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Technology Compendium for Energy Efficiency and Renewable Energy Opportunities in Ceramic Sector

Khurja Ceramic Cluster

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

September 2020

Disclaimer

This document is prepared to provide overall guidance for conserving energy and costs. It is an output of a research exercise undertaken by Confederation of Indian Industry (CII) supported by the United Nations Industrial Development Organization (UNIDO) and Bureau of Energy Efficiency (BEE) for the benefit of the ***Ceramic Industry located at Khurja, Uttar Pradesh, India***. The contents and views expressed in this document are those of the contributors and do not necessarily reflect the views of CII, BEE or UNIDO, its Secretariat, its Offices in India and elsewhere, or any of its Member States.

Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India

(A GEF funded project being jointly implemented by UNIDO & BEE)

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Compendium of

Energy Efficiency and Renewable Energy Technologies for Khurja Ceramic Cluster

September 2020

Developed under the assignment

Scaling up and expanding of project activities in MSME Clusters

Prepared by

Confederation of Indian Industry
125 Years - Since 1895

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Acknowledgement

Acknowledgement

This assignment was undertaken by Confederation of Indian Industry (CII) as a project management consultant under the Global Environment Facility (GEF) funded project ‘Promoting Energy Efficiency and Renewable Energy in selected MSME clusters in India.’ The Technology Compendiums are meant to serve as an informative guide to the clusters that the project is currently working in and also to the other potential clusters across the country.

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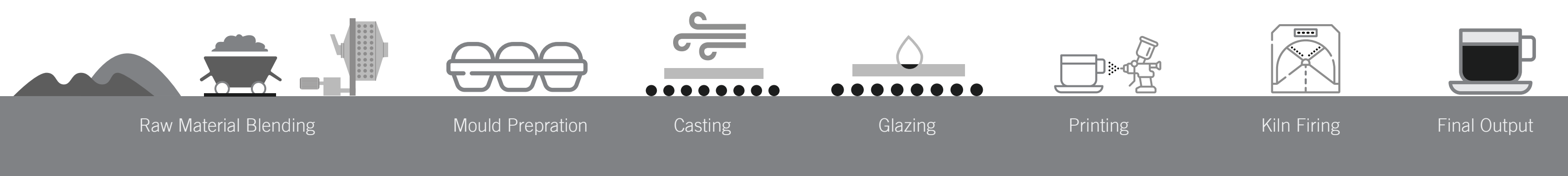
CII Team



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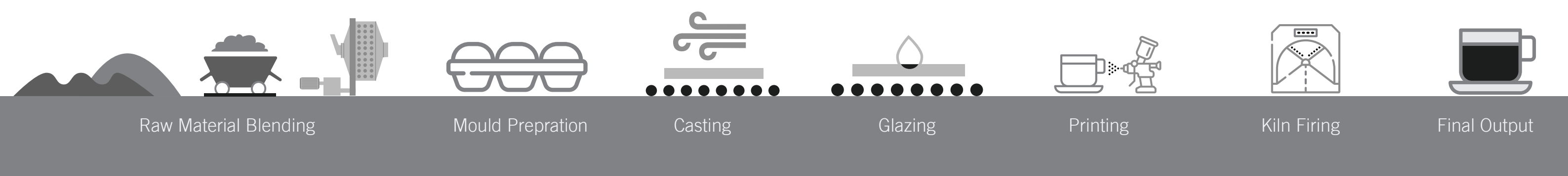

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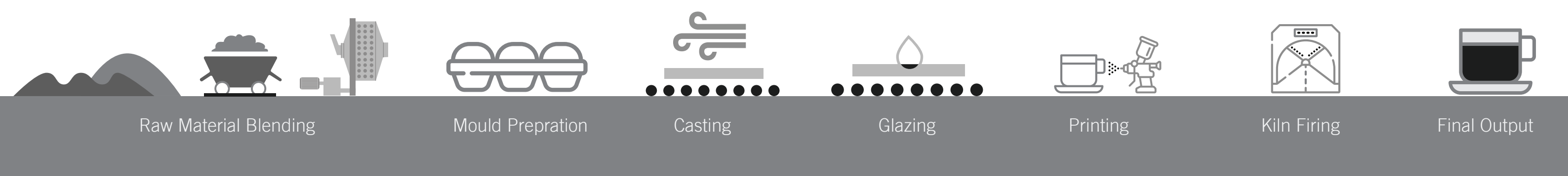

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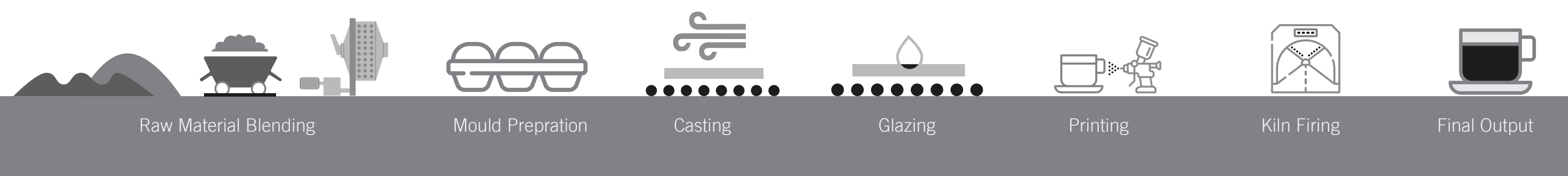

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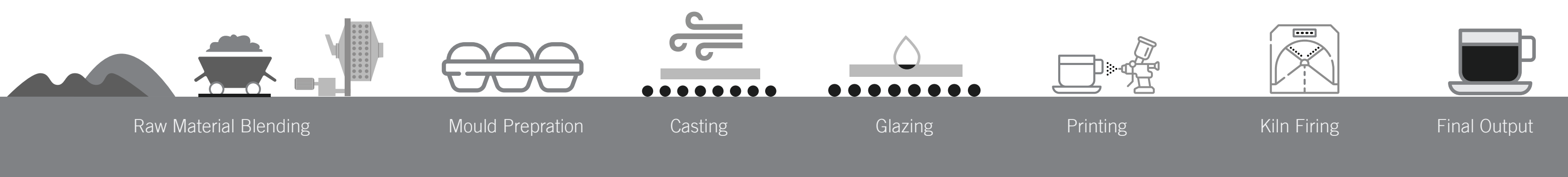

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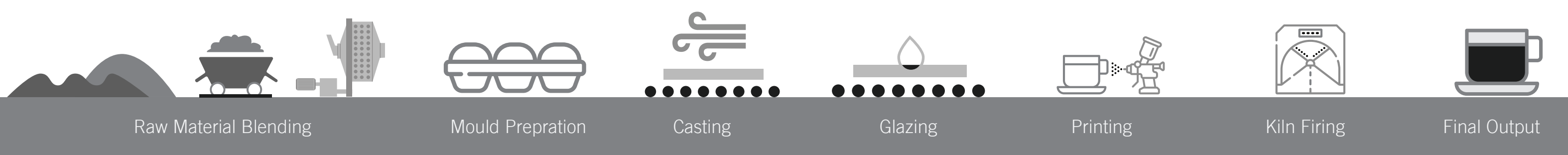
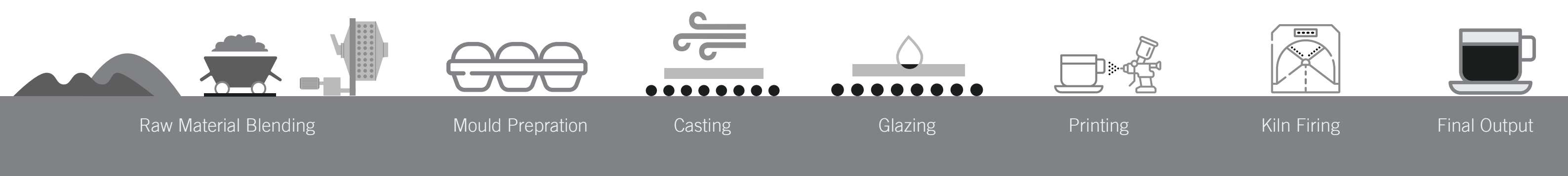


List of Abbreviations

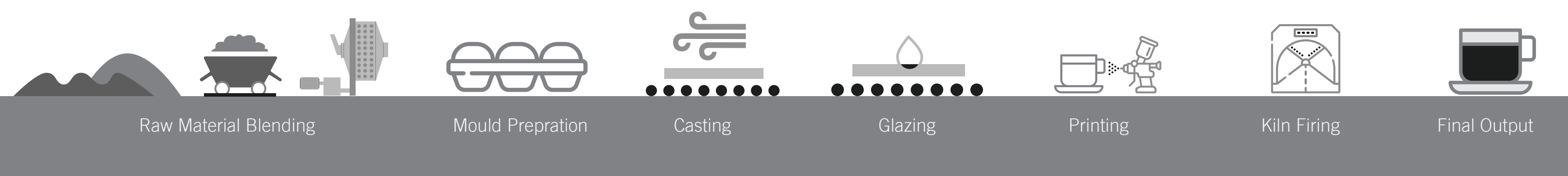
AC	Alternating Current
APFC	Automatic Power Factor Controller
BEE	Bureau of Energy Efficiency
BLDC	Brushless Direct Current
CAGR	Compound Annual Growth Rate
CFD	Computational Fluid Dynamics
CII	Confederation of Indian Industry
DC	Direct Current
DPR	Detailed Project Report
EE	Energy Efficiency
GCRT	Grid connected Roof top
GCV	Gross Calorific Value
GEF	Global Environment Facility
GHG	Greenhouse Gas
GI	Galvanized Iron
HHO	Hydroxy gas
hp	Horsepower
IEEE	The Institute of Electrical and Electronics Engineers
INR	Indian Rupee
IoT	Internet of Things
LED	Light Emitting Diode
LSP	Local Service Provider
LT	Low Tension
MNRE	Ministry of New and Renewable Energy
MPPT	Maximum Power Point Tracker
MSM	Million Square Metre
MSME	Micro, Small and Medium Enterprises
NG	Natural Gas
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer



PCU	Power Conditioning Unit
PF	Power Factor
PID	Proportional Integral Derivative
PLC	Programmable Logic Controller
PMU	Project Management Unit
PNG	Piped Natural Gas
PV	Photovoltaic
RE	Renewable Energy
SEC	Specific Energy Consumption
SMPS	Switched-Mode Power Supply
TOE	Tonne of Oil Equivalent
UNIDO	United Nations Industrial Development Organization
UOM	Unit of Measurement
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery

Unit of Measurement

CFM	Cubic Feet per Minute
°C	Degree Celsius
hp	Horsepower
INR	Indian Rupee
kg	Kilogram
kg/cm^2	Kilogram Force per Square Centimetre
kCal	Kilocalorie
km	Kilometre
kVA	kilo-volt-ampere (apparent power)
kVAr	kilovolt-ampere-reactive (reactive power)
kW	Kilo Watt
kWh	Kilo Watt Hour
kWp	Kilo Watt Peak
LPM	Litre per minute
m	Metre
m^2	Square metre
MT	Metric Tonne
mmWc	Millimeter water column
m^3/hr	Cubic metre per hour
m^3/min	Cubic metre per minute
m/s	Metre per second
ppm	Parts per million
SCM	Standard Cubic Metre
TCO_2	Tonne of Carbon dioxide
TPD	Tonne Per Day
TOE	Tonne of Oil Equivalent



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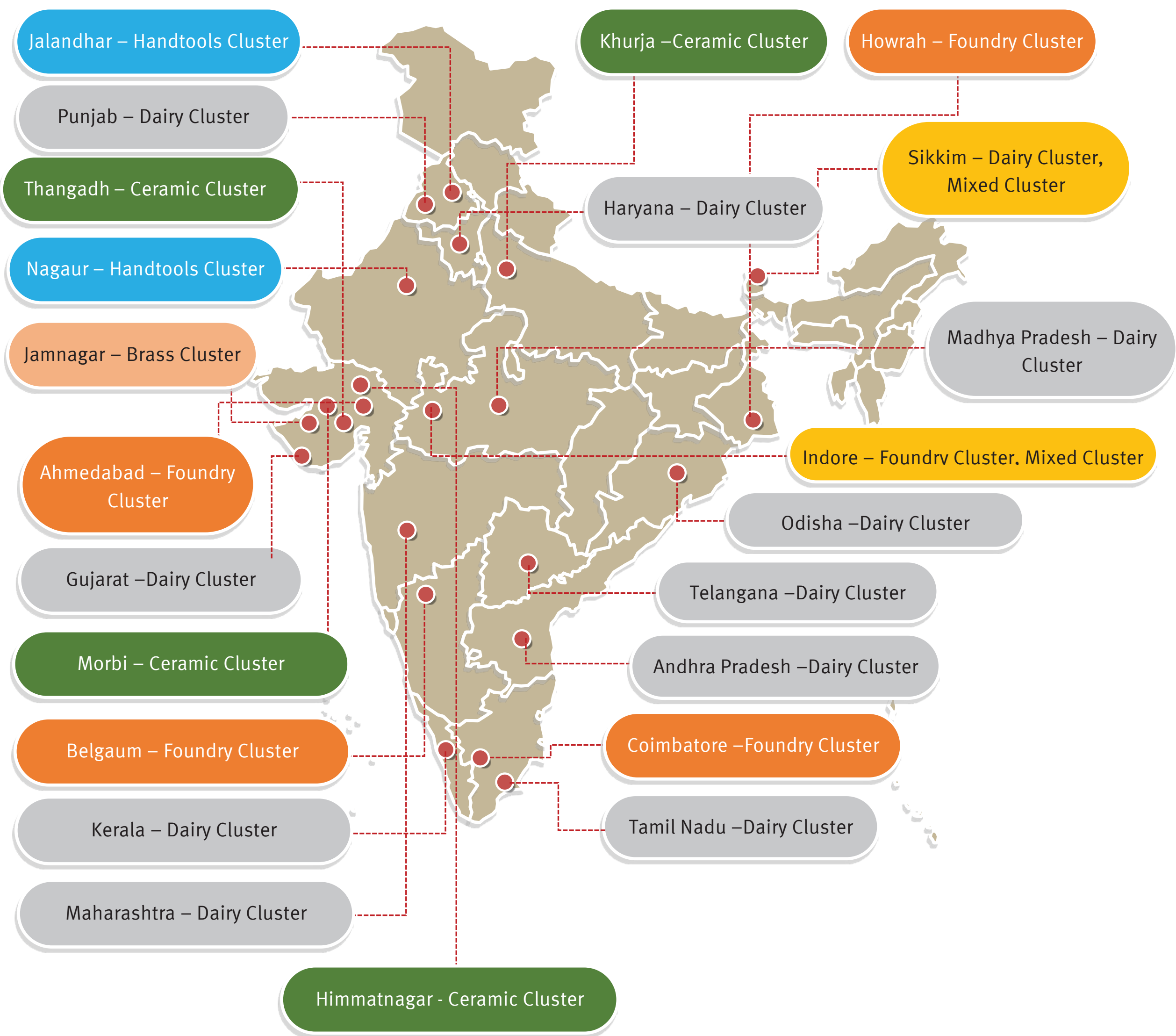
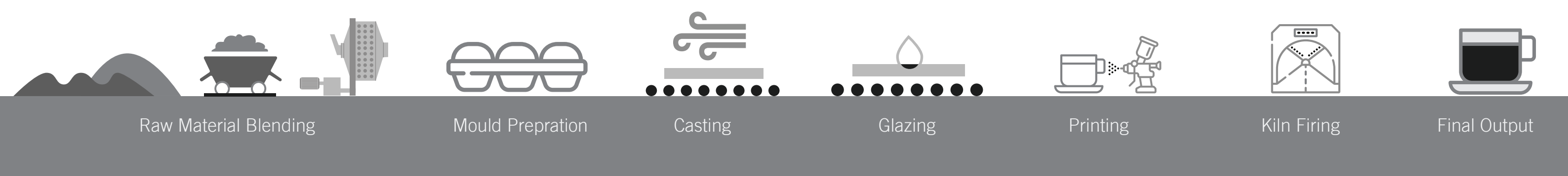
About Project & Technology Compendium

About the Project

The United Nations Industrial Development Organization (UNIDO), in collaboration with the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, is executing a Global Environment Facility (GEF) funded national project titled ‘Promoting energy efficiency and renewable energy in selected MSME clusters in India’. The project was operational in 12 MSME clusters across India in five sectors, respectively: Brass (Jamnagar); Ceramics (Khurja, Thangadh and Morbi); Dairy (Gujarat, Sikkim and Kerala); Foundry (Belgaum, Coimbatore and Indore); Hand Tools (Jalandhar and Nagaur). The Project has now scaled-up and expanded its activities to 11 new clusters, namely in Dairy (Tamil Nadu, Odisha, Madhya Pradesh, Andhra Pradesh & Telangana, Haryana, Maharashtra & Punjab), Foundry (Ahmedabad & Howrah), Ceramic (Himmatnagar) Mixed Cluster (Indore & Sikkim) in order to reach out to MSME’s at national level.

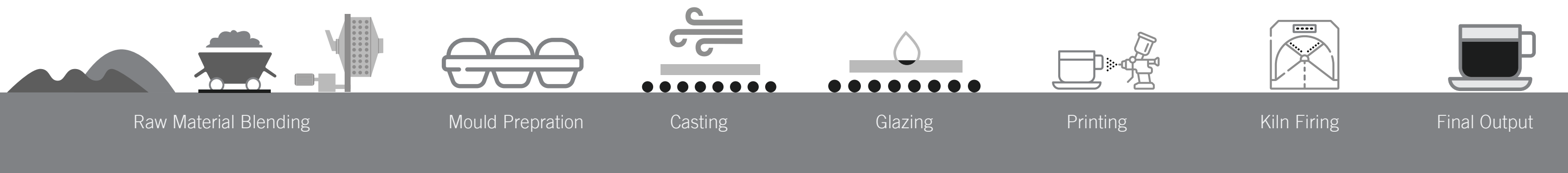
This project so far has supported 303 MSME units in implementing 603 Energy conservation Measures and thus resulted in reduction of about 10,850 TOE energy consumption and avoided 62,868 metric tons of CO_2 emissions as on date.





The key components of the project include:

- ❖ Increasing capacity of suppliers of EE/RE product suppliers / service providers / finance providers
- ❖ Increasing the level of end user demand and implementation of EE and RE technologies and practices by MSMEs.
- ❖ Scaling up of the project to more clusters across India.
- ❖ Strengthening policy, institutional and decision-making frameworks.
- ❖ Significant progress has been made in the project and it is now proposed to scale up and expand. The activities envisaged under the scaling up phase of the project include:
    - ✧ Establishment of field level Project Management Cell (PMC)
    - ✧ Organizing cluster level awareness program and identification of potential MSME enterprises
    - ✧ Development of cluster specific EE and RE based technology compendiums
    - ✧ Providing implementation support and other related activities to the identified enterprises



About the Technology Compendium

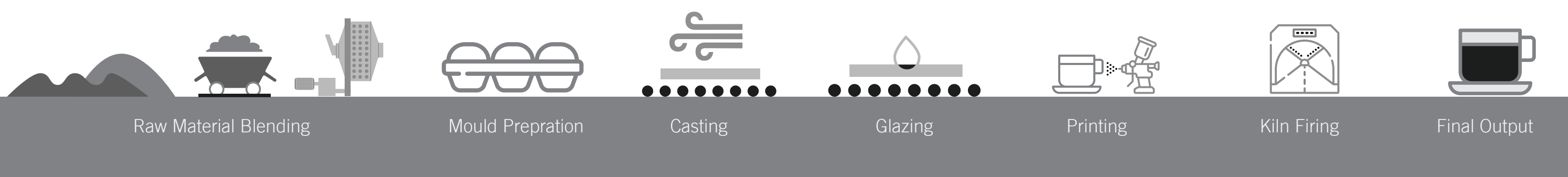
Ceramic industry in India is about 100 years old. It comprises ceramic tiles, pottery ware and crockery items. Ceramic products are manufactured both in the large and small-scale sector with wide variation in type, size, quality and standard. Though there are many large companies in the ceramics sector, small and medium enterprises (SMEs) account for more than 50% of the total market in India.

The SME players in ceramic sector today face challenges and opportunities resulting from rising energy cost, environmental concerns and competitiveness. The increase in the price of raw materials and fuel increases the total cost of production, which in turn hampers the profit margin of the manufacturers. The energy cost accounts for 30 to 40% of total production cost. Adopting energy efficient equipment, systems, measures and best practices could offer substantial cost savings and improvement in profit margins.

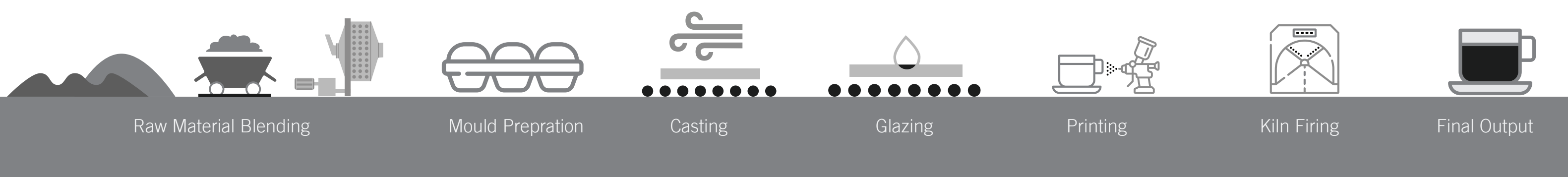
This technology compendium is prepared with the objective of accelerating the adoption of energy efficient technologies and practices in ceramic units in Khurja. It focuses on equipment upgrades, new technologies and best practices for improving energy efficiency. The case studies included in the compendium provide all the necessary information to enable ceramic units to implement them in their operations. The case studies are supported with technology background, baseline scenario, merits, challenges, technical feasibility, financial feasibility and technology provider details. The energy efficiency measures included in the report cover more than 90% of energy consumption in a ceramic unit.

Thermal energy accounts for 80-90% of the total energy consumption. Tunnel kilns in pottery ware units are the major source of fuel consumption. The electricity is mainly used for raw material preparation (ball mills drive, slurry transfer pumps, spray dryer fans, etc.), blowers in kiln, pumps and compressors. Over the years, there has been significant technological improvement in the process and utilities area and the ceramic units in Khurja have been able to improve the energy efficiency in their operations. However, various opportunities remain for improvement in energy efficiency. To be competitive and have environment-friendly operations, energy efficiency is critical.

- ❖ The objective of this compendium is to act as a catalyst to facilitate dairies towards continuously improving the energy performance, thereby achieving world class levels (with a thrust on energy & environmental management).
- ❖ The compendium includes general energy efficiency options as well specific case studies on applicable technology upgradation project which can result in significant energy efficiency improvements.
- ❖ The suggested best practices may be considered for implementation only after detailed evaluation and fine-tuning requirements of existing units.
- ❖ In the wide spectrum of technologies and equipment applicable for energy efficiency, it is difficult to include all aspects in this manual. However, an attempt has been made to include the more common implementable technologies across all the ceramic units.



- The user of the compendium has to fine-tune the energy efficiency measures suggested in the compendium to their specific unit requirements to achieve maximum benefits.
- The technologies collated in the compendium may not necessarily be the ultimate solution, as energy efficiency through technology upgradation is continuous process and will eventually move towards better efficiency with advancement in technology.
- The ceramic industry in Khurja should view this manual positively and utilize this opportunity to implement the best operating practices and energy saving ideas during design and operations stages and thus work towards achieving world class energy efficiency.



