UNITED NATIONS
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Technology Compendium for

Energy Efficiency and Renewable Energy Technologies in

Ludhiana Hand-tool Cluster

March 2022

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Disclaimer

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

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

Energy Efficiency and Renewable Energy Technologies in Ludhiana Hand-tool Cluster

March 2022

Developed under the assignment

Scaling up and expanding of project activities in MSME clusters

Prepared by

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DESL Team

Contents

List of Abbreviations

BEE	Bureau of Energy Efficiency
CIHT	Central Institute of Hand Tools
DESL	Development Environergy Services Limited, New Delhi, India
EE	Energy Efficiency
EET	Energy Efficient Technologies
GEF	Global Environment Facility
JCIC	Ludhiana Chamber of Industries and Commerce
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
PSEB	Punjab State Electricity Board
PSIDC	Punjab State Industrial Development Corporation
PV	Photovoltaic
RE	Renewable energy
SPM	Special Purpose Machine
UNIDO	United Nations Industrial Development Organization

Unit of Measurement

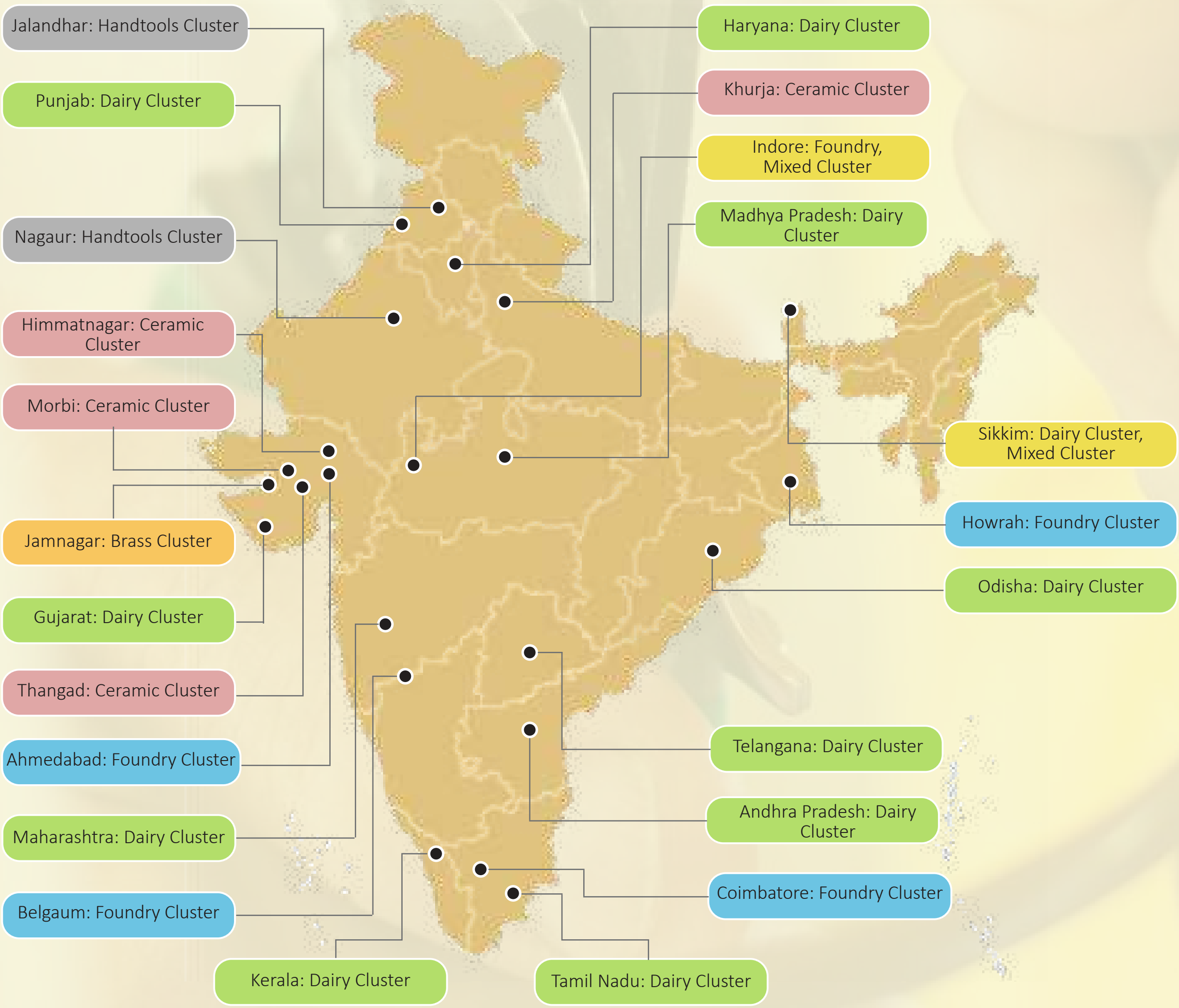
Parameters	UOM	Parameters	UOM
Ampere	A	Liter(s)	l
Approximate	~	Liter per kilogram	l/kg
Centimeter	cm	Mega Joule	MJ
Centimeter Square	cm^2	Mega Volt Ampere	MVA
Cubic Centimeter	cm^3	Mega Watt Hour per Day	MWh/d
Cubic Feet per Minute	CFM	Meter	m
Cubic meter	m^3	Meter cube	m^3
Cubic meter per day	m^3/d	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 resulted in reduction of about 10,850 TOE of energy consumption and avoided 62,868 metric tons of CO_2 emissions as on date. The key components of the project include:

- Increasing capacity of suppliers of EE/RE product suppliers / service providers / finance providers
- Increasing the level of end user demand and implementation of EE and RE technologies and practices by MSMEs.
- Scaling up of the project to more clusters across India.
- Strengthening policy, institutional and decision-making frameworks.



Clusters intervened by the project

About the Technology Compendium

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

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

- The compendium will act as a ready reckoner to the MSME units for continuously improving their energy performance leading to a cost-effective and sustainable production process.
- In the wide spectrum of technologies and equipment applicable for the sectors for energy efficiency, it is difficult to include all the energy conservation aspects in this manual. However, an attempt has been made to include more common implementable technologies across sector.
- 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 up gradation' options.
- The technologies collated in the compendium may not necessarily be the ultimate solution as the energy efficiency through technology up gradation 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 Ludhiana Cluster is a prominent Hand-Tool cluster in India, which consists of a large number of micro, small and medium enterprises (MSME) units involved in the production of forged hand-tools hammers, auto parts, agricultural equipments hand-saws, screw-drivers, wrenches, chisels, scrapers, wire-strippers, hand drills, pliers, vises, spanners, files, etc. The cluster came into existence around the time of Indian independence in 1947, when skilled labourers settled there and started manufacturing hand tools. Subsequently, the government of Punjab through Punjab State Industrial Development Corporation (PSIDC) set up an industrial estate on the outskirts of Ludhiana city which is today a hub of hand tools.

A substantial quantity of hand tools production is exported to countries like USA, UK, Germany, Italy, Australia and Russia. The cluster has an important role in hand tool sector revolution in terms of quality and reputation in the domestic and international market. The units are in operation since independence with very primitive technology used for production. The units are highly energy intensive with energy playing a significant role in the overall production cost. Significant potential for savings exists in the cluster through adoption of energy efficient and renewable energy technologies. The adoption of these technologies can make the units more cost competitive and sustainable.

