ENERGY PROFILE

RAJKOT MACHINE TOOLS CLUSTER

The Energy and Resources Institute

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

Promoting Energy Efficiency in SMEs
SAMEEEKSHA

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Certificate of originality

Original work of TERI done under the project 'Profiling of energy intensive small and medium enterprise (SME) clusters'.

Suggested format for citation

TERI. 2016
Energy Profile: Rajkot Machine Tools Cluster
New Delhi: The Energy and Resources Institute, 28 pp.
[Project Report No. 2015IE18]

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This document is an output of a research exercise undertaken by TERI supported by the Shakti Sustainable Energy Foundation (SSEF) for the benefit of MSME sector. While every effort has been made to avoid any mistakes or omissions, TERI and SSEF would not be in any way liable to any people/organizations by reason of any mistake/omission in the publication.

Published by

TERI Press
The Energy and Resources Institute
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi-110 003
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Acknowledgements

TERI places on record its sincere thanks to the Shakti Sustainable Energy Foundation (SSEF) for supporting the project on profiling of energy intensive Micro, Small, and Medium Enterprises (MSME) clusters in India.

TERI team is thankful to Machine Tools Manufacturers Association Rajkot (MTMA), Rajkot Engineering Association (REA), and Institute of Indian Foundrymen (IIF)—Rajkot Chapter for providing support and information related to Machine Tool units in Rajkot cluster. TERI extends its sincere thanks to Mr Dinesh Khambhayta, President, MTA, for organizing field visits and interactions with unit members during the study for preparation of this cluster profile report. TERI would also like to thank the President of REA and Chairman of IIF Rajkot Chapter Mr Bhavesh Patel and Mr Samir Monpara.

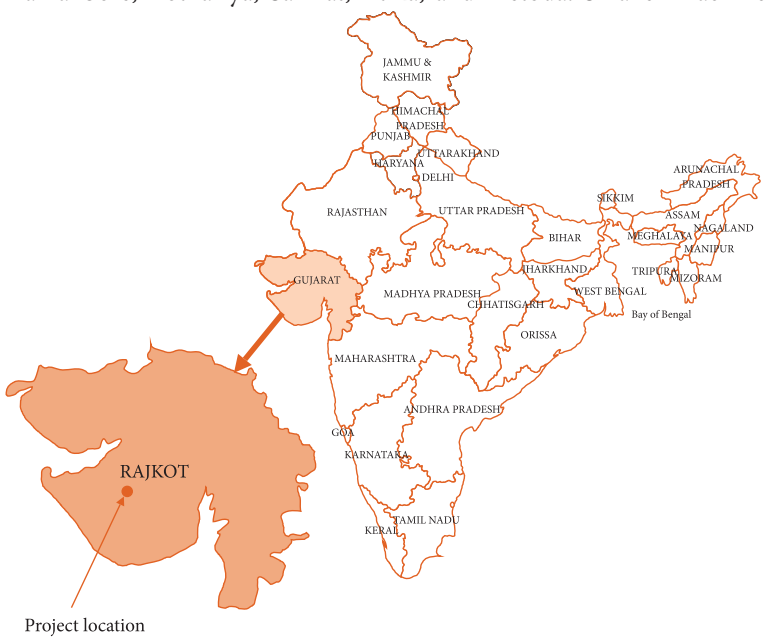
Last but not least, our sincere thanks to MSME entrepreneurs and other key stakeholders in the cluster for providing valuable data and inputs that helped in cluster analysis.

Rajkot Machine Tools Cluster

Overview of cluster

Machine Tool Manufacturing Cluster Rajkot, located in the state of Gujarat, is an important industrial cluster in India. Rajkot ranks first in production of conventional machine tools followed by Ludhiana and Batala; it stands next to Bengaluru in Computer Numerical Control (CNC) machine tools manufacturing. Rajkot is known as the main hub of machine tools manufacturing sector of India. It supplies machineries all over India. The industrial activities in the cluster got developed in 1960s, with setting-up of few small units, and as demand grew, many more units were established. Rajkot is one of the largest industrial clusters comprising foundry and forging industries that cater to the requirements of machine tool manufacturing. Today, Rajkot cluster hosts CNC/vertical machining centre (VMC), lathe, hydraulic and mechanical press, drilling machine, slotting machine, special purpose machines (SPMs), and accessory manufacturers.