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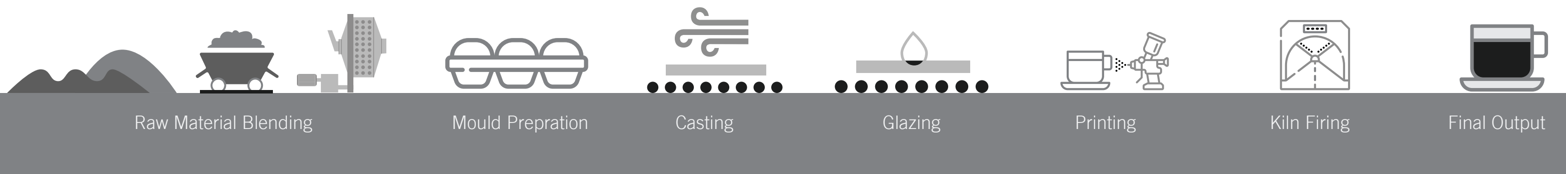
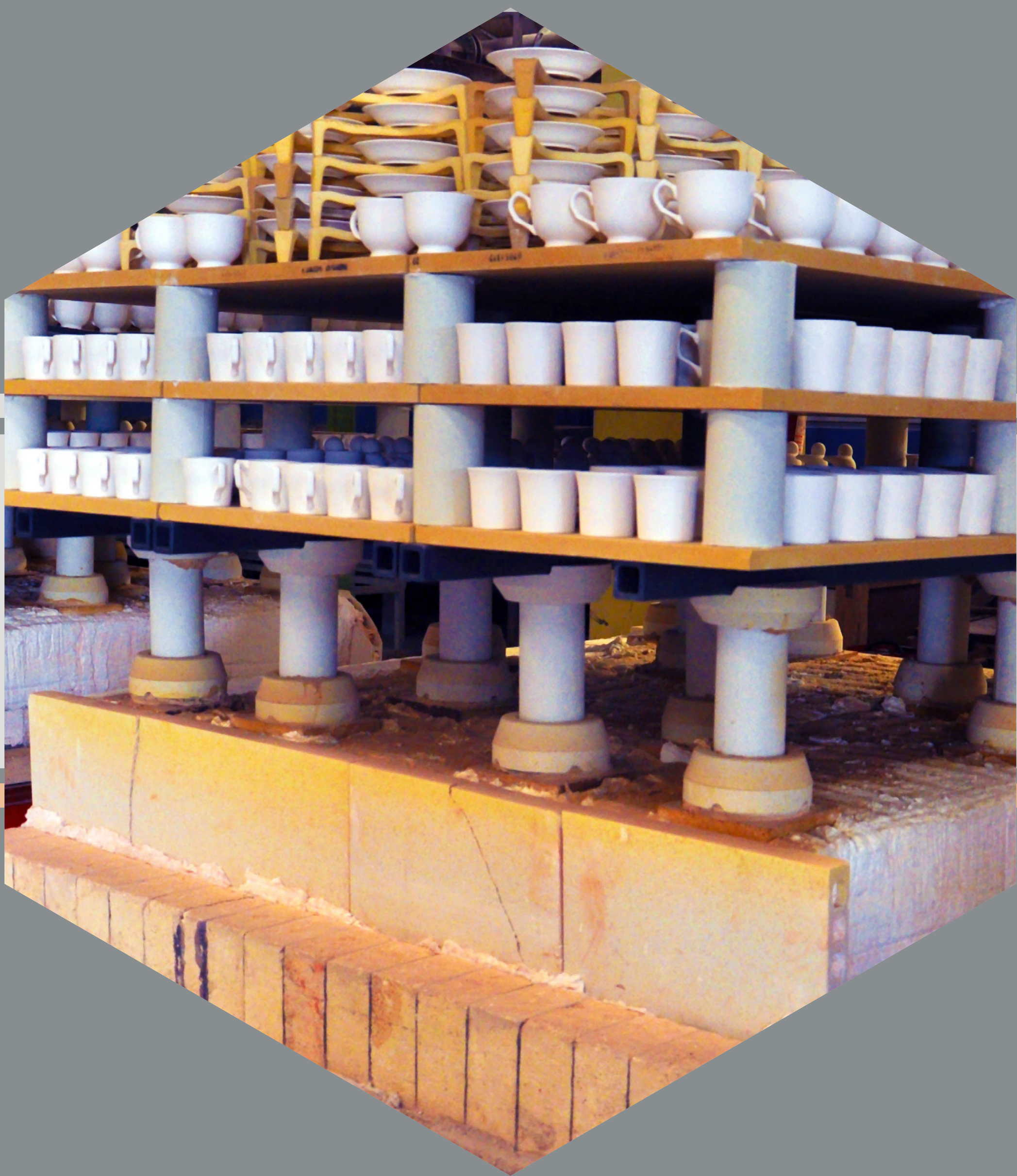


Executive Summary



Executive Summary

The United Nations Industrial Development Organization (UNIDO), in collaboration with the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, is executing a Global Environment Facility (GEF) funded national project called 'Promoting energy efficiency and renewable energy in selected MSME clusters in India'. The project execution is planned in multiple phases. The aim of the Phase-I of the project was to develop and promote a market environment for introducing energy efficiency and enhanced use of renewable energy technologies in process applications in the selected (12) energy-intensive MSME clusters in India, with feasibility for expansion to more clusters. Phase-II of the project is to scale up and expand the project activities to a greater number of enterprises in existing clusters, as well as 11 new clusters, for better implementation of energy efficiency technologies and practices.

Efficient use of energy in any facility is invariably the most important strategic area for manageability of cost or potential cost savings. Awareness of the personnel, especially operators in the facility, becomes a significant factor for the proper implementation of energy conservation initiatives. With this context, this Technology Compendium has been prepared, detailing various technologies and best practices to save energy.

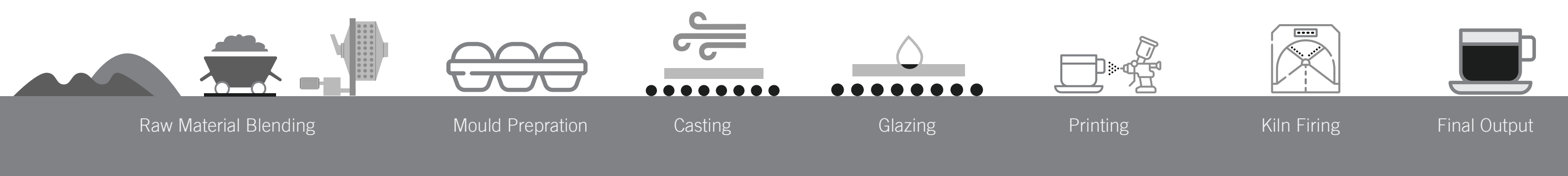
The information in this compendium is intended to help the ceramic units in Khurja Ceramic Sector to reduce energy consumption in a cost-effective manner while maintaining the quality of products manufactured. Further analysis on the economics of all measures as well as on their applicability to different production practices is needed to assess their cost effectiveness at individual ceramic units. Further, this shall also serve as a guide for estimating the feasibility of energy saving projects and ensure accelerated implementation.

Chapter 1 of the compendium provides an overview of the Indian Ceramic Industry and Khurja ceramic cluster.

Chapter 2 focuses on a brief overview of the pottery ware manufacturing process and energy consumption in ceramic units and also includes technology status/mapping of the Khurja Ceramic Sector.

Chapter 3 focuses on the importance of energy efficiency in ceramic industry and some of the common measures applicable to different sections of the ceramic unit. Energy efficiency measures are included for more than 90% of energy consumption areas in pottery ware manufacturing unit, such as raw material preparation, mould preparation, slip/slurry transfer, kiln, utilities and utilization of renewable energy. The chapter also includes some of the best practices on energy efficiency.

Chapter 4 provides detailed case studies for some of the high impact and implementable energy efficiency technologies in pottery ware manufacturing units. In this chapter, 17 case studies have been included in areas such as raw material preparation, mould preparation, slip/slurry transfer, kiln, utilities and utilization of renewable energy, etc. These technologies are described in detail, such as baseline scenario, proposed scenario, merits, demerits, etc.and wherever possible, a case reference from a ceramic unit that has implemented the

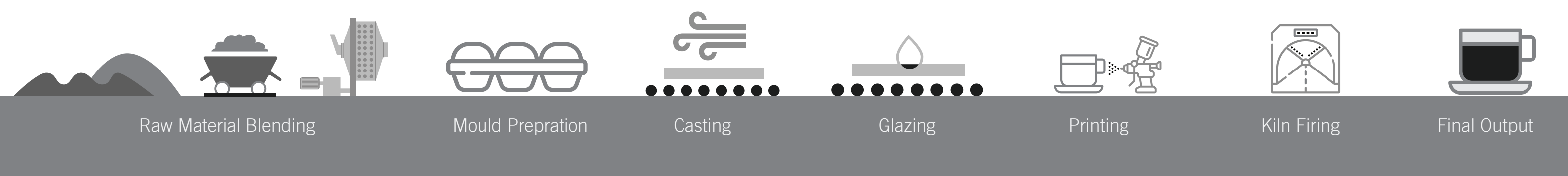


technology has been included. In most of the examples, typical energy saving data, GHG emission reduction, investments, payback period, etc., have been highlighted. Energy saving potential in this sector is estimated to be about 10-15%. High potential for improving energy efficiency in pottery ware units exists in the kilns via installation of high velocity kiln burner, excess air control system in kiln, waste heat recovery in tunnel kiln, reduction in kiln radiation losses, low thermal mass kiln cars, blunger in place of ball mill, high alumina balls in glaze ball mills, installation of energy efficient pumps, blowers and solar PV etc.

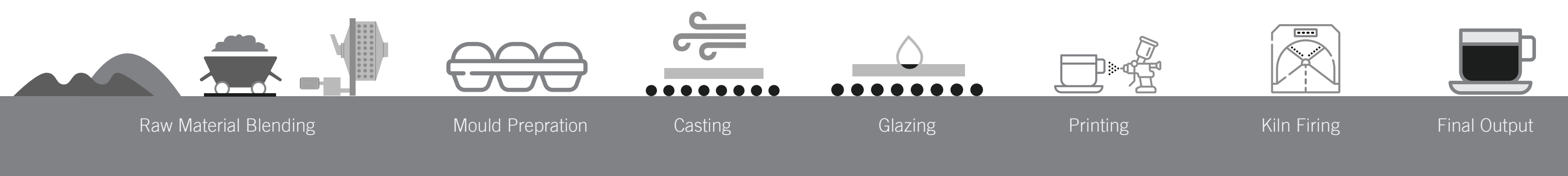
The following table summarizes a list of technologies included in the compendium:

Table 1: List of Technologies

Sr. No.	Technologies	Investment (INR Lakh)/ TOE	Payback (months)
	Kiln		
1	Waste heat recovery in tunnel kiln	0.34	12
2	Energy efficient coating inside kiln to reduce the radiation losses in kiln and reduce fuel consumption	0.33	12
3	Low thermal mass for reduction of kiln car losses in pottery ware units	0.38	14
4	Upgradation of oil-based firing system with natural gas firing system in tunnel kiln	0.26	7
	Raw Material Blending		
5	Reduction in ball mill power by installation of VFD on ball mill drive	0.73	12
6	High speed blunger in place of ball mill for raw material grinding process	1.40	22
7	High alumina media in glaze ball mill in the place natural stone/ pebble	1.55	23
8	Replacement of manual jigger with double roller head automatic jigger	65.21	15
	Utilities		
9	Installation of VFD in screw compressor to avoid unloading	0.63	12
10	Installation of Screw Compressor with VFD in place of reciprocating compressor	1.86	29
11	Energy conservation in compressor by modifying airline system	1.09	15
12	Transvector nozzle in compressed air hose pipe for mould cleaning application	0.83	12
13	Retrofit of energy efficient ceiling fans in place of conventional fans	1.08	16
14	Installation of on-off controller system in agitator motor	0.19	3
15	Retrofit of energy efficient motors in place of old rewinded motors	2.5	39
16	Power factor correction & harmonic mitigation at main LT incomer	-	11



Sr. No.	Technologies	Investment (INR Lakh)/ TOE	Payback (months)
	Renewable Energy		
17	Solar rooftop system	2.9	43
	New & Innovative technologies		
18	Solar-Wind hybrid system	5.3	85
19	Installation of Energy Efficient burners in place existing old conventional burner in kiln firing	0.82	30



Indian Ceramic Industry

1. Indian Ceramic Industry

1.1. Background

The Indian ceramic industry contributes considerably to India's economic progress. With growing urbanization and increasing use of ceramic pottery and sanitary ware in the Indian construction sector, the industry is expected to grow further at an increased rate. Indian ceramic industry is dominated by ceramic tile industry. In 2017, India strengthened its position as the world's 2nd largest tile producer and consumer country, accounting for 7.97% (1,080 million sqm)[1] of the global production. Though there are many large companies in the ceramics sector, small and medium enterprises (SMEs) account for more than 50% of the total market in India. Gujarat accounts for 70% of the total output.

Table 2: Top 5 Ceramic Tile Manufacturing Countries of the world (in MSM)

Country	2015	2016	2017	% of world production in 2017
China	5,970	6,495	6,400	47.23
India	850	955	1,080	7.97
Brazil	899	792	790	5.83
Vietnam	440	485	560	4.13
Spain	440	492	530	3.91
Total	12,460	13,255	13,552	100

MSM: Million Square Metre

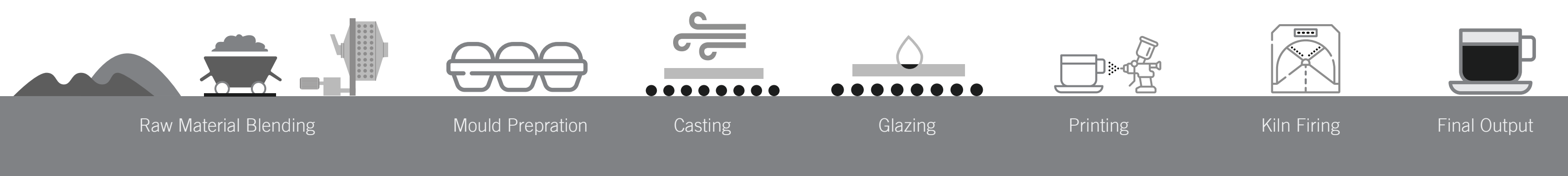
Morbi, a small industrial town near Rajkot, is the second largest tiles manufacturing cluster in the world – accounting for ~90% of total production of ceramic products in India. Himatnagar, a town near Ahmedabad, also houses some major tile manufacturing units.

With an installed capacity of more than 40 million pieces/year, India is the world's second largest sanitaryware producer after China. The rapid growth in sanitaryware production has been concentrated in Morbi & Thangadh in Gujarat.

Khurja, a small town in Uttar Pradesh, and Naroda in Ahmedabad, manufacture pottery wares.

Khurja town had a population of 1,42,636 as per at the last general census in 2011 and is currently the sixth largest town of the National Capital Region. The two main employment and livelihood sources in Khurja are pottery and agriculture, at roughly 50% each. The pottery industry directly employs about 25,000 workers with another 5,000-7,000 employed in various support services and allied activities. The share of ceramic products in India is shown below:

[1] *Ceramic world review*
[2] *Ceramic world review*
[3] *Status Quo and Outlook 2022: Indian Ceramics Industry - Report published by Messe Muenchen India & EAC International Consulting*



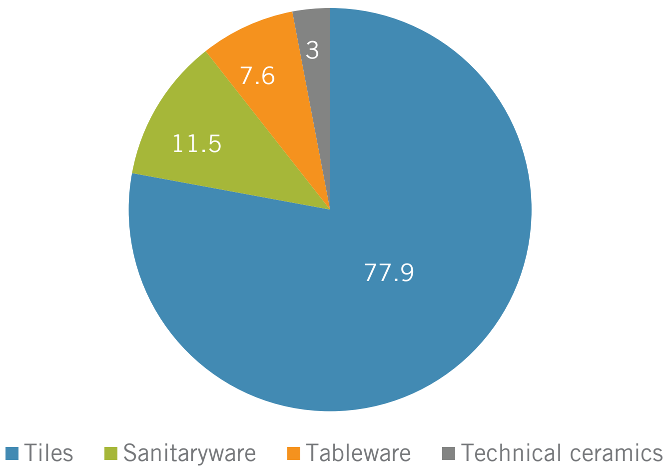


Figure 1: Ceramic product market share (2017)

The SME ceramic industry has developed in clusters in Khurja in Uttar Pradesh, Morbi, Thangadh and Ahmedabad in Gujarat. Khurja cluster produces crockery and electrical insulators, Morbi cluster produces mostly tiles and pottery ware products; Thangadh cluster produces pottery ware; Naroda in Ahmedabad produces crockery items and Himatnagar in Ahmedabad produces mostly tiles and crockery items. The table below lists the clusters, no. of ceramic units in each cluster and their major products.

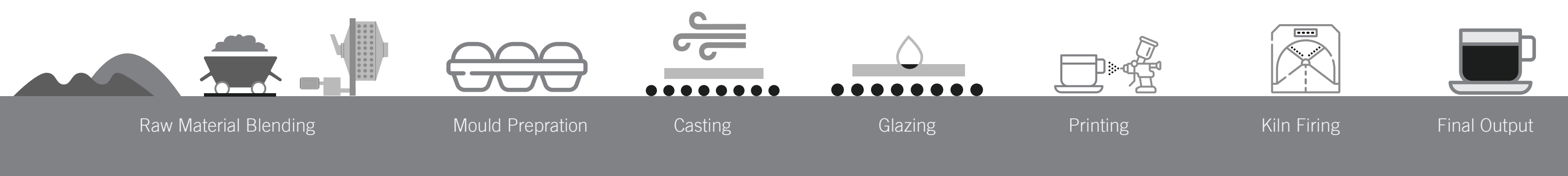
Table 3: Cluster Level Details

Location	Products	No. of units (approx.)
Morbi	Ceramic tiles (major product), Pottery ware, technical & industrial ceramics	700
Thangadh	Pottery ware (major product), Refractories	160
Himatnagar	Wall & floor tiles	21
Naroda	Crockery	23
Khurja	Crockery, electrical insulators	220

In tiles category, the main product segments are the Wall tile, Floor tile, Vitrified tile and Industrial tile segments. The market shares (in value terms) are 20%, 23%, 50%, and 7% respectively for Wall, Floor, Vitrified, and Industrial tiles.

Indian sanitary basic segment is dominated by unorganized players whereas the standard, premium and luxury segment is dominated by organized players. Pottery ware signifying crockery and tableware category is largely unorganized.

Ceramic industry is a highly energy-intensive industry. After raw materials, electricity and fuel cost is the second largest cost element in the total cost of production. The energy cost accounts for 25-30% of the total production cost. According to estimates, 10-20% of energy saving is possible in the ceramic units by adoption of latest energy efficient technology, processes, best practices, etc.



1.2. Ceramic Sector Growth Prospects

The key drivers for the ceramic product in India are the boom in housing sector coupled with government policies fueling strong growth in housing sector. Government focus on infrastructure development is expected to result in driving demand for Indian ceramics further, sanitary ware and bathroom fittings industry. Indian government spending on construction and real estate, including affordable housing is set to boost demand for ceramic products in the country. With many new projects lined up in the country, the construction sector is growing at an approximate rate of 7-8%. The demand for industrial ceramic products such as ceramic tiles, pottery ware, sanitary wares and pipes required in construction applications too is expected to increase.

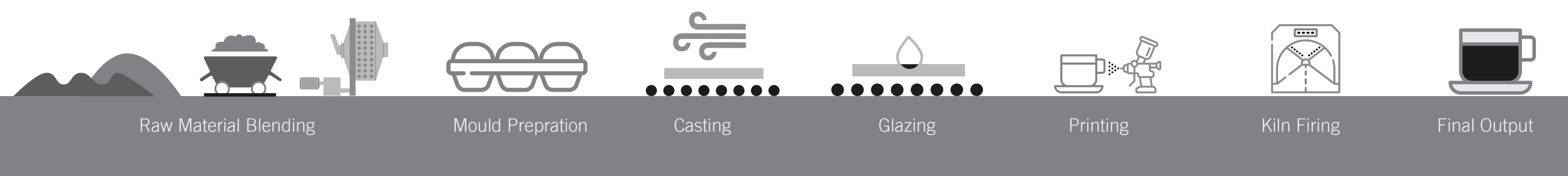
Indian ceramic industry is dominated by ceramic tiles industry, with a market of 4.9 Billion EUR in 2017; overall ceramic industry is expected to grow at 9% CAGR to become a 7.5 Billion EUR market by 2022[4]. Indian sanitary ware market is estimated to be worth 560 million EUR in 2017. Basic segment is dominated by unorganized players whereas standard, premium and luxury segments are dominated by organized players.

Ceramic product manufacturers face challenges due to the rise in the cost of production, which, in turn, hampers the profit margin of the manufacturers. The increase in the price of raw materials such as zirconium and titanium and fuel such as compressed natural gas, (CNG) which constitutes 30% of the input cost for manufacturing ceramic tiles, increases the total cost of production.

The growth in tile industry was mainly driven by the transformation of ceramic tiles from being typically hygiene products into adornment and aesthetic solutions for every household. The potential is huge considering the per capita consumption of ceramic tiles in India. Currently it is at 0.50 square meter per person[5] in comparison to over 2 square meters per person for like countries like China, Brazil and Malaysia.

Crockery has by far become an integral part of every dining room not only because of its utility but also it can lend grandeur even to a humble little dwelling. The demand for crockery in India has undergone dramatic change. Crockery is no longer used only as a serve ware but as a lifestyle product. With cultural diversity and varied lifestyles in India, crockery market is one of the most vibrant market segments. A highly fragmented market, crockery has been one of the fastest growing segments over the past few years.

[4] Status Quo and Outlook 2022: Indian Ceramics Industry, Market study by EAC International Consulting on behalf of Messe Muenchen India, March 2018
[5] Indian Council of Ceramic Tiles and Sanitaryware (ICCTAS)



1.3. Khurja Ceramic Sector

Khurja is a small town in the Bulandshahar District of Western Uttar Pradesh. The Central Glass and Ceramic Research Institute, Kolkata, established its Khurja Centre in August 1981, under an assurance for continuous financial support from the Government of Uttar Pradesh. This centre is functioning to cater to the needs of developing creaming and allied industries in the state, particularly to the Ceramic Industries in the Small Scale and Rural Sector. Khurja having a 600 year old tradition of pottery manufacturing has now become a centre of Ceramic industry, having more than 494[6] units in the small-scale sector and one of the largest whiteware clusters in India.

The main items produced by independent pottery units in Khurja are crockery wares, art wares, electrical goods. Mostly whiteware is produced in Khurja, but there is also a small amount of high-fired terracotta being produced for export markets. Most pottery units in Khurja manufacture crockery (stoneware), HT/LT insulators and decorative wares (stoneware). There are only a few specialized units that manufacture sanitary wares, bone china and chemical porcelain.

Khurja's pottery products are sold all over India and also exported. Within India, products are sold directly and also indirectly through middlemen, shopkeepers and large godown owners. In our survey, units ranged from those with 100% direct sales to the market to others who sold everything through traders.

There are about 23 export-oriented pottery units in Khurja. Export clients include countries such as the United Kingdom, USA, Australia, New Zealand, United Arab Emirates, etc. The major export items are ceramic artware, insulators and scientific porcelain.

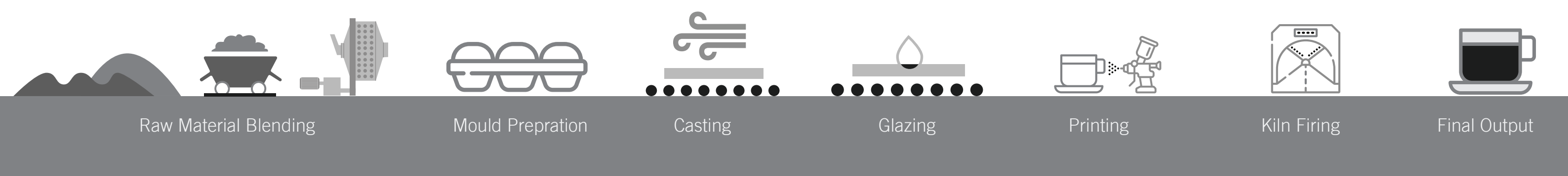
Clay, the most important material required for manufacturing, is generally obtained from Rajasthan and other parts of India.

The various types of kilns operational in Khurja are generally tunnel kilns for pottery ware and shuttle kilns for insulators. The energy efficiency of kilns is defined as the heat used or required to fire the ceramic product divided by the total heat supplied to the kiln. Tunnel Kilns mostly have manual control.

The pottery units in the Khurja cluster were earlier using either coal or diesel as fuel for kilns. These days they are replacing the conventional fuels with Natural Gas. Other electrical energy consuming equipment in pottery manufacturing units are ball mills, pumps and compressors, etc.

There are two active associations/research organizations in Khurja (KPMA & CGCRI) providing support to the ceramic units for improving the product quality and energy efficiency.

[6] *CGCRI Website*



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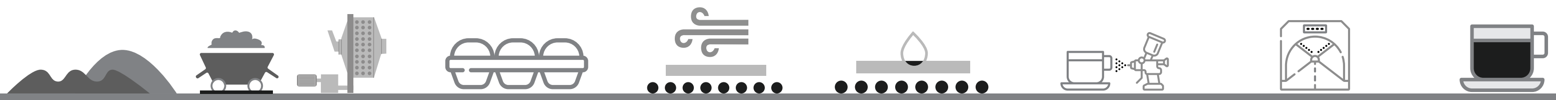


Manufacturing Process

2. Manufacturing Process

2.1. Ceramic Manufacturing Process Value Chain

Khurja has a 600-year-old tradition of pottery manufacturing and has by now become a major centre of the Indian Ceramic industry, with more than 494 units in the small-scale sector and one of the largest whiteware clusters in India.

Most pottery units in Khurja manufacture crockery (stoneware), HT/LT insulators and decorative wares (stoneware). There are only a few specialized units that manufacture sanitary wares, bone china and chemical porcelain.

