UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

Energy Efficiency and Renewable Energy Opportunities in

Eastern Zone Metal Industries

Volume II: Forging Sector

September 2020

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Disclaimer

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 Eastern Zone Metal Industries

Volume II: Forging Sector

September 2020

Developed under the assignment

Scaling up and expanding of project activities in MSME clusters

Prepared by

DESL

Development Environergy Services Ltd
L-11-A, Plot No.C-001/A1, 11th Max Towers,
Sector-16B, Noida - 201301
Uttar Pradesh, (Delhi NCR)

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List of Abbreviations

BEE	Bureau of Energy Efficiency
DESL	Development Environergy Services Limited
EE	Energy Efficiency
EET	Energy Efficient Technologies
GEF	Global Environment Facility
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
PV	Photovoltaic
RE	Renewable energy
SPM	Special Purpose Machine
UNIDO	United Nations Industrial Development Organization

Unit of Measurement

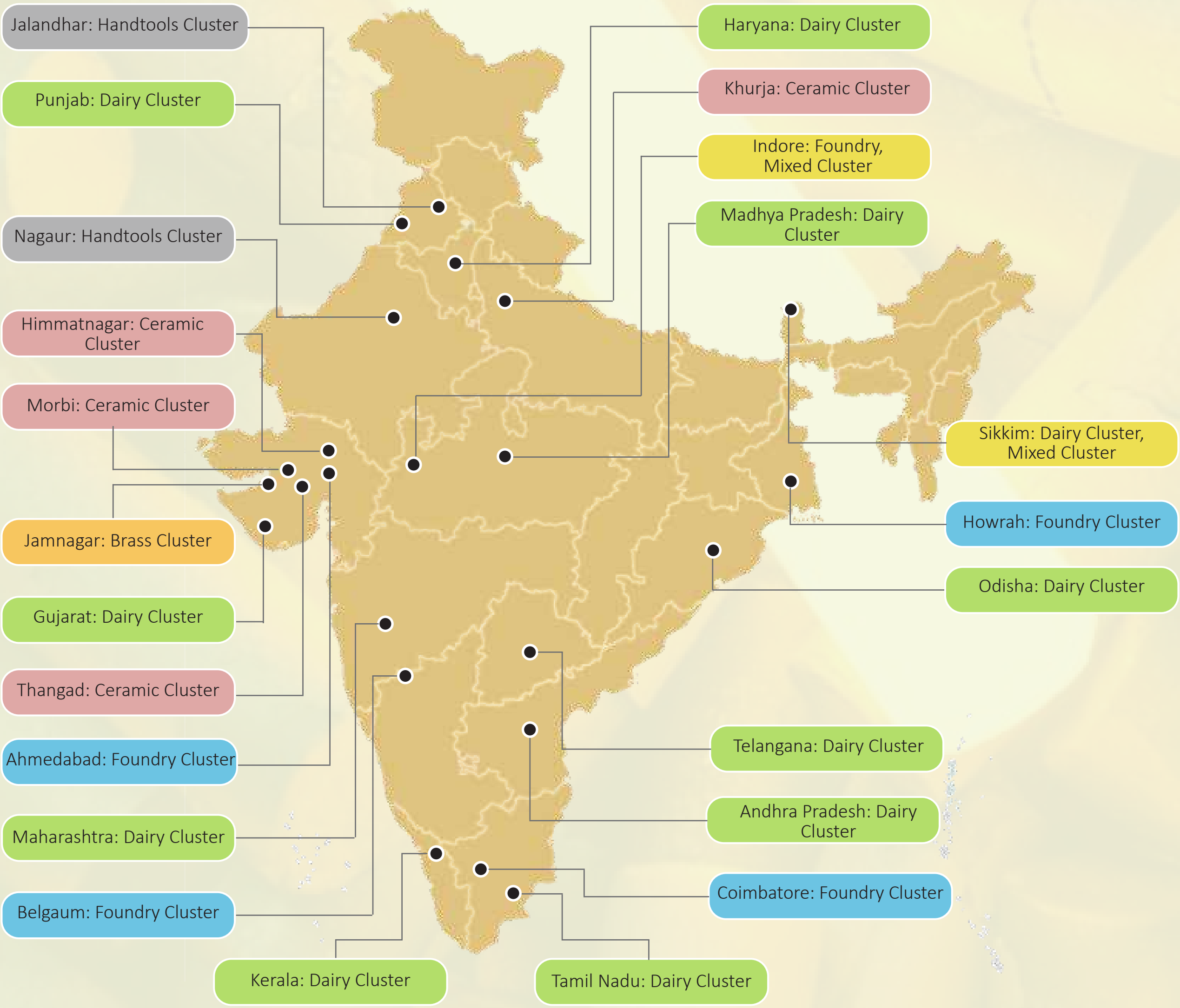
Parameters	UOM	Parameters	UOM
Ampere	A	Litre(s)	l
Approximate	~	Litre per kilogram	l/kg
Centimeter	cm	Mega Joule	MJ
Centimeter Square	cm^2	Mega Volt Ampere	MVA
Cubic Centimeter	cm^3	Mega Watt Hour per Day	MWh/d
Cubic Feet per Minute	CFM	Meter	m
Cubic meter	m^3	Meter cube	m^3
Cubic meter per day	m^3/d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



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

The Indian Forging Industry has always been a major growth driver of the Indian manufacturing sector and is one of the important industries for the success of automobile, power sector and general engineering in the country. The forged products include rough forgings and/or machined parts like Crankshafts, Connecting Rods, Camshafts, Shifted Fork, Steering Components, Crown Propeller Shafts, Gear Box Components; Crown Wheel and Pinions, Front Axle Beams, Rear Axle Shafts, Earth Moving Link, Railway Tyres, Flanges/ Pipe Fittings, Industrial Valves, etc.

The Indian forging industry has close to 400 forging units, of which 83 percent can broadly be categorized as small and medium enterprises (SMEs); while 9 percent are medium units and the rest are large manufacturing plants. In terms of production and sales, the MSMEs contribute to approximately one-third of the total output. The industry provides employment for over 300,000 people. At present, the total capacity of the industry is 30 lakh MT (FY2019) with a total production valued at Rs 45,000 crore to Rs 50,000 crore. More than 60 percent sales of the forging sector are from the automotive sector.

The major forging clusters in India are Maharashtra, Punjab, Gujarat, Tamil Nadu, Haryana, Delhi, Karnataka, Jharkhand, West Bengal and Andhra Pradesh. The eastern zone of the country houses some of the key forging clusters in India which includes Howrah in West Bengal and Jamshedpur in Jharkhand. The forging sector is a highly energy intensive cluster using both thermal and electrical energy. Most of the units in the sector use old and obsolete technologies leading to significant energy bills. 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, and Government of India towards scaling up the penetration of low-cost Energy Efficient Technologies (EETs) in the foundry, forging and steel re-rolling mill units located in the eastern zone of the unit. A total of 80 MSME units in the cluster comprising foundry, forging and steel re-rolling mill units 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. The extensive research and ground level deployment of various teams have made it possible to consolidate the list of energy efficient and renewable energy technologies applicable for the steel re-rolling mill sector. 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 capacities of the units. 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 complemented 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 also been compiled at the end for easy reference of the units.

The technology compendium will act as a ready reckoner to the MSME unit owners and help them select relevant technologies for their units. The technology compendium also consists of case studies on actual implementation of the technologies and benefits realized thereof. Although the compendium consists of some general information on the technologies, the same will require customization based on individual unit's requirement. The BEE-UNIDO project thus plays a pivotal role in making a transformational change in the sector which will lead to the units becoming cost competitive; thereby resulting in a sustainable future.

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 forging sector

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)	Energy Efficient Metallic Recuperator	0.5 – 1.5	0.7 – 2	< 1 year
		Energy Efficient Motors	0.02-0.5	0.03-0.55	< 1.5 year
B	Medium Investment Technologies (up to Rs 10 lakhs)	Energy Efficient FO Fired Forging Furnace	3 – 6	2 - 4	< 1.5 year
		Energy Efficient LPG Fired Forging Furnace	4 -7	4 - 7	< 1 year
		Special Purpose Machine	2 -15	2.5 - 10	< 1.5 years
		Energy efficient compressed air network	1.5 – 8	2.25 - 10	< 1 year
		Veenering of Heat Treatment Furnace	1 – 1.5	2 – 2.5	< 1 year
		Energy Efficient Lighting	10 – 50	3 – 15	< 3 years
C	High Investment Technologies (more than Rs 10 lakhs)	IGBT based electric induction heater	11-25	5-15	< 2.5 years
		Solar Photovoltaic System for Power Generation	40 – 200	10 - 50	< 4 year
		Energy Efficient Screw Compressor with VFD and PM Motor	3 – 16	4 - 20	< 1 year
		Energy Efficient Pumps	2 – 6	3 - 8	< 1 year

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

1 About the Cluster

1.1 Sector overview

Figure 1: Eastern Zone map

The Indian Forging Industry has always been a major growth driver of the Indian manufacturing sector and is one of the important industries for the success of automobile, power sector and general engineering in the country. Briefly, the composition of the Indian forging sector can be categorized into four sectors – large, medium, small and tiny. As is the case world over, a major portion of this industry is made up of small and medium units / enterprises (MSMEs).

The industry was previously more labour intensive, but now with increasing globalization it is becoming more capital intensive. The Association of Indian Forging Industry (AIFI) is the umbrella organization of the forging Industry in India with more than 250 members across India. Its members' products include rough forgings and/or machined parts like Crankshafts, Connecting Rods, Camshafts, Shifted Fork, Steering Components, Crown Propeller Shafts, Gear Box Components; Crown Wheel and Pinions, Front Axle Beams, Rear Axle Shafts, Earth Moving Link, Railway Tyres, Flanges/Pipe Fittings, Industrial Valves, etc. The forging industry, which is a major supplier to the auto companies and a critical industry that generates employment, has been continuously plagued with incessantly rising industrial fuel and steel prices resulting in rising input costs and shrinking margins.

The major forging clusters in India are Maharashtra, Punjab, Gujarat, Tamil Nadu, Haryana, Delhi, Karnataka, Jharkhand, West Bengal and Andhra Pradesh. The eastern zone of the country, mainly concentrated in Howrah in West Bengal and Jamshedpur in Jharkhand, houses around 8% of the total operational units in the country. The major raw material for the sector includes Carbon Steel, Alloy Steel, Stainless Steel, Super Alloy, Special Steel, Titanium and Aluminium. The small and very small units are mainly dependant on manual labour, however, medium and large units are semi /largely mechanized and some of the large units are world class.

Quality standards in the industry are in compliance with the applicable quality standards. The impact and changes in the Indian automobile industry is directly proportional to the Indian forging industry, so forging industry is often referred to as the backbone of the automobile industry. While the automotive industry is the main customer for forging sector, the industry's continuous efforts in upgrading technologies and diversifying product range have enabled it to expand its base of customers to foreign markets. Increase in cheap imports from China and aesthetic imports from Japan, Korea, Taiwan, Europe and Germany for components such as Axle assemblies, Power steering assemblies, Transmission Gear boxes, Crank Shaft, connecting rods, gear change finger (GC Finger), etc. are increasingly causing threat to the Indian forging sector.

The forging sector in India is highly energy intensive with most of the small and medium sector units using obsolete and inefficient technologies. The sector mainly comprises a forging furnace which is either fired by fossil fuel like furnace oil, HSD, LPG, Natural gas or operated by electricity. The other section comprises forging hammer and/or machines like lathe, drilling, milling which caters to the finishing operation. Heat treatment furnaces are also deployed by some units, which are typically fossil fuel fired or electrically operated. Compressed air also forms a key utility in some of the forging units. Based on requirement, some of the forged products are subjected to electroplating. Thus, electricity and fuel comprise the major energy source for forging units.

1.2 Forging Sector in the Eastern Region

The eastern zone of the country, comprising the states of West Bengal and Jharkhand, houses close to 8% of the total forging units in the country. Some of the key clusters located in the eastern zone of the country that house forging units are Howrah in West Bengal and Jamshedpur in Jharkhand. The units in Jamshedpur mainly cater to the automotive sector mainly driven by Tata Motors; whereas the units in West Bengal cater to a variety of forging products.

The Association of the Indian Forging Industry (AIFI) has been the spokes body of the Indian Forging Industry for over four decades. It has played a major role in encouraging proactive dialogue between all the relevant stakeholders like the industry and Government (both in terms of suggestions for policy making and problem-solving), as also between the industry and the market (User industries - domestic and global.)