The United Nations Industrial Development Organization (UNIDO) is playing a pivotal role jointly with the Bureau of Energy Efficiency (BEE), Ministry of Power, and Government of India towards scaling up the penetration of low-cost energy efficient technologies (EETs) in the Ludhiana Hand-tool Cluster. A total of 20 MSME Hand-tool industries in the cluster are envisaged to be supported technically to become energy efficient and cost competitive.

The extensive research and ground level deployment of various teams has made it possible to consolidate list of energy efficient and renewable energy technologies applicable for the Ludhiana Hand-tool cluster. While most of these technologies have proven implementation record, some of the technologies are still in the developmental stage and will require efforts for implementation.

The compendium for energy efficient and renewable energy technologies has been compiled and consolidated, keeping in mind different types and capacities of the hand-tool unit. This compendium can be used as a single point information booklet for various economically viable energy efficient and renewable energy technologies applicable in the cluster. Each technology has been 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 been also 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 unit. 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 Ludhiana hand tool cluster has significant potential in terms of energy saving. 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 Ludhiana Hand Tool Cluster

Category	Description	Technology	Investment (Rs in Lakhs)	Saving Potential (Rs in Lakhs)	Simple Pay-back (Rs in Lakhs)
A	Low Investment Technologies (up to Rs 2 lakhs)	Installation of Solar Water Heater	1.3-2	0.7-1	<2 years
		Replacement of conventional motors with energy efficient (IE 3 class efficiency) motors	1.3-2	1.1-1.8	<1.5 years
		Installation of metallic recuperator	0.6-1	0.7-1.3	< 1 year
		Installation of EE pumps	1-2	0.75-1	< 2 years
B	Medium Investment Technologies (up to Rs 10 lakhs)	Installation of energy efficient FO fired forging furnace	4-6	2-4	< 2 years
		Installation of special purpose machine	2 -5	1-4	<1.5 years
		Installation of screw compressor	5-10	2.5-4	<3 years
C	High Investment Technologies (more than Rs 10 lakhs)	Installation of solar PV system	70-80	15-20	< 4 years
		Installation of IGBT based induction heater	11-15	5-8	<2.5 years

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

About the Cluster 1

1.1 Cluster overview

Ludhiana district is located between latitude 30°54'0" North 75°34'12" East. From is position in Punjab, it shares its borders in North with Jalandhar, in South with Sangrur & Fatehgarh, in east with RupNagar, and in west with Moga district. The district has a geographical area of 3767 square kilometers, representing 7.5 percent of the total area of Punjab.

Figure 1: Map of Ludhiana

Ludhiana is an important hand tools cluster in India. A wide range of hand tools are manufactured in the cluster. There are over 250 units manufacturing hand tools in the cluster.

The turnover of the cluster is around Rs 750 crore (Rs 7500 million). Most of the units manufacture an array of hand tools like spanners, screw drivers, pliers, bench vices, tyre levers and hammers and so on. A medium scale unit produces around 50-70 tons of materials per month. The production of the unit depends upon the number of hammers installed in the unit. The production of the clusters is presently affected because of frequent power cuts, ranging from 4-6 hours a day. There are many of industry associations in the cluster, i.e. Ludhiana Hand Tools Manufacturers Association, Hand Tool manufacturers association, Fasteners Manufacturers association & Auto Parts Manuacturers Association).

These associations play an important role in taking up issues pertaining to the industry with the government. In addition, the Central Institute of Hand Tools (CIHT) set up by Government of India with the assistance of UNDP and Government of Punjab in Ludhiana has played a pivotal role in the development of hand tools industry in the cluster. The institute offers various services to the industry in the area of

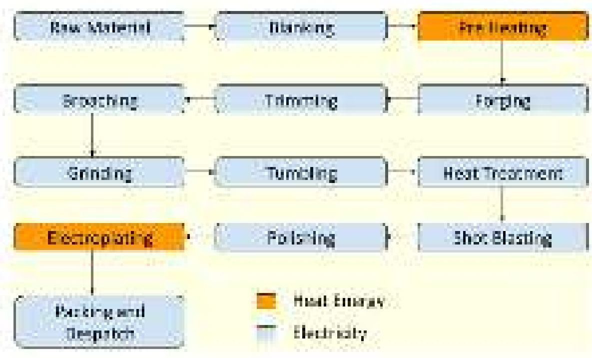


Figure 2: Hand-tool process

design and manufacture of various tools and improvement of the manufacturing processes. The institute is equipped with CNC machines, heat treatment shop and forging shop.

1.2 Manufacturing Process

The hand-tool industries in the cluster are mainly involved in production of spanners, screw drivers, pliers, bench vices, tyre levers and hammers. The units' sources alloy steel from the market which is forged and machined to give desired shapes and sizes of the hand-tools. The forging furnace, the hammer power press, electroplating 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 below:

From process point of view, forging furnace is the major energy consuming equipment followed by annealing furnace and forging hammer. Induction motors are used for providing motive power to common shaft, shearing machines, press machines, air compressors, etc. However, in the case of finishing units, major processes include grinding, tumbling, heat treatment, shot blasting and polishing. Herein, major energy consuming equipment is motors, which are used for driving common shaft for machines and electroplating units.

1.3 Technology status and energy use

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

Typically, the specific electricity consumption in the units varies between 1,900 to 2,225 kWh/ton (0.163 to 0.191 toe/ton); the specific oil consumption in the forging furnaces varies between 139 to 179 Liter/ton (0.139 to 0.179 toe/ton);

Figure 3: Hand-tool process

and the specific oil consumption of heat treatment furnaces is about 120 Liter/ton (0.120 toe/ton) on an average. Hence, the final energy intensity in the cluster varies between 0.303 and 0.487 GJ/ton. (Source: www.sameeeksha.org)

The forging furnace consumes about 80% of the oil consumption of a typical unit. The oil-fired forging furnaces used in the cluster are of outmoded designs leading to very high fuel consumption. Nowadays, natural gas is available in the cluster. Redesigning and changeover from the oil-fired conventional forging furnaces to gas-fired energy efficient furnaces would lead to substantial energy saving. 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. In the case of electroplating, to fulfill the hot water requirement, units are using hot water generated from oil/wood fired boiler, which may be replaced by solar water heater. Most of the units are equipped with very old and rewound induction motors which are consuming very high electricity, maybe a matter of consideration as per as energy efficiency is concerned.

Table: Cost of energy in Ludhiana Hand Tool Cluster

S.No.	Industrial Power Supply	Category	Fixed Charges per Month	Energy Charges
1	Small	Upto 20 kVA	80/kVA	5.37/kVAh
2	Medium	Above 20 kVA & upto 100 kVA	120/kVA	5.80/kVAh
3	Large			
	General Industry	Above 100 kVA & upto 1000 kVA	165/kVA	5.98/kVAh
		Above 1000 kVA & upto 2500 kVA	225/kVA	6.08/kVAh
		Above 2500 kVA	260/kVA	6.19/kVAh
	PIU Industry	Above 100 kVA & upto 1000 kVA	170/kVA	6.02/kVAh
		Above 1000 kVA & upto 2500 kVA	260/kVA	6.33/kVAh
		Above 2500 kVA	295/kVA	
4	For use of electricity exclusively during night hours applicable for industrial consumers (Large Supply/Medium Supply/Small Power)		50% of Fixed Charges specified under relevant category	4.83/kVAh
5	Coke(8-15% Ash)			25-35 INR
6	Coke(26-32% Ash)			14-38 INR
7	Diesel(for DG)			100 INR

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

2

2.1 Baseline Scenario

A re-heating furnace commonly known as 'forging' furnace forms the heart of the hand-tool industries, consuming the majority of the plant's energy. The forging furnace is used to heat the raw material (MS blanked piece) to the required forging temperature before being transferred to the hammer press. The Ludhiana hand-tool cluster consists mostly of continuous type furnace oil fired forging furnaces (a few units also have LPG fired forging furnaces), which are locally made of fire bricks covered with steel sheet. The insulation used in the furnaces is ok in most units (for bigger size furnaces that heat whole metal piece) as the skin temperatures range from 50 to 60°C on side walls, roof, etc. But in case of smaller sized furnaces, which heats only part of the metal, (remaining part of metal is outside the furnace heating zones) insulation is very poor as surface temperatures are in the range of 130-140°C.