There are an estimated 15,000 micro, small, and medium enterprise (MSME) units in Rajkot, of which majority are foundry and engineering units. The cluster is spread within Rajkot and neighbouring Gujarat Industrial Development Corporation (GIDC) industrial estates. The engineering industry is diverse in nature. Some of the major engineering segments include foundry, agro and diesel pump sets, machine tools, auto components, kitchenware and hardware, forging, and diesel engine. Rajkot is one of the largest producers of conventional lathe machines, press machines, CNC/VMC, and SPMs. There are about 400 machine tool and allied manufacturing units located in the cluster. Some of the larger geographical concentrations of machine tool manufacturing units include Shapar, Aji, Bamanbore, Kothariya, Samrat, Atika, and Metoda. Smaller machine tool manufacturers



produce up to 15-HP capacity, while the bigger manufacturers produce machine tool sets up to 50 HP. Leading machine tool manufacturers in the cluster include Jyoti CNC, Singhal Power press, Macpower CNC machines, Weldor Engineering, Kawa Machine Tools, and Gujarat Lathe Manufacturing.

Products, market, and production capacities

The raw materials used in machine tool industries are mainly castings and engineering components that include foundation bed, shafts, gears, sheet metal components, and screws. Castings are sourced from foundries and other raw materials are procured from allied component manufacturers. Machine tools manufacturers traditionally cater to the needs of engineering sector. Major products manufactured by machine tool units include conventional lathe machines, press machines, CNC and VMC machines, drilling machines, bending machines, power press, SPMs, etc. along with machine tool accessories such as gears, centring tools, lead screw, bush, chuck, etc. Few manufacturers export CNC and VMC machines for different industrial sectors, such as automobile component manufacturers, bearing industries, machining industries, aerospace, furniture and hardware industries, sheet metal components, forging industries, electrical and electronic manufacturing industries, etc. The machine tool industries in Rajkot cluster may be categorized as follows:

Categorization of machine tool industries in Rajkot cluster

Category	Number of units
Metal cutting	200
Metal forming	120
Machine tool accessories	80

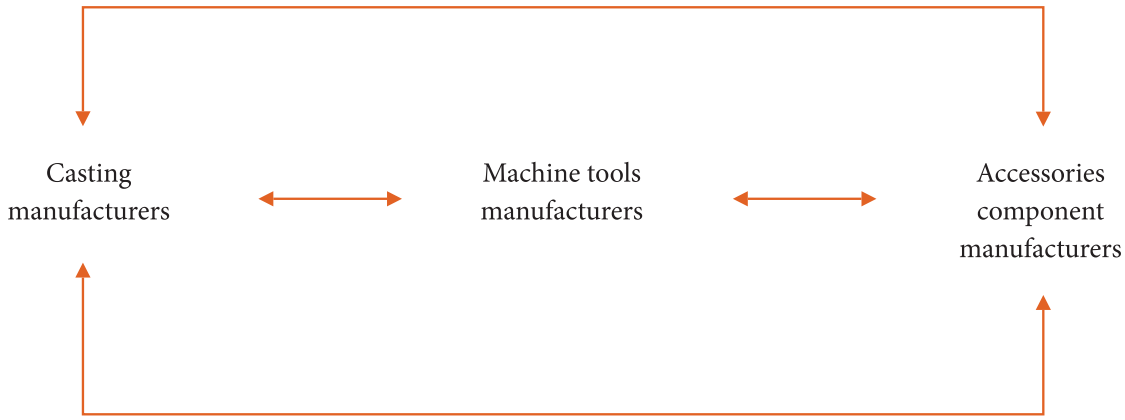
Further, based on the quantum of production, these categories can be classified into three capacities as shown in the following table.

Capacities of machine tool units

Category	Units	Capacity A	Capacity B	Capacity C
Metal cutting	Number of machines	25	300	2,000
Metal forming	Number of machines	30	150	400
Machine tool accessories	Number of pieces	24,000	300,000	–

Casting and forged machine parts required for machine tool manufacturing are generally sourced from foundries, forging, and component industries. For example, machine tool industry needs components, such as machine foundation bed, shaft, which are manufactured in foundry and forging industries. The linkage between machine tools and associated industries is shown.

