UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

Energy Efficiency and Renewable Energy Technologies in

Nagaur Hand-tool Cluster

September 2020

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Disclaimer

This document has been prepared to provide overall guidance for conserving energy and costs. It is an output of a research exercise undertaken by DESL supported by the United Nations Industrial Development Organization (UNIDO) and Bureau of Energy Efficiency (BEE) for the benefit of the Hand-tool units located at Nagaur, Rajasthan, India. The contents and views expressed in this document are those of the contributors and do not necessarily reflect the views of DESL, BEE or UNIDO, its Secretariat, its Offices in India and elsewhere, or any of its Member States.

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

A GEF funded Project being jointly implemented by

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Technology Compendium for

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

September 2020

Developed under the assignment

Scaling up and expanding of project activities in MSME clusters

Prepared by

DESL

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DESL Team

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List of Abbreviations

AVVNL	Ajmer Vidyut Vitran Nigam Limited
BEE	Bureau of Energy Efficiency
DESL	Development Environergy Services Limited, New Delhi, India
EE	Energy Efficiency
EET	Energy Efficient Technologies
GEF	Global Environment Facility
MNRE	Ministry of New and Renewable Energy
NHMA	Nagaur Hand Tools Manufacturers Association
NHTA	Nagaur Hand Tools Traders Association
MoMSME	Ministry of Micro, Small and Medium Enterprises
MSME	Micro Small and Medium Enterprises
PMC	Project Management Cell
PV	Photovoltaic
RE	Renewable Energy
RFC	Rajasthan Finance Corporation
RIICO	Rajasthan State Industrial Development and Investment Corporation
SPM	Special Purpose Machine
UNIDO	United Nations Industrial Development Organization

Unit of Measurement

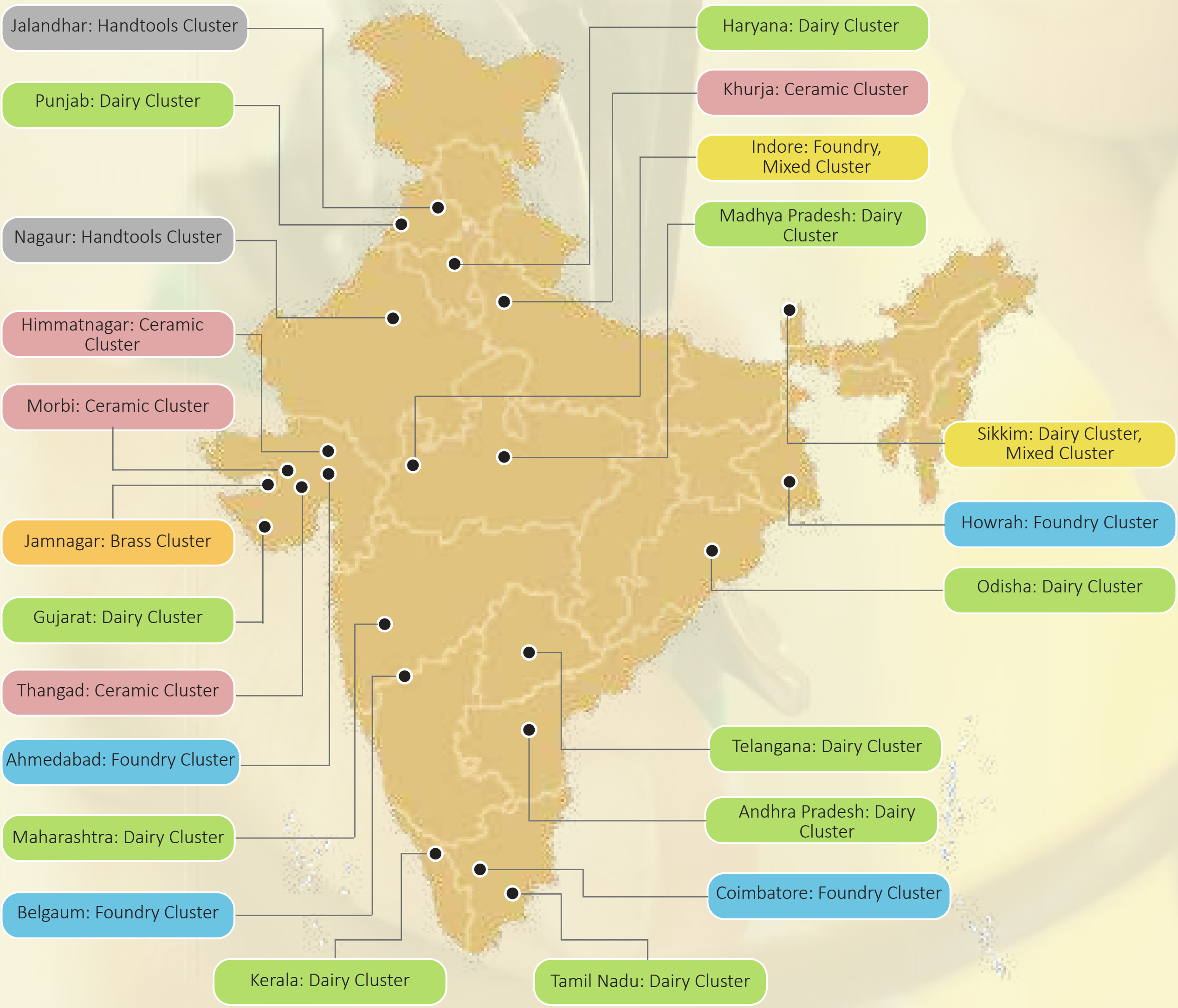
Parameters	UOM	Parameters	UOM
Ampere	A	Liter(s)	l
Approximate	~	Liter per kilogram	l/kg
Centimeter	cm	Mega Joule	MJ
Centimeter Square	cm^2	Mega Volt Ampere	MVA
Cubic Centimeter	cm^3	Mega Watt Hour per Day	MWh/d
Cubic Feet per Minute	CFM	Meter	m
Cubic meter	m^3	Meter cube	m^3
Cubic meter per day	m^3/d	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