Monitoring and control systems are mostly not-available for the furnace operation (for FO fired furnaces), although a few units have installed thermo-couples for display of furnace internal temperature. The forging furnace comprises a brick chamber with an opening in the front side 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. The forging furnace in the cluster is 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 material discharge window (usually at sides of furnace) and the front opening for raw material charging. These furnaces are operated manually with no provision for waste heat recovery (one unit had installed recuperator for pre-heating combustion air from ambient temperature to about 105-120°C. 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 overall thermal efficiencies of these furnaces are extremely low ranging from 8 to 12 percent (less than 5% for smaller sized FO fired furnaces). The capacity of the forging furnace at Ludhiana hand-tool cluster varies in between 40 to 120 kilogram per hour with specific fuel consumption ranging from 0.13 to 0.38 liters of furnace oil per kilogram of product. The daily production per FO fired forging furnace ranges from 500 to 1,200 kilograms of products per day.

Various options including use of waste heat recovery systems for preheating combustion air, better insulation, reducing the radiation loss from furnace openings, temperature control systems, and excess air control systems, use of appropriate burner system to improve the combustion efficiency and monitoring and control system for optimum performance can lead to improvement in the efficiency of the furnace significantly.

Figure 3: Conventional furnace oil fired forging furnace in Ludhiana hand-tool cluster

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:

Reducing furnace opening - Covering raw material feeding door with flexible insulated gate: In the existing furnaces, the raw material is fed to the furnace from the front side. The door area from where the raw material is fed is much larger than the material sizes. The material feeding side opening sizes are larger, as the raw material sizes vary with batch and some amount of clearance is provided for smooth travel of material into the furnace. It was observed that at least 30-40% of the door area can be covered with insulated flexible gates which will considerably reduce the radiation losses from the feeding side. The raw material feeding door and the material exit window can also be kept fully covered when raw material is not being fed and when not required during breaks (lunch, etc).

Waste heat recovery: The energy efficient furnace will be equipped with a heat exchanger (recuperator) 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.

Temperature monitoring and excess air control system: The furnace is to be equipped with thermocouples to monitor the furnace temperature. A PID based control system to be introduced to

Table 2: Details of conventional forging furnace in Ludhiana hand tool units

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
UoM	t/y	kg/ d	%	l/kg	h/d	d/y
	160-300	300-1,500	8-12	0.13-0.38	10-22	300

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

The replacement of conventional furnace with energy efficient furnace will lead to the following benefits:

- Improved combustion leading to lesser specific fuel consumption
- Reduced furnace start-up time up to 30%
- Increased productivity
- Improved working conditions
- Reduced burning loss up to 30%

2.4 Limitation of technology

The reheating 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 220 tons per year, operating for 10 hours per day and 312 days per year. The cost benefit analysis for adoption of the technology has been tabulated below (Table 3):

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

Table 3: Energy & GHG emission saving potential, investment required & cost benefit analysis of energy efficient forging furnace

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Productivity	kg/ h	70	70
2	Operating hours per day	h/d	12	12
3	Operating days per year	d/y	300	300
4	Fuel consumption	l/h	7.29	5.77
5	GCV	kcal/kg	10,500	10,500
6	Density of furnace oil	kg/l	0.96	0.96
7	Raw material input temperature	^0C	35	35
8	Product final temperature	^0C	1,250	1,100
9	Specific heat of EN8 Cast Steel	kcal/kg K	0.117	0.117
10	Furnace Direct Efficiency	%	13.54	15
11	Specific fuel consumption	l/kg	0.104	0.082
12	Annual fuel consumption	l/y	26,250	20,768
13	Annual fuel saving	l/y		5,482
14	Furnace oil cost	Rs/l		42.00
15	Annual Monetary Saving	Rs in lakhs		2.30
16	Investment	B Rs in lakhs		7.00
17	Simple Payback	Y		3.04
18	Annual energy saving	toe/y		5.53
19	Annual GHG emission reduction	tCO_2/y		11.95

**Emission Factor of furnace oil=2.26984 kgCO2/kg fuel IPCC 2006 (V2; C1 and C2)*

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
	70-120	4-6	2-4	< 2 years

Case Study 1: Energy Efficient Forging Furnace

M K Forgings, Jalandhar majorly manufactures a range of Hand Tools including Pliers & Spanners and was using a Furnace Oil fired furnace (capacity-150kg/h) for its forging operations with a specific fuel consumption of 135 litres/ton. The furnace also led to high-scale formation. The average production from the furnace was around 1.2 Ton.

Forging furnaces is the key thermal energy consuming area in a Hand tool unit. The forging furnace in the cluster is 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. The project envisaged energy and cost saving by installing Energy Efficient (EE) furnace oil fired forging furnace with optimised design.The unit has installed a new refractory lined furnace oil fired forging furnace as a replacement to their existing Furnace Oil fired forging furnace.

Sl. No.	Parameter	UoM	Values	
			Baseline	Post Implementation
1	Annual operating days	d/y	300	300
2	Average production per day	kg	1200	1200
3	Annual production	kg/y	360000	360000
4	Specific FO consumption	kg/ton	135	113.0
5	Annual FO consumption	kg/y	48600	40680
6	FO fuel cost (including taxes)	Rs/kg	43	43
7	Annual FO cost	Rs Lakh/y	20.9	17.5
8	Annual Fuel cost saving	Rs Lakh/y		3.4
9	Investment cost for EE FO furnace	Rs Lakh		3.5
10	Simple payback period	Y		1.03
11	CO2 emission for FO oil	t/t	2.27	2.27
12	GCV of FO	kcal/kg	10500	10500
13	GCV of FO	kcal/kg		10500
14	Annual Energy Saving	TOE/y		8.3
15	Annual GHG Emission Reduction	tCO2/y		18.0

**Emission factor of LDO , FO & LPG taken as 3.0705 kgCO2/kg, 2.27 kgCO2/kg and 2.98 kgCO2/kg of fuel as per IPCC guideline 2006 (V2; C1 and C2)*

Technology 2: Replacement of Existing Motors with IE 3 Class Energy Efficient Motors

3

3.1 Baseline Scenario

After the raw material is heated to the forging temperature, the same is transferred to the power hammer p ress, 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 hand- tool 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 hand-tool 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 damaged bearings leads to rise in motor winding temperature ultimately leading to failure. These electrical failure leads to the next obvious step, i.e. motor re-winding. The motor efficiency further decreases with each re-winding campaign mostly because it is carried out by unskilled workers. Normally, a unit carries out 7-8 times of motor rewinding within its life span of 10 years.

3.2 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 using improved lubricating system And high quality bearings. Wind age loss is reduced by Using energy efficient fans

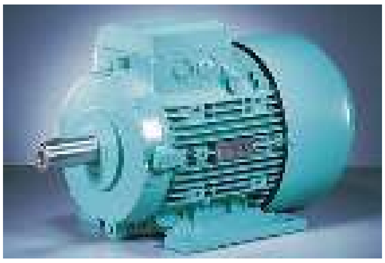


Figure 4: Energy efficient motor

- 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.

