COMPREHENSIVE ENERGY AUDIT REPORT

"PROMOTING ENERGY EFFICIENCY AND RENEWABLE ENERGY TECHNOLOGY IN SELECTED MSME CLUSTERS IN INDIA"

Synnova Ceramic Ltd.

Abhepar Road, Thangadh-363530, Gujarat, India

Submitted to

ENERGY IS LIFE
B E E
CONSERVE IT

BUREAU OF ENERGY EFFICIENCY

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Submitted by

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DESL places on record its sincere thanks to Global Environment Facility (GEF), United Nations Industrial Development Organization (UNIDO) and Bureau of Energy Efficiency (BEE) for vesting confidence in DESL to carry out the assignment "Conducting energy audit and dissemination programs in MSME clusters" under their national project *"Promoting energy efficiency and renewable energy in selected MSME clusters in India".*

As a part of this assignment, work in Thangadh Ceramic cluster was awarded to DESL and DESL is grateful to GEF-UNIDO-BEE PMU for their full-fledged coordination and support throughout the study

The study team is indebted to Mr. Shantilal Patel and Mr. Dilip Patel, M/s Synnova Ceramics for showing keen interest in the energy audit and also thankful to the management of M/s Synnova Ceramics for their wholehearted support and cooperation for the preparation ofthis comprehensive energy audit report, without which the study would not have steered to its successful completion.Special thanks to other members of the unit for their diligent involvement and cooperation.

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

Last but not the least, the interaction and deliberation with Mr. Kirti Maru, President, Panchal Ceramic Association Vikas Trust , technology providers and all those who were directly or indirectly involved throughout the study were exemplary. The entire exercise was thoroughly a rewarding experience for DESL.

DESL Team

DESL Team

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ABBREVIATIONS

Abbreviations	Expansions
APFC	Automatic Power Factor Correction
BEE	Bureau of Energy Efficiency
CEA	Comprehensive Energy Audit
DESL	Development Environergy Services Limited
DG	Diesel Generator
EE	Energy Efficiency
EPIA	Energy Performance Improvement Action
GEF	Global Environmental Facility
HSD	High Speed Diesel
HVAC	Heating Ventilation and Air Conditioning
PCAVT	Panchal Ceramic Association Vikas Trust
LED	Light Emitting Diode
LT	Low Tension
MD	Maximum Demand
MSME	Micro, Small and Medium Enterprises
MT	Metric Tonnes
MTOE	Million Tonnes of Oil Equivalent
PF	Power Factor
PNG	Piped Natural Gas
PGVCL	Paschim Gujarat Vij Company Limited
R & C	Radiation & Convection
RE	Renewable Energy
SEC	Specific Energy Consumption
SEGR	Specific Energy Generation Ratio
SLD	Single Line Diagram
SME	Small and Medium Enterprises
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drives

EXECUTIVE SUMMARY

Bureau of Energy Efficiency (BEE) in association with United Nations Industrial Development Organization (UNIDO) and Global Environmental Facility (GEF) is implementing a project titled "Promoting energy efficiency and renewable energy technology in selected MSME clusters in India". The objective of the project is to give impetus to the energy efficiency initiatives in the small and medium enterprises (SMEs) sector in India.

As part of this project DESL have been engaged to implement the project in the MSME ceramic cluster in Thangadh, Gujarat. The ceramic cluster in Thangadh consists of three distinct types of units – pottery works, insulator works and sanitary wares. The production process of all these three types of units are mostly same with main difference being the amount of ceramic material ratios being mixed in ball mill and heating time required in kilns for the 3 different products. The main fuel used in the MSME ceramic units of Thangadh is Pressurized Natural Gas (PNG).

The project awarded to DESL consists of four major tasks:

1) Conducting pre-activity cluster level workshop
2) Conducting comprehensive energy audit (CEA) at 6 units selected by the cluster association – Panchal Ceramic Association Vikas Trust(PCAVT)
3) Submission of reports – comprehensive energy audit, cluster level best operating practices for 5 major energy consuming equipment / process, list of common regularly monitored parameters for measurement of major energy consuming parameters, list of energy audit equipment.
4) Conducting three cluster level post audit training workshops

Brief Introduction of the Unit

Table 1 Details of Unit

Name of the Unit	Synnova Ceramic Ltd
Constitution	Private Limited
MSME Classification	Medium
No. of years in operation	NA
Address: Registered Office:	Abhepar Road, Thangadh-363530, Gujarat, India
Factory :	Abhepar Road, Thangadh-363530, Gujarat, India
Industry-sector	Ceramics
Products Manufactured	Sanitary Ware
Name(s) of the Promoters / Directors	Mr. Shantilal Patel, Mr. Dilipbhai Patel

Comprehensive Energy Audit

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:** Detail 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

Production process of the unit

The main process equipment in the unit includes the following:

- The main energy utilizing equipment is kiln in which the fuel used is Pressured Natural Gas. The temperature maintained in kiln is approx. 1160 – 1200 °C (in heating zone).
- There are other equipment viz. air compressor, ball mill, jigger jollies which also contribute to the production process and consumes electrical energy.
- The raw material used is a mixture of chinaclay, boleclay, thanclay, feldspar and quartz which is mixed along with water to form a plastic mass. The water and air is removed from this plastic mass in various process machines and the material shaped as per requirement using dies and fired in kiln for hardening. Later the material is cooled and packed for dispatch.

Identified Energy Performance Improvement Actions (EPIA)

The comprehensive energy audit covered all equipment which was operational during the field study. The main energy consuming areas in the unit are kilns which accounts for more than 80% of the total energy used.

The identified energy performance improvement actions in the kilns were providing proper insulation on the kiln to reduce radiation and convection heat loss from kiln surface and excess air control. It is also proposed to implement energy efficient fans for cooling and drying of molds and energy efficient LED lights in place of conventional tube lights. Other EE measures proposed were power factor improvement. The details of energy improvement actions are given in Table – 2.

Table 2 Summary of EPIA

Sl. No.	Name of the project	Estimated energy saving		Monetary savings	Estimated investment	Simple payback period	Annual Emission reduction
		PNG	Electricity				
		SCM/y	kWh/y	Rs. lakh/y	Rs. lakh	y	tCO2/y
1	Skin loss reduction from the kiln	6053.1		2.3	0.70	0.3	10.8
2	Excess air control in kiln	42769.6	233	16.5	7.00	0.4	76.2
3	Installation of LED fixture instead of 45,35 W CFL system		8456	0.6	0.49	0.8	7.5
4	Installation of energy efficient fan instead of conventional fan		117600	8.6	21	2.4	104.7
5	Solar Air drying		329685	24.1	25.5	1.1	370.5
	Total	48822.7	455975	52.2	59.9	1.2	569.7

The projects proposed will result in energy savings of up to 15.3% in the plant on implementation.

1 INTRODUCTION

1.1 Background and Project objective

Bureau of Energy Efficiency (BEE) in association with United Nations Industrial Development Organization (UNIDO) and Global Environmental Facility (GEF) is implementing a project titled "Promoting energy efficiency and renewable energy technology in selected MSME clusters in India". The objective of the project is to give impetus to the energy efficiency initiatives in the small and medium enterprises (SMEs) sector in India.

The targeted 12 MSME clusters under the project and the indicative information are given below:

Table 3 List of 12 targeted MSME clusters covered under the project

S.No	Sub – sector	Cluster
1	Brass	Jagadhri, Jamnagar
2	Ceramic	Khurja, Morbi, Thangarh
3	Dairy	Gujarat, Madhya Pradesh
4	Foundry	Belgaum, Coimbatore, Indore
5	Hand tools	Jalandhar, Nagaur

The objectives of this project are as under:

- 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 MSMEs;
- Scaling up of the project to national level;
- Strengthening policy, institutional and decision making frameworks.

1.2 Scope of work for Comprehensive Energy Audit

The general scope of work for comprehensive energy audits is as follows:

- Data Collection
  - Present energy usage (month wise) for all forms of energy from June-2014 to May-2015 (quantity and cost).
  - Data on production for corresponding period (quantity and cost).
  - Data on production cost and sales for the corresponding period (cost)
  - Mapping of process
  - Company profile including name of company, constitution, promoters, years in operation, products manufactured.
  - Existing manpower and levels of expertise
  - List of major equipment and specifications
- Analysis :-
  - Energy cost and trend analysis

- Energy quantities and trend analysis
- Specific consumption and Trend analysis
- Scope and potential for improvement in energy efficiency

- Detailed process mapping to identify major areas of energy use.
- To identify all areas for energy saving in the following areas
  - Electrical: Power factor improvement, transformer loading, power quality tests, motor load studies, compressed air systems (including output efficiency tests), conditioned air provisions, cooling water systems, lighting load, electrical metering, monitoring and control system.
  - Thermal: Assessment to ascertain direct and indirect kiln efficiencies with intent to optimize thermal operations, heat recovery systems etc.
- Evaluate the energy consumption vis-à-vis the production levels and to identify the potential for energy savings/energy optimization (both short term requiring minor investments with attractive payback, and mid-long terms requiring moderate investments and with payback ranging from 2 to 2.5 years).
- Classify parameters related to EE enhancements such as estimated quantum of energy saving, investment required, time frame for implementation, payback period, re-skilling of existing man power etc. and to classify the same in order of priority.
- Assess the scope of application of renewable energy.
- Identify and recommend proper "energy monitoring system" for effective monitoring and analysis of energy consumption, energy efficiency.