The following figure indicates the value chain of ceramic manufacturing industry, from raw materials to final products (end use):

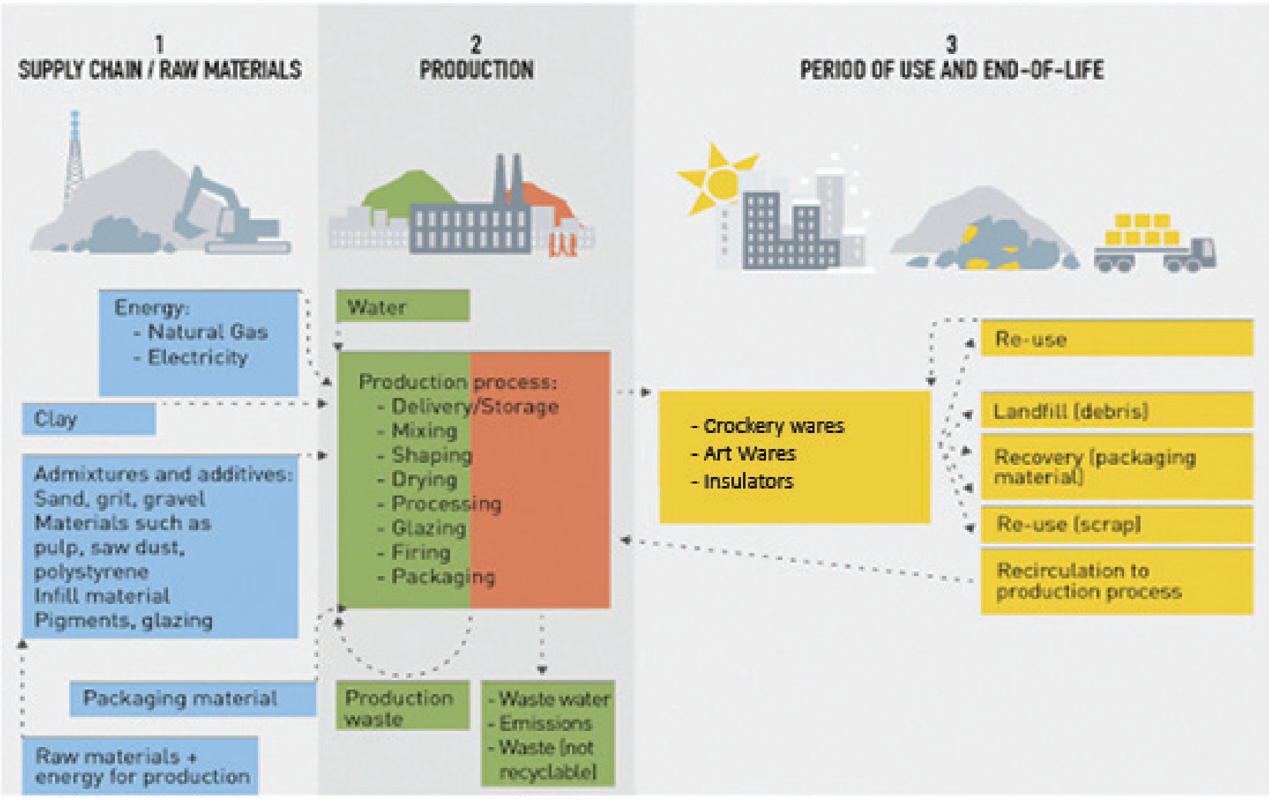


Figure 2: Ceramic Manufacturing Process Value Chain

The major operations in ceramic manufacturing process are described below:

i) Raw Materials: This includes the raw materials and energy used for production.

a. **Raw material for production:**

Most of the units in Khurja cluster procure raw material through local agents in Khurja. In addition to these, there are other raw materials and chemicals that are used in the glazes such as zinc oxide, zirconia, barium carbonate, chromium oxide and soda feldspar. A few pottery units are sufficiently large and financially strong, so as to procure the raw material directly from places like Rajasthan, Delhi, Ahmedabad, Bikaner, Bihar, etc. and certain chemicals from Agra and as such, they do not have to deal with intermediary traders.

b. Energy for production: Ceramic manufacturing units use both electrical energy and thermal energy for production. Electrical energy constitutes 15-20% of the overall consumption. Main areas of usage are in kiln, ball mills, pump and compressor. Major amount of thermal energy is used as natural gas in kiln firing.

• Energy Use in Pottery Units:

	% consumption	
Stage of production	With drying	Without drying process
Processing of raw materials	5-6	20
Fabrication of pieces	8-10	
Drying process	20-25	80
Firing operation	60-65	

ii) Production Process:

There are three broad steps in manufacturing ceramics: preparation of the raw materials, preparation of the greenware and firing.

1. Clay is ground and mixed in a mixer. The clay is then mixed with water and made workable.
2. Clay is poured into moulds, extra material is cleaned or trimmed. Additional parts such as handles added if required.
3. The greenware is loaded onto trays and then placed in kilns. Terracotta and earthenware are fired immediately whilst porcelain and some other products are glazed and then fired.

iii) Final Products usage: The products are used in items such as crockery wares, art wares, electrical goods, sanitary wares, tiles, household items, etc.

2.2. Process flow for ceramic pottery manufacturing

The majority of the units in Khurja Ceramic sector manufacture a wide variety of crockery, art ware and electrical goods. Mostly, whiteware is produced in Khurja, but there is also a small amount of high-fired terracotta being produced for export. Most pottery units in Khurja manufacture crockery (stoneware), HT/LT insulators and decorative wares (stoneware). There are only a few specialized units that manufacture sanitary wares, bone china and chemical porcelain.

Ceramic pottery manufacturing process

The various types of crockery, art ware and electrical goods manufactured here largely have a common process of production, which is shown below. Depending on the type of product, there may be a slight change in the composition of the raw material.

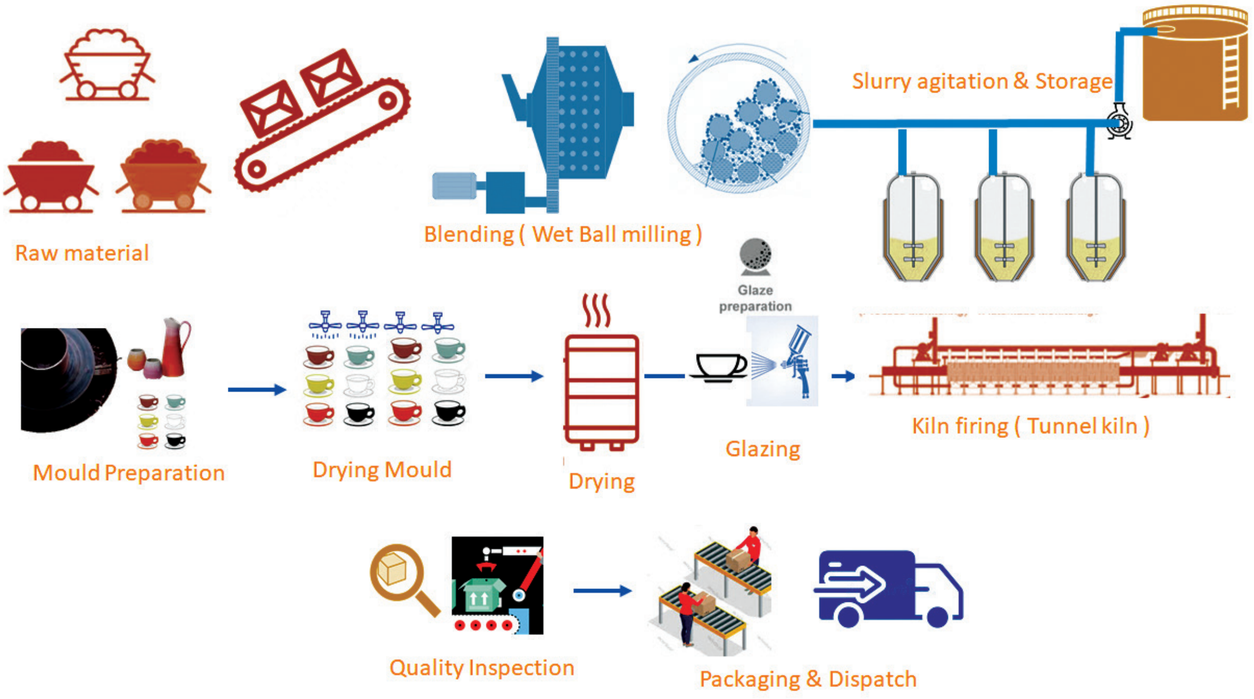


Figure 3: Ceramic Pottery Manufacturing Process Flow

Raw material blending:

Ball mills and blungers are used for grinding. Raw materials such as china clay, plastic ball clay, potash, feldspar and quartz are mixed with water in proper proportions and grinded in a ball mill to form a homogenous mixture, i.e., slurry. Ball mills have pebbles and inner lining; depending on raw material quality and quantity, the blending time varies; hence, ball mills are operated in batch process.

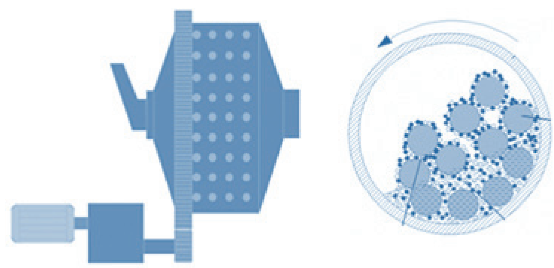


Figure 4: Raw Material Blending (Wet ball milling)

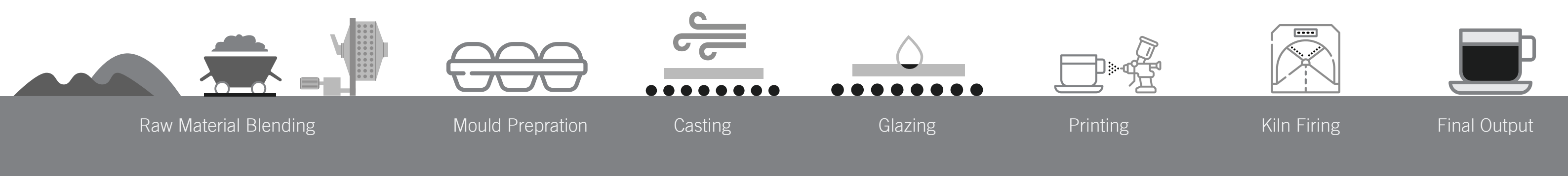


Figure 5: Slip agitation and storage

Slurry Agitation and transfer system:

After completion of wet grinding in ball mills, the slurry is stored in the underground tanks fitted with agitator motor in each tank, for continuous mixing to maintain uniformity and avoid settling of solid particle. Slurry is then pumped to mould through a slurry transfer pump.

Mould Preparation: In this section the moulds are prepared as per the requirement of shape and size casting. The case mould is made in the moulding section by mixing of water with Plaster of Paris in a proper proportion. Once the mould is prepared, it is to be dried to remove the excess water from the mould. This stage is crucial to increase the life of the mould.

Figure 6: Mould Preparation

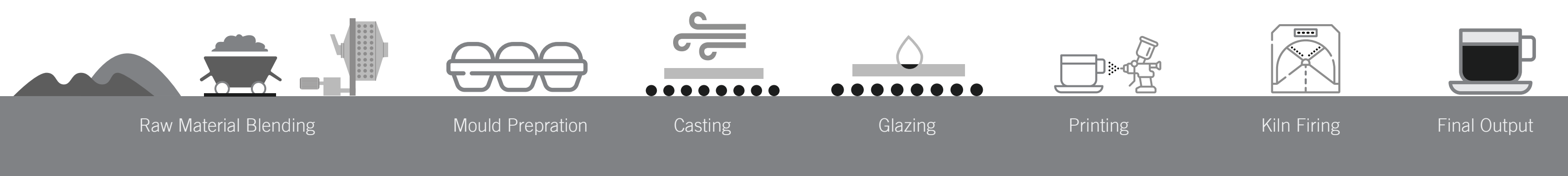
Figure 7: Cast House

Casting:

The slip is poured into the mould and allowed to form the casting layer on the mould. Casting is removed from the mould. This cast is allowed to dry in atmospheric temperature for few hours to one day in natural drying using the ceiling fans.

Glazing: Glaze is separately prepared from Glaze ball mill by grinding the following components Silica, Alkalis, Lead, Boron, Zirconium, Iron, Chromium and Cobalt stored in storage tanks. The pottery is dried from the casting section enters glazing section; the cast is then dipped in glaze. After glazing, sprayed ware is loaded in kiln car for firing.

Figure 8: Glazing



Kiln Firing:

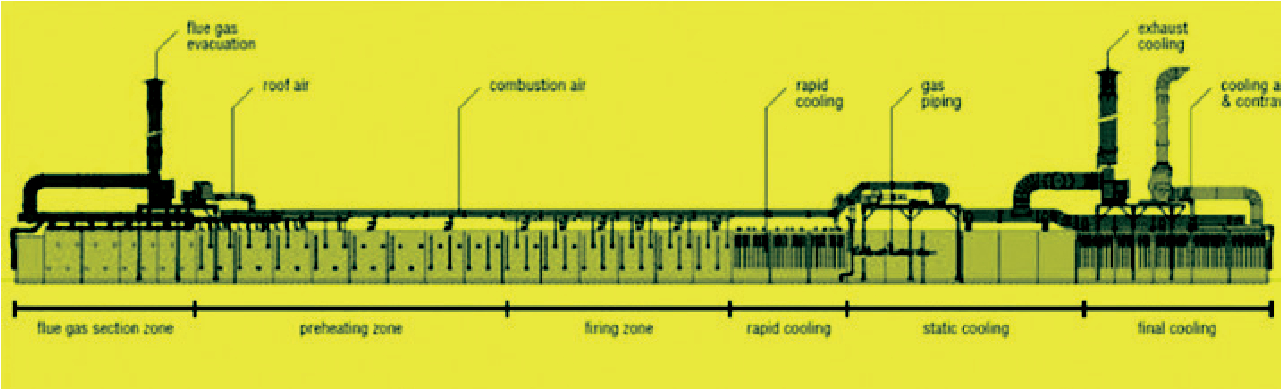


Figure 9: Tunnel Kiln firing

After glazing, dust and other impurities are removed from the ware through blowing air, then the kiln car with wares is sent to tunnel kiln for firing. In preheating zone, mechanically and chemically combined water has been removed from the ware. At firing zone, at 1,100-1,250°C, all the raw materials are fused together and glaze is fused evenly. In the cooling zone, sudden cooling is done to create a glossy surface. After firing, the wares are sent to quality inspection.

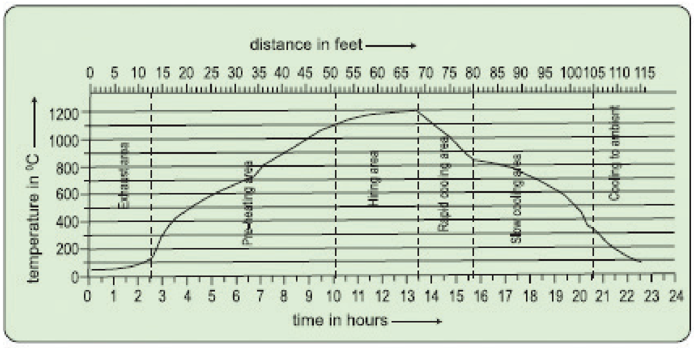


Figure 10: Firing Cycle of kiln

The kiln firing is done in two stages

1) Preheating zone (500-750°C)

2) Firing zone (1,100-1,250°C).

After firing, cast are cooled in two zones:

1) Rapid cooling zone (600- 900°C)

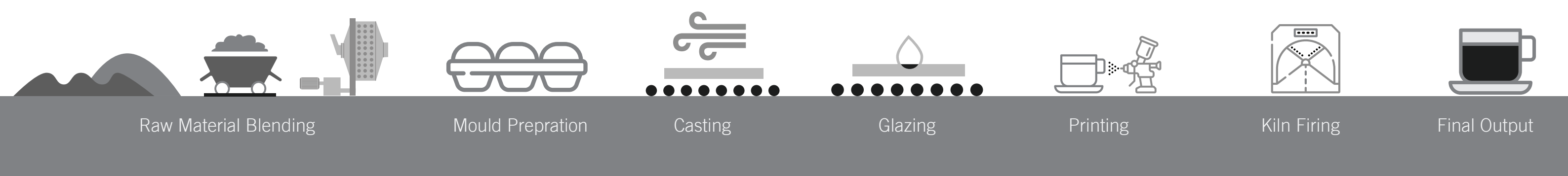
2) Cooling zone (200- 500°C)

Quality Inspection:

In this stage of the process, all wares from the kiln are inspected and sorted according to the defects. If ware is defect-free, it will be sent to the packing section for packing.

Packing:

It is the final stage of the pottery ware manufacturing/production process. All pottery ware that pass quality standards are packed and dispatched to the warehouse.



2.3. Energy consumption in pottery ware manufacturing units

The pottery ware industry uses energy in the form of thermal for kiln firing, and electricity for process and utilities. The cost of energy sources used in the industry is increasing continuously, which in turn increases the processing expenses and, therefore, the product cost. Energy costs typically constitute 30-40% of the overall manufacturing cost. Following table provides an overview of major energy consuming areas pottery ware unit:

Table 4: Energy consumption overview for pottery ware unit

S No.	Equipment	Process Requirement	Primary Energy
1	Ball mill	Grinding	Electricity
2	Pumps	Slurry Transfer	Electricity
3	Ceiling fans and compressed air	Casting	Electricity
4	Ball mill and compressed air	Glaze preparation	Electricity
5	Tunnel kiln	Firing	NG

Energy consumption of pottery ware unit depends on capacity of tunnel kilns, and the level of automation in kiln and ball mills. The industry uses energy in the form of fuel for kiln firing and electricity for process and utilities.

Energy costs typically constitute 30-40% of the overall production cost. The share of primary energy (thermal and electrical) in a typical manufacturing unit is primarily dominated by thermal energy.

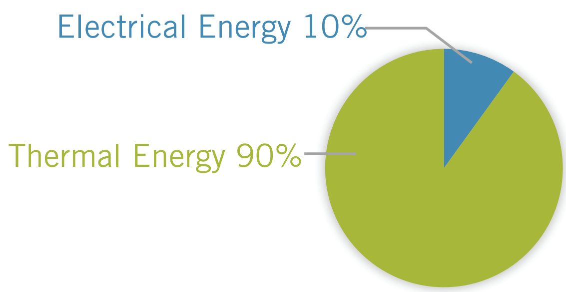


Figure 11: Energy Cost Breakup

The major portion of energy consumption in a typical pottery ware manufacturing unit goes to the use of natural gas for firing in tunnel kiln. A certain portion of energy consumption goes to the blending and other utilities.

In pottery ware unit, the major energy consuming equipment includes tunnel kiln, ball mills, air compressors, lightings, pumps and motors. The figure below highlights the overall energy balance of a ceramic unit.

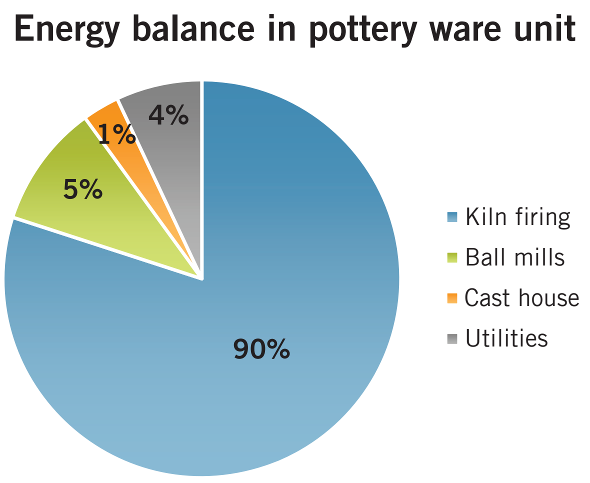
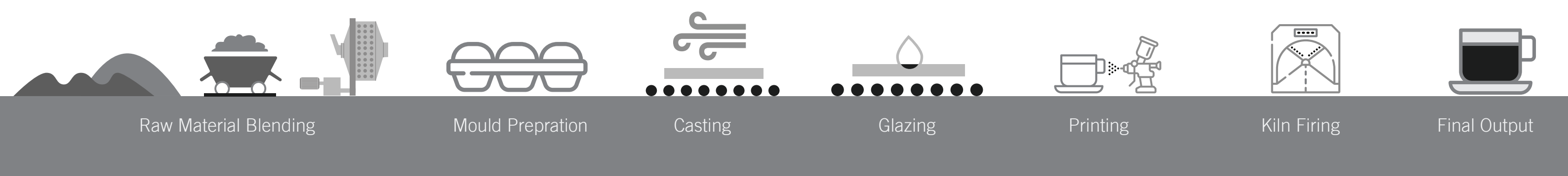


Figure 12: Energy Balance in pottery manufacturing unit

Pottery ware manufacturing units in Khurja have seen significant improvement in energy and productivity in the past few years due to increased levels of automation and technology development. This has helped in improving product quality and operating conditions while reducing product losses, maintenance time, manpower requirement and energy consumption. Innovations like optimization of ball mill operation using PLC and VFD have helped immensely. The units have also installed energy efficient compressors and LED lighting, all of which have led to a conservation of energy as well as improvement in operating conditions.



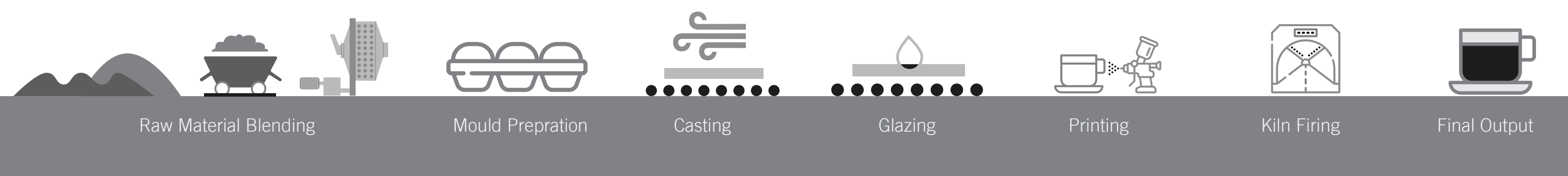
2.4. Technology Status in Khurja Ceramic Sector

Most of the units in Khurja have expanded over time with upgradation of equipment and technologies, expansion and automation and process control. Many of the units have also adopted latest technologies in kiln firing and other important areas.

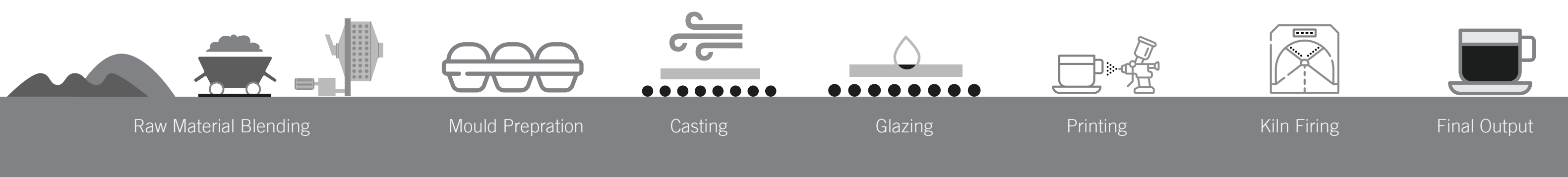
Following is the technology status for the units in Khurja ceramic sector:

Table 5: Technology Status – Khurja Ceramic Sector

Sr. No	Area	Current Status
1	Energy Sources	Thermal energy accounts for 80 to 90% of total energy use in ceramic units. Electrical Energy – The units procure electricity from distribution companies in Uttar Pradesh (depending on region) and pay in the range of INR 7-8/kWh. Thermal energy is mostly met through natural gas. In Khurja, the natural gas is available through City/Industrial Gas Distribution Network (Adani Gas). In pottery ware manufacturing natural gas is used in tunnel kiln firing.
2	Kiln Firing	The pottery ware manufacturing units in Khurja use continuous firing techniques in tunnel kiln at 1,100-1,250°C. Few of the units have upgraded kiln and have incorporated various energy conservation measures such as automation, low thermal mass kiln cars (in tunnel kiln), etc. However, not all the units use Waste Heat Recovery and energy efficient burners and this presents a good opportunity for upgradation from conventional burners.
3	Blending	Units use ball mills to blend the raw material and prepare slurry. Many units have installed VFD on ball mills and some units have changed inner lining and grinding balls with alumina. However, not many units have implemented blunger technology in place of ball mills and there is a lot of potential for energy saving in blunger technology implementation.
4	Slurry Transfer system	The slurry is transferred from slurry collection tank to casting house using the electro mechanical driven pump. At present, the units are using local slurry pumps, leaving a potential for implementation of energy efficient slurry pumps.
5	Cast house	In pottery ware units, castings that are made from mould are dried under natural air through ceiling fans. The ceiling fans installed are conventional fans consuming 70 W power at full speed. Potential exists to replace with energy efficient fans which consumed 50% less power than conventional ceiling fans
6	Others	The other equipment and technologies to support process are pumping, electrical distribution, compressed air systems and others.
6a	Pumps	The pumps are installed for water and slurry transfer. The efficiency of the pumps needs to be evaluated, as many pumps are old. There is a good scope for improvement by avoiding throttling (installation of VFD, trimming of impeller) or by installation of high efficiency pumps (more than 70% efficiency).



Sr. No	Area	Current Status
6b	Electrical Distribution	Power Factor: Most of the units have installed APFC for power factor improvement. However, there are certain opportunities which units can tap in electrical distribution, such as installation of energy efficient transformers, optimal loading of transformers, installation of energy efficient motors, installation of VFD, soft starters, auto star delta conversion, power quality, etc.
6c	Compressed Air	Compressed air in units is used for instrument air application, mould preparation (pottery ware) and glazing. However, there are certain opportunities which units can tap in compressed air distribution and utilization, such as aluminium piping for leakage reduction, transvector nozzle in cleaning applications, etc.