About the Project

The United Nations Industrial Development Organization (UNIDO), in collaboration with the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India, is executing a Global Environment Facility (GEF) funded national project titled 'Promoting energy efficiency and renewable energy in selected MSME clusters in India'. The project aims to develop and promote a market environment for introducing energy efficiency (EE) and enhanced use of renewable energy (RE) technologies in process applications in selected energy intensive industrial clusters, comprising micro, small and medium enterprises (MSMEs). The project is supported by the Ministry of Micro, Small and Medium Enterprises (MoMSME) and Ministry of New and Renewable Energy (MNRE). The project was operational in 12 MSME clusters across India in five sectors namely Brass (Jamnagar); Ceramics (Khurja, Thangadh and Morbi); Dairy (Gujarat, Sikkim and Kerala); Foundry (Belgaum, Coimbatore and Indore); Hand Tools (Jalandhar and Nagaur) in its first phase. The Project has now scaled-up and expanded its activities to additional 11 new clusters, namely in Dairy (Tamil Nadu, Odisha, Madhya Pradesh, Andhra Pradesh & Telangana, Haryana, Maharashtra & Punjab), Foundry (Ahmedabad & Howrah), Ceramic (Himmatnagar), Mixed Cluster (Indore & Sikkim) to reach out to MSME's at national level.

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

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



Clusters intervened by the project

About the Technology Compendium

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

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

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

Executive Summary

The Nagaur Hand-tool Cluster comprises significant number of micro, small and medium enterprises (MSME) units involved in the production of forged hand-tools consisting mainly of pliers and hammers. The cluster is of importance in terms of its historic evolution and reputation in terms of quality production. The cluster is highly labour intensive and depends on the skill sets of the workers for development of quality products. The units are in operation for over 3 to 4 decades with very primitive technologies 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)jointly with the Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India, is playing a pivotal role towards scaling up the penetration of low-cost energy efficient technologies (EETs) in the Nagaur hand-tool cluster. A total of 50 MSME Hand-tool industries in the cluster are envisaged to be supported technically to become energy efficient and cost competitive.

This document is the outcome of the enormous research carried out in the sector, energy audits conducted in representation units and stakeholders' consultation. The extensive research and ground level deployment of various teams has made it possible to consolidate the list of economically viable energy efficient and renewable energy technologies applicable for the Nagaur 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 units. This compendium can be used as a ready reckoner 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 units. The technology compendium also consists of case studies on actual implementation of the technologies and benefits realized thereof. Although the compendium consists of some general information on the technologies, the same will require customization based on individual unit's requirement. The Nagaur 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 willlead to cost competitiveness of the units, 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 Nagaur 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)	Replacement of conventional motors with energy efficient (IE 3 class efficiency) motors	0.03-0.55	0.06-0.34	< 2 years
		Replacement of existing belts with Poly-Vee and Cogged Belts	0.08-0.15	0.06-0.11	< 1.5 years
		Replacement of belt driven motors common shaft to direct coupled motor	1-2	1.5-2	< 1.5 years
B	Medium Investment Technologies (up to Rs 10 lakhs)	Installation of energy efficient FO fired forging furnace	3- 5	2-4	< 2 years
		Installation of solar PV system	4-12	1.1-3.3	< 4.5 years
		Installation of special purpose machine	2 -5	1-4	< 1.5 years
C	High Investment Technologies (more than Rs 10 lakhs)	Installation of IGBT based induction heater	11-15	5-8	< 2.5 years

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

About the Cluster 1

1.1 Cluster overview

Nagaur district is located between latitude 26.25' and 27.40' North and longitude 73.10' and 75.15' East and is an important district in the state of Rajasthan. Nagaur shares its borders in north with Bikaner & Churu, in South with-Ajmer & Pali, in east with Sikar & Jaipur and in west with Jodhpur district. The district has a geographical area of 17.718 square kilometers, representing 5.18 percent of the total area of Rajasthan and ranks sixth among the districts of the state.

Figure 1: Map of Nagaur

Nagauris an important hand-tool cluster in India. A wide range of hand tools are manufactured in the cluster with units engaged both in forging and finishing operations. Most of the forging units are concentrated in Basni industrial area, which has been developed by Rajasthan State Industrial Development and Investment Corporation (RIICO) and Rajasthan Finance Corporation (RFC). Other processes such as machining, assembling, grinding and polishing are carried out in units based in Loharpura area. Generally, the products from forging units from Basni area are sent for other finishing operations to Loharpura area. A few of the units have facility to carry out both forging and machining operations under the same premises.

