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

DELIVERABLE 4: COMPREHENSIVE ENERGY AUDIT REPORT

UNIT CODE FT-01: Lexus Granito (India) Ltd.

Submitted to

GEF-UNIDO-BEE Project Management Unit

BUREAU OF ENERGY EFFICIENCY

Submitted by

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Disclaimer

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

DESL is indebted to M/s. Lexus Granito (India) 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. Anil B. Detroja, MD

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

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

DESL Team

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ABBREVIATIONS

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

UNITS AND MEASURES

Parameters	Unit of Measurement (UOM)
Calorific value	CV
Degree Centigrade	^{0}C
Horse power	hp
Hour(s)	h
Hours per year	h/y
Indian Rupee	INR/Rs
Kilo Calorie	kCal
Kilo gram	kg
Kilo volt	kV
Kilo volt ampere	kVA
Kilo watt	kW
Kilo watt hour	kWh
Kilogram	kg
Litre	L
Meter	m
Meter Square	m^2
Metric Ton	MT
Oil Equivalent	OE
Standard Cubic Meter	scm
Ton	t
Tons of Oil Equivalent	TOE
Ton of CO_2	tCO_2
Ton per Hour	t/h
Ton per Year	t/y
Voltage	V
Watt	W
Year(s)	Y

CONVERSION FACTORS

TOE Conversion	Value	Unit	Value	Unit
Electricity	1	kWh	0.000086	TOE/kWh
Coal	1	MT	0.55	TOE/MT
Natural Gas	1	scm	0.00082	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.

Lexus Granito (India) Ltd. has been selected as one of the 20 units for detailed energy audit. Landgrace Ceramic is a floor 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	Lexus Granito (India) Ltd.
Year of Establishment	2011
Address	8-A, National Highway, Lakhdhirpur Road, Morbi
Products Manufactured	Floor Tiles & wall tiles
Name(s) of the Promoters / Directors	Mr. Anil B. Detroja

➨ 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 slurry.
- **Agitator:** Slurry 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.
- **Hydraulic Press:** The required shapes of the final product are made in hydraulic press. Here the product is called biscuit.
- **Dryer:** Biscuits are sent to dryer for pre drying after it is passed through kiln.
- **Glaze mill:** For producing glazing material used on the product.
- **Kiln:** Biscuits are baked in the roller kiln at 1100-1150°C and again baked after glazing
- **Sizing:** After cutting, sizing and polishing, tiles are packed in boxes and then dispatched.

The main utility equipment installed are:

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

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

➨ IDENTIFIED ENERGY CONSERVATION MEASURES

The identified energy conservation measures include the following:

- Excess air control at Wall Tiles Kiln: During the study it was found that excess air levels in the coal gas fired kiln is 8% against the desired level of 5%. It is recommended to install an oxygen sensor and PID controller, so that the air flow can be adjusted or automatically.etc according to fuel firing.
- Excess air control for Vitrified Tiles (VT) Old Kiln: During the study it was found that excess air levels in the coal gas fired kiln is 7.1 % against the desired level of 5%. It is recommended to install an oxygen sensor and PID controller, so that the air flow can be adjusted or automatically.etc according to fuel firing
- Excess air control for Vitrified Tiles (VT) New Kiln: During the study it was found that excess air levels in the coal gas fired kiln is 8% against the desired level of 3%. It is recommended to install an oxygen sensor and PID controller, so that the air flow can be adjusted or automatically.etc according to fuel firing.
- Optimization of resource consumption in clay section: Water quality increases batch timing and resource consumption (water, electricity and coal in HAG). Bore well water is having TDS level upto 1,200 ppm which can be improved by installing softener plant which may reduce TDS level upto 400 ppm.
- Insulation at cyclone separator of hot air generator (HAG) VT New: Average surface temperature measured during the study was 95°C of cyclone separator and 110°C of duct

connecting HAG to cyclone separator, resulting surface temperature will be 55°C after recoating of insulation etc.

- Insulation at rapid and firing zone in VT New Kiln: Average surface temperature measured during the study was 190°C of hot air pipes in rapid cooling zone and 130°C of hot air pipes in firing zone, resulting surface temperature will be 55°C after recoating of insulation etc.
- Replacement of Inefficient Pumps: Water pumps were used for circulating water in heat exchanger of press in wall tiles and vitrified tiles respectively, having low efficiencies (pump-1: 24% , pump-2: 20%, pump-3: 24% and pump-4: 30%). It is recommended to replace these with more efficient pumps
- Timer controller at stirrer motor: At present 12 stirrer motors are operated continuously. A timer controller is recommended to be installed so that operating hours of each will reduce upto 12 hour
- Installation of VFD with screw compressor for WT plant: During unload condition; compressor is consuming 37% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy upto 15% of present consumption
- Installation of VFD with screw compressor for VT old plant: During unload condition; compressor 1 of the same is consuming 47% without doing work. A VFD can take care variable air demand by changing RPM of compressor and will help to save energy upto 15% of present consumption
- Timer controller at sizing machine.
- Waste heat recovery from flue gas at VT kiln of old plant: The flue gas measured at kiln exhaust was 250°C. At the same time, inlet temperature of combustion air was 35°C. It is recommended to install a recuperator in flue gas line to recover this waste heat (increase combustion air temperature upto 165°C) and reduce the fuel consumption
- Waste heat recovery from flue gas at VT kiln of new plant: The flue gas measured at kiln exhaust was 250°C. At the same time, inlet temperature of combustion air was 35°C. It is recommended to install a recuperator in flue gas line to recover this waste heat (increase combustion air temperature upto 72°C) and reduce the fuel consumption.
- Installation of Harmonic filter for Wall Tiles plant.
- Installation of voltage servo stabilizer
- V belt replacement with REC belt
- Installation of Energy monitoring system
- Installation of solar PV system

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

Table 1: Summary of ECMs

Sl. No.	Energy Conservation Measures	Annual Energy Savings Electricity kWh/y	NG scm	Coal MT/y	TOE Equivt. MTOE/y	Monetary Savings Lakh Rs/y	Investment Lakh Rs	Simple Payback Period Months	Annual Emission Reduction tCO_2/y
1a	Kiln excess air control - Wall kiln	70,684		181	105	20.47	18.48	11	441
1b	Excess air control for VT New Kiln	73,764	156046		147	54.97	18.48	4	361
1c	Excess air control for VT Old Kiln	45,612		166	95	17.21	18.48	13	388
2a	Skin loss reduction at new vitrified kiln		35122		32	11.04	10.05	11	68
2b	Skin loss reduction at old vitrified kiln			18	10	5.77	2.68	6	39
3a	Waste heat recovery from smoke with new vitrified kiln			88	48	7.17	11.34	19	185
3b	Waste heat recovery from smoke with old vitrified kiln			505	277	41.33	87.12	25	1068
4	Insulation of new HAG surface and connecting duct			31	17	2.57	3.84	18	66
5a	Optimization of resources in clay section for new vitrified ball mill	17,452		587	324	71.47	39.60	7	1256
5b	Optimization of resources in clay section for old vitrified ball mills	6,986		587	323	70.63	39.60	7	1247
6	Replacement of inefficient pumps with efficient pumps	138,605			12	11.08	4.16	5	114
7	Time controller with stirrer motors	129,967			11	10.39	7.20	8	107
8	Time controller with sizing machine	51,310			4	4.10	3.25	9	42
9a	Installation of VFD with air compressor 1 of VT old plant	44,933			4	3.59	4.75	16	37
9b	Installation of VFD with air compressor of wall tile plant	42,860			4	3.43	4.75	17	35
10	Installation of harmonic filter with wall tile plant incomer	25,829			2	2.07	6.34	37	21
11	Installation of energy monitoring system	458,535		310	210	62.09	18.11	4	1033
12a	Installation of servo stabilizer at wall tile incomer	175,287			15	14.02	15.84	14	144
12b	Installation of servo stabilizer at new vitrified tile incomer	814,654			70	65.14	31.68	6	668
12c	Installation of servo stabilizer at old vitrified tile incomer	266,802			23	21.33	31.68	18	219
13	Replacement of V belt with Rec belt	28,795			2	2.30	0.79	4	24
	Total	**2392077**	**191168**	**2472**	**1736**	**502**	**378**	**9.0**	7560

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

- Reduction in energy cost by 11.1%
- Reduction in electricity consumption by 10.4%
- Reduction in thermal energy consumption by 13.1%
- Reduction in greenhouse gas emissions by 14.6%

➨ FINANCIAL ANALYSIS

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

Table 2: Financial indicators

#	Energy Conservation Measure	Investment Lakh Rs	Internal Rate of Return %	Discounted Payback Period Months
1a	Kiln excess air control - Wall kiln	18.48	84%	4.18
1b	Excess air control for VT New Kiln	18.48	226%	1.59
1c	Excess air control for VT Old Kiln	18.48	67%	4.97
2a	Skin loss reduction at new vitrified kiln	10.05	80%	4.24
2b	Skin loss reduction at old vitrified kiln	2.68	166%	2.18
3a	Waste heat recovery from smoke with new vitrified kiln	11.34	42%	7.14
3b	Waste heat recovery from smoke with old vitrified kiln	87.12	26%	9.43
4	Insulation of new HAG surface and connecting duct	3.84	44%	6.82
5a	Optimization of resources in clay section for new vitrified ball mill	39.60	139%	2.58
5b	Optimization of resources in clay section for old vitrified ball mills	39.60	134%	2.64
6	Replacement of inefficient pumps with efficient pumps	4.16	204%	1.77
7	Time controller with stirrer motors	7.20	108%	3.25
8	Time controller with sizing machine	3.25	94%	3.70
9a	Installation of VFD with air compressor 1 of VT old plant	4.75	52%	6.08
9b	Installation of VFD with air compressor of wall tile plant	4.75	51%	6.21
10	Installation of harmonic filter with wall tile plant incomer	6.34	11%	13.34
11	Installation of energy monitoring system	18.11	259%	1.39
12a	Installation of servo stabilizer at wall tile incomer	15.84	63%	5.23
12b	Installation of servo stabilizer at new vitrified tile incomer	31.68	154%	2.30
12c	Installation of servo stabilizer at old vitrified tile incomer	31.68	45%	6.78
13	Replacement of V belt with Rec belt	0.79	218%	1.63

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	Lexus Granito (India) Ltd.		
Plant Address	8-A, National Highway, Lakhdhirpur Road,Morbi		
Constitution	Properiership		
Name of Promoters	Anil B. Detoraja		
Contact person	Name :Ashish Movaliya		
	Designation: Electrical Engineer		
	Phone number:7567500106		
Year of commissioning of plant	2011		
List of products manufactured	Wall tile(WT) , 300 x 300 mm (7 tiles/box) Vitrified Floor tile(VT) , 600 x 600 mm (4 tiles/box)		
Installed Plant Capacity	11,000 boxes/day for WT 14,000 boxes/day for VT		
Financial information (Lakh Rs)	2014-15	2015-16	2016-17
Turnover	420	657	467

Description	Details		
Net profit	Not provided by the unit		
No of operational days in a year	Days/Year	330	
	Hours/Day	24	
	Shifts /Day	2	
	Shift timings	-	
Number of employees	Category	Number	
	Staff	150	
	Worker		
	Casual Labor		
Details of Energy Consumption	Source	Yes/ No	Use
	Electricity (kWh)	Yes	Entire process and utility
	Coal (kg)	Yes	Spray dryer through coal gasifier
	Diesel (liters)	Yes	DG set; rarely used
	Natural Gas	Yes	Only in kiln 2 and sometimes in dryer
	Other (specify)	No	-
Have you conducted any previous energy audit?	No		
If Yes	Year of energy audit		
	Conducted by		
	Recommendations implemented	Yes/No	
	Type of ECM		
Visit Dates	Visit # 1	11-May-2018	
	Visit # 2	25-May-2018	
	Visit # 3	26-June-2018	
Interested in DEA	Yes		
	Interested		

1.3 Methodology and Approach

The study was conducted in 3 stages:

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

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

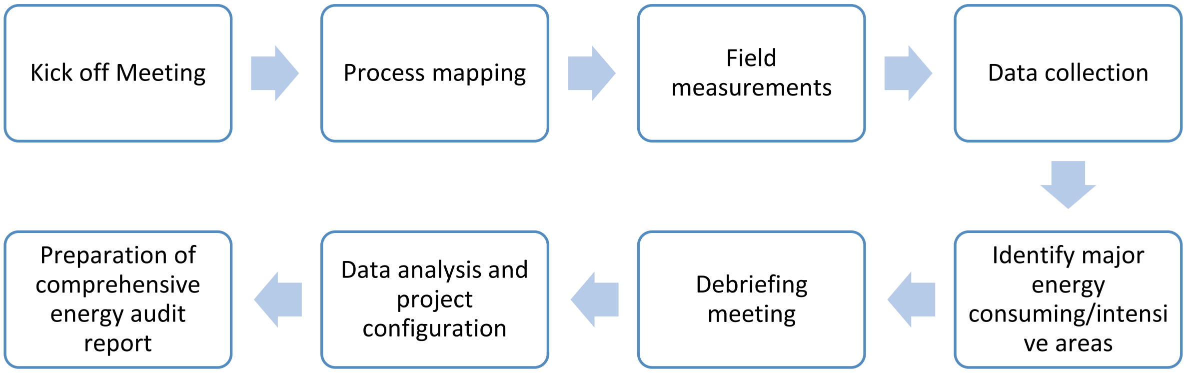

Figure 1: General methodology

The field work was carried out during 13th to 17th 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

Sl. No.	Instruments	Parameters Measured
4	Digital Clamp on Power Meter – 3 Phase and 1 Phase	AC Amp, AC-DC Volt, Hz, Power Factor, Power
5	Flue Gas Analyzer	O_2%, CO_2%, CO in ppm and Flue gas temperature, Ambient temperature
6	Digital Temperature and Humidity Logger	Temperature and Humidity data logging
7	Digital Temp. & Humidity meter	Temp. & Humidity
8	Digital Anemometer	Air velocity
9	Vane Type Anemometer	Air velocity
10	Digital Infrared Temperature Gun	Distant Surface Temperature
11	Contact Type Temperature Meter	Liquid and Surface temperature
12	High touch probe Temperature Meter	Temperature upto 1,300°C
13	Lux Meter	Lumens
14	Manometer	Differential air pressure in duct
15	Pressure Gauge	Water pressure 0 to 40 kg

1.5 STRUCTURE OF THE REPORT

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

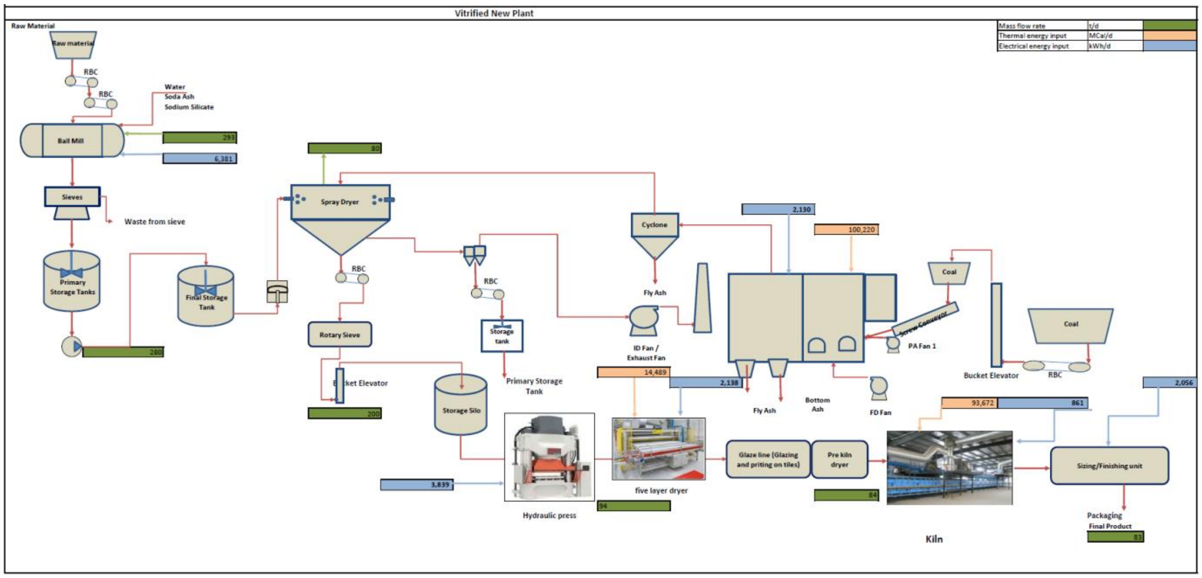

Figure 2: Process Flow Diagram of Vitrified tiles new plant

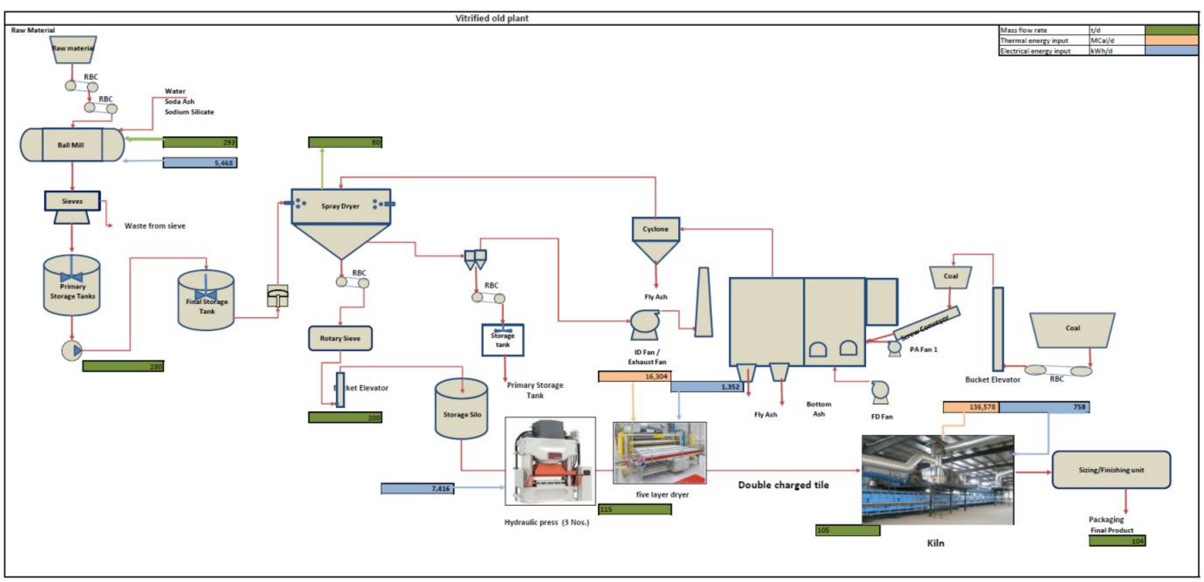

Figure 3: Process Flow Diagram of Vitrified tile old plant

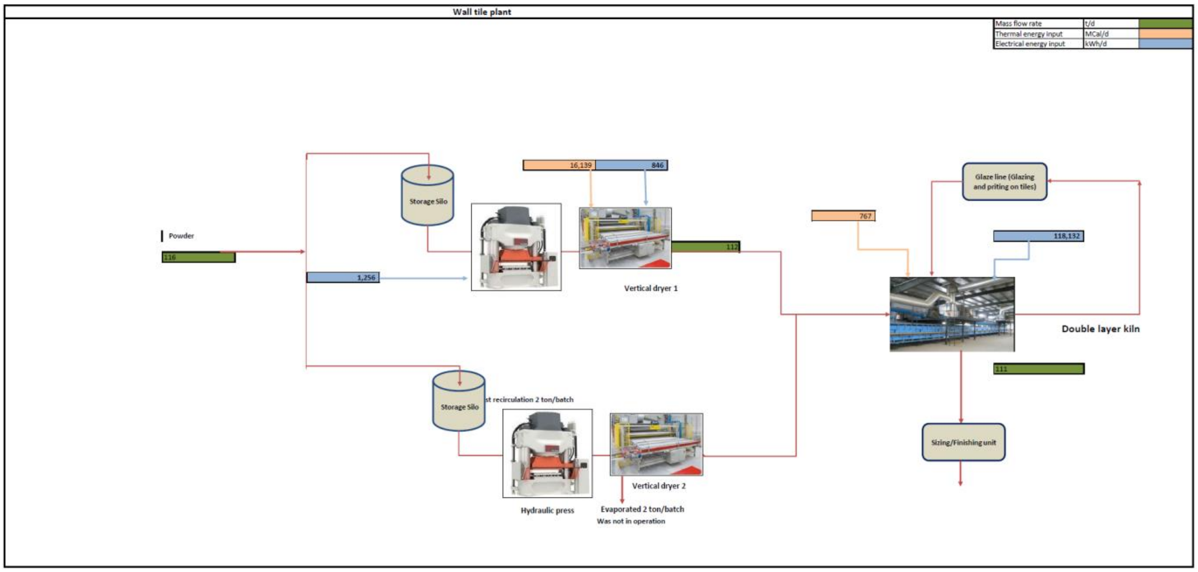

Figure 4: Process Flow Diagram of Wall Tiles plant

The process description is as follows:

- The raw material used is a mixture of china clay, bole clay, than clay, talc, potash, feldspar and quartz which is mixed along with water to form slurry.
- The raw materials are mixed and ground using pebbles together with water in the Clay ball mill for a period of 5 to 6 hours.
- Slurry is then pumped using hydraulic piston into spray dryer where moisture content of slurry is reduced from 35-40% to about 5-6% and output of spray dryer is in powder form.
- Clay in powdered form is stored in silos for 24 hours and then conveyed to hydraulic press machine where it is pressed and tiles is formed of required size, output of press is called biscuit.
- Biscuit is then baked initially in horizontal dryer at about 140-150^{o}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^{o}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.

Above process is explained for vitrified tiles new only since wall tile press directly fed with powder from outside and other tiles (vitrified old) are double charged and directly feed to kiln without any glazing.

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 slurry.

- **Hot air generator:** Hot air generator is used to generate hot air which is used in spray dryer for evaporation of moisture present in slurry.
- **Glaze 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 slurry 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.
- **Roller Kiln:** The kiln is the main energy consuming equipment and plant is consisting three kilns as named wall tile kiln, VT new and VT old. Wall tile kiln where the tile is passed twice, once in biscuit form and second time after glazing and printing. The kilns are about 176 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1,150°C to 1,200°C depending upon the type of the final product. Once the tiles come out of the kiln. The materials are further gone for sizing, finishing and quality tested and packed for dispatch. In vitrified tile old kiln tiles enter only after glazing and drying in five layers dryer. In vitrified tiles old kiln, double charged tiles enters in kiln from dryer directly without glazing.

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 tile	Pieces per box
	mm×mm	kg	m^2	#
Wall tiles	300 x 300	11	0.09	7
Vitrified floor tiles	600 x 600	28	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: Production details

Month	Production (Nos. of boxes)		Production (m^2)			Production (MT)		
	Product 1 (300X300)	Product 2 (600X600)	Product 1 (300X300)	Product 2 (600X600)	Total (m^2)	Product 1 (300X300)	Product 2 (600X600)	Total (MT)
Nov 17		1,55,362		2,23,721	2,23,721	-	4,350	4,350
Dec-17		2,55,300		3,67,632	3,67,632	-	7,148	7,148
Jan-18	2,30,289	4,41,209	1,45,082	6,35,341	7,80,423	2,533	12,354	14,887
Feb-18	1,85,490	3,55,379	1,16,859	5,11,746	6,28,605	2,040	9,951	11,991
Mar-18	1,89,751	3,63,542	1,19,543	5,23,501	6,43,043	2,087	10,179	12,266
Apr-18	92,840	4,06,561	58,489	5,85,449	6,43,937	1,021	11,384	12,405
May-18	1,16,978	5,12,271	73,696	7,37,670	8,11,366	1,287	14,344	15,630

Month	Production (Nos. of boxes)		Production (m²)			Production (MT)		
Jun-18	40,888	1,79,055	25,759	2,57,840	2,83,599	450	5,014	5,463
Jul-18	63,821	2,79,483	40,207	4,02,456	4,42,663	702	7,826	8,528
Aug-18	1,37,991	6,04,290	86,935	8,70,177	9,57,112	1,518	16,920	18,438
Sep-18	64,510	2,82,504	40,642	4,06,805	4,47,447	710	7,910	8,620
Oct-18	97,836	4,28,440	61,636	6,16,954	6,78,591	1,076	11,996	13,073

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 wall tiles kiln and VT old kiln through coal gasifier
  - Natural gas for VT new kiln, five layer dryer old & new and vertical dryers
  - Coal for hot air generators

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

Table 7: Energy use and cost distribution

Particular	Energy cost		Energy use	
	Rs Lakhs	% of total	MTOE	% of total
Grid – Electricity	1,803.64	40	1,972	13.5
Thermal-Coal	1,271	28.2	8,527	58.3
Thermal – NG	1,437.91	31.9	4,116	28.2
Total	4,512.54	100	14,614	100

This is shown graphically in the figures below:

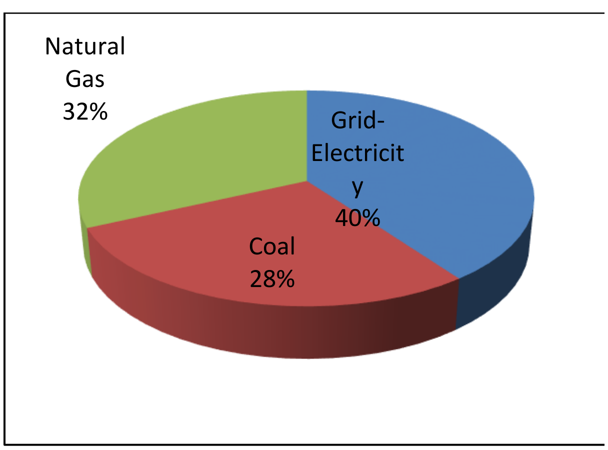

Figure 5: Energy cost share

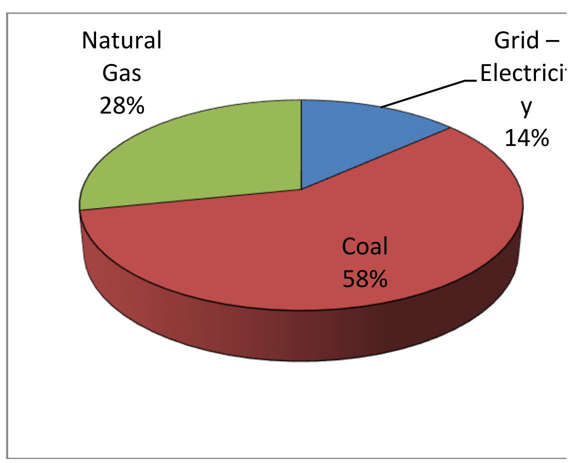

Figure 6: Energy use share

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 40% of the energy cost and 13.5% of the overall energy consumption.
- Source of thermal energy is from combustion of coal gas, which is used for firing in the wall tile kiln and VT old kiln.
- Coal used (in form of coal gas) in kiln and spray dryer through coal gasifier account for 28.2% of the total energy cost and 58.3% of overall energy consumption. Coal is also used in hot air generator to generate hot air.
- Natural gas used in VT new kiln and dryers account for 31.9% of total energy cost and 28.2% of overall energy consumption.