1.3 The Process

The forging units are mainly involved in production of products for auto parts, earth moving & mining, steel

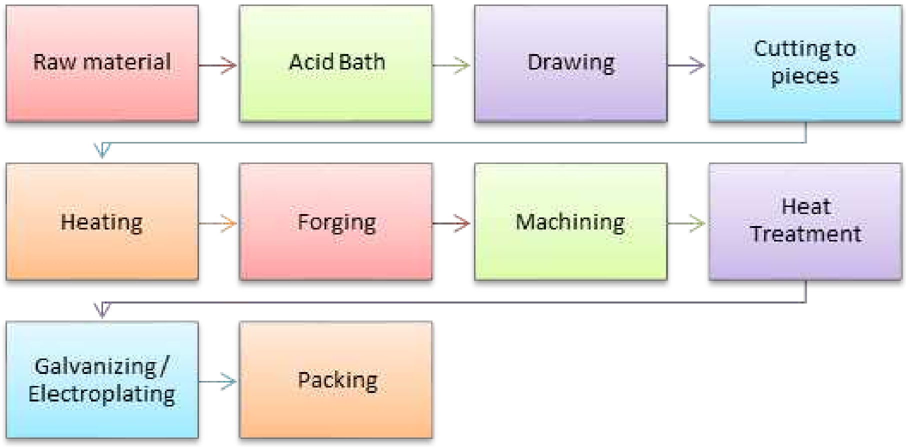


Figure 2: Typical forging process

plants, railways, mining, oil exploration etc. The major raw material used includes carbon steel, alloy steel, stainless steel, super alloy, special steel, titanium and aluminium. The forging furnace, the hammer power press, the heat treatment furnace and the finishing machines form the key equipment for the sector. The process flow from raw material to final finished product is shown in the Figure 1.

From process point of view, forging furnace is the major energy consuming equipment followed by heat treatment furnace and finishing machines.

1.4 Technology status and energy use

The specific energy consumption (SEC) of the forging units depends on the processes adopted by that unit. For example, the larger units carry out all the operations such as forging, heat treatment, machining and galvanizing in-house. Many smaller units are acting as vendors of large units, and can hence carry out only a few of the operations.

The forging furnace consumes about 60% of the total energy consumption of a typical unit. The oil-fired forging furnaces forms the most common type of furnace used in the sector which are of outmoded designs leading to very high fuel consumption. Also, heat treatment furnaces suffer from a high skin loss due to poor insulation and low efficiency due to poor temperature control. Even in places where the temperature controllers are installed, the units face a problem with their malfunctioning. Introduction of good quality temperature controller and thermocouple would solve the above problem and lead to a huge amount of energy savings. Most of the units are equipped with very old and rewound induction motors which consume very high electricity, maybe a matter of consideration as far as energy efficiency is concerned.

The figure below shows the energy share of different critical equipment in a typical forging unit:

Most of the forging units in the country use old and obsolete technologies which lead to significant energy consumption. A significant opportunity exists for cost saving by adoption of energy efficient and renewable energy technologies.

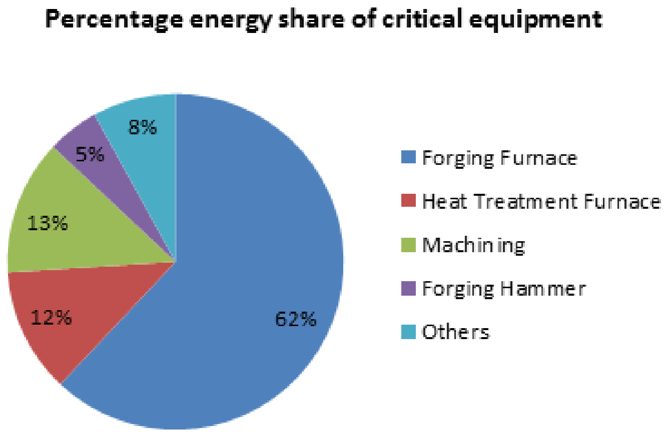


Figure 3: Energy share of critical equipment

(Source: Energy audit conducted by DESL)

2 Technology 1: Replacement of Conventional Forging Furnace with Energy Efficient Forging Furnace

2.1 Conventional Practice

Figure 4: Typical FO fired forging furnace

A re-heating furnace commonly known as 'forging' furnace forms the heart of a typical forging industry, consuming majority of the plant's energy. The forging furnace is used to heat the raw material to the required forging temperature before being transferred to the hammer press. The forging furnace can be either continuous type or batch type. Most of the forging furnaces are fired using furnace oil. The insulation used in these furnaces is poor. 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.

The forging furnaces in most of the forging units are of very primitive design with no control in terms of fuel and air flow. The furnaces are often operated in higher than rated capacity leading to higher burning losses. Also, substantial amount of heat is wasted from the discharge end and the top opening for raw material charging. These furnaces are operated manually with no provision for waste heat recovery. Also, there is absolutely no control in the air and fuel supply into the furnace. The poor design of the furnace leads to high start-up time and high specific energy consumption. The average start-up time for these furnaces was observed to be as high as 1.5 to 2 hours. The overall thermal efficiencies of these furnaces are extremely low, ranging from 8 to 12 percent. The capacities of the typical forging furnaces in MSME units vary in between 70 to 350 kilogram per batch with specific fuel consumption ranging from 0.14 to 0.18 liters of furnace oil per kilogram of product. The annual production of forging units typically ranges from 100 to 700 tons of materials.

Various options including use of waste heat recovery systems for pre-heating of combustion air, better insulation, use of appropriate burner system to improve combustion efficiency and monitoring and control system for optimum performance can lead to improvement in the efficiency of the furnace significantly.

2.2 Energy Efficient Technology

Significant energy can be saved by replacement of conventional forging furnace with energy efficient forging furnace. The key components of the energy efficient design of the forging furnace are as follows:

- **Furnace oil heating and pumping unit:** The furnace oil tank is located at the top of the furnace. Furnace oil is fed into the furnace by virtue of gravity. Typically, furnace oil is not heated to the desired viscosity level. It is proposed to introduce a furnace oil heating and pumping unit to supply furnace oil at required temperature and pressure. The temperature of furnace oil is maintained at 80-90°C.

Figure 5: Energy efficient FO fired forging furnace

- **Optimum refractory & insulation:** The existing wall linings comprise fire bricks refractory without any insulation backup. It is proposed to equip the furnace with high Alumina refractory bricks backed by ceramic fiber insulation. The optimum refractory and insulation will ensure minimum radiation loss from the furnace walls.
- **Reducing furnace openings:** The openings in the furnace leads to significant loss of energy which needs to be minimized to the extent possible.
- **Waste heat recovery:** The energy efficient furnace will be equipped with a heat exchanger to recover the waste heat from the flue gas to preheat the combustion air. With every 21°C rise in the combustion air, it is expected to have a saving of 1% in the specific fuel consumption.

Table 2: Details of conventional forging furnace forging units

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
UoM	t/y	kg/ batch	%	l/kg	h/d	d/y
	100 - 1000	70-350	8-12	0.14-0.18	8-12	300

- **Temperature monitoring and control system:** The furnace is to be equipped with thermocouples to monitor the furnace temperature. A PID based control system to be introduced to monitor and control the fuel flow and corresponding air flow into the furnace. To maintain proper air-fuel ratio, a ratio controller with solenoid valve in the air and fuel line to be introduced.

The energy efficient design of the furnace will aim at efficient combustion, proper air-fuel ratio, monitoring and control of furnace parameters and optimum waste heat recovery. The energy efficient design will increase the furnace efficiency to 15-18% compared to conventional furnace efficiency of 8-11%.

2.3 Benefits of technology

Replacement of conventional furnace with energy efficient forging furnace will lead to following benefits:

- Improved combustion leading to lesser specific fuel consumption.
- Reduced furnace start-up time by at least 25-30%.
- Increased productivity by at least 5-10%.
- Reduced batch time for heating by at least 5-10%.
- Improved working conditions.
- Reduced burning loss.

2.4 Limitation of technology

The re-heating furnace, even after modification, will require a significant start-up time, since the units are operated only for 8-10 hours daily. The fuel consumption can be further reduced by increasing the operational hours of the units.

2.5 Energy & GHG emission saving potential, Investment required &cost benefit analysis

To understand the cost-benefit analysis from replacement of conventional furnace with energy efficient furnace, let us consider a forging unit of 200 kg/h, operating for 10 hours per day and 300 days per year. The cost-benefit analysis for adoption of the technology is tabulated below:

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

Table 3: Cost benefit analysis of energy efficient forging furnace

Sl. No.	Parameter	Unit	As Is	To be
1	Productivity	kg/ h	200	200
2	Operating hours per day	h/d	10	10
3	Operating days per year	d/y	300	300
4	Specific Fuel consumption	l/kg	0.16	0.12
5	GCV	kcal/kg	9,600	9,600
6	Density of furnace oil	kg/l	0.96	0.96
7	Raw material input temperature	^{0}C	35	35
8	Product final temperature	^{0}C	1,200	1,200
9	Specific heat of EN8 Cast Steel	kcal/kg K	0.117	0.117
10	Furnace Direct Efficiency	%	9.24	12.33
11	Annual fuel consumption	l/y	96,000	72,000
12	Annual fuel saving	l/y		24,000
13	Furnace oil cost	Rs/l		35
14	Annual Monetary Saving	Rs in lakhs		8.4
15	Investment	Rs in lakhs		5
16	Simple payback	y		0.60
17	Annual energy saving	toe/y		22
18	Annual GHG emission reduction	tCO_2/y		71

**Emission factor of furnace oil taken as 77.4 tCO_2/TJ as per IPCC guideline 2006 (V2).*

Table 4: Investment, savings and simple pay back for EE forging furnace

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kg/ batch	Rs in Lakhs	Rs in Lakhs	y
	70-350	3-6	2-4	< 1.5 years

Case Study 1: Installation of FO Fired EE Forging Furnace

Vishal Tools & Forging, Jalandhar is one of the leading and well established manufacturers/exporters of professional quality hand tools for over two decades. The company specializes in full range of spanners, wrenches including standard recess panel, fully-mirror polished and raised panel as per DIN/BS/ASME specifications. The production range also includes full range of wrenches, pliers, vices, garage tools, carpentry tools, striking tools and tool aprons produced as per international requirement. The products are exported globally mainly U.K., Europe, USA, Canada, Mexico, Central & South America, Australia and South East Asia. Forging furnace forms one of the key processes in a typical hand tool unit. In 2018, the unit replaced their existing furnace oil fired forging furnace which was catering to a 1.5 ton hammer with an energy efficient forging furnace. The new design of the furnace included improved insulation, temperature based control panel, energy efficient burner and a waste heat recovery system. The unit was able to save significantly in terms of energy and also enhanced their quality standards.

Parameters	UoM	Baseline	Post Implementation
Productivity	kg/h	200	200
Annual operating hours	h/y	3,600	3,600
Annual production	t/y	720	720
Specific fuel consumption (FO)	l/t	130	110
Furnace oil cost	Rs/l	42	
Annual Fuel Cost	Rs in Lakh/y	36.28	31.75
Annual Monetary Saving	Rs in Lakh/y	4.5	
Investment	Rs in Lakh	5.0	
Simple Pay-back	Months	13	
Annual Energy Savings	toe/y	9.95	
Annual GHG Emission Reduction	tCO_2/y	32.23	

**Emission factor of Furnace Oil as per IPCC Guideline is 77.4 tCO_2/TJ*
***Source: Energy audit carried out under GEF-UNIDO-BEE project*

Technology 2: Fuel Shift from FO to LPG for Small Forging Furnaces

3

3.1 Conventional Practice

A re-heating furnace commonly known as 'forging' furnace forms the heart of a typical forging industry, consuming majority of the plant's energy. The forging furnace is used to heat the raw material to the required forging temperature before being transferred to the hammer press. The forging furnace can be either continuous type or batch type. Most of the forging furnaces are fired using furnace oil. The insulation used in these furnaces is poor. 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 of primitive design with efficiency as low as 4 to 8 percent. There is no monitoring and control system available for the furnace operation. The forging furnace comprises a brick chamber with an opening in the front side for charging of raw material. The furnace temperatures are not monitored and the combustion blower (FD fan) supplies high quantity of air (than required for combustion) at high pressures. Due to this, the flame length becomes very large and it impinges on the opposite side doors and was comes out from front side raw material feeding door which results in high radiation and convection losses. Temperature of flue gas is over 500-550^{0}C for most cases.