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 5: 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

Table 4: Details of motor in Ludhiana hand tool cluster

Parameters	Annual capacity	Rated motor power	Motor Efficiency	Rewinding	Hours of operation	Days of operation
UoM	t/y	Hp	%	Nos.	h/d	d/y
	160-600	1-50	75-88	4-7	8-12	312

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):

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

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	73.1	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	160L	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 5: Motor efficiency values as per IEC 60034-30

3.2 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.

3.3 Limitation of technology

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

3.4 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 3,600 hours per year. The cost benefit analysis for adoption of the technology has been tabulated below:

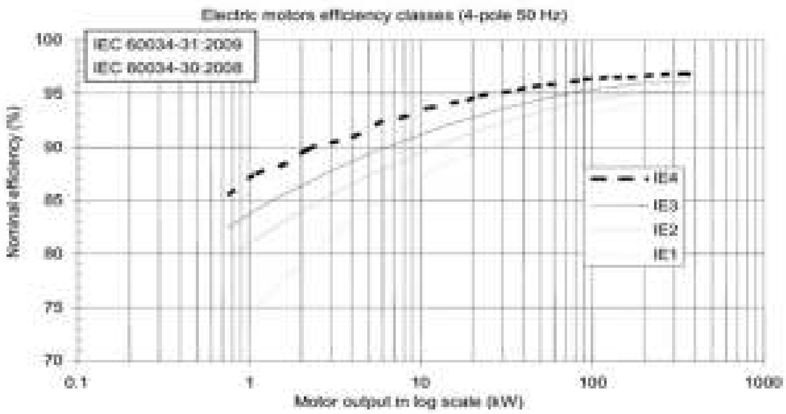


Figure 6: IE efficiency classes for 4 pole motors at 50 Hz

Table 6: 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 tCO2/MWh from IPCC 2006 (V2;C1 and C2)*

Case Study 2: Installation of Energy Efficient Motors

In Kaysons International, Jalandhar there were 36 numbers (2.2 kWX 6 nos., 3.7 kW X 18 nos.,5.5 kW X 4 nos.,7.5 kW X 7 nos., 37 kW X 6 nos.) of inefficient motors, total cumulative power is 222 kW of inefficient motors.

Decreased motor efficiency is due to reasons that include voltage fluctuations, improper lubrication and damaged bearings that may lead to rise in motor winding temperature, and ultimately leading to failure. These electrical failures lead to the next obvious step, i.e. motor rewinding. Normally, a unit carries out 7-8 times of motor rewinding within its life span of 10 years. Each rewinding campaign leads to an efficiency drop by 1-2%. Jalandhar hand tools cluster using conventional motors that were operating at 75% of operational efficiency.

The unit has installed 36 Nos. of IE3 motors under NMRP in place of conventional motors.

Sl. No.	Parameter	UoM	Values	
			Baseline	Post Implementation
1	Total Number of motors	No.	36	36
2	Cumulative Rated Capacity	kW	222	222
3	Average Efficiency of motor	%	73.8%	88.6%
4	Cumulative Input Power	kW	150.4	125.3
5	Estimated energy saving	kWh/y	105522	
6	GCV of electricity	kcal/kWh	860	860
7	Energy Cost	Rs/kWh	8	8
8	Monetary Savings	Rs in lakhs/ Y	8.44	
9	Investment	Rs in lakhs	9.90	
10	Simple Payback	Y	1.2	
11	Annual Energy Saving	TOE/y	9.07	
12	Annual GHG Emission Reduction	tCO2/y	94.97	

**Emission factor of electricity as 0.90 kgCO2/kWh as per IPCC guideline 2006 (V2; C1 and C2)*

4 Technology 3: Replacement of conventional machine with special purpose machine

4.1 Baseline Scenario

The hand-tool units at Ludhiana use manually operated conventional machines for various machining job work like facing, turning, grinding, drilling, etc. These machine 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 machine operates 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 machine 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 operation 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 7: A conventional drilling machine

4.2 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.\ 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.

Figure 8: A special purpose drilling machine

Table 7: Details of conventional machines in Ludhiana hand tool cluster

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
	160-600	1-5	5-10	1,200-1,800	8-12	312

4.3 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

4.4 Limitations of technology

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

4.5 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 3,120 hours per year. The cost benefit analysis for adoption of the

Table 8: : 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)*

Table 9: Investment, savings and simple pay back for special purpose machines

Parameters	No. of pieces to be processed	Investment	Annual monetary savings	Simple payback
Units	Pcs/d	Rs in Lakhs	Rs in Lakhs	Y
	1,200-2,400	2-5	1-4	$<$ 1.5 years

Case Study 3: Replacement Of Conventional Lathe Machine With Special Purpose Machine

Anant Tools, Jalandhar was using conventional lathe machines to perform various operations such as cutting,sanding, knurling,drilling to the workpiece to create an object. It takes more energy, time and manpower to complete the operation. Special Purpose Machines offer tremendous scope for high volume production at low investment and at low cost of production when compared to CNC machines. SPM, Special Purpose Machines is a high productivity machine, with specially designed tooling and fixture, dedicated for mass producing the same component day in and day out

The unit installed one drilling and tapping special purpose machine & the company was able to save substantially in terms of energy cost.

Sl. No.	Parameter	UoM	Values	
			Baseline	Post Implementation
1	Number of SPM with EE motor	#	2	1
2	Rated capacity of motor	kW	1	1
3	Measured power	kW	1.99	1.0
4	Annual electricity saving	kWh/y	2978	
5	Extra Available hours for production (1 machines)	h/y	600	
6	Punching pieces	pieces/h	60.0	
7	Per piece punching cost	Rs./piece	1	
8	Electricity tariff	Rs/kWh	8	
9	Annual monetary saving	Rs Lakh/y	0.59827	
10	Estimated investment	Rs Lakh/y	0.60000	
11	Payback	years	1.0	
12	GCV of electricity	kcal/kWh	860	
13	Energy saving	TOE/y	0.26	
14	Total emission reduction	t/t	2.47	

**Emission factor of Electricity taken as 0.9 tCO2/MWh as per IPCC guideline 2006 (V2; C1 and C2)*

Technology No. 4: Optimization of Compressed Air Distribution Network

5

5.1 Baseline Scenario

Compressed air is one of the major utilities of hand tool units in Ludhiana, 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 / cm² 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 are one of the major energy losses in the compressed air system as these result 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.

5.2 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 / cm²). 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 build 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.

5.3 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

5.4 Limitations of technology

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

Table 10: Compressor details for Ludhiana hand tool cluster

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

5.5 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 / cm2 and unloads at 8.2 kg/cm2. The unit operates 3,130 hours per year. The cost benefit analysis for adoption of the technology has been tabulated below:

Table 11: 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
Presenttotalpowerconsumptionbyboththeparallelrunningcompressors	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 12: Investment, savings and simple payback for compressed 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 3: Efficient Compressed Air Distribution System

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 certifications 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:

1. No corrosion, hence no rust in air flow.
2. Smooth interior allowed laminar flow.
3. The pipes are lightweight, hence easy to transport and fit.
4. Cutting is far easier than metal pipes.
5. 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.

Parameters	UoM	Values	
		Baseline	Post Implementation
Existing Compressor Type		Reciprocating/Screw	Reciprocating /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 tCO2/MWh*
***Source: Energy audit carried out by DESL*

Technology No. 5: Installation of Solar Photovoltaic System for Power Generation

6

6.1 Baseline Scenario

Electricity is the key component of the total production in a hand-tool industry. The connected load in individual units varies from 9 kW to 45 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.

