UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

Energy Efficiency and Renewable Energy Technologies in

Jamnagar Brass Cluster

September 2020

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Disclaimer

This document has been prepared to provide overall guidance for conserving energy and costs. It is an output of a research exercise undertaken by DESL supported by the United Nations Industrial Development Organization (UNIDO) and Bureau of Energy Efficiency (BEE) for the benefit of the Brass units located at Jamnagar, Gujarat, India. The contents and views expressed in this document are those of the contributors and do not necessarily reflect the views of DESL, 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

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

Energy Efficiency and Renewable Energy Technologies in Jamnagar Brass Cluster

September 2020

Developed under the assignment

Scaling up and expanding of project activities in MSME clusters

Prepared by

DESL

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DESL Team

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List of Abbreviations

BEE	Bureau of Energy Efficiency
DESL	Development Environergy Services Limited, New Delhi, India
EE	Energy Efficiency
EET	Energy Efficient Technologies
GEF	Global Environment Facility
GHG	Greenhouse Gases
GVVNL	Gujarat Vidyut Vitran Nigam Limited
MNRE	Ministry of New and Renewable Energy
MoMSME	Ministry of Micro, Small and Medium Enterprises
MSME	Micro Small and Medium Enterprises
PMC	Project Management Cell
PNG	Piped Natural Gas
PV	Photovoltaic
RE	Renewable Energy
SPM	Special Purpose Machine
SPM	Suspended Particulate Matter
UNIDO	United Nations Industrial Development Organization

Unit of Measurement

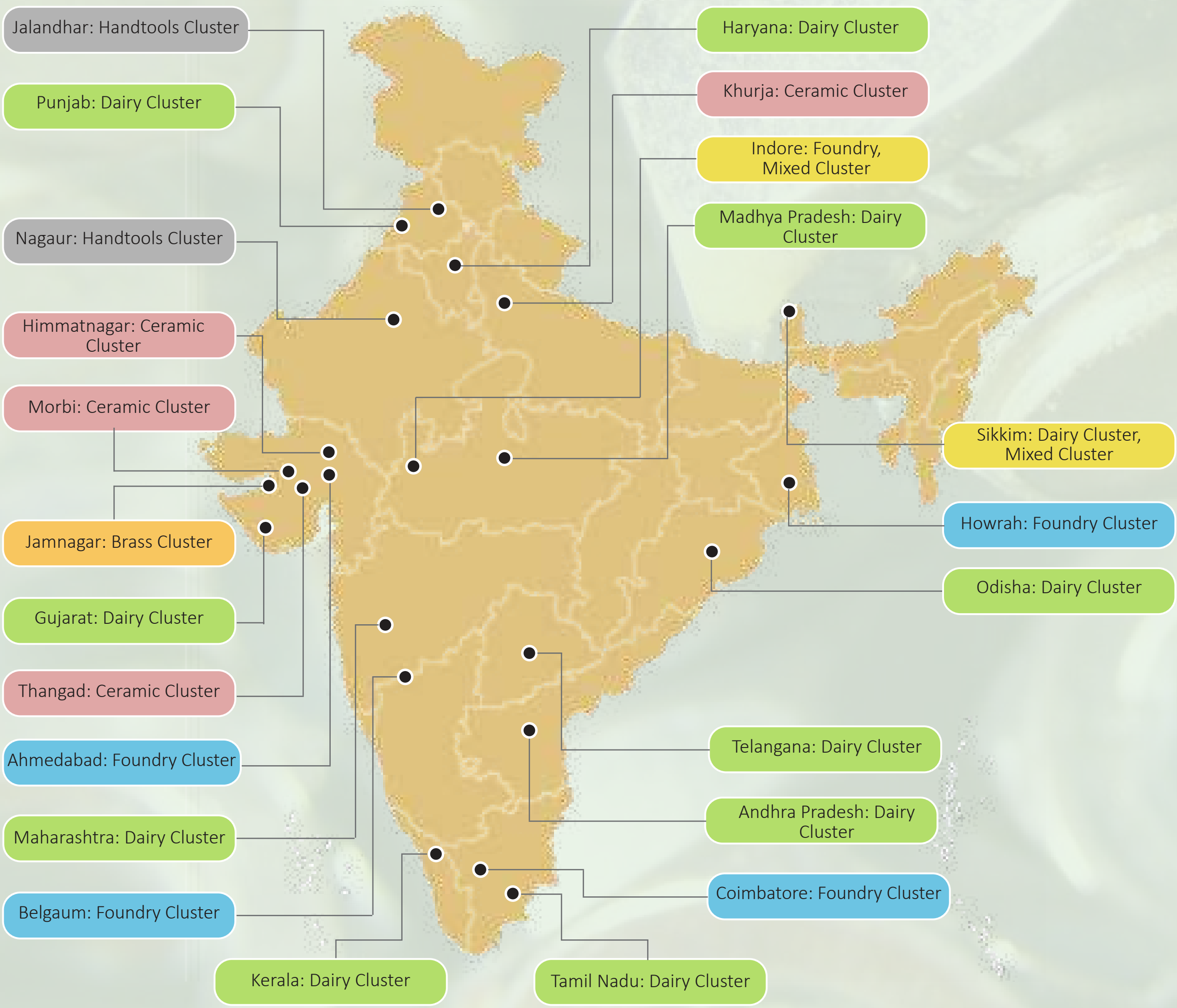
Parameters	UOM	Parameters	UOM
Ampere	A	Mega Joule	MJ
Approximate	~	Mega Volt Ampere	MVA
Centimeter	cm	Mega Watt Hour per Day	MWh/d
Centimeter Square	cm^2	Meter	m
Cubic Centimeter	cm^3	Meter cube	m^3
Cubic Feet per Minute	CFM	Meter Cube per hour	m^3/h
Cubic meter	m^3	Meter per minute	m/min
Cubic meter per day	m^3/d	Meter cube per second	m^3/s
Cubic meter per hour	m^3/h	Metric Ton	mt
Day(s)	d	Milligram	mg
Decibel	dB	Milligram per liter	mg/l
Degree Centigrade	^0C	Millimeter	mm
Degree Fahrenheit	^0F	Million	Mn
Dry Bulb Temperature	DBT	Million Tons of Oil Equivalent	MTOE
Giga Watt	GW	Minus	-
Giga Watt Hour	GWh	Minute(s)	min
Giga Watt Hour per Day	GWh/d	Normal Meter Cube	Nm^3
Giga Watt Hour per year	GWh/y	Normal Meter Cube per Hour	Nm^3/h
Gross Calorific value	GCV		
Hectare	ha	Parts Per Million	ppm
Hertz	Hz	Per Annum	p.a.
Horse power	hp	Percentage	%
Hour(s)	h	Plus	+
Hours per year	h/y	Plus or minus (Deviation)	±
Indian Rupee	INR	Power Factor	PF
Kilo Ampere	kA	Revolution per Minute	rpm
Kilo Calorie	kCal	Rupees	Rs
Kilo gram	Kg	Rupees per kilo Watt Hour	Rs/kWh
Kilo Joule	kJ	Rupees per Metric Ton	Rs/MT
Kilo ton	Kt	Second	s
Kilo volt	kV	Square Meter	m^2
Kilo volt ampere	kVA	Standard meter cube	Sm^3
Kilo Volt Root Mean Square	kV rms	Tesla	T
Kilo watt	kW	Ton	t
Kilo watt hour	kWh	Ton of CO_2	tCO_2
Kilocalorie per kilogram	kCal/kg	Ton per Day	t/d
Kilogram per ton	kg/t	Ton per Year	t/y
Kilogram per day	kg/d	Voltage	V
Kilo volt	kV	Watt	W
Kilo volt root mean square	kV-rms	Wet Bulb Temperature	WBT
Liter(s)	l or (L)	Year(s)	y
Year on Year	YOY		

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 aims to develop and promote a market environment for introducing energy efficiency (EE) and enhanced use of renewable energy (RE) technologies in process applications in selected energy intensive industrial clusters, comprising micro, small and medium enterprises (MSMEs). The project is supported by the Ministry of Micro, Small and Medium Enterprises (MoMSME) and Ministry of New and Renewable Energy (MNRE). The project was operational in 12 MSME clusters across India in five sectors namely Brass (Jamnagar); Ceramics (Khurja, Thangadh and Morbi); Dairy (Gujarat, Sikkim and Kerala); Foundry (Belgaum, Coimbatore and Indore); Hand Tools (Jalandhar and Nagaur) in its first phase. The Project has now scaled-up and expanded its activities to additional 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) 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.



Clusters intervened by the project

About the Technology Compendium

The Micro, Small and Medium Enterprises (MSME) sector in India are an important contributor to the country's economy. However, the sector faces challenges resulting from rising energy costs, environmental concerns and competitiveness. Most of the industries from the MSME sector use old and obsolete technologies leading to significant energy consumption. Studies show a significant potential in these units through adoption of energy efficient and renewable energy technologies.

The technology compendium has been prepared with the objective of accelerating the adoption of energy efficient and renewable energy technologies and practices applicable in the identified energy-intensive MSME sectors. The sector-wise technologies listed in the document consists of details about the baseline scenario, energy efficient alternatives available, advantages, limitations and cost benefit analysis for the same. The technology wise information is also supported by relevant case studies wherein benefits related to actual implementation of these technologies has been captured. Some notable points pertaining to the document are listed below:

- The compendium will act as a ready reckoner to the MSME units for continuously improving their energy performance leading to a cost-effective and sustainable production process.
- In the wide spectrum of technologies and equipment applicable for the sectors for energy efficiency, it is difficult to include all the energy conservation aspects in this manual. However, an attempt has been made to include more common implementable technologies across each of these sectors.
- The user of the compendium has to fine-tune the energy efficiency measures suggested in the compendium to their specific plant requirements, to achieve maximum benefits.
- The compendium also consists of a list of technology suppliers where the listed technologies can be sourced. However, in addition to the list provided in the compendium, there may be many more suppliers / consultants from where the technologies can be sourced.
- The technology compendium consists of list of energy efficient and renewable energy technologies under the broad categories of 'low investment', 'medium investment' and 'high investment measures'. Also due care has been taken to include technologies related to 'fuel switch', 'retrofit measures' as well as 'technology upgradation' options.
- The technologies collated in the compendium may not necessarily be the ultimate solution as the energy efficiency through technology upgradation is a continuous process and will eventually move towards better efficiency with advancement in technology.
- The document provides overview of the various available energy efficient and renewable energy technologies applicable in the targeted sectors. This provides an opportunity to the MSME units to implement the best operating practices and energy saving ideas during design and operations and to facilitate achieving world class energy efficiency standards.