Energy Efficiency Opportunities

3. Energy Efficiency Opportunities

3.1. Energy efficiency in pottery ware units

The ceramic pottery ware manufacturing operations are highly energy intensive. The kiln firing and raw material blending are important and energy consuming areas for any manufacturing unit and improving energy efficiency in these areas is critical.

Over the years, there has been significant technology improvement in process and utilities area and units have been able to improve the energy efficiency in their operations. However, various opportunities exist for units to improve their energy efficiency and to be competitive and have environment-friendly operations; energy efficiency is critical to achieve these goals.

The manufacturing units have been implementing various energy conservation measures across various production process. The energy efficiency at a unit can be viewed at two levels – equipment & component level and process level. The energy efficiency at equipment or component level can be achieved by adopting various new technologies, preventive maintenance, optimum utilization, or replacement of old equipment with new and energy efficiency equipment. In addition to improving energy efficiency at equipment or component level, the Khurja ceramic cluster has made significant improvements in process level efficiency through various energy conservation measures such as automation, process control & optimization, process integration or implementation of new and efficient process.

Often, energy efficiency measures when implemented at the ceramic tile/pottery ware manufacturing operations, not only result in improvement in energy efficiency but also in productivity and quality improvement as well. To summarize, the energy efficiency strategy for Khurja Ceramic Sector can be focused at three levels:

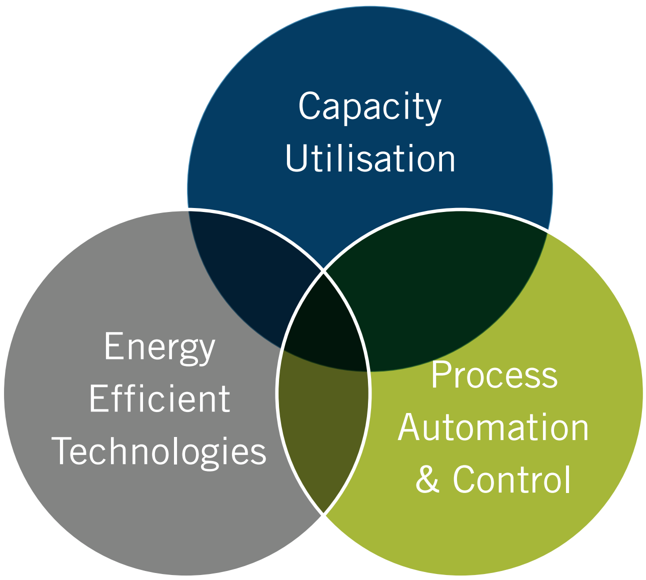
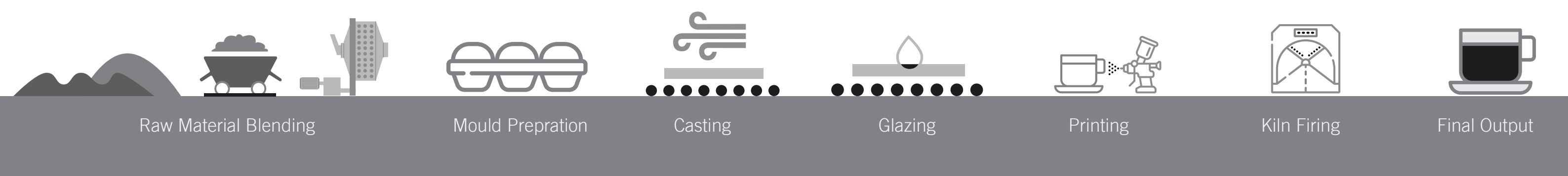


Figure 13: Energy Efficiency Approach – Khurja ceramic unit



3.2. Energy Efficiency Measures

There are various energy consuming areas within a pottery ware manufacturing unit which can be classified as primary energy consuming areas, such as thermal energy for kiln firing, raw material blending in ball mill, utilities and other processes of the unit. The following figure provides an overview of energy usage in a pottery ware unit:

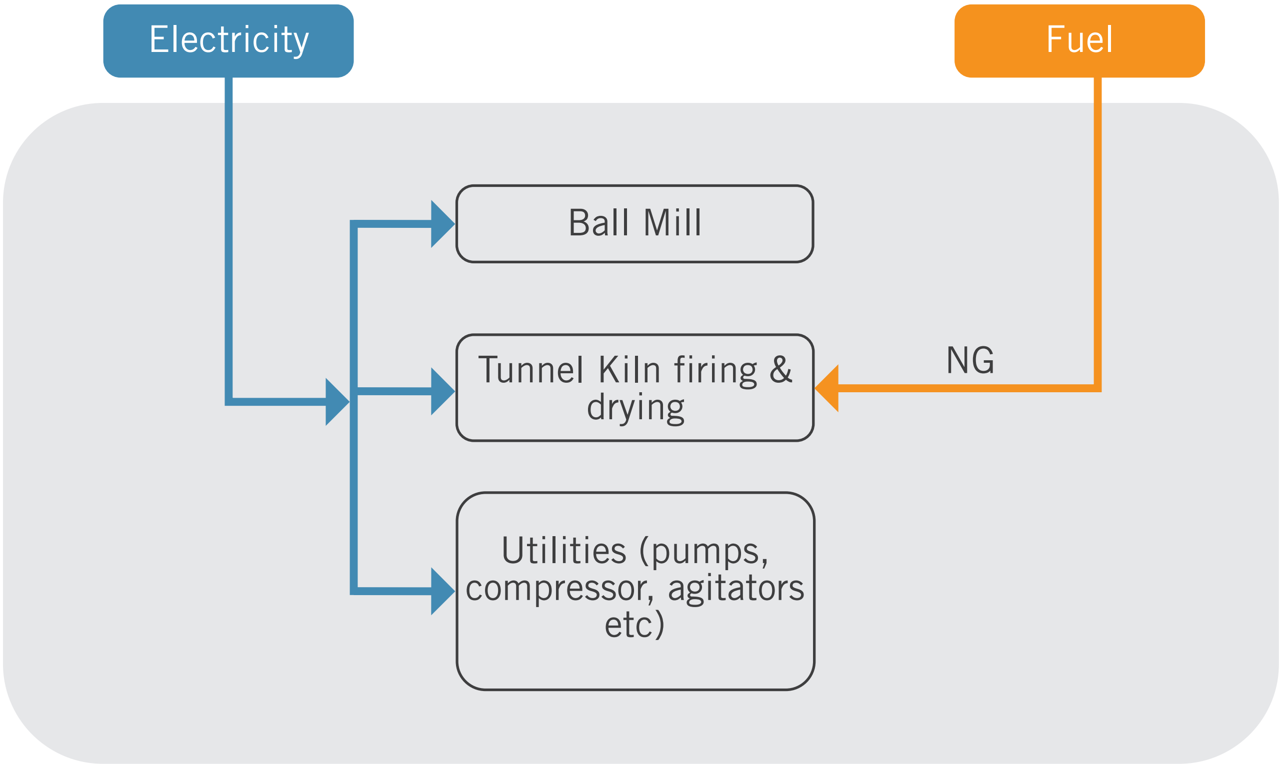


Figure 14: Pottery ware manufacturing unit – Energy Consumption Overview

The following section provides an overview of some of the key energy efficiency measures in the major energy consuming areas in a ceramic pottery ware unit. In further sections, some of the latest applicable technologies are covered.

3.2.1. Energy Efficiency in Tunnel Kiln firing

Kiln firing is energy intensive and an important process as raw casting in pottery ware units are required to be fired at 1,100-1,250°C for fusion of raw materials. The energy efficiency in kiln is an important area as it accounts for approximately 80 to 85% of the total energy cost. Following are some of the key energy conservation measures in tunnel kiln firing and insulation system:

Table 6: Energy Efficiency Measures in Kiln Firing Systems

Energy Efficiency in Kiln	
Firing	
Use of energy efficient burner	Recuperation (use of heat hot air from cooling zone as combustion air)
Excess air control system	Kiln automation & control
Maintaining adequate kiln temperature	Maintaining adequate kiln draft
Heat Losses reduction	
Improved insulation	Low thermal mass in kiln car
Proper kiln maintenance	Waste heat recovery from exhaust flue gas
Energy efficient coating for reduction of radiation loss from kiln	Energy efficient combustion and rapid cooling blowers
VFD on kiln combustion blowers	
Management Systems	
Effective monitoring of key parameters (fuel consumption, production, energy)	Root cause analysis

3.2.2. Energy efficiency in raw material preparation process

Pottery ware manufacturing process involves blending of raw materials to form slurry, slurry storage and transfer system, coasting house for shaping and glazing section. Some of the possible energy efficiency measures in process areas in pottery ware unit are highlighted in the table below.

Table 7: Energy efficiency in raw material preparation process

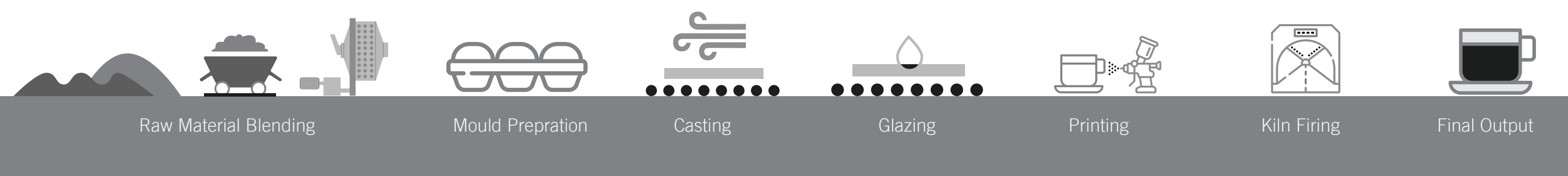
Energy Efficiency in Blending Systems (Ball mills)	
Blending (Ball mills)	
Maintaining the adequate media size and composition	Operating the ball mill at 65% - 75% of critical speed
Alumina lining inside the mill	High alumina grinding balls
Automation & control of ball mills through timer and PLC	Installation of VFD on ball mill motors
Energy efficient ball mill motor drive	V-belt to flat cogged belt
Slurry Agitation and transfer system	
Use of energy efficient agitators	Energy efficient motors installation for agitation
Delta to star conversion of lightly loaded motors in agitators	Energy efficient slurry transfer pumps
Cast house	
Use of energy efficient BLDC ceiling fans for drying the raw ware	
Others	
Use of blunger technology in place of ball mill	Use of solar energy for pumping
Replacement of manual jigger with double roller head automatic jigger	

3.2.3. Energy Efficiency in Utilities

The utilities such as compressed air, electrical distribution systems, lighting and other areas are also energy consuming sections in a pottery ware manufacturing unit and here too, several energy efficiency improvement opportunities are available. The following table provides an overview of possible energy efficiency opportunities in utilities areas:

Table 8: Energy Efficiency in Utilities

Energy Efficiency in Utilities	
Compressed Air Systems	
Use of energy efficient screw compressors	Transvector nozzle for cleaning purpose
Optimum generation pressure	Use of VFD in compressor
Avoiding compressed air leakage	Energy efficient air dryers
Auto drain valves	Proper distribution systems
Pneumatic equipment to electric equipment	Appropriate ventilation in compressor room
Electrical Distribution Systems	
Automatic power factor controller	Harmonic filters
Energy efficient transformers	Optimum voltage and line balance
Optimum loading of transformers	Energy monitoring systems
Pumps	
Energy efficient pumps	Trimming of impellers
VFD for pumps	Pumping system layout
Motors	
Energy efficient motors	Star to delta conversion
kVAr compensators	Preventive maintenance
Optimum loading	Belt driven to direct coupled
Lighting & Fans	
Use of BLDC ceiling fans	Use of LED
Use of natural light (light pipe)	
Renewable Energy	
Solar PV installation	Hybrid solar-wind system



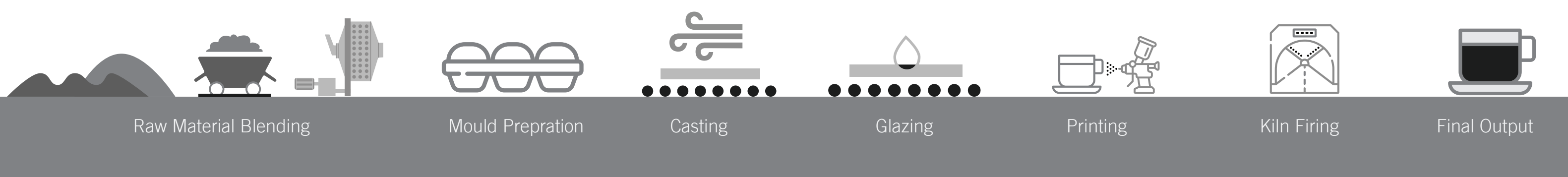
Energy Efficient Technologies – Case Studies

4. Energy Efficient Technologies – Case Studies

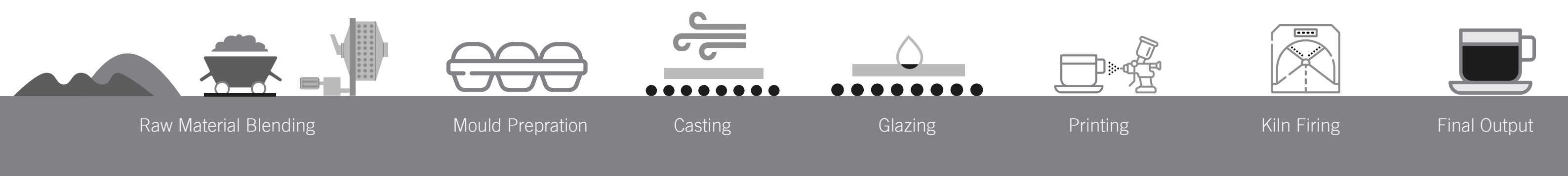
The following chapter focuses on some of the above-mentioned technologies which are promising and have been implemented in a few ceramic units and have great potential for implementation (Case Study). These technologies are described in more detail and wherever possible, a case reference from a unit that has implemented the technology has been included. In most of the examples, typical energy saving data, Greenhouse Gas (GHG) emission reduction, investments, payback period, etc., have been highlighted. As these case studies are included to provide confidence to ceramic units to implement technologies, the applicability of these measures may vary from unit to unit and further technical and financial analysis would be required for individual units. Following case studies are mentioned in detail in the subsequent section:

Table 9: Case Studies for Khurja ceramic Sector

Sr. No.	Technologies
	Ceramic Kiln Firing and Insulation
1	Waste heat recovery in tunnel kiln
2	Energy efficient coating inside kiln to reduce the radiation losses in kiln and reduce fuel consumption
3	Low thermal mass for reduction of kiln car losses in pottery ware units
4	Upgradation of oil-based firing system with natural gas firing system in tunnel kiln
	Raw Material Blending
5	Reduction in ball mill power by installation of VFD on ball mill drive
6	High speed blunger in place of ball mill for raw material grinding process
7	High alumina media in glaze ball mill in the place natural stone/pebble
8	Replacement of manual jigger with double roller head automatic jigger
	Utilities
9	Installation of VFD in screw compressor to avoid unloading
10	Installation Screw Compressor with VFD in place of reciprocating compressor
11	Energy conservation in compressor by modifying airline system
12	Transvector nozzle in compressed air hose pipe for mould cleaning application
13	Retrofit of Energy Efficient ceiling fans in place of conventional fans
14	Installation of on-off controller system in agitator motor
15	Retrofit of energy efficient motors in place of old rewinded motors
16	Power factor correction & harmonic mitigation at main LT incomer



Sr. No.	Technologies
	Renewable Energy
17	Solar rooftop system
	New & Innovative technologies
18	Solar-Wind hybrid system
19	Installation of Energy Efficient burners in place of existing old conventional burners in Kiln firing



4.1. Case studies in ceramic kiln

4.1.1. Waste heat recovery in tunnel kiln

Baseline details

The unit has installed a tunnel kiln of 10 TPD capacity for firing pottery ware moulds. The open flame tunnel kiln is a continuous type kiln, wherein the raw product is fed at one side and on the other side the finished product is taken out. The raw product undergoes firing and cooling cycles, as it moves from the front end to the back end of the kiln. Kiln performance is directly related to the temperature maintained & thermal efficiency at various zones of the kilns. There are three zones in horizontal kiln/ tunnel kiln: preheating zone, firing zone & cooling zone. The temperature of the combustion air plays an important role in increasing the thermal efficiency of kiln. Exhaust heat is released from tunnel kiln by two ways: the first is flue gas released at a temperature of around 200-220°C and the second is hot air from final cooling zone at a temperature of around 120°C. At present, exhaust gas from tunnel kiln is released to atmosphere and combustion air is used at an ambient temperature.

There is a potential to reduce the fuel consumption in tunnel kiln by using preheating combustion air. Using the hot air from final cooling zone as a combustion air in tunnel kiln will lead to a decrease in fuel consumption.

Implementation Details

Hot air which is exhausted from the final cooling zone of tunnel kiln at a temperature of around 120°C, can be used directly as a combustion air in tunnel kiln. This will increase the thermal efficiency of firing and lead to savings of about 2 to 3% on total natural gas consumption in tunnel kiln.

Results:

- Reduced specific energy consumption for pottery ware products manufactured.
- Increased thermal efficiency.
- Reduced fuel (natural gas) costs by 2-5%.

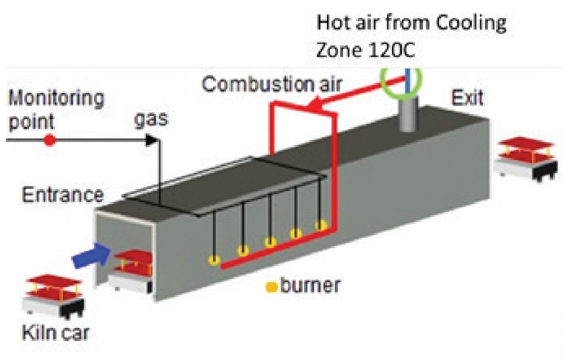


Figure 15: Implementation of WHR

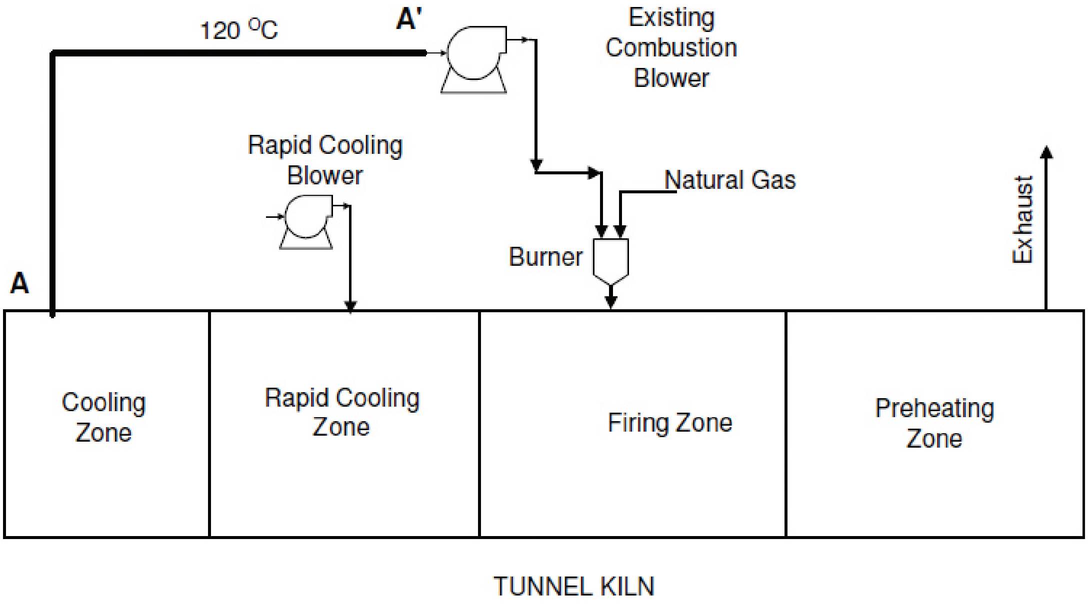


Figure 16: Hot air from Cooling Zone for Combustion air

In Khurja ceramic cluster, as majority units are crockery and pottery, the fuel consumption of the kilns is in the range of 850-1,300 SCM/day. The expected energy savings to be achieved by using hot air as combustion air in tunnel kiln is 594 Lakh kCal annually. The annual monetary saving for this project would be INR 1.98 Lakh, with an investment of INR 2 Lakh and a payback period of 12 months.

Table 10: Expected Cost Benefit Analysis – Waste heat recovery in tunnel kiln in pottery ware unit

Parameter	Value	UOM
Production	8.0	Ton/day
Natural Gas consumption before installation of WHR system	1,000	SCM/day
Inlet combustion air temperature (before)	40	°C
Inlet combustion air temperature (after installation of WHR system)	120	°C
Natural Gas Consumption after installation of WHR system	980	SCM/day
Operational hours	24	Hours/day
Operational days	330	Days/annum
Saving of natural gas	6,600	SCM/ annum
Cost of natural gas	30	INR/SCM
Monetary saving	1.98	INR Lakh/annum
Investment	2.00	INR Lakh
Simple payback period	12	Months

Energy & GHG Savings

Annual Thermal Savings
594 Lakh kCal

Annual Energy Savings
5.9 TOE

Annual GHG Savings
17.8 T CO_2

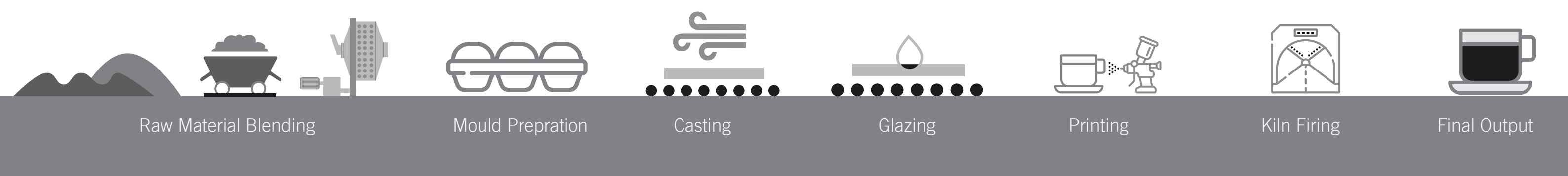
Replication Potential

Implementation can be done in all other units where similar kilns are used for production. However, periodic monitoring and measurement of kiln excess air level in flue gas is essential.

Technology Supplier Details:

Table 11: Technology Supplier Details – Waste Heat Recovery in kiln

Description	Details
Name of Company	Neptune Industries Pvt Ltd
Contact Person	Mr Chandresh
Designation	General Manager
Contact	Mobile: +91-9879206992
Address	VT Industrial Park, Ahmedabad Mehsana Highway, Jagudan, Mehsana 382710 (Gujarat) INDIA.



4.1.2. Energy efficient coating inside kiln to reduce the radiation losses in kiln and reduce fuel consumption

Baseline details

The unit has installed a tunnel kiln of 10 TPD capacity for firing pottery ware moulds. Maximum efficiency of the kiln is in the range of 30% to 40% and remaining 60% to 70% are losses from the kiln. Radiation losses accounts for 15% to 20% of total energy loss. In a kiln, the surface temperature at firing zone is in the range of 80 to 100°C. Minimizing the radiation loss from the kiln surface will result in reducing the fuel consumption.

The figure shows the various zones in kiln, the surface temperature recorded at various zone is indicated in below table.

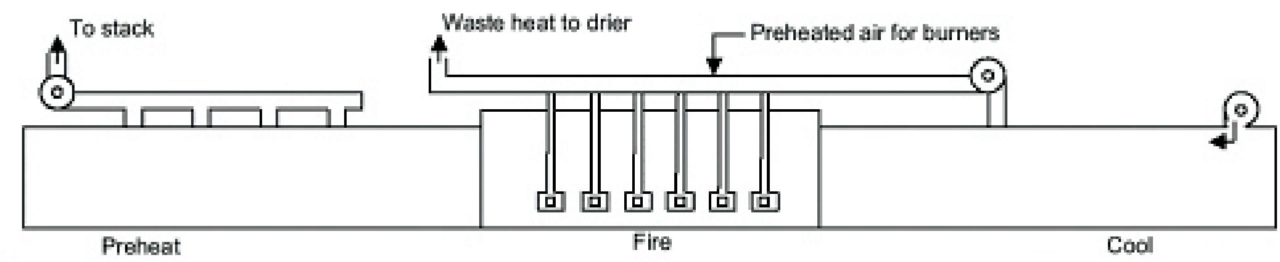


Figure 17: Various Zones in Kiln

Table 12: Zone wise average surface temperature in Kiln

Zone	Left wall Avg (°C)	Right wall Avg (°C)
Pre Heating	57	58
Firing	83	94
Cooling Zone	72	62

Figure 18: Surface temperature at firing zone in kiln

In order to reduce the radiation losses from kiln surface, the ceramic unit have applied energy efficient coating inside the kiln at firing zone and preheating zone. This has resulted in reduction in radiation losses and fuel consumption.

Implementation Details

The energy efficient coating is most suitable for ceramic kiln. It is applied in the kiln on bricks as well as on the exterior of the kiln. The coating is applied in multiple layers and allowed to dry. The coating can withstand temperature up to 1,500°C. This will reduce the kiln surface temperature by 10 to 15°C.