6.2 Energy efficient technology

Power generation using solar energy through 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 photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to convert the output from direct to alternating current, as well as mounting, cabling, and other electrical accessories to set up a working system. It may also use a solar tracking system to improve the system's overall performance and include an integrated battery solution.

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tons 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 industries at Ludhiana 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.

Figure 21 : Solar PV installation

The average solar irradiance for Ludhiana is 5.23 kWh/mtr²/day. The solar radiation graph for Ludhiana has been shown in the figure below:

6.3 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

6.4 Limitation of technology

Adoption of solar photovoltaic needs high capital investment. Generation of dust in the industrial area causes hindrance on the efficiency of the photovoltaic system.Installation of solar PV system in roof top requires the structural strength, which needs to be analysed as per site conditions.

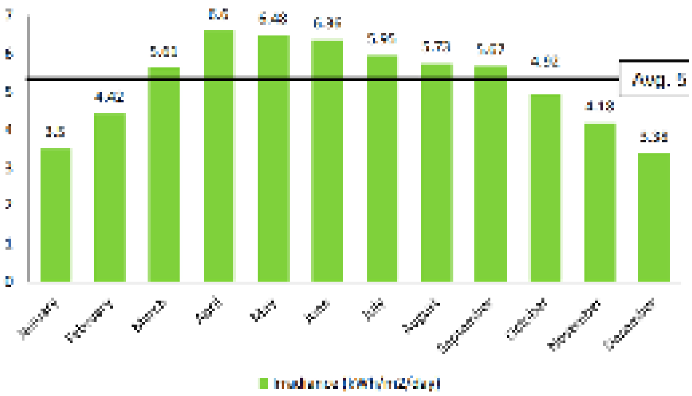


Figure 22: Solar radiation intensity for Ludhiana, Punjab

6.5 Energy & GHG emission saving potential, Investment required & cost benefits analysis

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

The investment required, energy savings and simple payback for different capacity range of solar PV system are tabulated below:

Table 14: Investment, savings and simple pay back for special purpose machines

Parameters	Capacity of Solar PV system	Investment	Annual monetary savings	Simple payback
Units	kWp	Rs in Lakhs	Rs in Lakhs	y
	200	70-80	15-20	< 4 years

Table 13: Energy & GHG emission saving potential, Investment required &cost benefit 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 4: Installation of Solar PV system

PYN For Ajay Industries ,Jalandhar, Grid electricity was the main energy input. The contract demand is 712 kVA and the annual energy consumption is 2,247,777 kVAh/y. The grid unit cost varies from Rs 7/kWh to Rs 8/kWh. The unit has installed 106 kW solar PV for electricity generation. This resulted in electricity and monetary savings. Photovoltaic (PV) effect is the conversion of sunlight energy into electricity. In a PV system, the PV cells exercise this effect. Semi-conducting materials in the PV cell are doped to form P-N structure as an internal electric field. The p-type (positive) silicon has the tendency to give up electrons and acquire holes while the n-type (negative) silicon accepts electrons. When sunlight hits the cell, the photons in light excite some of the electrons in the semiconductors to become electron-hole (negative-positive) pairs. Since there is an internal electric field, these pairs are induced to separate. As a consequence, the electrons move to the negative electrode while the holes move to the positive electrode. A conducting wire connects the negative electrode, the load, and the positive electrode in series to form a circuit. As a result, an electric current is generated to supply the external load. This is how the PV effect works in a solar cell.

S.No.	Parameter	UoM	Values	
			Baseline	Posts Implementation
1	Source of Power		Grid Power	Solar PV
2	Supply voltage	kV	11	11
3	Contract demand	kVA	712	712
4	Installed Solar PV Capacity	kW	0	106
5	Annual Energy Consumption	kVAH/y	2,247,777	2,247,777
6	Annual Power Generation through Solar	kWh/y	0	134,640
7	Annual Power Generation through Solar	kVAH/y	0	137,388
8	Annual Energy Consumption (Grid Power)		2,247,777	2,110,389
9	Cost of Power (excluding demand charges)	Rs./ kVAH	5.8	5.80
10	Annual Cost of Energy	Rs in Lakhs/y	130.4	122.40
11	Annual Monetary Savings	Rs in Lakhs/y		7.97
12	Investment Required @	Rs in Lakhs		42.0
13	Accelerated Depreciation @ 40% (in the 1st year)	Rs in Lakhs		16.8
14	Tax Savings through Accelerated Deprecation @ 30% (in the 1st year)	Rs in Lakhs		5.04
15	Net Cost of Solar PV Plant	Rs in Lakhs		36.94
16	Payback Period	y		4.6
17	Emission Reduction	$tCO2/y$		121.2
18	Energy generation	TOE/y		11.58

**Emission factor of Electricity taken as 0.9 tCO2/MWh as per IPCC guideline 2006 (V2; C1 and C2)*

Technology No. 6: Installation of High Efficiency Metallic Recuperator

7

7.1 Baseline scenario

At present, forging units in Ludhiana 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 are as low as 9-12%. Waste flue gas loss accounts for upto 70% of the total heat loss in the furnace. The walls of the forging furnaces stores a considerable amount of heat which can be reused for combustion air preheating. The flue gas temperature in such furnaces can range somewhere between 350-400^{0}C. A significant portion of this can be reused to achieve a considerable fuel saving.

7.2 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.

7.3 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.

7.4 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.

7.5 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 70 kg capacity having exhaust flue gas temperature of 340 ^{0}C is considered:

Table 15: 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	^{0}C	340	157
4	Combustion air temperature	^{0}C	35	218
5	Increase in combustion air temp	t/h		183
6	Fuel saving (As per thumb-rule, with every 21^{0}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 kgCO2/kg fuel IPCC2006 (V2;C1 and C2)*

Table 16: Investment, savings and simple pay back for metallic recuperator

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	0.6-1	0.7-1.3	< 1 year

Case Study 4: 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*

Technology No. 7: Replacement of Reciprocating Compressor with Energy Efficient Screw Compressor 8

8.1 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 at Ludhiana, 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 increased.

8.2 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.

8.3 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.

8.4 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.

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

To understand the cost benefit analysis, let us consider a 20hp compressor with compressed air demand of 80-85 cfm with 3,620 hours of annual operation. The cost benefit analysis for adoption of the technology is tabulated below: & RE Technology Compendium.

Table 17: 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	0.17
4	Average air required	CFM	69.0	69.0
5	Average power consumption	kW	22	11.7
6	Compressor capacity	CFM	85	
7	Running hours per day	h/d	12	12
8	Annual operating days	d/y	300	300
9	Annual energy consumption	kWh/y	79,200	42,228
10	Annual energy saving	kWh/y	-	36,972
11	Weighted Avg. electricity cost	Rs/kWh		7.25
12	Monetary savings	Lakh Rs/y	-	2.68
13	Investment	Lakh Rs	-	8.00
14	Payback period	Months	-	3.0
15	Annual energy saving	toe		3.2
16	Annual GHG emission reduction	tCO_2		38.0

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

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

Parameters	Capacity of EE screw compressor	Investment	Annual monetary savings	Simple payback
Units	kW	Rs in Lakhs	Rs in Lakhs	y
	11.7	8	2.68	0.25

Case Study 4: 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
Cumulative 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. 8: Installation of energy efficient pumps

9

9.1 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.