The furnace's internal volume is also larger than required, which results in unnecessary heating up of the extra volume to high temperatures. The operators judge the furnace's internal temperature based on visual (manual) judgment of colour of furnace internal to decide if the required material temperature has been achieved or not.

The furnaces are often operated in higher than rated capacity leading to higher burning loss. Also, a substantial amount of heat is wasted from the discharge end and the front opening for raw material charging. 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 rising price of furnace oil makes it necessary for the units to explore for an alternate heating methodology.

3.2 Energy Efficient Technology

It is proposed to replace the conventional furnace oil based re-heating furnace with LPG fired system. LPG is a cleaner fuel to burn than oil which means it won't produce byproducts like soot, and therefore may need less maintenance. LPG has a higher heating value, allowing heating the furnace at a lower price. LPG doesn't contain sulphur, so it burns a lot cleaner than energy resources like oil. Liquid Petroleum Gas burns consistently, making it more reliable than other forms of energy.

Figure 6: LPG fired forging furnace

Apart from the furnace modifications suggested in the earlier chapter, LPG fired furnace will require a gas fired burner and pipelines required for continuous feeding of LPG. LPG is available in cylinders and multiple cylinders can be installed in series to ensure continuous supply of gas.

As the LPG burner comes with fuel and air control systems, their combustion efficiency is superior to FO fired burners. These burners also attain faster heating rates, so the metal can be able to reach the desired temperature earlier than present condition, thereby increasing the productivity by 3 to 4 times.

In case of the small forging process, the LPG fired system can be used to heat the metal bar to the forging temperature which is typically 1,050-1,100^{0}C depending on the material.

3.3 Benefits of technology

As a superior alternative to furnace oil heating, LPG heating provides faster, more efficient heat in forging applications. The process relies on better air-fuel mix to produce heat within the part that remains confined to precisely targeted

Table 5: Details of conventional forging furnaces

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
UoM	t/y	kg/ batch	%	l/kg	h/d	d/y
	100 - 1000	70-350	8-12	0.14-0.18	8-12	300

areas. This results in better combustion and reduction in dry flue gas loss due to extra excess air supplied (in present FO fired). The new LPG fired furnace design will also help in reduction in 20-30% of extra furnace volume, thus the total heat supplied will also come down and reduce energy wastage.

Benefits of using LPG fired furnaces for forging are:

- Faster heating for improved productivity and higher volumes
- Precise, even heating of all or only a portion of the part
- A more cleaner and lesser polluting method of heating
- Cost-effective, reduces energy consumption compared to FO heating methods

3.4 Limitation of technology

The gas connection is still not up to the mark in the cluster. Availability of the gas would be another issue, which may be a constraint to the implementation of the project.

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

To understand the cost-benefit analysis from replacement of conventional FO furnace with energy efficient LPG furnace, let us consider a forging unit with 200 kg/hr production, operating for 6 hours per day and 300 days per year. The cost benefit analysis for adoption of the technology has been tabulated below:

Table 6: Cost benefit analysis for LPG fired forging furnace

Sl. No.	Parameter	Unit	As Is	To be
1	Productivity	kg/ h	200	200
2	Operating hours per day	h/d	6	6
3	Operating days per year	d/y	300	300
4	Annual production	t/y	360	360
5	Specific Fuel consumption (FO)	l/kg	0.14	
6	Specific Fuel consumption (LPG)	SCM/kg		0.07
7	GCV	kcal/kg	9,600	10,500
8	Density	kg/l ; kg/SCM	0.96	0.6
9	Raw material input temperature	^{0}C	35	35
10	Product final temperature	^{0}C	1,200	1,200
11	Specific heat of EN8 Cast Steel	kcal/kg K	0.117	0.117
12	Furnace direct efficiency	%	10.56	30.91
13	Annual fuel consumption	l/y ; SCM/y	50,400	25,200
14	Annual fuel saving (FO equivalent)	l/y		27,360
15	Fuel cost	Rs/l; Rs/SC<	35	40
16	Annual fuel cost	Rs in lakhs /y	17.64	10.08
17	Annual monetary saving	Rs in lakhs		7.56
18	Investment	Rs in lakhs		6
19	Simple payback	y		0.8
20	Annual energy saving	toe/y		25
21	Annual GHG emission reduction	tCO_2/y		82

**Emission factor of Furnace oil considered as 77.4 tCO2/TJ as IPCC Guidelines 2006 (V2;C1 and C2)*
*** Price of LPG is considered on the basis of data collected from units*

Case Study 2: Installation of LPG Fired EE Forging Furnace

Victor Forgings is a family owned business and is one of the leading manufacturers of Hand tools since its establishment in 1954. The company manufacture, design and specialize in vast range of Spanners, Wrenches, Pliers, Vices, Hammers, Automotive tools, Carpentry tools and D.I.Y tools. The company is awarded with ISO-9001:2008, ISO 14001-2004 by TUV RHEINLAND and SA-8000 certifications by BSI. The state-of-the-art factory includes in house facilities like Designing, Tool Room, Forging-Shop, Heat-treatment, Electroplating, Chemical and Testing laboratories. The company is involved in export of the hand-tools to more than 50 countries worldwide which includes USA, Europe, South America, South East Asia and with a number of world's leading Brands & Stores.

The company took a key initiative towards energy efficient production in the year 2018 by installing an energy efficient LPG fired forging furnace. The new furnace was equipped with an efficient raw material charging system, 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.

Parameters	UoM	Baseline	Post Implementation
Productivity	kg/h	200	200
Annual operating hours	h/y	3,600	3,600
Annual production	t/y	720	720
Specific fuel consumption (FO)	l/t	120	
Specific fuel consumption (LPG)	kg/t		60
Furnace oil cost	Rs/l	42	
LPG Cost	Rs/kg		41.3
Annual Fuel Cost	Rs in Lakh/y	36.29	17.84
Annual Monetary Saving	Rs in Lakh/y	18.45	
Investment	Rs in Lakh	6.5	
Simple Pay-back	Months	4.3	
Annual energy savings	toe/y	34.27	
Annual GHG emission reduction	tCO_2/y	110.96	

**Emission factor of Furnace Oil as per IPCC Guideline is 77.4 tCO_2/TJ*
***Source: Energy audit carried out under GEF-UNIDO-BEE project*

4 Technology 3: Replacement of Fossil Fuel Fired Forging Furnace with IGBT Based Electric Induction Heater

4.1 Conventional Practice

Typically, the forging industry comprises batch type furnace oil/ LPG fired forging furnaces, which are locally made of fire bricks covered with steel sheet. These furnaces are of primitive design with efficiency as low as 8 to 12 percent. There is no monitoring and control system available for the furnace operation. The forging furnace consists of a brick chamber with an opening at the front for charging of raw material. The furnace is equipped with locally manufactured burners which are used for oil firing. Combustion air is supplied using a blower.

Figure7: An oil fired forging furnace

The furnaces are often operated in higher than rated capacity leading to higher burning loss. Also, substantial amount of heat is wasted from the discharge end and the top opening for raw material charging. 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 capacities of the forging furnaces vary in between 70 to 350 kilogram per batch with specific fuel consumption ranging from 0.14 to 0.18 liters of furnace oil per kilogram of product. The rising price of furnace oil makes it necessary for the units to explore for an alternate heating methodology.

4.2 Energy Efficient Technology

It is proposed to replace the conventional oil based or LPG based forging furnace with induction heating system. As the Induction heater attains instant heating, the metal could be able to reach the desired temperature within 6-8 seconds, thereby increasing the productivity by 3 to 4 times.

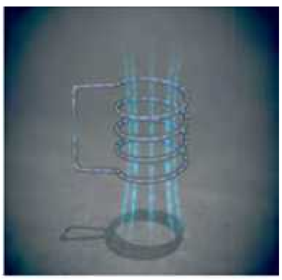


Figure 8: An Induction heating coil

Induction heating is the process of heating an electrically conducting object by electromagnetic induction, where eddy currents are generated within the metal and resistance leads to Joule heating of the metal. So, it is possible to heat a metal without direct contact and without open flames. An induction heater consists of an electromagnet (coil), through which a high-frequency alternating current (AC) is passed. The frequency of the alternating current used depends on the object size, material type, coupling (between the work coil and the object to be heated) and the penetration depth.

An induction heating system consists of an inductor (to generate the magnetic field) and a converter (to supply the inductor with a time-varying electrical current). Alternating current flowing through an electro-magnetic coil generates a magnetic field.

The strength of the field varies in relation to the strength of the current passing through the coil. The field is concentrated in the area enclosed by the coil; Eddy currents are induced in any electrically conductive object—a metal bar, for example—placed inside the coil. The phenomenon of resistance generates heat in the area where the eddy currents are flowing. Increasing the strength of the magnetic field increases the heating effect. However, the total heating effect is also influenced by the magnetic properties of the object and the distance between it and the coil. In case of the forging process, the induction heating system is used to heat the metal bar to the forging temperature which is typically 1,150-1,200^{0}C depending on the material.

Figure 9: An induction billet heater

4.3 Benefits of technology

As a superior alternative to furnace oil heating, induction heating provides faster, more efficient heat in forging applications. The process relies on electrical currents to produce heat within the part that remains confined to precisely targeted areas. High power density means extremely rapid heating, with exacting control over the

Table 7: Details of conventional forging furnace

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
UoM	t/y	kg/ batch	%	l/kg	h/d	d/y
	100 – 1000	70-350	8-12	0.14-0.18	8-12	300

heated area. Recent advances in solid-state technology have made induction heating a remarkably simple and cost-effective heating method. Benefits of using induction heating for forging are:

- Rapid heating for improved productivity and higher volumes
- Precise, even heating of all or only a portion of the part
- A clean, non-contact method of heating
- Safe and reliable – instant on, instant off heating
- Cost-effective, reduces energy consumption compared to other heating methods
- Easy to integrate

4.4 Limitation of technology

An electric induction heater will require additional power load in the unit. Also, the LT load connection has to be switched over to HT. A significant time is required for the load sanction. Also, a security deposit with the power distribution company is required to get the additional load connection.

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

To understand the cost-benefit analysis from replacement of conventional furnace with electric induction heater, let us consider a forging unit of 162 tons per year, operating for 6 hours per day and 300 days per year.

The cost-benefit analysis for adoption of the technology is tabulated below:

The investment required, energy savings and simple payback for different capacity range of IGBT based induction heater have been tabulated below:

Table 8: Energy & GHG emission saving potential, investment required & cost benefit analysis for IGBT based induction heater

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	kg/ h	90	208
2	Operating hours per day	h/d	6	0.54
3	Operating days per year	d/y	300	300
4	Annual production	t/y	162	162
5	Hourly fuel consumption (baseline)	l/h	14.17	
6	Specific fuel consumption (baseline)	l/kg	0.16	
7	GCV	kcal/kg	10,100	
8	Density of furnace oil	kg/l	0.96	
9	Raw material input temperature	^0C	35	35
10	Product final temperature	^0C	1,200	1,200
11	Specific heat of EN8 Cast Steel	kcal/kgK	0.117	0.117
12	Hourly electrical energy consumption including all accessories (post implementation)	kWh		104.00
13	Specific energy consumption (post implementation)	kWh/kg		0.50
14	Furnace Direct Efficiency	%	8.57	31.70
15	Annual energy consumption	kcal/y	247,248,000	6,96,60,000
16	Annual energy saving	kcal/y		17,75,88,000
17	Annual fuel saving	l/y		17,583
18	Furnace oil cost	Rs/l		35
19	Annual Monetary Saving	Rs in lakhs		6.15
20	Investment (Induction Heater)-1	Rs in lakhs		10.00
22	Sanction load	hp	59	200.00
23	Contract demand	kVA	46	165.00
24	Increment in contract demand	kVA		119.23
25	Supply voltage	V	440	11,000.00
26	Fixed charged	Rs/hp and Rs/kVA	75	185.00
	Annual Fixed charges	Rs/y	53,100	3,66,300
27	Investment demand expansion-2	Rs in lakhs		3.13
28	Total investment	Rs in lakhs		13.13
30	Simple Payback	y		2.13
29	Annual energy saving	toe/y		17.76
30	Annual GHG emission reduction	tCO_2/y		55.25

**Emission factor of furnace oil as per IPCC guideline 2006 (V2) taken as 77.4 tCO_2/TJ*

Table 9: Investment, savings and simple pay back for IGBT based electric induction heater

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
UoM	kW	Rs in Lakhs	Rs in Lakhs	Years
	80-200	11-25	5-15	< 2.5 years

Case Study 3: Installation of IGBT based electric induction heater

Kohinoor Forging, established in the year 1990, is a major manufacturer of claw hammer, ball pin hammer and sledge hammer in Nagaur, Rajasthan. Initially, the unit was using furnace oil fired forging furnace in their unit. The efficiency of the furnace was poor at only 7-8%. Also, the plant's working environment was poor as handling of furnace oil was difficult. In the year 2014, the unit decided to shift to electric induction biller heater. The unit installed a 100 kW billet heater to take care of their heating requirement. The contract demand was enhanced from 44 kW to 150 kW. The unit successfully eliminated the furnace oil based furnace. The furnace oil consumption of 80 liters/day was replaced with 1,300 kWh/month of electricity consumption, considering same production. Investment made for the demand enhancement and the induction heater was Rs 13 lakhs. The unit was able to save Rs 6.3 lakhs per year. Thus, the investment was recouped within 2 years. The installation of the induction heater led to GHG emission reduction of 52 tCO_2/y.