Executive Summary

Jamnagar, known as the brass city of India, has been an important industrial centre since long for brass related parts. Jamnagar is inhabited by various types of brass related work units which include Brass foundry; Brass parts manufacturing, Electroplating and Extrusion units. There are about 3,500 brass related units alone in Jamnagar. Majority of these Brass units in Jamnagar are in operation since last 15 to 20 years, using very primitive technology for production.

The units are highly energy intensive with energy playing a significant role in the overall production cost. Significant potential for savings exists in the cluster through adoption of energy efficient and renewable energy technologies. The adoption of these technologies can make the units more cost competitive and sustainable.

The United Nations Industrial Development Organization (UNIDO) is playing a pivotal role jointly with the Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India towards scaling up the penetration of low-cost energy efficient technologies (EETs) in the Jamnagar Brass Cluster.

A total of 80 MSME Brass industries in the cluster are envisaged to be supported technically to become energy efficient and cost competitive.

This document is an outcome of the enormous research carried out in the sector, energy audits conducted in representation units and stakeholders' consultation conducted. The extensive research and ground level deployment of various teams has made it possible to consolidate list of energy efficient and renewable energy technologies applicable for the Jamnagar brass cluster. While most of these technologies have proven implementation record, some of the technologies are still in the developmental stage and will require efforts for implementation.

The compendium for energy efficient and renewable energy technologies has been compiled and consolidated, keeping in mind different types and capacity of the brass unit. This compendium can be used as a single point information booklet for various economically viable energy efficient and renewable energy technologies applicable in the cluster. Each technology has been complimented by a techno-commercial analysis report; in order to provide the readers with in-depth understanding of the technology. Each technology comes up with information on tentative investment, energy saving potential, cost savings and simple pay-back.

A vendor list has been also compiled at the end for easy reference of the units.

The technologies identified for the sector have been categorized into three groups and comprise both energy efficient and renewable energy technologies applicable for the sector.

Table 1: Energy Efficient and Renewable Energy Technologies for Jamnagar Brass Cluster

Category	Description	Technology	Investment (Rs in Lakhs)	Saving Potential (Rs in Lakhs)	Simple Pay-back (Rs in Lakhs)
A	Low Investment Technologies (up to Rs 2 lakhs)	Modification of coal based pit furnace	1-3	2-5	< 1 year
		Replacement of conventional motors with energy efficient (IE 3 class efficiency) motors	0.05-0.15	0.01-0.08	< 2 years
		Installation of EE pumps	0.75-1.5	0.3-0.6	< 2 years
		Installation of FRP Blades in Cooling Tower	0.25-0.50	0.3-0.6	< 1 year
B	Medium Investment Technologies (up to Rs 10 lakhs)	Installation of NG based brass melting furnace	5-15	4-12	< 1.5 years
		Installation of high efficiency in metallic recuperator	1-10	2-12	< 1 year
C	High Investment Technologies (more than Rs 10 lakhs)	Installation of IGBT based induction melting furnace	11-40	3-25	< 3.5 years
		Installation of piped natural gas based energy efficient reheating furnace	10-25	5-15	< 2.5 years
		Installation of solar PV system	8-400	2.25-112.5	< 4 years

**The figures on investment and savings are tentative and have been based on budgetary quotations and technical calculations; the actual figure may vary.*

About the Cluster 1

1.1 Cluster overview

Jamnagar District Is located in the North West of Gujarat State. It is bounded partly by Gulf and partly by the desert of Kutch in the North, Junagadh District in the South, Rajkot District in the East and Arabian Sea in the West. The District has a geographical area of 14,125 sq. km. It is spread between 21.42' to 22.57' Latitude and 68.57' to 70.37' Longitudes.

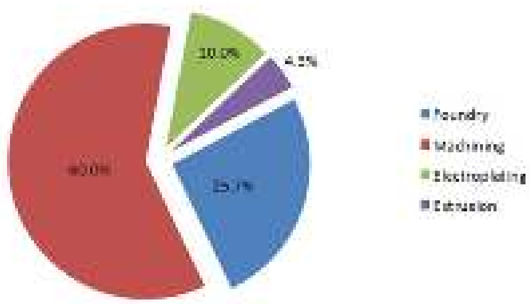


Figure 1: Number of units in Jamnagar brass cluster

Jamnagar is one of the largest brass industry clusters in India. There are around 3,500 brass units in the cluster: 900 foundries, 150 extrusion units, 2,100 machining units, and 350 electroplating units. The units produce between 200–400 tons per annum (tpa). Most of these units have been operating for about 15–20 years. Unlike other brass clusters in India, Jamnagar produces brass products that require extensive machining processes like turning, milling, grinding, drawing, boring, threading, and so on. The brass products from the cluster range from 1 gram to 10 kilogram in weight, and from 0.5 mm to 600 mm in length and diameter. (Source: www.sameeeksha.org)

Major products manufactured in Jamnagar Brass cluster are:

- Building hardware like door & window hinges, stoppers, knobs, studs, handles.
- Brass rods, rounds, hollow rods, square, sections, coils and wire.
- Sanitary & bathroom fittings like venetian blinds, hangers, taps, curtain fittings.
- Electronic & Electrical accessories like socket pin, battery terminal, switches, tester, computer sockets.
- Automobile & Cycle tube valves, industrial control valves.
- Agricultural Implements like tractor accessories.

1.2 The Process

The production process in the cluster is broadly divided into casting units and extrusion units. While the extrusion units are involved in the production of brass wires; the casting units are involved in manufacturing of a variety of products; some of which are also electroplated, based on the end users' requirement. Some of the units in the cluster are involved only in machining and electroplating of brass products. The process flow for the two broad categories of units are depicted in the figures below:

There are some units which are involved in production of varied products for which the process flow is modified accordingly.

From process point of view, Induction furnace, re-heating furnace, coal pit furnaces are the major energy consuming equipment followed by extrusion press and other machining and lathe machines. The casting units use coal based pit

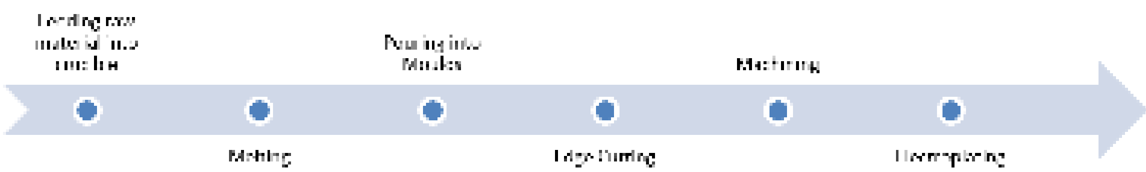


Figure 2: Brass casting unit process flow

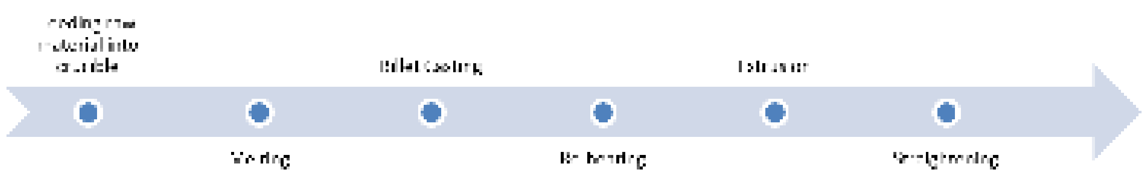


Figure 3: Brass extrusion unit process flow

furnace whereas both furnace oil and natural gas are used for the re-heating furnaces.

1.3 Technology status and energy use

The Jamnagarbrass cluster is distinctly differentiated in four types of units:

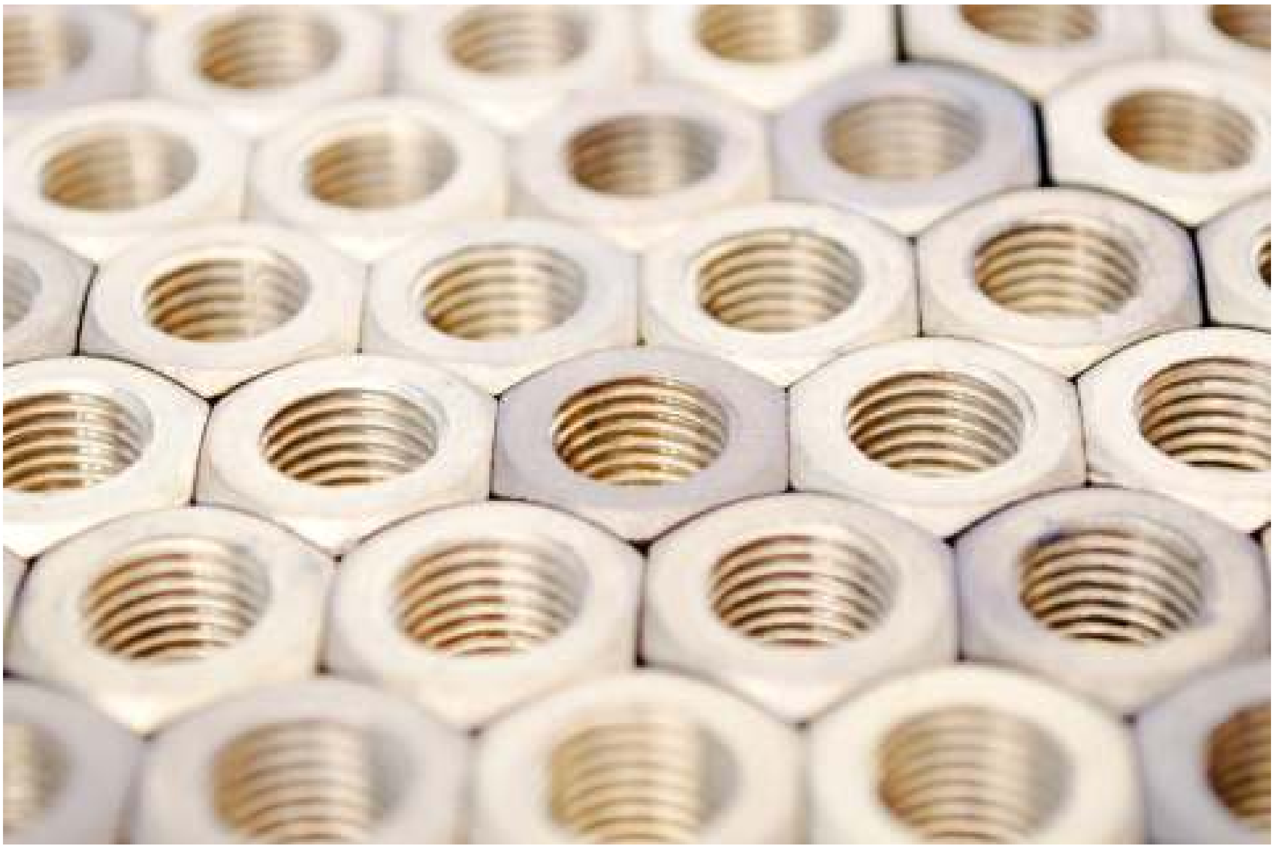
- Extrusion units.
- Foundry units.
- Machining units.
- Electroplating units.