1.3 Methodology

1.3.1 Boundary parameters

Following boundary parameters were set on coverage of the audit.

- Audit covered all possible energy intensive areas & equipment which were working during the field study
- All appropriate measuring system including portable instruments were used
- The identified measures normally fall under short, medium and long-term measures

1.3.2 General methodology

The following flow chart illustrates the methodology followed for carrying out different tasks.

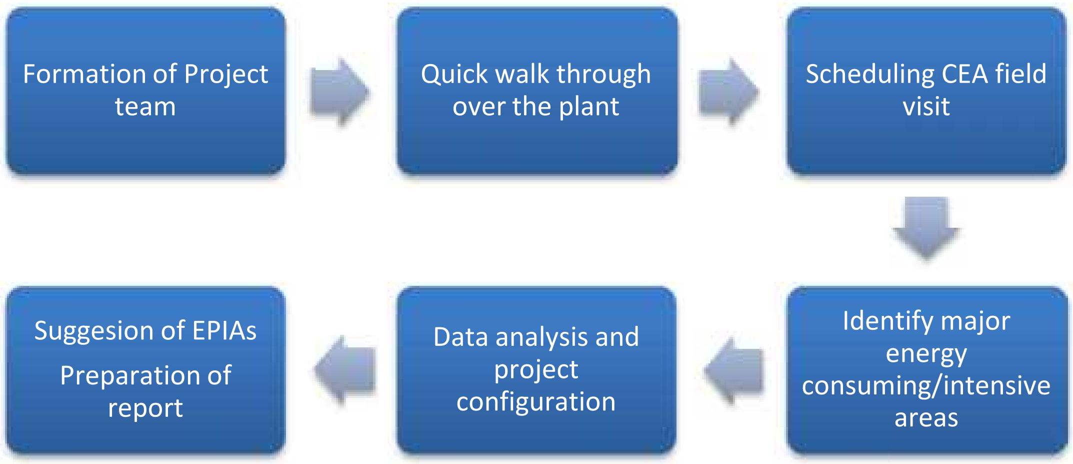


Figure 1 General methodology

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:** Detail 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 energy audit report

1.3.3 Comprehensive energy audit – field assessment

A quick walk through was carried out on 26th June, 2015 before the start of audit with a view to:

- Understand the manufacturing process and collect historical energy consumption data
- Obtaining cost and other operational data with a view to understand the impact of energy cost on the financial performance of the unit
- Assess the energy conservation potential at a macro level
- Finalize the schedule of equipment's and systems for testing and measurement

The audit identified the following potential areas of study;

- PNG fired tunnel kiln
- Electrical motors used in process
- Fans and lighting loads

Further activities carried out by the team after walk through study included:

- Preparation of the process & energy flow diagrams
- Study of the system & associated equipment.
- Conducting field testing & measurement
- Data analysis for preliminary estimation of saving potential at site

- Discussion with the unit on the summary of findings and measures identified

Audit methodology involved system study to identify the energy losses (thermal/ electrical) followed by finding solutions to minimize the same. This entailed data collection, measurements/ testing of the system using calibrated, portable instruments, analyzing the data/ test results and identifying the approach to improve the efficiency. The following instruments were used during the energy audit.

Table 4 Energy audit instruments

Sl. No.	Instruments	Make	Model	Parameters Measured
01	Power Analyzer – 3 Phase (for un balanced Load) with 3 CT and 3 PT	Enercon and Circutor	AR-5	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 1 sec interval
02	Power Analyzer – 3 Phase (for balance load) with 1 CT and 2 PT	Elcontrol Energy	Nanovip plus mem	AC Current, Voltage, Power Factor, Power, Energy, Frequency, Harmonics and data recording for minimum 2 sec interval
03	Digital Multi meter	Motwane	DM 352	AC Amp, AC-DC Voltage, Resistance, Capacitance
04	Digital Clamp on Power Meter – 3 Phase and 1 Phase	Kusam - Meco	2745 and 2709	AC Amp, AC-DC Volt, Hz, Power Factor, Power
05	Flue Gas Analyzer	Kane-May	KM-900	O2%, CO2%, CO in ppm and Flue gas temperature, Ambient temperature
06	Digital Temperature and Humidity Logger	Dickson		Temperature and Humidity data logging
07	Digital Temp. & Humidity meter	Testo	610	Temp. & Humidity
08	Digital Anemometer	Lutron and Prova	AM 4201 And AVM-03	Air velocity
09	Vane Type Anemometer	Testo	410	Air velocity
10	Digital Infrared Temperature Gun	Raytek	Minitemp	Distant Surface Temperature
11	Contact Type Temperature Meter	Testo	925	Liquid and Surface temperature
12	High touch probe Temperature Meter	CIG		Temperature upto 1300°C
13	Lux Meter	Kusum Meco (KM-LUX-99)		Lumens

		and Mastech		
14	Manometer	Comark	C 9553	Differential air pressure in duct
15	Pressure Gauge	Wika		Water pressure 0 to 40 kg

1.3.4 Comprehensive energy audit – desk work

Post audit off-site work carried out included

- Revalidation of all the calculations for arriving at the savings potential
- Quick costing based on DESL database or through vendor interactions as required
- Configuration of individual energy performance improvement actions
- Preparation of audit report

2 ABOUT THE MSME UNIT

2.1 Particulars of the unit

Table 5 General particulars of the unit

S. No	Particulars	Details
1	Name of the unit	Synnova Ceramic Ltd.
2	Constitution	Private
3	Date of incorporation / commencement of business	NA
4	Name of the contact person Mobile/Ph.No. E-mail ID	Mr. Shantilal Patel (Director) +91-98252-22620 NA
5	Address of the unit	Abhepar road, Thangadh-363530, Gujarat, India
6	Industry / sector	Ceramic
7	Products manufactured	Sanitary Wares
8	No. of operational hours	24
9	No. of shifts / day	3
10	No. of days of operation / year	300
11	Whether the unit is exporting its products (yes / no)	Yes
12	No. of employees	NA

