretical Air Required	5.84	*kg/kg of fuel*
Excess Air supplied	42.86	*%*
Actual Mass of Supplied Air	8.35	*kg/kg of fuel*
Mass of dry flue gas	8.01	*kg/kg of fuel*
Amount of Wet flue gas	9.35	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.38	*Kg of H2O/kg of fuel*
Amount of dry flue gas	7.97	*kg/kg of fuel*
Specific Fuel consumption	637.66	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	784955	*Kcal/ton of tiles*
Sensible heat of fuel	0	*Kcal/ton of tile*
Total heat input	784955	*Kcal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	255156	*Kcal/ton of tile*
Heat loss in dry flue gas	270768	*Kcal/ton of tile*
Loss due to H2 in fuel	41472	*Kcal/ton of tile*
Loss due to moisture in combustion air	834	*Kcal/ton of tile*
Loss due to partial conversion of C to CO	236	*Kcal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	54	*Kcal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	15263	*Kcal/ton of tile*
Total heat loss from kiln (surface) body	1682	*Kcal/ton of tile*
Heat loss due to unburnt in Fly ash	0	*Kcal/ton of tile*
Heat loss due to unburnt in bottom ash	0	*Kcal/ton of tile*
Heat loss due to kiln car	0	*Kcal/ton of tile*
Unaccounted heat losses	199490	*Kcal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	1682	*Kcal/tons*
Kiln heat utilization	32.5	*%*

2. Heat Balance Diagram

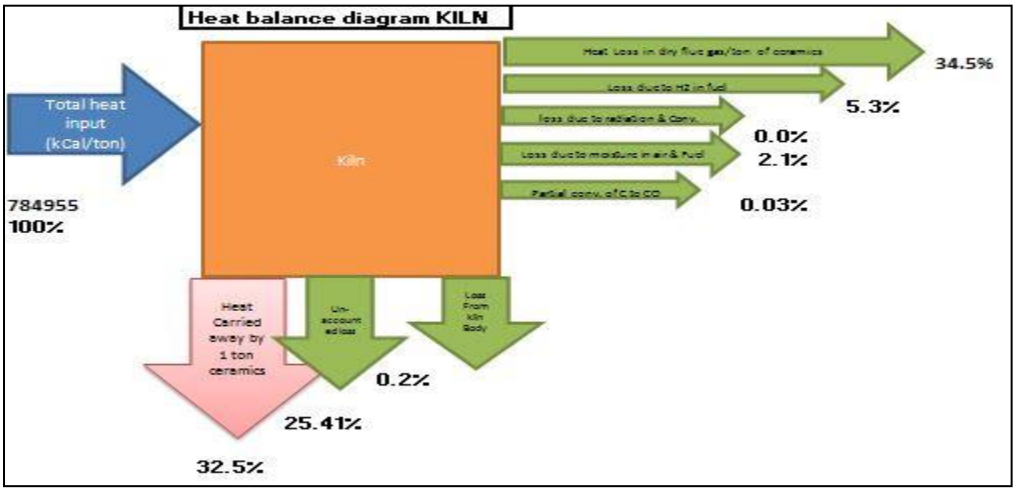


Figure 45: Heat Balance diagram for Kiln

3. Kiln heat utilization calculations

Performance analysis	UOM	Value
Fuel fired		Coal
Fuel through put	kg/h	733.33
Fuel composition		
Carbon	%	0.70
Hydrogen	%	0.04
Oxygen	%	0.13
Nitrogen	%	0.01
Moisture	%	0.04
Ash	%	0.07
GCV of fuel fired	kcal/kg	5500.00
Atmospheric conditions		
Nitrogen	%	77%
Oxygen	%	20%
Water vapour	%	3%
Coal Gas analysis		
Carbon dioxide	%	7%
Carbon monoxide	%	21%
Methane	%	3%
Hydrogen	%	14%
Nitrogen	%	53%
Water vapour	%	3%
Ashes generated	%	9%
Calculations		
Amount of gas produced	kg mole	137.50
Volume of the gas produced	Sm3/h	3044.41
Density of coal gas	kg/m3	1.05
Mass flow of coal gas	kg/h	3181.54
Coal gas fed to horizontal dryer	kg/h	233.44
Coal gas fed to kiln	kg/h	2948.10

Performance analysis	UOM	Value
Volume of air required	kg mole	94.46
Volume of air required	Sm3/h	2117.17
Density of air	kg/Sm3	1.29
Amount of air required	kg/h	2737.50
HHV of gas produced	kcal/Sm3	1231
HHV of gas produced	kcal/kg	1178

7.6 Annex-6: List of Vendors

ECM-1: Waste heat recovery from flue gas

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Encon Thermal Engineers Pvt Ltd	Faridabad	Mob: 9971499075	
2	Knackwell Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445,	9824037124, 9624042423	http://www.knackwellengineers.com/ darshan@kanckwell.com ravi@kanckwell.com
3	Aerotherm Products	No. 2406, Phase 4, G. I. D. C. Estate Vatva, Ahmedabad - 382445,	+91-9879104476, 9898817846	http://www.aerotherm.in