Major raw materials used by extrusion and foundry units are brass scrap imported from USA, European and Gulf countries. They also use in-house generated scrap, lathe turning, etc. as a raw material.

The extrusion units have induction furnaces of different capacities (i.e. 300 to 2 ton) for melting of raw material. Billets are made by pouring of molten metal in water cooled moulds; these billets are reheated using FO/Gas reheating furnace to 650-750^{0}C before being transferred to extrusion press.

Foundry units have coal based pit furnace having capacity of 250-450 kg for melting of raw material, which is subsequently used in for pouring into different moulds to obtain various shapes.

The finishing operations are carried out in the machining and electroplating units. These units have lathe machines, water heater and drill machines.



Technology 1: Installation of New IGBT Based Induction Furnace

2

2.1 Conventional Practice

An induction furnace consists of a non-conductive crucible holding the charge of metal to be melted, surrounded by a coil of copper wire. A powerful alternating current flows through the wire. The coil creates a rapidly reversing magnetic field that penetrates the metal. The magnetic field induces eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, flowing through the electrical resistance of the bulk metal, heat it, by Joule heating.

Electric induction furnaces in India have been conventionally equipped with thyristor based inverter system allowing them to run on low to medium frequency. Heat produced per unit power in such cases is low, leading to higher cycle time for melting. In most cases, the power factor remains low and specific power consumption shoots up during low load condition. Most furnaces are not equipped with energy monitoring and data logging system. In some induction furnace plants, furnaces are more than eight to 10 years old. These furnaces have old coil system and do not have monitoring system for water conductivity. All this increases the specific power consumption & also leads to lesser yield.

2.2 Energy Efficient Technology

The inverter based power supply is an important factor for the operation of the induction furnace. More power can be fed into the induction furnace by increasing the frequency. With increased power, the melting can be fast, thus leading to reduction in specific power consumption. With the development of insulated-gate bipolar transistor (IGBT) based inverter, operating the furnace with higher frequency is possible. The hybrid inverter design has advantages of both parallel and series inverters and utilizes IGBT's capabilities to better control the inverter. The power conversion efficiency of these technologies is good compared to the earlier thyristor based control. Also, the power factor is maintained at a good level at any load. In IGBT based equipment, the major benefit is of power factor which is 0.98 during complete melting also sintering cycle. Also, less input kVA is required to run the same equipment which means we will get the same liquid metal with lesser input kVA.

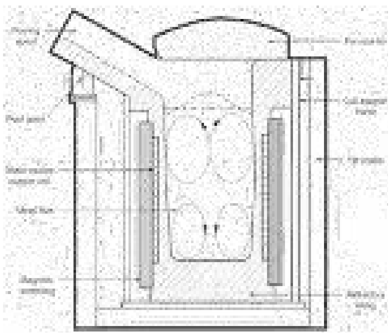


Figure 4: Schematic diagram of Induction Furnace

2.3 Benefits of technology

The replacement of conventional thyristor based power management system with IGBT based power management system will lead to the following benefits:

- Reduced specific power consumption
- Increased productivity
- Reduced time for melting cycle

2.4 Limitation of technology

IGBT power management system is not available for furnace capacity lower than 1 ton per hour.

2.5 Investment required, Energy & GHG saving potential & Cost Benefit Analysis

The table below (Table 3) illustrates energy saving potential by replacing a conventional (thyristor based) induction furnace with IGBT based induction furnace.

The investment required, energy savings and simple payback for different capacity range of furnaces have been tabulated below (Table 4):

Table 2: Details of induction furnace in Jamnagar brass extrusion units

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific power consumption	Hours of operation	Days of operation
Units	t/y	t/Heat	%	kWh/t	h/d	d/y
Values	600-4,000	0.30-2.00	50-60%	270-340	8-24	300

Table 3: Cost benefit analysis of IGBT based Induction furnace

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Average Production per heat	t	0.912	0.912
2	Average Heat Time	minutes	75	70
3	Average number of heats in a day	Heat/d	12	12
4	Specific Power Consumption	kWh/t	307.0	288.6
5	Total production	t/y	3,283	3,283
6	Annual Power consumption	kWh/y	1,008,000	947,520
7	Annual fuel saving	kWh/y		60,480
8	Power Tariff	Rs/kWh		7.5
9	Annual Monetary Saving	Rs in lakhs		4.54
10	Investment	Rs in lakhs		16
11	Simple Payback	y		3.5
12	Annual energy saving	toe/y		5.20
13	Annual GHG emission reduction	tCO_2/y		54.43

**Emission factor for electricity taken from IPCC guidelines 2006 (V2; C1 and C2) as 1 MWh = 0.9 tCO_2*

Table 4: Investment, savings and simple pay back for IGBT Based Induction Melting Furnace

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kg/ batch	Rs in Lakhs	Rs in Lakhs	years
	300-2,000	11-40	3-25	< 3.5 years

Case Study 1: Replacement of Thyristor based induction furnace to IGBT based Induction furnace

Established in 1985, Shree Ganesh Enterprise has gained success in the market by manufacturing a remarkable assortment of Brass Insert, Brass DP Parts, Brass Joint Socket, Brass Electrical Pins, etc. The unit has developed a well functional and spacious infrastructural unit where they manufacture these components in an efficient manner.

In 2018, the unit took an initiative to replace their old conventional thyristor based Induction furnace with new energy efficient IGBT induction furnace, which led to higher production at lower electricity consumption.

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Average Production per heat	t	0.3	0.3
2	Average Heat Time	minutes	75	70
3	Average number of heats in a day	Heat/d	12	12
4	Specific Power Consumption	kWh/t	333.3	306.7
5	Total production	t/y	1,080	1,080
6	Annual Power consumption	kWh/y	360,000	331,200
7	Annual fuel saving	kWh/y		28,800
8	Power Tariff	Rs/kWh		7.5
9	Annual Monetary Saving	Rs in lakhs		2.16
10	Investment	Rs in lakhs		8
11	Simple Payback	y		3.7
12	Annual energy saving	toe/y		2.48
13	Annual GHG emission reduction	tCO_2/y		25.92

** Emission factor for electricity taken from IPCC guidelines 2006 (Vs; C1 and C2) as 1 MWh = 0.9 tCO_2*

Technology 2: Installation of piped natural gas based energy efficient reheating furnace

3.1 Conventional Practice

Typically, the extrusion units in Jamnagar brass cluster have pusher type oil fired reheating furnaces, which are locally made of fire bricks covered with steel sheet. These furnaces are of very primitive design; have poor preheating of charge. They do not have waste heat recovery system and poor heat transfer efficiency between hot flue gasses & billets. In most of the units, there is no monitoring and control system available for the furnace operation. The furnace is equipped with locally manufactured burners which are used for oil firing. Combustion air is supplied using a blower. These furnaces are operated manually with no provision for waste heat recovery. The poor design of the furnace leads to high start-up time and high specific energy consumption. The capacity of the reheating furnace at Jamnagar brass cluster varies in between 500 to 2,500 kilogram per hour with specific fuel consumption ranging from 50-60 liters of furnace oil per ton of product. The daily production ranges from 3 to 8 tons of products per day. The rising price of furnace oil makes it necessary for the units to explore an alternate heating methodology.

Figure 5: An oil fired reheating furnace

3.2 Energy Efficient Technology

In reheating furnaces, use of natural gas fuel as replacement of furnace oil leads to cleaner and healthier production. PNG line is available in some parts of the country which can be used as fuel for the re-heating furnace. Natural gas as fuel not onlyallows a better environment for the unit; but also provides significant improvement in the furnace's internal environment. Natural gas firing controlled with PID control system for optimum air to fuel ratio control can lead to optimum specific fuel consumption and burning loss. Also, the efficiency of the furnace improves significantly due to waste heat recovery system, leading to a longer furnace life.

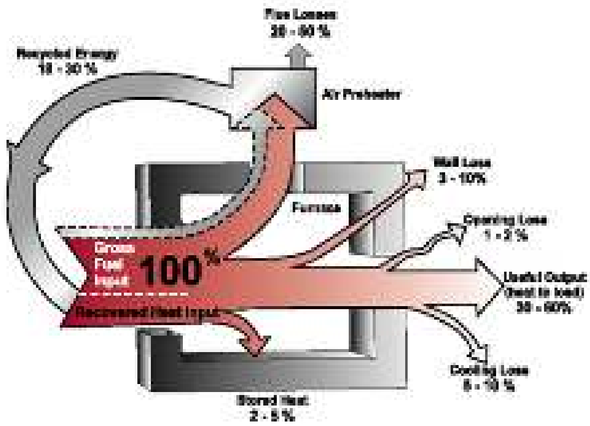


Figure 6: Sankey diagram of heat loss with benefit of Waste heat recovery system

3.3 Benefits of technology

As a superior alternative to furnace oil heating, gas re-heating with waste heat recovery and PID control provides faster, more efficient heat in reheating applications. PID control system gets feedback from thermocouple/oxygen analyzer and provides optimum air to fuel ratio control. Benefits of using natural gas for reheating furnaces are as follows:

- Improved productivity and higher volumes
- Cost-effective, reduces energy consumption

3.4 Limitation of technology

Piped natural gas line is not available in all areas.

3.5 Investment required, Energy & GHG saving potential & Cost Benefit Analysis

The following section provides the details of replacement of gas firing with natural gas firing in re-heating furnace in terms of energy & greenhouse gas (GHG) saving potential, investment required and cost-benefit analysis. The calculations have been provided considering a 0.6t/h furnace.