2.3.1 Analysis of Electricity Consumption

2.3.1.1 Supply from Utility

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

Table 8: Details of Electricity Connection

Particulars	Description
Consumer Number	26,825
Tariff Category	HTP-I
Contract Demand, kVA	5000
Supply Voltage, kV	66

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 297	475
Energy Charges (Rs./kWh)	
Normal Hours	4.3
Peak Hours	0.85
Night Time	0.4
Fuel Surcharge (Rs./kVAh)	Variable
Electricity duty (% of total energy charges)	15%
Meter charges (Rs./Month)	0.00

(As per bill from Nov-17 to Oct-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
Nov-17	11,30,870	84,81,525	7.50
Dec-17	16,10,698	1,20,80,234	7.50
Jan-18	26,07,480	2,04,09,849	7.83
Feb-18	21,00,240	1,66,55,778	7.93
Mar-18	21,48,480	1,70,00,029	7.91
Apr-18	23,67,360	1,83,12,297	7.74
May-18	18,14,400	1,44,54,618	7.97
Jun-18	10,85,400	94,46,213	8.70
Jul-18	18,59,760	1,48,35,504	7.98
Aug-18	21,25,440	1,66,13,351	7.82
Sep-18	16,00,560	1,29,59,540	8.10
Oct-18	24,76,080	1,91,14,698	7.72

2.3.1.3 Month-wise electricity consumption and cost analysis

Average electricity consumption is 19, 10,564 kWh/month and cost is Rs. 150 Lakhs per month (Nov-17 to Oct-18). The average cost of electricity is Rs. 7.89/kWh, corresponding to the month Nov-17 to Oct-18. The figure below shows the month wise variation of electricity purchase and variation of cost of electricity.

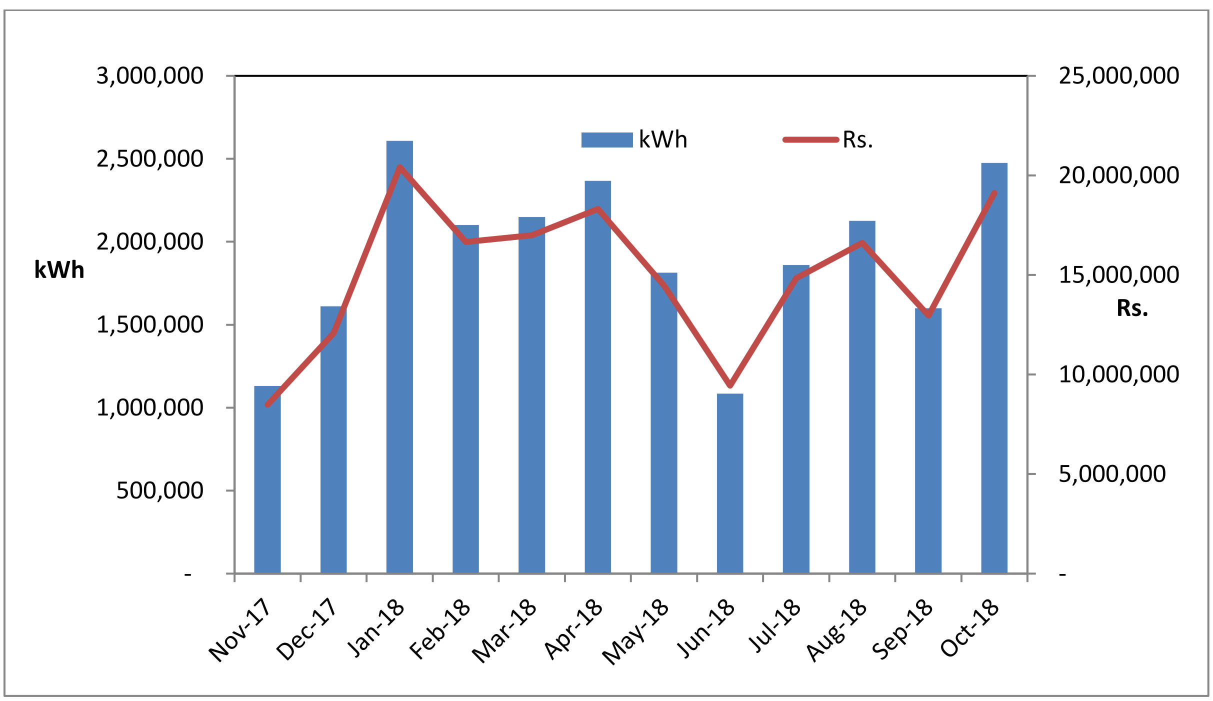

Figure 7: Month wise Variation in Electricity Consumption

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

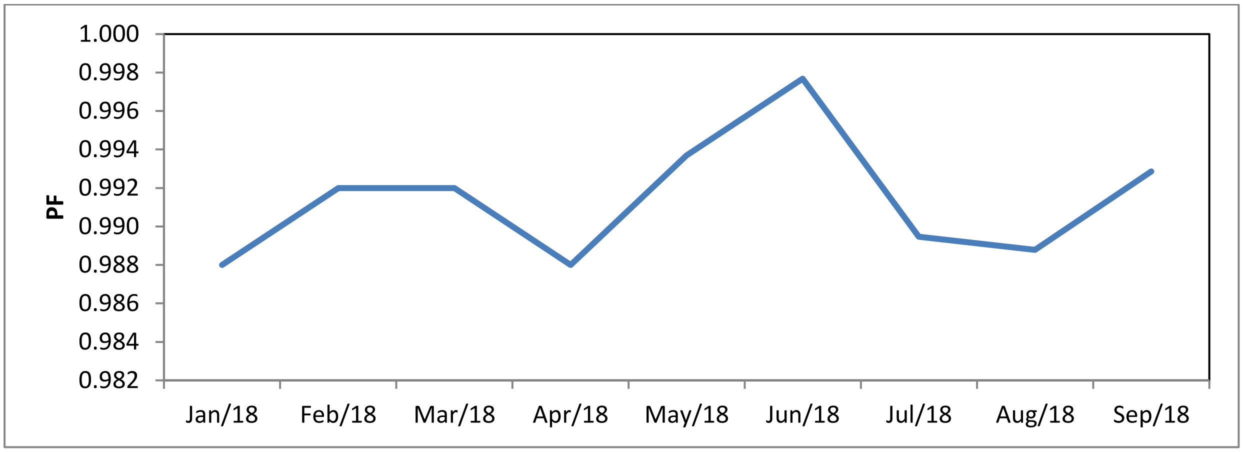

Figure 8: Month wise variation in Power Factor

The utility bills of the unit reflect the power factor. Historical data was available in duration from Jan 18 to Sept 18. The average power factor was found to be 0.991 and the maximum being 1.0.

Maximum Demand: Maximum demand as reflected in the utility bill is 4680 kVA from the bill analysis1.

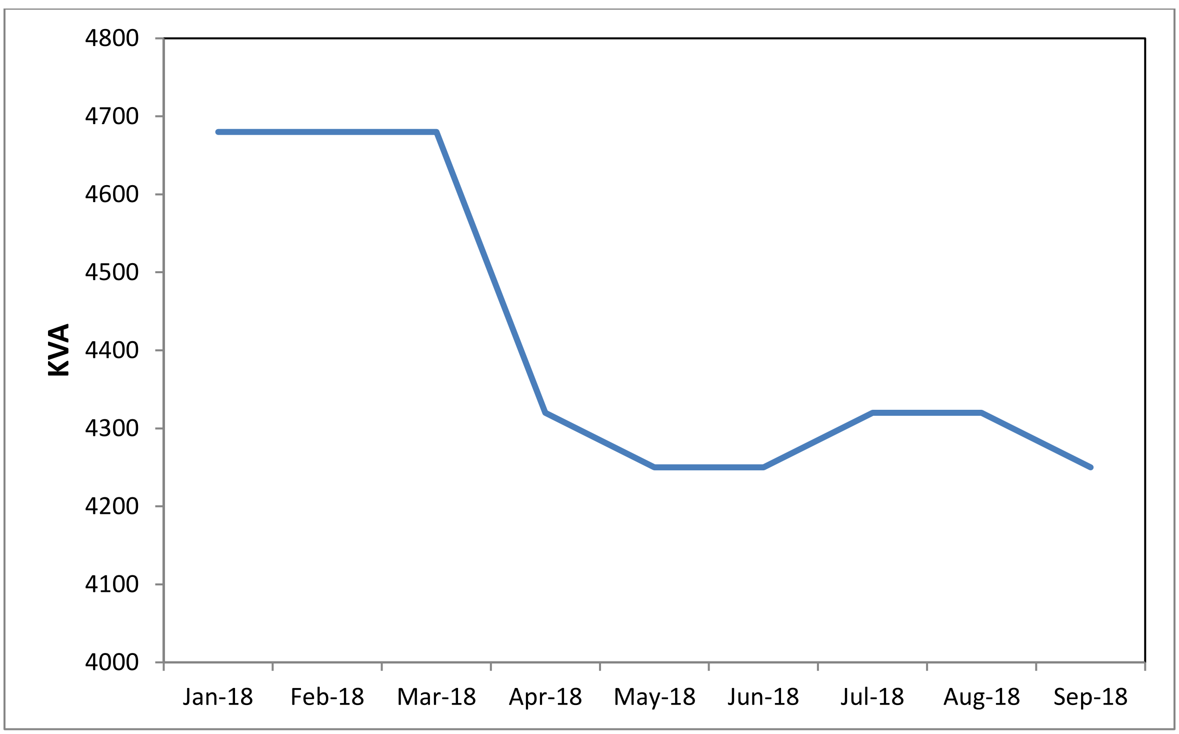

Figure 9: Month wise variation in Maximum Demand

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

2.3.1.4 Single Line Diagram

Single line diagram of plant is shown in figure below:

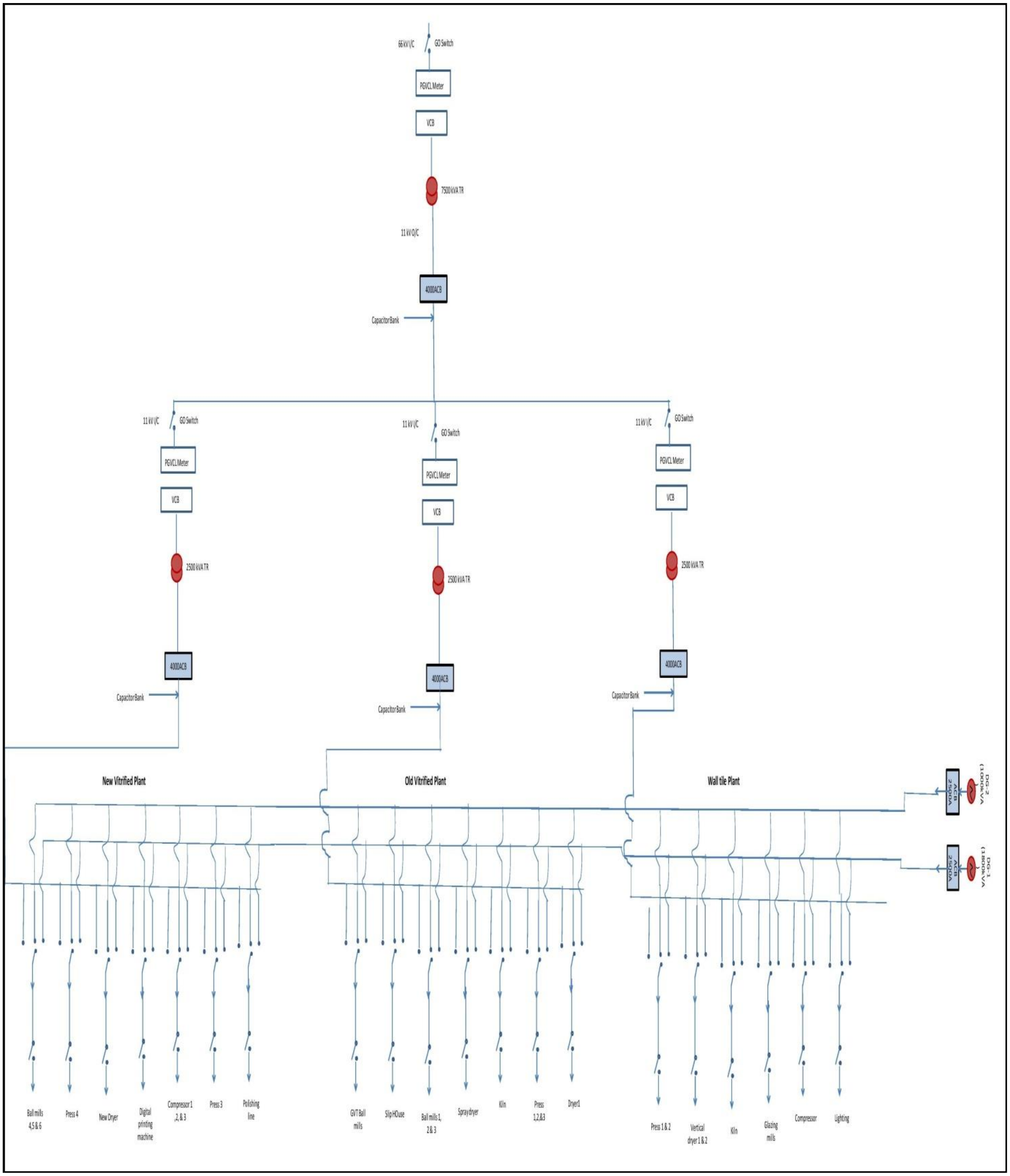

Figure 10: Single Line Diagram (SLD)

2.3.1.5 *Electricity consumption areas*

The plant total connected load is 5862.8 kW, which includes:

- Plant and machinery load is 5632.75 kW.
- Utility load is (lighting, air compressor and fans) 230 kW including the single phase load.

Table 11 : Equipment wise connected load (Estimated)

Sl. No.	Equipment	Capacity (kW)
1	Coal Gasifier	398
2	Clay ball mill section	1,836
3	Hot Air Generator (HAG) + Spray dryer	651
4	Hydraulic presses	1,142
5	Kiln	837
6	Dryer	526
8	Sizing & finishing	242
9	Utilities	209
10	Lighting	21
Total Connected Load		5,862.8

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

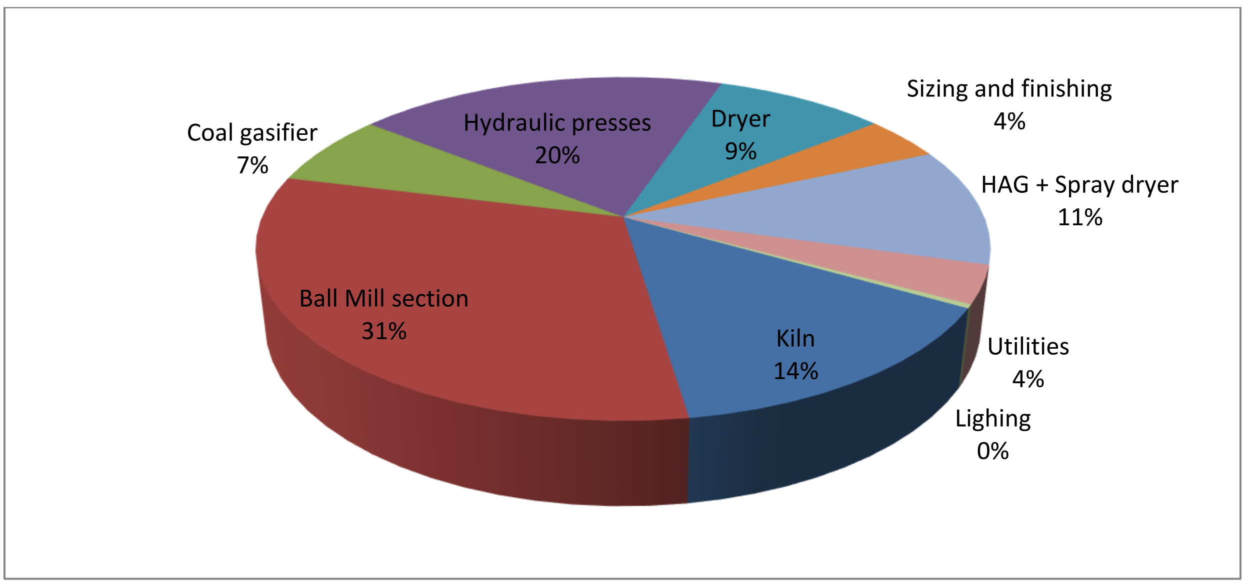

Figure 11: Details of connected load

As shown in the figure, the maximum share of connected electrical load is for Clay ball mill section-31%, for hydraulic press- 20%, for Kiln – 14%, for the Hot air generator & spray dryer – 11% & 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:

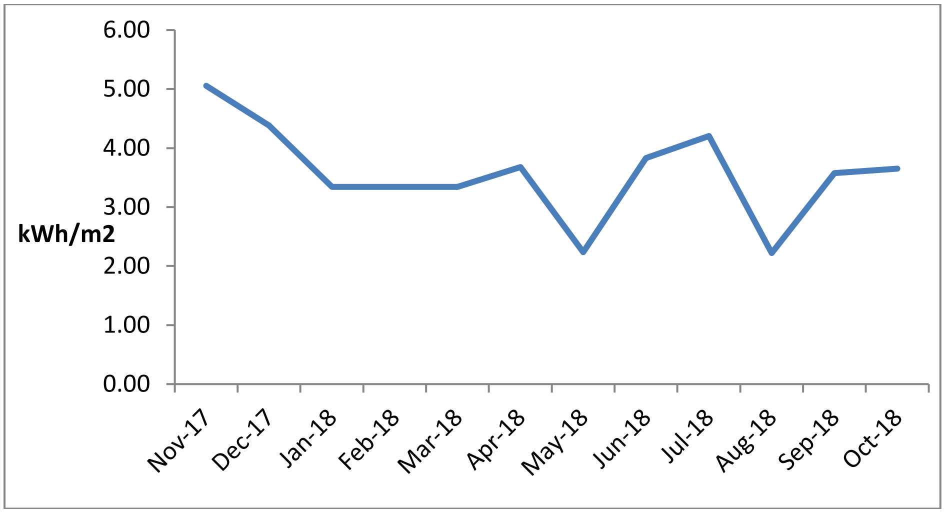

Figure 12: Month wise variation in Specific Electricity Consumption

The maximum and minimum values are within ±25% of the average SEC of 3.57 kWh/m^2 indicating 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. Based on the gas bill shared for the month of Nov-17 to Oct-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	Coal Used	Coal Cost	Coal cost	NG used	NG cost	NG cost
	MT	Rs	Rs/MT	scm	Rs	Rs/scm
Nov-17	497.5	40,74,117	8,190	320,000	9,920,000	31.00
Dec-17	817.4	66,94,829	8,190	328,000	10,168,000	31.00
Jan-18	1,735.3	1,42,12,031	8,190	341,000	10,571,000	31.00
Feb-18	1,397.7	1,14,47,327	8,190	377,918	12,915,255	34.17
Mar-18	1,429.8	1,17,10,259	8,190	415,710	12,915,255	31.07
Apr-18	2,085.1	1,70,76,969	8,190	412,864	12,915,255	31.28
May-18	1,515.9	1,24,15,549	8,190	146,252	4,576,231	31.29
Jun-18	380.9	31,19,898	8,190	218,545	6,838,270	31.29
Jul-18	1,323.8	1,08,41,922	8,190	454,625	14,225,226	31.29
Aug-18	1,806.4	1,47,94,170	8,190	494,720	15,479,794	31.29
Sep-18	670.5	54,91,722	8,190	488,857	15,296,330	31.29
Oct-18	1,858.4	1,52,20,083	8,190	574,318	17,970,423	31.29

Month	Coal Used	Coal Cost	Coal cost	NG used	NG cost	NG cost
Average	1,293	105,91,573	8,190	381,067	11,982,587	31.4

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

- Average monthly coal consumption is 1,293 tons and average cost Rs. 106 Lakhs/month
- Average monthly NG consumption is 381,067 scm and average cost Rs. 120 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:

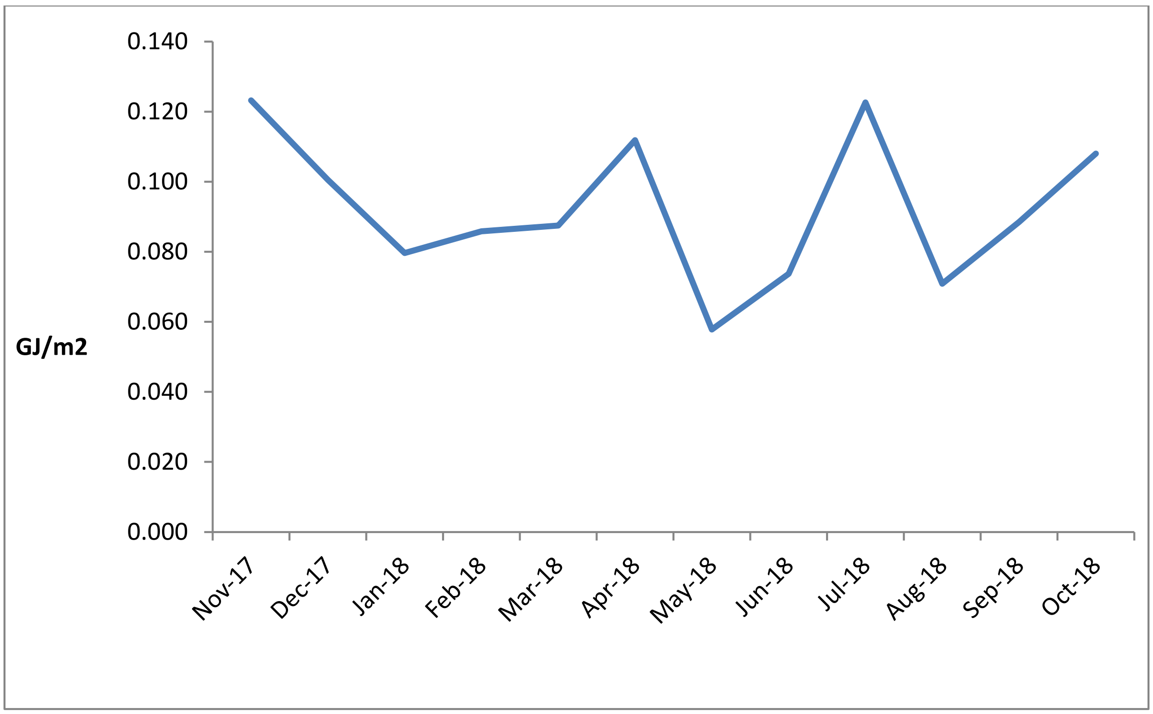

Figure 13: Month wise variation in Specific Fuel Consumption

The average SFC is 0.0925 GJ/m^2. SFC is high in the months of Nov-17 (production was 223,721 m^2 and thermal consumption was 27,568 GJ) and low in the month of May-18 (production was 811,366m^2 and thermal consumption was 46,908 GJ). 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 dryer are required.

2.3.3 Specific energy consumption

2.3.3.1 Analysis based on data collected during EA.

Plant doesn't maintain record for coal consumption data in plant so it came from general discussion with plant personnel. Specific energy consumption (SEC) on the basis of data collected during energy audit is shown in below table:

Table 13: Specific energy consumption of wall tile

Particulars	Units	Value
Average production	m^2/h	265
Power consumption	kW	390
Coal consumption	kg/h	896
NG consumption	scm/h	Nil
Energy consumption	kgOE/h	492.3
SEC of plant	$kgOE/m^2$	1.86

Table 14: Specific energy consumption of vitrified tile

Particulars	Units	Value
Average production	m^2/h	400
Power consumption	kW	2,231
Coal consumption	kg/h	1,103
NG consumption	scm/h	586
Energy consumption	kgOE/h	1,134
SEC of plant	$kgOE/m^2$	2.835

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 15: Section wise specific energy consumption (per unit production)

Particulars	NG	Coal	Electricity
	scm/t	kg/t	kW/t
Clay ball mills			10.1
Agitator			2.8
HAG VT old		102	6.2
HAG VT new		91	10.9
Spray Dryer VT new			2.6
Spray Dryer VT old			1.9
Five layer Dryer VT new	18.67		24.8
Five layer Dryer VT old	17.8		12.5
Vertical dryer WT	15.3		
Hydraulic Press VT new			44.5
Hydraulic Press VT old			68.8
Hydraulic Press WT			43.2
Kiln VT new	126		10.4
Kiln VT old		239	7.3
Kiln WT		194	6.9
Sizing unit VT new			24.8

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

2.3.3.3 Based on yearly data furnished by unit

Based on the available information, various specific energy consumption (SEC) parameters have been estimated as shown in the following table:

Table 16: Overall: specific energy consumption

Parameters	Units	Value
Annual Grid Electricity Consumption	kWh/y	2,29,26,768
Self-Generation from DG Set	kWh/y	-
Annual Total Electricity Consumption	kWh/y	2,29,26,768
Annual Thermal Energy Consumption (Imported Coal)	t/y	15,519
Annual Thermal Energy Consumption (NG)	scm/y	45,72,810
Annual Energy Consumption	MTOE	14,614
Annual Energy Cost	Rs. Lakh	4,513
Annual production	m^2	69,08,139
	t	1,32,799
SEC; Electrical	kWh/m^2	3.32
	kWh/t	173
SEC; Thermal	GJ/m^2	0.076
	GJ/t	4
SEC; Overall	MTOE/ m^2	0.0021
	MTOE/t	0.11
SEC; Cost Based	Rs./m^2	65.3
	Rs./t	3,398

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

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

- Conversion Factors
  - Electricity from the Grid : 860 kCal/kWh
- GCV of NG : 9,000 kCal/scm
- GCV of Indonesian Coal : 5,495 kCal/kg
- CO_2 Conversion factor
  - Grid : 0.82 kg/kWh
  - Indonesian 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 17: Baseline parameters

Parameters	Units	Value
Cost of electricity	Rs/ kWh for May-2018 to Sep-2018	8.00
Cost of Coal	Rs./MT	8,190
Annual operating days	d/y	330
Operating hours per day	h/d	24
Annual production	m^2	707,211

2.4 WATER USAGE AND DISTRIBUTION

Water requirement is met using submersible pumps (2 numbers). These pumps lift water from ground and which is collected in raw water tank. From this raw water tank, water is distributed to various sections as per requirement through different pumps. Water consumption on daily basis is about 250-300 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.