Particulars	UoM	Baseline	Post Implementation
Type of forging furnace		Furnace oil fired	Electric Induction billet heater
Annual production	t/y	162	162
Furnace efficiency	%	7-8	30-35
Furnace oil consumption	l/d	80	0
Contract demand	kW	44	150
Electricity consumption	kWh/d	33	89
Monetary saving in terms of energy consumption	Rs /d	2,380	
Monetary savings (annual)	Rs in lakh/y	6.3	
Investment (for equipment)	Rs in lakh	10	
Investment (for additional contract demand)	Rs in lakh	3	
Total investment	Rs in lakh	13	
Payback	y	2	
GHG emission reduction	tCO_2/y	52	
Annual energy consumption reduction	toe/y	83.5	

**Emission factor of Furnace Oil as per IPCC Guideline is 77.4 tCO_2/TJ*
***Source: Energy audit carried out under GEF-UNIDO-BEE project*

Technology No. 4: Replacement of Existing Motors with IE 3 Class Efficiency Energy Efficient Motors

5

5.1 Conventional Practice

After the raw material is heated to the forging temperature, the same is transferred to the power hammer press, where the heated charge is forged to the desired shape. The forged material is finally machined using conventional machines for the desired product output. The power hammer press and finishing machines form an important part of the forging industries. The forging hammer is of mechanical type which is driven by an electric motor. The finishing machines consisting of lathe, milling and drilling machines which are driven by electric motors are connected with individual machines. These motors consume a major power of the total energy consumption of a typical forging unit.

Three- phase induction motors are most commonly used to run various applications in a hand-tool unit. The rated capacity of these motors range between 1-7.5 hp (Lathes etc.) to 50 hp (forging hammer motors). 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 ensure 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 forging 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 standstill. Motor failures can be attributed to mechanical and electrical failures. Causes such as improper voltage, voltage fluctuations, improper lubrication and damaged bearings lead to rise in motor winding temperature, ultimately leading to failure. These electrical failures lead 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.

5.2 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

Figure 10: Energy efficient motor

- 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 drop when they are loaded less than 50%. However, the efficiency of energy efficient motors is always higher than conventional motors, irrespective of the loading.

Table 10: Details of motor in forging units

Parameters	Annual capacity	Rated motor power	Motor Efficiency	Rewinding	Hours of operation	Days of operation
UoM	t/y	hp	%	Nos.	h/d	d/y
	100-1000	1-50	75-88	4-7	8-16	330

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:

Table 11: Specification of 7.5 hp energy efficient motor

SN	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

The motor efficiency as per IEC 60034-30 for 2-pole, 4-pole and 6-pole at 50 Hz frequency is tabulated below (Figure 5):

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

Figure 11: Motor efficiency values as per IEC 60034-30

The efficiency graph for 4-pole IE 1 to IE 4 class efficiency motors at 50 Hz frequency is shown below in Figure 6.

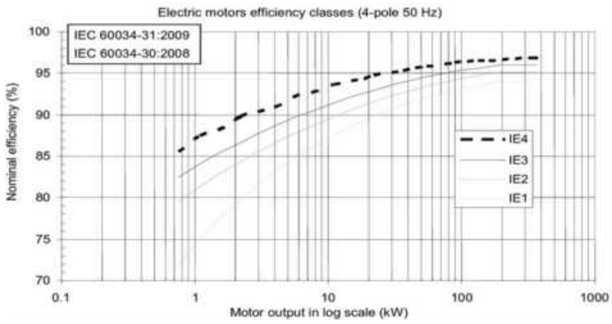


Figure 12: IE efficiency classes for 4 pole motors at 50 Hz

5.3 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.

5.4 Limitation of technology

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

5.5 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 50 hp. The unit operates 3,100 hours per year. The cost benefit analysis for adoption of the technology has been tabulated below:

Table 12: Energy & GHG emission saving potential, investment required and cost benefit analysis for energy efficient power press hammer

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Rated Power for power press hammer	hp	50	50
2	Rated Power for power press hammer	kW	37.0	37
3	Motor Efficiency	%	75.00	93.90
4	Annual operating hours	h/y	3,600.00	3,600
5	Motor loading	%	27.00	21.57
6	Annual energy consumption	kWh/y	97,200	77,636
7	Annual energy saving	kWh/y		19,564
8	Average power tariff	Rs/kWh		7.25
9	Annual monetary saving	Rs in lakhs		1.42
10	Investment	Rs in lakhs		1.55
11	Simple Payback	y		1.09
12	Annual energy saving	toe/y		1.68
13	Annual GHG emission reduction	tCO_2/y		17.61

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

Case Study 4: Installation of IE 3 class efficiency motor

Kohinoor Forging, established in the year 1990, was using an 18.5 kW motor in the drop hammer which was old and also under loaded. Based on technical recommendation, the motor was replaced with a 15 kW IE-3 class efficiency motor. The installation led to a monitory saving of Rs 31,000 per year. Thus, the unit was able to recover the investment of Rs 35,000 in little over one year's time.

Particulars	UoM	Baseline	Post Implementation
Type of motor		IE 1	IE 3
Motor Rating	kW	18.5	15
Motor Loading	%	75	90
Motor efficiency (considering 2 times rewinding)	%	85	92.10
Annual operating hours	h/y	2,500	2,500
Annual energy consumption	kWh/y	40,808	36,600
Annual energy saving	kWh/y	4208	
Annual Monetary saving	Rs in lakh/y	0.31	
Investment	Rs in lakhs	0.35	
Payback	months	13.5	
GHG emission reduction	tCO_2/y	3.78	
Annual energy consumption reduction	toe/y	0.36	

**Emission factor taken as 0.9 tCO_2/MWh as per IPCC Guideline 2006 (V2)*

6 Technology No. 5: Replacement of conventional machine with special purpose machine

6.1 Baseline Scenario

Conventionally, forging units use manually operated conventional machines for various machining job work like facing, turning, grinding, drilling, etc. These machines run on electrical motors having the capacity varying from 1 hp to 5 hp with production/ machining of 1,200~1,800 pieces per day. Since these machines are manually operated, the process through which components are manufactured is very slow and time consuming. Apart from the slow process, it is also difficult to maintain the quality of the product in case of manual machining. It is often observed that the machines operate ideally (without any component loaded on to the machines) and the operator is busy in doing some other work/activity. All these factors lead to valuable resource; energy, manpower, time and money. Conventional machines include manually operated lathe, drilling, threading machines. A particular job work needs to be machined worked in two to three machines for completion. E.g. A metal piece is first fed into the lathe for turning and facing operations. After this, the job needs to be transferred to some other machine for threading operations and drilling needs to be done in a third machine. In some cases, the trimming operation is done in a separate machine. Thus, for a single job work, a number of machines are required which leads to lower productivity, higher energy consumption and lower efficiency due to manual intervention in each process.

Figure 13: A conventional drilling machine

6.2 Energy efficient technology

The superior alternative of conventional machines is automatic special purpose machine (SPMs). These machines run on pre-installed programs, and are equipped to carry out multi-tasking at a single time. Thus, consumption of electricity only happens when there is a function or operation required on the component. In the ideal condition, the machine remains in dead mode/ no operation mode. The machine also has an automatic feeder to automatically load the component for machining. The cycle time of the each component is fixed in the business logic of the PLC / SPM, therefore each component will take specific time for processing or machining. The SPM machines result in 30-50% of the energy savings depending upon the type of component, operation, material, cycle time. A Special Purpose Machine (SPM) is a kind of multi-tasking machine used for machining purpose. A special purpose machine is used as a replacement to conventional machines like lathe, drilling or trimming machine. A special purpose machine is designed based on the customized requirement of a unit and may be used for one or multiple tasks as per the design. For example, a conventional drilling machine is operated manually and machines one piece at a time. Three different machines are operated simultaneously to machine the required number of pieces. The three drilling machines can be replaced by a single special purpose drilling machine which can process three jobs at a time, thus increasing productivity and reducing energy consumption.

Figure 14: Special purpose drilling machine

The sequence of operation in a special purpose machine is pre-set using timers and sensors. The entire operation is maintained using pneumatic and mechanical control. For ease of operation, each special purpose machine is equipped with an automatic feeder. Replacement of conventional machines with special purpose machines usually increases machine productivity by 5 times, easing the life of the operators by avoiding manual intervention during each operation.

Table 13: Details of conventional machines in forging units

Parameters	Annual capacity	Rated motor power	No. of machines per unit	No. of piece processed	Hours of operation	Days of operation
UoM	t/y	hp	%	Pcs /d	h/d	d/y
	100-1000	1-5	5-10	1,200-1,800	8-16	312

6.3 Benefits of technology

Replacements of conventional machines with special purpose machine have multi-fold benefits which include:

- Reduced specific energy consumption
- Improved working conditions
- Improved process efficiency
- Improved productivity
- Less operation and maintenance cost

6.4 Limitations of technology

Special purpose machines are designed based on customized needs of the industry. Flexibility in operation is hampered after the changeover.

6.5 Energy & GHG emission saving potential, Investment required & Cost benefit analysis

To understand the cost benefit analysis, let us consider a typical unit having 3 drilling machines driven by individual motors of 5 hp each. These machines are replaced with a single special purpose drilling machine powered by a 7.5 hp motor. The unit operates 3,600 hours per year. The cost benefit analysis for adoption of the technology has been tabulated below:

Table 14: : Energy & GHG emission saving potential, Investment required & Cost benefit analysis of special purpose machine

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Rated Power for drilling machine	hp	5	7.5
2	No. of drilling machine	Nos.	3	1
3	Rated Power for drilling machine	kW	11.1	5.5
4	Productivity	Pcs/h	102	306
5	Specific energy consumption	kWh/pcs	0.109	0.0180
6	Annual operating hours	h/y	3,600	3,600
7	Annual production	Pcs/y	367,200	367,200
8	Annual energy consumption	kWh/y	39,960	6,600
9	Annual energy saving	kWh/y		33,360
10	Average power tariff	Rs/kWh		7.25
11	Annual monetary saving	Rs in lakhs		2.42
12	Investment	Rs in lakhs		2.00
13	Simple Payback	y		0.8
14	Annual energy saving	toe/y		2.87
15	Annual GHG emission reduction	tCO_2/y		30.02

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

Case Study 5: Installation of Special Purpose Drilling Machine

Victor Forgings is a family owned business and is one of the leading manufacturers of Hand tools since its establishment in 1954. The company manufactures, designs and specializes in vast range of Spanners, Wrenches, Pliers, Vices, Hammers, Automotive tools, Carpentry tools and D.I.Y tools. The company is awarded with ISO-9001:2008, ISO 14001-2004 by TUV RHEINLAND and SA-8000 certifications by BSI. The state-of-the-art factory includes in-house facilities like Designing, Tool Room, Forging-Shop, Heat-treatment, Electroplating, Chemical and Testing laboratories. The company is involved in export of their product to more than 50 product countries worldwide which include USA, Europe, South America, South East Asia and a number of world's leading Brands & Stores.