There are about 55 hand tool units in the Nagaur cluster. In the recent past, several units have been closed due to poor market conditions. The turnover of the cluster is around Rs 35 crore (Rs 350 million). Pliers and hammers contribute for about 75% of the total production in the cluster. Other tools such as tin cutters, watchmaker and goldsmith tools are made in cottage industries located in Loharpura area. Most of the units sell their product in the domestic markets. A few units cater to the needs of Nagaur hand tool cluster, who in turn export the manufactured products. (Source: www.sameeeksha.org)

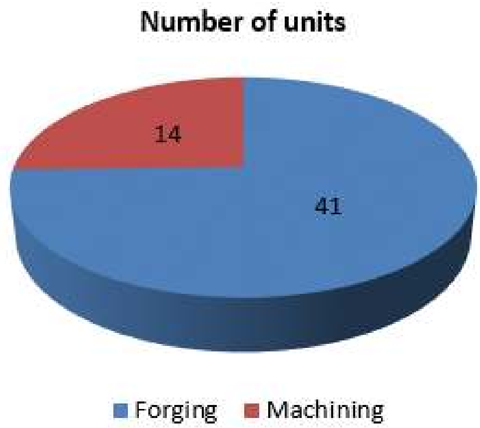


Figure 2: Number of forging and machining units in Nagaur hand tool cluster

The cluster provides employment to more than 2,000 skilled and non-skilled workers. There are two industry associations in the cluster – (1) Hand Tools Industries Association - Nagaur and (2) Hand Tools Traders Association – Nagaur. The NHMA comprises mainly entrepreneurs from the Basni road industrial area. A large number of micro units situated in Loharpura area are not part of any of these associations. There is a Hand Tool Design Development and Training Centre at Nagaur which was set up in 1988 with an objective to develop small and tiny units in the area. Very few units avail the services of this centre.

1.2 The process

The hand-tool units in the cluster are mainly involved in production of pliers and hammers. The unit sources alloy steel from market which is forged and machined to give the desired shape and size of the hand-tools. The forging furnace, the hammer power press 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:

Figure 3: Hand-tool process

From process point of view, the re-heating furnace is the major energy consuming equipment, followed by motors which are used to provide motive power to the common shaft, shearing machine, press machines, etc. Most of the re-heating furnaces in the cluster are furnace oil fired.

In case of finishing units in the Loharpura area, major processes include broaching for cutting teeth in pliers, drilling for making hole for rivet, riveting of pliers, preliminary hardening of pliers' teeth and packaging. Here, the major energy consuming equipment is the motors which are used for driving the common shaft for machines. There is also a little usage of LPG which is used for hardening of plier teeth.

1.3 Technology status and energy use

The Nagaur hand-tool cluster is distinctly differentiated in two types of units (1) the forging units (2) the finishing units. Major raw material used by the forging units are rectangular iron bars of EN8 steel grade of sizes varying from 12 to 15 mm. The raw material is procured in bulk from Mandi Gobindgarh (Punjab) and other local traders. The raw material, once sheared into the required length is fed in the batch type re-heating furnace. Most of the re-heating furnaces in the cluster operate with furnace oil. The batch type furnace can accommodate approximately 200 pieces of 340 grams each in a single batch. The charge is heated to a temperature of around 1,150^{0}C before being transferred to the power hammer press for forging operation.

Forging includes (1) Drop forging, (2) Spring forging and (3) Hand forging. The forging units use drop hammer in case they manufacture full forging pliers and/ or hammers of more than 750 grams. In case the units have installed drop hammer, they also manufacture half forging pliers and low weight hammers. The drop hammers in the cluster are generally purchased second hand from Ludhiana or Ajmer. Spring hammers are mostly used for manufacturing half forging pliers and / or less than 750 gram hammers. The spring hammer is connected with a belt and shaft arrangement. The spring hammer continuously hammers, whereas the drop hammer is pulled once the job is placed.

The third type of forging, i.e. hand forging is carried out by artisans using the traditional technology, i.e. anvil and hammer. Traditional techniques are used for heat treatment, i.e. heating the material and quenching it in water. Most of the time, heating is done in the furnaces, but in case of pliers the heat treatment is carried out using oxy-acetylene flame.

The finishing operations carried out in the Loharpura area include machining, assembling, grinding and polishing operations. These units have lathe machines and drill machines. The machining units use a common shaft fitted with pulley and belt for running various machines.

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

2

2.1 Conventional Practice

A re-heating furnace commonly known as 'forging' furnace forms the heart of a typical hand-tool industry, consuming majority of the plant's energy. The forging furnace is used to heat the raw material to the required forging temperature before being transferred to the hammer press. The Nagaur hand-tool cluster consists mostly of batch type furnace oil fired forging furnaces, which are locally made of fire bricks and covered with steel sheet. The insulation used in these furnaces are poor. There is no monitoring and control system available for the furnace operation. The forging furnace comprises a brick chamber with an opening in 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 4: Conventional furnace oil fired forging furnace

The forging furnaces in the cluster are of very primitive design with no control in terms of fuel and air flow. The furnaces are often operated in higher than rated capacity leading to higher burning losses. Also, substantial amount of heat is wasted from the discharge end and the top opening for raw material charging. These furnaces are operated manually with no provision for waste heat recovery. Also, there is absolutely no control in the air and fuel supply into the furnace. The poor design of the furnace leads to high start-up time and high specific energy consumption. The average start up time for these furnaces was observed to be as high as 1.5 to 2 hours. The overall thermal efficiencies of these furnaces are extremely low, ranging from 8 to 12 percent. The capacities of the forging furnaces at Nagaur 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.

Various options including use of waste heat recovery systems for pre-heating of combustion air, better insulation, 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.