Table 13: Zone-wise temperature after applying energy efficient coating in kiln

S.No	Before	After (Expected)
1	Preheating: 58°C	Preheating: 45-50°C
2	Firing Zone: 90°C.	Firing zone: 75-82°C

Results:

- ❖ Saving of up to 2 to 5% in fuel consumption.
- ❖ Life of coating would be 4-5 years.
- ❖ Life of ceramic fibre and refractory bricks will increase resulting in indirect saving.

Cost Benefit Analysis

In Khurja ceramic cluster as majority units are pottery & crockery units, the fuel consumption of the kiln is in the range of 850-1,300 SCM/day. The expected energy savings to be achieved by use of energy efficient coating is 891 Lakh kCal annually. The annual monetary saving for this project is INR 2.97 Lakh, with an investment of INR 3.00 Lakh and a payback period of 12 months.

Table 14: Cost benefit analysis – Energy efficient coatings in kiln in pottery ware unit

Sr. No.	Particular	Value	UOM
1	Production	8.0	Tonne/day
2	Natural gas consumption (before)	1,000	SCM/day
3	Natural gas consumption (after)	970	SCM/day
4	Working days per annum	330	Days
5	Savings in Natural Gas Consumption	9,900	SCM/annum
6	Cost of Natural Gas	30	INR/SCM
7	Savings	2.97	INR Lakh/annum
8	Investment (for firing & preheating zone coating area of 1,000 sq ft)	3.00	INR Lakh
9	Simple payback period	12	Months

Energy & GHG Savings

Annual Thermal Savings
891 Lakh kCal

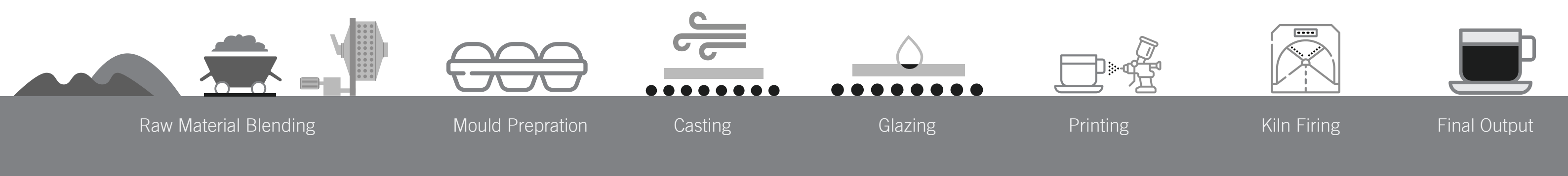
Annual Energy Savings
8.9 TOE

Annual GHG Savings
26.7 T CO_2

Technology Supplier Details:

Table 15: Technology Supplier Details – Energy efficient coatings in kiln

Description	Details
	Supplier 1
Name of Company	Innovative Surface Coating Technology, Nagpur
Contact Person	Mr Nikhilesh R
Designation	Co-Founder
Contact	Mobile: +91-8788384913
	Supplier 2
Name of Company	HIR Industries, Himatnagar, Gujarat
Contact Person	Mr David Patel
Designation	Director
Contact	Mobile: +91-9099021334



4.1.3. Low thermal mass for reduction of kiln car losses in pottery ware units

Baseline details

The unit has installed a tunnel kiln of 10 TPD capacity for firing pottery ware moulds. The unit has installed a tunnel kiln for firing pottery ware moulds. The open flame tunnel kiln is a continuous type kiln, wherein the raw product is fed at one side and on the other side the finished product is taken out. The raw product undergoes firing and cooling cycles, as it moves from the front end to the back end of the kiln. The material movement through the tunnel kiln is by kiln cars, run on rails. The kiln cars are like train bogies designed to hold the products. Natural gas is used as a fuel in tunnel kiln. The kiln cars are constructed with refractory and insulating bricks. Due to high thermal mass, kiln cars consume considerable amount of heat energy supplied to the kiln.

Figure 19: Existing High Thermal mass refractory in Kiln car

Implementation Details

The weight reduction of the kiln cars gives the significant amount of energy savings in tunnel kiln. Low thermal mass materials (LTM) are now being used for kiln car construction, which reduces the weight of the kiln car considerably. Weight of car furniture was reduced from 465 kg per car to 358 kg per car (23% weight reduction).

Figure 20: Low thermal Mass in Kiln car

Results:

- Reduced specific energy consumption in tunnel kiln.
- Increased thermal efficiency.
- Reduced fuel (natural gas) costs by 10-15%.

Cost Benefit Analysis

In Khurja ceramic cluster as majority of units are crockery units, the fuel consumption of the kiln is in the range of 850-1,300 SCM/day. The expected energy savings to be achieved by use of low thermal mass in kiln car is 2,228 Lakh kCal annually. The annual monetary saving for this project is INR 7.42 Lakh, with an investment of INR 7.50 Lakh and a payback period of 12 months.

Table 16: Cost benefit analysis – Low Thermal Mass

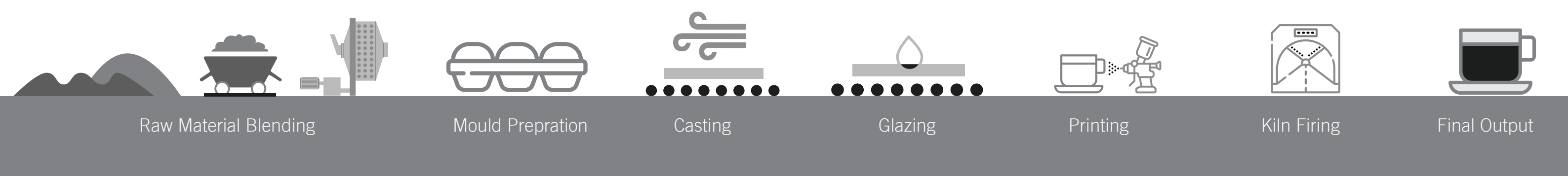
Description	Value	Units
Production	9.0	Tonne/day
No of kiln cars	30	Nos.
Natural Gas Consumption (before)	1,000	SCM/day
Natural Gas Consumption (after)	925	SCM/day
Working days per annum	330	Days
Savings in Natural Gas Consumption	24,750	SCM/annum
Cost of Natural Gas	30	INR/SCM
Monetary saving	7.42	INR Lakh/annum
Investment	8.50	INR Lakh
Simple payback period	14	Months

Energy & GHG Savings

Annual Thermal Savings
2,238 Lakh kCal

Annual Energy Savings
22.30 TOE

Annual GHG Savings
66.60 T CO_2



Replication Potential

Low thermal mass car technology can be replicated in all the ceramic units in the cluster. It is advised to take proper care regarding the strength of the kiln car during the redesigning. Implementation of the technology can be done in one kiln car and later replicated to the other kiln cars based on the results.

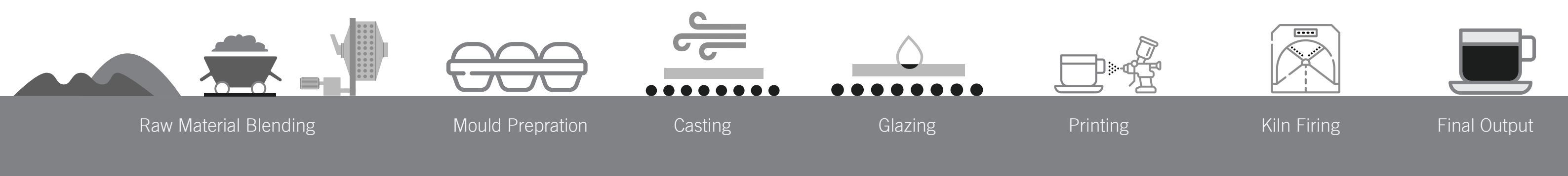
Merits and limitations of the technology

- Ceramic Fibre is a health hazard and is considered to be carcinogenic. Ultralite material is benign material and has no side effects to living beings.
- Periphery wall required for implementation of Ultralite insulation.
- 5 mm layer of ceramic paper is required to be installed at the base of the kiln car to ensure that Ultralite material does not leak through any possible leaks in the base of the car 10 mm layer of ceramic fibre required on top of the kiln car for cover purposes.

Technology Supplier Details:

Table 17: Technology supplier details Low thermal mass

Description	Details
Name of Company	Interkiln Advanced Technical LLP
Contact Person	Mr Kushang Sanghavi
Designation	Managing Partner
Contact	Mobile: + 91- 9998980044
Email – ID	kushang@interkiln.co.uk
Address	Sanghavi Chamber, Near Navrangpura Police Station, Opp. Sweet Home Shop, Navrangpura, Ahmedabad – 380009. Gujarat. India.



4.1.4. Upgradation of oil-based firing system with natural gas firing system in tunnel kiln

Baseline details

In few ceramic potteryware manufacturing process in Khurja, fuel oil fired tunnel kiln is used in firing process. A typical tunnel kiln operates continuously, and number of products per day largely depends on overall production capacity and market demand. Few of the tunnel kiln units use fuel oil while other units use natural gas. These kilns are constructed traditionally without any scientific inputs. Traditional tunnel kilns have different geometrical shape depending on the user convenience, quantity of products to be fired and space availability within the factory premises. Most of the tunnel kilns are built using ordinary red fire clay/IS–8 brick with minimal insulating arrangement to avoid structural heat losses.

Flue gas released from the kiln is at a temperature of over 800°C and used for pre-heating of the product before exhausted through chimney. Combustion air is used at ambient temperatures. The kilns use only temperature indicators to monitor temperature of kiln chamber; no other instrumentation is used for monitoring and controlling of process parameters.

The unit has six numbers of burners used during firing; and all six burners continue during firing period. Generally, the firing temperature is maintained constant after attaining maximum firing temperature (1200°C) depending on the products under firing without any flame out. The firing practices are same across different tunnel kilns. There are no proper fuel train and air train with monitoring instrument for fuel and airflow; hence the units do not keep records of key operating parameters. The fuel combustion is controlled through eye judgments and flame colour.

Figure 21: Tunnel Kiln

Implementation Details

The unit replaced existing fuel oil-based firing system with natural gas firing system in kiln with same capacity of production. This switch over helped in reducing energy consumption and overall operating cost. Existing fuel oil based firing can be appropriately modified to use natural gas as fuel and improve its energy and environment performance. The proposed modification is designed to avoid any radical change in constructional and operational practices so that workers are receptive to these changes. The design is evolved considering the existing kiln condition and process requirement to ensure trouble free operation during firing cycle. Keeping safety of operating natural gas fired system, the existing firing system is modified with an appropriate gas and air train with low pressure burner and better instrumentation and controls for temperature measurements, fuel pressure, air pressure, air ratio, etc. The modified system will help in minimising human errors.

The followings are the salient feature of the modified natural gas-based firing system of tunnel kiln:

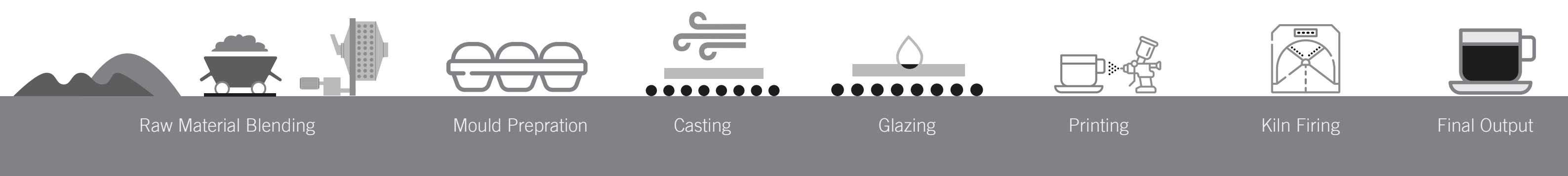
- Introduction of proper gas train and air train with safety devices
- Installation of compatible low-pressure burner
- Installation of proper measuring instruments to monitor and control main process parameters

Cost Benefit Analysis

The expected energy savings to be achieved by upgradation of oil-based firing system with natural gas firing system in tunnel kiln is 11,264 Lakh kCal annually. The annual monetary saving for this project is INR 52.56 Lakh, with an investment of INR 30.00 Lakh and a payback period of 7 months.

Table 18: Cost benefit analysis – Replacing fuel oil-based firing system with natural gas firing system in tunnel kiln

Description	Value	UOM
Production	9	Tonne/day
Fuel oil consumption (before)	1,230	Litre/day
Average cost of fuel (fuel oil)	61,500	INR/Day
Natural gas consumption (after)	1,085	SCM/day
Average cost of fuel (Natural Gas)	45,570	INR/day
Working days per annum	330	Days
Savings in fuel cost	52.57	INR/annum
Investment	30	INR Lakh
Simple payback period	7	Months



Energy & GHG Savings

Annual Thermal Savings

11,264 Lakh kCal

Annual Energy Savings

112 TOE

Annual GHG Savings

337 T CO_2

Technology Supplier Details:

Table 19: Technology supplier details – Natural gas firing system in tunnel kiln

Description	Details
	Supplier – 1
Name of Company	Adani Gas Ltd
Contact	Mobile: +91 79 27623264
Address	Plot no. - 79/1, Near Gopal ji Dairy, Village - Hajaratpur, Khurja, Uttar Pradesh - Pin Code - 203131
	Supplier – 2
Name of Company	M B Engineers
Contact Person	Mr Madan Bhati
Designation	Manager
Contact	Mobile: +91 9999957244
Address	Office :2266, Sector 03, Ballabhgarh ,Faridabad -121004 (HR) Works : Rajiv Colony, Near Fogat School, Sector 56A, Faridabad

4.2. Case Studies in Raw Material Blending

4.2.1. Reduction in ball mill power by installation of VFD on ball mill drive

Baseline details

The unit has installed a ball mill with 4 MT capacity having 15 hp drive for grinding of raw materials. The unit has installed a ball mill for grinding of raw materials. Ball mill is a batch type grinding process and used in all types of ceramic units. As per the process requirement, motor should run at full speed during the start of batch and after a particular time period, it should rotate at lower speed. Existing unit has no control system installed and operates directly on starter.

Implementation Details

A VFD is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. A variable frequency drive is a specific type of adjustable-speed drive which controls the speed of motor according to the requirement. The speed of the motor can be reduced by installing variable frequency drive on ball mill motor and operating speed can be programmed based on time. This will result in saving in power consumption to the extent of 15% in ball mills and blunger. This concept is applicable to glaze preparation ball mill in glaze section also. The project is successfully implemented in few ceramic units.

Results:

- Reduced specific energy consumption
- Reduction in electricity consumption in grinding process up to 15%

Cost Benefit Analysis

In Khurja ceramic cluster as majority of the units are crockery units, the maximum capacity of ball mill drive is 10 - 20 hp. The expected energy savings to be achieved by installing VFD in ball mill drive is 0.10 Lakh kWh annually. The annual monetary saving for this project is INR 0.66 Lakh, with an investment of INR 0.60 Lakh and a payback period of 12 months.

Table 20: Expected cost benefit analysis – Installing VFD in ball mill drive in Khurja pottery ware units

Parameter	Values	Units
Capacity of ball mill	4.0	MT
Ball mill motor capacity	15.0	hp
Power consumption	13.70	kW

Parameter	Values	Units
Operating hours	14	hrs/day
Operational days	330	days/annum
Ball mill annual energy consumption (before)	63,360	kWh/annum
Ball mill annual energy consumption after installation of VFD and optimizing the speed (15 % savings)	53,856	kWh/annum
Annual energy savings	9,504	kWh/annum
Annual monetary savings	0.66	INR Lakh/annum
Investment for VFD	0.60	INR Lakh
Simple payback period	12	Months

Energy & GHG Savings

Annual Electricity Savings

0.10 Lakh kWh

Annual Energy Savings

0.82 TOE

Annual GHG Savings

7.8 T CO_2

Replication Potential

The project can be implemented in all other units where a similar kind of ball mill is used. Also, all new units & green field projects can implement this project.

Technology Supplier Details:

Table 21: Technology Supplier details for VFD

Description	Details
Name of Company	Danfoss Industries Pvt Ltd
Contact Person	Mr Hiran Thakkar
Designation	Manager
Contact	Mobile:+91 7940327341
Address	No. 703, 7th Floor, Kaivanna Complex, Opp. Bank of Baroda, Near Panchwati Cross Road, Ahmedabad-380015

4.2.2. High speed blunger in place of ball mill for raw material grinding process

Baseline details

In ceramic pottery ware manufacturing process, ceramic body preparation is one of the important processes. This process includes mixing of raw material with water to produce slurry. Most of the units in the cluster use ball mills for this operation ranging 2 MT to 6 MT capacity. Generally, ball mills will consume more time in loading and unloading due to the nature of design, which provides small feeding at the top. This is turn requires more labour work. It also requires grinding media for the operation, which will consume half of the space, so less productivity is achieved when compared to blunger technology.

The starting torque of ball mill motor is high due to uneven starting load, which consumes more power than the normal operation.

Figure 22: Conventional Ball Mill system

Implementation Details

The turbo blunger is a heavy duty blunger used for rapid preparation of slip, achieving an 80% reduction in the blunging time compared to normal propeller-type dissolvers. It is operated by means of a special rotor fixed to the bottom of the tank, which propels the material against a ring of fixed paddles (1st phase). An auxiliary impeller, available on request, is fixed at a point halfway up in the tank for the blending of material in power form (quartz, feldspar) with the slip (2nd phase). The average dissolving time for raw or already treated clay, including loading and unloading operations, is approx. 2 hours for a liquid with a specific weight of 1.4 kg/m^3. The average duration of the 2nd phase is 1 hour for a liquid with a specific weight of 1.8 kg/m^3. All parts involved in the dissolving process (rotor, fixed paddles, base of tank) are constructed in special steel of high wear resistance and easy to replace. All heavy-duty blungers are furthermore provided with a trap for collection of stones, which are periodically removed. Maintenance is extremely simple and reduced to a minimum.

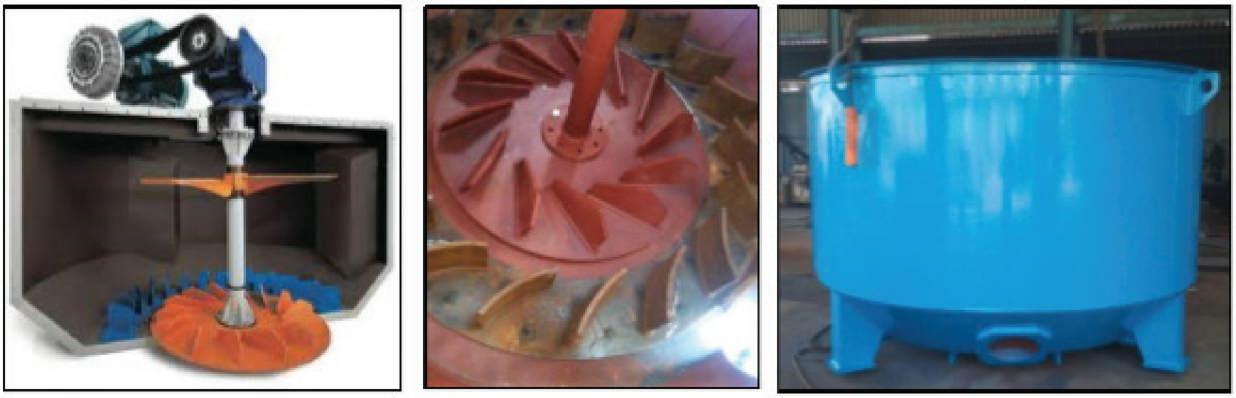


Figure 23: High Speed Turbo Blunger

Cost Benefit Analysis

The expected energy savings to be achieved by use of high speed blunger is 0.99 Lakh kWh annually. The annual monetary saving for this project is INR 6.45 Lakh, with an investment of INR 12.00 Lakh and a payback period of 23 months.

Table 22: Cost benefit analysis – High speed blunger

Parameter	A	B	UOM
	Ball mill	High speed blunger	
Charge Production	24	24	MT/day
Capacity	6	5	MT
No. of ball mills/blunger	2	2	Nos
Motor capacity	40	20	hp
Power consumption	23.8	14	kW
Operational hours for one charging	5	3	hrs/batch
Power consumed in 720 MT charges per month	14,323	6,048	kWh/month
Total power consumption per annum	1,71,876	72,576	kWh/annum
Electricity cost per annum	11.17	4.71	INR Lakh
Annual monetary saving	6.45		INR Lakh/annum
Investment	12.00		INR Lakh
Simple payback period	22		Months

Energy & GHG Savings

Annual Electricity Savings
0.99 Lakh kWh

Annual Energy Savings
8.54 TOE

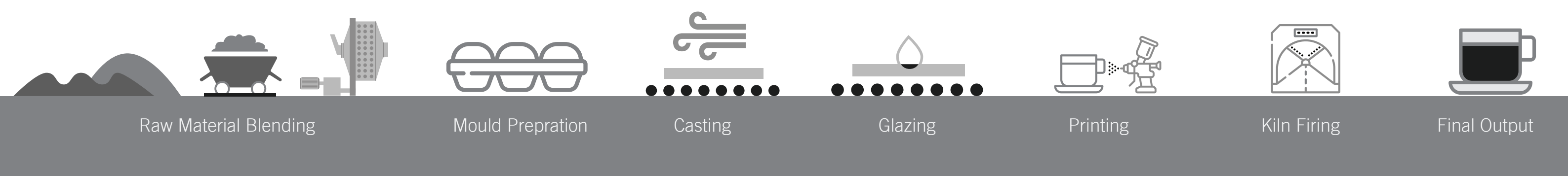
Annual GHG Savings
81.4 T CO_2

Replication Potential

Learnings from successfully implementing high speed blunger technology in two units can be used very well to replicate in the other units in the cluster.

Merits and limitations of technology

- Particle size in Blunger remains the same and is not disturbed at all; in ball mill, all materials are added and then it leads to grinding and change in property and structure of the raw material. In Blunger, we have open body structure and in ball mill we have a closed body structure. Fineness and openness of the structure remains the same in blunger.
- There is least contamination, if any, whereas in ball mill the material gets ground and superfine which is impossible to remove and this leads to defects like pin hole, blisters, cracks, etc., which can be very detrimental.
- The rotor and stator mechanism in blunger creates a heavy vortex which helps in dissolving and faster mixing of all raw material; there are special anti-sloshing baffles which create a resistance to the mixing and help in faster dissolution of the material, making the process less power consuming.
- The stator and rotor are made of special wear resistant Hardox plates of grade 500, having a hardness of 500, which helps in a longer life of system and less maintenance.
- There is reduction in weight of the product by almost 10%, as the structure is open body; this helps in bringing down the cost of the final product and majorly energy and manpower saving.
- Load cell also can be placed below the tank for weighing the entire batch and make recipes as per weight.



Technology Supplier Details:

Table 23: High Speed Blunger Technology Supplier details

Description	Details
Name of Company	Dynovo Global Solutions Pvt Ltd
Contact Person	Mr. Jatan Shah
Designation	Managing Partner
Contact	Mobile:+ 91-9699817245
Address	203, Crystal Tower, 75 Gundavali Road No. 3, Off, Sir Mathuradas Vasanji Rd, Andheri East, Mumbai, Maharashtra 400069

4.2.3. High alumina media in glaze ball mill in the place natural stone/pebble

Baseline details

In ceramic pottery ware manufacturing process, ceramic glaze grinding is one of the important processes. This process of glaze grinding is done in ball mill by adding same ratio of material and media. Most of the units in the cluster use natural stone media. Generally, these media are mined or naturally available stoned pebbles and are very irregular in shape and size. Such non-uniform grinding media take higher time for grinding and generate higher residue.

Figure 24: Mined Stone Pebble

Implementation Details

Figure 25: High Alumina Ball

As compared with natural pebbles grinding media, the alumina grinding balls have better performance in terms of wear resistance, uniform size, high density and high mechanical strength. The high density and ultra-hardness of the alumina grinding ball enable increased loading of ball mill. The alumina grinding ball is compact and uniform in shape, increasing the colliding probability and grinding efficient. The alumina grinding ball can help in less contamination to the raw material and keep the chemical composition stabilized. Thus, the alumina grinding ball is a better option for glaze grinding that ensures quality of production.

Cost Benefit Analysis

The expected energy savings to be achieved by use of high alumina balls in place of stone/ pebble is 0.375 Lakh KWh annually. The annual monetary saving for this project is INR 2.52 Lakh, with an investment of INR 3.00 lakh and a payback period of 14 months.

Table 24: Cost benefit analysis – High Alumina ball/Lining Grinding

Parameters	Units	Natural Media	High Alumina Media
Electrical motor capacity	hp	15	15
Grinding hour for one charge	hrs	21	20

Parameters	Units	Natural Media	High Alumina Media
Power consumed per one charge	KWh	234.4	122.7
Total Charge per month		28	28
Total power consumption per month	kWh	6,562	3,437
Cost of power per unit	INR/kWh	7	7
Cost of power consumption per month	INR Lakh	0.45	0.24
Monetary savings per annum	INR Lakh/annum	2.52	
Investment	INR Lakh	5.00	
Simple payback Period	Months	23	

** Considering ball mill size of 6 FT X6FT with material load of 2,000 Kg grinding media balls*

Energy & GHG Savings

Annual Electricity Savings

0.37 Lakh kWh

Annual Energy Savings

3.225 TOE

Annual GHG Savings

30.75 T CO_2

Replication Potential

Learnings from successfully implementing high alumina grinding media can be used very well to replicate in around 100 units of the cluster.