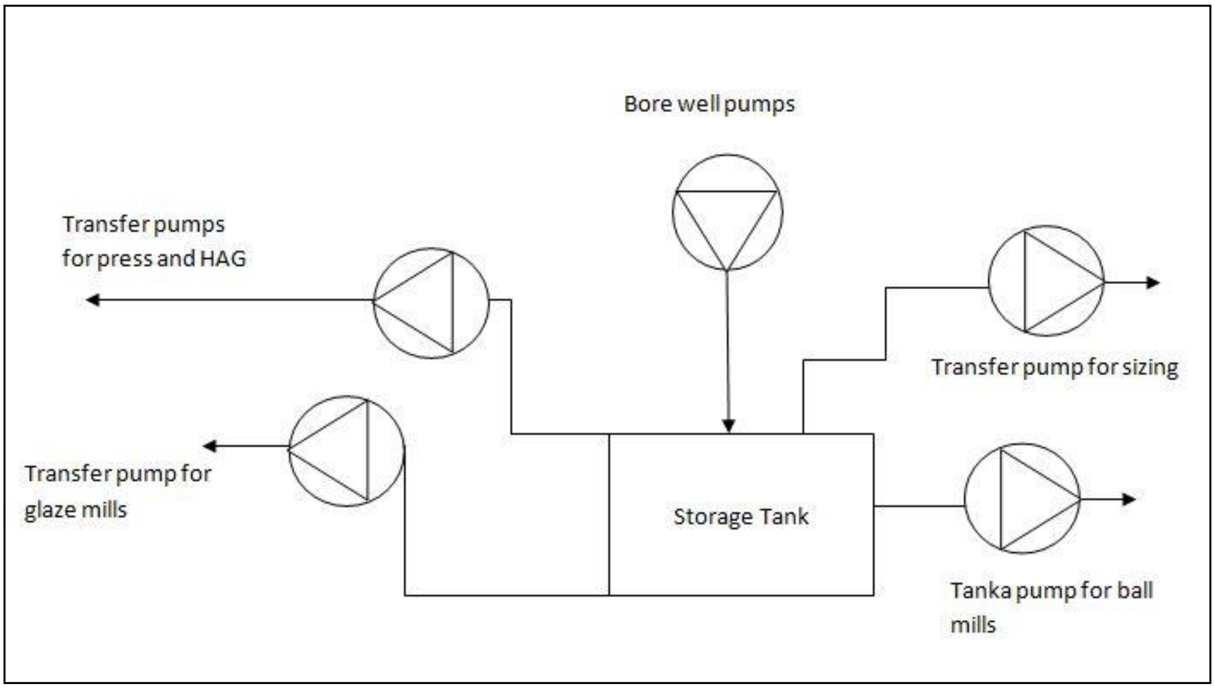

Figure 14: Water Distribution Diagram

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). Installation details of submersible pumps are tabulated hereunder.

Table 18: Submersible pump details

Parameters	Unit	Submersible Pump
Make		
Motor rating	HP	10
RPM	rpm	2,900
Quantity	Number	2

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

3. CHAPTER -3 PERFORMANCE EVALUATION OF THERMAL EQUIPMENT

3.1 KILNS

3.1.1 Specifications

There are total three kilns in the plant. Coal gas is used as a fuel in the kiln to heat the Wall tiles & Vitrified tiles (old plant) to the required temperature & natural gas fuel is used in the kiln to heat the Vitrified tiles (new plant) to the required temperature. The required air for fuel combustion is supplied by a blower (FD fan). Cooling blower and rapid cooling blowers are used for cooling the tiles after combustion zone to get required tile quality and at the starting point, a smoke blower is installed which preheats the tiles before combustion zone of kiln. Kiln consists 837 kW electrical load of which 22 kW is for upper rollers, 22 kW is for lower rollers, 3.8 kW is for upper layer blower, 75*3 kW are for smoke blowers, 55*3 kW are for combustion blowers, 45*3 kW are for rapid cooling blowers, 110*3 kW are for hot air blowers and 90*3 kW are for final cooling blowers

Table 19: Kiln Details

Sl. No	Parameter	Unit	Wall Tiles	Vitrified Tiles Old	Vitrified Tiles New
	Make		Modena	SACMI	SACMI
1	Kiln operating time	H	24	24	24
2	Fuel consumption	scm/h	2,918	434	4,007
3	Number of burner to left	-	96	111	102
4	Number of burner to right	-	96	111	102
5	Cycle Time	Minutes	80	65	55
6	Pressure in firing zone	mm WC	50	50	50
7	Maximum temperature	°C	1,090	1,230	1,230
8	Waste Heat recovery option		No	Yes	Yes
9	Kiln Dimensions (Length X Width X Height)				
	Preheating Zone	M	84 x 0.8 x 3.6	71.4 x 0.8 x 3.6	69.3 x 0.8 x 3.6
	Firing Zone	M	25.2 x 1.87 x 3.6	25.2 x 1.87 x 3.6	29.4 x 1.87 x 3.6
	Rapid Cooling Zone	M	12.6 x 0.8 x 3.6	12.6 x 0.8 x 3.6	12.6 x 0.8 x 3.6
	Indirect cooling Zone	M	25.2 x 0.8 x 3.6	25.2 x 0.8 x 3.6	27.3 x 0.8 x 3.6
	Final cooling zone	M	37.8x 0.8 x 3.6	25.2x 0.8 x 3.6	21x 0.8 x 3.6

3.1.2 Field measurement and analysis

During DEA, measurement of power consumption for all blowers, surface temperature of kiln, flue gas analysis, air flow measurement of blowers and section wise temperature profile of kiln were done. Coal gas generated in the gasifier is used at both kiln and the horizontal drier; therefore, the consumption in kiln has been calculated based on heat load of the kiln during DEA. Flue gas analysis (FGA) study was conducted and result of same is summarized in the table below:

Table 20: FGA Study of Kiln

Parameter	Wall Tiles	Vitrified Tiles Old	Vitrified Tiles New
Oxygen Level measured in Flue Gas	8%	7.1%	8.05%
Ambient Air Temperature	40.2 ºC	40.2 ºC	45 ºC
Exhaust Temperature of smoke	215 ºC	250	250 ºC

From the above table, it is clear that the oxygen level measured in flue gas was high. The inlet temperature of raw material in kiln was in the range of 35 – 42ºC which was the ambient air temperature. Surface temperature was high, throughout the surface of the kiln as shown in the table below:

Table 21: Surface temperature of kiln

Zone	Temperature (ºC)
Ambient Temperature	40.2
Pre-heating zone Average Surface Temperature	51.0
Heating zone Average Surface Temperature	69.2
Rapid cooling zone Average Surface Temperature	55.0
Indirect cooling zone Average Surface Temperature	60.0
Final cooling zone Average Surface Temperature	55.0

The temperature profile of the kiln is shown below:

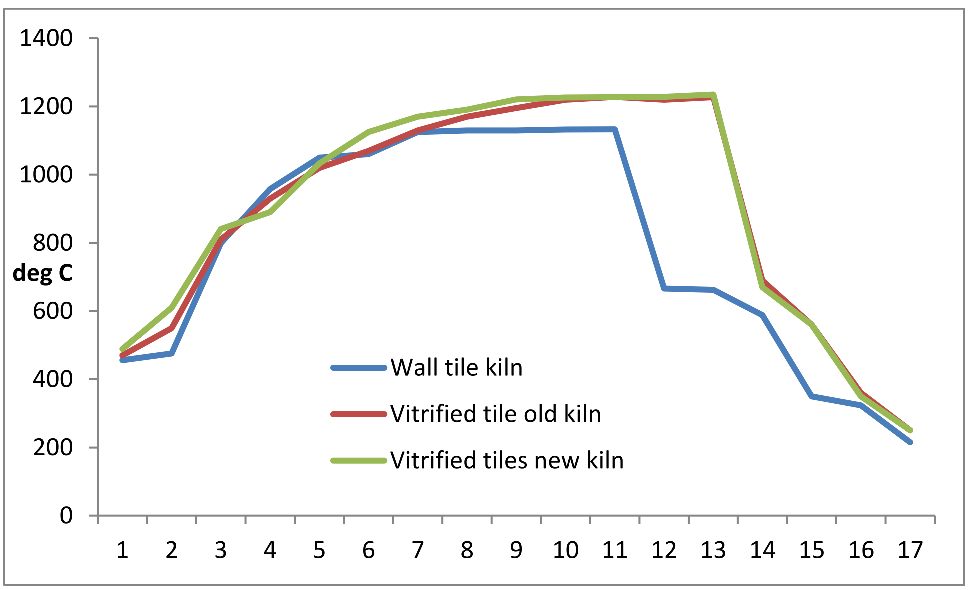

Figure 15 : Temperature Profile of Kiln

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

Table 22: Power measurements of all blowers

Kiln	Equipment	Average Power (kW)	Power factor
Wall kiln	Upper Rapid Blower	11.2	1
	Lower Rapid Blower	1.99	1
	Heat Exchanger Blower	8.1	1

Kiln	Equipment	Average Power (kW)	Power factor
	Suction Cooling Blower	4.01	1
	Final Cooling Blower	6.65	1
Vitrified old kiln	Final Cooling Blower	8.89	1
	Hot Air Blower	7.95	1
	Rapid Cooling Blower	11.3	0.99
	RLW Blower	3.46	1
Vitrified new kiln	Rapid Cooling Blower	6.35	1
	RLW Blower	1.61	1
	Hot Air Blower	12.7	1
	Final Cooling Blower	15.2	1

3.1.3 Observations and performance assessment

Heat utilization has been calculated for all three kilns based on the flue gas analysis study conducted during visit. Heat utilization of the wall kiln is 32.5%, vitrified new kiln is 43.2% and vitrified old kiln is 25.1%. Summary of all losses is shown in below figure:

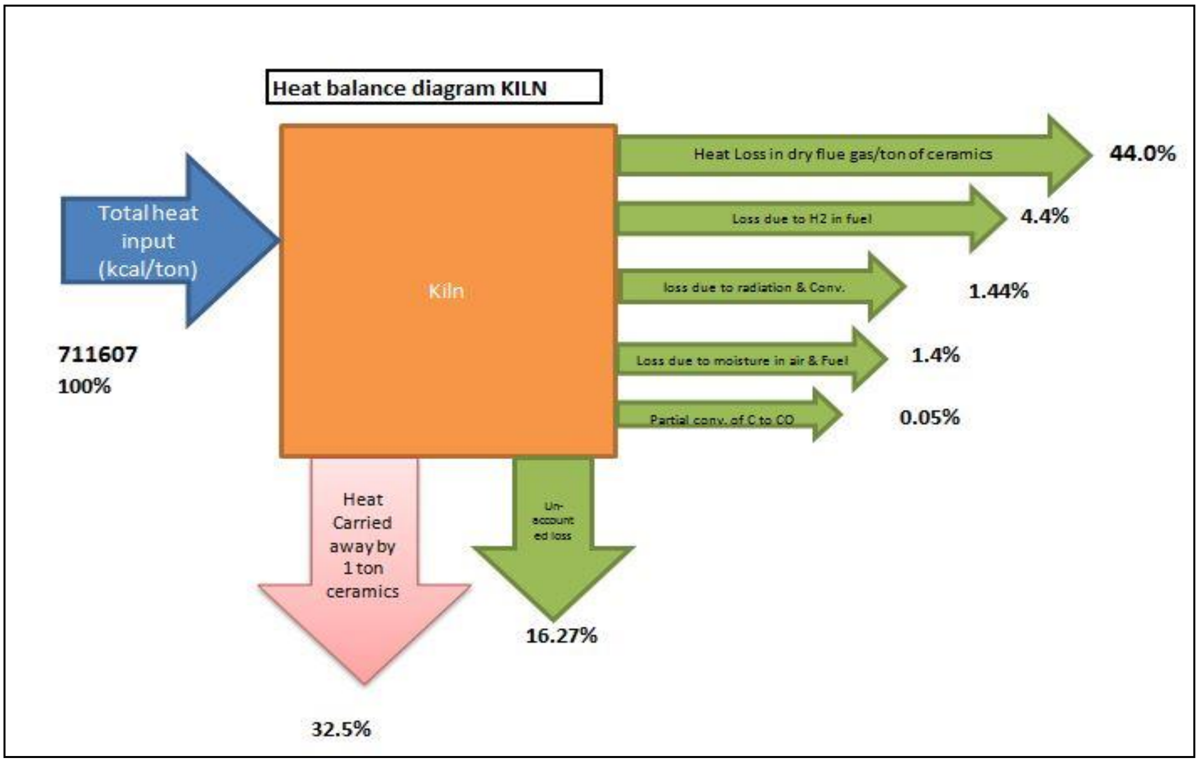

Figure 16: Heat balance diagram of Wall Kiln

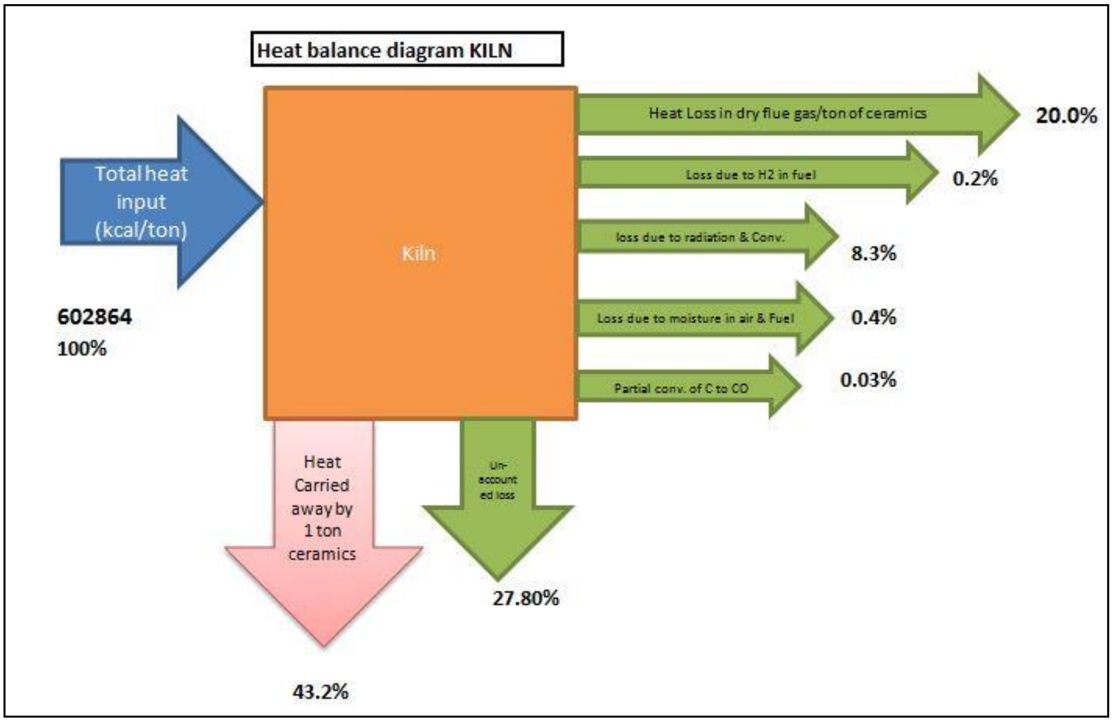

Figure 17: Heat balance diagram of new Vitrified Kiln

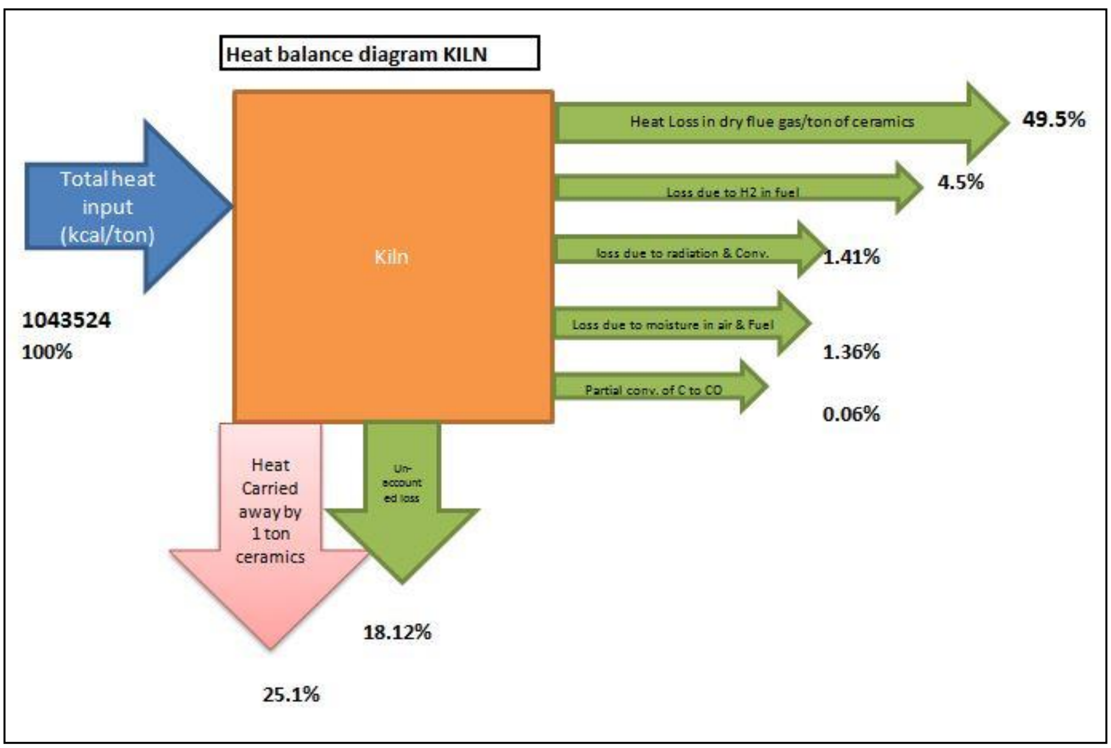

Figure 18: Heat balance diagram of old Vitrified Kiln

Causes of unaccounted losses arising due to following reasons:

1. Kiln leakage observed in old VT kiln

2. Rollers are getting heated itself by kiln heat
3. Inspection holes are closed by aluminnum dart which increases radiation loss
4. Hot air fans body are uninsulated
5. Atmopsheric air dilution in kiln

Detailed calculation is included in Annexure-5.

3.1.4 Energy conservation measures (ECM)

Energy conservation measures are described in below sections:

3.1.4.1 ECM #1: Kiln -Excess Air Control

Technology description

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

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

Study and investigation

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

Flue gas analysis of kilns is given in below table:

Table 23: Flue gas analysis

Parameters	Units	WT	VT new	VT old
O_2 in flue gas	%	8.	8.05	7.1
CO_2 in flue gas	%	7.3	7.5	7.9
CO in flue gas	ppm	30	30	40

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 24: Kiln Excess Air Control – Wall kiln (ECM-1a)

Parameters	Units	Present	Proposed
Fuel Saving			
Oxygen level in flue gas	%	8.0	5.0
Excess air control	%	61.5	31.3
Dry flue gas loss	%	44%	
Saving in fuel (Every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%)	Scm/t	632	612
Specific fuel consumption	kg/ton of tile	4.6	4.6
Saving in specific fuel consumption	scm/h		88.37
Operating hours per day	h/d		22.84
Operating days per year	d/y		330
Annual fuel savings	scm/y		24
Annual coal saving	t/yr		181
Fuel cost	Rs/MT		8,190
Annual fuel cost saving	Rs Lakh /y		14.8
B. Power saving at combustion blower			
Mass flow rate of air	t/h	34.83	28.30
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	7.9	6.4
Total pressure rise	Pa	2,000	2,000
Measured power of blower	kW	19.25	10.33
Total power saving	kW		8.92
Operating hours per day	h/d		24
Operating days per year	d/y		330
Annual energy saving	kWh/y	70,684	
Weighted Cost of electricity	Rs/kWh	8.0	
Annual energy cost saving	Lakh Rs/y	5.65	
Overall energy cost saving	Lakh Rs/y	20.5	
C. Summary of Savings			
Coal saving	kg/y	181,000	
Electricity saving	kWh/y	70,684	
Monetary savings	Lakh Rs/y	20.5	
Estimated investment	Lakh Rs	18.5	
Payback Period	Months	11	
IRR	%	84	
Discounted payback period	Months	4.2	

Table 25: Kiln Excess Air Control – new Vitrified kiln (ECM-1b)

Parameters	Units	Present	Proposed
Fuel Saving			
Oxygen level in flue gas just before firing zone	%	8.0	3.0
Excess air percentage in flue gas	%	62.1	16.7

Parameters	Units	Present	Proposed
Dry flue gas loss	%	20%	
Fuel saving 1% in 10% reduction in excess air: Specific fuel consumption	SCM/t	126	120
Average production in Kiln	t/h	3.4	3.4
Saving in specific fuel consumption	SCM/h		19.70
Operating hours per day	h/d		330
Annual operating days	d/y		24
Annual fuel saving	SCM/y		156046
Fuel cost	Rs/SCM		31
Annual fuel cost savings	Lakh Rs/y		49.1
B. Power saving at combustion blower			
Mass flow rate of air	t/h	8.84	6.36
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	2.0	1.4
Total pressure rise	Pa	3,000	3,000
Measured power of blower	kW	14.85	5.54
Total power saving	kW		9.31
Operating hours per day	h/d		24
Operating days per year	d/y		330
Annual energy saving	kWh/y	73,764	
Weighted Cost of electricity	Rs/kWh	8.0	
Annual energy cost saving	Lakh Rs/y	5.9	
Overall energy cost saving	Lakh Rs/y	55	
C. Summary of Savings			
Natural gas saving	scm/y	156,046	
Electricity saving	kWh/y	73,764	
Monetary savings	Lakh Rs/y	55	
Estimated investment	Lakh Rs	18.5	
Payback Period	Months	4	
IRR	%	223	
Discounted payback period	Months	1.6	

Table 26: Kiln Excess Air Control – old vitrified kiln (ECM-1c)

Parameters	Units	Present	Proposed
Fuel Saving			
Oxygen level in flue gas	%	7.1	5.0
Excess air control	%	51.4	31.3
Dry flue gas loss	%	50%	
Saving in fuel (Every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%)	Scm/t	926	907
Specific fuel consumption	kg/ton of tile	4.3	4.3
Saving in specific fuel consumption	scm/h		80.91
Operating hours per day	h/d		330
Operating days per year	d/y		24
Annual fuel savings	scm/y		641
Annual coal saving	t/yr		166
Fuel cost	Rs/MT		8,190
Annual fuel cost saving	Rs Lakh /y		13.6
B. Power saving at combustion blower			

Parameters	Units	Present	Proposed
Mass flow rate of air	t/h	44.84	38.86
Density of air	kg/m^3	1.23	1.23
Mass flow rate of air	m^3/s	10.2	8.8
Total pressure rise	Pa	2,000	2,000
Measured power of blower	kW	16.50	10.74
Total power saving	kW		5.76
Operating hours per day	h/d		24
Operating days per year	d/y		330
Annual energy saving	kWh/y	45,612	
Weighted Cost of electricity	Rs/kWh	8.0	
Annual energy cost saving	Lakh Rs/y	3.65	
Overall energy cost saving	Lakh Rs/y	17.2	
C. Summary of Savings			
Coal saving	kg/y	166,000	
Electricity saving	kWh/y	45,612	
Monetary savings	Lakh Rs/y	17.2	
Estimated investment	Lakh Rs	18.5	
Payback Period	Months	13	
IRR	%	68	
Discounted payback period	Months	4.9	

3.1.4.2 ECM #2: Skin loss reduction at kiln

Technology description

A significant portion of the losses in a kiln occurs as radiation and convection loss from the kiln walls and roof. These losses are substantially higher on areas of openings or in case of infiltration of cold air. Ideally, optimum amount of refractory and insulation should be provided on the kiln walls and roof to maintain the skin temperature of the furnace at around 45-50°C, so as to avoid heat loss due to radiation and convection. Refractories are heat-resistant materials that constitute the linings for high-temperature kilns. In addition to being resistant to thermal stress and other physical phenomena induced by heat, refractory must also withstand physical wear and corrosion by chemical agents.

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

Kiln wall is designed in combinations of refractory and insulation layers, with the objective of retaining maximum heat inside the kiln and avoid losses from kiln walls.

Study and investigation

There are mainly five different zones in kiln, i.e. pre- heating, firing, rapid cooling, indirect cooling and final cooling zones. The surface temperature of each zones were measured. The average surface temperature of kiln body in the firing zone must be in the range of 60-70oC and it was measured as 69.8oC; hence the kiln surface does not has significant loss. But there were uninsulated pipe in rapid cooling zone and firing zone where surface temperature was observed as 170 °C which is to be properly insulated to keep the surface temperature within the specified range. Some photographs of kiln surface are shown below:

Figure 19: Kiln surface

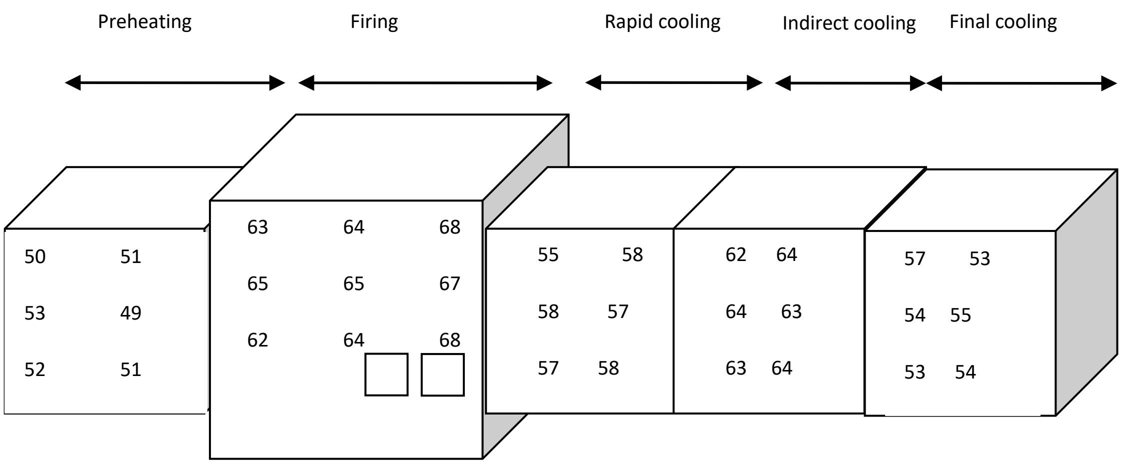

Figure 20: Vitrified new kiln surface temperature schematic diagram

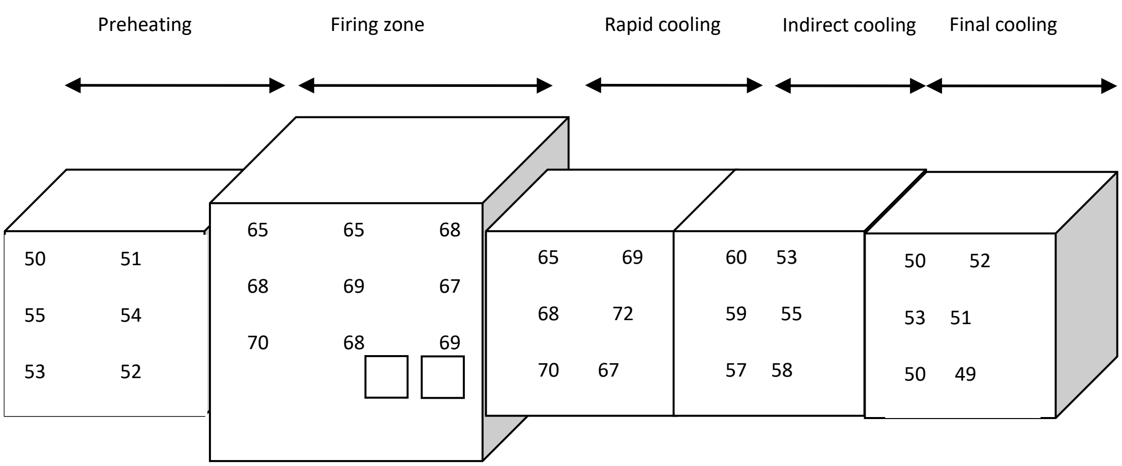

Figure 21: Vitrified old kiln surface temperature schematic diagram

Recommended action

Recommended surface temperature of the firing zone has to be brought to within 55°C to reduce the heat loss due to radiation and convection and utilize the useful heat. The amount of heat lost through radiation and convection in each zone is given in the table below.