Table 5: Details of FO fired reheating furnace

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
Units	t/y	kg/ h	%	l/t	h/d	d/y
Values	600-4,000	500-3,000	10-20	50-60	6-12	300

Table 6: Investment, savings and simple pay back for NG based EE reheating furnace

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	kg/ h	600	600
2	Operating hours per day	h/d	6	6
3	Operating days per year	d/y	300	300
4	Annual production	t/y	1,080	1,080
5	Hourly fuel consumption (baseline)	l/h	27	
6	Specific fuel consumption (baseline)	l/kg	0.045	
7	GCV	kcal/kg	10,100	10,750
8	Density of fuel	kg/l	0.96	0.8
9	Raw material input temperature	^0C	35	35
10	Product final temperature	^0C	720	720
11	Specific heat of Brass	kcal/kg^{0}C	0.0912	0.0912
12	Hourly gas consumption (post implementation)	m^3/h		20.5
13	Specific energy consumption (post implementation)	m^3/kg		0.034
14	Furnace Direct Efficiency	%	14.3	21.3
15	Annual energy consumption	kcal/y	471,225,600	317,340,000
16	Annual energy saving	kcal/y		153,885,600
17	Annual fuel saving	l/y		15,871.04
18	Furnace oil cost	Rs/l		34
19	Annual Monetary Saving	Rs in lakhs		5.40
20	Investment	Rs in lakhs		12
21	Simple Payback	y		2.22
22	Annual energy saving	toe/y		15.38
23	Annual GHG emission reduction	tCO_2/y		61.25

**Emission factor of furnace oil = 2.68 kgCO$_2$/kg, Natural Gas = 1.87 kgCO$_2$/m^3 is taken from IPCC guidelines 2006 (V2; C1 and C2)*

The investment required, energy savings and simple payback for different capacity range of furnaces have been tabulated below (Table 7):

Table 7: Investment, savings and simple pay back for NG based EE reheating furnace

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kg/ batch	Rs in Lakhs	Rs in Lakhs	years
	500-3,000	10-25	5-15	< 2.5 years

Case Study 2: Replacement of FO Fired Reheating Furnace with Piped Natural Gas Fired Reheating Furnace

Gold Metal Extrusion manufactures extruded brass rod, brass ingot, brass billet, extruded brass profile, extruded brass section in conformation to different standards like IS, BS, DIN, ASTM etc. The company is awarded with ISO-9001:2008 by TUV RHEINLAND.

The company took a key initiative towards energy efficiency and use of clean energy for production in the year 2018 by installing energy efficient natural gas fired re-heating furnace with waste heat recovery system. The new furnace was equipped with a temperature based controller, a waste heat recovery system and energy efficient gas burners. With this initiative, the company was able to save substantially in terms of energy cost. The new furnace also ensured better and consistent heating leading to enhanced quality.

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	kg/ h	1,500	1,500
2	Operating hours per day	h/d	6	6
3	Operating days per year	d/y	300	300
4	Annual production	t/y	2,700	2,700
5	Hourly fuel consumption (baseline)	l/h	67.5	
6	Specific fuel consumption (baseline)	l/kg	0.045	
7	GCV	kcal/kg	10,100	10,750
8	Density of fuel	kg/l	0.96	0.8
9	Raw material input temperature	^{0}C	35	35
10	Product final temperature	^{0}C	720	720
11	Specific heat of Brass	kcal/kg^{0}C	0.0912	0.0912
12	Hourly gas consumption (post implementation)	m^3/h		51
13	Specific energy consumption (post implementation)	m^3/kg		0.034
14	Furnace Direct Efficiency	%	14.3%	21.4%
15	Annual energy consumption	kcal/y	1,178,064,000	789,480,000
16	Annual energy saving	kcal/y		388,584,000
17	Annual fuel saving	l/y		40,076
18	Furnace oil cost	Rs/l		34
19	Annual Monetary Saving	Rs in lakhs		13.63
20	Investment	Rs in lakhs		12
21	Simple Payback	y		0.88
22	Annual energy saving	toe/y		38.85
23	Annual GHG emission reduction	tCO_2/y		126.12

** Emission factor of furnace oil = 2.68 kgCO2/kg, Natural Gas = 1.87 kgCO_2/m^3 is as per IPCC guidelines 2006 (Vs; C1 and C2)*

4 Technology No. 3: Installation of Solar Photovoltaic System for Power Generation

4.1 Baseline Scenario

Electricity is the key component of the total production in a brass industry. The units at Jamnagar get power from the Gujarat Vidyut Vitran Nigam Limited (GVVNL). The connected load in individual units varies from 10 kW to 2,000 kW. Power generated from fossil fuel based power plants is a threat for the country's natural resources as well as the environmental impacts. Switching over to renewable energy for power generation is an important contribution towards the country's sustainable development.

4.2 Energy efficient technology

Power generation using solar photovoltaic system is a sustainable alternative to survive in the growing competitive market environment. A photovoltaic system, also called as PV system or solar power system, is a power system designed to supply usable solar power by means of photovoltaic. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to convert the output from direct to alternating current, as well as mounting, cabling, and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution.

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts. Nowadays, most PV systems are grid-connected, while off-grid or stand-alone systems account for a small portion of the market.

Figure 7: Solar PV installation

The industries at Jamnagar have a significant potential to generate power using solar photovoltaic system by either going for roof-top installation or ground mounted installation. Using a net metering system, the total electrical energy generated using photovoltaic system can be accounted for and deducted from the total grid supplied electricity.

4.3 Benefits of technology

Adoption of solar photovoltaic system has the following benefits:

- Captive generation of electrical energy
- Clean and greener source of electricity
- Can be integrated with grid with net metering system
- Minimal operating and maintenance cost
- Long service life
- Only one time investment

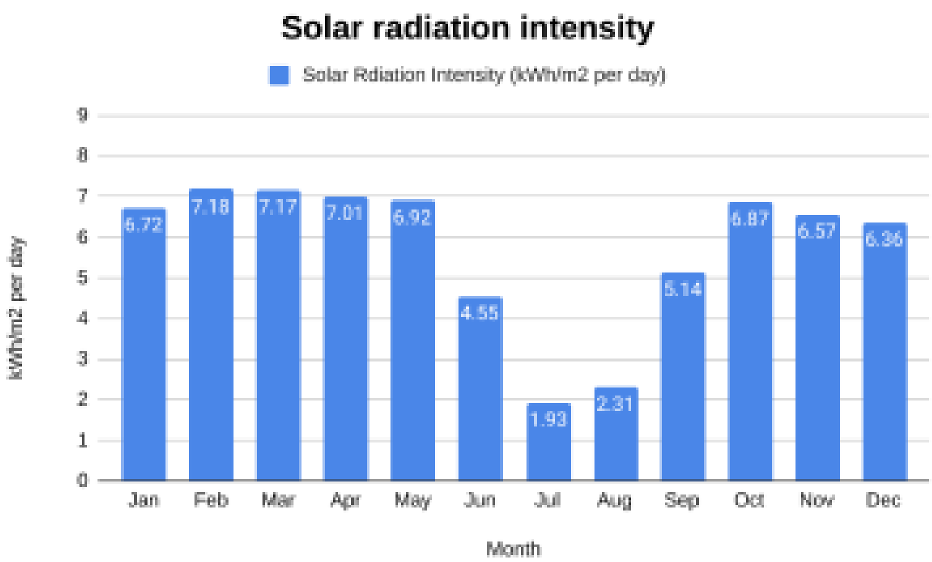


Figure 8: Solar radiation intensity for Jamnagar, Gujarat

4.4 Limitation of technology

- Adoption of solar photovoltaic needs high capital investment.
- Generation of dust in the industrial area causes hindrance on the efficiency of the photovoltaic system.

4.5 Cost benefit analysis

To understand the cost benefit analysis, let us consider a solar PV system of 20 kWp capacity. The cost benefit analysis for adoption of the technology has been tabulated below:

The investment required, energy savings and simple payback for different capacity range of installation have been tabulated below:

Table 8: Investment, savings and simple pay back for Solar PV Installation

Sl.No.	Parameter	Unit	Value
1	Capacity of Solar PV system	kWp	20
2	Area required	Sq. m.	160
3	Solar power generation capacity	kWh/kWp	5
4	Generation potential	kWh/d	100
5	Annual solar radiation days	d/y	300
6	Generation potential	kWh/y	30,000
7	Electricity charges	Rs/kWh	7.5
8	Annual monetary saving	Rs in Lakh	225,000
9	Investment	Rs in Lakh	800,000
10	Simple Payback	y	4
11	Annual energy savings	toe/y	3
12	Annual energy saving	toe/y	2.58
13	Annual GHG emission reduction	tCO_2/y	27

**Emission factor for electricity taken from IPCC guidelines 2006 (V2; C1 and C2) as 1 MWh = 0.9 tCO_2*

Table 9: Investment, savings and simple pay back for Solar PV Installation

Parameters	Installation Capacity	Investment	Annual monetary savings	Simple payback
Units	kWp	Rs in Lakhs	Rs in Lakhs	years
	20-1,000	8-400	2.25-112.5	< 4 years

Case Study 3: Installation of Solar Photovoltaic system for power generation

Rajhans Impex Pvt Ltd (RIPL) is an autonomous family run company, established in the year 2004. Since its inception Rajhans Impex has sought to raise the bar in the brass extrusion industry. With modern manufacturing processes and technology the company provides quality products & services. It has carved a niche in the industry by rapid innovation and prompt response to the market trends. As a result, today Rajhans Impex is a preferred name not only amongst domestic brass semis consumers but also among overseas consumers.

In 2018, the unit took an initiative to switch over to renewable energy for power generation. The unit installed a 220 kWp Solar Photovoltaic Roof top mounted system.