Technology Supplier Details:

Table 25: Technology Supplier Details Alumina Lining and Grinding Pebbles

Description	Details
Name of Company	Parishram enterprise
Contact Person	Mr. Vinu Bhai
Designation	Managing Partner
Contact	Mobile:+ 98253 75834
Address	Near Ranuja ceramic, Thangadh, Gujarat 363530

4.2.4. Replacement of manual jigger with double roller head automatic jigger

Baseline details

In ceramic pottery ware manufacturing process manual Jiggers are used for mould preparation. The jiggers are being operated by skilled workers. Each jigger machine is operated by one skilled worker who loads, moulds and unloads the product from the jigger machine. The average yield from manual jigger machine is about 85%. About 5-8 jigger machines are usually connected with a common shaft which is operated with motor of 0.75 kW – 1.5kW rating. Jigger machines are being operated for one shift of around 8 hours.

As compared to manual jigger machine, automatic double roller head jigger machine is faster and produces moulded products of consistent quality. Hence, skilled workers are not required in case of auto jigger machines. It would require one semi-skilled worker for feeding the machine and one unskilled worker for removal of green pieces from the machine since the speed of automatic double head jigger machine is quite high.

Figure 26: Manual Jigger vs automatic double roller head jigger machine

Therefore, automatic double head jigger is a more energy efficient and economical in comparison with manual jiggers. The yield with automatic jigger is 95% as compared to 85% of manual jigger.

Implementation Details

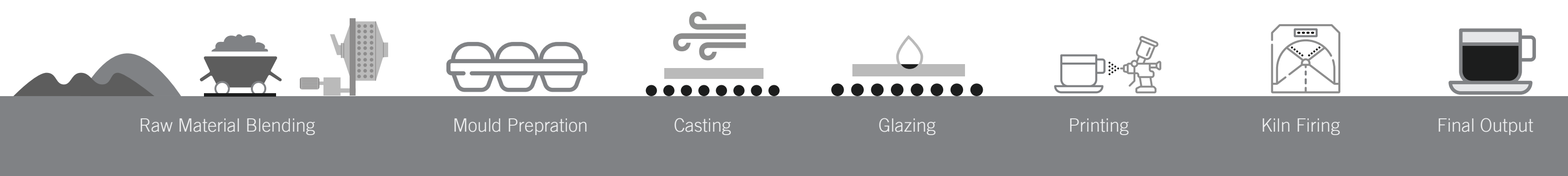
The ceramic pottery ware enterprise has installed 5 Jigger machines, producing 30,000 moulding pieced per day. The enterprise replaced existing manual jigger machines with efficient automatic double head jigger machines of same capacity which helped them to reducing specific power consumption and overall operating cost.

Cost Benefit Analysis

The expected energy savings to be achieved by installing the efficient automatic double head jigger machines is 5,376 kWh annually. The annual monetary saving for this project is INR 24.00 Lakh, with an investment of INR 30.00 Lakh and a payback period of 15 months.

Table 26: Cost benefit analysis – Automatic double head jigger machines

Parameter	Value	UOM
Operating duration	8	hr/day
Connected load per machine	1.5	kW
Total number of manual machines	5	Nos
Total number of automatic machines	3	Nos
Annual energy consumption of manual machines	13,440	kWh/yr
Annual energy consumption of automatic machines	8,064	kWh/yr
Average moulding production capacity	30,000	piece/day
% increase in yield of green moulds	10	%
% increase in yield after firing	8	%
Average kiln production output	76	Lakh piece/annum
Additional production (approx.)	6,75,000	piece/annum
SEC for actual production	1.92	kWh/'000 piece
Annual Energy Savings	5,376	kWh/annum
Annual monetary savings	37,632	INR/annum
Average product cost	3.5	INR/Piece
Additional Revenue generation	23.62	INR Lakh/annum
Net Monetary saving	24.0	INR Lakh/annum
Investment	30.0	INR Lakh
Simple payback Period	15	Months



Energy & GHG Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
5,376 kWh	0.46 TOE	4.4 T CO_2

Technology Supplier Details:

Table 27: Technology supplier details – Automatic double head jigger machines

Description	Details
Name of Company	Hi Tech Engineering Works
Contact Person	Mr Riysast
Designation	Manager
Contact	Mobile: +91 9897159787
Address	Khaweshgyan, Bagh Rlsaldar Police Chowki, Khurja - 203131

4.3. Case Studies in Utilities

4.3.1. Installation of VFD in screw compressor to avoid unloading

Baseline Scenario

The unit has installed a reciprocating compressor of 4.25 m³/min compressed air in units is used for instrument air, mould preparation and glazing. Most of the smaller ceramic enterprises in Khurja use compressors of the range of 2kW to 37kW (mix of reciprocating & screw). The ceramic unit under consideration has installed a 22kW screw compressor to cater to the requirements in the process & instrumentation section. The maximum working pressure of the compressed air in the system is in the range of 6-7 kg/cm². The operating characteristics of the compressor is as shown:

Table 28: Unit compressor loading pattern

Tag No	Load %	Unload %	Load power, kW	Unload power, kW
Unit air compressor 22 kW	60.5	39.5	22 kW	7.6 kW

The loading percentage of the compressor is only 60.5%, indicating a potential for VFD installation in the compressor. During the time the compressor goes into unload mode, there is no useful work done. Also, since the compressor is of screw type, the losses during unloading are higher in comparison to that for a reciprocating system.

Concept of VFD

Any compressor is designed to go into load & unload conditions. The load & unload pressures for any compressed air system are set such that the average pressure delivered will be the required system pressure. The higher set point of the compressor therefore is a loss.

Also, in the present scenario, the installed compressor is of much higher capacity as compared to the system requirement, which is clear from the 39.5% unload that the compressor is operating with.

In these two conditions, the most suitable option is to go for a variable frequency drive (VFD). The difference between the normal & VFD condition in a compressor is as shown below:

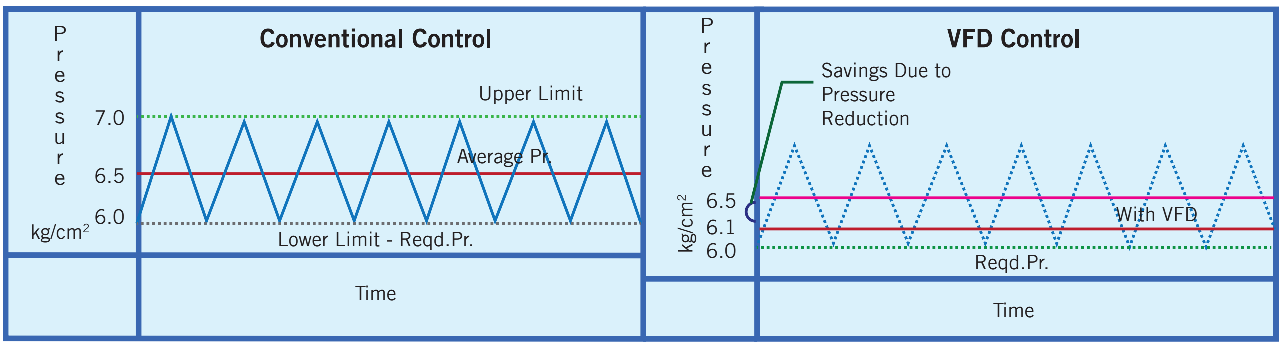


Figure 27: Capacity control of compressor

As can be seen from the figure, the VFD can be given a set point equal to that which is required in the system. The additional power that the compressor consumes over the required pressure will be the savings achieved.

Implementation details

It is recommended to install VFD and operate that with closed loop for all the above listed compressors to avoid the unloading of the compressor. The feedback for VFD can be given as required receiver pressure. By installing VFD, the compressor can be operated in a pressure bandwidth of ±0.1 bar. Saving potential of 7.6 kW is available by means of installation of VFD in the Main unit air compressor.

Merits

- Reduced fluctuations in pressure.
- Ease of operation.
- Reliability.

Limitations

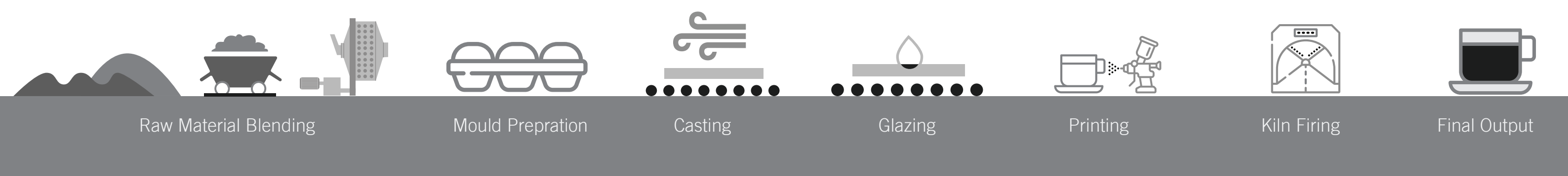
- Viable only up to 40% unload situations.
- Maintenance issues.
- Space constraints.

Cost Benefit Analysis

The expected savings by installation of VFD in the compressor is 18,249 units annually. The annual monetary saving for this project is INR 1.03 Lakh, with an investment of INR 0.90 Lakh. Payback period for the project is 11 months.

Table 29: Cost Benefit Analysis

Parameters	UOM	Value
Unloading power of compressor	kW	7.6
Percentage unloading	%	30.5
Power savings	kW	2.31
Annual operating hours	hrs	7,900
Annual energy savings	kWh	18,249
Power cost	INR/kWh	5.66
Annual savings	INR Lakh/annum	1.03
Investment	INR Lakh	0.99
Simple payback period	Months	12



Energy & GHG Savings

Annual Electricity Savings
0.18 Lakh kWh

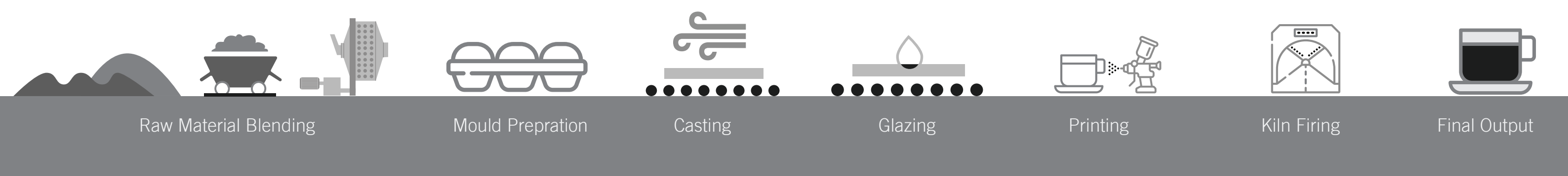
Annual Energy Savings
1.57 TOE

Annual GHG Savings
15 T CO_2

Technology Supplier Details:

Table 30: Technology Supplier Details

Description	Details
Supplier Name	Tirupati Automation
Contact Person	Mr Bhavesh Vamja
Email Id	tirupatiautomation@gmail.com
Phone No	+91- 9879411415 , +91- 8000682152
Address	Shiv Plaza-2, Shop No-14 & 15, Matel Road, At- Dhuva, Ta. Wankaner, Dist. Morbi (Guj)



4.3.1. Installation screw compressor with VFD in place of reciprocating compressor

Baseline Scenario

Compressed air in ceramic units is used for instrument air, mould preparation and glazing process. Most of the units are using reciprocating type compressors without any automation; these compressors run on load/unload mode. The percentage of loading depends on the process requirement. Generally, compressor in ceramic units run on 60–70% in loaded condition remaining 30–40% in Unload condition. During unload condition, the compressor does not deliver any air, but consumes unload power, which increases the specific power consumption.

On other hand, reciprocating compressor, due to its design, is prone to wear & tear and thus the compressor volumetric efficiency reduces over a period of time.

Figure 28: Reciprocating Compressor

Implementation Details

The existing compressor has been replaced with energy efficient screw air compressor with VFD. VFD operated screw compressor has two functions: one, it varies the RPM of the compressor based on pressure variation at the load or perform end and two, it also reduces the no load power consumption during unloading condition by bringing the motor to a halt. Such operation prevents consumption of power during unload condition.

<u>Merits</u>

- ❖ Maintenance is simple in screw-based air compressors.
- ❖ By using VFD in screw air compressors, the operating pressure of air compressor can be precisely controlled.
- ❖ The leakage in the compressed air system is proportional to the operating pressure.

Cost Benefit Analysis

The expected savings by installation of energy efficient screw compressor in place of reciprocating compressor is 61,285 kWh annually. The annual monetary saving for this project is INR 4.01 Lakh with an investment of INR 9.80 Lakh and payback for the project is 29 months.

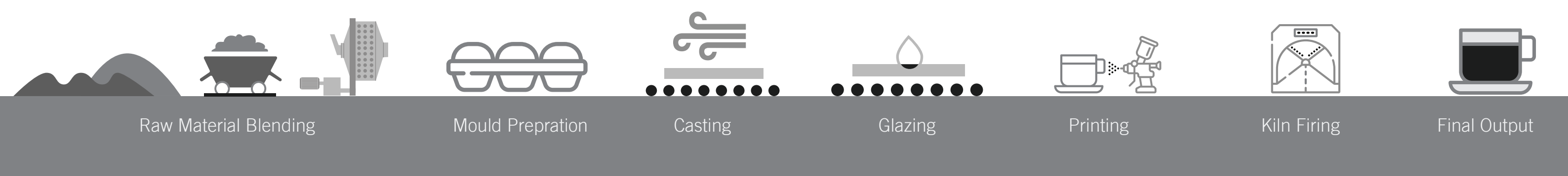


Table 31: Cost Benefit Analysis

Parameters	Value	UOM
Total installed capacity	4.25	m^3/min
Actual air delivery	3.05	m^3/min
Volumetric Efficiency	71.66	%
Input motor power	28	kW
Specific power consumption	9.19	kW/m^3/min
Proposed power consumption	6	kW/m^3/min
Reduction of power consumption	18	kW
Reduction in annual energy consumption	61,285	kWh/annum
Monetary savings	4.01	INR Lakh/annum
Cost of maintenance inclusive of taxes	9.8	INR Lakh
Simple payback period	2.4	Years

Energy & GHG Savings

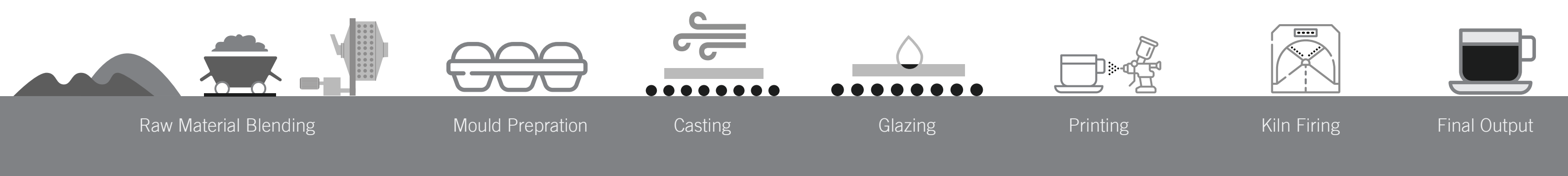
Annual Electricity Savings
0.61 Lakh kWh

Annual Energy Savings
5.27 TOE

Annual GHG Savings
50.25 T CO_2

Replication Potential

Learnings from successful implementation of compressor with VFD system can be used for implementation in over 80 units in the cluster.



Technology Supplier Details:

Table 32: Technology Supplier Details – Air Compressor

Description	Details
Supplier Name	Kaeser Compressor
Contact Person	Mr Jignesh
Email Id	jignesh.shah@kaeser.com
Phone No	+91- 9909944506
Address	Sakar-9, 1105, Ashram Rd, beside Old Reserve Bank, Muslim Society, Navrangpura, Ahmedabad, Gujarat 380009

4.3.2. Energy conservation in compressor by modifying airline system

Baseline Scenario

The existing system is operating with a 50 hp compressor and the air distribution network is made up of metallic pipeline having a lot of joints & welds, due to which there was a lot of frictional loss & leakage, which led to energy loss. The new pipe material has a smooth surface inside, which can minimize frictional losses. This material can be bent easily so that there is no necessity to use joiners. With the use of this material, we can minimize joints and hence avoid air leakage. This will help minimize energy consumption.

Figure 29: Existing compressed air piping

Implementation Details

Figure 30: HDPE Aluminium Pipe line

Multilayer pipes (MLC) (Generic Name Pe-Al-Pe Pipe) are made of five layers. The inside & outside layers comprise HDPE (High Density Polyethylene) tightly bonded with melt adhesives to intermediate layer of Aluminium Core, which is longitudinally overlapped. These pipes offer the advantages of both metal and plastic pipe, with none of their shortcomings. The working life of MLC pipes is more than 20 years.

Because the internal surface of the MLC pipes is smooth, the flow rate in these pipes is 30% more than GI Pipes. MLC Pipes are bendable and hence require a smaller number of fittings and require minimum joints. MLC Pipes are corrosion-resistant and scale-free. Plastic layer resist deterioration by corrosion due to moisture. There will be some friction loss in MLC pipe due to internal fittings but the overall performance of the Piping System will be better than other pipes as there are a smaller number of fittings required.

Merits

- ❖ Reduction in air leakages.
- ❖ Life cycle is more than 12 to 15 years.

Cost Benefit Analysis

The expected savings by installation of VFD in the compressor is 37,440 units annually. The annual monetary saving for this project is INR 2.85 Lakh, with an investment of INR 3.50 Lakh and the payback for the project is 15 months.

Table 33: HDPE Aluminium Cost benefit analysis

Parameters	Value	UOM
Before: 50 hp Compressor operating		
Energy consumption per hour	37.5	kW
Energy consumption for two shifts/day	600	kWh
Energy consumption for 26 working days	15,600	kWh
After Implementation: 40 hp Compressor operating		
Energy consumption per hour	30	kW
Energy consumption for two shift/day	480	kWh
Energy consumption for 26 working days	12,480	kWh
Saving in energy/annum	37,440	kWh
Saving in energy/annum	2.85	INR Lakh/annum
Cost of maintenance inclusive of taxes	3.50	INR Lakh
Simple payback period	15	Months

Energy & GHG Savings

Annual Electricity Savings

0.38 Lakh kWh

Annual Energy Savings

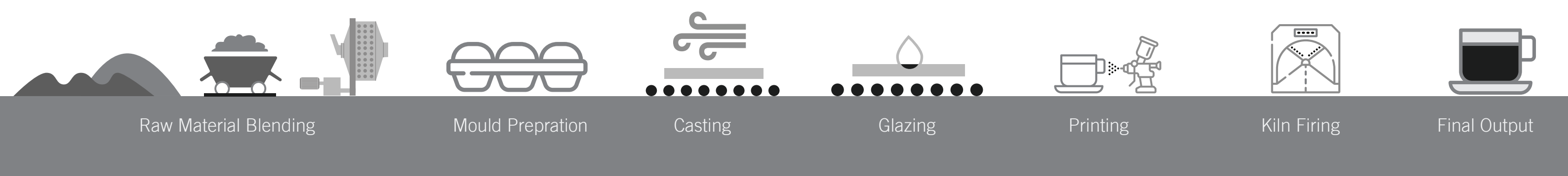
3.21 TOE

Annual GHG Savings

30.70 T CO_2

Replication Potential

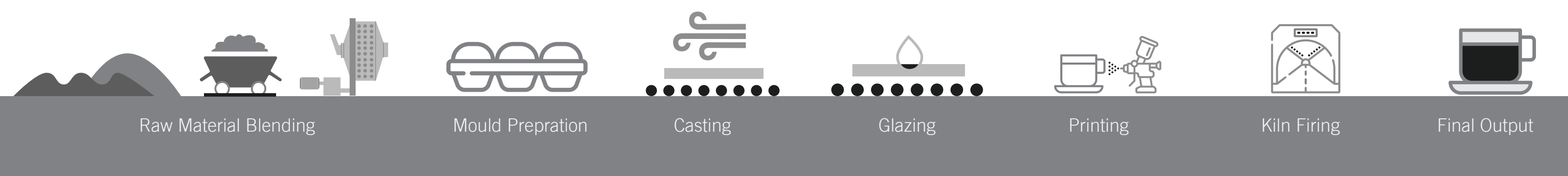
This technology has been adopted by the foundry unit and similar application can be done in all Khurja sector ceramic manufacturing units.



Technology Supplier Details:

Table 34: Technology Supplier Details – HDPE Aluminium Piping

Description	Details
Supplier Name	S R Engineers
Contact Person	Mr Rajesh
Phone No	+91-8688876444
Address	Chennareddy Enclave Road, Indira Nagar Colony, Shanakar Nagar, Peerzadiguda, Hyderabad, Telangana -500039



4.3.3. Transvector nozzle in compressed air hose pipe for mould cleaning application

Baseline Details

Utilization of compressed air for servicing application such as cleaning and drying is not uncommon and is also not a recommended practice for such applications. The service air points are being used at a pressure of 5.5 kg/cm², resulting in wastage of energy. Application of compressed air is common in all crockeryware units for mould cleaning purpose. For instance, using cleaning air from a hose of ½” dia. at 5.5 kg/cm², the amount of air consumed is approximately 336 cfm. Considering that the compressor operates at a specific energy consumption of 0.18 kW/cfm, the total energy consumed is 60 kW/hr.

For cleaning applications, the volume of airflow is the governing factor and not the operating pressure of the compressed air. Therefore, cleaning can be effectively achieved with a low pressure compressed air as well, thereby saving significant amount of energy.

As per the standards, reduction in the generation pressure in a compressor by 1 bar would reduce the power consumption by 6 – 10 %. As the compressor is operated at higher pressure than is required, there is a scope of saving energy.

Proposed System

Utilize a dedicated compressor at low pressure or a blower (if pressure from blower is enough) for service air applications. In order to further optimize the compressed air intake, transvector nozzles can be utilized for cleaning applications.

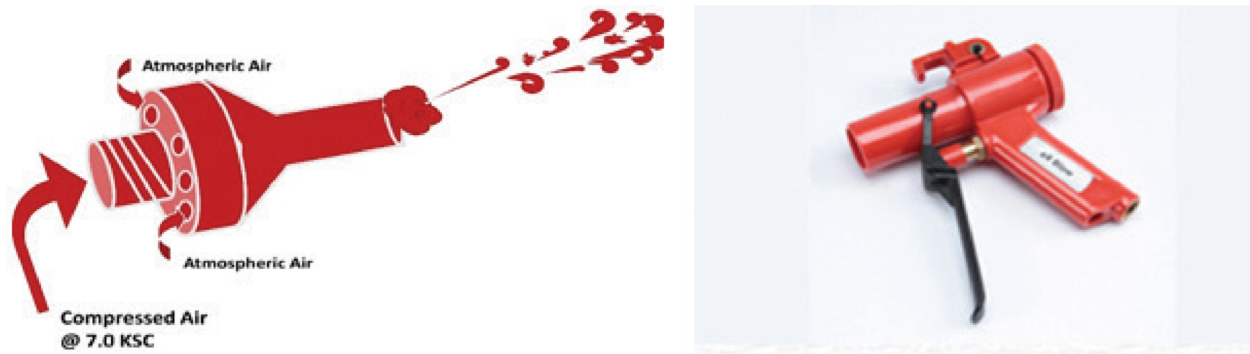


Figure 31: Transvector Nozzle

When compressed air enters the nozzle or jet, it fills a chamber with only one exit path – a thin annular orifice. As air passes through this orifice, the venturi effect of the orifice entrains the free surrounding air as it exits. This results in increased airflow volume more than supplied by the compressed air.

Hence the required volume and pressure required for cleaning application is met by consuming minimum amount of compressed air. Installing transvector nozzles indirectly saves load on the compressor and saves the energy consumed by the compressor. Results show that as much as 30 to 40% of the atmospheric air is utilized, thereby reducing the compressed air consumption, which indirectly saves load on the compressor and saves the energy consumed by the compressor.

Cost Benefit Analysis

The expected energy savings by replacing 10 nozzles would be INR 0.29 Lakh with an investment of INR 0.30 Lakh with a payback period of 12 Months – 13 months.

Table 35: Cost Benefit Analysis – Transvector Nozzles

Description	Value	Unit
Number of cleaning points considered	10	Nos
Flow through 0.5” hose at 5.5 bar pressure (as per standard)	46	CFM
Savings in compressed air consumption with transvector nozzle	23	CFM
Present SEC	0.18	kW/CFM
Total savings with transvector nozzle	4.14	kW
Average annual operating hours	1,000	Hours
Annual savings	0.29	INR Lakh/annum
Investment required	0.30	INR Lakh
Simple payback period	12 – 13	Months

Replication potential

Application of compressed air is common in all crockeryware units for mould cleaning purpose and thus the implementation of transvector nozzle can be replicated in all the production units.