ECM -2: Insulation improvement in kiln section

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	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 Mr. Rajneesh Phone : 0161-2819388 Mobile : 9417004025	Email: kk.mitra@lloydinsulation.com
3	Shivay Insulation	20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009	Mobile- 9712030444	shivayinsulation@gmail.com

ECM-3: Excess air control in HAG

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

Sl.No.	Name of Company	Address	Phone No.	E-mail
		Gujarat, India		
3	Knackwell 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-4: Insulation improvement in HAG section

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	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 Mr. Rajneesh Phone : 0161-2819388 Mobile : 9417004025	Email: kk.mitra@lloydinsulation.com
3	Shivay Insulation	20, Ashiyan, Haridarshan Society, Nr. D'mart, New Adajan Road Surat-395009	Mobile- 9712030444	shivayinsulation@gmail.com

ECM-5: 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	Plot-27, Survey-47, Jivraj Industrial Area Near	70439 55777	marketing@rajwater.com

	(Gujarat) Pvt Ltd	Falcon Pump, Gondal Rd, Vavdi, Rajkot, Gujarat 360004		www.rajwater.com

ECM -6: PID Controller in CT fans

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Cogent Controls	205, Vinay Industrial Estate, Chincholi Bunder Link Road, Malad – West, Mumbai - 400064	Tel: 022-28750421 Mob: 9820032946	COGENT CONTROLS [enquiry@cogentcontrols.com]
2	SHIWKON controls	33-34-35, First Floor, Shakti Chamber - 1, N. H. 8A, Opposite Adarsh Hotel, Morbi-363642	93750 50704	morbi@shiwkon.com
3	Happy Instruments	20, Prafullit Society, Near Navo Vas Rakhial Gam Ahmedabad- 380021,	8048707581	https://www.happyinstrument.co.in/

ECM-7: Retrofit of VFD for compressor -1 & 2

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

ECM-9: Replacement of inefficient pumps

Sl.No.	Name of Company	Address	Phone No.	E-mail
1	Trivium Power Engineers Pvt. Ltd.	F 73, SECTOR 11, ace honda showroom, Noida, Uttar Pradesh, 201301, India	Mob: +91 9999684606 Fax: 0120 4269637	
2	Kirloskar Brothers Ltd	1st floor, Kalapi Avenue, Opp. Vaccine Institute, Old Padra Road, Vadodara	Mr. Sanjeev Jadhav 0265-2338723/2338735	aksur@bdq.kbl.co.in

3	KSB Pumps Ltd	Neel Kamal, Ashram Road, Opposite Sales India, Ashram Road, Ahmedabad, Gujarat 382410	Mr. Jayesh Shah 098794 83210	https://www.ksb.com/ksb-in/ksb-in-india/

ECM-10: Retrofit of VFD in Gasifier & Press CT pumps

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

ECM-11: Installation of Harmonic filter

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

ECM-12: Cable loss minimization

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Cummins Power Generation Contact Person: Rishi Gulati Senior Manager- Power Electronics	Cummins India Limited Power Generation Business Unit 35/A/1/2, Erandawana, Pune 411 038, India	Phone: (91) 020-3024 8600 , +91 124 3910908	cpgindia@cummins.com rishi.s.gulati@cummins.com
	Krishna	ESTERN CHAWLA	Mob:	krishnaautomationsyste

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
2	Automation System Contact Person: Vikram Singh Bhati	COLONY, NEAR KAUSHIK VATIKA, GURGAON CANAL BALLBGARH FARIDABAD 121004	9015877030, 9582325232	ms@gmail.com
3	Next Gen Power controls	8, Rashmi Growth Hub Estate, Near Shree Sai Palace Hotel Odhav, Ahmedabad-382415, Gujarat, India	08048110759	

ECM-13: Voltage optimization in lighting circuits

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Beblec (India) Private Limited	N-3, Phase-3, SIDCO Industrial Estate, Hosur-635126	04344-276358/278658/ 276958/59/ 400687	info@beblec.com nirmala@beblec.com
2	SERVOKON System ltd. (Manufacturer/Exporter)	Servokon House,C-13,Radhu palace road, opp.scope minar,Laxmi Nagar, Delhi-110092	75330088 Toll free:18002001786	http://www.servokonstabilizer.com/contact-us.html
3	SERVOMAX INDUSTRIES LIMITED (Manufacturer)	Plot No:118A, 2nd Floor, Road Number 70, Journalist Colony,Jubilee Hills, Hyderabad, Telangana - 500033 BRANCH: #166A, 2nd Floor,Pratap Nagar, Mayur Vihar,Phase-I, New Delhi-110092	+91 9111234567	customercare@servomax.in www.wervomax.in

ECM-14: V Belt with REC belt replacement

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

ECM-15: 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 (Co's Act)	%	15.00%
Effective Income Tax Rate	%	26.750%
Effective MAT Rate	%	21.644%
Discount factor	%	15.000%