Sl. No.	Parameter	Unit	Value
1	Capacity of Solar PV system	kWp	220
2	Area covered	Sq. m.	2,200
3	Solar power generation capacity	kWh/kWp	4.5
4	Generation potential	kWh/d	990
5	Annual solar radiation days	d/y	365
6	Generation potential	kWh/y	3,61,350
7	Electricity charges	Rs/kWh	6
8	Annual monetary saving	Rs in Lakh	21.68
9	Investment	Rs in Lakh	100
10	Simple Payback	y	4.6
11	Annual energy savings	toe/y	31.07
12	Annual GHG emission reduction	tCO_2/y	235.21

** Emission factor for electricity taken from IPCC guidelines 2006 (Vs; C1 and C2) as 1 MWh = 0.9* tCO_2

Technology No. 4: Replacement of Coal Pit Furnace with Gas Fired Melting Furnace

5

5.1 Baseline Scenario

Brass melting foundry units are using high grade coal as fuel for melting purpose. The conventional coal has low efficiency of around 15-17%, and it generally takes 1.5 to 2 hours for the material to melt completely. It was observed that the coal fired pit furnace has poor efficiency due to poor combustion space, improper location and size of burners and improper capacity of blower system etc. Also, there is no waste heat recovery system to recover the heat losses from hot flue gasses in pit furnaces. Coal has been traditionally used as the most common form of energy. However, firing coal into the pit furnace is dirty process and also causes threat to health of the workers due to the local level pollution. Coal also increases the suspended particulate matter (SPM) level of the factory's environment thus causing threat to the nearby locality. Piped natural gas is already available for GIDC-II, GIDC-III and near Gokulnagar industrial area, for Shankar Tekri area work is in progress and most likely will be completed within 3-4 months.

5.2 Energy efficient technology

Use of natural gas as fuel as replacement of coal leads to cleaner and healthier production. Piped gas line is available in some parts of the country which can be used as fuel for the pit furnaces. Natural gas as fuel not only allows a better environment for the unit; but also provides significant improvement in the furnace internal environment. Natural gas firing, if controlled in a proper fashion, can lead to optimum specific fuel consumption and burning loss. Also, the efficiency of the furnace improves significantly, leading to a longer furnace life.

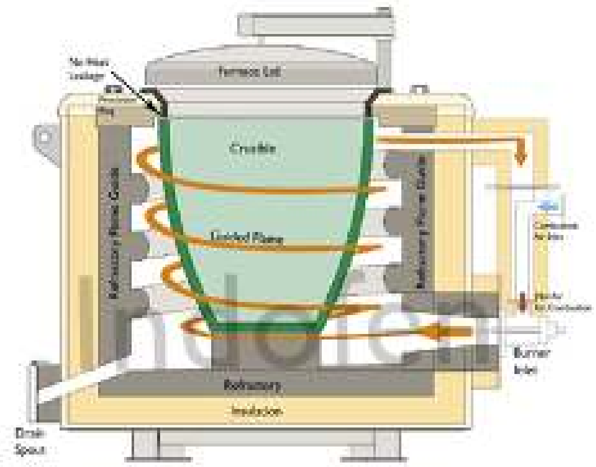


Figure 9 : Schematic diagram of Gas based melting furnace

5.3 Benefits of technology

As a superior alternative to coal pit furnace, gas pit furnaces are more efficient. Benefits of using natural gas for pit furnaces are as follows:

- Improved productivity and higher volumes.
- Cost-effective, reduces energy consumption.
- Improved working environment& furnace life.

5.4 Limitation of technology

Piped natural gas line is not available in all areas.

Lack of awareness about technology and its design; also un-availability of local vendors is an issue.

Table 10: Details of coal pit furnaces

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
Units	t/y	kg/ h	%	kg/t	h/d	d/y
Values	300-800	250-350	12-17	55-75	6-12	300

5.5 Cost benefit analysis

The cost-benefit analysis for adoption of the technology has been tabulated below (Table 11):

The investment required, energy savings and simple payback for different capacity range of furnaces have been tabulated below (Table 12):

Table 11: Cost benefit analysis of gas pit furnace

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	kg/ h	400	400
2	No of heat per day	h/d	6	6
3	Number of days	d/y	300	300
4	Annual production	t/y	720	720
5	fuel consumption per cycle	kg/heat	38	
6	Specific fuel consumption	kg/t	0.095	
7	GCV of Coal	kcal/kg	7,200	
8	Raw material input temperature	^0C	35	35
9	Product final temperature	^0C	990	990
10	Specific heat of Brass	kcal/kg^0C	0.0912	0.0912
11	Sensible Heat absorbed by the Material	kcal	34,838.4	34,838.4
12	Latent heat fusion of Brass	kcal/kg	40.15	40.15
13	Latent heat of molten Brass material	kcal	16,060	16,060
14	Total heat absorbed in Brass molten material	kcal	50,898.4	50,898.4
15	Hourly gas consumption	m^3/h		23
16	GCV of PNG	kcal/m^3		8,600
17	Specific energy consumption	m^3/kg		0.058
18	Furnace Direct Efficiency	%	18.6%	25.7%
19	Annual energy consumption	kcal/y	492,480,000	356,040,000
20	Total connected load	hp		5
21	Total electricity consumption	kWh/y		25,652
22	Cost of electricity	Rs/kWh		7.5
23	Annual energy saving	kcal/y		114,379,211
24	Annual fuel saving	t/y		15.9
25	Cost of coal	Rs/t		32,000
26	Annual Monetary Saving	Rs in lakhs		5.08
27	Investment	Rs in lakhs		6
28	Simple Payback	y		1.2
29	Annual energy saving	toe/y		11.44
30	Annual GHG emission reduction	tCO_2/y		37.51

**Emission factor of coal = 2.57 kg of CO_2/kg from IPCC Guidelines 2006 (V2; C1 and C2)*

Table 12: Investment, savings and simple pay back for NG based brass melting furnace

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kg/ batch	Rs in Lakhs	Rs in Lakhs	year
	200-500	5-15	4-12	< 1.5 years

Technology No. 5: Modification of Coal Fired Pit Furnace

6

6.1 Baseline Scenario

The coal/coke-fired pit furnaces are used for brass melting due to their simple construction and easy operation. The maintenance cost of such furnaces is low. The simple schematic diagram of traditional pit furnace is shown in the figure below. The traditional pit furnace is constructed by digging below the floor level. The furnace wall is built by using local brick and mud. The furnace is divided into two parts; (i) Combustion chamber and (ii) Ash chamber. A grid made of steel bars is placed in between the combustion chamber and ash pit to hold the coal/coke for combustion. In the combustion chamber, a clay-graphite crucible is placed in the centre of the hearth on the coal/coke bed. The surrounding gap between the wall and crucible is also partially filled with coal/coke for better efficiency of melting. Brass and its scrap are put into the crucible with help of tongsfor melting. A hand-operated or electrical blower is used to blow air into the combustion chamber through the ash pit. The capacity of the brass melting furnace is, in general, 150-300kg.

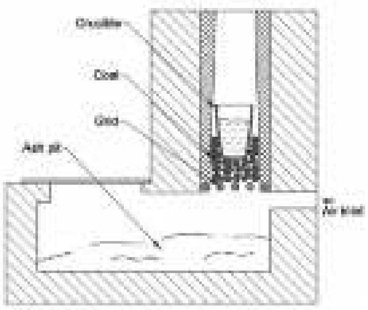


Figure 10: Schematic diagram of conventional coal based brass melting furnace

The drawbacks of the traditional brass melting furnace are:

Not fuel-efficient;

- The top of furnace is open, resulting in indirect culate matter, which makes the surrounding area polluted;
- The artisans are directly exposed to heat and fumes, as they work by sitting nearly at top opening of the furnace;
- Duringmelting, lots of zinc vapour comes out of the furnace which the artisans directly inhale;
- Cold air is fed into the furnace for burning of coal/coke resulting in higher fuel consumption;
- Higher oxidation loss of molten metal, thus, degrades the quality of brass.

6.2 Energy efficient technology

The existing traditional furnace is proposed to be modified by introducing some structural changes in the traditional furnace, in addition to accommodating a heat recovery system. The schematic diagram of energy-efficient brass melting pit furnace is shown. The modified brass melting furnace was prepared by digging the ground below the floor level. Normal bricks and clay were used to build the base of the furnace. The ash pit was built by constructing two parallel walls of bricks on the base of the furnace pit. The artisans clean the ash pit only once in a week. Therefore, the ash pit had to be big enough to hold the ash of coal/coal for 6 days of continuous operation. In addition, the ash pit was designed in such a way that it did not hinder the air flow to the melting chamber. A square grid fabricated from mild steel rod was kept at the bottom of the melting chamber that supported coke in combustion chamber and allowed only ash to fall in the ash chamber. The walls were constructed from local bricks and mud was used as mortar. A layer of clay coating was applied to the base and walls of the furnace when brickwork was completed. A cylindrical melting chamber was prepared in the middle of the furnace. Desired amount of coke was paced over the grid and then clay graphite was placed over the coke bed. After placing the crucible in the centre of the combustion chamber of furnace, the annular gap between the crucible and wall was filled with coke to ensure that the crucible remained in the centre of the furnace and was heated uniformly. A clay-lined mild steel lid was placed on the furnace top to ensure no leakage of out-going hot gases. A preheater fabricated from mild steel plate was placed and fitted adjacent to the furnace wall such that the air for combustion got preheated when it passed through the preheater to the combustion chamber by the outgoing hot gases.

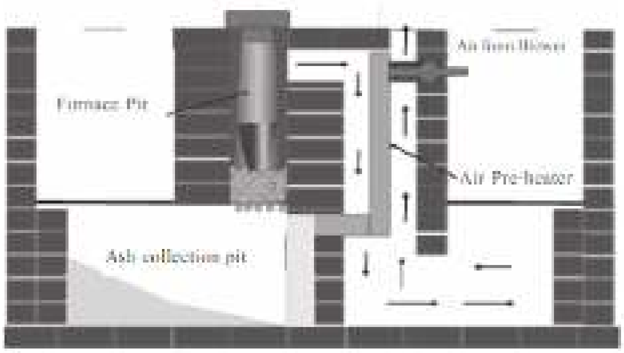


Figure 11: Schematic diagram of modified coal based brass melting furnace

6.3 Benefits of technology

The advantages of the developed energy-efficient brass melting furnace are:

- Reduction in coke consumption by 20-40%
- Reduction in melting time by 25%
- Considerably less toxic emissions to the atmosphere

- The artisans are not exposed to toxic flue along with heavy suspended particulate matter since the top of the furnace is closed
- The oxidation loss of materials is less

6.4 Limitation of technology

None.