9.2 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 includes:

- 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 cavitations.
- 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 (VFD) 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.

9.3 Benefits of technology

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

- Energy savings of 10-10%
- Increase in pump efficiency by 10-20%
- Longer life
- Less wear & tear
- Reduced operating and maintenance cost.

9.4 Limitation of technology

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

9.5 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 19: 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		1000
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
18	Annual electricity savings	kWh/y	86.90	
19	Electricity charges	Rs/kWh	7.16	
20	Operating hours per day	h	24	
21	Number of operating days in a year	Nos.	300	
22	Annual monetary saving	Rs in Lakh/y	6.22	
23	Price of installing EE pumps	Rs in Lakh	3.20	
24	Simple payback period	months	6.17	
25	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)*

Table 20: Investment, savings and simple pay back for EE pumps

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	1-2	0.75-1	$<$ 2 years

Case Study 4: EE SCREW COMPRESSOR

Puree Engineering, Jalandhar was using an old reciprocating compressor (Cumulative Power 30 HP). The specific energy consumption of the compressor was quite high. In addition to the higher energy consumption, the unit was facing problems of frequent breakdown and higher maintenance cost.

The unit implemented an energy efficient screw compressor of 30 HP, as a replacement for the old compressor. The screw compressor led to a quiet and efficient operation including lesser maintenance. The compressor is VFD enabled and equipped with an IE 3 class efficiency motor.

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.

Sl. No.	Parameter	UoM	Values	
			Baseline	Post Implementation
1	Rated capacity of compressor	kW	22.4	22.4
2	Measured power	kW		21.0
3	Power saving as compared to baseline	%		20.00
4	Saving in power	kW	4.20	
5	Operating hour per day	h/d	12	
6	Operating day per year	d/y	300	
7	Annual electricity saving	kWh	15120	
8	Electricity tariff	Rs/kWh	8	
9	Annual monetary saving	Rs Lakh/y	1.21	
10	Investment	Rs Lakh/y	3.50	
11	Payback	Years	2.9	
12	CO2 emission for electricity	t/MWh	0.90	
13	GCV of electricity	kcal/kWh	860.00	
14	Annual Energy Saving	TOE/y	1.30	
15	Annual GHG Emission Reduction	tCO2/y	13.61	

Emission factor of Electricity taken as 0.90 kgCO2/kWh as per IPCC Guideline 2006 (V1; C1 & C2)

10 Technology No. 9: Energy Efficient Lightings

10.1 Baseline Scenario

Lighting accounts on average for about 10 to 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.

10.2 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.

10.3 Benefits of technology

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

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

10.4 Limitation of technology

Replacement of conventional lights will attract high investment.

10.5 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.

Table 21: 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 tCO2/MWh for electricity from IPCC 2006 (V2;C1 and C2)*

Table 22: Investment, savings and simple payback for EE lighting

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	12.71	10.40	1.2

Case Study 4: EE Lights

Cutwell Engineers, Ludhiana was using 40 numbers of 60 W Metal halide lamps for the factory lighting in various sections. These lights were inefficient and were consuming more power and providing lower lux levels which results in poor visibility and could lead to slips etc while walking in that area.

The unit replaced the old inefficient lights with 40 numbers of 25 W LED lights. These LED lamps provide higher lux levels and also consume less power. This resulted in better visibility in that area and ensured energy savings.

An LED bulb produces light by passing the electric current through a semiconducting material - the diode - which then emits photons (light) through the principle of electroluminescence. A material (diode) casts light when power is applied to it. Electrons jump from one side (an electron-full side) to another (an electron-deficient side) across a junction (the “p-n junction”).

When power is applied to the p-n junction, the side lacking in electrons wants to be filled up with the charged electrons from the other side, and when power is applied the electrons get eager to move. During this process, light is created. The fact that LED lights do not rely on heat to produce its light means it runs cooler and is much more energy-efficient than an incandescent light bulb or common T-12 tube lights.

Sl. No.	Parameter	UoM	Values	
			Baseline	Post Implementation
1	Type of light	#	Conventional light	LED
2	Total number of light	#	40.0	40.0
3	Rated capacity of light	W	60.0	25.0
4	Total power consumption	W	60	25.0
5	Saving in power	W	35	
6	Operating day per year	d/y	300	
7	OPerating hour per day	h/d	10	
8	Annual electricity saving	kWh	4200	
9	Electricity tariff	Rs/kWh	8	
10	Annual monetary saving	Rs Lakh/y	0.3	
11	Cost of LED	Rs/Piece	2450.0	
12	Investment	Rs Lakh/y	0.08	
13	Payback	Y	0.2	
14	CO2 emission for electricity	t/MWh	0.9	
15	GCV of electricity	kcal/kWh	860	
16	Annual Energy Saving	TOE/y	0.36	
17	Annual GHG Emission Reduction	tCO2/y	3.78	

**Emission factor of Electricity taken as 0.90 kgCO2/kWh as per IPCC Guideline 2006 (V1; C1 & C2)*

Technology No. 10: Solar water heater in electroplating bath

11

11.1 Baseline Scenario

Electroplating forms an important segment of the hand tool industry, which requires hot water in its process. Presently, hot water is generated in a biomass / LDO fired hot water generator (boiler). Typically, water is heated to a temperature of around 60-70°C (in most cases). The hot water is required to heat the various baths like Nickel, Chromium and Phosphate. The heating takes place through conduction heat transfer wherein the hot water is circulated in coils inside the baths and the water returns back to the boiler after transferring its heat to the bath solution (water + nickel etc). In most of the baths, heat transfer is not effective; as these baths also operated their secondary electrical coil heaters to maintain the desired temperature levels (like 70°C for nickel bath). This is due to scaling deposits in the hot water pipelines.

The TDS of hot water is typically as high as 400 ppt which confirms this lower heat transfer problem being faced by the plants. Most plants do not operate any water treatment plant. The poor efficiency level of the boiler leads to higher fuel consumption in such systems.

11.2 Energy Efficient Technology

It is proposed to partially replace the LDO/Biomass operated boiler in the electroplating process with evacuated tube collector (ETC) based solar water heater. Solar water heater uses the sun energy to heat water during the day. This hot water is stored inside an insulated solar hot water tank for use whenever required. The sun rays have enough energy to heat water up to 55°C to 70°C which can be utilized for the electroplating section.

With no maintenance requirement, solar heater provides a low cost long term solution to getting hot water. For operations in night or during cloudy days, the solar water heater can Have an inbuilt electric heating element for backup. Basically, solar water heater does conversion of sunlight into renewable energy for water heating using a solar thermal collector.

11.3 Benefits of technology

Major benefits of replacing LDO / Biomass based hot water generator with solar water heater are:

- Clean and greener source of electricity
- Only one time investment
- Less maintenance

11.4 Limitation of technology

The major limitation of the technology is as follows:

- Not suitable for temperature >700C.
- Cannot be used during nights or cloudy days
- Requires substantial space for installation.

The following section provides the details of energy and GHG saving potential, investment required and cost benefit analysis for replacement of a biomass fired hot water generator (boiler) with solar water heater for a typical forging unit.

11.5 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 hot water generator (boiler) with solar water heater for a typical forging unit.