2.2 Energy Efficient Technology

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

- **Furnace oil heating and pumping unit:** The furnace oil tank in the existing furnace is located at the top of the furnace. Furnace oil is fed into the furnace by virtue of gravity. Typically, furnace oil is not heated to the desired viscosity level. It is proposed to introduce a furnace oil heating and pumping unit to supply furnace oil at required temperature and pressure. The temperature of furnace oil is maintained at 80-90 ^{0}C.
- **Optimum refractory & insulation:** The existing wall linings comprise fire bricks refractory without any insulation backup. It is proposed to equip the furnace with high Alumina refractory bricks backed by ceramic fiber insulation. The optimum refractory and insulation will ensure minimum radiation loss from the furnace walls
- **Reducing furnace openings:** The openings in the furnace will be minimized to the extent possible. The existing top opening of the furnace will be covered whenever raw material is not fed into the furnace. A separate opening will be provided for the flue gas passage into the chimney.
- **Waste heat recovery:** The energy efficient furnace will be equipped with a heat exchanger to recover the waste

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

Parameters	Annual capacity	Furnace Capacity	Thermal Efficiency	Specific fuel consumption	Hours of operation	Days of operation
Units	t/y	kg/ batch	%	l/kg	h/d	d/y
	150-600	70-120	8-12	0.14-0.18	4-8	300

heat from the flue gas to preheat the combustion air. With every 21^{0}C rise in the combustion air, it is expected to have a saving of 1% in the specific fuel consumption.

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

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

2.3 Benefits of technology

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

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

2.4 Limitation of technology

The re-heating furnace, even after modification, will require a significant start-up time, since the units are operated only for 4-8 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 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 furnaces have been tabulated below:

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	3- 5	2-4	< 2 years

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	90	90
2	Operating hours per day	h/d	6	6
3	Operating days per year	d/y	300	300
4	Fuel consumption	l/h	14.17	8.43
5	GCV	kcal/kg	10,100	10,100
6	Density of furnace oil	kg/l	0.96	0.96
7	Raw material input temperature	^{0}C	35	35
8	Product final temperature	^{0}C	1,200	1,200
9	Specific heat of EN8 Cast Steel	kcal/kg K	0.117	0.117
10	Furnace Direct Efficiency	%	8.57	15
11	Specific fuel consumption	l/kg	0.16	0.094
12	Annual fuel consumption	l/y	25,500	15,182
13	Annual fuel saving	l/y		10,318
14	Furnace oil cost	Rs/l		35.00
15	Annual Monetary Saving	Rs in lakhs		3.61
16	Investment	Rs in lakhs		5.00
17	Simple Payback	y		1.38
18	Annual energy saving	toe/y		10.42
19	Annual GHG emission reduction	tCO_2/y		33.75

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

Technology 2: Replacement of Fossil Fuel Fired Forging Furnace with IGBT Based Electric Induction Heater

3

3.1 Conventional Practice

Typically, the forging industry in Nagaur 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 Nagaur 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.

3.2 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

3.3 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 5: Details of conventional forging furnace in Nagaur 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

3.4 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.

3.5 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 6: 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	10100	
8	Density of furnace oil	kg/l	0.96	
9	Raw material input temperature	⁰C	35	35
10	Product final temperature	⁰C	1200	1200
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 7: 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	

4 Technology 3: Replacement of Existing Motors With IE3 Class Efficiency Energy Efficient Motors

4.1 Conventional Practice

After the raw material is heated to the forging temperature, the same is transferred to the power hammer press, where the heated charge is forged to the desired shape. The forged material is finally machined using conventional machines for the desired product output. The power hammer press and the finishing machines form important part of the hand-tool industries. The forging hammer is of mechanical type which is driven by an electric motor. The finishing machines comprising lathe, milling and drilling machines are driven by a common shaft which is also powered by an electric motor. These motors consume 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 hp to 30 hp. The 3-phase induction motors have 2 main parts: the stator or the stationary part and the rotor or the rotating part. Stator is made by staking 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 as the synchronous speed.

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

Motor efficiency is defined as the ratio of mechanical power output to electrical power input. In most of the applications in a hand-tool unit, conventional motors (of IE 1 rating) are used with an efficiency range from 75 to 88% depending on the size. At times, motor fail and work of a unit may come to complete stand still. Motor failures can attribute to mechanical and electrical failures. Causes such as improper voltage, voltage fluctuations, improper lubrication and damaged bearings lead to rise in motor winding temperature ultimately leading to failure. These electrical failures lead to the next obvious step, i.e. motor re-winding. The motor efficiency further decreases with each re-winding campaign; as it is mostly carried out by unskilled workers. Normally, a unit carries out 7-8 times motor rewinding within its life span of 10 years. Considering 1% efficiency drop in each rewinding campaign; it may lead to a loss of approximately Rs 40,000 per kWh.

4.2 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 about 8-10% of the total losses. Friction loss is reduced by using improved lubricating system and high quality bearings. Windage loss is reduced by using energy efficient fans
- Stray load loss accounts for 4-5% of the total losses. Use of optimum slot geometry and minimum overhang of stator conductors reduces stray load loss
- Conventional motors operate in a lower efficiency zone when they are loaded less than 60%. The efficiency of energy efficient motors 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

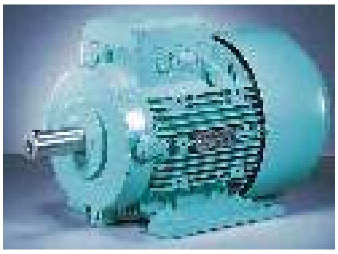


Figure 10: Energy efficient motor

Table 8: Details of motor in Nagaur hand tool cluster

Parameters	Annual Production capacity	Rated motor power	Motor Efficiency	Rewinding	Hours of operation	Days of operation
UoM	t/y	hp	%	Nos.	h/d	d/y
	150-600	1-30	75-88	4-7	4-8	300