6.5 Cost benefit analysis

The cost benefit analysis for modification in coal pit furnace has been tabulated below (Table 13):

The investment required, energy savings and simple payback for different capacity range of furnaces have been tabulated below (Table 14):

Table 13: Cost benefit analysis of modification in coal pit furnace

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	kg/ h	400	400
2	No of heat per day	h/d	6	6
3	Number of days	d/y	300	300
4	Annual production	t/y	720	720
5	fuel consumption per cycle	kg/heat	38	34.2
6	Total fuel consumption	t/y	68.4	61.6
7	Annual fuel saving	t/y		6.8
8	Cost of coal	Rs/t		32,000
9	Annual Monetary Saving	Rs in lakhs		2.19
10	Investment	Rs in lakhs		1.5
11	Simple Payback	y		0.69
12	Annual energy saving	toe/y		4.92
13	Annual GHG emission reduction	tCO_2/y		17.58

**Emission factor of coal = 2.57 kg of CO_2/kg from IPCC guideline 2006 (V2; C1 and C2)*

Table 14: Investment, savings and simple pay back for EE coal based pit furnace

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kg/ batch	Rs in Lakhs	Rs in Lakhs	years
	200-300	1-3	2-5	< 1 year

Technology No. 6: Replacement of Metal Blades with FRP Blades in Cooling Tower Fan

7

7.1 Baseline Scenario

The induction furnace unit has cooling towers to serve the cooling water needs of coil and panel cooling. The cooling water from the cooling tower comes to the pump suction by gravity and the pump supplies it to the coil and panel of the furnace. The cooling water from the furnace then goes back to the cooling tower. Existing cooling towers have induced axial flow fans with metallic/aluminum blades. It is well known that metallic/aluminum blades are heavier and need relatively greater starting torque.

7.2 Energy efficient technology

The use of FRP blades instead of metallic/aluminum blades will save energy and improve the performance of the cooling towers owing to the better aerodynamic shape of its blades. The power measurements show that the fan with FRP blades consumes less power compared to the metallic blade fan. The difference in power consumption is around 25 to 30%. It is recommended to replace existing metallic/aluminum fan blades in the cooling tower with fibre reinforced plastic blades.

7.3 Benefits of technology

Benefits of using FRP blades are as follows:

- Higher Efficiency
- Reduces the amount of stress placed upon the gearbox and driveshaft
- Higher Durability

7.4 Limitation of technology

None.

7.5 Cost benefit analysis

The cost benefit analysis for fibre reinforced plastic/polymer is tabulated below (Table 15):

The investment required, energy savings and simple payback for different capacity range of cooling towers have been tabulated below (Table 16):

Table 15: Cost benefit analysis of FRP blades

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Rated power of CT fan	kW	3.73	3.73
2	Power consumption of CT fan	kW	2.80	2.1
3	Operating hours per day	h	20	20
4	Number of operating days ina year	No.	300	300
5	Power consumption of CT fan	kWh/y	16,785	12,589
6	Annual energy saving	kWh/y		4,196
7	Electricity charges	Rs/kWh		7.5
8	Annual monetary saving in INR	Rs in Lakh/y		0.315
9	Price of FRP blades	Rs in Lakh		0.25
10	Simple payback period	y		0.79
11	GHG reduction potential	tCO_2/y		3.78

**Emission factor for electricity taken from IPCC guidelines 2006 (V2; C1 and C2) as 1 MWh = 0.9 tCO2*

Table 16: Investment, savings and simple payback for FRP fans in cooling towers

Parameters	Rated Capacity	Investment	Annual monetary savings	Simple payback
Units	kW	Rs in Lakhs	Rs in Lakhs	years
	3.7-5.5	0.25-0.50	0.3-0.6	< 1 year

Case Study 4: Replacement of Metal blades with FRP blades in Cooling tower fan

Rajhans Metals Pvt. Ltd. is an alloys extrusion unit located in Jamnagar, Gujarat. They were established in 1988 and manufacture over 2,400 customized brass components. Unit has the capacity to produce around 18,000 MT per annum.

The plant installed energy efficient fibre reinforced plastic blades in place of aluminium blades in their existing cooling tower. FRP fans typically outperform Aluminum fans primarily because of manufacturing limitations of the production of aerodynamic shapes with Aluminum. The very nature of FRP allows making any desired shape and twist in the blade as needed to achieve maximum performance.

The plant saved substantially in their energy bill.

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Rated power of CT fan	kW	3.73	3.73
2	Power consumption of CT fan	kW	2.80	2.1
3	Operating hours per day	h	20	20
4	Number of operating days in a year	No.	300	300
5	Power consumption of CT fan	kWh/y	16,785	12,589
6	Annual energy saving	kWh/y		4,196
7	Electricity charges	Rs/kWh		7.5
8	Annual monetary saving in INR	Rs in Lakh/y		0.315
9	Price of FRP blades	Rs in Lakh		0.25
10	Simple payback period	y		0.79
11	GHG reduction potential	tCO_2/y		3.78

** Emission factor for electricity taken from IPCC guidelines 2006 (Vs; C1 and C2) as 1 MWh = 0.9 tCO_2*

Technology No. 7: Energy Efficient Pump 8

8.1 Baseline Scenario

A pumping system is an integral part of auxiliaries in the induction furnace operation. Pumps are installed for coil cooling, heat exchanger and panel cooling. Mainly, monobloc type pumps are used in the cooling water circuit of the induction furnaces. The pumping system contributes to around 5 to 6% of the total energy consumption for per ton of production. Existing pumps were found to be old and inefficient in majority of the units. The performance evaluation of some of the existing coil cooling pumps indicates operating efficiency to be around 40%, which is quite low.

8.2 Energy efficient technology

In order to reduce the power consumption of the auxiliary system, it is recommended to replace the existing pump with an energy-efficient pump matching the designed head and flow. A comparison of performance of existing pumps with the more energy efficient pumps available in the market revealed that there is significant energy saving potential, if these pumps are replaced.

8.3 Benefits of technology

Installation of new energy efficient pumps has the following benefits:

- Higher efficiency
- Low power consumption

8.4 Limitation of technology

None.

8.5 Cost benefit analysis

The cost benefit analysis for replacement of old pumps with energy efficient pumps is tabulated below:

The investment required, energy savings and simple payback for different capacity range of pumps have been tabulated below:

Table 17: Cost benefits analysis for energy efficient pumps

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Rated power of CT pump	kW	5	5
2	Rated Motor efficiency	%	85%	88.4%
3	Power consumption of CT pump	kW	4.25	3.0
4	Pump efficiency	%	40%	55%
5	Work done by pump (Hydraulic Power)	kW	1.45	1.45
6	Operating hours per day	h	20	20
7	Number of operating days in a year	No.	300	300
8	Total power consumption	kWh/y	25,500	17,832
9	Annual energy saving	kWh/y		7,668
10	Electricity charges	Rs/kWh		7.5
11	Annual monetary saving in INR	Rs in Lakh/y		0.575
12	Price of energy efficient pumps	Rs in Lakh		1
13	Simple payback period	y		1.74
14	GHG reduction potential	tCO_2/y		6.90

**Emission factor for electricity taken from IPCC guidelines 2006 (V2; C1 and C2) as 1 MWh = 0.9 tCO_2*

Table 18: Investment, savings and simple pay back for EE pumps

Parameters	Rated Capacity	Investment	Annual monetary savings	Simple payback
Units	kW	Rs in Lakhs	Rs in Lakhs	Years
	3.7-5.5	0.75-1.5	0.3-0.6	< 2 years

Case Study 5: Installing new energy efficient horizontal multistage pump

Adinath Extrusion Pvt. Ltd. is a foundry unit located in Jamnagar, Gujarat. Established in 2009, the company manufactures various brass components. The plant installed an energy efficient horizontal multistage pump in place of an old centrifugal pump for circulating water to cool the induction coil of the furnace. Horizontal multistage pumps have low noise and long-life and are of compact design. They can operate with liquids up to 70 deg C.

Sl. No.	Parameter	Unit	Value
1	Energy Saving	kWh/m	1,440
2	Energy Saving	kWh/y	17,280
3	Electricity charges	Rs/kWh	7.5
4	Annual monetary saving	Rs in Lakh	1.296
5	Investment	Rs in Lakh	0.45
6	Simple Payback	y	0.4
7	Annual energy savings	toe/y	14.86
8	Annual GHG emission reduction	tCO_2/y	15.55

** Emission factor for electricity taken from IPCC guidelines 2006 (Vs; C1 and C2) as 1 MWh = 0.9 tCO_2*

Technology No. 8: Installation of High Efficiency Metallic Recuperator in Re-heating Furnace

9

9.1 Baseline Scenario

Most of the extrusion units use top-fired pusher type re-heating furnaces with solid, liquid or gaseous fuel. In a typical furnace, only 30-40% of the total heat input is converted to useful heat. Rest of the energy is lost through different areas and forms.

The waste flue gas loss forms the major loss in a re-heating furnace which accounts for 30-35% of the total heat input. Exhaust flue gas from the furnace at a temperature of 450-600 ^{0}C has a potential to be re-used in the furnace. Traditionally, flue gases from the re-heating furnace are let out into the atmosphere through the chimney, resulting in wastage of significant heat of flue gas.

9.2 Energy efficient technology

As an alternative to the conventional practice, a recuperator, i.e. a heat exchanger is installed in the flue duct and used to recover the waste heat from the flue gases.

In a recuperator, heat exchange takes place between the flue gases and the inlet combustion air through metallic or ceramic walls. Ducts or tubes carry the combustion air to be pre-heated; the other side consists of the waste heat stream. The system works based on the basic principle of Physics which says energy moves from a hot body to a cold. Thus, in the process, the inlet combustion air from atmosphere is pre-heated using the waste gas. The pre-heated combustion air is fed directly into the burner. The result is saving in terms of fuels, increase in flame temperature and improvement in furnace efficiency.

9.3 Benefits of technology

Installation of recuperator has the following benefits:

- Pre heated combustion air improves efficiency.
- Increased productivity.
- Less fuel consumption.

9.4 Limitation of technology

None.