Table 23: Energy & GHG emission saving and cost benefit analysis for replacement of biomass based hot water generator with solar water heater (SWH)

Sl. No.	Parameters	Units	Value	
			Baseline	To Be
1	Total make-up water to be heated in hot water generator	l / h	200.00	200
2	Fuel used		Biomass	SWH
3	Sp. Heat (Cp) of water	kcal / (kg-^{0}C)	1	1
4	boiler efficiency (assumed)	%	60	
5	Inlet water temperature (after cleaning of hot water pipe scaling) – Assumed	^{0}C	30	
6	Heated water temperature	^{0}C	75	
7	Density of water	kg / m^{3}	1,000	1,000
8	GCV of fuel	kcal / kg	3,900	
9	Present fuel consumption to heat the make-up water	kg / h	3.85	
10	hours per day - for SWH working	h / d	12	
11	Days per year for SWH working	d / y	300	
12	Present fuel consumption per year (that can be replaced by SWH)	kg / y	13,846	
13	Cost of biomass	Rs / kg	5.5	
14	biomass savings per year by introduction of SWH for preheating make-up water	Rs Laky / y		0.76
15	Investment Cost of SWH system for 200 Lets/d (@Rs 20,000 for 100 Lets); approx.	Rs Laky		1.50
16	Payback	y		2.0

Table 24: Investment, savings and simple pay back for solar water heater

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	1.50	0.76	2

Technology No. 11: Replacement of Fossil Fuel Fired Forging Furnace with IGBT Based Electric Induction Heater

12

12.1 Baseline Scenario

Typically, the forging industry in Ludhiana hand-tool cluster comprises batch type furnace oil 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 comprises a brick chamber with an opening at the top 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.

Figure 5: 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 at Ludhiana hand-tool cluster vary in between 70 to 120 kilogram per batch with specific fuel consumption ranging from 0.14 to 0.18 liters of furnace oil per kilogram of product. The daily production ranges from 200 to 1,200 kilograms of products per day. The rising price of furnace oil makes it necessary for the units to explore for an alternate heating methodology.

12.2 Energy Efficient Technology

It is proposed to replace the conventional oil based re-heating 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. 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 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.

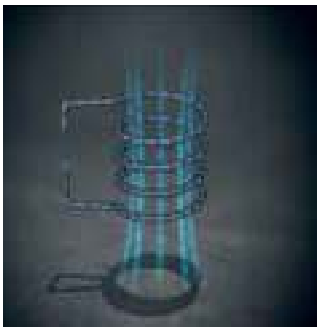


Figure 6: An Induction heating coil

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 according to the intensity 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 7: An induction billet heater

12.3 Benefits of technology

As a superior alternative to furnace oil heating, induction heating provides faster, more efficient heating 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

Table 25: Details of conventional forging furnace in Ludhiana hand tool cluster

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
	150-600	70-120	8-12	0.14-0.18	4-8	300

extremely rapid heating, with exacting control over the 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 and even heating of all or only a portion of the part
- A clean, non-contact method of heating
- Safe and reliable – instant On and Off heating
- Cost-effective, reduces energy consumption compared to other heating methods
- Easy to integrate

12.4 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.

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

To understand the cost-benefit analysis for replacement of conventional furnace with energy efficient furnace, 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 has been tabulated below:

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

Table 26: Energy & GHG emission saving potential, investment required & cost benefit analysis for IGBT based induction furnace

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
21	Sanction load	HP	59	200.00
22	Contract demand	kVA	46	165.00
23	Increment in contract demand	kVA		119.23
24	Supply voltage	V	440	11,000.00
25	Fixed charged	Rs/hp and Rs/kVA	75	185.00
26	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
29	Simple Payback	y		2.13
30	Annual energy saving	toe/y		17.76
31	Annual GHG emission reduction	tCO_2/y		55.25

**Emission factor of furnace oil = 77.4 tCO2/TJ IPCC 2006 (V2; C1 and C2)*

Table 27: Investment, savings and simple pay back for EE forging furnace

Parameters	Furnace Capacity	Investment	Annual monetary savings	Simple payback
Units	kW	Rs in Lakhs	Rs in Lakhs	y
	80-120	11-15	5-8	< 2.5 years

Case Study 1: Installation of Induction Billet 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 i.e. 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.

Figure 8: Conventional forging furnace

Figure 9: Electric Induction Billet Heater at Kohinoor Forging

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	

13 Technology No. 12: Fitch Fuel Catalyst

12.1 Baseline Scenario

Specific fuel consumption of a furnace depends upon the capacity and loading. Significant energy can be saved by optimising the combustion efficiency.The furnaces in the cluster are in the range of 300-1500 kg . Significant energy can be saved by optimising the combustion efficiency. Hydrocarbon fuels are not perfect or uniform. Fuel is a mixture of about 40 primary and as many as a thousand secondary species of hydrocarbon molecules. The short chain types of molecules presentare too short and light and the asphalt types of molecules are too long & heavy. Refineries cannot remove many of the poorly performing molecules and once fuel leaves the refinery or is stored, it is subject to attack by Oxygen, Ozone & Microorganisms (Bacteria, yeast & mold) that grow in the fuel. All these processes degrade the fuel. This poor fuel does not combust completely in the furnace and does not yield the maximum potential energy. Some of it forms carbon deposits and some enters as unburnt hydrocarbons into the exhaust. It is recommended to install a Fitch fuel catalyst in the fuel line to ensure optimum combustion efficiency and reduced energy consumption.

12.2 Energy efficient technology

As the name indicates, the Fitch fuel catalyst (FFC) is a catalyst. By definition, a catalyst is a substance that initiates or accelerates a chemical reaction without itself being affected. Accordingly, the FFC is not a fuel additive / consumable, but a special alloy that does not dissolve in the fuel. The FFC is effective on all hydrocarbon fuels (both Oil & Gas), and contains no moving parts so there is no breakdown due to wear and tear. The FFC reverses any degradation that may have occurred prior to the fuel being introduced to the furnace. It reformulates the fuel to a state that is capable of a more complete combustion.

12.3 Benefits of technology

- Fuel savings in the range 4-8%
- Reduced Toxic Emissions
- Complete combustion
- Reduced bacteria growth in stored fuel

12.4 Limitations of Technology

Models are available as per fuel consumption, Proper selection required before implementation.

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

The cost benefit analysis for the same is as follows:

Table: Cost benefit analysis fitch fuel catalyst

S. No.	Parameter	UoM	Values	
			Baseline	Post Implementation
1	Annual operating days	d/y	300	300
2	Average production per day	kg	1100	1100
3	Annual production	kg/y	330000	330000
4	Specific FO consumption	kg/ton	135	129.6
5	Annual FO consumption	kg/y	44550	42768
6	FO fuel cost (including taxes)	Rs/kg	45	45
7	Annual FO cost	Rs Lakh/y	20.0	19.2
8	Annual Fuel cost saving	Rs Lakh/y		0.8
9	Investment cost for Fitch Fuel Catalyst	Rs Lakh		3.5
10	Simple payback period	y		4.36
11	CO_2 emission for FO oil	t/t	2.27	2.27
12	GCV of FO	kcal/kg	10500	10500
13	GCV of FO	kcal/kg		10500
14	Annual Energy Saving	TOE/y		1.9
15	Annual GHG Emission Reduction	tCO_2/y		4.0

**Emission factor of LDO , FO & LPG taken as 3.0705 kgCO2/kg, 2.27 kgCO2/kg and 2.98 kgCO2/kg of fuel as per IPCC guideline 2006 (V2; C1 and C2)*

Conclusion

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

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

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

Ludhiana is an important hand tools cluster in India. A wide range of hand tools are manufactured in the cluster. There are over 150 units manufacturing hand tools in the cluster. The hand-tool industries in the cluster are mainly involved in production of spanners, screw drivers, pliers, bench vices, tyre levers and hammers. The units' sources alloy steel from the market which is forged and machined to give desired shapes and sizes of the hand-tools. The forging furnace, the hammer power press, electroplating and the finishing machines form the key equipment for the sector. 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):