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 presented below:

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

Table 9: Specification of 7.5 hp energy efficient motor

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

Table 10: Motor efficiency values as per IEC 60034-30

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

The efficiency graph for 4-pole IE 1 to IE 4 class efficiency motors at 50 Hz frequency is shown below:

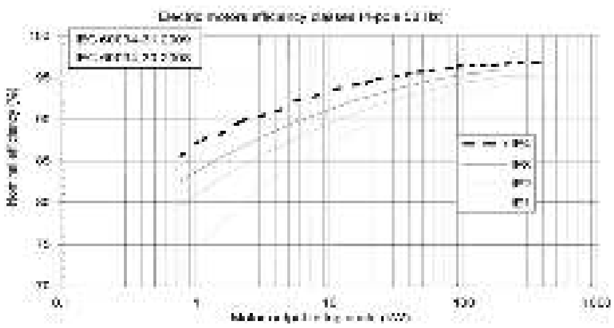


Figure 11: IE efficiency classes for 4 pole motors at 50 Hz

4.3 Benefits of technology

The implementation of IE 3 class efficiency motors 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

4.4 Limitation of technology

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

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

To understand the cost-benefit analysis, let us consider a typical unit with the rated capacity of the power press hammer as 20 hp and the same for the common shaft as 7.5 hp. The unit operates 1,800 hours per year.

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

Table 11: Energy & GHG emission saving potential, investment required and cost benefit analysis for energy efficient motors

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Rated Power for power press hammer	hp	20	20
2	Rated Power for power press hammer	kW	14.9	14.9
3	Motor Efficiency	%	83.00	92.10*
4	Rated Power for common motor shaft	hp	7.5	7.5
5	Rated Power for common motor shaft	kW	6	6
6	Motor Efficiency	%	83.00	89.60
7	Annual operating hours	h/y	1,800	1,800
8	Motor loading	%	80	80
9	Annual energy consumption	kWh/y	35,578	32,307
10	Annual energy saving	kWh/y		3,271
11	Average power tariff	Rs/kWh		7.5
12	Annual monetary saving	Rs in lakhs		0.25
13	Investment	Rs in lakhs		0.44
14	Simple Payback	y		1.76
15	Annual energy saving	toe/y		0.28
16	Annual GHG emission reduction	tCO_2/y		2.94

*Motor efficiency as per IEA
**Emission factor = 0.9 tCO2/MWh *from IPCC 2006 (V2;C1 and C2)*

The investment required, energy savings and simple payback for different ratings of IE class efficiency energy efficient motor (4 pole motors) are tabulated in Table 12:

Table 12: Investment, savings and simple pay back for IE 3 motors

Parameters	Motor Rating	Investment	Annual monetary savings	Simple payback
Units	hp	Rs in Lakhs	Rs in Lakhs	y
	1-30	0.03-0.55	0.06-0.34	< 2 years

Case Study 2: Installation of energy efficient motor

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

Particulars	UoM	Baseline	Post Implementation
Type of motor		IE 1	IE 3
Motor Rating	kW	18.5	15
Motor Loading	%	75	90
Motor efficiency (considering 2 times rewinding)	%	85	92.10
Annual operating hours	h/y	2,500	2,500
Annual energy consumption	kWh/y	40,808	36,600
Annual energy saving	kWh/y	4,208	
Annual Monetary saving	Rs in lakh/y	0.31	
Investment	Rs in lakhs	0.35	
Payback	months	13.5	
GHG emission reduction	tCO_2/y	3.78	
Annual energy consumption reduction	toe/y	0.36	

Technology No. 4: Replacement of Conventional Machine with Special Purpose Machine

5

5.1 Baseline Scenario

The hand-tool units at Nagaur use manually operated conventional machines for various machining job work like facing, turning, grinding, drilling, etc. These machines run on electrical motors having the capacity varying from 1 hp to 3 hp with production/ machining of 600~1,500 pieces per day. Since these machines are manually operated, the process through which components are manufactured is very slow and time consuming. Apart from the slow process, it is also difficult to maintain the quality of the product in case of manual machining. It is often observed that the machines are idle (without any component loaded on to the machines) and the operator is busy in doing some other work/activity. All these factors lead to loss of 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 operation. After this, the job needs to be transferred to some other machine for threading operations and drilling needs to be done in a third machine. In some cases, the trimming operation is done in a separate machine. Thus, for a single job work, a number of machines are required which leads to lower productivity, higher energy consumption and lower efficiency due to manual intervention in each process.

Figure 12: A conventional drilling machine

5.2 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 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 energy savings depending upon the type of component, operation, material, cycle time. A special purpose machine (SPM) is a kind of multi-tasking machine used for machining purpose. A special purpose machine is used as a replacement to conventional machines like lathe, drilling or trimming machine. A special purpose machine is designed based on the customized requirement of a unit and may be used for one or multiple tasks as per the design. For example, a conventional drilling machine is operated manually and machines one piece at a time. Three different machines are operated simultaneously to machine the required number of pieces. The three drilling machines can be replaced by a single special purpose drilling machine which can process three jobs at a time, thus increasing productivity and reducing energy consumption.