9.5 Cost benefit analysis

The cost benefit analysis for high efficiency metallic recuperator is tabulated below (Table 19):

The investment required, energy savings and simple payback for different capacity range of furnaces have been tabulated below (Table 20):

Table 19: Cost benefits analysis for high efficiency metallic recuperator

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	t/ h	1.2	1.2
2	Operating hours per day	h/d	7	7
3	Operating days per year	d/y	300	300
4	Combustion air temperature	^{0}C	50	350
5	Specific fuel consumption	m^3/t	45.00	38.9
6	Annual fuel consumption	m^3/t	113,400	97,936
7	Productivity	t/ h	1.2	1.2
8	Annual saving in gas consumption	m^3/y	15,464	
9	Monetary saving due to saving in gas consumption	Rs in lakhs	4.48	
10	Investment required for a high efficiency metallic recuperator	Rs in lakhs	3.5	
11	Simple pay-back	y	0.78	
12	Annual energy savings	toe/y	13.30	
13	Annual GHG emission saving*	tCO_2/y	28.92	

Table 20: Investment, savings and simple pay back for metallic recuperator

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kg/ batch	Rs in Lakhs	Rs in Lakhs	years
	500-3,000	1-10	2-12	< 1 year

10 Technology No. 9: Replacement of Existing Motors with IE 3 Class Energy Efficient Motors

10.1 Baseline Scenario

Three- phase induction motors are most commonly used to run various applications in a brass unit. The rated capacity of these motors range between 1 to 10 hp. The 3 phase induction motors have 2 main parts: the stator or the stationary part and the rotor or the rotating part. Stator is made by stacking thin slotted highly permeable steel lamination inside a steel cast or cast iron frame. Windings pass through slots of stator. When a 3 phase AC current is passed through it, it produces a rotating magnetic field. The speed of rotation of the magnetic field is called the synchronous speed.

The rotor similar to a squirrel cage is placed inside the magnetic field; current is induced in bars of squirrel cage which is shortened by end ring. In effect, the rotor starts rotating. To aid such electromagnetic induction, insulated iron core laminas are packed inside the rotor; such small slices of iron ensures that the eddy current losses are minimal. The rotor always rotates at a speed slightly less than the synchronous speed; the difference is referred to as slip. Rotational mechanical power is transferred through a power shaft. Energy loss during motor operation is dissipated as heat; so a fan at the other end helps to cool down the motor.

Motor efficiency is defined as the ratio of mechanical power output to electrical power input. In most of the applications in a brass unit, conventional motors (of IE 1 rating) are used with an efficiency range from 75 to 88% depending on the size. At times, motor fail and work of a unit may come to a complete stand still. Motor failures can be attributed to mechanical and electrical failures. Causes such as improper voltage, voltage fluctuations, improper lubrication and damaged bearings leads to rise in motor winding temperature ultimately leading to failure. These electrical failure leads to the next obvious step, i.e. motor re-winding. The motor efficiency further decreases with each re-winding campaign; as it is mostly carried out by unskilled workers. Normally, a unit carries out 7-8 times of motor rewinding within its life span of 10 years.

10.2 Energy Efficient Technology

Compared to conventional motors, the efficiency of energy efficient motors (Premium Efficiency class-IE3), available in the market ranges from 80-95% depending on the size. Energy Efficient Motors operate at higher efficiencies compared to conventional motors, due to the following design improvements:

- Stator and rotor copper losses constitute for 55-60% of the total losses. Copper losses are reduced by using more copper conductors in stator and by using large rotor conductor bars.
- Iron loss accounts for 20-25% of the total losses. Using a thinner gauge, low loss core steel and materials with minimum flux density reduces iron losses. Longer rotor and stator core length, precise air gap between stator and rotor also reduce iron losses.
- Friction and Windage losses constitute for about 8-10% of the total losses. Friction loss is reduced by using improved lubricating system and high quality bearings. Windage loss is reduced by using energy efficient fans.
- Stray load loss accounts for 4-5% of the total losses. Use of optimum slot geometry and minimum overhang of stator conductors reduces stray load loss.
- Conventional motors operate in a lower efficiency zone when they are loaded less than 60%. The efficiency of Energy Efficient motors drops when they are loaded less than 50%. However, the efficiency of energy efficient motors is always higher than conventional motors, irrespective of the loading.

When old motors are rewound more than 5 times, energy efficient motors can be considered as an ideal replacement. The technical specification of 7.5 hp energy efficient motor is presented below:

Figure 12: Energy efficient motor

The motor efficiency as per IEC 60034-30 for 2-pole, 4-pole

Table 21: Details of motor in Jamnagar brass cluster

Parameters	Rated motor power	Motor Efficiency	Rewinding	Hours of operation	Days of operation
UoM	hp	%	Nos.	h/d	d/y
	1-10	75-88	4-7	8-12	312

Table 22: Specification of 7.5 hp energy efficient motor

Sl. No.	Parameter	Unit	Value
1	Capacity of Motor	hp	7.5
2	Duty type		Continuous duty
3	Performance		Premium IE 3 class efficiency conforming to IEC: 60034-30.
4	Type of Motor		AC Induction
5	Motor Power	kW	5.5
6	Rated Current	A	10
7	Rated Voltage	V	415
8	PF		0.8
9	Frequency	Hz	50
10	Efficiency at full load	%	89.63

and 6-pole at 50 Hz frequency is tabulated in Table 23.

The efficiency graph for 4-pole IE 3 class efficiency motors at 50 Hz frequency is shown below:

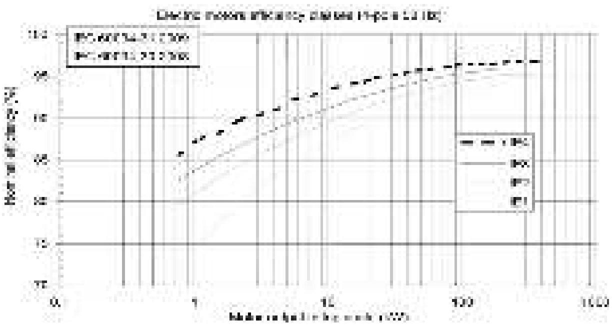


Figure 13: IE efficiency classes for 4 pole motors at 50 Hz

10.3 Benefits of technology

The implementation of IE 3 class efficiency motor in place of conventional motors leads to following benefits:

- Reduced specific energy consumption
- Lower breakdown
- Improved process efficiency
- Improved productivity
- Less operation and maintenance cost.

10.4 Limitation of technology

An energy efficient motor requires a higher initial capital investment compared to conventional motors.

10.5 Energy & GHG emission saving potential, Investment required & Cost Benefit Analysis

To understand the cost benefit analysis, let us consider a typical unit with the rated capacity of the power press hammer as 10 hp. The unit operates 3,600 hours per year. The cost benefit analysis for adoption of the technology has been tabulated in Table 24.

The investment required, energy savings and simple payback for different capacity range of motors have been tabulated in Table 25:

Table 23: Motor efficiency values as per IEC 60034-30

kW	2-Pole			4 Pole			6 Pole		
	Frame Size	Efficiency %		Frame Size	Efficiency %		Frame Size	Efficiency %	
		IE2	IE3		IE2	IE3		IE2	IE3
0.37	71	72.2	75.5	71	70.1	73	80	69	71.9
0.55	71	74.8	78.1	80	75.1	78	80	72.9	75.9
0.75	80	77.4	80.7	80	79.6	82.5	90S	75.9	78.9
1.1	80	79.6	82.7	90S	81.4	84.1	90L	78.1	81
1.5	90S	81.3	84.2	90L	82.8	85.3	100L	79.8	82.5
2.2	90L	83.2	85.9	100L	84.3	86.7	112M	81.8	84.3
3.7	100L	85.5	87.8	112M	86.3	88.4	132S	84.3	86.5
5.5	132S	87	89.2	132S	87.7	89.6	132M	86	88
7.5	132S	88.1	90.1	132M	88.7	90.4	160M	87.2	89.1
11	160M	89.4	91.2	160M	89.8	91.4	160L	88.7	90.3
15	160M	90.3	91.9	160L	90.6	92.1	180L	89.7	91.2
18.5	160L	90.9	92.4	180M	91.2	92.6	200L	90.4	91.7
22	180M	91.3	92.7	180L	91.6	93	200L	90.9	92.2

Table 24: Energy & GHG emission saving potential, investment required and cost benefit analysis for energy efficient motors

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Rated Power for power press hammer	hp	10	10
2	Rated Power for power press hammer	kW	7.5	7.5
3	Motor Efficiency	%	85.00	89.00
4	Annual operating hours	h/y	3,600	3,600
5	Motor loading	%	80.00	80.00
6	Annual energy consumption	kWh/y	25,411	24,269
7	Annual energy saving	KWh/y		1,142
8	Average power tariff	Rs/KWh		7.25
9	Annual monetary saving	Rs in lakhs		0.08
10	Investment	Rs in lakhs		0.15
11	Simple Payback	y		1.81
12	Annual energy saving	toe/y		0.10
16	Annual GHG emission reduction	tCO_2/y		1.03

**Emission factor = 0.9 tCO_2/MWh from IPCC 2006 (V2;C1 and C2)*

Table 25: Investment, savings and simple pay back for EE motors

Parameters	Rated Capacity	Investment	Annual monetary savings	Simple payback
Units	kW	Rs in Lakhs	Rs in Lakhs	Years
	1.5-7.5	0.05-0.15	0.01-0.08	< 2 years

Case Study 6: Installation of Energy Efficient Motors

Established in 1973, Sterling Cast & Forge, Jalandhar is one of the leading manufacturers, suppliers & exporters of hand tools & garden tools, tower pincers, water pump pliers, lock grip pliers, end cutting, nippers, long- nose, side cutter & carpenter pincer. Unit had a reciprocating air compressor with 15 kW IE1 motor. The company in association with EESL took a significant step towards conserving energy by replacing their old motor with energy efficient IE-3 class motor. The unit installed 11 kW IE-3 class efficiency motor in place of the existing 15 kW motor in the air compressor.

Parameters	UoM	Baseline	Post Implementation
Rated Capacity of Motors	kW	15	11
Annual operating hours	h/y	3,600	3,600
Reduction in rated capacity	kW	4	
Annual energy consumption	kWh/y	37,800	31,680
Annual energy saving	kWh/y	6,120	
Power Tariff	Rs/kWh	8	
Annual Monetary Saving	Rs in Lakh/y	0.49	
Investment	Rs in Lakh	0.35	
Simple Pay-back	months	0.7	
Annual Energy Savings	toe/y	0.53	
Annual GHG Emission Reduction	tCO_2/y	5.51	

** Emission factor for electricity taken from IPCC guidelines 2006 (Vs; C1 and C2) as 1 MWh = 0.9 tCO_2*

Conclusion

The compendium consists of a list of energy efficient and renewable energy technologies applicable for the micro, small and medium enterprises (MSME) units in the targeted sectors. The listed technologies have been grouped into three broad categories of 'low investment', 'medium investment' and 'high investment' technologies. In most cases, MSME units use old and obsolete technologies leading to higher energy consumption. There is a significant potential for cost savings through the adoption of these energy efficient and renewable energy technologies. The compendium consists of a list of commonly applicable energy efficient and renewable energy technologies in the cluster. These technologies need to be customized based on individual unit's requirements. The techno-commercial feasibility depends on the process, operational conditions and other variable parameters in a particular unit. Also, all technologies may not be applicable in every unit.