The cost benefit analysis of the energy conservation measure is given below:

Table 27: Cost benefit analysis – new Vitrified kiln (ECM 2a)

Parameter	Units	As IS	To Be
No of uninsulated pipe in rapid zone	#	50	50
No of uninsulated pipe in firing zone	#	204	204
pipe size in rapid zone	mm	51	51
Pipe length in rapid zone	m	1.5	1.5
Pipe size in firing zone	mm	25	25
Pipe length in firing zone	m	0.50	0.50
Rapid zone surface area	m^2	11.97	11.97
Firing zone surface area	m^2	8.14	8.14
Average surface temperature of pipes in firing zone	°C	130	55
Average surface temperature of pipes in rapid zone	°C	190	55
Ambient air temperature	°C	35	35
Heat loss in firing zone	$kcal/h/m^2$	1,401	220
Heat loss in rapid zone	$kcal/h/m^2$	2,751	220
Heat loss in firing zone	kcal/h	11,405	1,791
Heat loss in rapid zone	kcal/h	32,931	2,633
Total heat loss	kcal/h	44,336	4,424
GCV of fuel	kcal/scm	9,000	9,000
Heat loss in terms of fuel	scm/h	4.9	0.5
Fuel saving	Rs/scm		4.4
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	scm/y		35,123
Fuel cost	Rs/scm		31
Annual fuel cost saving	Rs Lakh/y		11.04
Estimated investment	Rs Lakh		0.8
Simple payback period	Months		1
IRR	%		80
Discounted payback period	Months		4.2

Table 28: Cost benefit analysis – old Vitrified kiln (ECM 2b)

Parameter	Units	As IS	To Be
No of uninsulated pipe in rapid zone	#	28	28
Recuperator pipe size	mm	51	51
Pipe length	m	1.2	1.2
Rapid zone surface area	m^2	5.36	5.36
Average surface temperature of pipes in rapid zone	°C	170	55
Ambient air temperature	°C	35	35
Heat loss in rapid zone	$kcal/h/m^2$	2,261	220
Heat loss in rapid zone	kcal/h	12,126	1,180

Parameter	Units	As IS	To Be
Total heat loss	kcal/h	12,126	1,180
GCV of fuel	kcal/scm	1,231	1,231
Heat loss in terms of fuel	scm/h	9.8	1.0
Fuel saving	scm/h		8.9
Operating hours per day	h/d	24	24
Annual operating days	d/y	330	330
Annual fuel saving	SCM/y		70,398
Annual coal savings	t/y		18
Fuel cost	Rs/MT		8190
Annual fuel cost saving	Rs Lakh/y		5.77
Estimated investment	Rs Lakh		0.4
Simple payback period	Months		1
IRR	%		161
Discounted payback period	Months		2.2

3.1.4.3 ECM #3: Waste heat recovery from flue gas

Technology description

Utilization of additional 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 250°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 smoke temperature at stack by further 50°C.

Recommended action

It is recommended to decrease the smoke temperature at kiln so that the outlet temperature could be decreased from 250°C to 200°C, thereby increasing the more Heat utilization in kiln in kiln and increasing the temperature of fresh air entering in HAG. This would help to reduce amount of fuel consumption.

Table 29: Waste heat recovery from flue gas- new vitrified kiln [ECM-3a]

Particulars	Units	Value
Smog temperature at smog blower	°C	250.0
Smog flow rate	t/h	8.44
Waste gas flow	kg/h	8444.7
Specific heat of waste gas	kcal/kgK	0.2398
Smog temperature after recuperator	°C	200.0
Heat available at recuperator inlet	kcal/h	506196
Heat recovered	%	20%
Specific heat of FD blower air	kcal/kgK	0.24
Ambient temperature of air	°C	35.0
Mass flow rate of FD blower air	kg/h	6927
Effectiveness of HE-1	%	60%

Particulars	Units	Value
FD blower air temperature after recuperator	°C	**71.5**
Heat saving	kcal/h	60744
GCV of coal	kcal/kg	5495
Fuel savings	kg/h	11.1
Operating hours per day	h/d	330
Operating gays per year	d/y	24
Annual running hours	h/y	7920.0
Annual coal saving	kg/y	87558
Coal price	Rs./kg	8.2
Monetary saving	Rs. Lakh/y	7.2
Investment	Lakhs	11
Simple payback Period	months	19
IRR	%	41
Discounted payback period	Months	7.2

Table 30: Waste heat recovery from flue gas- old vitrified kiln [ECM-3b]

Particulars	Units	Value
Smog temperature at smog blower	°C	250.0
Smog flow rate	t/h	48.68
Waste gas flow	kg/h	48676.3
Specific heat of waste gas	kcal/kgK	0.2398
Smog temperature after recuperator	°C	200.0
Heat available at recuperator inlet	kcal/h	2917785
Heat recovered	%	20%
Specific heat of FD blower air	kcal/kgK	0.24
Ambient temperature of air	°C	35.0
Mass flow rate of FD blower air	kg/h	11257
Effectiveness of HE-1	%	60%
FD blower air temperature after recuperator	°C	**164.6**
Heat saving	kcal/h	350134
GCV of coal	kcal/kg	5495
Fuel savings	kg/h	63.7
Operating hours per day	h/d	330
Operating gays per year	d/y	24
Annual running hours	h/y	7920.0
Annual coal saving	kg/y	504697
Coal price	Rs./kg	8.2
Monetary saving	Rs. Lakh/y	41.3
Investment	Lakhs	87
Simple payback Period	months	25
IRR	%	26
Discounted payback period	Months	9.4

3.2 Coal Gasifier

3.2.1 Specifications

Coal gasifier produces coal gas from coal at controlled combustion by partial combustion using coal and water vapor. Coal gas is used in wall kiln and vitrified kiln. There were two gasifier dedicated for wall kiln and vitrified old kiln. The specification of coal gasifier is given below:

Table 31: Specifications of coal gasifier

Particular	Units	Wall tile	Vitrified old
Make		Radhey	Radhey
Coal consumption	t/d	25	60
Water consumption	l/d	2,000	4,000
FD Blower	kW	2 x 37	2 x 37
Cooling water pump	kW	2 x 5	2 x 5

3.2.2 Field measurement and analysis

During DEA, the following activities were carried out:

- Measurement of power consumption of cooling water pumps and FD blower
- Air flow measurement of FD blower
- Nos. of lifts daily basis from log book

Coal consumption data is not maintained by plant. Kiln cycle time varies between 45-60 minute depending on the production. During the DEA, the kiln cycle time was 60 minutes. Coal lift data is given in below table:

Table 32: Numbers of lift daily basis

Date	Wall tile coal gasifier	Vitrified tile coal gasifier
08/11/2018	54	
09/11/2018	54	61
10/11/2018	53	61
11/11/2018	53	62
12/11/2018	53	62
13/11/2018	53	61
14/11/2018	55	64
15/11/2018	55	64

Table 33: Average power consumption of pumps and blower

Particulars	Units	Wall tile coal gasifier	Vitrified tile coal gasifier
FD fan	kW	3.44	5.17
Cooling water pump 1	kW	6.89	5.13
Cooling water pump 2	kW	8.87	5.36
Cooling water pump 3	kW	Stand by	Stand by

FD blower and cooling water pumps was operating with VFDs in both gasifiers. Average air flow for wall tile gasifier was 2,097 m^3/h and for vitrified tile gasifier was 1,532 m^3/h at FD fan suction.

There is monitoring system for coal gas generation quantity but not in working condition.

3.2.3 Observations and performance assessment

Performance of coal gasifier has been determined in terms of specific energy consumption (coal required for producing 1 scm coal gas). Based on observations during DEA, the specific energy consumption of coal gasifier was 0.26 kg/scm. Specific electricity consumption will be considered as how much power consumed for 1 scm coal in plant which is 0.018 kWh/scm. Since blowers and pumps are operating with VFDs, no energy conservation measure is proposed.

3.3 DRYERS

3.3.1 Specifications

There are two five layer dryers are installed for vitrified tile production and two vertical dryers are installed for wall tiles production. These are used for pre drying of tiles before entering into kiln. The specifications of dryers are given below table:

Table 34: Specifications of horizontal dryer

Particular	Units	Five layer dryer – VT new	Five layer dryer - old	Vertical dryer 1
Capacity	Nos. of tiles/h	1,164	1,500	1,920
Fuel type		Natural Gas	Natural Gas	Natural Gas
Exit temperature of tiles	ºC	135	135	135

3.3.2 Field measurement and analysis

During DEA, the following measurements were done:

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

Data measured during study is tabulated below:

Table 35: Average power and PF measurement of blowers at new five layers dryer

Particular	Power (kW)	Power Factor
Chimney Fan-1	3.17	0.97
Chimney Fan-3	3.35	0.99
Chimney Fan-2	2.57	0.99
Fan-1	9.8	0.72
Fan-2	9.9	0.72
Fan-3	10	0.73
Fan-4	9.8	0.72
Fan-5	9.9	0.72
Fan-6	10	0.73
Fan-7	9.9	0.72
Fan-8	10	0.73
Fan-9	9.8	0.72

Table 36: Average power and PF measurement of blowers at old five layers dryer

Particular	Power (kW)	Power Factor
R.F-5	8.49	1
R.F-2	8.41	1
R.F-4	9.42	1
R.F-1	9.6	1
R.F-3	7.65	1
R.F-6	5.66	1
R.F-7	7.1	1
Humid Air Ejector-1	1.54	1
Humid Air Ejector-2	1.56	1

Table 37: Natural gas consumption data (scm/d)

Date	Five layer dryer – VT new	Five layer dryer - old
8 Nov 18	1,623	240
9 Nov 18	1,674	258
10 Nov 18	1,622	224
11 Nov 18	1,524	252
12 Nov 18	1,638	224

Natural gas consumption in vertical dryer is calculated by subtracting summation of NG consumption in five layer dryers and kiln from main meter reading which is 74.7 scm/h.

Hot air blower discharge duct from kilns is utilized in five layer dryers and vertical dryers who help in fuel savings. NG is firing in all dryers' long hot air. All blowers are operating with VFDs. The power profile and PF profile of blowers installed in dryer are shown in annexure 4:

3.3.3 Observation and Performance assessment

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

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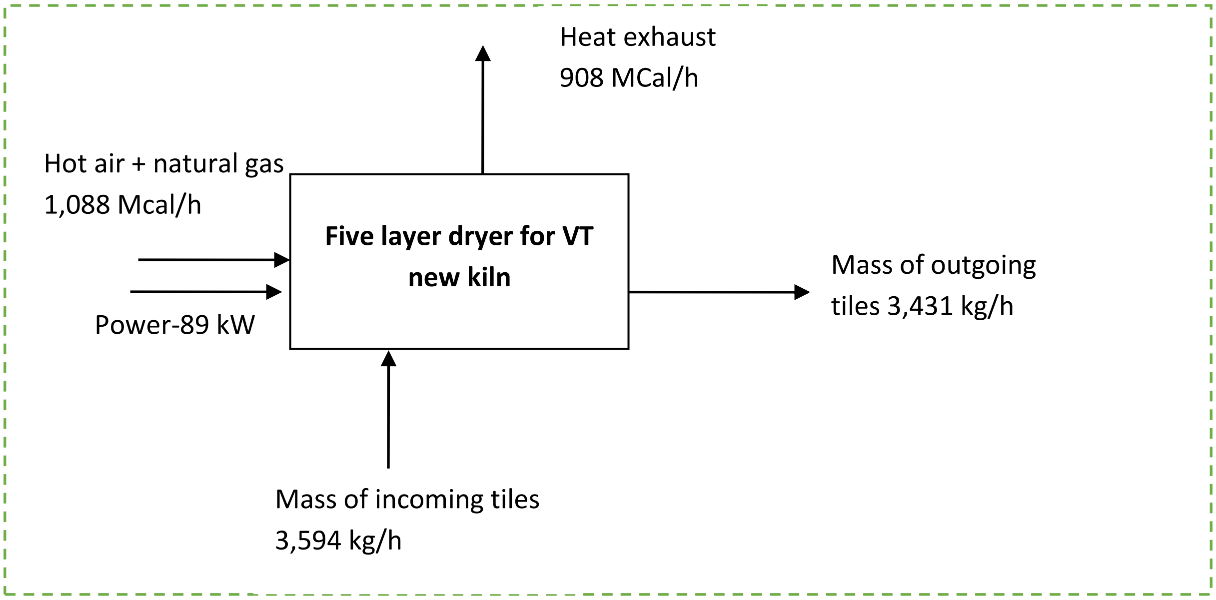


Figure 22: Mass and energy balance of five layer dryer VT new

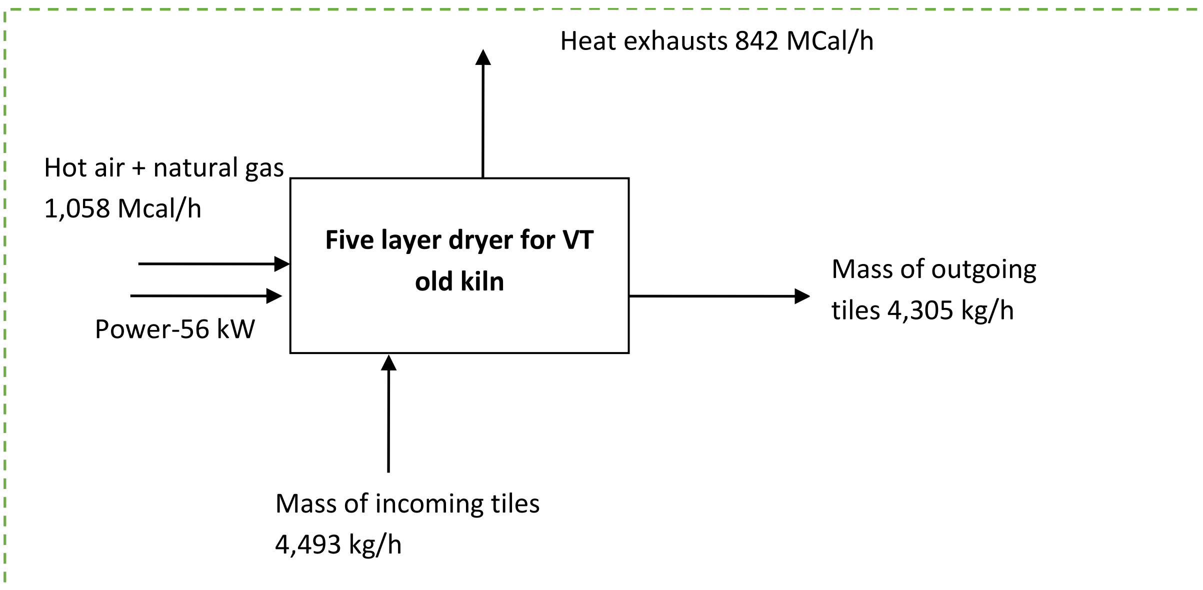
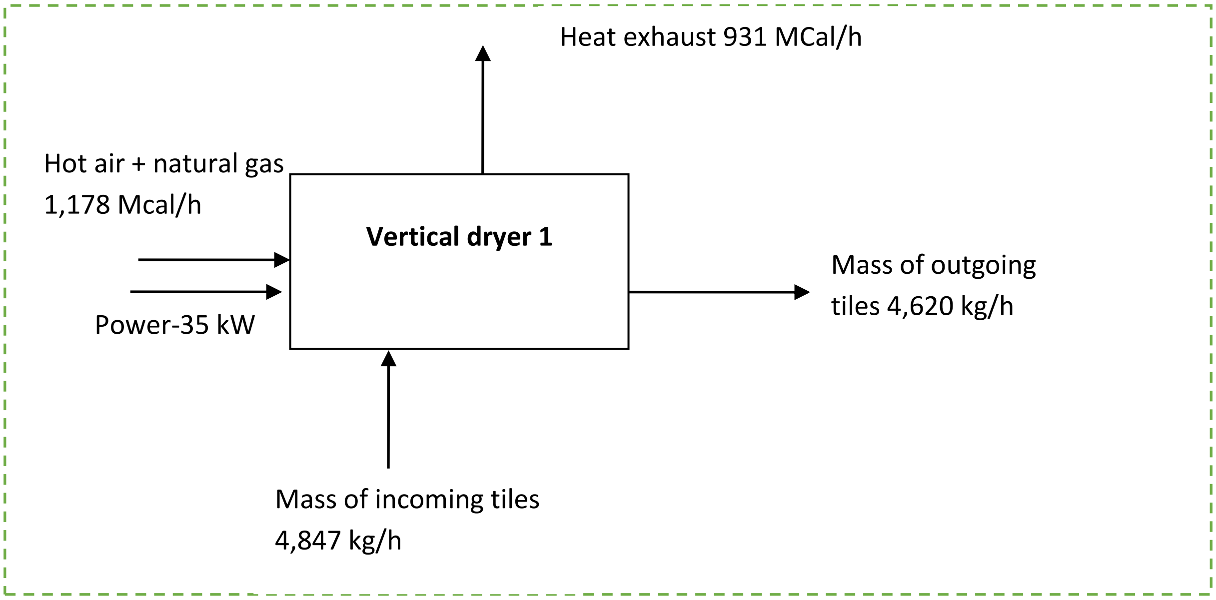


Figure 23: Mass and energy balance of five layer dryer VT old



Mass of tiles are entering into dryers are calculated from mass of tiles entering into kiln at given moisture. Based on observations during DEA, the specific electricity consumption of five layer dryer for VT new is 24.8 kWh/ton of tile and specific thermal energy is 18.7 scm/ton of tile, same for fiver layer dryer of VT old is 12.5 kWh/ton of tile and 2.22 scm/ton of tile (Specific thermal energy is good due to all hot air is using in same dryer only) respectively. Specific electricity consumption of vertical dryer for wall tile is 7.2 kWh/ton of tile and specific thermal energy is 15.3 scm/ton of tile

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

3.4 Hot Air Generators & Spray Dryers

3.4.1 Specifications

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

Table 38: Specifications of Hot air generator (HAG)

Particular	Units	Vitrified old HAG	Vitrified new HAG
Fuel type		Indonesian coal	
Exhaust air temperature	°C	750	750
FD fan	kW	55	45
ID fan	kW	160	132
Coal crusher	kW	45	45

The specifications of spray dryers are given below:

Table 39: Specifications of spray dryer

Particular	Units	Vitrified old HAG	Vitrified new HAG
Powder generation capacity	t/h	15	8
Inlet slurry moisture	%	35	35
Outlet powder moisture	%	6	6
Slip house pump	hp	30	20

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
  - Exhaust air temperature
  - Surface temperature
  - Inlet and outlet moisture of powder
- Spray drier
  - Power consumption of slip house pump

Details of measurements on HAG are given below:

Table 40: Field measurement at site

Particular	Units	Vitrified old HAG	Vitrified new HAG
Air velocity at FD fan suction	m/s	12.3	9.7
Suction area	m^2	0.2	0.2
Exit temperature of air	° C	750	750
Surface temperature	° C	110	
Average power consumption-FD Fan	kW	2.67 (PF=1.0)	5.26 (PF=0.99)
Average power consumption-ID Fan	kW	19.8 (PF=1)	86.7 (PF=1)
Slip house pump	kW	16 (PF=1)	10.7 (PF=1)

Table 41: Moisture data of slurry

Date	Vitrified old HAG		Vitrified new HAG	
	Inlet moisture (%)	Outlet moisture (%)	Inlet moisture (%)	Outlet moisture (%)
09/11/2018	6.4	6.35	31.5	31.5
10/11/2018	6.05	5.85	26.4	26.4
11/11/2018	6	6.1	30.4	30.4
12/11/2018	6.1	6.3	32	32.5
13/11/2018	6.05	5.9	31.3	32.1

3.4.3 Observations and performance assessment

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

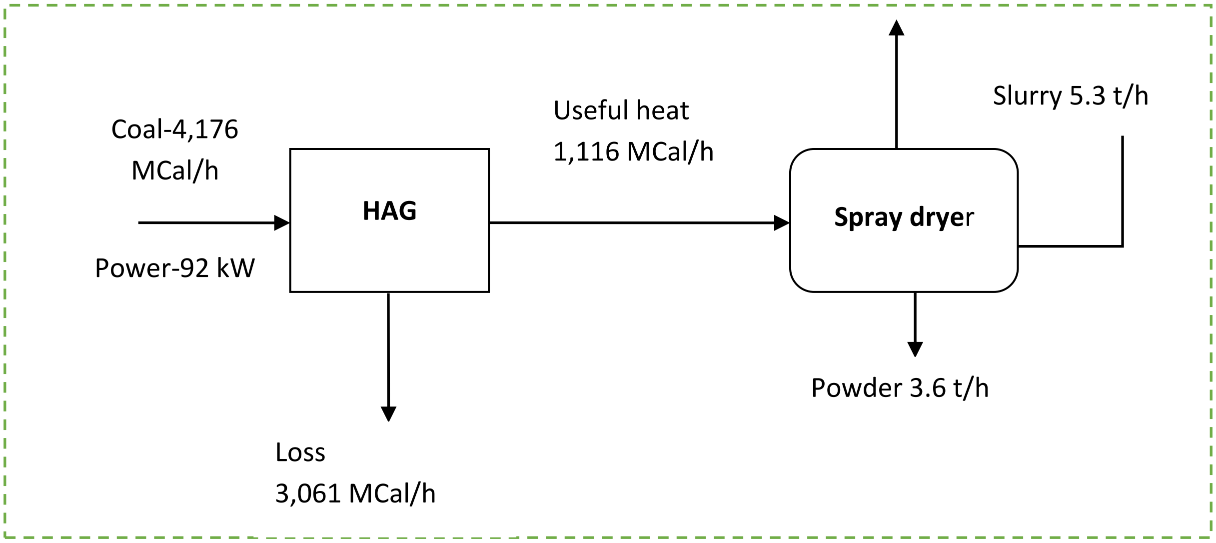


Figure 24: Energy and mass balance of new chain stocker HAG and spray dryer

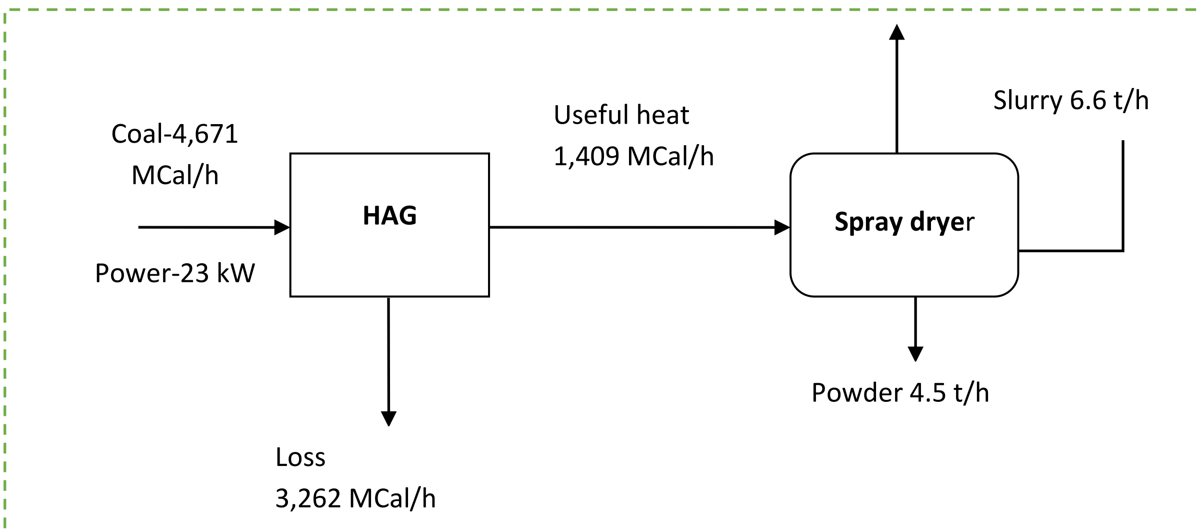


Figure 25: Energy and mass balance of old chain stocker HAG and spray dryer

Coal consumption is taken as per thumb rule as discussed plant personnel in other industries also.. Performance of HAG is measured in terms of specific electricity consumption (electrical energy used for generating 1 ton powder) and specific thermal energy measure (fuel used for generating one ton powder). Based on observations during DEA, for new chain stoker HAG the specific electricity consumption of HAG is 10.9 kW/ton and specific thermal energy is 91 kg of coal/ton and for old chain stoker HAG the specific electricity consumption of HAG is 2.8 kW/ton and specific thermal energy is 102 kg of coal/ton.

Operation is optimized and no energy conservation measure is proposed.