In 2018, the unit took an initiative to replace their old conventional broaching machine with more efficient and more productive double spindle type, which led to higher production at lower electricity consumption. Compared to the former (which had 1 X 20 hp motor) that broaches only 1 piece at a given time, the new machine had 2 spindles controlled by 2 separate motors (2 X 10 hp) coupled to the same machine. The new machine delivered about twice the production when compared to the former.

Parameter	Unit	Baseline	Post Implementation
No. of Motor in broaching machine		1	2
Rated Power for drilling machine	hp	20	10
No. of drilling press	Nos.	1	2
Rated Power for drilling machine	kW	14.92	14.92
Productivity	pcs/h	300	600
Specific energy consumption	kWh/pcs	0.0497	0.0249
Operating hour per day	h/d	12	12
Annual operating days	d/y	313	313
Annual operating hours	h/y	3,756	3,756
Annual production	pcs/y	1,126,800	2,253,600
Annual increase in production		1,126,800	
Annual energy saving	kWh/y	28,020	
Average power tariff	Rs/kWh		6.84
Annual Monetary Saving	Rs in lakhs /y		1.92
Investment	Rs in lakhs		3.75
Simple Payback	y		2.0
Annual Energy Saving	toe/y		2.3
Annual GHG emission reduction	tCO_2/y		24.94

**Emission factor of Electricity as per IPCC Guideline is 0.9 tCO_2/MWh*
***Source: Energy audit carried out under GEF-UNIDO-BEE project*

Technology No. 6: Optimization of Compressed Air Distribution Network

7

7.1 Baseline Scenario

Compressed air is one of the major utilities of for forging industries, as they are used in several operations like shot blasting, air guns, pneumatic material pushers in furnaces, etc. The compressed air is generated at 7.5 to 8 kg / cm^2 by a single compressor or sometimes with 2 compressors running in parallel generating compressed air which is stored in a common receiver tank. Tank volumes vary depending on the sizes of compressors. In few of the units visited in the cluster the receiver volumes were of 500 Liters.

Types of compressors used in the plant are either screw type or reciprocating type. The compressors were powered by AC induction motors of capacities 11-22 kW. The compressed air is generated by the compressor which is stored in the receiver tank and from there it is distributed to the entire plant at individual user points by pipeline network. The pipelines used are of MS or GI material and their sizes vary from ½ inch to 2 inches.

During plant visits, a lot of compressed air leakages were observed as evident from hissing sounds during lunch breaks or shift changes when most of the machines are shut down. The air leakages is one of the major energy losses in the compressed air system as this results in wastage of air generated. In some units, the leakages were about 30-40% of total compressed air generated by the compressors. Major points of such leakages are pipe joints, bends, elbows etc. Further, there is also pressure drops in the system due to friction loss in pipelines. This results in the compressors generating more air to make up for the air leaks and pressure drops thus increasing energy consumption.

7.2 Energy efficient technology

For reducing compressed air leakages in distribution network, the present leakage levels have to be quantified in the plant. For this, a leakage test needs to be conducted. During lunch breaks or during plant closure at late evenings, when all machines are stopped, the compressors need to be run and allowed to build up to cut-off pressure (usually 7.5 to 8.5 kg / cm^2). The compressor fills up the entire pipeline by building up pressure during loading and when the desired working pressure is attained, it will cut-off (or unload). During unloading, the compressor motor usually runs at about 30% of loading power but does not supply air (it only performs dummy strokes). When the entire pipeline is pressurized at desired pressure, the compressor will unload and should remain unloaded as the air is not being used at end-user points. But due to leakages in system, the line pressure will start to drop and once the pressure drops to cut-in point, the compressor will again start on-load to built up the pressure again in the pipelines. This cycle will keep repeating and the loading and unloading times need to be recorded. From this, the % leakage in the system can be calculated using the below formula.

% Leakage = [Loading time / (Loading time + Unloading time)] x 100

The % leakage in a good pipeline distribution network should be below 8-10% of total generated air. But if the % leakage is higher, then it can be reduced by plugging the leakages and replacing the pipelines with low friction lines like HDPE-Al-HDPE lines. These lines reduce the pressure drop in pipelines due to reduced friction and are less prone to leakage than conventional lines. Moreover, these lines come with readily replaceable joints, elbows, valves, etc which can be fitted at leakage points with minimum disturbance to system. These pipelines help in limiting the leakages to desirable limits (less than 10%) and also avoid system pressure drops, as they have much smoother interiors, thus reducing frictional pressure drops in the system.

7.3 Benefits of technology

Replacements of conventional MS / GI pipelines with low friction pipelines have multi-fold benefits which include:

- Reduced pressure drops in pipelines
- Reduced air leaks
- Reduced specific energy consumption of compressor
- Improved compressed air distribution efficiency
- Reduced loading duration of compressors
- Lower power consumption by compressor motor
- Less operation and maintenance cost for compressed air distribution network

Table 15: Compressor details for forging sector

Parameters	Annual capacity (1 furnace)	Rated motor power	No. of compressors per unit	Rated FAD	Hours of operation	Days of operation
UoM	t/y	kW	%	m^3 / min	h/d	d/y
	200-250	11-22	2-3	1.5-3.3	8-10	313

7.4 Limitations of technology

Plant shutdown may be planned properly to avoid any production loss. The entire air circuit may be revamped in different phases.

7.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

To understand the cost benefit analysis, let us consider a typical unit having 2 screw compressors of 11 kW and 22 kW motors running in parallel. Both the compressors are run simultaneously to fill up the common receiver from where the air is distributed to end user points by MS / GI pipelines. The compressor loads at 7 kg / cm^2 and unloads at 8.2 kg/cm^2. The unit operates 3,130 hours per year. The cost benefit analysis for adoption of the technology has been tabulated below:

Table 16: Optimization of compressed air distribution network

Parameters	UOM	AS IS	TO BE
Rated kW of 2 compressors of 22 kW & 11 kW each	kW	33.0	33.0
Rated cfm of both compressors (54.34 cfm + 117.86 cfm)	cfm	172.2	172.2
Cut in Pressure	kg/cm^2	7.0	7.0
Cut out Pressure	kg/cm^2	8.2	8.2
Actual Free Air Discharge delivered by 2 compressors running in parallel	cfm	42.5	42.5
Actual Leakages in distribution lines (2 compressors run in parallel)	%	36.3	10.0
	cfm	15.44	4.25
Present total power consumption by both the parallel running compressors	kW	32.06	
Operating hours per day	h / d	10.00	10.00
Operating days per year	d / y	313.00	313.00
Reduction in compressed air leakages (Proposed)	cfm		11.19
Energy savings proposed by arresting the leakages	kW		8.44
Proposed annual energy savings	kWh / y		26,420
Wt. avg. cost of electricity	Rs / kWh		8.50
Proposed annual monetary savings	Rs. Lakh / y		2.25
Proposed Investment	Rs. Lakh		1.50
Payback period	y		0.67
Annual energy savings	Toe / y		2.27
Annual GHG emission reduction	tCO_2 / y		23.78

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

Table 17: Investment, savings and simple payback for compresed air distribution network

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	1.50	2.25	0.67

Case Study 6: Energy efficient compressed air network

Hariom Precision Alloys Private Limited, Alwar is one of the leading manufacturers of SG Iron and Grey Iron Casting in India. The company has adopted a quality management system & has acquired ISO: 9001:2000 certification in the year 2002. The company is committed to produce quality goods along with complete customer satisfaction and also comply with Pressure Equipments Directive 97/23/EC for Pressure Equipments. Compressed air was a key element in the unit's production process. The plant had around 1,000 meters of compressed air line. Studies reported significant air loss due to leakage leading to higher energy consumption. In 2018, the unit revamped their entire compressed air network using state-of-the-art ring main system. Also High Density Polyethylene (HDPE) pipelines were used. The benefits of HDPE pipes over conventional metal pipes were:

- No corrosion, hence no rust in air flow.
- Smooth interior allowed laminar flow.
- The pipes are lightweight, hence easy to transport and fit.
- Cutting is far easier than metal pipes.
- Plastic pipes can be glued together, which is less costly and quicker than welding metal.

The efficient compressed air system led to significant saving in terms of energy coupled with other benefits like low maintenance and longer life. There was significantly lower pressure drop in the compressed air network.

Parmeters	UoM	Values	
		Baseline	Post Implementation
Existing Compressor Type		Recproprocating /Screw	Recproprocating /Screw
Rated Capacity	kW	45	45
Rated Capacity	hp	60	60
Rated cfm	cfm	250	250
Operating Pressure	kg/cm^2	7	5
Power consumption (reduction in the delivery pressure by 1 bar in a compressor can reduce the energy consumption by 6 – 10 %)	kW	45	38
Annual operating hours	Hr	7,920	7,920
Electricity Tariff	Rs/kWh	7	7
Annual Energy saving	kWh		53,175
Annual Monetary Saving	Lakh Rs/y		3.7
Investment	Lakh Rs		7
Payback	Month		22.6
Annual energy saving	Toe		5
Annual GHG emission reduction	tCO_2		48

**Emission factor of Electricity as per IPCC Guideline is 0.9 tCO_2/MWh*
***Source: Energy audit carried out by DESL*

8 Technology No. 7: Installation of Solar Photovoltaic System for Power Generation

8.1 Baseline Scenario

Electricity is a key component of the total production in a forging industry. The connected load in individual units varies from 50 to 1,500 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.

8.2 Energy efficient technology

Power generation using solar energy using a 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.

Figure 15: Roof Top Solar PV Installation

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.

The forging units 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. The industries at Jamshedpur and Howrah have a potential to install 200 kW solar PV system within an area span of 1,600 m^2. Average annual solar irradiation for Jamshedpur, Jharkhand is 4.86 kWh/m^2/day (Figure 16). Average annual solar irradiation for Howrah, West Bengal is 4.2 kWh/m^2/day (Figure 17).

8.3 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

8.4 Limitations of technology

The limitations of the PV technology are as follows:

- Adoption of solar photovoltaic needs high capital investment
- Generation of dust in the industrial area causes hindrance on the efficiency of the photovoltaic system
- The periodic cleaning should be adopted during the operation of the system.

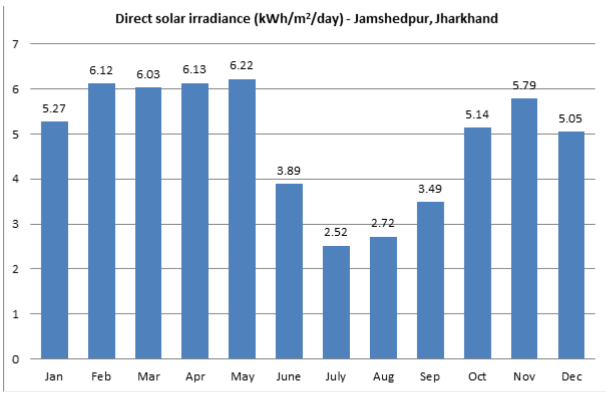


Figure 16: Direct normal solar irradiance for Jamshedpur (kWh/m^2/day)

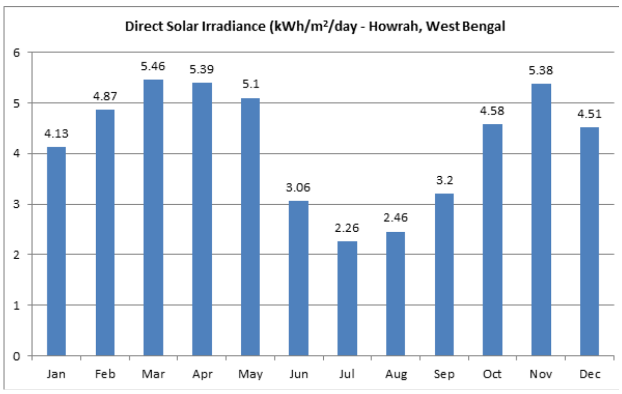


Figure 17: Direct normal solar irradiance for Howrah (kWh/m^2/day)

8.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

To understand the cost benefit analysis, let us consider a solar PV system of 200 kWp capacity. The cost benefit analysis for adoption of the technology has been tabulated below:

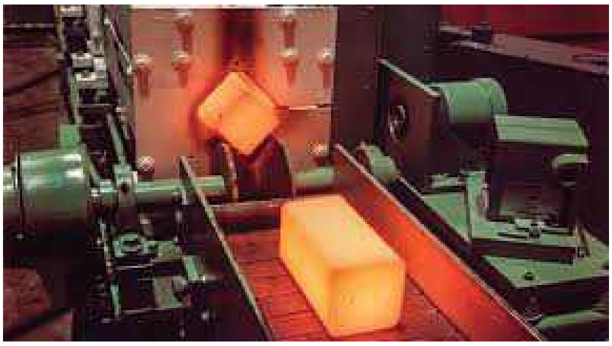


Table 18: Energy & GHG emission saving potential, Investment required &cost benefits analysis for solar PV system

Sl. No.	Parameters	Unit	Value
1	Capacity of Rooftop Solar	kWp	200
2	Rooftop area required	m^2	1,600
3	Solar power generation capacity	kWh/kWp	4.46
4	Generation potential	kWh/d	892
5	Annual solar radiation days	d/y	312
6	Generation potential	kWh/y	278,304
7	Electricity charges	Rs/kWh	7.25
8	Annual monetary saving	Rs Lakh/y	20
9	Cost of installation	Rs. Lakh	80
10	Simple Payback	y	4
11	GHG reduction potential	tCO_2/y	250

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

Case Study 7: Installation of Solar PV

PYN Precision Components Pvt. Ltd., Faridabad, established in the year 1977, is a major manufacturer of Auto components and Aerospace components. Initially, the unit was consuming 100% electricity from grid at a rate of Rs. 8.6 /kWh. Available roof top area was 400 sq. m with structures suitable for Solar PV based power generation. The plant installed a 40 kW solar PV system during 2016-17. Annual electricity generation from the solar PV system was 67,160 kWh/y out of the total annual electricity consumption of 795,220 kWh/y. The plant was able to achieve an annual monetary saving of Rs 5.8 lakhs with an investment of Rs 36 lakhs. The investment will be recouped in approximately 6 years' time.