3 DETAILED TECHNICAL FEASIBILITY ASSESSMENT OF THE UNIT

3.1 Description of manufacturing process

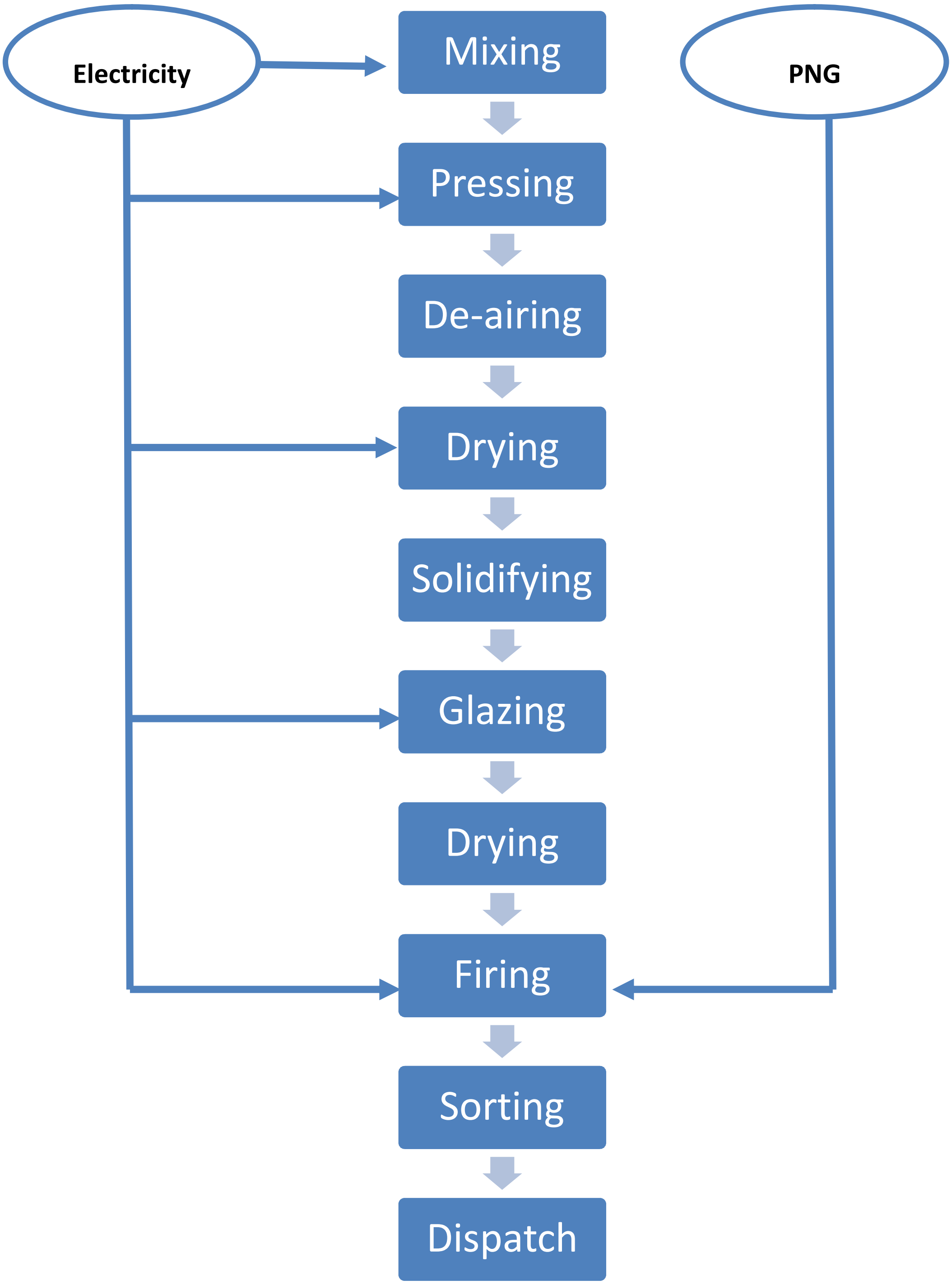


Figure 2 Process Flow Diagram

3.1.1 Process description

Synnova Ceramic Ltd. is a sanitary ware ceramic manufacturer

The process description is as follows:

- The raw materials clay, feldspar and quartz are mixed together with water in the ball mill for a period of 3 to 5 hours.
- It is then transferred in to the agitator tank for thorough mixing. With the help of centrifugal mud pump, the mixture is transferred to the sieve filter to remove water.
- The slurry is allowed to dry after pouring it in to mold dyes made of plaster of Paris. Pressing of slurry is done using pressurized air to ensure tight bonding in the mold and leaving no chance of cavities.
- The molds are allowed to dry under ceiling fans for about 1-2 days depending on atmospheric humidity.
- Then the materials are glazed, painted and stacked on the kiln cars for firing to obtain strength. The firing zone temperature in the kiln is maintained at 1140 – 1185^{o}C.
- After firing, the products are quality checked, packed and dispatched.

3.2 Inventory of process machines/ equipment and utilities

The major energy consuming equipment's in the plants are

- **Ball mill:** Here the raw materials like clay, feldspar and quartz are mixed in the ratio of 2:1:1 respectively along with water to form a plastic mass.
- **Air Compressor:** Pressurized air is used at several locations in a unit viz. pressing of slurry, air cleaning, glazing etc.
- **Agitator:** The plastic mass after mixing in ball mill is poured in to a sump where an agitator is fitted for thorough mixing of materials and preventing it to settle at the bottom.
- **Jigger jollies:** The required shapes of the final product are made by the jigger jollies along with molds and then dried for the complete removal of moisture.
- **Tunnel Kiln:** The shaped materials are glazed, painted and then stacked on the kiln car which is then sent for firing in the tunnel kiln with the help of pusher motor kept at a specified rpm. The tunnel is about 53 m long and the temperature gradually increases up to firing zone and then decreases (in the cooling zone) with the highest temperature being 1183^{o}C. Once the kiln car comes out of the cooling zone the materials are further cooled, quality tested and packed for dispatch.

3.3 Types of energy used and description of usage pattern

Both electricity and thermal energy is used in different manufacturing processes. The overall energy use 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 DG sets for whole plant

- Thermal energy is used for following applications :
    - PNG for tunnel kiln

Total energy consumption pattern for the period June-14 to May-15, from different sources are as follows:

Table 6 Energy cost distribution

Particular	Energy cost distribution		Energy use distribution	
	Rs. In Lakhs	% of total	MTOE	% of total
Grid – Electricity	46.2	13.54	53.75	7.56
Diesel – DG	NA	0	0	0
Thermal – PNG	294.9	86.46	657.07	92.44
Total	341.1	100	710.82	100

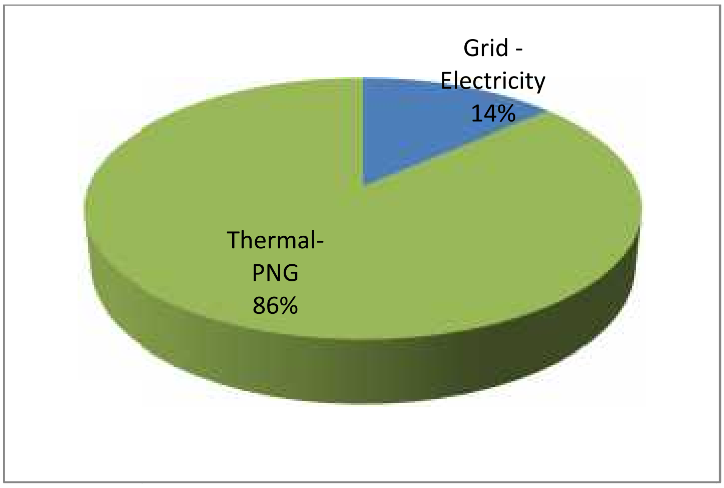


Figure 3 Energy cost share (Rs. Lakh)

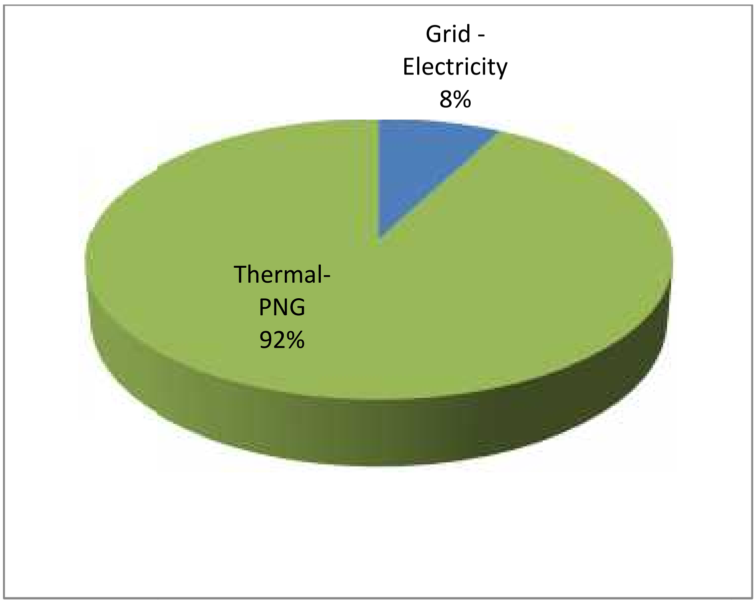


Figure 4 Energy use share (MTOE)

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 in DG sets when the grid power is not available. Source of thermal energy is from combustion of PNG, which is used for firing in the kiln.
- PNG used in kilns account for 86% of the total energy cost and 92% of overall energy consumption.
- Electricity used in the process accounts for the remaining 8% of the energy cost.

3.4 Analysis of electricity consumption by the unit

3.4.1 Electricity load profile

Following observation has been made from the utility inventory.