Energy & GHG Savings

Annual Electricity Savings

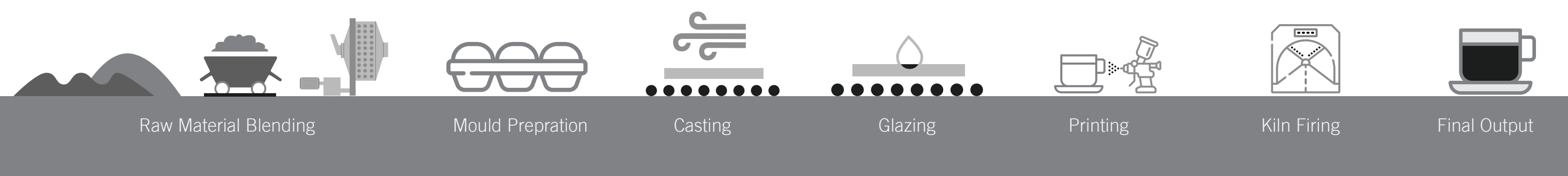
0.04 Lakh kWh

Annual Energy Savings

0.36 TOE

Annual GHG Savings

3.40 T CO_2



Technology Supplier Details

Table 36: Technology Supplier Details – Transvector Nozzle

Description	Details
Supplier Name	General Imsubs P. Ltd
Contact Person	Mr Kaushalraj
Email Id	air@giplindia.com
Phone No	+91-9327030174
Address	General Imsubs P. Ltd. 3711/A, GIDC, Phase-IV, Vatva Ahmedabad 382445, India

4.3.4. Retrofit of energy efficient ceiling fans in place of conventional fans

Baseline Details

In cast house, moulds slow drying process is an essential component of the pottery ware production process. The moulds drying process takes a minimum of 12-24 hours, depending on the atmospheric conditions. The moulds are kept in a storage area and are dried by air from the ceiling fans. In Khurja ceramic cluster enterprises use ceiling fans for drying & comfort cooling. The number of fans in each unit varies from 30 to 500 numbers in large units. There are close to 300 ceiling fans installed for drying purpose in the unit considered for this case study.. The drying process leads to loss of moisture in the moulds/casting and the process has to be slow, otherwise cracks will develop in the casting. After drying, the moisture content is 1.5% to 0.5%. During this process, the ware loses its weight and shrinks in size.

Implementation Details

The BLDC Technology or Brushless DC Motor: A BLDC fan takes in AC voltage and internally converts it into DC using SMPS. The main difference between BLDC and ordinary DC fans is the commutation method. A commutation is basically the technique of changing the direction of current in the motor for the rotational movement. In a BLDC motor, as there are no brushes, so the commutation is done by the driving algorithm in the electronics. The main advantage is that over a period of time, due to mechanical contact in a brushed motor, the commutators can undergo wear and tear. This thing is eliminated in BLDC Motor, making the motor more rugged for long-term use and also using less energy for rotation due to no mechanical contact. The expected electrical energy reduction is approximately 60% from the actual consumption. The fans are provided with timer-based remote control. This feature can be utilized for auto switching off the fan after the required process time.

Results:

- Reduced specific energy consumption for products manufactured.
- Reduced electricity bill costs by 60%.
- Increased production.

Cost Benefit Analysis

The expected energy savings to be achieved by replacement of existing ordinary fans with energy efficient BLDC fans is 0.677 Lakh kWh annually. The annual monetary saving for this project is INR 4.73 Lakh, with an investment of INR 6.3 Lakh and a payback period of 16 months.

Table 37: EE BLDC fans Cost Benefit Analysis

Parameter	Value	UOM
Quantity of conventional fans	300	Units
Operating hours	16	Hrs
Energy consumption with existing fans	360	kWh
Energy consumption With BLDC fans	134.4	kWh
Energy savings	225.6	kWh
Annual energy saving	67,680	kWh/annum
Energy cost saving	4.73	INR Lakh/annum
Investment	6.30	INR Lakh
Simple payback period	16	Months

Energy & GHG Savings

Annual Electricity Savings

0.677 Lakh kWh

Annual Energy Savings

5.82 TOE

Annual GHG Savings

55.47 T CO_2

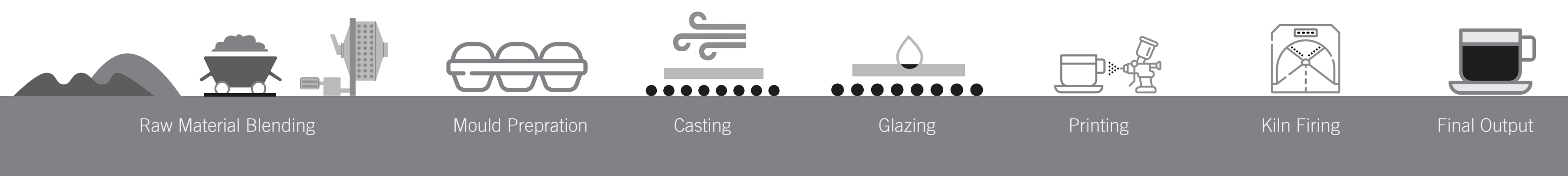
Replication Potential

This method can be adopted in all other units where a similar kind of cast house drying is done. Also, all new units and green field projects can implement this project.

Technology Supplier Details

Table 38: Technology Supplier Details for BLDC EE Fans

Description	Details
	Supplier – 1
Supplier Name	Atomberg
Contact Person	Mr Rohit Sharma
Designation	Manager
Contact	Mobile:+ 91-9980993600
Address	Plot No. 130 B, TTC Industrial Area Shirawane, Navi Mumbai - 400706
	Supplier – 2
Supplier Name	Canfan Private Limited
Contact Person	Mr Rajesh
Designation	Manager
Contact	Mobile:+ 91-9372413113
Address	20, Jeevarathnam, 2nd Street, Shanthi Nagar, Ksr Nagar, Ambattur, Chennai, Tamil Nadu - 600053



4.3.5. Installation of on-off controller system in agitator motor

Baseline details

The ceramic unit has underground tanks fitted with agitator motor of capacity 3hp in each of the 4 tanks for continuously mixing to maintain uniformity and avoid settling of solid particle. Initially when the fresh charge comes from ball mill/blunger, loading on motor is in between 60 to 75%. After some time as the raw material become uniform then loading on motor decreases, the loading on agitator motors is between 30% to 65%. These motors operate for about 24 hours in a day.

Implementation Details

Installation of automatically ON–OFF control system on the agitator motors do not affect the uniformity (quality) of slurry. It results in saving in electricity consumption in agitator motors. This system automatically switches ON agitator motors for about 10 minutes and then switches OFF for about 5 minutes. This means that in one hour, agitator motors operate for about 40 minutes and remain switch off for about 20 minutes. This could result in approximately 30% saving in electricity consumption of agitator motors.

Cost Benefit Analysis

The expected energy savings to be achieved by installing on-off controller system is 0.19 Lakh kWh annually. The annual monetary saving for this project is INR 1.28 Lakh, with an investment of INR 0.30 Lakh and a payback period of 3 months.

Table 39: Cost Benefit analysis – On-off controller system in agitation system

Parameter	Values	Units
Motor Capacity	3	hp
Number of motors	4	nos
Operating hours	10	Hours/day
Operational days	330	Days
Present electricity consumption in agitator	60,984	kWh/annum
Electricity saving due to use of On-Off controller	18,295	kWh/annum
Total working days	330	Days
Unit cost	7	INR/kWh
Annual monetary savings	1.28	INR Lakh/annum
Investment	0.30	INR Lakh
Simple payback period	3	Months

Energy & GHG Savings

Annual Electricity Savings
0.19 Lakh kWh

Annual Energy Savings
1.57 TOE

Annual GHG Savings
15 T CO_2

Replication Potential

This method can be adopted in all the ceramic units. Also, all new units & green field projects can implement this project.

Technology Supplier Details

Table 40: Technology supplier details – On-off controller system for agitator motor

Description	Details
Supplier Name	Tirupati Automation
Contact Person	Mr Bhavesh Vamja
Email Id	tirupatiautomation@gmail.com
Phone No	+91-9879411415 , +91-8000682152
Address	Shiv Plaza-2,Shop No-14 & 15, Matel Road, At- Dhuva, Ta. Wankaner, Dist. Morbi (Gujarat)

4.3.6. Retrofit of energy efficient motors in place of old rewinded motors

Baseline details

The unit has installed a ball mill of 4 MT capacity with 15 hp drive for grinding of raw materials. As per the process requirement, motor should run at full speed during the start of batch and after a particular time period it should rotate at less speed. The detailed assessment study of the ball mill and actual actual power consumption was done. The electrical motor drives associated with ball mills were found to be rewinded multiple times because of which the body temperature and electricity consumption was observed to be very high as compared to similar size ball mill motor.

Implementation Details

IE3 standard motors will improve motor operating efficiency as compared to old rewinded motors. IE3 motors have superior efficiency and can be operated from 50% to 100% since they have a flatter curve than conventional motors due to:

- ❖ Increasing the mass of rotor conductors/ conductivity.
- ❖ Precision air gaps to reduce current requirements.
- ❖ Improved winding and lamination design to minimize power consumption.

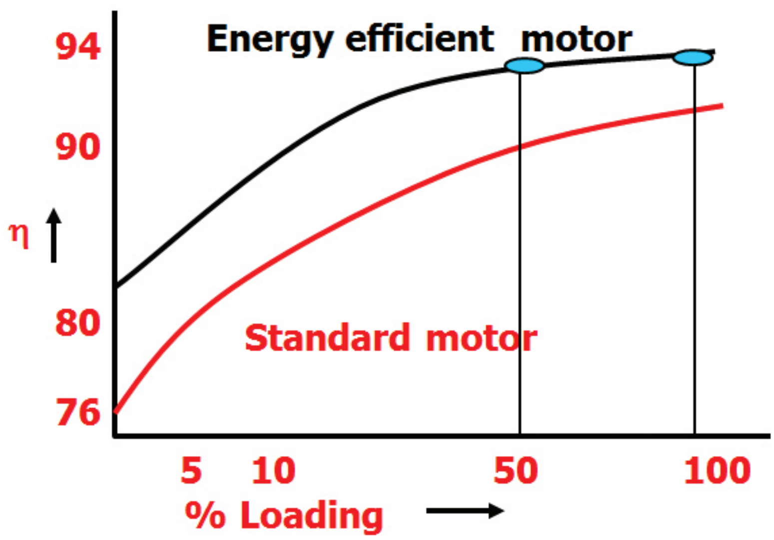
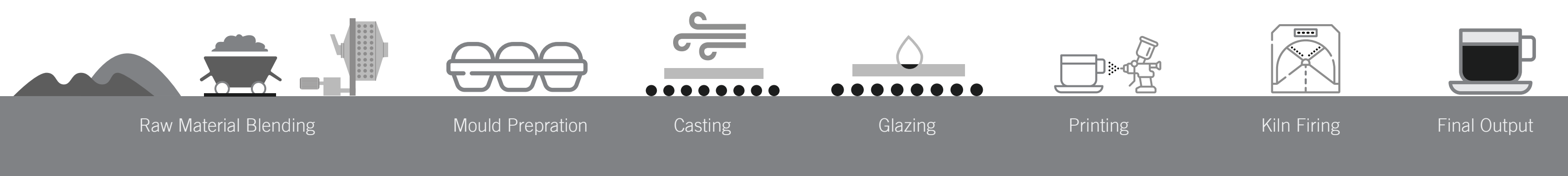


Figure 32: % loading for energy efficient motor



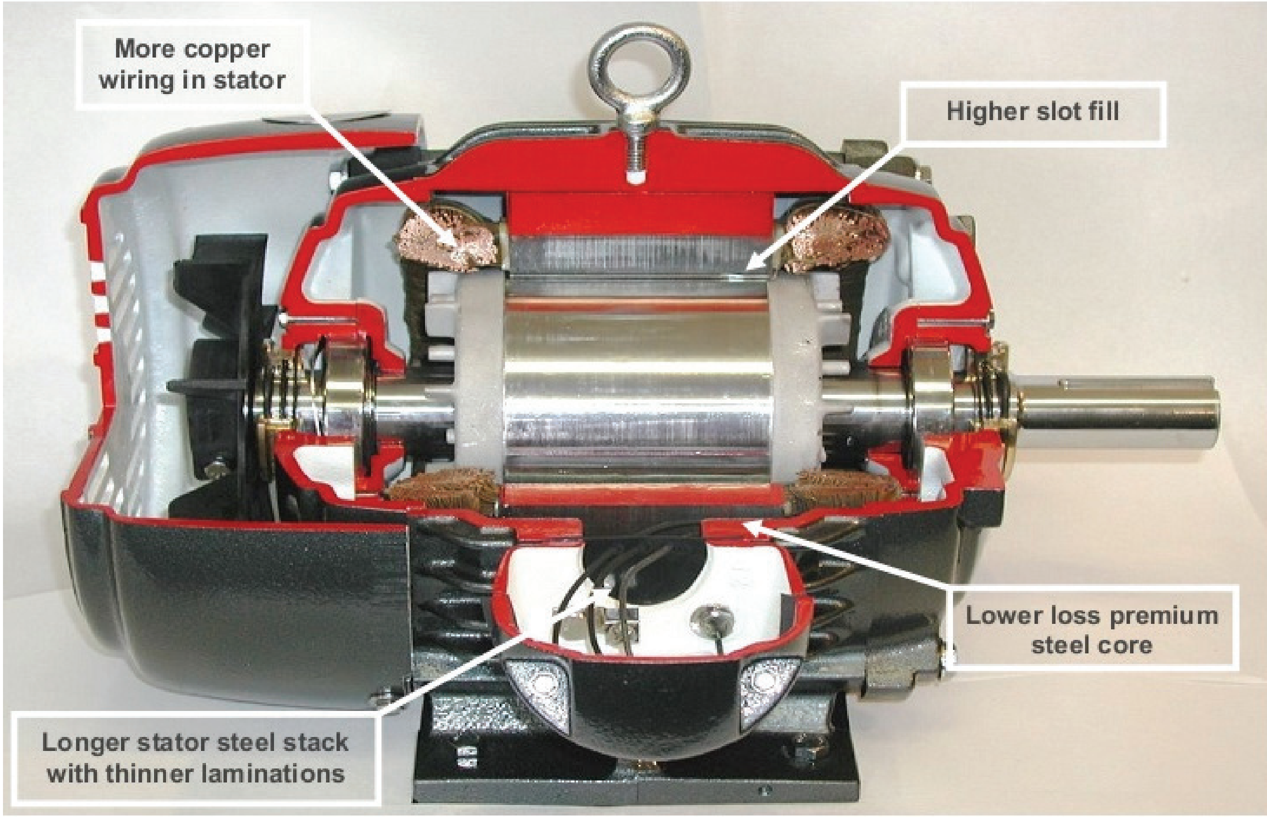


Figure 33: Energy efficient motor

Replacement of the existing standard efficiency motors by energy efficient motors will result in significant saving of electricity consumption in ball mill motors.

Cost Benefit Analysis

The expected energy savings to be achieved by installing energy efficient motors is 0.02 Lakh kWh annually. The annual monetary saving for this project is INR 0.14 Lakh, with an investment of INR 0.45 Lakh and a payback period of 39 months.

Table 41: Cost benefit analysis of energy efficient motors

Parameter	Values	Units
Ball mill drive capacity	15	hp
Existing Efficiency (Old motor)	88	%
EE motors Energy Efficiency (IE3)	94	%
Operational days	330	Days
Power consumption by old motor	32,340	kWh/annum
Power consumption by IE3 motor	30,275	kWh/annum
Power saving	2,065	kWh/annum
Annual monetary savings	0.14	INR Lakh/annum

Parameter	Values	Units
Investment	0.45	INR Lakh
Simple payback period	39	Months

Energy & GHG Savings

Annual Electricity Savings
0.02 Lakh kWh

Annual Energy Savings
0.18 TOE

Annual GHG Savings
1.7 T CO_2

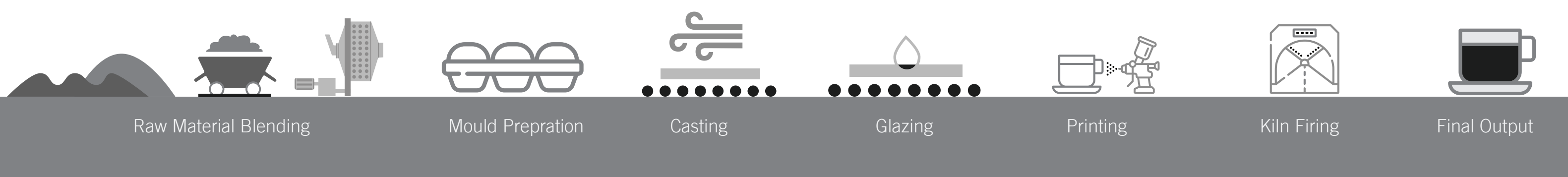
Replication Potential

This method can be adopted in all other units. Also, all new units & green field projects can implement this project.

Technology Supplier Details:

Table 42: Technology Supplier details – Energy efficient motors

Description	Details
	Supplier - 1
Name of Company	Rotomotive Drives
Contact Person	Mr Gagendra
Designation	Manager
Contact	Mobile:+91-9377511911
Address	223, Napa Talpad,, Gana Borsad Road, Taluka Borsad., Anand, Gujarat 388560
	Supplier - 2
Name of Company	Siemens
Contact Person	Mr Vedavyas Nayak
Designation	Cluster head - Drives
Contact	Mobile: +91-9632077220
Address	Birla Aurora, Level 21, Plot No. 1080, Dr. Annie Besant Road, Worli, Mumbai – 400030



4.3.7. Power factor correction & harmonic mitigation at main LT incomer

Baseline details

In the existing unit facility, due to harmonic and capacitor deration the power factor at the LT Main incomer is observed lower than 0.95 and the total harmonic distortion is observed to be 40%. Existing detuned APFC and normal APFC for reactive compensation was ineffective. Harmonics was very high at load level as well as at LT incomer. Due to reduction of power factor, the kVA billing in the unit facility increased.

Effect of Harmonics:

- Extra heating/noise of transformers.
- Circuit breaker & protective relays malfunction.
- Erratic operation of computers, telecommunication, video monitors & electronic test equipment.
- Failure of capacitors.
- De-rating of generators.
- Malfunction of measuring instruments.
- Overheating of motors.

Proposed system

Fast acting hybrid filter solution at the main LT incomer to improve power factor and active filter for the harmonic mitigation.

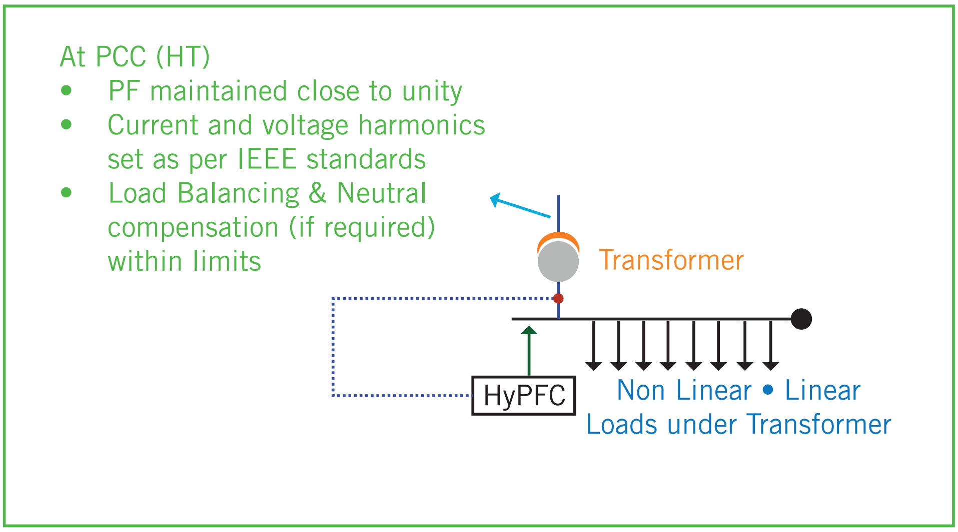


Figure 34: Connection diagram

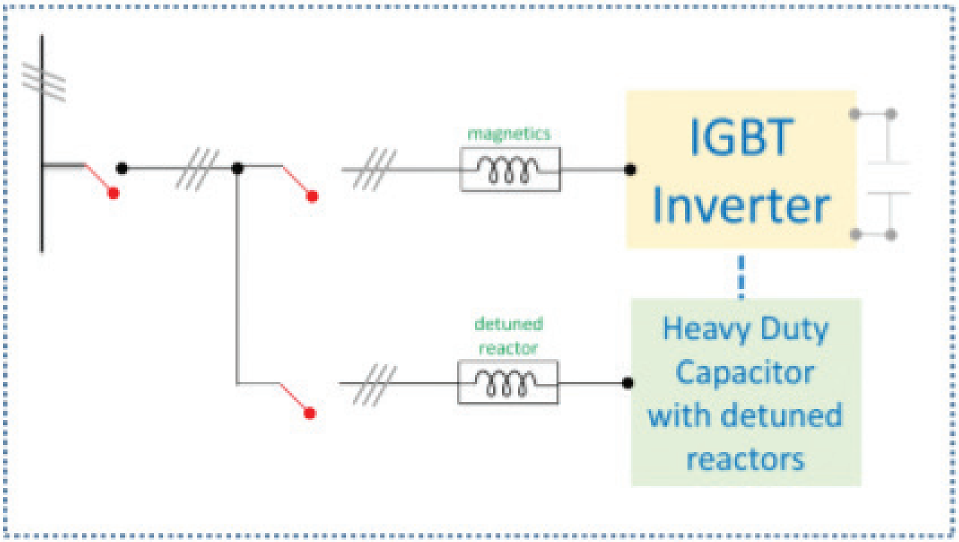


Figure 35: Operation of hybrid filter

Hybrid power factor correction system has following advantages over conventional system (detuned APFC/RTPFC):

- Instantaneous true PF compensation up to unity.
- Step less reactive compensation.
- Responses in microseconds.
- Leading/lagging both compensation.
- Harmonics compensation as per IEEE-519 standards.
- Runs on DG as well as grid.
- Maintenance free.

S.No.	Feeder Name	Filter Status	Arms (A)				iTHD(%)			iTDD(%)			Power			PF	dPF	Reduction in kVA	Reduction in kVA (%)
			R	Y	B	N	R	Y	B	R	Y	B	kW	kVAr	kVA	Mean	Mean		
ESS-1 Transformer (2000kVA, 11/0.433kV), HPFC (600kVAr)																			
1	Main LT Incomer	OFF	940	884	852	83	10	10	11	8	7	8	726	300	825	0.88	0.88	99	12%
		ON	1019	1012	986	83	7	5	7	6	5	6	726	0	726	1.00	1.00		
ESS-3 Transformer (2000kVA, 11/0.433kV), HPFC (600kVAr)																			
2	Main LT Incomer	OFF	1147	1215	1148	8	6	6	6	4	4	4	792	309	852	0.93	0.93	60	7%
		ON	1093	1156	1091	8	2	3	2	2	2	2	792	-18	792	1.00	1.00		
2.1	ABS Paint shop, A/F-3,	OFF	422	500	458	-	35	33	37	27	30	31	300	83	329	0.91	0.96	10	3%
		ON	405	474	447	-	20	19	20	15	16	16	300	81	319	0.94	0.96		
ESS-4A Transformer (2000kVA, 11/0.433kV), HPFC (400kVAr)																			
3	Main LT Incomer	OFF	1049	946	985	90	14	18	15	12	14	12	765	120	789	0.97	0.99	16	2%
		ON	1107	1006	1045	90	5	6	5	4	5	4	765	69	773	0.99	1.00		

Figure 36: Reduction in kVA with & without operation of Hybrid Filter

Improvement in power factor leads to reduction in kVA demand thereby reduction in energy consumption and leads to saving in cost.

Cost Benefit Analysis

By installing new generation maximum demand controller cost saving potential of INR 5.0 Lakh can be achieved with an investment of INR 4.50 Lakh and a payback period of 11 months.

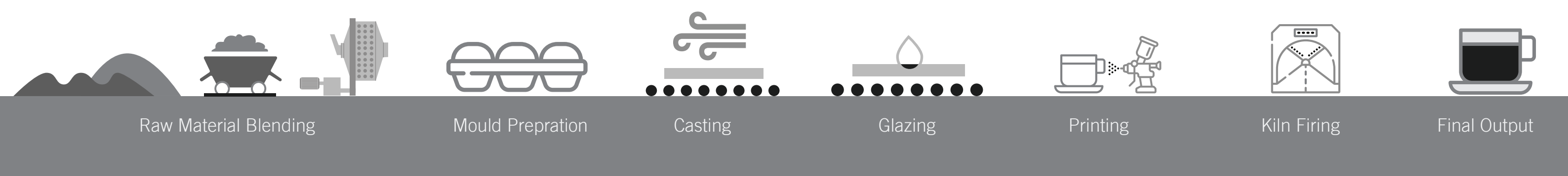
Table 43: Cost Benefit Analysis – Power factor improvement

Parameter	Values	UOM
Reduction in kVA	15	kVA
Operational hours	16	Hours/day
Operational days	330	Days
Annual savings	79,200	kVAh/annum
Annual monetary savings	5.00	INR Lakh/annum
Investment	4.50	INR Lakh
Simple payback period	11	Months

Technology Supplier Details

Table 44: Technology Supplier – Power factor improvement hybrid filter

Description	Details
Supplier Name	P2P Power solutions
Address	RPS Palms, Sec-88, Faridabad-121002
Contact Person	Mr. Priyaranjan Sinha
Email Id	youdit@youdit.co.in
Phone No	+91-9811456950



4.4. Case studies in renewable energy

4.4.1. Solar rooftop system

Baseline Scenario

Electricity cost constitutes 15 to 20% of total energy cost in a ceramic unit. As the ceramic units are spread across a large land area with broad sheds having significant roof areas, there is significant potential for the units to generate solar power for in-house applications through rooftop solar photovoltaic (PV) systems. Renewable energy is deemed to be the best substitute for conventional fossil fuel. The ceramic unit has enough rooftop area which can be utilized to install solar PV for self-generation of electricity rather than purchasing from grid. Few ceramic units in Khurja cluster have installed rooftop solar systems up to 20 kWp and operating successfully.