Figure 13: A special purpose drilling machine

Table 13: Details of conventional machines in Nagaur 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
	150-600	1-3	5-10	600-1,500	4-8	300

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

Sl. No.	Parameter	Unit	Baseline	Post Implementation
1	Rated Power for drilling machine	hp	2	3
2	No. of drilling machine	Nos.	3	1
3	Rated Power for drilling machine	kW	4.5	2.2
4	Productivity	Pcs/h	142	425
5	Specific energy consumption	kWh/pcs	0.032	0.0053
6	Annual operating hours	h/y	3,600	3,600
7	Annual production	Pcs/y	5,10,000	5,10,000
8	Annual energy consumption	kWh/y	16,107	2,685
9	Annual energy saving	kWh/y		13,423
10	Average power tariff	Rs/kWh		7.5
11	Annual monetary saving	Rs in lakhs		1.01
12	Investment	Rs in lakhs		2.00
13	Simple Payback	y		1.99
14	Annual energy saving	toe/y		1.15
15	Annual GHG emission reduction	tCO_2/y		12.08

**Emission factor = 0.9 tCO2/MWh from IPCC 2006 (V2;C1 and C2)*

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.

5.3 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.

5.4 Limitations of technology

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

5.5 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 2 hp each. These machines are replaced with a single special purpose drilling machine powered by a 3 hp motor. The unit operates 3,600 hours per year. The cost-benefit analysis for adoption of the technology is tabulated above (Table 14).

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

Table 15: 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
	600-1,500	2 -5	1-4	<1.5 years

Case Study 3: Installation of special purpose machine

Bharat International is a major manufacturer of auto components in Ludhiana, Punjab. Initially, the unit used multiple drilling machines to process 90 pieces per hour. The manpower utilization was low due to the machine productivity. During 2017, the unit implemented a special purpose drilling machine in the unit. This enhanced the productivity to 390 pieces per hour. The unit achieved dual benefits of increased productivity and reduced specific energy consumption.

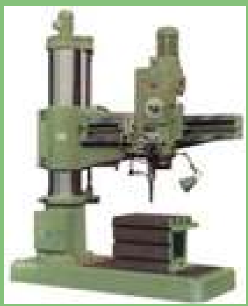


Figure 14: Conventional drilling machine

Figure 15: Special purpose drilling machine at Bharat International

Parameters	UoM	Baseline	Post Implementation
Power consumption by conventional drilling machine and SPM	kW	6.6	2.2
Productivity on conventional drilling machine and SPM	pcs./h	90	270
specific power consumption on Conventional and SPM	kWh/pcs.	0.07	0.01
specific power consumption on Conventional and SPM	kcal/pcs.	63.07	7.01
Cost of energy consumption	Rs./pcs.	0.55	0.06
production	Pcs./annum	216,000	216,000
Reduction in cost of energy	Rs/pcs.		0.49
Reduction in specific energy consumption in kcal	kcal/pcs.		56.06
Annual cost saving	Rs in lakh		1.1
Investment	Rs in lakh		2.5
Payback	y		2.3
Annual energy saving	toe		1.2
Annual GHG emission reduction	tCO_2		13

6 Technology No. 5: Replacement of Conventional V-Belt and Flat Beltwith Poly-Vee and Cogged Belt in Pulley Driven Machines

6.1 Baseline Scenario

The hand-tool units at Nagaur commonly use a common shaft to drive all machines. The rated RPM of the motor is stepped down to the desired RPM of the process using a belt and pulley. Belt drives provide flexibility in the positioning of the motor relative to the load. Pulleys (sheaves) of varying diameters allow the speed of the driven equipment to be increased or decreased. A properly designed belt transmission system provides high efficiency, low noise, does not require lubrication, and presents low maintenance requirements. However, certain types of belts are more efficient than others, offering potential energy cost savings.

Figure 16: Common shaft with flat belt

The majority of belt drives use V-belts. V-belts use a trapezoidal cross section to create a wedging action on the pulleys to increase friction and the belt's power transfer capability. Joined or multiple belts are specified for heavy loads. V-belt drives can have a peak efficiency of 95% to 98% at the time of installation. Efficiency is also dependent on pulley size, driven torque, under or over-belting, and V-belt design and construction. Efficiency deteriorates by as much as 5% (to a nominal efficiency of 93%) over time if slippage occurs because the belt is not periodically re-tensioned. Flat belts are used on load side which are highly inefficient and are almost on the verge of breaking in most of the units. Poor quality of belts do affect the electricity consumption of common shaft motors.

Figure 17: Common shaft with V-belt

6.2 Energy efficient technology

A good practice for such systems, which are mostly driven by belts, is to install cogged belts on load side and poly-Vee belts on drive side. These installations will also require modification in pulleys as well since existing pulleys are flat and without any crowning.

The majority of belt drives on drive side use classical V-belts which have a trapezoidal cross section to create a wedging action on the pulleys to increase friction and improve the belt's power transfer capability. V-belt drives can have a peak efficiency of 95 to 96% at the time of installation.

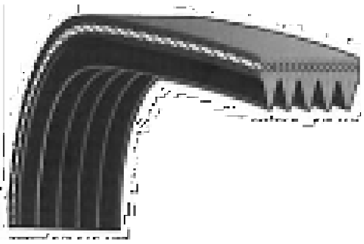


Figure 18: Cross-section of poly-Vee belt

However, efficiency is also dependent on following major factors:

- Pulley size
- Driven torque
- Under or over-belting
- V-belt design and construction

Figure 19: Cogged belt

Over the time, the efficiency deteriorates by as much as 5% (to a nominal efficiency of below 90%), if slippage occurs because the belt is not periodically re-tensioned. The suggested option is a poly-Vee belt for drive side which has a number of V-belt type trapezoidal sections along the length of the belt. On the load side, low efficiency flat belts are used whichshould be replaced by energy efficient cogged belts whichhave slots that run perpendicular to the belt's length. Theslots reduce the bending resistance of the belt. Cogged beltscan be used with the same pulleys as equivalently rated V-belts.They run cooler, last longer, and have an efficiency that is about 2 percent higher than that of standard V-belts.