- The plant and machinery load is 198 kW
- The utility load (fan, air compressor & lighting) is about 140 kW including the single phase load
- The plant total connected load is approximately 340kW

Table 7 Equipment wise connected load

Sr. No	Description	Qty	Rated Capacity (hp)	Total
1	Ball Mill	1	125	125
2	Glazing Ball Mill	5	12	60
3	Air Compressor	3	30+30+40	100
4	Ceiling Fan	700	55	57.75
5	Air Blower	4	7.5+7.5+5+5	25
6	Disperser Motor	2	2	4
7	Slurry Pump	2	4	8
8	Dust collector	10	2.5	25
9	Vibrator	1	21	21
10	Molding	1	3	3
11	Mixer	1	3	3
12	Hopper	1	11	11
13	Conveyor belt	1	4	4
14	Lighting	54	40	3.24

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

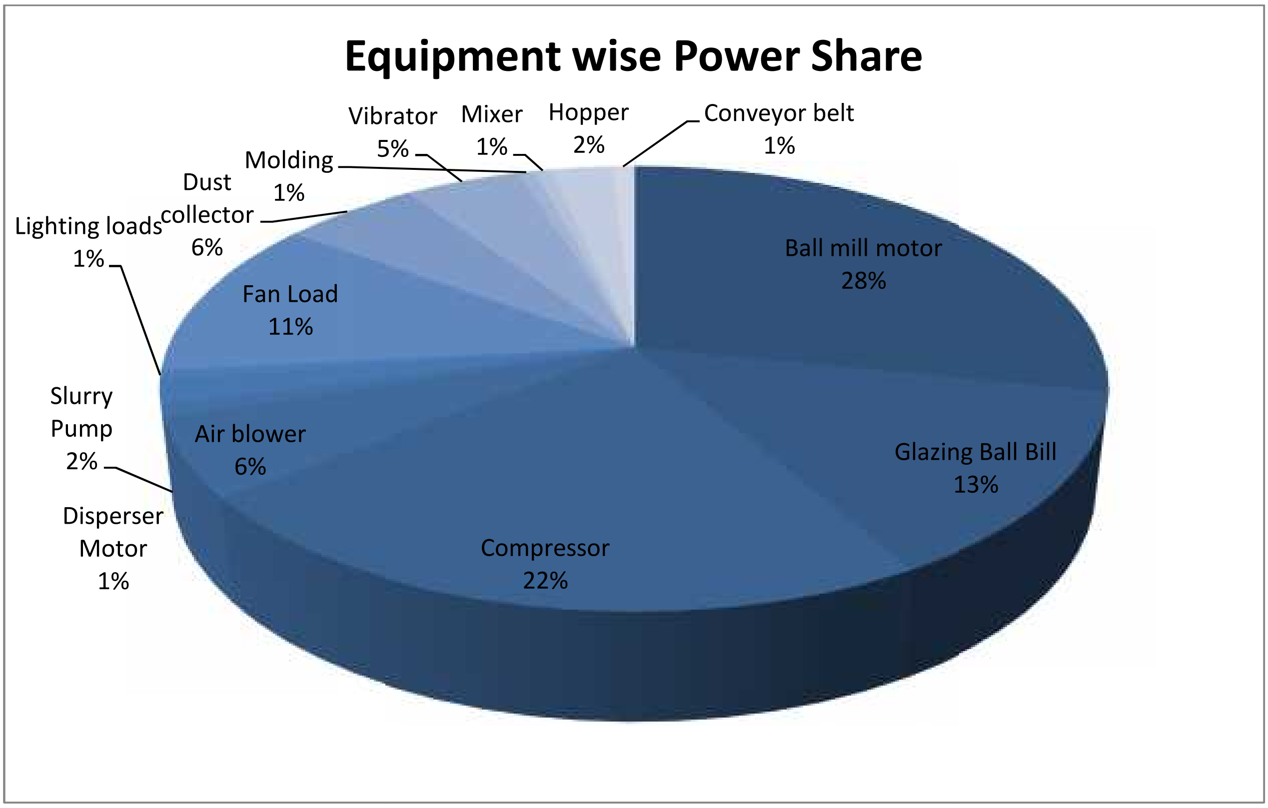


Figure 5 Details of connected load

As shown in the pie chart of connected loads, the maximum share of connected electrical load is for the ball mill – 41%, followed by air compressor – 22%, Ceiling fan – 11%, Kiln air blowers and dust collectors each –6 %, Other machinery including vibrator – 5 %, slurry mud pump – 2% and lighting load, mixer, molding and conveyor belt, disperser motor – 1% each and hopper of 2%.

3.4.2 Supply from utility

Electricity is supplied by the Paschim Gujarat Vij Company Ltd. (PGVCL).
The tariff structure is as follows:

Table 8 Tariff structure

Particulars	Tariff structure	
Energy Charges	4.7	Rs./kWh
Reactive power charges	0.1	Rs./kVARh
Fuel Surcharge	1.60	Rs./kVAh
Electricity duty	0.1	Rs./kWh
Meter charges	750	Rs.

(As per bill for May – 15)

The single line diagram of electrical distribution system is shown in the figure below:

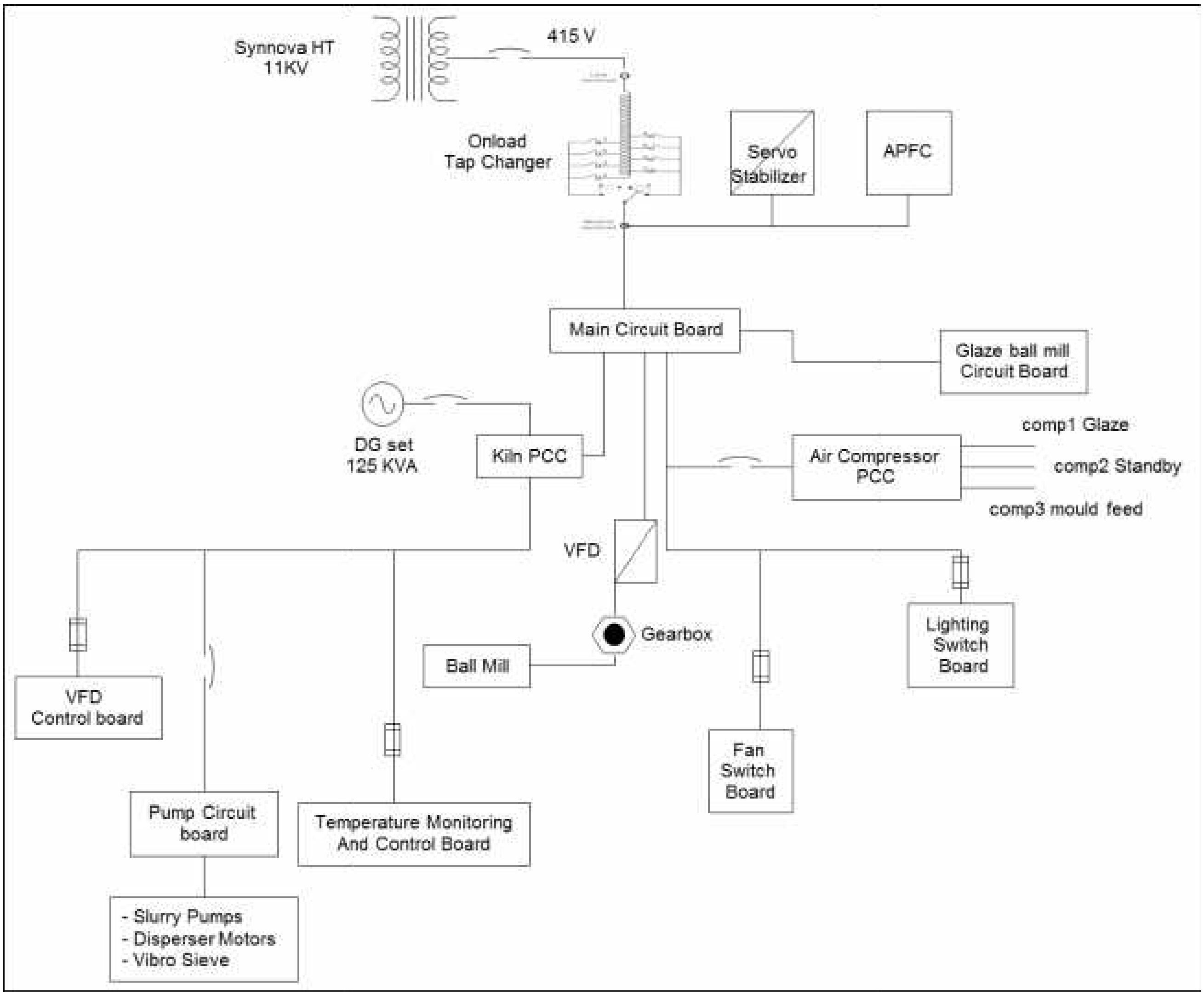


Figure 6 SLD of electrical load

Power factor

The utility bills of the unit reflect the power factor. A study was conducted by logging the electrical parameters of the main incomer using a power analyzer. The average power factor was found to be 1 with the minimum being 0.905 and the maximum being 1.

Maximum demand

Maximum demand as reflected in the utility bill is 236 kVA from the bill analysis.