- Solar water heater
- Energy efficient motors
- High efficiency metallic recuperator
- Energy efficient blowers

Medium Investment Technologies (up to Rs 10 lakhs):

- Energy efficient FO fired forging furnace
- Special purpose machine
- Screw compressor with VFD and PM motor

High Investment Technologies (more than Rs 10 Lakhs):

- IGBT based induction heater
- Solar photovoltaic system for power generation

Through this technology compendium the project hopes to maximize the environment benefits that would lead to Energy savings and GH G 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 energy efficient reheating furnace					
1	R.K. Industrial Enterprises	Parvatya Colony II, Parvatiya Colony, Sector 52, Faridabad, Haryana 121005	Mr. Naresh Gupta, Proprietor	+91-9971550234 +91-9350543850	naresh@ rkindenterprises.com
2	Refine Structure & Heat control Unit	A227, Guru Teg Bahadur Path, Nehru Nagar, Pani Pech , Jaipur - 302016 , Rajasthan India	Mr. V.K. Sharma, Chief Executive	+91-9829060615	refinefurnace@gmail. Com
3	Delta Energy Nature	F-187, Industrial Area, Phase-VIII-B, Mohali-160062	Mr. Gurinder Jeet Singh, Proprietor	+91-9814014144 +91-9316523651	dengjs@yahoo.com denjss@ rediffmail.com
Technology : IE 3 class efficiency energy efficient motor					
1	Bharat Bijlee	Electric Mansion 6th Floor Appasaheb Marathe Marg Prabhadevi, Mumbai 400 025		+91 22 2430 6237 / 6071	info@bharatbijlee.com
2	Crompton Greaves	Church Road, PO BOX 173 Jaipur 302 001, Rajasthan, India	Mr. Sunil Dutt, Proprietor	+91 141 3018800 /01	sunil.dutt@cgglobal. Com
3	Siemens Limited	Birla Aurora, Level 21, Plot No. 1080, Dr. Annie Besant Road, Worli, Mumbai – 400030, India		1800 209 1800	
Technology : Special Purpose Machine					
1	PMT Machine	B-165/I, Kailash Nagar, Behind, Cancer Hospital Rd, Sherpur, Ludhiana, Punjab141009		+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
Technology : Solar PV System					
1	Inter Solar System Pvt. Ltd.	901-A, Industrial Area, Phase-II, Chandigarh - 160 002		+91-8437254139	info@intersolarsystems. Com
2	Wolta Power System	B-91, 1st Floor, Sector 64, Noida - 201301, Uttar Pradesh, India	Mr. Amit Singh, CEO	+91-9266533533	info@ woltapowersystem.com
3	Solar Maxx	III Floor, Krishna Square, Subhash Nagar, Jaipur 302016, Rajasthan, India		+91-141-400 9995	info@solarmaxx.co.in
Technology : Metallic Recuperator					
1	Entech Furnace	Plot No. 186, Sector-24 Faridabad, Haryana (India)	Mr. Vinay Agnihotri	(+91-9810005354)	info@entecfurnaces. Com
2	En Eff Thermal Engineers	536/25c/1a, Industrial Area-C, Sua road, Dhandari Kalan, Ludhiana, Punjab, 141010, India	Mr. Captain Singh (GM)		
3	AAB Heat Exchanger Pvt. Ltd.	Plot No. 375, Sector-24, Faridabad-121005	Mr. Amitoj Singh (Director)	08048719066	

Sl. No.	Name	Address	Contact person	Phone Number	Email Id
Technology 1: Energy Efficient FO Fired Forging Furnace					
1.	R.K. Industrial Enterprises	Parvatya Colony II, Parvatiya Colony, Sector 52, Faridabad, Haryana 121005	Mr. Naresh Gupta, Proprietor	+91-9971550234 +91-9350543850	naresh@rkindenterprises.com
2.	Refine Structure & Heatcontrol Unit	A 227, Guru Teg Bahadur Path, Nehru Nagar, Pani Pech , Jaipur - 302016 , Rajasthan India	Mr. V.K. Sharma, Chief Executive	+91-9829060615	refinefurnace@gmail.com
3	Delta Energy Nature	F-187, Industrial Area, Phase-VIII-B, Mohali-160062	Mr. Gurinder Jeet Singh, Proprietor	+91-9814014144 +91-9316523651	dengjs@yahoo.com denjss@rediffmail.com
Technology 2: IGBT Based Billet Induction Heater					
1	Plus Therm Induction	No. 117/ A, 9th A Cross, Off. Rajgopal Nagar Main Road, behind Eshwar Motors, Phase 3, Peenya, Bengaluru, Karnataka 560058	Mr. Kiran M.S.	+91-8048718506	
2	Akal Induction Private Limited	G. T. ROAD, Opp. GNBL College for Women,Phagwara, Punjab, India. 144401	Mr. S. Jatinder Singh Kundli, CEO	+91 9815221313 +91 9878600087	akalinduction@gmail.com
3	K B G Induction	E-30, Old Industrial Area, Bahadurgarh - 124507, Haryana, India	Mr. Kulbhushan Goyal	+91-8068343604	
4	High Tech Induction	Factory: 552 M.I.E., Part -A, (1 Km. From Tikri Border Delhi), Bahadurgarh (H.R.) Office: 21, Ext.-1B, Nangloi, Delhi -110041		+91-9910376946, +91-9278850575	hitechinduction1@gmail.com
5	Boss Engineers	236/1, Guru Angad Dev Street, Opp. I.T.I., Gill Road, Ludhiana-141003	Mr. Onkar Singh Thakur, Proprietor	+919814074418 +91-9914979252	info@bossengineers.com
Technology 3: IE 3 class efficiency energy efficient motor					
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2	Crompton Greaves	Padam Bhawan, Station Road, Jaipur - 302006, Opposite HDFC Bank	Mr. Mohit Baid	+91-9152663901	mohitbaid86@gmail.com
3	ABB India	32-A, Ram Nagar Colony, Vanasthali Marg, Jaipur - 302001, Rajasthan,	Mr. Mohan Jalwal	+91-8068215064	
4	Bharat Bijlee	Electric Mansion 6th Floor Appasaheb Marathe Marg, Prabhadevi Mumbai 400 025		+91 22 2430 6237 / 6071	info@bharatbijlee.com
Technology 4: Special Purpose machine					
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Technology 5: Solar PV System					

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2	Wolta Power System	B-91, 1st Floor, Sector 64, Noida - 201301, Uttar Pradesh, India	Mr. Amit Singh, CEO	+91-9266533533	info@woltapowersystem.com
3	Solar Maxx	III Floor, Krishna Square, Subhash Nagar, Jaipur 302016, Rajasthan, India		+91-141-400 9995,	info@solarmaxx.co.in
		Technology 6: Gear box			
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2	Bafared India Pvt. Ltd.	Plot No E-28 Anand Nagar Industrial Area, M.I.D.C, Ambarnath (E), 421506, Dist. Thane,Maharashtra , India.	Mr. Vilas V. Dikey	+91-9220922815 +91-7506648459	response@befaredindia.com
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		Technology 7: Poly-Vee and Cogged Belt			
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2	Montana International	71/73, Nagdevi Street, 2nd Floor, Mumbai - 400 003, Maharashtra, India.	Miss. Swati Lokhande	+91 9167799866 / 9167799135 +91 75060 61908	response@indriesbelts.com
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