3.4.4 Energy conservation measures (ECM) – ECM # 4 – Insulation of new HAG surface and connecting duct

Technology description

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

Study and investigation

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

Recommended action

It is recommended to insulate the HAG duct connecting cyclone separator.
Estimated cost benefit is given in the table below:

Table 42: Saving and cost benefit by Insulating HAG duct [ECM-4]

Parameters	Unit	AS IS	To Be	AS IS	To Be
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	95	55	110	55
Average coal loss due to high skin temperature	kg/h	3.6	1.8	3.6	1.4
Average coal saving	kg/h		1.7		2.2
Annual operating hour	h/y	7,920	7,920	7,920	7,920
Annual coal saving	MT/y		14		18
Fuel cost	Rs/MT	8190	8190	8190.0	8190.0
Annual fuel cost saving	Rs Lakh/y		1.13		1.44
Net saving	Rs Lakh/y	2.57			
Estimated insulation cost	Rs Lakh	3.84			
Payback period	Month	18			
IRR	%	44			
Discounted payback period	Months	6.8			

4. CHAPTER: 4 PERFORMANCE EVALUATION OF ELECTRICAL EQUIPMENT

4.1 CLAY BALL MILLS

4.1.1 Specifications

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

Table 43: Specifications of Clay ball mills

Particular	Units	Value
Numbers of Clay ball mills	#	7
Capacity of each Clay ball mill	t/batch	40
Water consumption in each Clay ball mill	M^3/batch	18
SMS (chemical consumption)	kg/batch	150
STPP (chemical consumption)	kg/batch	25
Water TDS	ppm	1,500
Nos. of batch per day		10

4.1.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all Clay ball mills

FD blower and cooling water pumps was operating with VFDs. All power profile is included in Annexure-4. Average power consumption and power factor are given in below table:

Table 44: Average power consumption of Clay ball mills

Equipment	Average Power (kW)
Clay ball mill#7	125
Clay ball mill#6	141
Clay ball mill#5	128
Clay ball mill#2	100

4.1.3 Observations and performance assessment

Mass of slurry from each clay ball mill is considered as same as rated capacity. By considering same mass, Mass balance of Clay ball mill (power consumption is measured during DEA) is given below:

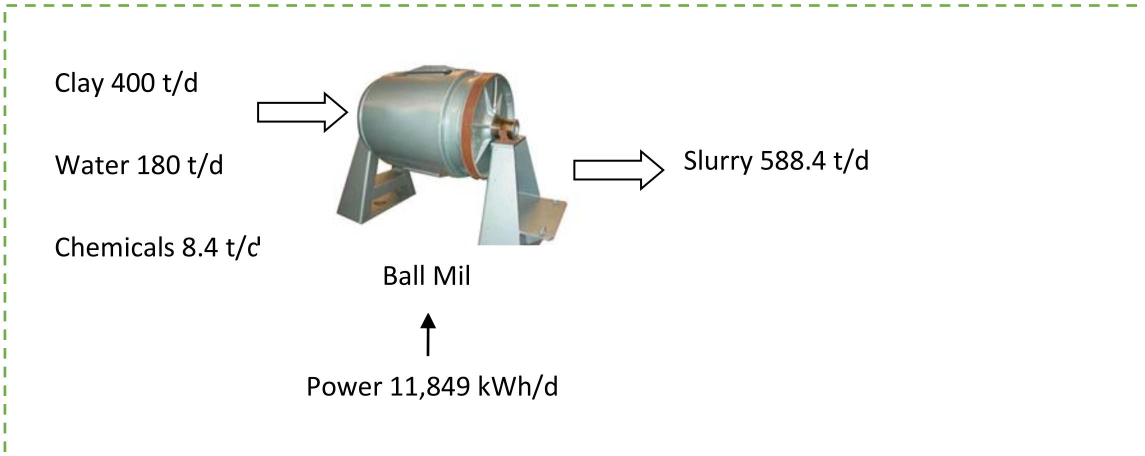


Figure 26: Energy and mass balance of Clay ball mill

Performance of Clay ball mills measure in terms of specific energy consumption (power consumed for preparation of 1 ton of slurry). Based on observations during DEA, the specific energy consumption of coal was 10.1 kW/ton. TDS of bore well water is very high; this should be controlled by installing softener plant, which will enable resource savings.

4.1.4 Energy conservation measures (ECM) – ECM # 5 –Optimization of Resource Consumption in Clay Section

Technology description

It was observed that the TDS of water used in clay section is 1,500 ppm, which results in higher consumption of water, chemicals and electricity per batch of slurry preparation and later higher coal consumption for spray dryer.

Study and investigation

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

Recommended action

It is recommended to install brackish water plant which will blend RO water with raw water to get desired TDS of water(less than 300 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 45: Saving and cost benefit by using improved water quality in new ball mill [ECM-5a]

Parameters	Unit	AS IS	TO BE
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	18.00	15.30
Water saving	m^3		2.70
Electricity used per batch	kWh	352.6	341.99
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kCal/kg	5,495	5,495
Eff. Of HAG	%	85%	85%
Coal saving per batch	kg		356
Chemical saving per batch			
SMS	kg	150	105
STPP		25	17.5
Per Unit Cost			
Water	Rs./m^3	5.00	5.00
Electricity	Rs/kWh	8.00	8.00
Coal	Rs/kg	8.19	8.19
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		4,637
Total batches per day	#	5	5
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		4,455.0
Electricity	kWh/y		17,452.20
Coal	t/y		586.64
Chemical	kg/y		86,625.00
Annual cost savings	Lakh Rs/y		76.52
Operating cost- Water Treatment	Rs/m^3		20.00
	Lakh Rs/y		5.05
Net monetary savings	Lakh Rs/y		71.47
Estimated investment	Lakh Rs		39.60
Payback period	Months		6.65
IRR	%		139
Discounted payback period	Months		2.6

Table 46: Saving and cost benefit by using improved water quality in old ball mill [ECM-5b]

Parameters	Unit	AS IS	TO BE
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	18.00	15.30

Parameters	Unit	AS IS	TO BE
Water saving	m^3		2.70
Electricity used per batch	kWh	141	137
Temperature of water	°C	25	25
Boiling temp. of water	°C	100	100
GCV of coal	kCal/kg	5,495	5,495
Eff. Of HAG	%	85%	85%
Coal saving per batch	kg		356
Chemical saving per batch			
SMS	kg	150	105
STPP		25	17.5
Per Unit Cost			
Water	Rs./m^3	5.00	5.00
Electricity	Rs/kWh	8.00	8.00
Coal	Rs/kg	8.19	8.19
Chemical			
SMS	Rs/kg	22.00	22.00
STPP	Rs/kg	85.00	85.00
Cost Savings per batch	Rs		4,587
Total batches per day	#	5	5
Annual operating days	d/y	330	330
Annual resource savings			
Water	m^3/y		4,455.0
Electricity	kWh/y		6,986
Coal	t/y		587
Chemical	kg/y		86,625
Annual cost savings	Lakh Rs/y		75.68
Operating cost- Water Treatment	Rs/m^3		20.00
Monetary savings due to water reduction	Lakh Rs/y		5.05
Net monetary savings	Lakh Rs/y		70.63
Estimated investment	Lakh Rs		39.60
Payback period	Months		6.73
IRR	%		134
Discounted payback period	Months		2.6

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 47: Specifications of hydraulic presses

Particular	Units	Wall tile	Vitrified tile new	Vitrified tile old
Numbers of press	#	2	1	3
Capacity of press	kW	160	200	133
Cycle (stock) per mins	N/m	8		

Particular	Units	Wall tile	Vitrified tile new	Vitrified tile old
Nos. of tiles per stock		4		
Water Circulation Pump	#s	2	1	3

4.2.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all presses and water circulation pumps

Average power consumption of water circulation pumps and presses are given below:

Table 48: Specifications of hydraulic presses

Particular	Units	Value
Vitrified tile press #4	kW	160
Vitrified tile press #3	kW	76
Vitrified tile press #2	kW	128
Vitrified tile press #1	kW	106
Wall tile press press#2	kW	82.2
Vitrified tiles press CWP 1	kW	6.3
Vitrified tiles press CWP 2	kW	5.1
Vitrified tiles press CWP 3	kW	10
Wall tiles press CWP 2	kW	6.1

4.2.3 Observation and performance assessment

Mass of tiles produced from press is calculated on the basis of tiles entering into kiln at given moisture. All water circulating pumps were running at low efficiency.

Performances of hydraulic presses can measures in terms of specific energy consumption (power consumed for preparation of 1 ton of tile). Based on observations during DEA, the specific energy consumption was 44.5 kW/ton for VT new press, 68.8 kW/ton for VT old press and 43.2 kW/ton for wall tile press.

4.2.4 Energy conservation measures (ECM) - ECM #6: Replacement of inefficient bore well pump with efficient pump

Technology description

Replacing inefficient cooling tower pump with energy efficient pump to reduce the power consumption.

Study and investigation

The unit is having 4 cooling tower pumps. Efficiency of existing pumps is 24%, 20%, 24% and 30% respectively.

Recommended action

It is recommended to replace inefficient pumps with energy efficient pumps. New pumps shall have efficiency up to 70%. The cost benefit analysis is given below:

Table 49: Replacement of inefficient with energy efficient pump [ECM-6]

Parameters	Units	AS IS Hydraulic press wall tile water circulation pump WT	TO BE	AS IS Hydraulic press wall tile water circulation pump VT 1	TO BE	AS IS Hydraulic press wall tile water circulation pump VT2	TO BE	AS IS Hydraulic press wall tile water circulation pump VT 3	TO BE
Design Parameters		CWP 2		CWP 1		CWP 2		CWP 3	
Motor I/P Power	kW	10	10	10	10	10	10	15	15
Measured Parameters									
Flow rate Q	m^3/h	22.0	22.0	19.0	19.0	18.0	18.0	44.0	44.0
Suction Pressure	kg/cm^2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Discharge Pressure	kg/cm^2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Motor Input Power	kW	6.1	2.12	6.3	1.83	5.1	1.73	10.0	4.23
Flow rate Q	m^3/s	0.0061	0.0061	0.0053	0.0053	0.005	0.005	0.012	0.012
Total head developed	m	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Liquid horse power	kW	1.26	1.26	1.09	1.09	1.03	1.03	2.52	2.52
Motor Input power	kW	6.09	2.12	6.28	1.83	5.06	1.73	9.98	4.23
Motor Loading	%	61	21	63	18	51	17	67	28
Overall system efficiency	%	21	60	17	60	20	60	25	60
Pump efficiency	%	24	70	20	70	24	70	30	70
Average working hours	h/d	24	24	24	24	24	24	24	24
Annual working days	d/y	330	330	330	330	330	330	330	330
Annual energy consumption	kWh/y	48,233	16,758	49,738	14,473	40,075	13,736	79,042	33,516
Annual energy saving	kWh/y	-	31,475		35,265	-	26,339		45,526
Cost of Electricity	Rs/kWh	Z	8.00		8.00		8.00		8.00
Annual energy cost saving	Lakh Rs /y		3		2.82		2		3.64

Parameters	Units	AS IS TO BE Hydraulic press wall tile water circulation pump WT	AS IS TO BE Hydraulic press wall tile water circulation pump VT 1	AS IS TO BE Hydraulic press wall tile water circulation pump VT2	AS IS TO BE Hydraulic press wall tile water circulation pump VT 3
Total annual energy cost saving	Lakh Rs /y	11.08			
Total estimated investment	Lakh Rs	4.16			
Payback period	Months	4.5			
IRR	%	204			
Discounted payback period	Months	1.8			

4.3 AGITATOR

4.3.1 Specifications

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

Table 50: Specifications of agitators

Particular	Units	Value
Numbers of agitators in tank	#	24
Numbers of agitator in operation	#	12
Capacity of each agitator motor	hp	7.5

4.3.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of all agitator motors

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

Table 51: Power consumption of agitator motors

Equipment	kW
Agitator no.11	4.17
Agitator no.12	3.65
Agitator no.13	2.13
Agitator no.14	2.46
Agitator no.15	2.28
Agitator no.16	3.25

Equipment	kW
Agitator no.17	2.88
Agitator no.01	2.76
Agitator no.02	2
Agitator no.03	1.66
Agitator no.05	2.78
Agitator no.07	2.8

4.3.3 Observations and performance assessment

Mass of slurry considered as same as slurry prepared in clay ball mills. During DEA it is observed that all motors operate same time. It is suggested that all motor should operate by timer control.

Performance of agitator motors can measure in terms of specific energy consumption (power consumed for holding 1 ton of slurry). Based on observations during DEA, the specific energy consumption of agitator motors were 2.8 kW/ton.

4.3.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.3.4.1 ECM #7: Timer Controller with stirrer motors

Technology description

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

Study and investigation

It was observed that all the agitators are equipped with VFD and all agitators are in continuous operation throughout the day.

Recommended action

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

Table 52: Stirrer Time Controller [ECM-7]

Particulars	Unit	AS IS	TO BE
No of agitator stirrer	Nos.	24	24
No of agitator stirrer running	Nos.	12	12
Rated power of agitator stirrer motor	kW	5.6	5.6
Running of each stirrer motor	h/d	24	12
Average power of stirrer motor	kW	2.7	2.7
Annual operating days	d/y	330	330
Annual power consumption	kWh/y	259,934	129,967

Particulars	Unit	AS IS	TO BE
Annual energy saving	kWh/y		129,967
Cost of Electricity	Rs/kWh		8.0
Annual energy cost saving	Lakh R./y	10.4	
Estimated investment	Lakh Rs	7.2	
Payback Period	Months	8.3	
IRR	%	108	
Discounted payback period	Months	3.3	

4.4 GLAZING

4.4.1 Specifications

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

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

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

The specifications of glazing mills are given below:

Table 53: Specifications of glazing machine

Particular	Units	Value
Numbers of glazing mills	Nos.	4
Capacity of glazing mill	HP	75

Glaze ball mills were not in operation during DEA so measurement and observation are not given for glaze ball mills.

4.5 SIZING MACHINE

4.5.1 Specifications

There were two sizing unit as old and new sizing which comprising many grinders along dust collector blower. The specifications of sizing machines are given below:

Table 54: Specifications of sizing machine

Particular	Units	Sizing line 1	Sizing line 2
Numbers of grinders	Nos.	20	20
Capacity of grinders	kW	3.5	3.5
Capacity of dust collectors blower	kW	37	37
Circulation water pump	hp	15	15

4.5.2 Field measurement and analysis

During DEA, the following measurements were done:

- Power consumption of cutters and pump

Average power consumption of cutters was 77.1 kW and circulation water pump was consuming 6.7 kW

4.5.3 Observations and performance assessment

During DEA it is observed that all cutters and circulation water was in operation during lunch time (tiles are not coming in sizing). It is suggested that to install time PID controller for controlling operation of cutters and pump as per demand.

Performance of sizing unit can measure in terms of specific energy consumption (power consumed for cutting one ton tiles). Based on observations during DEA, the specific energy consumption of sizing machine was 24.8 kW/ton.

4.5.3.1 ECM #8: Timer Controller with sizing machine

Technology description

A number of cutters are equipped with sizing machine, are running only to cut and finish tiles as per requirement. A timer-based control can help save energy. A number of units have implemented timer based control where idle time of cutters and circulation water pump can be avoided.

Study and investigation

It was observed that all the cutters and circulation water pump was operating while stile are not feeding in machine (observed during lunch time)

Recommended action

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

Table 55: Time Controller at sizing machine [ECM-8]

Parameters	Units	AS IS	TO BE
Rated power of sizing motor	kW	130	130
Water circulation pump running	#	1	1
Rated power of pump	kW	11.19	11.19
Running power of pump	kW	6.714	6.714
Daily running of each sizing machine	h/d	24	22
Operating days per year	d/y	330	330
Operating power of grinding machine	kW	77.7	77.7

Parameters	Units	AS IS	TO BE
Annual energy consumption	kWh/y	615,723	564,413
Annual energy saving	kWh/y		51,310
Unit cost of electricity	Rs/kWh		8.00
Annual monetary savings	Lakh Rs/y		4.10
Estimated Investment	Lakh Rs		3.25
Payback Period	Months		9.50
IRR	%		94
Discounted payback period	Months		3.7

During DEA, sizing line was not in operation, so measurement couldn't be possible.

4.6 AIR COMPRESSORS

4.6.1 Specifications

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

Table 56: Specifications of compressors

Particular	Units	Air compressor 1	Air compressor 2	Air compressor 3	Air compressor 4	Air compressor 5
Power rating	HP	45	37	45	37	45
Maximum pressure	Bar (a)	8.5	8	8.5	8	8.5

Air compressor 1 and 2 are dedicated for old vitrified plant, compressor 3 & 4 are dedicated for new vitrified plant and compressor 5 is dedicated for wall tile plant

- Receiver

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 57: Measured Parameters of Compressors

Equipment	Average Power (kW)	PF	Air flow rate (m^3/min)	% of time on load
Compressor-1	37.9	0.89	2.9	72
Compressor-2	42.8	0.87	3.2	
Compressor-3	52.2	0.84	5.5	
Compressor-4	51	51	5.2	
Compressor-5	36	0.96	6.3	67

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 was 0.27 kW/cfm of compressor 1, 0.28 kW/cfm of compressor-2, 0.36 kW/cfm for compressor-3, 0.38 kW/cfm of compressor-4 and 0.18 kW/cfm of compressor-5.

4.6.4 Energy conservation measures (ECM) - ECM #9: VFD installation with compressor

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 two compressors were captured to understand unload/load pattern of air compressor it was found that the compressor is getting unloaded for 35% of the time. There was only one receiver and it was not possible to conduct FAD test for compressor.

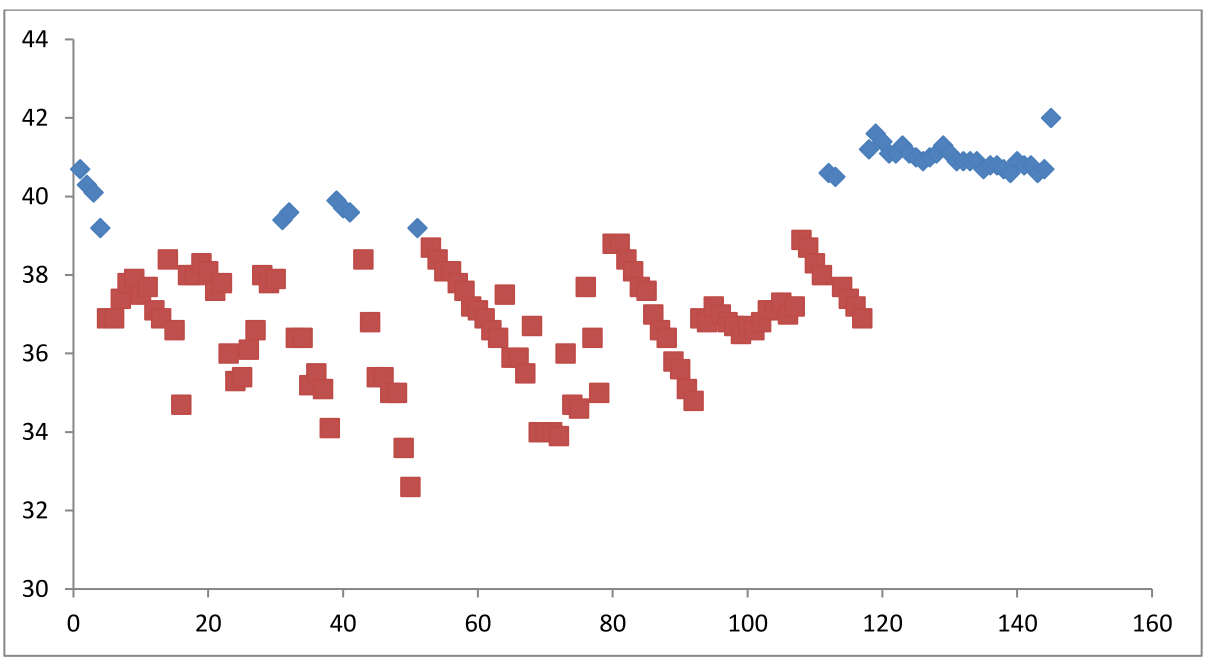


Figure 27: Load/Unload pattern of Compressor 1

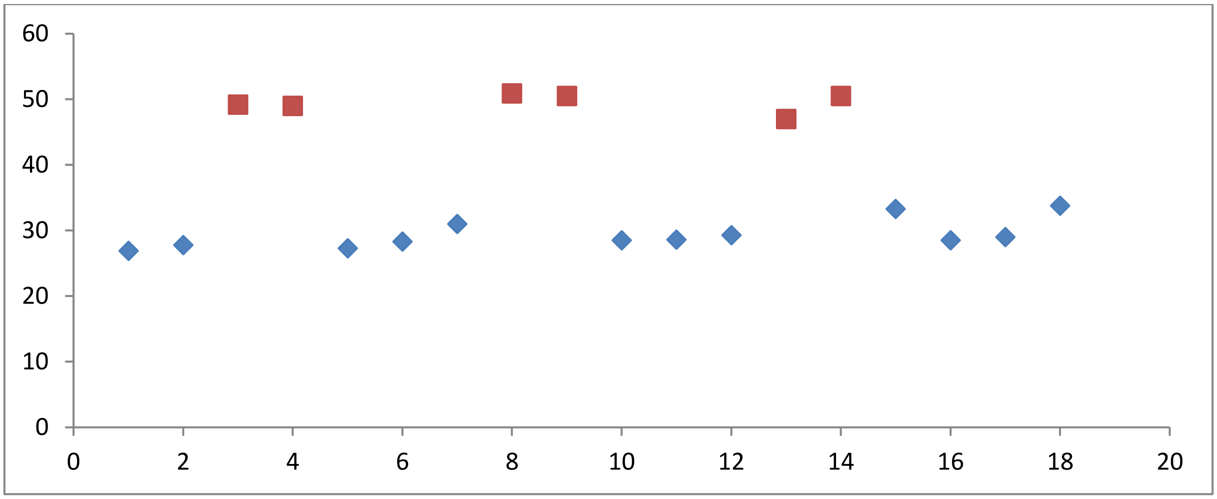


Figure 28: Load/Unload pattern of Compressor 5

Recommended action

It is recommended to install VFD on compressor 1 and compressor 5 which will cater to the variable air demand of the plant whereas other two compressors will run to meet the base load. The cost benefit analysis for this project is given below:

Table 58: VFD for compressor 1 [ECM-9a]

Parameters	Units	As Is	To Be
Compressor motor rating	kW	45	45
Average power consumption during loading	kW	40.68	-
Average power consumption during unloading	kW	36.70	-
On load time in percentage	%	28.17%	-
Off load time in percentage	%	71.83%	-
Average power consumption	kW	37.82	32.15
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	299,554	254,621
Annual energy saving	kWh/y		44,933
Unit cost of electricity	Rs/kWh		8.00
Annual monetary savings	Lakh Rs/y		3.59
Total annual monetary savings	Lakh Rs		3.59
Total estimated Investment	Lakh Rs		4.8
Payback period	Months		16
IRR	%		52
Discounted payback period	Months		6

Table 59: VFD for compressor 5 [ECM-9b]

Parameters	Units	As Is	To Be
Compressor motor rating	kW	45	45
Average power consumption during loading	kW	49.52	-
Average power consumption during unloading	kW	29.36	-

Parameters	Units	As Is	To Be
On load time in percentage	%	33.33%	-
Off load time in percentage	%	66.67%	-
Average power consumption	kW	36.08	30.67
Operating hours/day	h/d	24	24
Operating days/year	d/y	330	330
Annual energy consumption	kWh/y	285,736	242,876
Annual energy saving	kWh/y		42,860
Unit cost of electricity	Rs/kWh		8.00
Annual monetary savings	Lakh Rs/y		3.43
Total estimated Investment	Lakh Rs		4.75
Payback period	Months	45	16.64
IRR	%		51
Discounted payback period	Months		6.3

4.7 Lighting System

4.7.1 Specifications

The plant lighting system includes:

Table 60: Specifications of lighting load

Particular	Units	LEDs	CFL
Power consumption of each fixture	W	36	85
Numbers of fixtures	#	205	50

4.7.2 Field measurement and analysis

During DEA, the following measurements were done:

- Recording Inventory
- Recording Lux Levels

Table 61: Lux measurement at site

Particular	Units	Value
Office	Lumen/m^2	160
Kiln control room	Lumen/m^2	110
Kiln area	Lumen/m^2	60
Press	Lumen/m^2	70
Clay ball mill and agitators	Lumen/m^2	70
HAG and spray dryer new	Lumen/m^2	75
Horizontal dryer	Lumen/m^2	65

4.7.3 Observations and performance assessment

Adequate day lighting is used wherever possible. Already they have changed most of the fixtures with EE fixtures.

4.8 ELECTRICAL DISTRIBUTION SYSTEM

4.8.1 Specifications

Unit demand is catered by a HT supply (11kV) which is converted into LT supply (433V) by step down transformer (3*2.5 MVA). Automatic power factor correction system is installed in parallel to main supply. There were two DGs (capacity of 2.5 MVA) installed in main LT room for emergency purpose which are connected by means of change over. Power is distributed in plant by feeder which is shown in Figure 10.

4.8.2 Field measurement and analysis

During DEA, the following measurements were done:

- Whole plant load measurement by installing power analyzer at vitrified new, vitrified old and wall tile incomer feeder

4.8.3 Observations and performance assessment

After analyzing both feeders power profiling, it is observed that the maximum kVA recorded during study period was **5,000 kVA** at the plant feeder

The voltage profile of the vitrified new unit is not satisfactory and average voltage measured was **440 V.** Maximum voltage was **455 V** and minimum was **412 V.** The voltage profile of the vitrified old unit is not satisfactory and average voltage measured was **425 V.** Maximum voltage was **437 V** and minimum was **367 V.** The voltage profile of the wall tile unit is not satisfactory and average voltage measured was **432 V.** Maximum voltage was **447 V** and minimum was **418 V**

Average total voltage and current Harmonics distortion found **14.0%** & **5.54%** respectively during power profile recording for wall tile plant. Average total voltage and current Harmonics distortion found **6.4%** & **10.8%** respectively during power profile recording for tile vitrified new plant. Average total voltage and current Harmonics distortion found **5.9%** & **12.5%** respectively during power profile recording for tile vitrified old plant.

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

4.8.4 Energy conservation measures (ECM)

Detailed ECM is explained in below section:

4.8.4.1 ECM #10: Installation of harmonics Filter at wall tile incomer feeder

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 3.17 kW.