3.4.3 Month wise electricity consumption

Month wise total electrical energy consumption from different source is shown as under[1]:

Table 9 Electricity consumption & cost

	Electricity Used (kWh)	Electricity Cost (Rs.)
	kWh	**Rs.**
Jun-14	24027.7	168547.5
Jul-14	24027.7	168547.5
Aug-14	24027.7	168547.5
Sep-14	24027.7	168547.5
Oct-14	24027.7	168547.5
Nov-14	24027.7	168547.5
Dec-14	24027.7	168547.5
Jan-15	24175.0	168674.6
Feb-15	27120	191665.8
Mar-15	21609	157302.5
Apr-15	23160	155396.0
May-15	29210	195989.5
Total	**625014.2**	**4615227.4**

3.5 Analysis of thermal consumption by the unit

PNG is used as the fuel for firing in the kiln. PNG is available throughout Thangadh cluster with GSPC (Gujarat State Petroleum Company) as a common supplier[2].

Table 10 PNG used as fuel

Month	Fuel Consumption (SCM/Month)	Rs./Month
Jun-14	69615	2701062
Jul-14	69615	2701062
Aug-14	69615	2701062
Sep-14	69615	2701062
Oct-14	69615	2701062
Nov-14	69615	2701062
Dec-14	69615	2701062
Jan-15	69615	2701062
Feb-15	69615	2701062

[1] Electricity bill for the month of April-2015 and May-2015 were shared by unit owner. Electricity consumption for entire month has been extrapolated on that basis.

[2] Based on the gas bill shared for the month of May-15 an annual fuel consumption has been extrapolated

Mar-15	47117.8	2074736
Apr-15	45404.5	1806669
May-15	44982.6	1731592
Total	**764039.9**	**29922555**

3.6 Specific energy consumption

Annual production data was available from the unit in metric tonnes (MT). Based on the available information, various specific energy consumption parameters have been estimated as shown in the following table:

Table 11 Overall specific energy consumption

Parameters	Value	UoM
Annual Grid Electricity Consumption	625014	kWh
Annual DG Generation Unit	NA	kWh
Annual Total Electricity Consumption	625014	kWh
Annual Thermal Energy Consumption (PNG)	764039.9	SCM
Annual Energy Consumption; MTOE	691.72	MTOE
Annual Energy Cost	345.4	Lakh Rs
Annual Production	6900	MT
SEC; Electricity from Grid	90.58	kWh/MT
SEC; Thermal	110.73	SCM/MT
SEC; Overall	0.10	MTOE/MT
SEC; Cost Based	5005.8	Rs./MT

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 Diesel : 11,840 kCal/ kg
- Density of HSD : 0.8263 kg/litre
- GCV of PNG : 8600 kCal/scm
- CO_2 Conversion factor
  - Grid : 0.89 kg/kWh
  - Diesel : 3.07 tons/ ton

3.7 Baseline parameters

The following are the general base line 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 12 Baseline parameters

Electricity cost (Excluding Rs/kVA)	NA	Rs./ KVAH inclusive of taxes
Weighted Average Electricity Cost	7.3	Rs./ kWh for 2013-14

Percentage of total DG based Generation	NA	
Average Cost of PNG	38.6	Rs./SCM
Operating Days per year	300	Days / year
Operating Hours per day	24	Hours / day
Production	6900	MT

3.8 Identified energy conservation measures in the plant

Diagnostic Study

A detailed study was conducted during CEA in the unit and some observations were made and few ideas of EPIAs were developed. Summary of key observations are as follows:

3.7.1 Electricity Supply from Grid

The electrical parameters at the main electrical incomer feeder from PGVCL of the unit are recorded for 8 hours using portable power analyzer. Following observation has been made:

Table 13 Diagnosis of electric supply

Name of Area	Present Set-up	Observations during field Study & measurements	Ideas for energy performance improvement actions
Electricity Demand	Power is supplied to this unit from PGVCL through a personal distribution feeder. The contract demand of the unit is 225 kVA	The maximum kVA recorded during study period was74 kVA. As per utility bill; the MD is236 KVA which is more than the contract demand.	No EPIAs were suggested.
Power Factor	Unit has an HT connection and billing is in kVAh. The utility bills reflect the PF of the unit.	The average PF found during the measurement was 1.It varies between 0.98 and 1.	No EPIAs suggested
Voltage variation	The unit has a Servo stabilizer for voltage regulation.	The voltage profile of the unit is satisfactory and average voltage measured was 413 V. Maximum voltage was 418 V and minimum was 403 V.	No EPIAs suggested

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

3.7.3 Electrical consumption areas

The section-wise consumption of electrical energy is shown in Table 6. Over 88% of the energy consumption is in the manufacturing operations and about 12% is in utilities.

The details of measurements conducted, observation made and ideas generated for energy conservation measures are as follows:

<table>
<tr><th>Name of Area</th><th>Present Set-up</th><th>Observations during field Study & measurements</th><th>Proposed Energy performance improvement actions</th></tr>
<tr><td>Ball mill</td><td>There are 6ball mills in the unit out of which 1 is connected with125 HP motor and 5 with a 12 HP motor respectively. Ball mills account for 43% of overall electrical power consumption.</td><td>Out of the 5ball mills 2 of 1.5 T was on operation during CEA and its characteristics were studied.

The results of the study are below:<table><tr><th>Machine</th><th>Avg. kW</th><th>Avg. PF</th></tr><tr><td>Mill 1 (125 HP)</td><td>57.56</td><td>0.76</td></tr></table></td><td>No EPIAs were suggested for ball mill.</td></tr>
<tr><td>Air Compressor</td><td>The unit has 3 (1 running+ 1 Auxiliary + 1 Standby) air compressors. Rated load is 30+30+40 h[and operating set point pressure is 7.85</td><td>Many air leaks were found inside the unit. Loading power of compressor is as below:<table><tr><th>Machine</th><th>Avg. kW</th><th>Avg. PF</th></tr><tr><td>Air compressor 40 HP</td><td>27.9</td><td>0.86</td></tr></table></td><td>No EPIAs suggested</td></tr>
<tr><td>Kiln blower</td><td>The unit has kiln blowers which are used for supplying combustion and cooling air in the tunnel kiln. The blowers account for 5% of the total electricity consumption.</td><td>Data logging was carried out on the cooling zone blower to establish the power profile.

The results of the study are below:<table><tr><th>Machine</th><th>Avg. kW</th><th>Avg. PF</th></tr><tr><td>Cooling Zone</td><td>1.42</td><td>1</td></tr><tr><td>Fire Zone</td><td>1.52</td><td>1</td></tr><tr><td>Preheating</td><td>1.32</td><td>1</td></tr></table></td><td>No EPIAs suggested</td></tr>
</table>

3.7.4 Thermal consumption areas

As discussed in our earlier section Kiln accounts for about 86% of energy cost and 92% of the energy use. The details of present set-up, key observations made and potential areas for energy cost reduction have been mentioned in the table below:

Table 14 Kiln and Kiln car details

Sr. No	Parameter	Value	Unit
1	**Kiln Type**	Flatbed tunnel	
2	**Kiln Operating time**	24	hour
3	**Number of burner to left**	8	-
4	**Number of burner to right**	8	-
5	**Kiln car residence time**	17	hour
6	**Kiln cars per day**	48	-
7	**Stock weight per kiln car**	550-600	kg
8	**Waste Heat recovery option**	Recuperator installed	

Table 15 Kiln Dimensions

Zone	Height	Width	Length	UoM
Preheating	2	3.25	28	meter
Firing	2.	3.75	18	meter
Cooling	2	3.25	35	meter