9 Technology No. 8: Installation of High Efficiency Metallic Recuperator

9.1 Baseline scenario

At present, forging units mainly use fossil fuel fired reheating furnace. The re-heating operation is carried out in batch process and commonly fired by furnace oil. The efficiency of such furnaces is as low as 9-12%. Waste flue gas loss accounts for up to 70% of the total heat loss in the furnace. The walls of the forging furnaces store a considerable amount of heat which can be reused for combustion air preheating. The flue gas temperature in such furnaces can range somewhere between 350-4000C. A significant portion of this can be reused to achieve a considerable fuel saving.

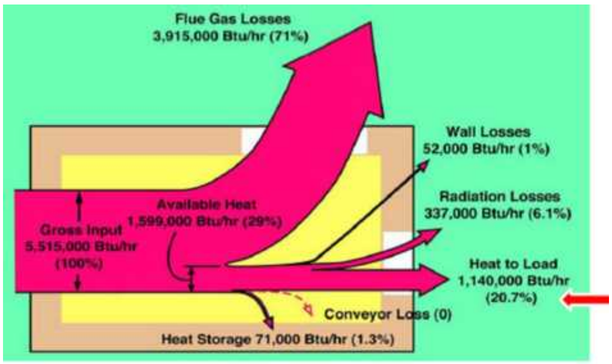


Figure 18: Sankey diagram of typical forging furnace

9.2 Energy efficient technology

As an alternative to the existing practice, a high efficiency metallic recuperator, i.e. a heat exchanger can be 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. Recuperator consists of a number of ducts or tubes which carry the combustion air to be preheated. These ducts are placed in a metallic chamber which carries the waste heat from the flue duct. 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 inlet combustion air from atmosphere is pre-heated using the waste gas. The preheated combustion air is fed directly into the burner. With every 21^{0}C rise in the combustion air temperature leads to a fuel saving by 1%. Thus, preheated combustion air leads to savings in terms of fuel, increase in flame temperature and improvement in furnace efficiency.

The recuperator's efficiency depends upon two important parameters - surface area and time available for heat exchange and recuperator material.

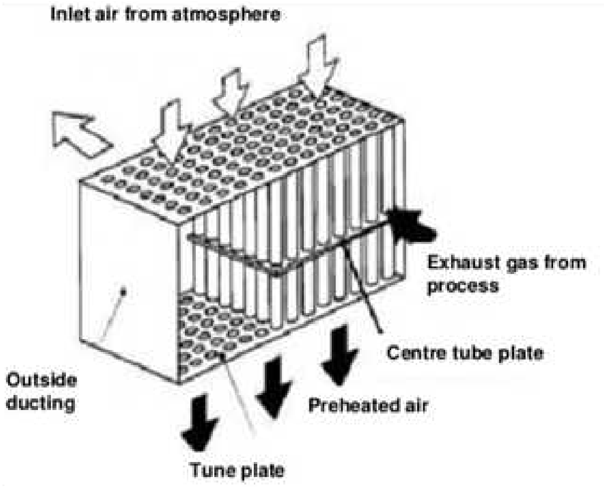


Figure 19: Metallic recuperator

9.3 Benefits of technology

There are several benefits to the installation of a recuperator in a fossil fuel fired furnace. These include:

- Reuse of waste flue gas
- Reduced fuel consumption
- Increase in combustion air temperature
- Increase in flame temperature
- Increase in furnace efficiency

For optimum efficiency, the recuperator pipes need to be built in stainless steel. Also, the surface area for heat transfer should be properly designed.

9.4 Limitations of technology

The implementation of the technology requires a modification of the existing furnace design as most of the flue gas is directly let out from the furnace from the furnace openings.

9.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

For calculating the energy and monetary benefits, a typical case of a reheating furnace of 200 kg capacity having exhaust flue gas temperature of 400^{0}C is considered:

Table 19: Cost benefit analysis for high efficiency metallic recuperator

Sl. No.	Parameters	UOM	Baseline	Post Implementation
1	Rated Capacity	t/h	0.07	0.07
2	Effectiveness of recuperator	%		0.6
3	Flue Gas Temperature	°C	340	157
4	Combustion air temperature	°C	35	218
5	Increase in combustion air temp	t/h		183
6	Fuel saving (As per thumb-rule, with every 21°C rise in the combustion air temperature leads to a fuel saving by 1%)	%		8.71%
7	Specific fuel consumption	l/h	7.29	6.66
8	Annual fuel saving	l/y		2,288
9	Annual monetary saving	Rs in lakh		0.96
10	Investment	Rs in lakh		0.75
11	Payback	Month		9.4
12	Annual energy saving	Toe		2.3
13	Annual GHG emission reduction	tCO_2		5.0

**Emission Factor of furnace oil=2.26984 $kgCO_2$/kg fuel IPCC2006 (V2;C1 and C2)*

Case Study 8: Installation of metallic recuperator in forging furnace

In 2017, a leading forging unit in Pune installed a recuperator in their existing forging furnace which was of 250 kg/h capacity. The combustion air inlet temperature was increased from 40 °C to 150 °C. With rise in the combustion air temperature, the unit was able to save 5% of the fuel consumption.

Parameters	UoM	Baseline	Post Implementation
Productivity	kg/h	250	250
Annual operating hours	h/y	3,600	3,600
Annual production	t/y	900	900
Specific fuel consumption (FO)	l/t	120	114
Furnace oil cost	Rs/l	42	
Annual Fuel Cost	Rs in Lakh/y	45.36	43.09
Annual Monetary Saving	Rs in Lakh/y	2.27	
Investment	Rs in Lakh	0.75	
Simple Pay-back	Months	4	
Annual Energy Savings	toe/y	4.97	
Annual GHG Emission Reduction	tCO_2/y	16.11	

**Emission factor of Furnace Oil as per IPCC Guideline is 77.4 tCO_2/TJ*
***Source: Energy audit carried out by DESL*

10 Technology No. 9: Replacement of Reciprocating Compressor with Energy Efficient Screw Compressor

10.1 Baseline Scenario

Air compressors are used for a wide variety of applications in a forging unit. In addition to its use in process application, compressed air finds its use in maintenance of most machines.

An air compressor is a power tool that creates and moves pressurized air. Air under pressure provides great force, which can be used to power many different kinds of tools. Conventionally, reciprocating air compressors, working by means of a piston and cylinder is the most commonly used compressor for industrial applications. When the machine is switched on, pressure changes suck air into the tank. The trapped air in the tank is placed under great pressure when the pistons move down. It is released by a discharge valve into another tank, where its release can be regulated and controlled through a valve. The valve discharges the pressurized air into space of its utilization. Pressurized air is measured in cubic feet, and the flow rate is measured in cubic feet per minute (CFM). A typical pressure rating for a small compressor used for industrial application is 7 kg/cm^2.

Traditionally, in the forging units, the compressed air is produced by way of multiple reciprocating air compressors located at different locations in the unit. Often there are different reciprocating air compressors for each individual processes. These compressors produce a lot of noise with a relatively high cost of compression. The operational efficiency too varies, ranging from 22 to 35 kW/100 cfm. This goes down as the age of the equipment increases.

10.2 Energy Efficient Technology

With time, technology upgradation takes place leading to more efficient operations. An energy efficient alternative to the conventional reciprocating compressor is a high efficiency rotary screw compressor with direct coupled energy efficient motor and equipped with a Variable Frequency Drive, which can cater to fluctuating compressed air requirement.

Rotary screw compressors are operated with the basic principle of a positive displacement machine where key elements are a pair of spiral rotors. During operations, the rotors turn and the spiral keys mash together forming chambers between the rotors and the casing wall. Rotation causes the chambers to move from the suction or intake side to the compression or discharge side. These chambers are connected to the suction nozzle via ports. As the chambers enlarge, they are filled with air flowing in through the nozzle. The rotor transports the gas towards the discharge side where the chamber shrinks and thus the retained air is compressed. Once the air is compressed, the chamber reaches another port connected to a discharge nozzle and the gas flows out. In fact, all the chambers between the two rotors are filled and emptied continuously. This means, that with the screw compressor, the compression process is more or less on-going. The design of a screw compressor combines the advantages of a positive displacement machine with those of a rotating machine making this type of compressor suitable for a wide range of requirements.

This type of compressor has only two moving parts which are not in contact with each other. There is, therefore, no friction and reduced possibility of breakdown. Moreover, the compressor works ceaselessly and produces much less noise when compared to the conventional reciprocating compressor. In addition to the design benefits of a rotary compressor, the VFD allows the operation of the compressor under variable load conditions, thereby saving energy. Also, the directly coupled energy efficient motor nullifies the transmission losses of a belt driven system and adds value in terms of the efficiency of the motor.

The operational efficiency of rotary screw compressor along with VFD and direct coupled energy efficient motor ranges from 16 to 19 kW/100 cfm.

10.3 Benefits of Technology

Advantages of screw compressor with VFD and directly coupled energy efficient motor include:

- 30-50 % reduction in specific power consumption of the compressor
- Noise free operation
- Longer compressor life
- Less maintenance.

10.4 Technology Limitation

Screw compressor with energy efficient motors and VFD is not economically feasible for very small capacity of compressed air demand. Also, for higher pressure application a reciprocating of centrifugal type compressor is feasible.

10.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

To understand the cost-benefit analysis, let us consider a 20 hp compressor with compressed air demand of 90 cfm with 6,000 hours of annual operation. The cost-benefit analysis for adoption of the technology is tabulated below:

Table 20: Cost benefit analysis for EE Screw compressor

Sl. No.	Parameters	Unit	Reciprocating	Screw compressor
1	Design pressure	kg/cm^2	8.0	8.00
2	Operating pressure (Compressor Panel Reading)	kg/cm^2	7.0	7.0
3	Specific power consumption	kW/cfm	0.32	0.16
4	Average air required	cfm	90	90
7	Running hours per day	h/d	20	20
8	Annual operating days	d/y	300	300
9	Annual energy consumption	kWh/y	1,38,240	69,120
10	Annual energy saving	kWh/y	-	69,120
11	Weighted Avg. electricity cost	Rs/kWh		7.5
12	Monetary savings	Lakh Rs/y	-	5.18
13	Investment	Lakh Rs	-	6.5
14	Payback period	y	-	1.25
15	Annual energy saving	toe		6
16	Annual GHG emission reduction	tCO_2		62

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

Case Study 9: Installation of energy efficient screw compressor

Laxmi Vishnu Silk Mills, Surat was incorporated in 1976. It has been a market trendsetter in creating wide range of cotton, polyester sarees & dress materials. Located in Bhestan, the unit is spread over an area of 50,000 sq ft with 100 skilled workers working in it. It has total "Grey to Pack in house facility." The unit has both dyeing and printing facility in its premises. The unit processes / manufacturers 32 lakhs meters of finished dress material per month. In textile processing, compressed air forms one of the key utilities which is used extensively in the process of dyeing and printing. The requirement for compressed air is met by the units by one or more compressor.