Table 62: Measured Harmonics Level at Main Incomer

Name & Sl. No.	Phase		Voltage	Amp.	THD V (%)	THD I (%)	Individual Current Harmonics				
							A3%	A5%	A7%	A9%	A11%
Main Incomer	R	Average	433	598	5.7	13.3	1.65	7.2	9.77	2.10	2.56
		Minimum	425	527	4.7	8.5	0.80	1.20	4.30	1.40	1.50
		Maximum	444	685	7.2	24.0	2.50	16.1	17.3	2.90	4.30
	Y	Average	433	581	5.4	14.4	1.95	6.3	11.63	0.45	2.60
		Minimum	424	496	4.5	9.5	0.80	0.60	5.50	0.00	1.30
		Maximum	444	660	6.8	27.6	3.40	15.8	21.9	1.60	4.60
	B	Average	430	528	5.5	14.3	0.53	6.4	11.60	0.96	2.16
		Minimum	422	451	4.6	8.6	0.10	0.40	4.70	0.00	0.40
		Maximum	441	603	7.1	27.9	1.50	16.2	22.3	2.10	4.00

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

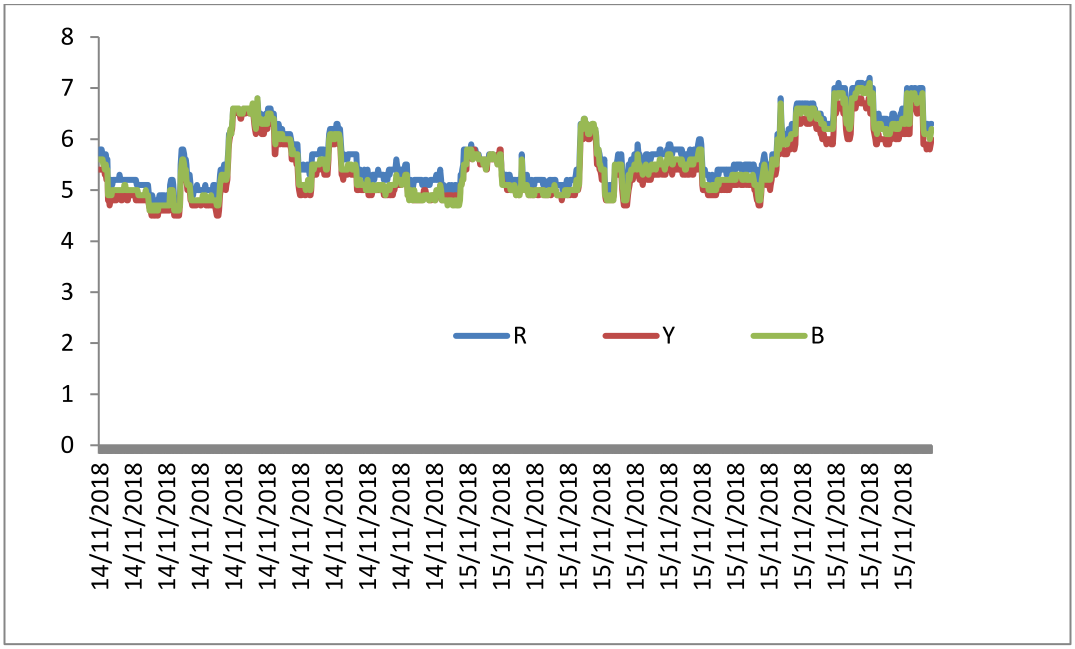


Figure 29: Voltage THD profile

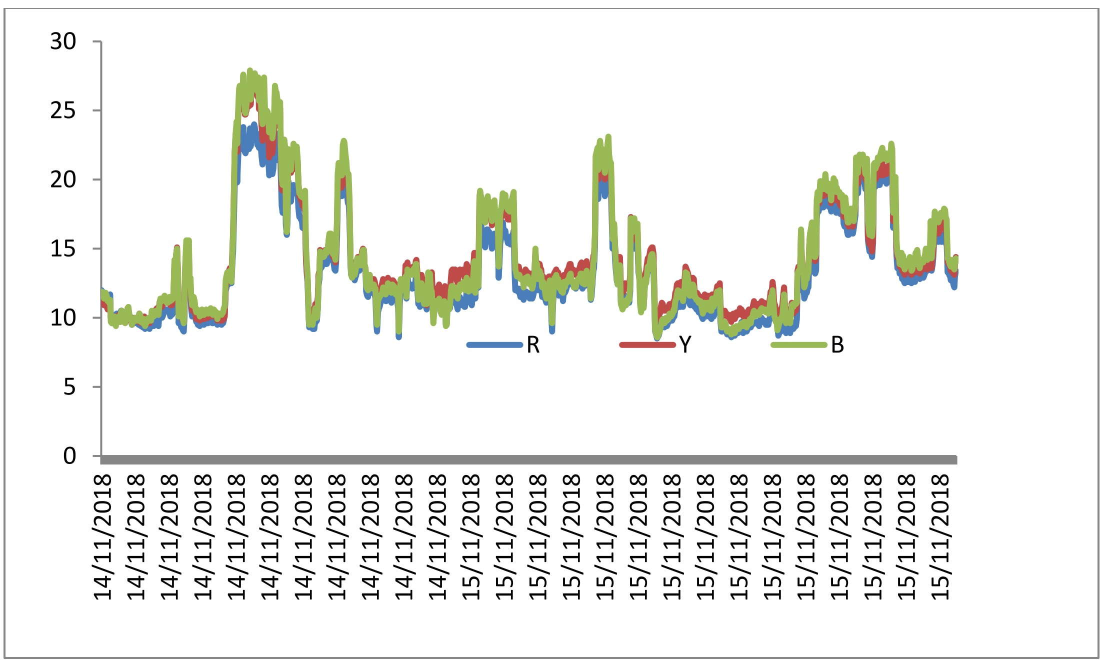


Figure 30: Ampere THD profile

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 80 A**. 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 recommend 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 63: Install active harmonics Filter [ECM-10]

Particulars	Unit	As Is	To be
Estimated losses due to Harmonics	kW	3.3	0
Saving potential by installation of active harmonics filter	kW	3	
Operating days	D	330	
Operating hours	H	24	
Saving potential	kWh/y	25,829	
Cost of Electricity	Rs./kWh	8	
Annual Saving	Rs./y	206,536	
Estimated rating of active harmonics filter	A	80	
Estimated Investment	Rs	633,600	
Payback Period	months	37	
IRR	%	11	
Discounted payback period	Months	13.3	

4.8.4.2 ECM #11: Installation of energy monitoring 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 3% from its present levels. The recommended locations for the energy meter are:

- Kiln
- Horizontal dryer

The cost benefit analysis for this project is given below:

Table 64: Cost benefit analysis [ECM-11]

Parameters	Unit	As Is	To Be
Energy monitoring saving for electrical system	%		2.00
Energy consumption of major machines per year	kWh/y	22,926,768	22,468,232
Annual electricity saving per year	kWh/y		458,535
Unit Cost	Rs/kWh		8.00
Annual monetary savings	Lakh Rs./y		36.67
Number of equipments	Nos.	49	49
Energy monitoring saving for thermal system	%	2.00	
Current fuel consumption for kiln	kg/y	15,518,788	15,208,413
Annual fuel saving per year	kg/y	310,376	
Unit Cost	Rs./kg	8.2	
Annual monetary savings	Lakhs Rs./y	25.42	
Number of equipments	Nos.	6	
Total monetary savings	Lakhs Rs.	62	
Estimate of Investment (Electrical + Thermal)	Lakhs Rs.	18.11	
Payback Period	Months	15.53	
IRR	%	259	
Discounted payback period	Months	1.4	

4.8.4.3 Energy conservation measures (ECM) - ECM #12: Installation of Servo stabilizer for incomer feeder

Technology description

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

Study and investigation

During field measurements, it was found that the present voltage was higher than the standard voltage which is 415V. According to the main LT Power Profiling of wall tile plant, maximum voltage was 444V & average voltage is 432V, vitrified new plant, maximum voltage was 456 V & average voltage is 440 V and vitrified old plant, maximum voltage was 434 V & average voltage is 425 V found.

Recommended action

A 1.0 MVA servo stabilizer is suggested to install on wall tile main LT panel, 2.0 MVA servo stabilizer is suggested to install on new vitrified tile and old vitrified main LT panel to optimize voltage. Servo stabilizer rating is suggested according to Electricity monthly billing demand. The cost benefit analysis for this project is given below:

Table 65: Cost Benefit analysis of wall tile main LT Optimization [ECM-12a]

Parameter	Unit	As Is	To Be
Maximum load (Measured)	kW	464	464
Maximum load (Measured)	kVA	484	484
Maximum demand as per electricity bill	kVA	5000	5000
Maximum voltage		444	415
Average voltage	V	432	410
Reduction in Voltage	%		5.1%
% reduction in energy consumption	%		9.92%
Average power factor of system	PF	0.91	0.91
Annual electricity consumption	kWh/y	3,407,597	3,407,597
Savings Estimate from other EPIAs	kWh/y		616,245
Actual energy considered for voltage regulation	kWh/y		2,791,352
Actual energy consumption after voltage regulation	kWh/y		2,514,583
Efficiency of servo stabilizer	%		95%
Period for which voltage regulation is required	Months/y		8
Net saving from voltage regulation	kWh/y		175,287
Unit cost of electricity	Rs/kWh		8.00
Annual monetary saving	Lakh Rs/y		14.02
Sizing of servo stabilizer	kVA		558
Rating of servo stabilizer	kVA		1,000
Estimated investment	Lakh Rs		15.84
Payback period	Months		13.56
IRR	%		63
Discounted payback period	Months		5.3

Table 66: Cost Benefit analysis of new vitrified tile main LT Optimization [ECM-12b]

Parameter	Unit	As Is	To Be
Maximum load (Measured)	kW	1377	1377
Maximum load (Measured)	kVA	1410	1410
Maximum demand as per electricity bill	kVA	5000	5000
Maximum voltage		456	415
Average voltage	V	440	410
Reduction in Voltage	%		6.7%
% reduction in energy consumption	%		13.03%
Average power factor of system	PF	0.91	0.91

Annual electricity consumption	kWh/y	12,048,756	12,048,756
Savings Estimate from other EPIAs	kWh/y		2,178,951
Actual energy considered for voltage regulation	kWh/y		9,869,805
Actual energy consumption after voltage regulation	kWh/y		8,583,509
Efficiency of servo stabilizer	%		95%
Period for which voltage regulation is required	Months/y		8
Net saving from voltage regulation	kWh/y		814,654
Unit cost of electricity	Rs/kWh		8.00
Annual monetary saving	Lakh Rs/y		65.14
Sizing of servo stabilizer	kVA		1,625
Rating of servo stabilizer	kVA		2,000
Estimated investment	Lakh Rs		31.68
Payback period	Months		5.84
IRR	%		154
Discounted payback period	Months		2.3

Table 67: Cost Benefit analysis of old vitrified tile main LT Optimization [ECM-12c]

Parameter	Unit	As Is	To Be
Maximum load (Measured)	kW	1,446	1,446
Maximum load (Measured)	kVA	1,482	1,482
Maximum demand as per electricity bill	kVA	5,000	5,000
Maximum voltage	V	434	415
Average voltage	V	425	410
Reduction in Voltage	%		3.5%
% reduction in energy consumption	%		6.88%
Average power factor of system	PF	0.99	0.99
Annual electricity consumption	kWh/y	7,470,415	7,470,415
Savings Estimate from other EPIAs	kWh/y		1,350,983
Actual energy considered for voltage regulation	kWh/y		6,119,432
Actual energy consumption after voltage regulation	kWh/y		5,698,165
Efficiency of servo stabilizer	%		95%
Period for which voltage regulation is required	Months/y		8
Net saving from voltage regulation	kWh/y		266,802
Unit cost of electricity	Rs/kWh		8.00
Annual monetary saving	Lakh Rs/y		21.33
Sizing of servo stabilizer	kVA		1,583
Rating of servo stabilizer	kVA		2,000
Estimated investment	Lakh Rs		31.68
Payback period	Months		17.82
IRR	%		45
Discounted payback period	Months		6.8

4.9 BELT OPERATED DRIVES

4.9.1 Specifications

There are 26 drives operated with V Belt of total capacity of 101 kW. Locations include

- Kilns (13)
- HAG (4)
- Dryers (9)

4.9.2 Field measurement and analysis

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

4.9.3 Observations and performance assessment

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

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

Technology description

Replacing conventional belt (V belt) with energy efficient belt REC (raw edged cogged) belt. REC belts transmit more power as compared to V belts; hence deliver rated RPM and more air supplied.
Benefits of Cogged belts & Pulley over V belts:

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

Study and investigation

The unit is having about 26 belt driven blowers in plant

Recommended action

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

Table 68: Replacement of conventional belt with REC belt [ECM-13]

Particulars	Units	AS IS	TO BE
Measured power of all belt driven blowers	kW	790	790
Running hours of blowers	h/d		3.60%
Average power of blowers	kWh/d	101	97
Annual operating days	d/y	24	24
Annual power consumption	kWh/y	330	330
Annual energy saving	kWh/y	28,795	
Electricity cost	Rs./kWh	8.00	
Annual energy cost saving	Rs. Lakh/y	2.30	

Estimated investment	Rs. Lakh	0.79
Payback Period	Months	4.13
IRR	%	218
Discounted payback period	Months	1.6

5. Chapter -5 Energy consumption monitoring

5.1 Energy Consumption Monitoring

In order to monitor the overall energy performance, the installation of a basic energy monitoring system has been proposed for the unit (ECM #11).

5.2 Best Operating Practices

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

Sl. No.	Equipment/System	Unique operating practices
1	Transformer	APFC installed to maintain power factor
2	Clay ball mill	VFD for energy saving. Timer control system
3	Spray Dryer and HAG	Cyclone separator and Wet scrubber for reducing pollution
3	Press	None
5	Horizontal Dryer	Waste heat from kiln is used in horizontal dryer with supplementary firing of coal gas.
6	Glaze Clay ball mill	Timer control in each Clay ball mill.
7	Kiln	VFD in each blower, waste heat used in air preheating section and horizontal dryer. PID control system for controlling chamber temperature in firing zone.
8	Sizing	Fully automatic system. Dust collection system installed.
9	Printing	Automated digital printing with fully auto control system
10	Lighting	LED lights

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 69 : 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

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

Parameter	UOM	Scenario-1	Scenario-2	Scenario-3
Power consumption	kWh/t	≤7.5	≤8.5	≤11
Remarks		Low dust emission, steady output		When the moisture is higher than 8%, the output drops. The cost increases accordingly.

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

The working principle is as follows:

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

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

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

a) Reduction in thermal energy consumption -70%
b) Reduction in water consumption- 75.4%
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

[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

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 31: Heat recovery system for combustion air

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

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

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

5.3.3 Roller Kiln Performance improvement by Total Kiln Revamping

The roller kiln is major energy consuming system in ceramic tile unit. Over a period of time, the losses from kiln increases for various reasons like operating practices, insulation deterioration, poor

[4] SACMI Kiln Revamping catalogue for roller kilns

maintenance, high breakdown level etc. It is beneficial to upgrade the kiln performance by total kiln revamping including following systems[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 32: 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

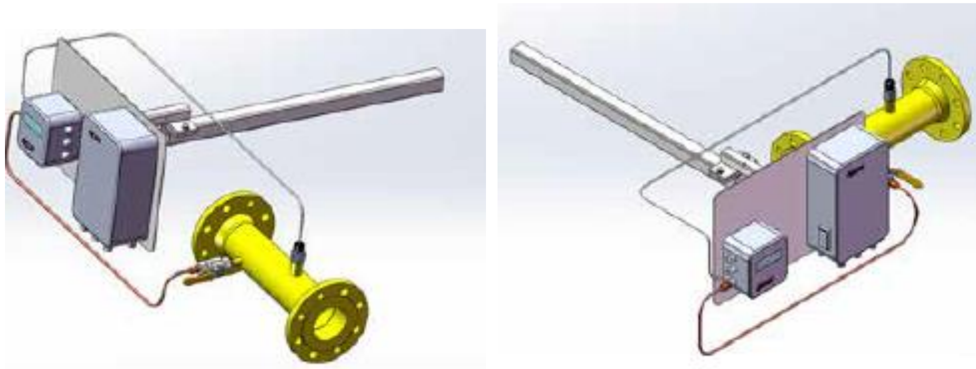


Figure 33: Combustion air control for burner

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 34: 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

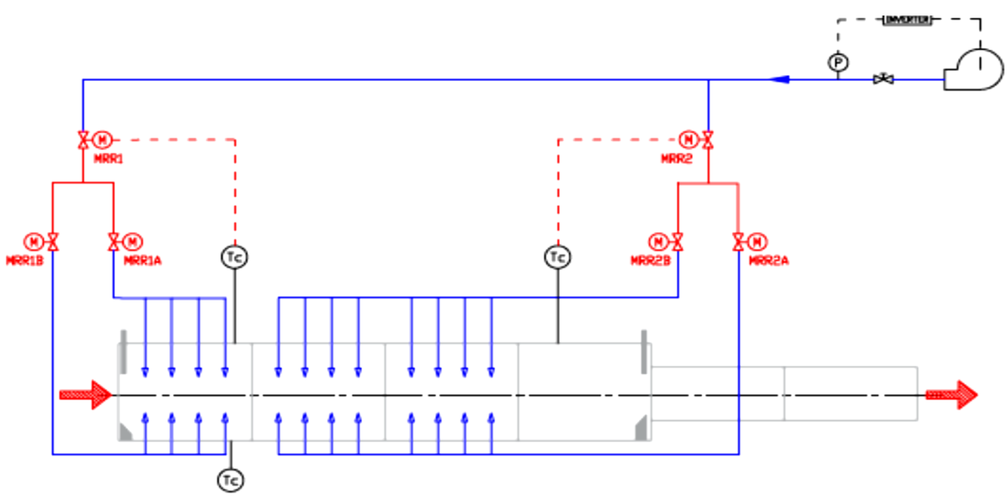


Figure 35: Fast cooling air management

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
    - Compelete consumption and production database available to corporate network and to management software using internet or database SQL protocols.

Figure 36: 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

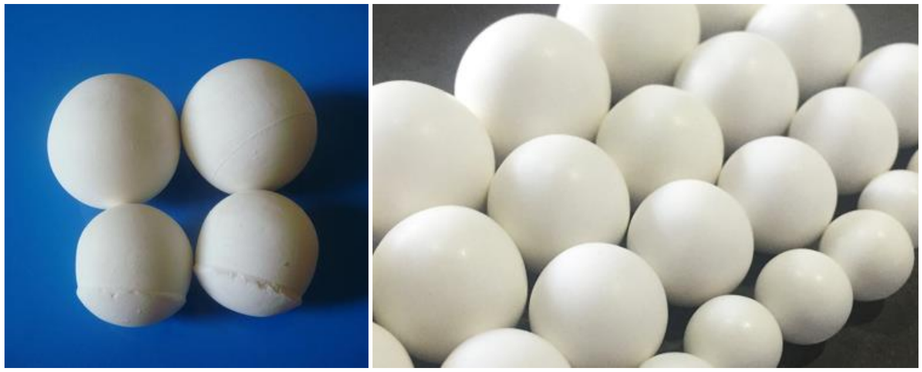


Figure 37: High Alumina pebbles for Ball mill

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

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

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

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

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

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

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

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

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

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

5.3.6 Use of Organic Binder in Porcelain/Granite Tiles Manufacture

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

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

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

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

5.3.7 Use of Direct blower fans instead of belt drive

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

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

Figure 38: Direct drive blower fan

6. Chapter -6 Renewable energy applications

The possibility of adopting renewable energy measures was evaluated during the DEA (details below).

The RCC roof top space available is 375m^2 and corresponding solar power potential will be 38kW. Other roof areas are sloping structures, where structural enhancement is required for solar PV installation. There is no ground space available for solar PV installation.

As per discussion with vendors, due to high dust content in the region, installation of solar PV is not feasible. The extent of degradation on account of dust is upto 40% (for 6g of dust per panel).

Therefore Solar PV installation is not recommended.

6.1.1 Energy conservation measures (ECM) - ECM #14: Installation of solar PV system

Technology description

The RCC roof top space available in plant is 375 m^2 under office admin and administrative building.

Study and investigation

During DEA, it was found that plant is having solar potential which will help to reduce GHG emission.

Recommended action

It is recommended to install solar PV system to meet plant energy requirement. The cost benefit analysis for this project is given below:

Table 70: Installation of solar PV system [ECM-14]

Parameters	Units	Value
Available area on roof	m^2	375
Capacity of solar panel	kW	38
Energy generation from solar panel	kWh/d	180
Solar radiation day per year	d/y	365
Average electricity generation per year	kWh/y	65,700
W. Average Electricity Tariff	Rs/kWh	8.00
Annual monetary savings	Rs Lakh/y	5.3
Estimate of Investment	Rs Lakh	19.5
Simple Payback	Months	45
IRR	%	4
Discounted payback period	Months	15.9

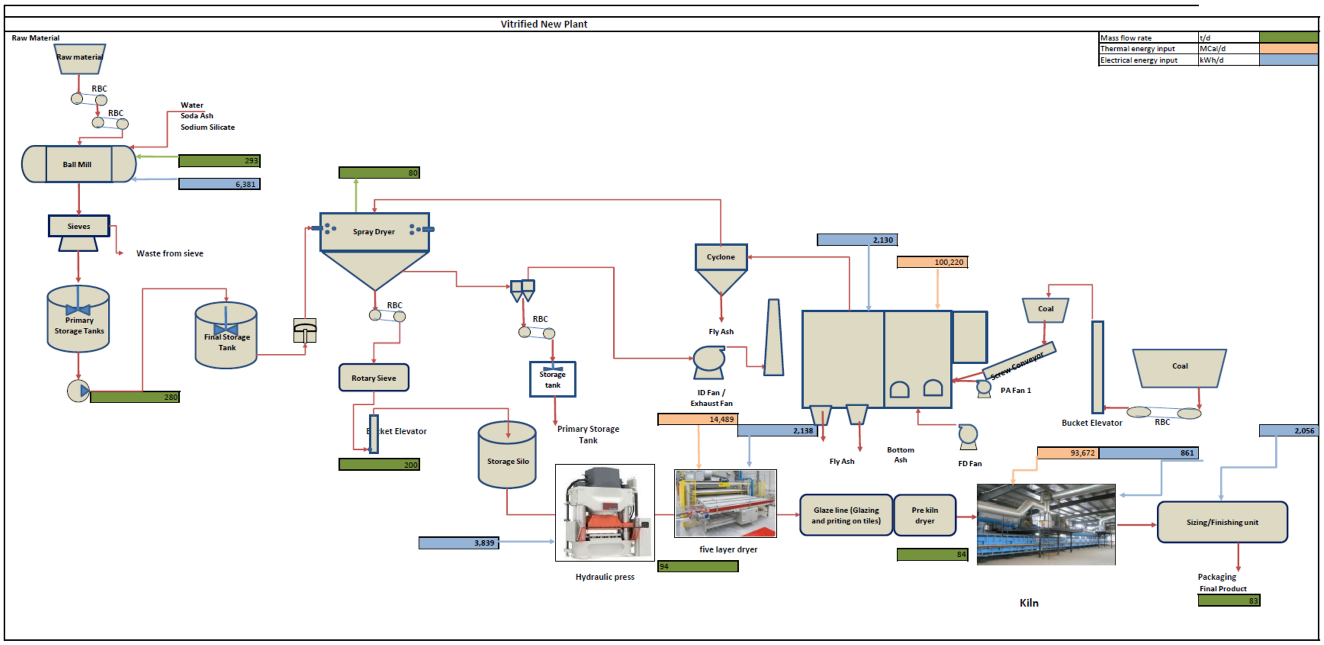
The project IRR is very low and hence the project is not considered feasible. The reasons are as follows:

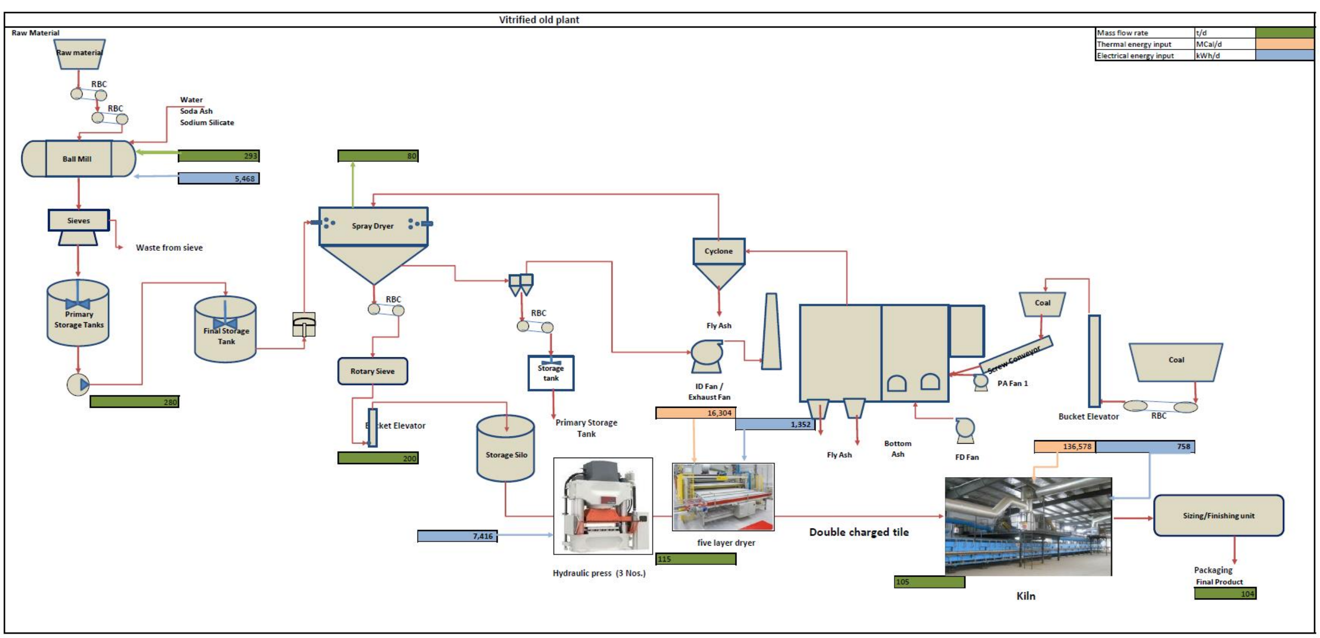
a) Increase in capital expenditure on account of
   a. Requirement for strengthening the structure for accommodating the solar panels
   b. Requirement for construction of walkways for cleaning of solar panels

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





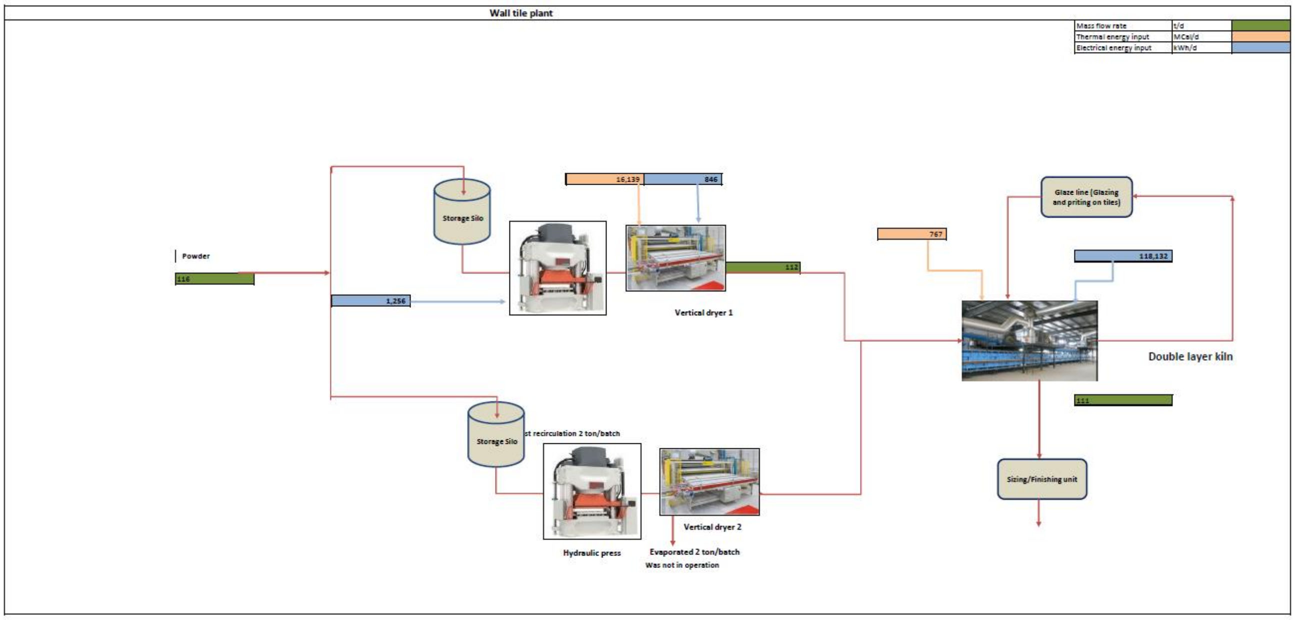


Figure 39: Process Flow Diagram of Plant

7.2 Annex-2: Detailed Inventory

Table 71: Detailed Inventory list

Parameters	Units	Value
Kiln	kW	837
Ball Mill section	kW	1,836
Coal gasifier	kW	398
Hydraulic presses	kW	1,142
Dryer	kW	526
Sizing and finishing	kW	242
HAG + Spray dryer	kW	651
Utilities	kW	209
Lighting	kW	21