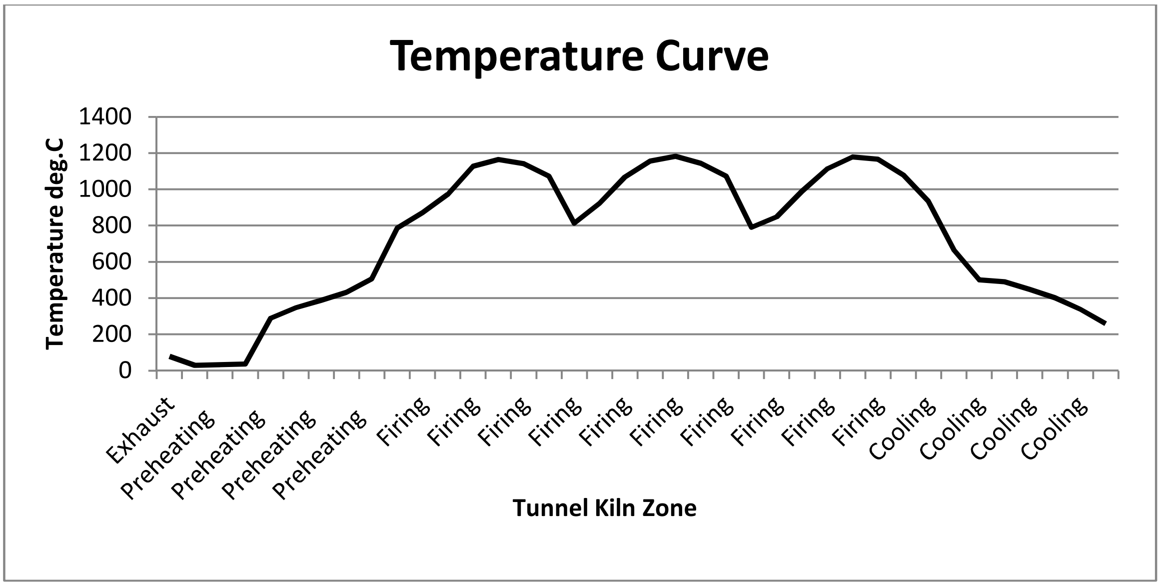


Figure 7 Temperature curve of tunnel kiln

<table>
<tr><th>Name of Area</th><th>Present Set-up</th><th>Observations during field Study & measurements</th><th>Proposed Energy performance improvement actions</th></tr>
<tr><td>Kiln</td><td>PNG is used as a fuel in the kiln to heat the ceramic material to the required temperature.

The required air for fuel combustion is supplied by a blower (FD fan).</td><td>The fuel consumption of kiln has been identified by dip stick method as no metering system was available.

<table><tr><th>Machine</th><th>Oxygen Level measured in Flue Gas</th><th>Ambient Air Temp</th><th>Exhaust Temperature of Flue Gas</th></tr><tr><td>Tunnel kiln</td><td>11.1</td><td>35Deg C</td><td>78Deg C</td></tr></table>
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 – 42deg C which was the ambient air temperature.</td><td>No waste heat recovery recommendations has been suggested as the exit flue gas temperature is low and cannot be used for waste heat recovery

Reducing the radiation and convection losses from the kiln surface by improving insulation is recommended in firing zone of kiln.

Reducing opening losses in kiln is recommended.</td></tr>
</table>

4 EE TECHNOLOGY OPTIONS AND TECHNO – ECONOMIC FEASIBILTY

During CEA of plant all energy consuming equipment and processes were studied. The analysis of all major energy consuming equipment and appliances were carried out and the same was discussed in earlier section of this report.

Based on the analysis, Energy Performance Improvement Actions (EPIA) has been identified; each of which are described below:

4.1 EPIA 1: Reduction in radiation and convection losses from surface of 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 45-50Deg C, so as to avoid heat loss due to radiation and convection. Refractories are heat-resistant materials that constitute the linings for high-temperature tunnel kilns. In addition to being resistant to thermal stress and other physical phenomena induced by heat, refractories must also withstand physical wear and corrosion by chemical agents.

Thermal insulations 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.

A kiln wall is designed in combinations of refractories and insulation layers, with the objective of retaining maximum heat inside the kiln and avoids losses from kiln walls.

Study and investigation

There are three different zones in kiln i.e. pre- heating, firing and 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 45-50 deg C and it was measured as 92˚C, hence the kiln surface has to be properly insulated to keep the surface temperature within the specified range.

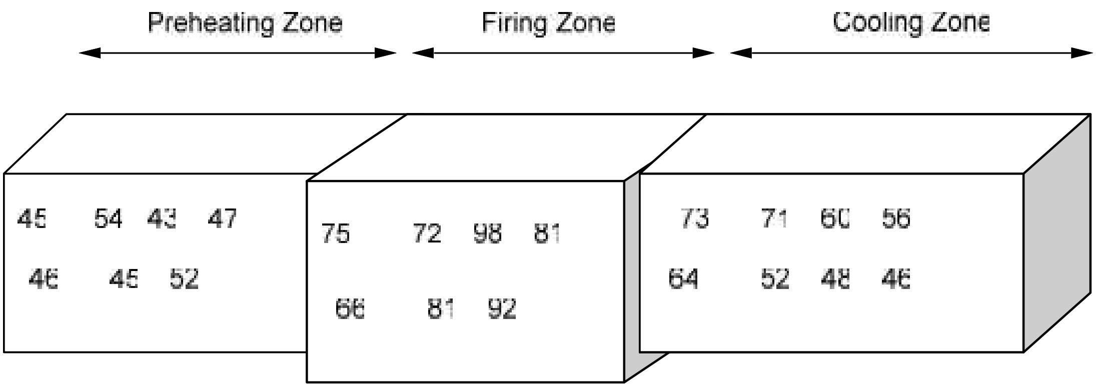


Figure 8 Surface temperature of kiln

Recommended action

Recommended surface temperature of the firing zone has to be brought to within 50 deg. 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.

Table 16 R & C losses

Total radiation and convection heat loss per hour	Units	Value
Pre-Heating Zone	kCal / hr	5,166
Heating Zone	kCal / hr	12,303
Cooling Zone	kCal / hr	12,935
Total R&C loss	kCal / hr	30,404

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

Table 17 Cost benefit analysis (EPIA 1)

Parameters	UoM	Value
Present average skin temperature of Heating zone	deg. C	60.30
Recommended skin temperature of Heating Zone	deg. C	50.00
Present heat loss due to Radiation & Convection from Work side wall	kCal / hr	12,303
Recommended heat loss due to Radiation & Convection from Heating zone	W / m2	43.84
	kCal / m2	37.70
	kCal / hr	5,073
Total reduction in heat loss due to Radiation & convection by limiting skin temperature at Heating zone	kCal / hr	7,230
Calorific value of Fuel	kCal / kg	13,030
Equivalent savings in Fuel	kg / hr	0.55

	Nm3 / hr	
Plant running time	days / year	300
	hrs / day	24
Annual savings in Fuel	**kg/y**	**3,995**
Cost of fuel	Rs / kg	58.485
Annual Monitory savings	**Rs / Year**	**233,652**
	Rs. Lacs / Year	**2.34**
Estimated investment	Rs. Lakh	0.7

4.2 EPIA 2: Excess air control

Technology description

It is necessary to maintain optimum excess air levels in combustion air supplied for complete combustion of 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 process requires 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 excess air results in excessive heat loss through the flue gases whereas too little excess air results in in-complete 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 excess air. This result in the formation of excess flue gases, taking away the heat produced from the combustion and increasing the fuel consumption. This also results in the formation of excess GHG emissions.

A PID controller if installed measures 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) is regulated and subsequently proper temperature and optimum excess air for combustion is attained in the kiln.

Study and investigation

Presently 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.

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. As a thumb rule, reduction in every 10 percent of excess air will save one percent in specific fuel consumption. The cost benefit analysis of the energy conservation measure is given below:

Table 18 Cost benefit analysis (EPIA 2)

Parameters	UOM	Present	Proposed
Oxygen level in flue gas	%	8.10	3.00
Excess air control	%	62.79	16.67
Dry flue gas loss	%	2.04	
Saving in fuel	With every 10% reduction in excess air leads to a saving in specific fuel consumption by 1%		
Specific fuel consumption	kg/t	88.70	84.60
Saving in specific fuel consumption	kg/h		3.92
Saving in fuel consumption per year	kg/y		28228
Savings in fuel cost	Rs. Lakh/y		16.51
Installed capacity of blower	kW	4.21	4.18
Operating hours	hrs/y	7200.00	7200.00
Electrical energy consumed	kWh/y	30312.00	30078.72
Savings in electrical energy	kWh/y		233.28
Cost of electrical energy	Rs. Lakh/y	2.21	2.20
Savings in terms of energy cost	Rs. Lakh/Y		16.53
Estimated investment	Rs. lakh		7.00
Simple payback	y		0.42

4.3 EPIA 3: Energy efficient light fixture

Technology description

Replacing conventional lights like T-12s, T-8s, CFLs, incandescent lamps etc with LED lights helps reduce the power consumption and also result in higher illumination (lux) levels for the same power consumption.