Laxmi Vishnu Silk Mills was equipped with five reciprocating compressors. The compressors were installed at a common location and distributed to different equipment / processes through a common receiver / header. Out of the five compressors, four were equipped with VFD. Based on the compressed air requirement of the plant, the compressor used to get automatically switched on and off. The compressors were equipped with individual air receivers with a total electricity load of 43 hp.

In 2019, the plant took a revolutionary step to replace their existing reciprocating compressor with a single screw compressor. The new compressor was energy efficient screw type and was equipped with VFD and 'Permanent Magnet' motor. The unit was able to save substantial energy consumption due to the new energy efficient screw compressor.

Reciprocating compressor

Energy Efficient Screw compressor

Particulars	UoM	Baseline	Post Implementation
Type of Compressor		Reciprocating	Screw with VFD & PM Motor
No. of compressor	Nos.	5	1
Cummulative motor ratings	kW	31.66	15
Total Capacity @ 7 bar pressure	cfm	52.73	15-88.6
Compressed air demand (based on study)	cfm	46.00	46.00
Operatings hours per day	h/d	24	24
Operating days per year	d/y	330	330
Annual compressed air demand		364,320	364,320
Specific power consumption (weighted average)	kW/cfm	0.32	0.16
Annual power consumption	kWh/y	116,582.4	58,291
Annual power saving	kWh/y	58,291	
Weighted average electricity cost	Rs/kWh	6.87	
Annual monetary savings	Rs in lakh/y	4.00	
Investment	Rs in lakh	6.75	
Simple Pay-back	months	20	
Annual Energy Savings	toe/y	5.01	
Annual GHG Emission Reduction	tCO_2/y	52.46	

**Emission factor of Electricity as per IPCC Guideline is 0.9 tCO_2/MWh*
*** Implemented under GEF-UNIDO-EESL project titled "Promoting Market Transformation for Energy Efficiency in MSMEs"*

Technology No. 10: Installation of energy efficient pumps

11

11.1 Baseline Scenario

Industrial pumps are used for a wide range of applications across many industries. Centrifugal pumps are the most preferred pumping devices in the hydraulic world. At the heart of the pump, lies the impeller. It has a series of curved vanes fitted inside the plates. When the impeller is made to rotate, it makes the fluid surrounding it also rotate. This provides a centrifugal force to the water particles to move radially out. Since rotational mechanical energy is transferred to the fluid, both pressure and kinetic energy of water will rise. As water gets displaced; a negative pressure is induced at eye. This negative pressure helps in sucking fresh water stream into the system again and this process continues. For proper operation, the pump is filled with water before starting.

Impeller is fitted inside a casing, so that water moving out will be collected inside it and move in the same direction of rotation of the impeller to the discharge nozzle. The casing has got increasing area along the flow direction. Such increasing area will help accommodate freshly added water stream and also helps in reducing exit flow velocity. Reduction in flow velocity will result in an increase in static pressure which is required to overcome resistance of pumping system. The pump is driven by a motor. Improper selection of pump and its poor control mechanism leads to inefficient operations. The design of an efficient pumping system depends on relationships between fluid flow rate, piping layout, control methodology, and pump selection. Before a centrifugal pump is selected, its application must be clearly understood.

Centrifugal pumps are frequently used in hand tool industries for cooling circuit and cooling tower applications. Most of the pumps are old and inefficient consuming significant energy.

11.2 Energy Efficient Technology

Energy efficiency of a pumping system relates to selection of correct pump with required head and flow, based on application and its control mechanism. Features of energy efficient technologies include:

- **Correct Impeller sizing:** The circumferential speed of the impeller outlet depends on the impeller diameter. Trimming of impeller is done to match operating point with specification.
- **Optimum blade angle:** Vanes are curved backward inside the impeller. The blade angle should be properly designed for optimum efficiency.
- If pressure in the suction side of the impeller goes below the vapour pressure of water, water will start to boil forming vapour bubbles and spoil impeller material over time. This phenomenon is known as cavitation. More the suction head, lesser should be the pressure at the suction side to lift water. This fact puts a limit to the maximum suction head a pump can have. So, careful pump selection is required to avoid problems of cavitation.
- Pump curves also indicate pump size and type, operating speed (in revolutions per minute), and impeller size (in inches). It also shows the pump's best efficiency point (BEP). The pump operates most cost effectively when the operating point is close to the BEP.
- Variable Frequency Drives (VFDs) are usually the most efficient flow and/or pressure control option. The greater the speed reduction, the greater the energy savings.
- Automatic control with hydro-pneumatic system: Operation of pumps to be controlled based on set point pressure and pumping demand.
- Proper sealing arrangement to arrest leakages from the pump casing.
- Use of energy efficient motors directly coupled with pump.

11.3 Benefits of technology

Major benefits of replacing the conventional pump with energy efficient pump are:

- Energy savings of 2-10%
- Increase in pump efficiency by 2-5%
- Longer life
- Less wear & tear
- Reduced operating and maintenance cost

11.4 Limitation of technology

Replacement of conventional pumps will not be economically feasible for very small pumping requirement.

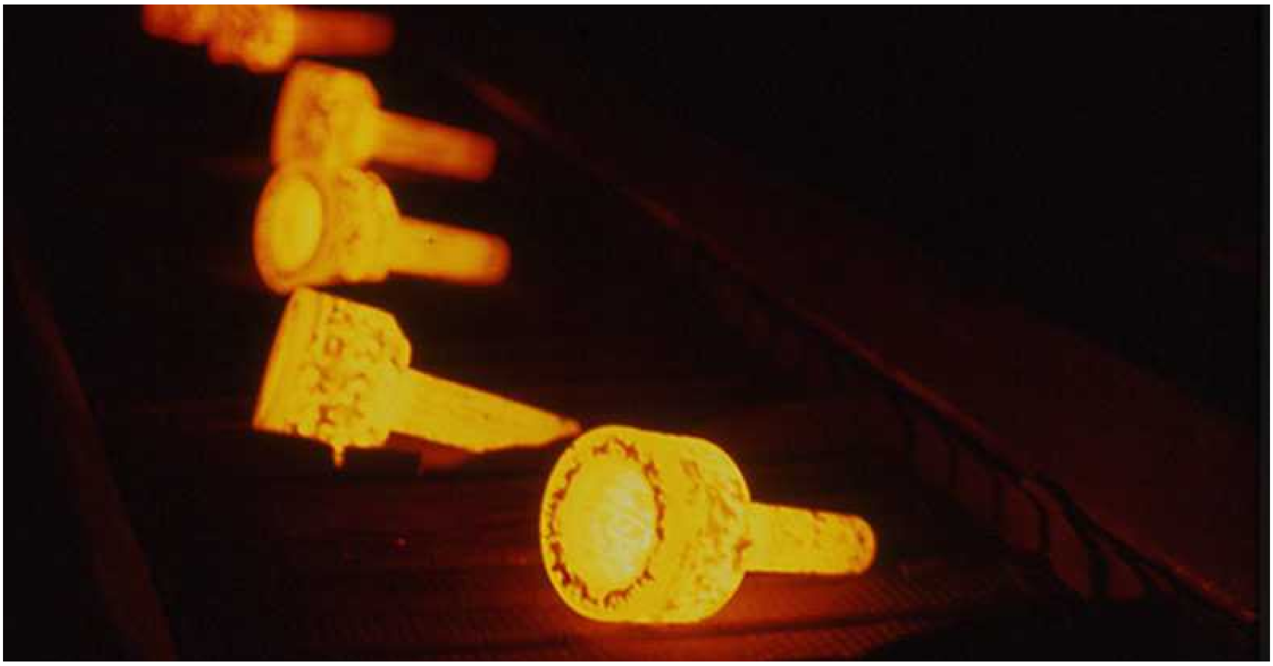
11.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

To understand the cost-benefit analysis, let us consider a pump with water flow of 26.07 l/sec with 43 m head.

Table 21: Energy & GHG emission saving and cost benefit analysis for sample calculation for energy-efficient pump

Sl. No.	Parameters	Unit	As Is	To be
1	Pipe thickness	m		0.004
2	Pipe diameter	m		0.121
3	Pipe Radius	m		0.057
4	Area	m^2		0.010
5	Velocity of water	m/s		2.60
6	Water flow	l/sec		26.07
7	Water flow	m^3/h		93.84
8	Total head	m		43
9	Fluid density	kg/m^3		1,000
10	Hydraulic power	kW		11
11	Power consumption of motor	kW		34
12	Motor efficiency	%		80
13	Power input to pump shaft	kW		27.5
14	Pump efficiency	%		40
15	Number of pump	Nos.	1	1
16	Power rating of pump	kW	37.3	22
17	Total energy consumption	kWh/y	245.3	158.40
20	Annual electricity savings	kWh/y	86.90	
21	Electricity charges	Rs/kWh	7.16	
22	Operating hours per day	h/d	24	
23	Number of operating days in a year	Nos.	300	
24	Annual monetary saving	Rs in Lakh/y	6.22	
25	Price of installing EE pumps	Rs in Lakh	3.20	
26	Simple payback period	y	0.6	
27	GHG reduction potential	tCO_2/y	67.78	

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



Case Study 10: Implementation of energy efficient pump

Integra Automation is a medium sector foundry unit located in Coimbatore region. Average monthly production of the unit is 1,000 MT. The plant installed an energy efficient multistage pump in place of an old centrifugal pump for circulating water to cool the induction coil of the furnace. Existing water pump for coil cooling had a pump efficiency of less than 60%; whereas energy efficient pump with IE3 motor led to a pump efficiency of 76.6%. Hence, coil cooling pump consumed lower power consumption than its earlier version.

Sl. No.	Parameter	Unit	Value
1	Energy Saving	kWh/y	33,120
2	Annual monetary saving	Rs in Lakh	2.48
3	Investment	Rs in Lakh	1.10
4	Simple Payback	y	0.45
5	Annual energy savings	toe/y	2.84
6	Annual GHG emission reduction	tCO_2/y	29.80

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

New EE Pump at Integra Automation

12 Technology No. 11: Energy Efficient Lightings

12.1 Baseline Scenario

Lighting accounts on average for about 15% of total electricity used in the units. Most of the conventional units use a variety of lighting fixtures like fluorescent tubes, incandescent & mercury vapour lamps, metal halide (MH) lamps, etc. in their offices and factory sheds. These conventional lighting fixtures consume a lot of energy. Also, lives of such fixtures are limited. Most of the units operate for whole day long and consume a significant portion of energy on account of lightings and fixtures. Also, due care is not given towards the lux level of different areas. Most of the units have sheds covered with asbestos sheet with negligible or no provisions for natural lightings.

12.2 Energy Efficient Technology

Recent developments in lighting technology combined with planned lighting control strategies can result in very significant cost savings, typically in the range of a third to a half of the electricity traditionally used for lighting. In new installations, energy efficient lighting costs little more to provide than the older less efficient kind. In retrofit situations, pay-back periods generally of between 1 and 5 years can be anticipated. Some of the important areas of energy conservation in a typical hand tool unit are:

- Replacement of conventional lighting with energy efficient LED lighting.
- Maximize the use of daylight to reduce the need for electric lighting. Roof lights are particularly efficient as they disperse light evenly over the whole floor area. Provision of natural lighting in the units using translucent sheets in the shed is suggested.
- Painting of surfaces (including the ceiling) with matt colours of high reflectance to maximize the effectiveness of the light output. Light/bright colours can reflect up to 80% of incident light; dark/deep colours can reflect less than 10% of incident light.

12.3 Benefits of technology

Major benefits of replacing conventional lighting with energy efficient lights are:

- Energy savings
- Longer life
- Reduced operating and maintenance cost

12.4 Limitation of technology

Replacement of conventional lights will attract high investment.

12.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

The following section provides the details of energy and GHG saving potential, investment required and cost benefit analysis for replacement of conventional lights with LED lightings for a typical forging unit.