7.3 Annex-3: Single Line Diagram

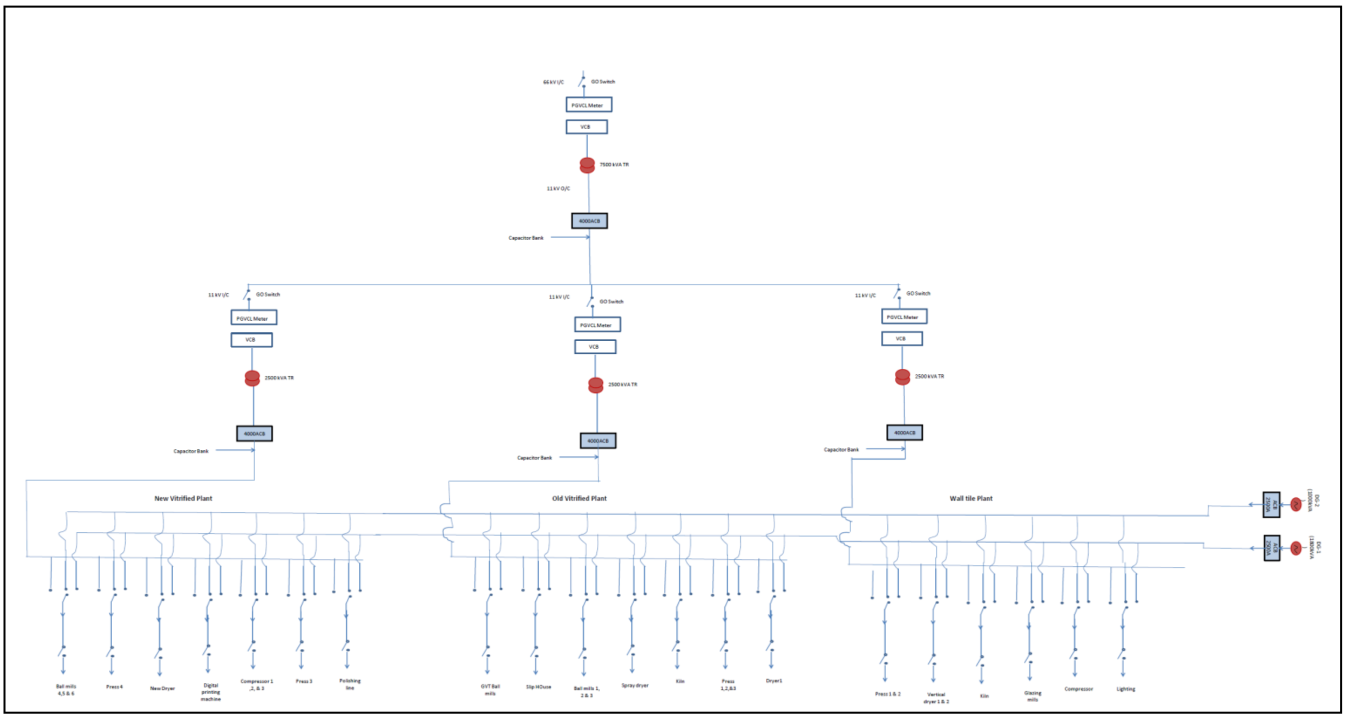


Figure 40: Single Line Diagram (SLD)

7.4 Annex-4: Electrical Measurements

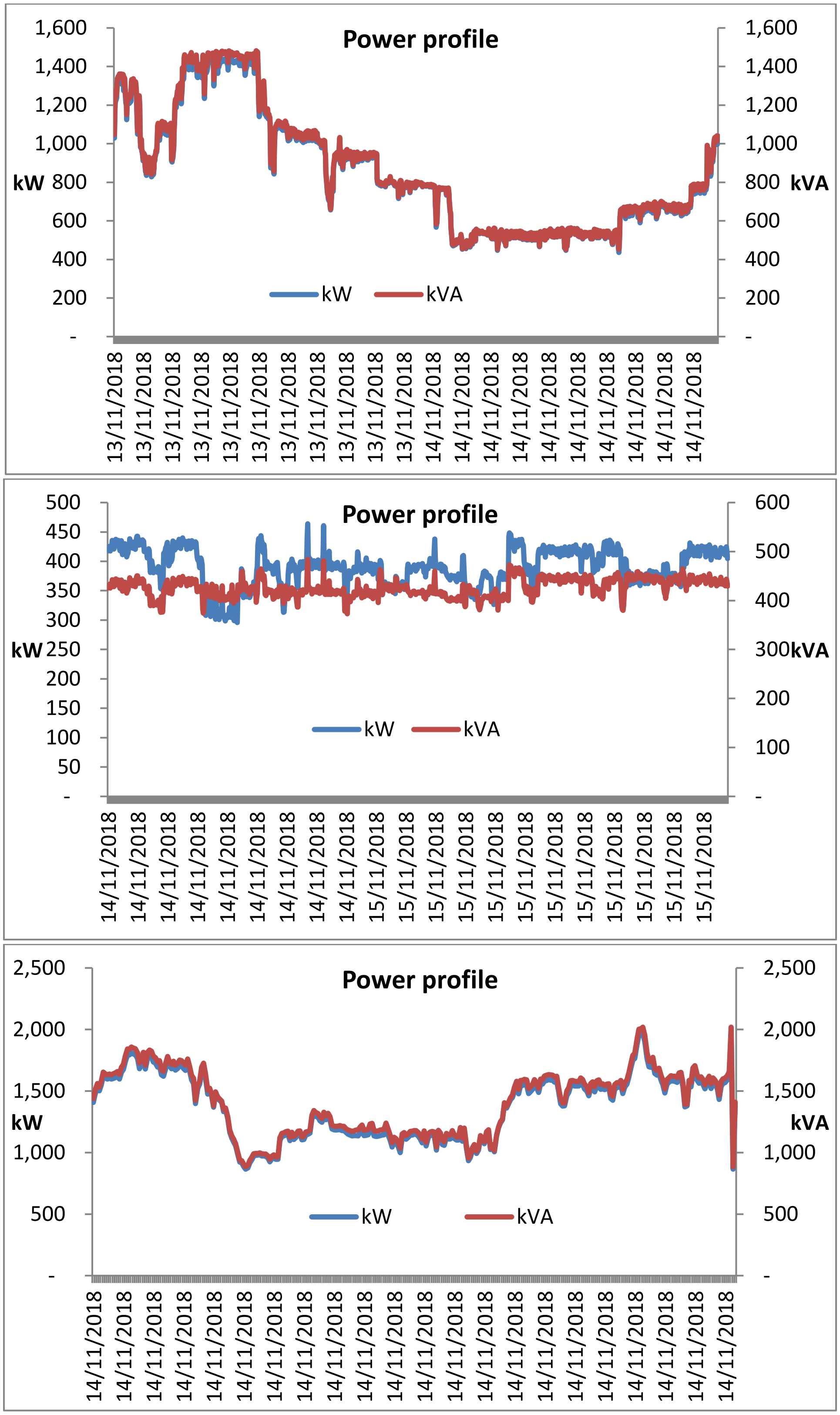
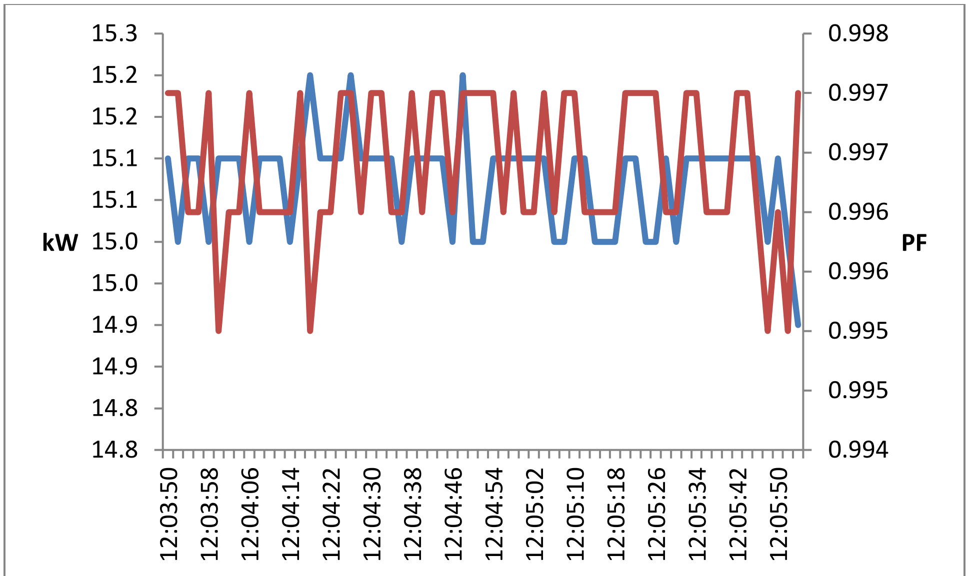


Figure 41: Power profile (kW) of Main Incomer


kW
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15.2
15.2
15.1
15.1
15.0
15.0
14.9
14.9
14.8
14.8
PF
0.998
0.997
0.997
0.996
0.996
0.995
0.995
0.994
12:03:50
12:03:58
12:04:06
12:04:14
12:04:22
12:04:30
12:04:38
12:04:46
12:04:54
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12:05:10
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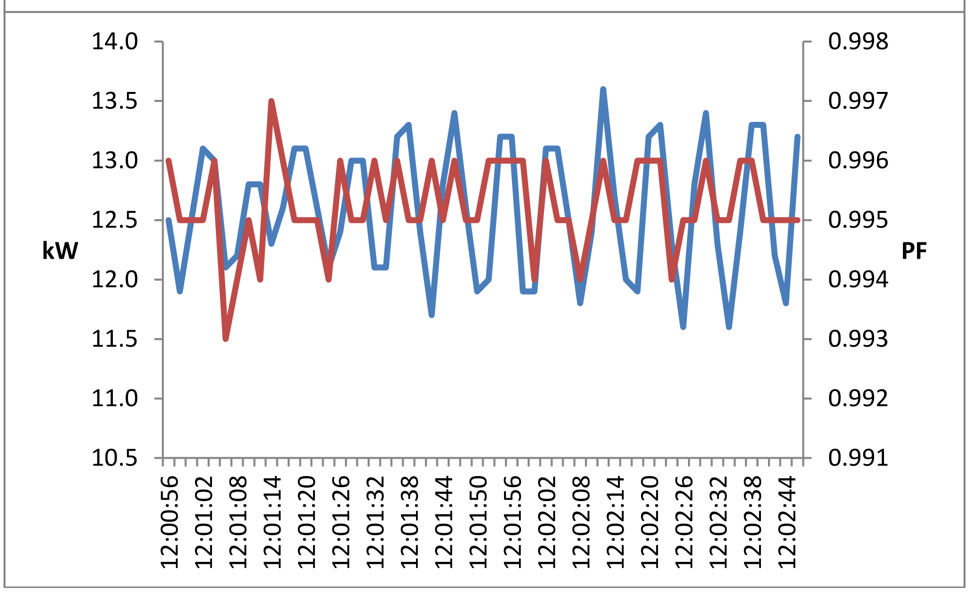
12:05:42
12:05:50


kW
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13.5
13.0
12.5
12.0
11.5
11.0
10.5
PF
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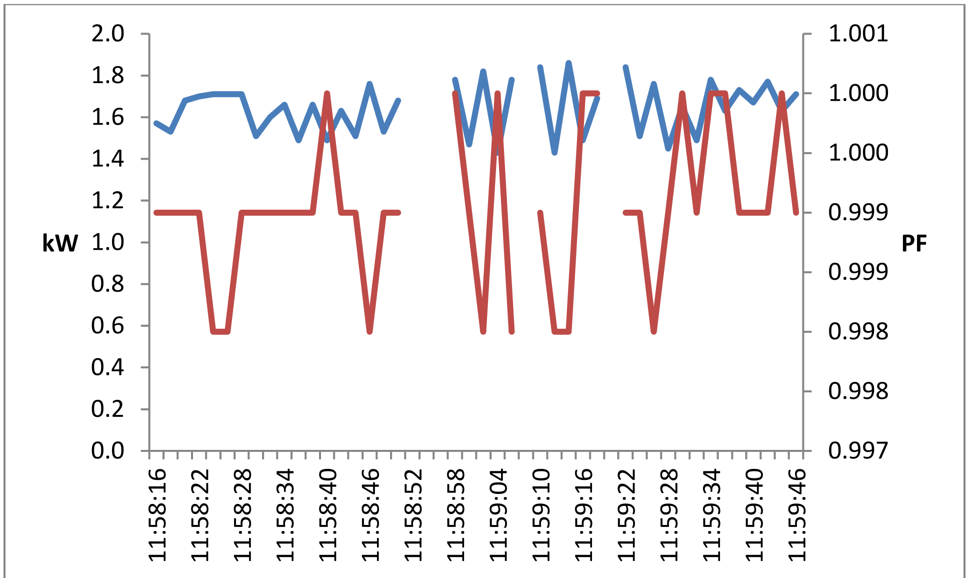
0.997
0.996
0.995
0.994
0.993
0.992
0.991
12:00:56
12:01:02
12:01:08
12:01:14
12:01:20
12:01:26
12:01:32
12:01:38
12:01:44
12:01:50
12:01:56
12:02:02
12:02:08
12:02:14
12:02:20
12:02:26
12:02:32
12:02:38
12:02:44


kW
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PF
1.001
1.000
1.000
0.999
0.999
0.998
0.998
0.997
11:58:16
11:58:22
11:58:28
11:58:34
11:58:40
11:58:46
11:58:52
11:58:58
11:59:04
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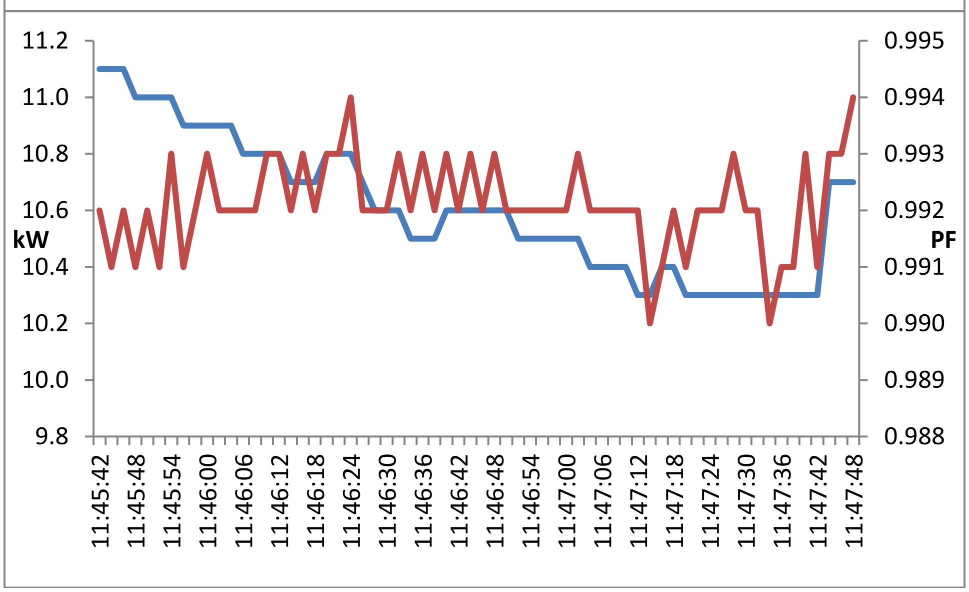
11:59:40
11:59:46


kW
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11.0
10.8
10.6
10.4
10.2
10.0
9.8
PF
0.995
0.994
0.993
0.992
0.991
0.990
0.989
0.988
11:45:42
11:45:48
11:45:54
11:46:00
11:46:06
11:46:12
11:46:18
11:46:24
11:46:30
11:46:36
11:46:42
11:46:48
11:46:54
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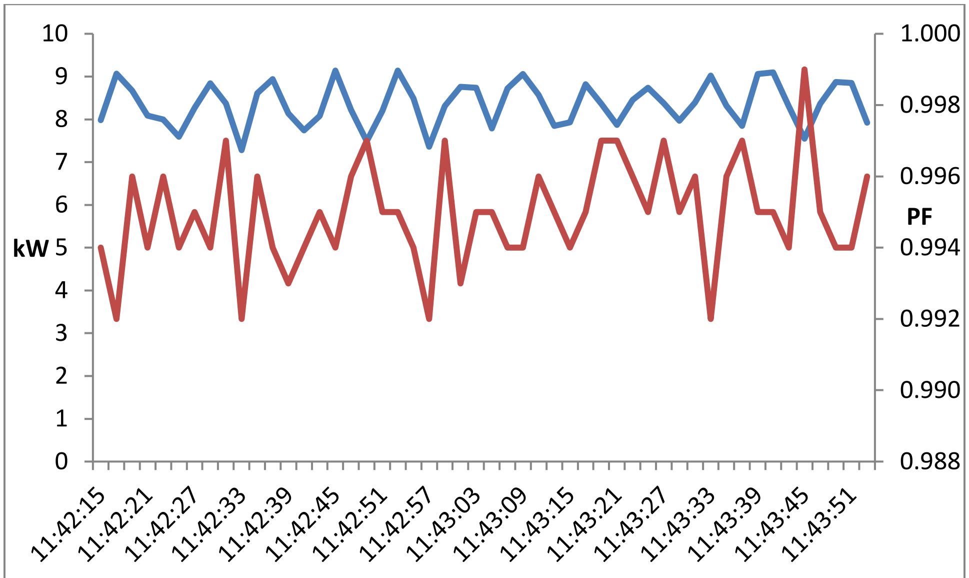
11:47:42
11:47:48



kW
PF
10
9
8
7
6
5
4
3
2
1
0
1.000
0.998
0.996
0.994
0.992
0.990
0.988
11:42:15
11:42:21
11:42:27
11:42:33
11:42:39
11:42:45
11:42:51
11:42:57
11:43:03
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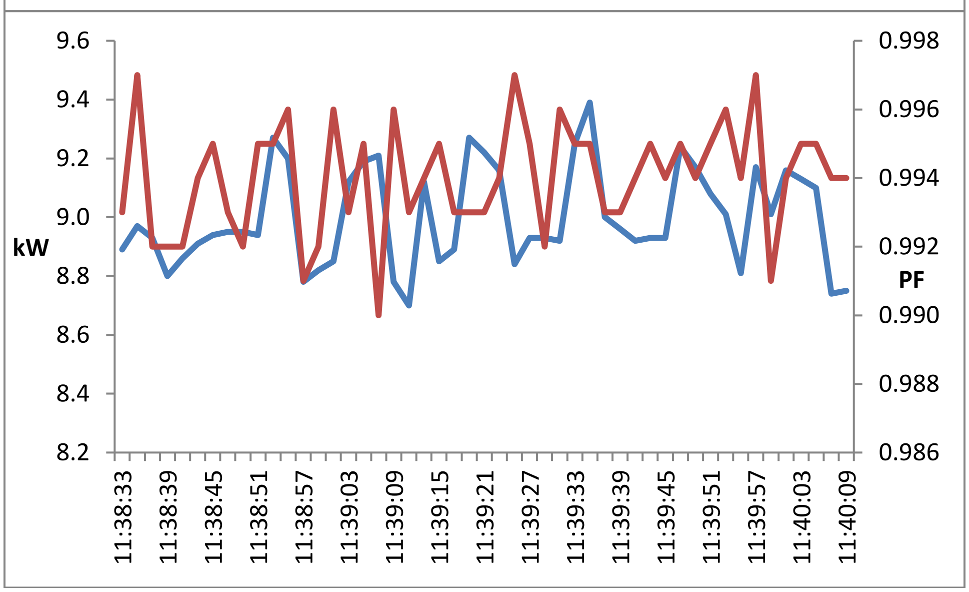
11:43:45
11:43:51



kW
PF
9.6
9.4
9.2
9.0
8.8
8.6
8.4
8.2
0.998
0.996
0.994
0.992
0.990
0.988
0.986
11:38:33
11:38:39
11:38:45
11:38:51
11:38:57
11:39:03
11:39:09
11:39:15
11:39:21
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11:39:57
11:40:03
11:40:09

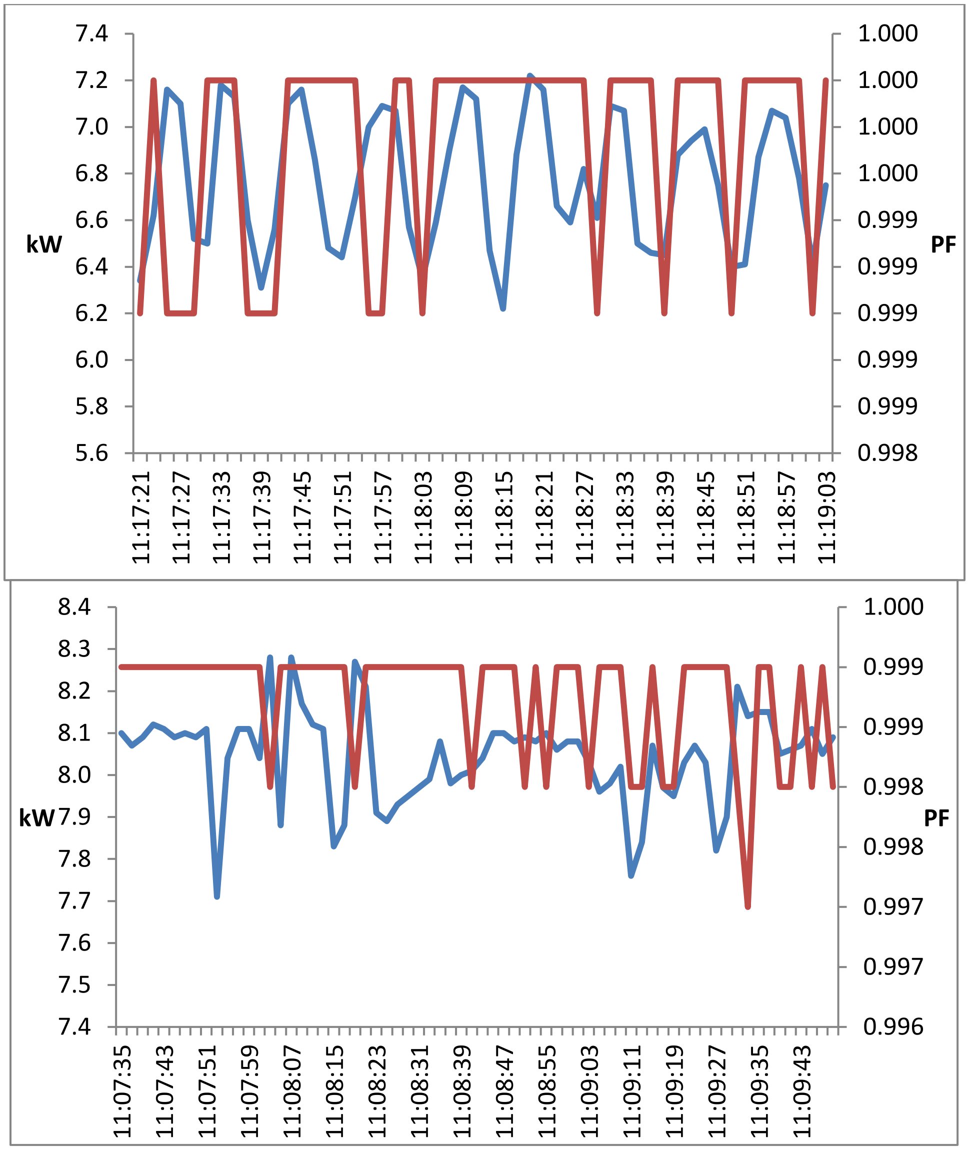
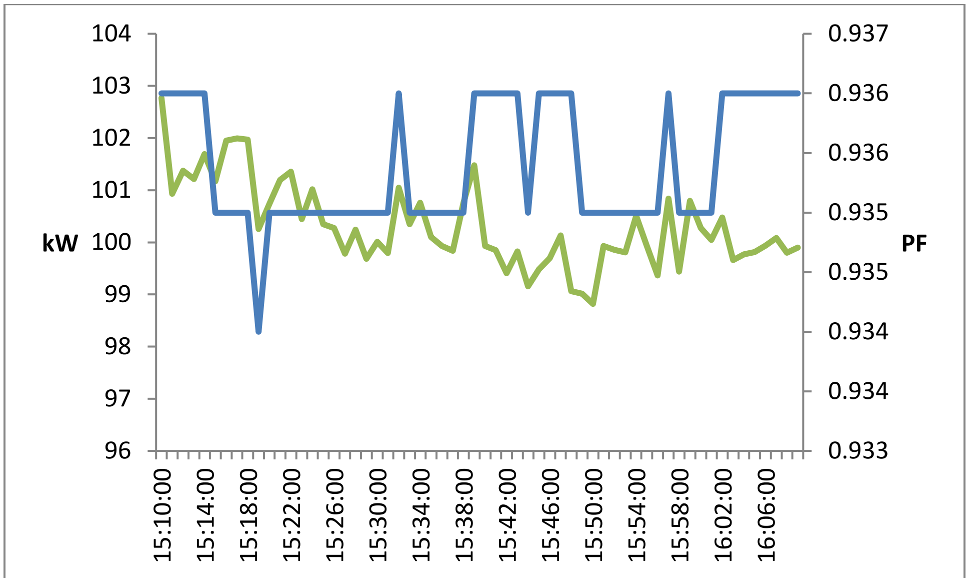


Figure 42: Power and PF profile of blowers of kiln


104
103
102
101
kW 100
99
98
97
96
0.937
0.936
0.936
0.935
PF
0.935
0.934
0.934
0.933
15:10:00
15:14:00
15:18:00
15:22:00
15:26:00
15:30:00
15:34:00
15:38:00
15:42:00
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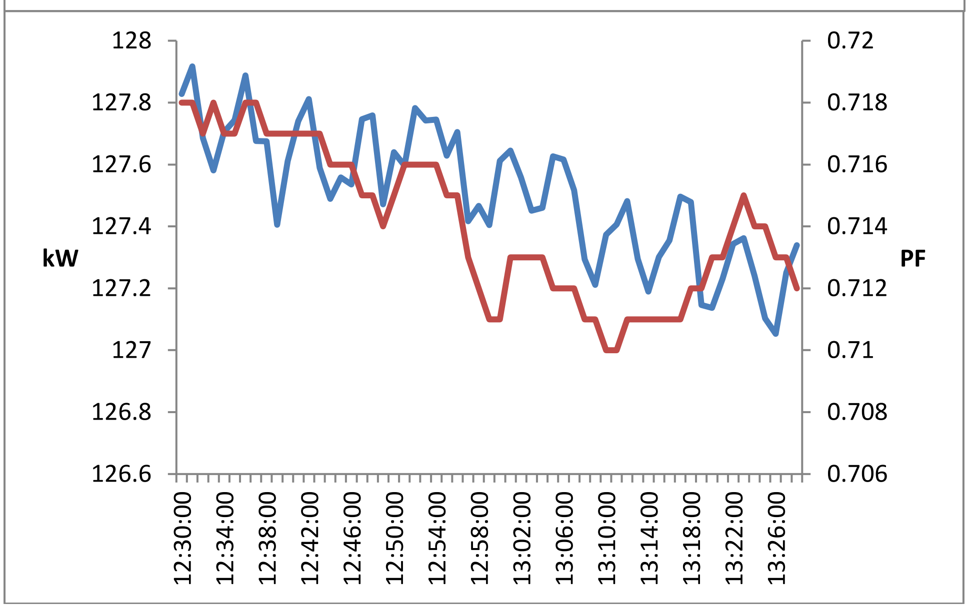
16:02:00
16:06:00