Study and investigation

The unit is having 54 CFLs of 45 W power

Recommended action

It is recommended to replace the above mentioned light fixtures with energy efficient LED lamps which shall help reduce present lighting energy consumption. The cost benefit analysis for the EPIA is given below:

Table 19 Cost benefit analysis (EPIA 3)

Particulars	Unit	Existing	Proposed
Fixture		**45 watt and 23 watt CFL**	**16 Watt LED light**
Power consumed by CFL 45 watt	W	45	16
Total no. of 45 watt CFL	Nos.	54	54
Power consumed by the CFL 23 Watt	W	23	16
Total no. of 23 watt CFL	Nos.	-	0
Total power consumption	kW	2	1
Operating Hours/day	Hr	18	18
Annual days of operation	Day	300	300
Energy Used per year/fixture	***kWh***	***13,122***	***4,666***
Energy Rate	Rs/kWh	**7.30**	**7.30**
Operating cost per year	Rs. Lakh/Year	0.96	0.34
Saving in terms of electrical energy	kWh/Year		8456
Savings in terms of cost	Rs. Lakh/Year		0.62
Investment per fixture of LED	Rs. Lakh		0.009
Investment of project	Rs. Lakh		0.49
Payback period	Years		0.79

4.4 EPIA 4: Replacing conventional ceiling fans with Energy efficient fans

Technology description

Replacing the old fans of conventional type installed in various sections of the plant with energy efficient fans will reduce the power consumption by half. The energy efficient fans have a noiseless operation and it is controlled by electronic drives which on speed reduction will automatically sense the rpm and reduce the power consumption. Since large number of ceiling fans are used in the ceramic units for drying purposes these EE fans can be best suited for energy conservation.

Study and investigation

The unit is having about 750 nos. of conventional ceiling fans out of which 700 are at continuous operation. These conventional fans can be replaced with EE fans.

Recommended action

It is recommended to replace the present ceiling fans with energy efficient fans. The cost benefit analysis of the same is given in the table below:

Table 20 Cost benefit analysis (EPIA 4)

Data & Assumptions:	UOM	Ordinary fan	Superfan
Number of fans in the facility	No	700	700
Run hours per day	H/d	16	16
Power consumption at Maximum speed	kW	0.07	0.04
Number of working days/year	days	300	300
Tariff for Unit of electricity	Rs./kWh	7.30	7.30
Fan unit price* (use '0' for ordinary fan if replaced)	Rs./piece	0	3000
Electricity consumption:			
Electricity demand	kW	49.00	24.50
Power consumption by fans in a year	kWh/y	235200	117600
Savings in terms of power consumption	kWh/y		117600
Savings in terms of cost	Rs. Lakh/y		8.58
Estimated investment	Rs. Lakh/y		21.00
Payback period	y		2.45

5 Renewable Energy Utilization

Solar Air Drying

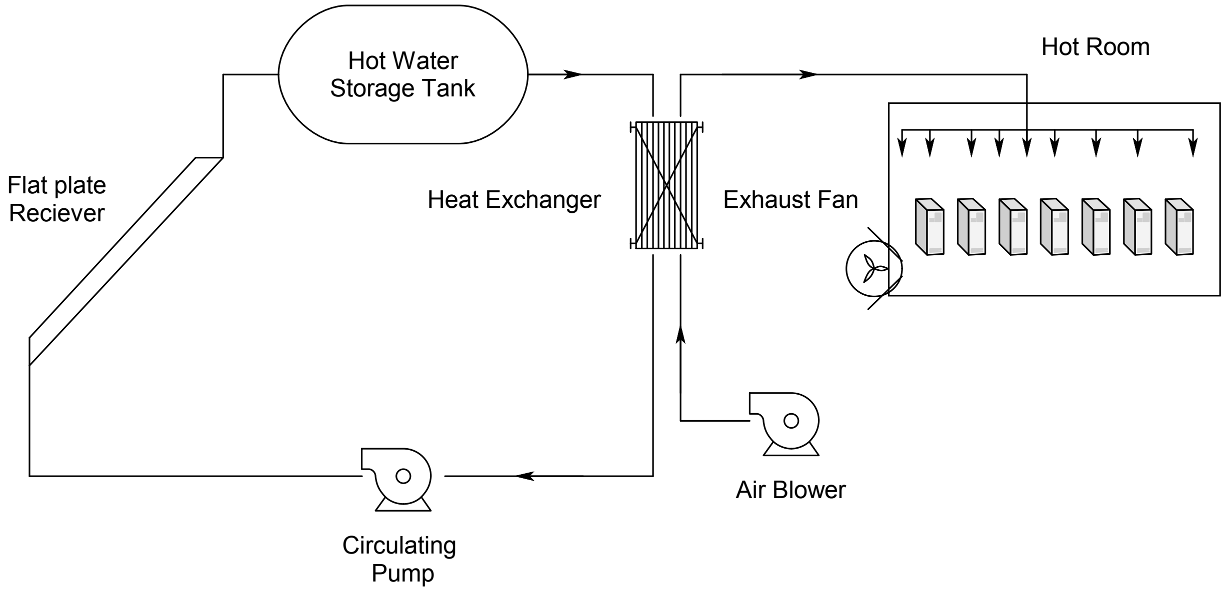


Figure 9 Solar air drying schematic diagram

Wet Solid molds in ceramic industries are conventionally dried using ceiling fans with 1200 mm blade diameter circulating air in open space. This method is extremely dependent on atmospheric conditions such as relative humidity in atmosphere and atmospheric temperature. Also drying rate is lower because the contact air to surface drying area is irregular. To overcome this, a proposal of hot room is introduced. Hot room is conceptually similar to Green House. In Hot room dry air with temperature above atmospheric temperature is distributed uniformly. This hot air is generated by heat exchange between solar water heater and suction air from air blower. Solar water heaters are technically and commercially available source of heat pumps. In this way electricity cost of conventional ceiling fans is saved and drying time is reduced which greatly decreases the production time at constant tunnel kiln operation time. But this setup requires additional investment such as solar water heater system, heat exchangers, air circulating system and hot room. Also operating cost of circulating pump and air blowers add up. A techno-commercial benefit is to be obtained by comparing increase in production to the increase in electricity cost. A calculation regarding reduction in drying rate using solar air drying is shown in below table.

Table 21 Increase in production rate due to solar air drying

Parameter	As is	To be	Unit
Humidity in atmosphere	40	40	%
Moisture content in mold	30	30	%
Final Moisture content	10	10	%
Weight of Drying Solid	20	20	kg
Moisture to be removed	4.6	4.6	kg
Drying Surface Area	0.72	0.72	m^2

Parameter	As is	To be	Unit
Drying Flux	0.003	0.01	kg/m^2s
Time Taken	11.83	3.55	hr
Drying Rate	0.233	0.777	kg/hr
Production Rate	23.00	25.3	tpd
Annual Production	6900.0	7590.0	ton
Power saving of drying fans	0	24.1	lakh/annum
Estimated Investment	25.5		Lakh
Payback (exclusive of profit in increase production rate& increase in power cost of air drying system)	1.1		year

Below table shows estimated investment on setting up solar air drying system for drying wet solid molds. Based on the current production rate the air drying system may be insufficient to cater drying load. The installation cost is taken **3 times** the cost mentioned in table below so as to cater the drying load.

Table 22 Solar air drying system installation cost

System	Capacity	unit	Initial Cost (Rs.)	Annual Power cost (Rs./annum)
Solar water heater	500	Liter per day (lpd)	66000	48240
	1000	lpd	110000	72360
Heat exchanger (fan coil Unit)			40000	
FD blower	10	kW	25000	482400
Exhaust Fan	2	kW	3000	96480
Hot room Ducting	60	m^2	30000	
Total Cost	with 500 lpd		1.64 Lakh	6.27 lakh
	with 1000 lpd		2.08 Lakh	6.51 Lakh

6 ANNEXURE

Kiln efficiency calculations

Input parameters

Input Data Sheet		
Type of Fuel	PNG	
Source of fuel	GSPC	
	Value	Units
Tunnel Kiln Operating temperature (Heating Zone)	1182	*Deg C*
Initial temperature of kiln car	36	*Deg C*
Avg. fuel Consumption	85.0	*kg/hr*
Flue Gas Details		
Flue gas temp.	78	*deg C*
Preheated air temp./Ambient	40	*deg C*
O2 in flue gas	8.1	*%*
CO2 in flue gas	8.6	*%*
CO in flue gas	1260	*ppm*
Atmospheric Air		
Ambient Temp.	40	*Deg C*
Relative Humidity	35	*%*
Humidity in ambient air	0.03	*kg/kgdry air*
Fuel Analysis		
C	*74.57*	%
H	*24.70*	%
N	*0.72*	%
O	*0.00*	%
S	*0.01*	%
Moisture	*0.0*	%
Ash	*0.00*	%
GCV of PNG	*13030*	kcal/kg
Ash Analysis		
Unburnt in bottom ash	*0.00*	%
Unburnt in fly ash	*0.00*	%
GCV of bottom ash	*0*	kcal/kg
GCV of fly ash	*0*	kcal/kg
Material and flue gas data		
Weight of Kiln car material	500	*Kg/Hr*
Weight of ceramic material being heated in Kiln	650	*Kg/Hr*
Weight of Stock	650	*kg/hr*
Specific heat of clay material	0.22	*Kcal/kgdegC*