6.3 Benefits of technology

Replacements of V-belts with cogged flat belts have following benefits:

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

6.4 Limitations of technology

Installation of these belts would require specialtype of pulley rather than traditional crowned pulleys for easy running of these belts.

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

To understand the cost-benefit analysis, let us consider a connected load of 7.5 hp using a V-belt based pulley drive to be replaced with cogged flat belt. The unit operates 3,000 hours per year. The cost-benefit analysis for adoption of the technology is tabulated below (Table 16):

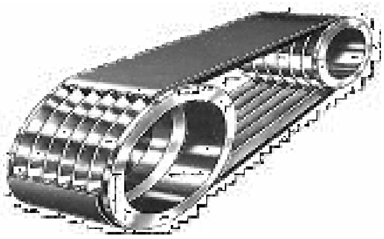


Figure 20: Pulley required for poly-Vee belt

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

Table 17: Investment, savings and simple pay back for cogged and poly-vee belts

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	0.08-0.15	0.06-0.11	< 1.5 years

Table 16: Energy & GHG emission saving potential, investment required &cost benefit analysis for energy efficient belt driven system

Sl.No.	Parameter	Unit	Baseline	Post Implementation
1	Type of belt		V Belt	Cogged Belt
2	Connected load	hp	7.5	7.5
3	Connected load	kW	5.59	5.59
4	Motor efficiency	%	85	85
5	Loading	%	80	80
6	Measured Power		5.3	5.0
7	Belt transmission efficiency	%	93	98
8	Shaft power at load end		4.16	4.16
9	Working hours	h/d	10	10
10	Working days	d/y	300	300
11	Annual power consumption	kWh	15,798	14,992
12	Power tariff	Rs/kWh	7.5	7.5
13	Total energy cost	Rs in Lakhs	1.18	1.12
14	Energy savings due to belt replacement	kWh/y	806	
15	Annual monetary saving	Rs in Lakh	0.06	
16	Investment	Rs in Lakh	0.08	
17	Payback period	y	1	
18	Annual energy saving	toe/y	0.07	
18	Annual GHG emission reduction	tCO_2/y	0.7	

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

7 Technology No. 6: Installation of Solar Photovoltaic System for Power Generation

7.1 Baseline Scenario

Electricity is the key component of the total production in a hand-tool industry. The units at Nagaur get power from the Ajmer VidyutVitran Nigam Limited. 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.

7.2 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 Nagaur 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 industries at Nagaur have a potential to install 20 kW solar PV system within an area of 160 m^2.The solar radiation graph for Nagaur has been shown in the figure below:

7.3 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

7.4 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.

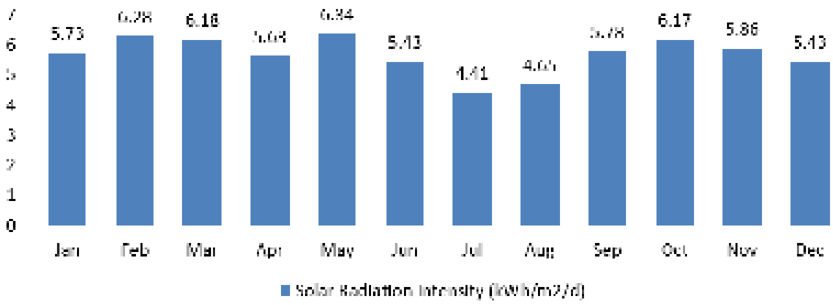


Figure 22: Solar radiation intensity for Nagaur, Rajasthan

** Naguar, Rajasthan Latitude 27.15 Longitude 73.75 Annual average: 5.65kWh/m^2/day*

7.5 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 19: 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
	10 -30	4-12	1.1-3.3	< 4.5 years

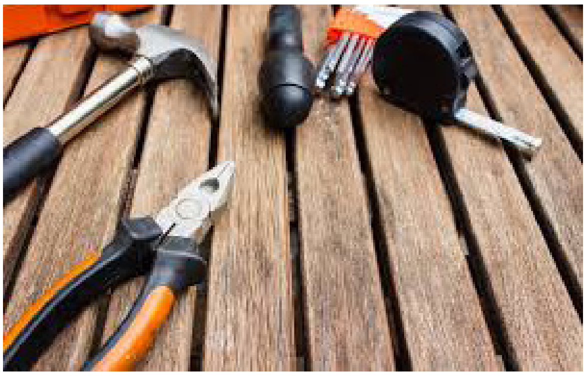
Table 18: Energy & GHG emission saving potential, Investment required &cost benefit analysis for solar PV system

Sl.No.	Parameter	Unit	Value
1	Capacity of Solar PV system	kWp	20
2	Area required	m^2	160
3	Solar power generation capacity	kWh/kWp	5
4	Generation potential	kWh/d	100
5	Annual solar radiation days	d/y	300
6	Generation potential	kWh/y	30,000
7	Electricity charges	Rs/kWh	7.5
8	Annual monetary saving	Rs in Lakh	225,000
9	Investment	Rs in Lakh	800,000
10	Simple Payback	y	3.6
11	Annual energy savings	toe/y	3
12	Annual GHG emission reduction	tCO2/y	27

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

Case Study 4: Installation of Solar PV system

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



8 Technology No. 7: Replacement of Belt Driven System with Direct Coupled Drive

8.1 Conventional Practice

Conventionally, the units in Nagaur use a belt and pulley based common shaft to drive the machines. The motor RPM is reduced to the desired machine speed using different diameters of pulley wheels. The belt and pulley system are inefficient wasting a significant amount of transmission efficiency of the motor system. Gradually the belts are loosened leading to slip. In order to accommodate the belt and pulley based system, the units are necessitated for a higher rated motor.