128
127.8
127.6
127.4
kW
127.2
127
126.8
126.6
0.72
0.718
0.716
0.714
PF
0.712
0.71
0.708
0.706
12:30:00
12:34:00
12:38:00
12:42:00
12:46:00
12:50:00
12:54:00
12:58:00
13:02:00
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13:22:00
13:26:00

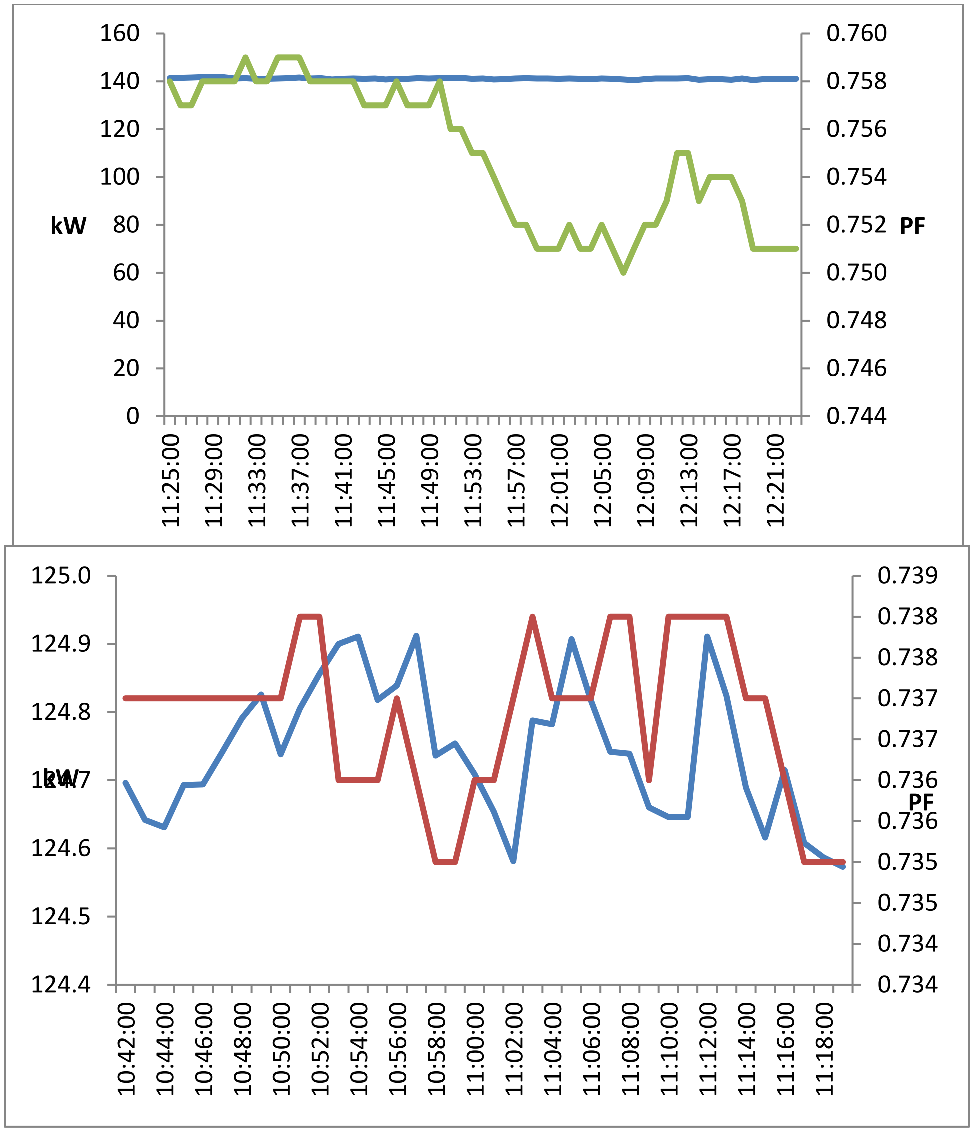

Figure 43: Power and PF profile of blowers of Clay ball mills

7.5 Annex-5: Thermal Measurements, Heat utilization in kiln, HAG Efficiency, Gasifier Performance

1. Heat utilization in wall tile kiln calculations

Input parameters

Input Data Sheet		
Type of Fuel	Coal Gas	
Source of fuel	Coal gasifier	
Particulars	**Value**	**Unit**
Kiln Operating temperature (Heating Zone)	1090	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	2,918	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	215	*°C*
Preheated air temp./Ambient	160	*°C*
O2 in flue gas	8.0	*%*
CO2 in flue gas	7.3	*%*
CO in flue gas	30	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kg dry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
O	*0.00*	%
S	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	1231	*kCal/scm*
Material and flue gas data		
Weight of ceramic material being heated in Kiln	4,620	*Kg/h*
Weight of Stock	4,620	*kg/h*
Specific heat of clay material	0.22	*KCal/kg°C*
Avg. specific heat of fuel	0.51	*KCal/kg°C*
fuel temp	40.2	*°C*
Specific heat of flue gas	0.24	*KCal/kg°C*

Input Data Sheet		
Specific heat of superheated vapor	0.45	*KCal/kg°C*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	15,364	*kCal/h*
Radiation and convection from heating zone surface	11,386	*kCal/h*
Radiation and convection from rapid cooling zone surface	8,642	*kCal/h*
Radiation and convection from indirect cooling zone surface	5,457	*kCal/h*
Radiation and convection from final cooling zone surface	6,336	*kCal/h*
Heat loss from all zones	**47,185**	*kCal/h*
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	1.33	*h*
Area of entry opening	2.1	*m^2*
Coefficient based on profile of kiln opening	0.7	
Average operating temperature of kiln	328	*deg K*

Efficiency calculations

Parameters	Value	Unit
Theoretical Air Required	7.72	*kg/kg of fuel*
Excess Air supplied	61.54	*%*
Actual Mass of Supplied Air	12.48	*kg/kg of fuel*
Mass of dry flue gas	12.36	*kg/kg of fuel*
Amount of Wet flue gas	13.48	*kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*kg of H_2O/kg of fuel*
Amount of dry flue gas	12.36	*kg/kg of fuel*
Specific Fuel consumption	604.29	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	711,607	*kCal/ton of tiles*
Sensible heat of fuel	711,607	*kCal /ton of tile*
Total heat input	711,607	*kCal /ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	230,956	*kCal/ton of tile*
Heat loss in dry flue gas	313,289	*kCal/ton of tile*
Loss due to H2 in fuel	31,310	*kCal/ton of tile*
Loss due to moisture in combustion air	981.31	*kCal/ton of tile*
Loss due to partial conversion of C to CO	341.73	*kCal/ton of tile*
Loss due to convection and radiation	10,253.56	*kCal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	8,705	*kCal/ton of tile*
Unaccounted heat losses	115,770	*kCal/ton of tile*
Heat loss from kiln body and other sections		

Parameters	Value	Unit
Heat utilization in kiln	34.8	*%*

2. Heat utilization in new vitrified tile kiln calculations

Input Data Sheet		
Type of Fuel	NG	
Source of fuel	Gujarat gas	
Particulars	Value	Unit
Kiln Operating temperature (Heating Zone)	1230	*° C*
Initial temperature of kiln tiles	45	*° C*
Avg. fuel Consumption	434	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	250	*° C*
Preheated air temp./Ambient	150	*° C*
O2 in flue gas	8.05	*%*
CO2 in flue gas	7.5	*%*
CO in flue gas	30	*ppm*
Atmospheric Air		
Ambient Temp.	45	*Deg C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*73.80*	%
H	*24.90*	%
N	*1.30*	%
O	*0.00*	%
S	*0.00*	%
Moisture	*0.00*	%
Ash	*0.00*	%
GCV of fuel	9000	*kCal/scm*
Material and flue gas data		
Weight of Kiln roller material	0	*kg/h*
Weight of ceramics material being heated in Kiln	3,448	*kg/h*
Weight of Stock	3,448	*kg/h*
Specific heat of clay material	0.22	*kCal/kg-oC*
Avg. specific heat of fuel		*kCal/kg-oC*
fuel temp	30	*deg C*
Specific heat of flue gas	0.24	*kCal/kg-oC*
Specific heat of superheated vapour	0.45	*kCal/kg-oC*
Heat loss from surfaces of various zone		
Radiation and convection from preheating zone surface	15,006	*kCal/h*

Radiation and convection from heating zone surface	15,183	*kCal/h*
Radiation and convection from rapid cooling zone surface	9,212	*kCal/h*
Radiation and convection from indirect cooling zone surface	6,305	*kCal/h*
Radiation and convection from final cooling zone surface	4,248	*kCal/h*
Heat loss from all zones	49,954	*kCal/h*
For radiation loss in furnace		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.92	*h*
Area of entry opening	2.1	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	328	*deg K*

Calculations	Kiln	Unit
Theoretical Air Required	17.23	*kg/kg of fuel*
Excess Air supplied	62.10	*%*
Actual Mass of Supplied Air	27.92	*kg/kg of fuel*
Mass of dry flue gas	26.68	*kg/kg of fuel*
Amount of Wet flue gas	28.92	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.24	*Kg of H2O/kg of fuel*
Amount of dry flue gas	26.68	*kg/kg of fuel*
Specific Fuel consumption	91.79	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	602,864	*kCal/ton of tiles*
Total heat input	602,864	*kCal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	260,700	*kCal/ton of tile*
Heat loss in dry flue gas	120,493	*kCal/ton of tile*
Loss due to H2 in fuel	1,347	*kCal/ton of tile*
Loss due to moisture in combustion air	2,575.92	*kCal/ton of tile*
Loss due to partial conversion of C to CO	152.05	*kCal/ton of tile*
Loss due to convection and radiation	50,013.90	*kCal/ton of tile*
Unaccounted heat losses	167,583	*kCal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	49,954	*Kcal/ton*
Heat utilization in kiln	43.24	*%*

3. Heat utilization in old vitrified tile kiln calculations

Input Data Sheet		
Type of Fuel	Coal Gas	
Particulars	**Value**	**Unit**

Kiln Operating temperature (Heating Zone)	1230	*°C*
Initial temperature of kiln tiles	40.2	*°C*
Avg. fuel Consumption	4,007	*scm/h*
Flue Gas Details		
Flue gas temp at smog blower	250	*°C*
Preheated air temp./Ambient	110	*°C*
O2 in flue gas	7.1	*%*
CO2 in flue gas	7.9	*%*
CO in flue gas	40	*ppm*
Atmospheric Air		
Ambient Temp.	40.2	*°C*
Relative Humidity	45	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*24.35*	%
H	*12.17*	%
N	*46.09*	%
S	*0.00*	%
O	*15.22*	%
Moisture	*2.17*	%
Ash	*0.00*	%
GCV of fuel	1231	*kCal/scm*
Ash Analysis		
Unburnt in bottom ash	*0.00*	%
Unburnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kCal/kg
GCV of fly ash	*0*	kCal/kg
Material and flue gas data		
Weight of ceramic material being heated in Kiln	4,327	*kg/h*
Weight of Stock	4,327	*kg/h*
Specific heat of clay material	0.22	*kCal/kg-oC*
Avg. specific heat of fuel	0.51	*kCal/kg-oC*
fuel temp	40.2	*deg C*
Specific heat of flue gas	0.24	*kCal/kg-oC*
Specific heat of superheated vapour	0.45	*kCal/kg-oC*
Heat loss from surfaces of various zone		
Pre-Heating Zone	12,732	*kCal/h*
Heating Zone	26,527	*kCal/h*
Rapid cooling Zone	9,212	
Indirect cooling zone	7,470	
Final cooling zone	7,470	
Heat loss from all zones	**63,411**	*kCal/h*

For radiation loss in Kiln		
Time duration for which the tiles enters through preheating zone and exits through cooling zone of kiln	0.82	*h*
Area of entry opening	1.2	*m2*
Coefficient based on profile of kiln opening	0.7	
Average operating temp. of kiln	343	*deg K*

Calculations	**Kiln**	**Unit**
Theoretical Air Required	7.72	*kg/kg of fuel*
Excess Air supplied	51.44	*%*
Actual Mass of Supplied Air	11.70	*kg/kg of fuel*
Mass of dry flue gas	11.58	*kg/kg of fuel*
Amount of Wet flue gas	12.70	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	1.12	*Kg of H2O/kg of fuel*
Amount of dry flue gas	11.58	*kg/kg of fuel*
Specific Fuel consumption	886.15	*kg of fuel/ton of tile*
Heat Input Calculations		
Combustion heat of fuel	1,043,524	*kCal/ton of tiles*
Total heat input	1,043,524	*kCal/ton of tile*
Heat Output Calculation		
Heat carried away by 1 ton of tile	261,756	*kCal/ton of tile*
Heat loss in dry flue gas	516,616	*kCal/ton of tile*
Loss due to H2 in fuel	46,576	*kCal/ton of tile*
Loss due to moisture in combustion air	1,104.18	*kCal/ton of tile*
Loss due to partial conversion of C to CO	618.77	*kCal/ton of tile*
Loss due to convection and radiation (openings in kiln - inlet & outlet of kiln)	14,688.54	*kCal/ton of tile*
Loss Due to Evaporation of Moisture Present in Fuel	13,069	*kCal/ton of tile*
Unaccounted heat losses	189,095	*kCal/ton of tile*
Heat loss from kiln body and other sections		
Total heat loss from kiln	14,656	*Kcal/ton*
Heat utilization in kiln	25.08	*%*

4. Heat Balance Diagram

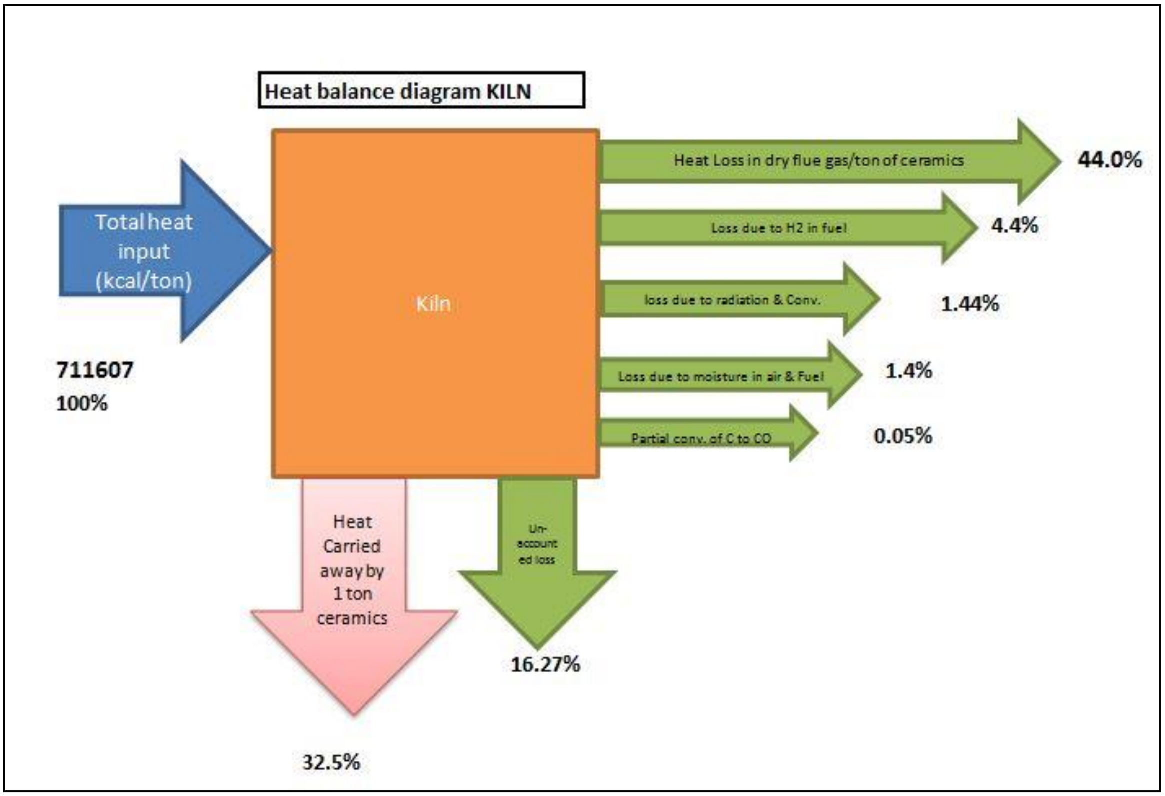

Figure 44: Heat balance of wall tile kiln

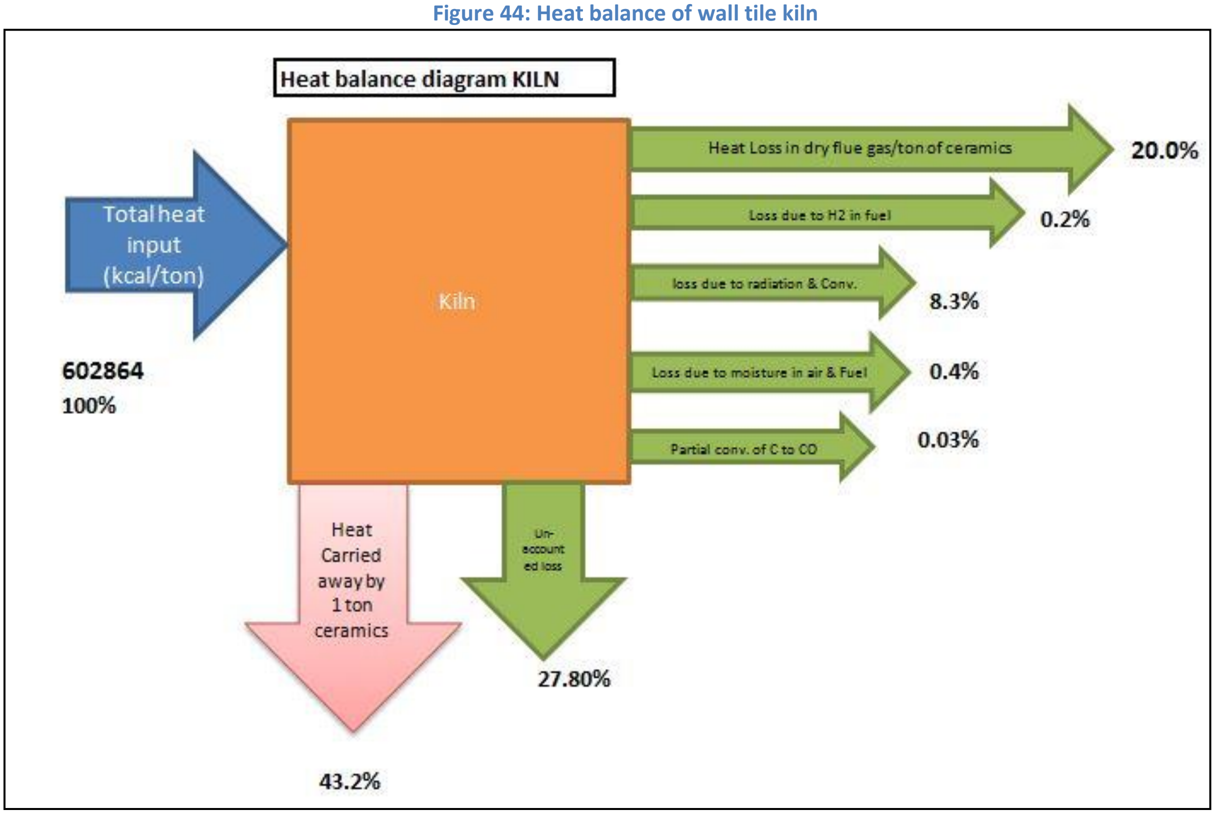

Figure 45: Heat balance of new vitrified tile kiln

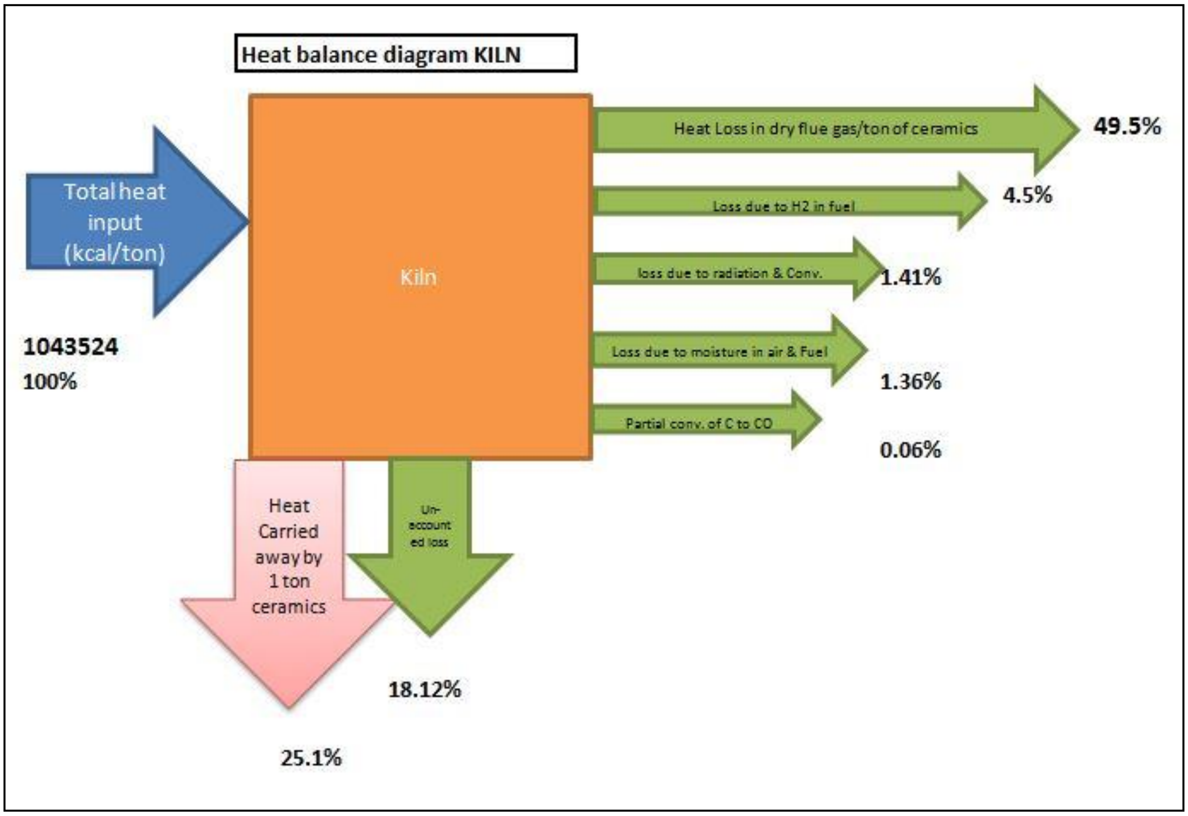

Figure 46: Heat balance of old vitrified tile kiln

7.6 Annex-6: List of Vendors

ECM – 1a, 1b &1c: Excess air control in kiln

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Nevco Engineers	90-A (2nd floor), Amrit Puri B, Main Road, East of Kailash, New Delhi – 110065	Tel : 011 – 26285196/197 Fax: 011 – 26285202	Nevco_delhi@yahoo.co.in
2	High-tech controls for ABB Oxygen Analysers	A 5, Vrindavan Tenament, Gorwa Behind SBI Bank, Near Sahyog Garden, Vadodara - 390016, Gujarat, India	Mr. Bhavik Parikh M: 8071640984	NA
3	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 2a & 2b: Radiation and convection loss reduction from surface of kiln

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Morgan Advanced Materials - Thermal Ceramics	P.O. Box 1570, Dare House Complex, Old No. 234, New No. 2, NSC Bose Rd, Chennai - 600001, INDIA	T 91 44 2530 6888 F 91 44 2534 5985 M 919840334836	munuswamy.kadhirvelu@morganplc.com mmtcl.india@morganplc.com ramaswamy.pondian@morganplc.com
2	M/s LLOYD Insulations (India) Limited,	2,Kalka ji Industrial Area, New Delhi-110019	Phone: +91-11-30882874 / 75 Fax: +91-11-44-30882894 /95 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 3a & 3b: WHR from kiln using HE

Sl. No.	Name of Company	Address	Phone No.	E-mail
1	Knackwell Engineers	C/2, Akshardham Industrial Estate, Near Ramol Over Bridge, Vatva, GIDC, Phase IV , Ahmedabad - 382445, Gujarat, India	9824037124, 9624042423	http://www.knackwellengineers.com/ darshan@kanckwell.com ravi@kanckwell.com
2	Aerotherm Products	No. 2406, Phase 4, G. I. D. C. Estate Vatva, Ahmedabad - 382445,	+91-9879104476, 9898817846	http://www.aerotherm.in
3	Aerotherm Systems Pvt Ltd	Plot No 1517, Phase III, GIDC, Vatwa Ahmedabad-382445	079 -25890158, 25895243	AeroThermSystems.com contact@aerothermsystems.com

ECM 4: Skin heat loss reduction from surface of kiln

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

ECM: 5a & 5b Using soft water in Clay ball mill

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

ECM - 6: Pumps replacement with Efficient pumps

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

ECM – 7 &8 : Installation of Electronic timer control

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

ECM 9a & 9b: VFD installation

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

ECM - 10: Installation of Harmonics filter

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Infinity Enterprise Private Limited	13, Crystal Avenue & Industrial Park, near Odhav Ring road circle, Odhav, Ahmedabad – 382415, Gujarat, India.	Mob: +91 8048412433	info@infinityenterprise.net
2	Amtech Electronics (India) Ltd	E-6 GIDC Electronics Zone, Gandhinagar	Mr. Sachin Patel 079-23289101/102	mktg2@amtechelectronics.com

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
3	Hitachi Hi-Rel Power Electronics Pvt. Ltd	B-117 & 118 GIDC Electronics Zone, Sector 25, Gandhinagar- 382044	Mr. V.Jaikumar 079 2328 7180 - 81	v_jaikumar@hitachi-hirel.com

ECM 11: Energy Monitoring System

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

ECM - 12: Voltage optimization using Servo-stabilizers

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
1	Protek Enterprises	Protek House, Opp Swaminarayan mandir, On I.O.C. road, Chandkela, Ahmedabad-382424, Gujarat, India.	Mob: +91 7965216521	info@protekg.com
2	SERVOKON System ltd. (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	+91 9111234567	customercare@servomax.in www.wervomax.in

Sl. No.	Name of Company	Address	Phone No.	E-mail / Website
		Vihar,Phase-I, New Delhi-110092		

ECM-13: V Belt with REC belt replacement

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

ECM 14: Solar PV system

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

7.7 Annex-7: Financial analysis of project

Table 72: Assumptions for Financial Analysis

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