The electricity generation potential at a specific location depends on the solar radiation received. The solar radiation received during each month throughout a year at Khurja is given below:

Table 45: Site Specification – Solar radiation at Khurja

Parameters	
Location	Latitude: - 28.25, Longitude: - 77.85
Direct Normal Irradiance	4.32 kWh/m²/day
Wind	6.24 m/sec
Humidity	15%

The following graphs highlights solar irradiance:

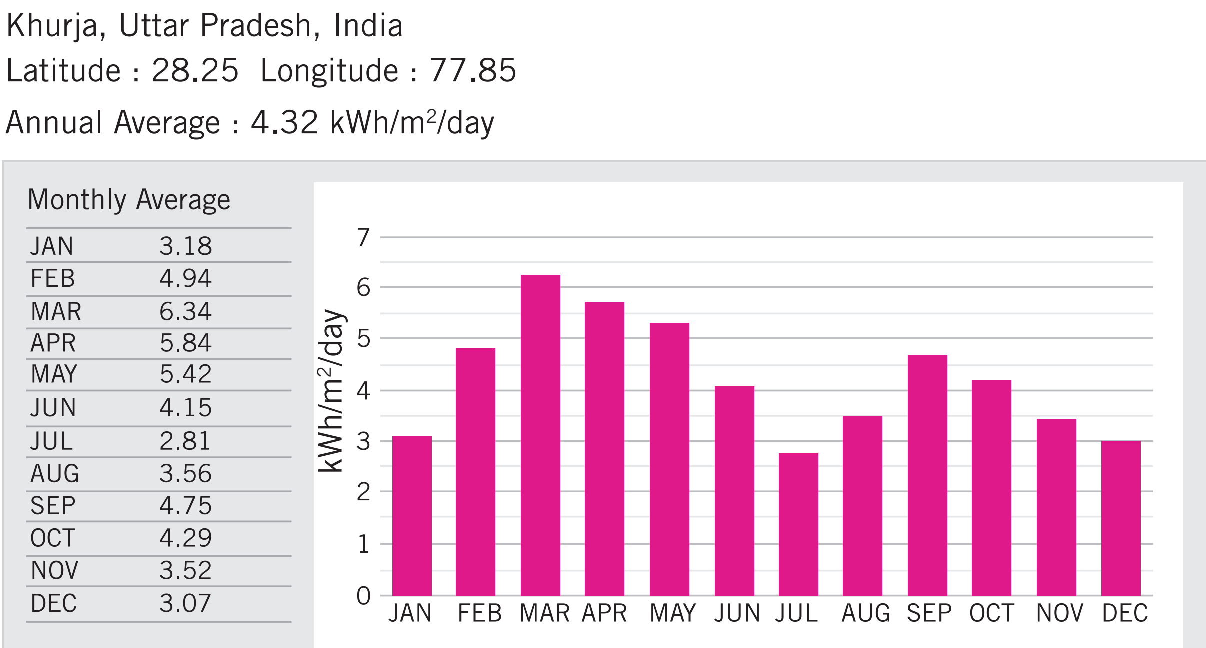


Figure 37: Solar Irradiance

Proposed System

The ceramic units in Khurja cluster has a potential of installing up to 25-30 kWp solar rooftop which can generate around 0.40 Lakh units of electricity annually. The proposed system will be a grid-tied solar PV power unit consisting solar PV array, module mounting structure, power conditioning unit (PCU) consisting of maximum power point tracker (MPPT), inverter and controls & protections, interconnect cables, junction boxes, distribution boxes and switches. PV Array is mounted on a suitable structure. Grid-tied solar PV system is without battery and should be designed with necessary features to supplement the grid power during daytime. In grid-connected rooftop or small solar PV system, the DC power generated from solar PV panel is converted to AC power using power converter and is fed to the grid either of 33 kV/11 kV three phase lines or of 440V/220V three/single phase line, depending on the local technical and legal requirements.

These systems generate power during the daytime, which is utilized by powering captive loads and feeding excess power to the grid. In case the power generated is not sufficient, the captive loads are served by drawing power from the grid.

Net Metering Business Model – The net metering-based rooftop solar projects facilitate the self-consumption of electricity generated by the rooftop project and allow for feeding the surplus into the grid network of the distribution by the licensee. The type of ownership structure for installation of such net metering-based rooftop solar systems becomes an important parameter for defining the different rooftop solar models. In a grid-connected rooftop photovoltaic power station, the generated electricity can sometimes be sold to the servicing electric utility for use elsewhere in the grid. This arrangement provides payback on the investment of the installer. Many consumers from across the world are switching to this mechanism owing to the revenue yield.

A commission usually sets the rate that the utility pays for this electricity, which could be at the retail rate or the lower wholesale rate, greatly affecting solar power payback and installation demand. The features/ requirements for grid-connected rooftop solar PV system are as follows:

Table 46: Features/requirements for Grid Connected Solar PV Systems (Rooftop)

S. No.	Features / Requirements	Values
1	Shadow free roof area required	10 sq. m or 100 sq. ft. per kWp
2	Roof suitable for Solar PV system	Concrete/ GI/ tin shed (Asbestos may not be suitable)
3	Orientation of the roof	South facing roof is most suitable. Installation may not be feasible beyond 5 deg slope.
4	Module installation	Modules are installed facing South. Inclination of modules should be equal closer to the latitude of the location for maximum energy generation.

S. No.	Features / Requirements	Values
5	Cost of the rooftop solar PV system	MNRE issues benchmark cost for GCRT Solar PV system and the cost for general category states for 2019-20 are as follows. This includes cost of the equipment, installation and O&M services for a period of 5 years. Above 1 kWp and up to 10 kWp: INR 54,000/ kWp Above 10 kWp and up to 100 kWp: INR 48,000/ kWp Above 100 kWp and up to 500 kWp: /INR 45,000/ kWp Based on discussions with a few project developers, average cost of the system (as per market conditions) is as follows: For 10 kWp system, INR 49,000/ kWp For 50 kWp system, INR 42,500/ kWp For 100 kWp system, INR 37,000/ kWp
6	Useful life of the system	25 years
7	Annual energy generation from Rooftop Solar PV system	18% CUF in 1st year, i.e., 1,578 kWh/ kWp / annum 0.7% degradation every year for the useful life of the system. On an average, 1,452 kWh/ kWp/ annum would be generated over the useful life.

Merits

- PV panels provide clean & green energy. During electricity generation with PV panels, there is no harmful greenhouse gas emissions.
- Technology development in solar power industry is constantly advancing, which can result in lower installation costs in the future.
- PV panels have no mechanically moving parts, except in cases of sun-tracking mechanical bases; consequently, they have far less breakages or require less maintenance than other renewable energy systems (e.g. wind turbines).

Limitations

- The initial cost of purchasing a solar PV system is high, which includes paying for solar panels, inverter, batteries, wiring and for the installation.
- Although solar energy can be still collected during cloudy and rainy days, the efficiency of the system drops, which results in lower generation of energy.
- Installing a large PV system takes up a lot of space.

Cost Benefit Analysis

The expected savings by installation of 25 kWp solar rooftop is 0.40 Lakh kWh annually. The annual monetary saving for this project is INR 2.80 Lakh, with an investment of INR 10.00 Lakh and a payback period of 43 months.

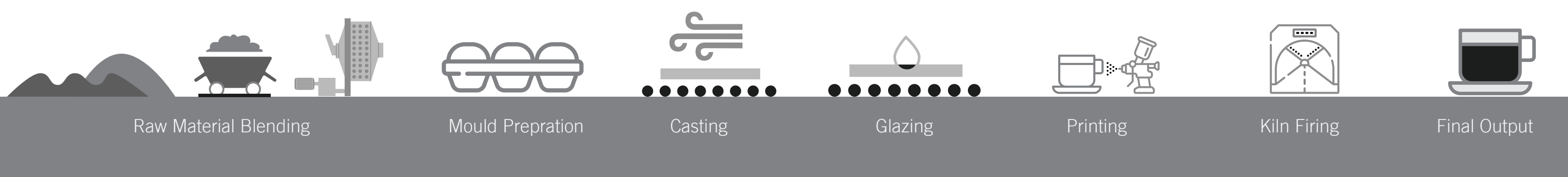


Table 47: Cost Benefit Analysis – Solar PV Systems

Parameters	Value	UOM
Proposed rooftop solar capacity	25	kWp
Annual units generation	1,600	kWh per kW/annum
Total energy generation	40,000	kWh/annum
Electricity cost	7	INR/kWh
Cost savings	2.80	INR Lakh/annum
Investment	10.00	INR Lakh
Simple payback period	43	Months

Energy & GHG Savings

Annual Electricity Savings

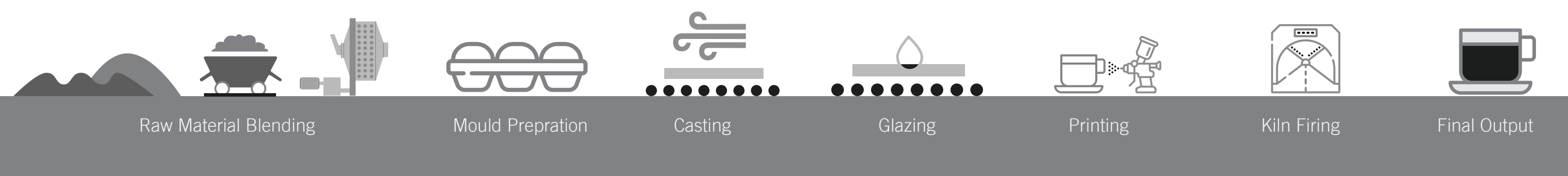
40,000 kWh

Annual Energy Savings

3.44 TOE

Annual GHG Savings

32.80 T CO_2



Technology Supplier Details:

Table 48: Technology supplier details – Solar rooftop system

Description	Details
	Supplier - 1
Name of Company	Raijin Solar Energy
Contact Person	Mr Jaydip Agrawat
Designation	Managing Director
Contact	Mobile: +91-9574511117
Address	909 to 911, Anand Mangal-3, Behind Kalyan Jewellers, Ambawadi, Ahmedabad, Gujarat 380006
	Supplier - 2
Name of Company	Mysun Solar
Contact Person	Mr Pravin
Designation	Manager
Contact	Mobile: +91-9890285988
Address	Unit No 816, 817 & 818, 8th Floor, Tower-1 Assotech Business Cresterra Plot No 22, Sector 135, Noida, Uttar Pradesh- 201301

4.5. Case studies in new & innovative technologies

4.5.1. Solar-Wind hybrid system

Baseline Scenario

Renewable energy is deemed to be the best substitute for conventional fossil fuel. Implementation of renewable energy posts various challenges, such as capital cost and consistency of power output, of which the latter can be solved by the installation of a Solar – Wind hybrid system. The rooftop area can be utilized to install a solar-wind hybrid system that can harness solar energy and wind energy to generate electricity.

Proposed System

The Solar–Wind Hybrid system is also known as a solar mill. The solar mill generates:

- ❖ Daytime energy from the sun and wind.
- ❖ Day & night energy from the wind energy.
- ❖ Energy even on cloudy days.
- ❖ More energy on hot sunny days due to cooling effect on solar panels by wind.

Figure 38: Solar-wind hybrid system

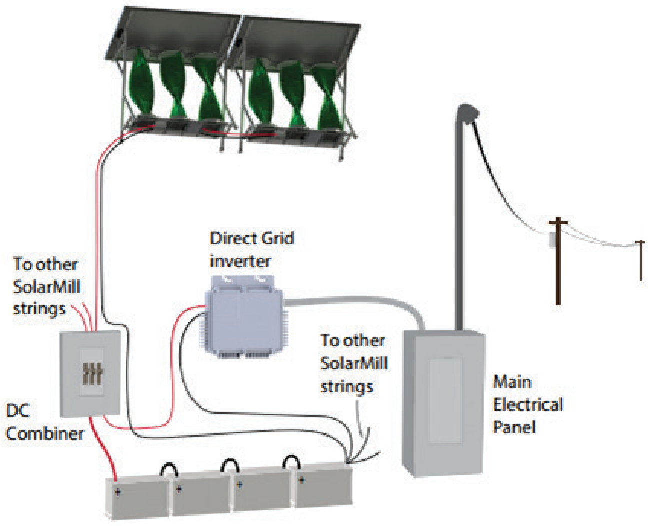


Figure 39: Hybrid mill connected to supply

It consists of three vertical axis wind turbines coupled to three permanent magnet generators. Automatic mechanical braking is provided once the wind speed goes beyond the cut-off speed. On-board smart electronics include dynamic Maximum Power Point Tracking (MPPT). It uses wind and solar resources on a 24/7/365 basis, allowing access to energy and very little interruption of services. The design life of solar mill is 25 years.

Specifications

The increase of renewable power per square foot of roof is obtained by combining two power sources. For a rooftop installation, combining solar and wind power is a complementary combination. For example, many locations are less windy in the middle of the day when the sun is at its peak and the wind picks up after dusk. Other advantages are solar module providing protection for the wind portions of the mechanism from direct rain and hail and assisting with the direction of air into the turbines.

Since this compact installation is designed for rooftops and urban atmosphere, savonous type of wind turbine is chosen for its low running speed and relative insensitivity to turbulence. Power generation begins at a wind speed of 5 kmph. Independent MPPT for both wind and solar is calibrated. Maximum power point tracking (MPPT) is an algorithm included in charge controllers used for extracting maximum available power. The power from both wind and solar generation is routed into a common 48V DC bus which has built-in charge control for a lead acid battery bank.

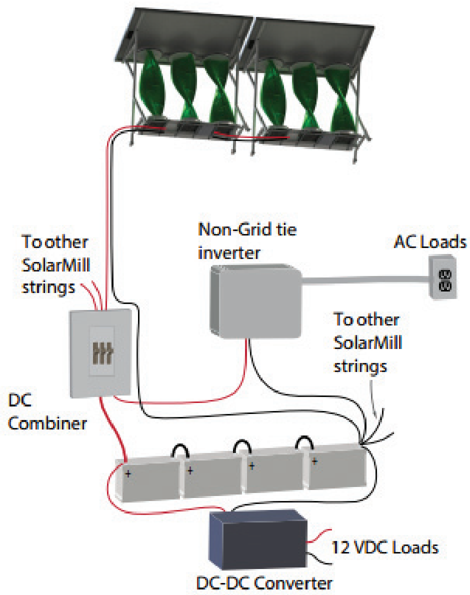


Figure 40: Hybrid mill connected to loads

Modes of Use

In grid-tied system, the bank of batteries is connected to one or more Direct Grid micro-inverters, which connect to the user's electrical panel. The inverters push power back to the grid efficiently when the batteries become fully charged.

In off-grid storage, the batteries can be used to supply power to electrical devices in off grid settings. This electrical energy can power DC powered devices through a voltage converter, or can power AC devices through an inverter.

Merits

- ❖ Power generation during daytime as well as night-time.
- ❖ Reliable power generation even on cloudy days.
- ❖ A compact hybrid solar mill to meet a portion of the unit's load after detailed study with vendors.
- ❖ Power generation stats at 2-5 m/s and mechanical braking occur beyond 18 m/s.
- ❖ The power generation can be monitored online.

Limitations

- ❖ Higher investment.

Cost Benefit Analysis

The expected savings in electrical energy to be achieved by installation of a 50 kWp Solar–Wind hybrid system is 54,750 units annually. The annual monetary saving for this project is INR 3.55 Lakh, with an investment of INR 25.00 Lakh and a payback period of 85 months.

Table 49: Cost Benefit Analysis – Solar-Wind Hybrid Systems

Parameters	UOM	Value
Installed Capacity of Solar-Wind Mill	kWp	25
Average generation per day per kWp	kWh	6.0
Area Required	m^2	30
Annual operating days	Days	365
Electricity Tariff	INR/kWh	6.5
Average Annual Energy Saving on conservative basis	kWh	54,750
Annual cost savings	INR Lakh/ annum	3.55
Investment	INR Lakh	25
Simple Payback Period	Months	85

Energy & GHG Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
54,750 units	4.71 TOE	44.90 T CO_2

Technology Supplier Details

Table 50: Technology Supplier Details – Solar-Wind Hybrid Systems

Description	Details
Supplier Name	Windstream Technologies
Contact Person	Mr Bhaskar Sriram
Email Id	bhaskars@windstream-inc.com
Phone No	+91 99599 18782
Address	G2-SSH Pride, Plot 273, Road No-78, Jubilee Hills, Hyderabad 500096

4.5.2. Installation of Energy Efficient burners in place of existing old conventional burners in kiln firing

Baseline details

In ceramic unit, kilns are the major source of fuel consumption. The unit has a production of 14 TPD. Natural gas is used mainly in kiln firing operations. Kiln performance is directly related to the temperature maintained & thermal efficiency at various zones in the kilns. In most of the ceramic units, conventional burners are used for fuel firing in kiln and there is no proper air flow control mechanism for maintaining proper combustion of fuel. The thermal efficiency of the kiln can be improved using high velocity burners. High velocity burners are better for tunnel and shuttle kiln wherein temperature uniformity is important.

About the technology

High velocity burners:

High velocity burners find application where the temperature uniformity within the job is very important for their quality and to have re-circulation of combustion gases.

Energy efficient high velocity burner is characterised with uniform and high flame length. Ceramic product requires temperature uniformly in the entire job. High velocity burner with excess air control system can provide uniform heat transfer for the entire job, thereby increasing the quality of ware and efficiency of kiln.

In a kiln, the re-circulation of products of combustion can substantially contribute to the speed of heating and temperature uniformity. For low temperature ovens and dryers, suitable re-circulating fans are generally provided to achieve temperature uniformity. However, fans are not practical for high temperature furnaces and kilns.

Figure 41: High velocity burner

Excess air can help in re-circulation, but this will result in wastage of fuel. 30% excess air for a 1,100°C kiln will require an additional 24% fuel than stoichiometric firing. In comparison, high velocity gases entrain and re-circulate more than seven times of its own volume will eliminate the need for fans or excess air.

Figure 42: High Velocity Burner with Flame

Features of high velocity burners

- 300 to 1,650°C operating temperatures.
- Inherently low emissions.
- 18,000 to 5,00,000 kCal/hr capacity range.
- 300°C preheated air.
- Wide air/fuel ratio flexibility.

Figure 43: Perfect combustion with correct air to fuel ratio

Figure 44: Improper air to fuel ratio

It is recommended to install the high velocity burner with precise control system for air to fuel ratio resulting in increasing the combustion efficiency and utilizing the heat uniformly through entire raw ware. 3-7% of fuel savings can be achieved.

Results:

- Reduced specific energy consumption in kiln.
- Increased thermal efficiency.
- Reduced fuel (natural gas) costs by 3-7%.

Cost Benefit Analysis

The expected energy savings to be achieved by using high velocity burners in kiln is 1,827 Lakh kCal annually. The annual monetary saving for this project is INR 6.10 Lakh, with an investment of INR 15.00 Lakh and a payback period of 30 months.

Table 51: Cost benefit analysis – Energy efficient burner

Parameter	Value	UOM
Production	14	Tonne/day
Natural gas consumption before intervention	1,540	SCM/Day
Operational hours	24	Hours/Day
Operational days	330	Days/annum
Natural gas consumption after implementation of intervention	1,478	SCM/day
Annual gas savings due to implementation of measure	20,328	SCM/annum
Cost of natural gas	30	INR/SCM
Annual monetary saving	6.09	INR Lakh/annum
Investment	15.00	INR Lakh
Simple payback period	30	Months

Energy & GHG Savings

Annual Thermal Savings
1,827 Lakh kCal

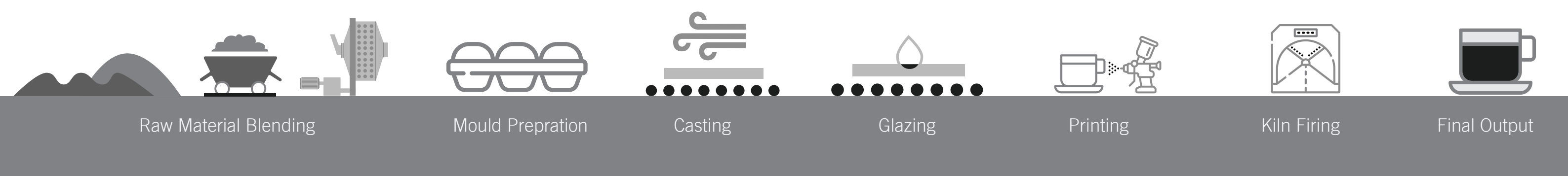
Annual Energy Savings
18.27 TOE

Annual GHG Savings
54.66 T CO_2

Technology Supplier Detail

Table 52: Technology supplier details – Energy Efficient Burner

Name	Details
Name of Company	Wesman Thermal Engineering
Contact Person	Mr Tushar Shah
Designation	General Manager
Contact	+91 9879206992
Address	A-442, Sakar-VII Nehru Bridge Corner, Ashram Road, Ahmedabad 380009 T: +91 (79) 40070474



5. Conclusion

In a typical pottery ware manufacturing unit, kiln firing and raw material blending operations are dominant energy users. Significant energy efficiency improvement opportunities in units exist in kiln firing and raw material blending via waste heat recovery, thermo ceramic coating to reduce the radiation losses in kiln, low thermal mass in kiln car, utilization of renewable energy, high alumina balls in glaze ball mill in the place natural stone/pebbles, high speed blunger in place of ball mill and increased automation. Through this compendium, some of the key technologies that are highly replicable in the cluster have been identified and for these technologies the case examples are included.

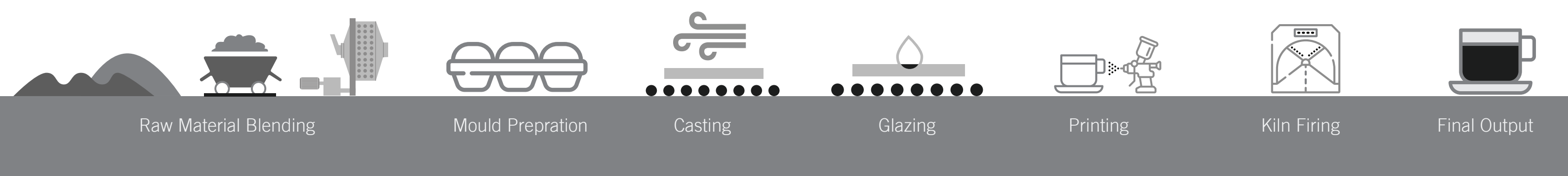
The identified technologies can be categorized into three heads, namely, Level 1, Level 2 and Level 3, based on the investment requirement and the payback, as follows:

Level 1: Low investment

- ❖ Reduction in ball mill power by installation of VFD on ball mill drive used in the grinding operation.
- ❖ Installation of VFD in screw compressor to avoid unloading.
- ❖ Retrofit of energy efficient ceiling fans in place of conventional fans.
- ❖ Transvector nozzle for compressed air sanitaryware mould cleaning application.
- ❖ Installation of on-off controller system in agitator motor.
- ❖ Retrofit of energy efficient motors in place of old rewinded motors.

Level 2: Medium investment

- ❖ High alumina balls in glaze ball mill in the place natural stone/pebbles.
- ❖ Energy conservation in compressor by modifying airline system.
- ❖ Thermo ceramic coating to reduce the radiation losses in kiln and reduce fuel consumption.
- ❖ Waste heat recovery in tunnel kiln – Use of Hot Air from cooling zone as combustion air in kiln firing.
- ❖ Low Thermal Mass for reduction of kiln car losses in pottery ware units.



Level 3: High investment

- Solar Rooftop system.
- High speed blunger in place of ball mill for raw material grinding process.
- Installation screw compressor with VFD in place of reciprocating compressor.
- Solar-Wind hybrid system.
- Upgradation of oil-based firing system with natural gas firing system in tunnel kiln.
- NG firing kiln and Automatic jigger.

The energy efficiency & renewable energy projects detailed in the case studies in this compendium indicate that there is a good potential for benefits in both low hanging and medium-to-high investment options. The ceramic units in Khurja can implement the low hanging fruits (with smaller investments) faster, as with minimum or no investments, several savings can be achieved. However, for the high investment projects, a detailed review in the form of DPR can be prepared.

The Khurja Ceramic sector should view this manual positively and utilize this opportunity to implement the best operating practices and energy saving ideas during design and operation stages and thus move towards achieving world class energy efficiency.

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