Figure 20: Energy Efficient Industrial Lighting

Table 22: Energy & GHG saving and Cost Benefit Analysis of replacement of incandescent lighting with LED : lighting

SN	Particulars	Units	Baseline					After Implementation					Savings
1	Wattage	W	70	150	250	400	55	40	70	125	150	20	
2	No. of units of sodium vapour lights	No's	85	7	77	65		85	7	77	65		
3	No. of conventional lights						108					108	
4	Power consumption	W	5,950	1,050	19,250	26,000	5,940	3,400	490	9,625	9,750	2,160	32,765
5	Daily working hours	h/d	12	12	12	12	12	12	12	12	12	12	
6	Annual working days	d/y	365	365	365	365	365	365	365	365	365	365	
7	Energy consumption	kWh/y	26,061	4,600	84,315	113,880	26,017	14,892	2,146	42,158	42,705	9,461	143,511
8	Monetary cost	Rs/y	188,942	33,350	611,284	825,630	188,623	107,967	15,559	305,646	309,611	68,592	1,040,455
9	Investment @ Rs. 3000 per 40 W LED, Rs 5000 per 70 W LED, Rs 6000 per 125 W LED, Rs 7000 per 150 W LED and Rs 600 per 20 W LED for 10 hr per day for 365 days	Rs/y	1,271,800										
10	Simple payback period	months	14-15										
11	Annual energy saving	toe/y	12.43										
12	Annual GHG emission reduction	tCO_2/y	129										

**Emission factor of coal as per IPCC guidelines is 0.9 tCO_2/MWh for electricity from IPCC 2006 (V2;C1 and C2)*

13 Technology No. 12: Solar water heater in electroplating bath

13.1 Baseline Scenario

The forging and heat treatment furnaces are major energy consuming operations in a typical forging unit, accounting for 60–70% of the total energy consumption. There is a big opportunity for energy conservation through insulation and waste heat recovery. The heat treatment furnace is operated in batches, and used for heat treatment processes like normalization, annealing and tempering. Depending on the heat treatment process, the material is heated up to 940 ^{0}C and soaked at this temperature for few hours before it is cooled. Conventionally, heat treatment furnace walls are lined with fire bricks, which have poor insulating properties. These refractory linings lead to significant energy losses due to absorption of heat and radiation.

13.2 Energy Efficient Technology

It is proposed to make the water treatment plant operational, remove scaling deposits on the hot water pipelines by cleaning and ensure proper heat exchange by hot water generated by boiler to the various baths. Once the plant achieves a return hot water temperature of about 60^{0}C (or less) due to better heat exchange from the hot water to the baths, by removal of pipe scaling and making operational of the water treatment plant, a solar water heater (SWH) may be installed before the boiler to pre-heat the hot water from return temperature levels to about 70^{0}C. This preheated water can then be supplied to the boiler to further increase its temperature to desired levels and then send it to the electroplating baths. The implementation is a 3 days long period and involves the following:

Day 1: Surface preparation like removal of carbon and other impurities from the refractory lining and levelling the refractory surfaces.

Day 2: Pasting the veering module in the mortar above the refractory material which will stick to the refractory and act as a hot face insulation. The process requires a 24-hour drying time.

Day 3: The final process involves applying heat retardant coating on the surface to increase surface emissivity. The coating requires 12 hours to dry. Once dried, the furnace is ready to restart.

13.3 Benefits of technology

By adopting veneering in the heat treatment furnace, following benefits can be achieved:

- During cold start, time required to reach desired temperature is reduced by 50%.
- Reduction in fuel consumption by 30-40%.
- Reduction in fuel consumption per cycle by 8-10%.
- Reduction in surface temperature from 120 ^{0}C to 55 ^{0}C thereby reducing radiation loss.

13.4 Limitation of technology

The veneering modules need to be properly selected to ensure proper life of the modules.

13.5 Energy & GHG emission saving potential, Investment required & Cost benefits analysis

The following section provides the details of energy and GHG saving potential, investment required and cost-benefit analysis for veneering in 700 kg/hr heat treatment furnace.

Figure 21: Heat treatment furnace veneering process

Table 23: Energy & GHG emission saving and cost benefit analysis for veneering in forging furnace

S.No	Parmeters	UoM	Values	
			Baseline	Post Implementation
1	Heat treatment furnace capacity	t/h	0.7	0.7
2	Cold start annual	nos.	72	72
3	Operating days	d/y	200	200
4	Temperature on the surface	^0C	90	60
5	Ambient Temperature	^0C	35	35
6	Surface Area	m^2	95.0	95
7	Heat loss from the surface per m^2	$kcal/h/m^2$	701	281.25
8	Annual energy saving	kcal/y		63,840,000
9	Annual fuel saving	l/y		6,080
10	Annual monetary saving	Rs in lakh		2.13
11	Investment	Rs in lakh		1.00
12	Payback	y		0.5
13	Annual energy saving	toe		6
14	Annual GHG emission reduction	tCO_2		14

** Type of fuel : Furnace oil ; GCV: 10500 kCal/litre; Emission factor : 2.26 kg CO_2/kg fuel (As per IPCC guidelines 2006 (V2)*

Conslusion

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.

The eastern zone of the country, comprising the states of West Bengal and Jharkhand, houses close to 8% of the total forging units in the country. Some of the key clusters located in the eastern zone of the country that house forging units are Howrah in West Bengal and Jamshedpur in Jharkhand. The units in Jamshedpur mainly cater to the automotive sector mainly driven by Tata Motors; whereas the units in West Bengal cater to a variety of forging products. 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):

- Energy efficient metallic recuperator
- Energy efficient motors

Medium Investment Technologies (up to Rs 10 lakhs):

- Energy efficient FO fired forging furnace
- Energy efficient LPG fired forging furnace
- Special purpose machine
- Energy efficient compressed air network
- Veenering of heat treatment furnace
- Energy efficient lighting

High Investment Technologies (more than Rs 10 Lakhs):

- IGBT based electric induction heater
- Solar photovoltaic system for power generation
- Energy efficient screw compressor with VFD and PM motor
- Energy efficient pumps

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

Sl. No.	Name	Address	Contact person	Phone No.	Email id
		Technology : Furnace oil fired / LPG energy efficient reheating furnace			
1.	Icon Trading	39, Barrackpore Trunk Rd, CIT, Satchasi Para, Kolkata, West Bengal 700002	Mr. Iqbal Khan, Managing Director	+91-8048718691	
2.	Associated Industrial Furnaces (P) Ltd.	Block-3A, 4th Floor, Unit No. - 401C Hidco Action Area II, Newtown, Rajarhat, Kolkata 700160		+91-33-40300400	info@associated-furnaces.com
3.	Jay Crucibles	Makardah (Near Saraswat Library), Howrah, 711409, West Bengal		+91-9432225152	jaycrucibles@gmail.com
4.	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
5.	Refine Structure & Heatcontrol Unit	A 227, Guru Teg Bahadur Path, Nehru Nagar, PaniPech , Jaipur - 302016 , Rajasthan India	Mr. V.K. Sharma, Chief Executive	+91-9829060615	refinefurnace@gmail.com
6.	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
		Technology : IE 3 class efficiency energy efficient motor			
1	Gupta Electric Company	29,Ganesh Chandra Avenue, Kolkata - 700013		+91-9831047870 +91-9330839670	sguptaelectric@gmail.com
2	Al-Ameen Enterprises	61-59, Netaji Subhas Rd, Fairley Place, B.B.D. Bagh, Kolkata, West Bengal 700001	Mr. Mohammad Rangwala, Partner	+91-8048719218	
3	Bharat Bijlee	Electric Mansion 6th Floor Appasaheb Marathe Marg, Prabhadevi Mumbai 400 025		+91 22 2430 6237 / 6071	info@bharatbijlee.com
4	Cromptom Greaves	Church Road, PO BOX 173 Jaipur 302 001, Rajasthan, India	Mr. Sunil Dutt, Proprietor	+91 141 3018800 /01	sunil.dutt@cgglobal.com
5	Siemens Limited	Birla Aurora, Level 21, Plot No. 1080, Dr. Annie Besant Road, Worli, Mumbai – 400030 India		1800 209 1800	
		Technology : Special Purpose Machine			
1	PMT Machine	B - 165/I, Kailash Nagar, Behind, Cancer Hospital Rd, Sherpur, Ludhiana, Punjab 141009		+919814020118	
2	Gahir Industries	Near Eastman Chowk, Industrial Area-C, Dhandari Kalan, Ludhiana-141003.(Pb.)		+91-98725-53000	spm@gahirindustries.com
3	Harkaram Industries	Plot No. 10320, St. No. 2, Gatta Mill, Bhagwan Chowk, Industrial Area - B Ludhiana- 141003, Pb	Mr. Inderveer Singh Mankoo, Proprietor	+91 9815143513 , +91 9316917985	info@harkaramindustries.com

Sl. No.	Name	Address	Contact person	Phone No.	Email id
		Technology : Solar PV System			
1	Mas Solar System Pvt. Limited	153, SIDCO Industrial Estate Malumichampatti Post, Coimbatore Tamil Nadu, INDIA - 641050		+91 9585556502 / 9585556504	marketing@ massolarsystems.com
2	Dev International	15,Doctor Thottam, Kalapatti - Kurumbapalayam Road, Coimbatore - 641 048.		+91 887 044 5566, +91 984 317 9797	dev@devsolar.com
3	Aadhi Solar	2-C/2, Kumaran Nagar, Opp VKR Kalyana Mandapam, Vilakuruchi Post, Coimbatore 641035		+91-9378133000	sales@aadhisolar.com
4	Sun Shell Power	DLF Galleria , Office No: 714 , 7th Floor Premises No 02-0124, Action Area 1B, Newtown, Kolkata, West Bengal 700156		033-40068535	info@sunshellpower. com
5	Modern Solar Private Limited	2/5, Sarat Bose Road, Sukhsagar, Building- 2 , Floor- 2, Kolkata 700 020		+91 903 805 1230	info@modernsolar.in
6	Wolta Power System	B-91, 1st Floor, Sector 64, Noida - 201301, Uttar Pradesh, India	Mr. Amit Singh, CEO	+91-9266533533	info@ woltapowersystem. com
7	Solar Maxx	III Floor, Krishna Square, Subhash Nagar, Jaipur 302016, Rajasthan, India		+91-141-400 9995,	info@solarmaxx.co.in
		Technology : Metallic Recuperator			
1	Eastern Equipment Pvt. Ltd.	12, Pretoria Street, Kolkata - 700071, India	Mr. Vikash Agarwal	+91 33 22900187	
2	Entech Furnace	Plot No. 186, Sector-24 Faridabad, Haryana (India)	Mr. Vinay Agnihotri	(+91-9810005354)	info@entecfurnaces. com
3	En Eff Thermal Engineers	536/25c/1a, Industrial Area-C, Sua road, Dhandari Kalan, Ludhiana, Punjab, 141010, India	Mr. Captain Singh (GM)		
4	AAB Heat Exchanger Pvt. Ltd.	Plot No. 375, Sector-24, Faridabad-121005	Mr. Amitoj Singh (Director)	08048719066	
		Technology : Energy Efficient (EE) Pump			
1	Grundfos Pumps India Pvt. Ltd.	Mangalam Chambers, Block- A, 3rd Floor, Room No.- 303, 24/26, Hemanta Basu Surani, Kolkata 700001		1800-102-2535	
2	Shakti Pumps Pvt. Ltd.	Plot No. 401, 402, & 413, Industrial Area Sector - 3, Pithampur, Dist. Dhar - 454774 (M.P.) India		+91 7292410500	
3	S GroEnterprize	Shop No. 18-19, Guru Nanak Market, Near Vishvkarma Chowk, Miller Ganj, Ludhiana-141003, Punjab, India	Mr. Malkiat Singh	+91-8048606530	
4	Vijay Laxmi Products	B-15/7, G.T. Road, Miller Ganj, Near Dukh Nivaran Gurudwara, Ludhiana-141003, Punjab, India	Mr. Ashish Dhiman	+91-8045337560	

For more details, please contact

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre
P.O. Box 300 · 1400
Vienna · Austria
Tel.: (+43-1) 26026-O
ENE@unido.org
www.unido.org

UNIDO
Regional Office in India
UN House
55, Lodi Estate
New Delhi - 110 003, India
office.india@unido.org

Bureau of Energy Efficiency
Government of India, Ministry of Power

4th Floor, Sewa Bhawan,
R. K. Puram,
New Delhi- 110 066, India
Tel: (+91) 011 2617 9699-O
gubpmu@beenet.in
www.beeindia.gov.in