8.2 Energy Efficient Technology

A significant power transmission loss can be saved by replacing the pulley based system with direct coupled motor with a gearbox. In place of a common shaft the machines can be individually coupled with the gearbox and motor. The RPM can be stepped down by suitable designing the gear ratio.


Figure 23: Pin on worm reduction gearbox for direct coupled machine

The implementation of the system will lead to higher productivity, lesser breakdown and reduced specific energy consumption. A direct coupled system has a better power transmission efficiency compared to a belt driven system. Also, loss of power due to slippage of belts can be avoided.


Figure 24: Inefficient belt and pulley drives

8.3 Energy & GHG saving potential, investment required & cost benefit analysis

To understand the cost-benefit analysis, let us consider a 90 tph capacity unit. The cost-benefit analysis for adoption of the technology is tabulated below (Table 20).

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

Table 21: Investment, savings and simple pay back for direct coupled drive

Parameters	Investment per unit	Annual monetary savings	Simple payback
Units	Rs in Lakhs	Rs in Lakhs	y
	1-2	1.5-2	< 1.5 years

Table 20: Energy & GHG saving potential, Investment Required, Cost benefit analysis for Direct Coupled Drive

Sl.No.	Particulars	Unit	Value
1	Number of belt drives	Nos.	4
2	Belt operated machines	Nos.	4
3	Rated power	kW	11
4	Reduction of energy by installation of direct coupled gear box	%	8
5	Rated power of direct coupled motor	kW	10.12
6	Daily operating hours	h/d	8
7	Annual operating days	d/y	300
8	Annual energy savings	kWh/y	24,288
9	Unit rate	Rs/kWh	7.5
10	Monetary savings	Rs Lakh/y	1.82
11	Estimated investment	Rs Lakh	1
12	Simple payback period	y	0.5
13	Annual energy savings	toe/y	2.09
14	Annual GHG emission reduction	tCO_2/y	21.9

**Emission factor = 0.9 tCO_2/MWh from IPCC 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.

Nagaur is an important hand-tool cluster in India. A wide range of hand tools are manufactured in the cluster with units engaged both in forging and finishing operations. There are over 50 units manufacturing hand tools in the cluster. Pliers and hammers contribute for about 75% of the total production in the cluster. Other tools such as tin cutters, watchmaker and goldsmith tools. The units' sources steel from the market which is forged and machined to give desired shapes and sizes of the hand-tools. The forging furnace and the hammer power press 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):

- Energy efficient motors
- Poly Vee and Cogged Belts
- Replacement of belt driven motors common shaft to direct coupled motor

Medium Investment Technologies (up to Rs 10 lakhs):

- Energy efficient FO fired forging furnace
- Energy efficient LPG 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 GHG emission reduction. The project titled "Promoting energy efficiency and renewable energy in selected MSME clusters in India" provides a unique opportunity to the MSME units to progress towards a sustainable future.

List of Vendors

Sl. No.	Name	Address	Contact person	Phone 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			
1	Siemens Limited	No 6, Park Street, A C Market, Jaipur, Rajasthan, 302001, India	Mr. Hitesh Sinha	+91-8068093303	
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			
1	PMT machine	B - 165/I, Kailash Nagar, Behind, Cancer Hospital Rd, Sherpur, Ludhiana, Punjab 141009	Mr. Vinod Kumar	+91-9814020118	
2	Gahir Industries	Near Eastman Chowk, Industrial Area-C, Dhandari Kalan, Ludhiana 141003.(Pb.)	Mr. Harminder Singh	+91-9872553000	

Sl. No.	Name	Address	Contact person	Phone Number	Email Id
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 5: Solar PV System			
1	Inter Solar System Pvt. Ltd.	901-A, Industrial Area, Phase-II, Chandigarh - 160 002	Mr. Bhupender Kumar	+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 6: Gear box			
1	Shanti Gears	"Dare House" NSC Bose Rd, Parry's Corner, George Town, Chennai, Tamil Nadu 600001, India.	Mr. Devashish	+91-8041948528	gcc@corp.murugappa.com
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
3	Agro Engineers	F-557, Indraprastha Industrial Area, Kota 324005, Rajasthan, India	Mr. Vinod Nama	+91.998 2584 955	info@agroengineers.com
		Technology 7: Poly-Vee and Cogged Belt			
1	Ashutosh Power TransBelts Ltd	707, "Hemkoot" Building, Opp. Capital Comm. Centre, Ashram Road, Ahmedabad-380009 Gujarat, INDIA	Mr. Deenbandhu Reengusia, Director	+91-79-26580282/ 26581238/ 26580929	info@aptbelts.com
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
3	CSH Belt	No.162 Jingsan road, Shengzhou, Zhejiang, China		+86-575-83706855	sales@cshbelt.com

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