In order to achieve maximum benefits of a particular technology, the same should be supported by good operating practices. Continuous capacity enhancement of the operators is important to achieve maximum benefits from technology up-gradation.

Micro, small and medium enterprises (MSMEs) are the growth accelerators of the Indian economy, contributing about 30% of the country's gross domestic product (GDP). Under such scenario, it becomes important for these industries to adapt to efficient technologies and practices. Accelerated adoption of energy efficient and renewable energy technologies can ensure a cost effective and energy efficient production process. With an overarching objective of bringing in a transformational change in the sector, the technology compendium provides information on options available to do so.

Jamnagar, known as the brass city of India, has been an important industrial centre since long for brass related parts. Jamnagar is inhabited by various types of brass related work units which include Brass foundry; Brass parts manufacturing, Electroplating and Extrusion units. There are about 3,500 brass related units alone in Jamnagar. Majority of these Brass units in Jamnagar are in operation since last 15 to 20 years, using very primitive technology for production. The technologies listed in the compendium cater to various sections of the industry.

The implementation of the technologies listed in the compendium will lead to multi-fold benefits including improvement in the factory environment, productivity, energy performance as well as the environmental sustainability. The technologies listed in the compendium have saving potentials in the range of 5% to 25%. The technologies discussed in the document include:

Low Investment Technologies (less than Rs 2 lakhs):

- Modification of coal based pit furnace
- Energy efficient motors
- Energy efficient pumps
- FRP blades in cooling tower

Medium Investment Technologies (up to Rs 10 lakhs):

- NG fired brass melting furnace
- High efficiency metallic recuperator

High Investment Technologies (more than Rs 10 Lakhs):

- IGBT based induction melting furnace
- NG fired brass re-heating furnace
- Solar Photovoltaic system for power generation

Through this technology compendium the project hopes to maximize the environment benefits that would lead to Energy savings and GHG emission reduction. The project titled "Promoting energy efficiency and renewable energy in selected MSME clusters in India" provides a unique opportunity to the MSME units to progress towards a sustainable future.

List of Vendors

Table 26: Technology supplier details

SN	Name	Address	Contact person	Phone No.	Email id
Technology : Energy efficient reheating furnace					
1.	R.K. Industrial Enterprises	Parvatya Colony II, Parvatiya Colony, Sector 52, Faridabad, Haryana 121005	Mr. Naresh Gupta, Proprietor	+91-9971550234 +91-9350543850	naresh@ rkindenterprises.com
2.	Refine Structure & Heatcontrol Unit	A 227, Guru Teg Bahadur Path, Nehru Nagar, Pani Pech , Jaipur - 302016, Rajasthan India	Mr. V.K. Sharma, Chief Executive	+91-9829060615	refinefurnace@gmail. com
3	Delta Energy Nature	F-187, Industrial Area, Phase- VIII-B, Mohali-160062	Mr. Gurinder Jeet Singh, Proprietor	+91-9814014144 +91-9316523651	dengjs@yahoo.com denjss@rediffmail.com
4	Enerex Solutions Private Limited	301, AMBIT, 1, Krishna Park Society, Pushkar Dham Main Rd, Rajkot, Gujarat 360005		+91-98980 07457 +91-99249 79001	info@enerex.in
Technology : FRP Blades					
1	Vega Aviation Products Private Limited	NH4A, Sy. No. 230, 231/2, Belgaum Khanpur Road, Desur, Belgaum, Karnataka	Mr. Vinayak J	+91-98802 44855	
2	SaiKrithi Enterprises	10/2, 8th Cross Street, 1st Main Road, Anna Nagar,Chennai	Mr. P. Elavarasan	080 49673040	
3	Northern Cooling Towers (PVT.) LTD.	Khasra No. 1090, Vikas Nagar Industrial Area,Ghaziabad, Uttar Pradesh	Mr. G.K Singh	+91-9811725729	
4	Adva Tech Engineers	11 & 12 Phase - I, Opp. Dena Bank, GIDC Vatva, Ahmedabad, Gujarat, 382445, India	Mr. Prerak Chokshi	+91-9327948859	
5	KDN Cooling Tower	Near Bunglow Bus Stand, Opp. Satnam Patel Weigh Bridge, Naroda, Ahmedabad, Gujarat, 382330, India	Mr. Darsh Taank	+91-8980602959	
6	Towertech Cooling Systems Pvt. Ltd.	Plot No: C1B-305/1, G.I.D.C. Kerala, Bavla-Bagodara Highway, Ahmedabad, Gujarat, 382240, India	Mr. Jignesh Shah	+91-97121 50985	sales@towertechindia. com
Technology : IE 3 class energy efficient motor					
1	Bharat Bijlee	Electric Mansion 6th Floor Appasaheb Marathe Marg Prabhadevi, Mumbai 400 025		+91 22 2430 6237 / 6071	info@bharatbijlee.com
2	Cromptom Greaves	Church Road, PO BOX 173 Jaipur 302 001, Rajasthan, India	Mr. Sunil Dutt, Proprietor	+91 141 3018800 /01	sunil.dutt@cgglobal. com
3	Siemens Limited	Birla Aurora, Level 21, Plot No. 1080, Dr. Annie Besant Road, Worli, Mumbai – 400030, India		1800 209 1800	
Technology : Gas Based Pit Furnace					
1	Amco Engineering	B/14, Silver Square Complex, Thaltej - Shilaj Road, Thaltej, Ahmedabad	Mr.Arunkumar	+91-9840623644	
2	Rajesh Industries	3 Maneklal Estate, Nr. Panchal Estate, b/s. S.B.I. Bank, Bapunagar, Ahmedabad	Mr. Rajesh Jadav	+91-9328406133	
3	Delta Furnaces	Plot No. 305, HSIIDC, Rai Industrial Estate Opposite Rajiv Gandhi Education City,Sonipat, Haryana	Mr. Amit kohili	08042973392	
Technology : Solar PV System					
1	Inter Solar System Pvt. Ltd.	901-A, Industrial Area, Phase-II, Chandigarh - 160 002		+91-8437254139	info@ intersolarsystems.com

SN	Name	Address	Contact person	Phone No.	Email id
2	Wolta Power System	B-91, 1st Floor, Sector 64, Noida - 201301, Uttar Pradesh, India	Mr. Amit Singh, CEO	+91-9266533533	info@ woltapowersystem.com
3	Solar Maxx	III Floor, Krishna Square, Subhash Nagar, Jaipur 302016, Rajasthan, India		+91-141-400 9995	info@solarmaxx.co.in
4	Adani Solar, India	Adani Solar, 2nd floor - South Wing, Shantigram, SG - Highway, Ahmedabad	Mr. Mahendra	+91-7069059173	
5	AMP SOLAR India	309, Rectangle One, Behind Sheraton Hotel, Saket, New Delhi	Mrs. RajniBandari	+91-9052717800	
6	Tata Solar	Limda Lane, jamnagar	Mr. BhavikKamdar	+91-9909914112	
Technology : Metallic Recuperator					
1	Entech Furnace	Plot No. 186, Sector-24 Faridabad, Haryana (India)	Mr. Vinay Agnihotri	+91-9810005354	info@entecfurnaces. com
2	En Eff Thermal Engineers	536/25c/1a, Industrial Area-C, Sua road, Dhandari Kalan, Ludhiana, Punjab, 141010, India	Mr. Captain Singh (GM)		
3	AAB Heat Exchanger Pvt. Ltd.	Plot No. 375, Sector-24, Faridabad-121005	Mr. Amitoj Singh (Director)	+91-8048719066	
Technology : Energy Efficient (EE) Pump					
1	International Aqua Solution	B XIII/1382, Shop No. 1, Opposite Jagraon Bridge, Karimpura,	Mr. Rahul Goyel	+91-8048801408	
2	S Gro Enterprize	Shop No. 18-19, Guru Nanak Market, Near Vishvkarma Chowk, Miller Ganj, Ludhiana-141003, Punjab, India	Mr. Malkiat Singh	+91-8048606530	
3	Vijay Laxmi Products	B-15/7, G.T. Road, Miller Ganj, Near Dukh Nivaran Gurudwara, Ludhiana-141003, Punjab, India	Mr. Ashish Dhiman	+91-8045337560	
4	Grundfos Pumps India Private Limited	B-1, 23, Shaswat Complex, Anand Nagar Society, Productivity Road, Productivity Road, Vadodara, Gujarat 390007		+91-98250 30858	
5	Jay Pumps Private Limited	Dantali, Gujarat 382165		+91-98792 08223	
Technology : IGBT Based Induction Melting Furnace					
1	Electrotherm (India) Ltd	Electrotherm (India) Ltd., A-1, Skylark Apartment, Satellite Road, Ahmedabad	Mr. Kalpesh Chavda	+91-9825150066	
2	Inductotherm (India) Pvt. Ltd.	Plot No. SM-6, Road No. 11, Sanand-2 Industrial Estate, BOL Village, Sanand, Ahmedabad	Mr. Nishant Singh	02717- 621000, +91-9375226751	
3	ORITECH Solutions	Plot No. 4 & 4P, Swastik Industrial Estate,Bavla Highway, Sari Ta. Sanand, opp. Aarvee Denim, Changodar, Gujarat	Mr. Shailesh Patel	+91-9374764116	
4	Plasma Induction	330/1P Vill-Hajipur, Motibhyon-Hajipur Road, Ta Kalol, Dist-Gandhinagar Gujarat	Mr. Samir Sadhu	+91-9904225550	
5	R.A. Induction	Shed-8, Survey No-20, Ambe Estate, Vavdi, Rajkot, Gujarat	Mr. Alpesh Devaiya	+91-9727718256	info@rainduction.com
6	Indo Power	Plot-56 A/4, Phase-1, road No B, bharat Cement Compound, Ahmedabad, Gujarat	Mr. Vivek Tank	+91-9033543955	info@indopower.in

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