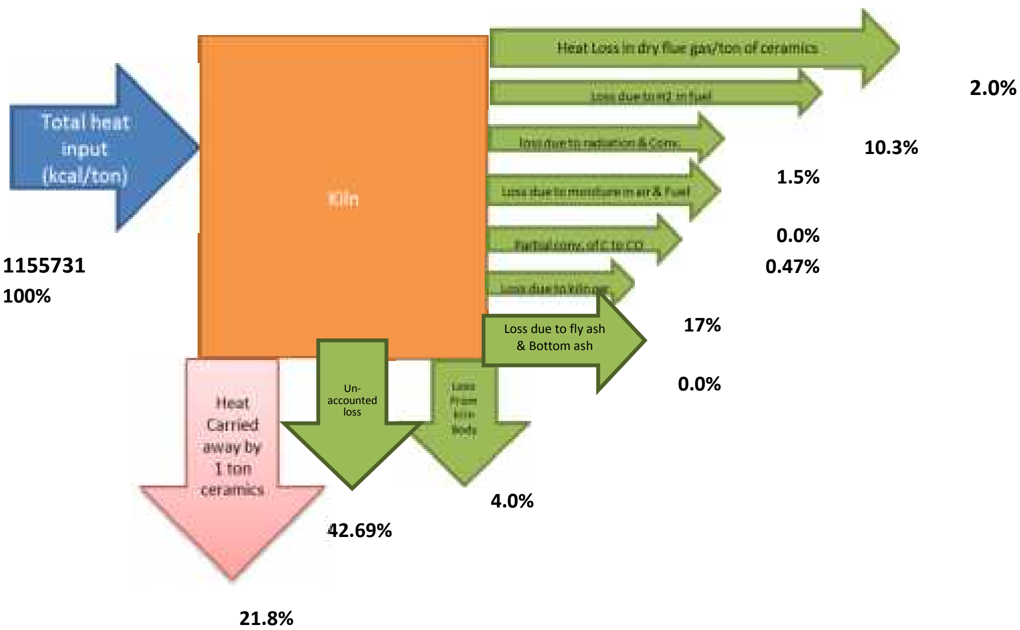
Specific heat of kiln car material	0.23	*Kcal/kgdegC*
Avg. specific heat of fuel	0.559	*Kcal/kgdegC*
fuel temp	40	*deg C*
Specific heat of flue gas	0.26	*Kcal/kgdegC*
Specific heat of superheated vapour	0.45	*Kcal/kgdegC*
Heat loss from surfaces of various zone		
Radiation and from preheating zone surface	5166	*kcal/hr*
Radiation and from heating zone surface	12303	*kcal/hr*
Radiation and from firing zone surface	12935	*kcal/hr*
Heat loss from all zones	30404	*kcal/hr*
For radiation loss in furnace(through entry and exit of kiln car)		
Time duration for which the Kiln car enters through preheating zone and exits through cooling zone of kiln	17	*Hr*
Area of opening in m2	4.505	*m2*
Co-efficent based on profile of kiln opening	0.7	
Max operating temp. at door	343	*deg K*

Efficiency calculations

Calculations	Values	Unit
Theoretical Air Required	17.25	*kg/kg of fuel*
Excess Air supplied	62.79	*%*
Actual Mass of Supplied Air	28.08	*kg/kg of fuel*
Mass of dry flue gas	26.85	*kg/kg of fuel*
Amount of Wet flue gas	29.08	*Kg of flue gas/kg of fuel*
Amount of water vapour in flue gas	2.22	*Kg of H2O/kg of fuel*
Amount of dry flue gas	26.85	*kg/kg of fuel*
Specific Fuel consumption	88.70	*kg of fuel/ton of billet*
Heat Input Calculations		
Combustion heat of fuel	1155731	*Kcal/ton of billet*
Sensible heat of fuel	0	*Kcal/ton of billet*
Total heat input	1155731	*Kcal/ton of billet*
Heat Output Calculation		
Heat carried away by 1 ton of ceramics (useful heat)	252120	*Kcal/ton of billet*

Calculations	Values	Unit
Heat loss in dry flue gas per ton of ceramics	23531	*Kcal/ton of billet*
Loss due to H2 in fuel	118519	*Kcal/ton of billet*
Loss due to moisture in combustion air	14	*Kcal/ton of billet*
Loss due to partial conversion of C to CO	5400	*Kcal/ton of billet*
Loss due to convection and radiation	17,079	*Kcal/ton of billet*
Loss Due to Evaporation of Moisture Present in Fuel	0.0	*Kcal/ton of billet*
Total heat loss from kiln (surface) body	46776	*Kcal/ton of billet*
Heat loss due to unburnts in Fly ash	0	*Kcal/ton of billet*
Heat loss due to unburnts in bottom ash	0	*Kcal/ton of billet*
Heat loss due to kiln car	198872	*Kcal/ton of billet*
Unaccounted heat losses	493421	*Kcal/ton of billet*
Total heat loss from kiln	46776	*Kcal/tons*
Kiln Efficiency	21.8	*%*

2. Heat Balance Diagram



7 LIST OF VENDORS

EPIA 1: Radiation and convection loss reduction from surface of kiln

S.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

EPIA 2: Excess Air Control

Sl. No.	Name of Company	Address	Phone No	E-mail /Website
Automation				
1	Delta Energy Nature Contact Person Gurinder Jeet Singh, Director	F-187, Indl. Area, Phase-VIII-Bm Mohali-160059	Tel.: 0172-4004213/ 3097657/ 2268197 Mobile: 9316523651 9814014144 9316523651	dengjss@yahoo.com den8353@yahoo.com
2	International Automation Inc	# 1698, First Floor, Canara Bank Building,	Office: +91-161-4624392,	Email: interautoinc@yahoo.com

Sl. No.	Name of Company	Address	Phone No	E-mail /Website
	Contact Person Sanjeev Sharma)	Near Cheema Chowk, Link Road, Ludhiana	Mobile: +91-9815600392	
3	Happy Instrument	Yogesh 20, Proffulit Society, Nr Navo Vas, Rakhial, Ahmedabad-380021	079-22771702 9879950702	yogesh@happyinstrument.com
4	Wonder Automation	Kulwinder Singh E-192, Sector 74, Phase 8-B, Industrial Area, SAS nagar Mohali	0172-4657597 98140 12597	info@wonderplctrg.com admn.watc@gmail.com hs@wonderplctrg.com

EPIA 3: Energy efficient light

S.No	Name of Company	Address	Phone No.	E-mail
1	Osram Electricals Contact Person: Mr. Vinay Bharti	OSRAM India Private Limited,Signature Towers, 11th Floor,Tower B, South City - 1,122001 Gurgaon, Haryana	Phone: 011-30416390 Mob: 9560215888	vinay.bharti@osram.com
2	Philips Electronics Contact Person: Mr. R. Nandakishore	1st Floor Watika Atrium, DLF Golf Course Road, Sector 53, Sector 53 Gurgaon, Haryana 122002	9810997486, 9818712322(Yogesh-Area Manager), 9810495473(Sandeep-Faridabad)	r.nandakishore@phillips.com, sandeep.raina@phillips.com

S.No	Name of Company	Address	Phone No.	E-mail
3	Bajaj Electricals Contact Person: Mr. Kushgra Kishore	Bajaj Electricals Ltd,1/10, Asaf Ali Road, New Delhi 110 002	9717100273, 011-25804644 Fax : 011-23230214 ,011-23503700, 9811801341(Mr.Rahul Khare), (9899660832)Mr.Atul Baluja, Garving Gaur(9717100273),9810461907(Kapil)	kushagra.kishore@bajajelectricals.com, kushagrakishore@gmail.com; sanjay.adlakha@bajajelectricals.com

EPIA 4: Replacing conventional ceiling fans with energy efficient fans

S.No	Name of Company	Address	Phone No.	E-mail
1	Super fans	351B/2A, Uzhaipalar street, GN Mills PO, Coimbatore. INDIA 641029.	Mob: 9489078737	Email: superfan@versadrives.com
2	Usha pumps Contact Person: Mr. KB Singh	J-1/162, Rajouri Garden, Rajouri Garden New Delhi, DL 110005	011(23318114),011 2510 4999,01123235861(Mr.Manish)r	Email: kb_singh@ushainternational.com