The manufacturers in Rajkot produce machine tools of two types (i) conventional and (ii) new technologies that include CNC, VMC, and horizontal machining centre (HMC). Majority of the manufacturers in the cluster are engaged in production of conventional machines, while few are involved in manufacturing customized machines



Linkages between industries

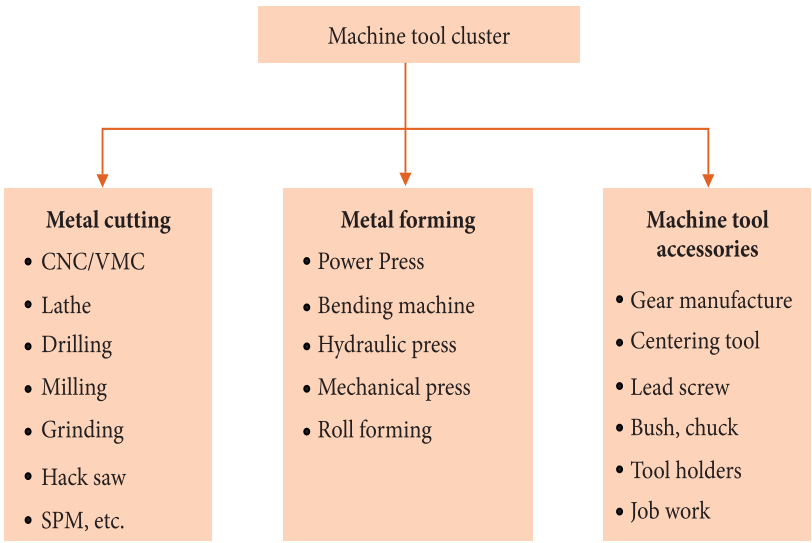
to meet client demands. It may be noted that the present market demand is more towards use of CNC and VMC machines as against conventional machines.

Product categories

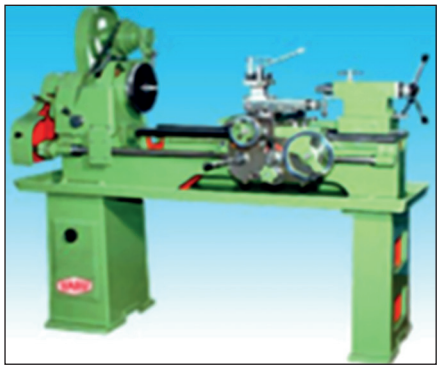
Different products manufactured in the cluster include CNC machine, lathe machine (light/medium/heavy duty), hydraulic press, surface grinding machine (manual/ hydraulic), cylindrical grinding machine, centring tool, spur gear, etc.

Production process

The manufacturing of machine tool encompasses a wide range of processes including planning process based on customer requirements, design and development of product, raw material procurement (castings and accessories), machining of components, painting sub-assembly and assembly, inspection and testing, packing, and dispatching. The process steps followed are summarized. A simplified process flow diagram of a typical machine tool unit is shown in the figure.



CNC machine

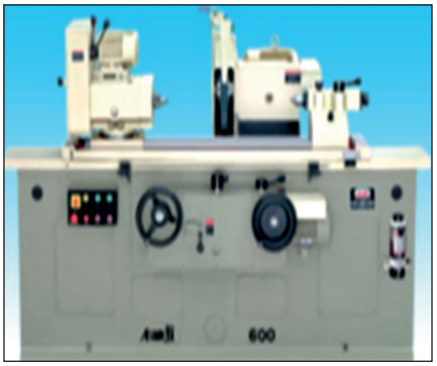


Lathe machine (Light/ medium/heavy duty)

Hydraulic press

Surface grinding machine (manual)

Surface grinding machine (hydraulic)



Cylindrical grinding machine

Centering tool

Spur gear

Gear blank

Assessment of customer requirements

Based on detailed discussions with customers on machine requirements, details such as specifications and capacity are prepared generally by sales department and forwarded to design and development department. Most of the smaller size units manufacturing conventional machines have standard designs that they have developed based on past experiences.

Design and development

Based on inputs from sales department, standard designs are used or customization/modification done on standard design to suit the needs of customers and preparation of bill of material as per machine design.

Raw material procurement

In majority of the metal cutting machine manufacturing industries, 70% of the raw material is casting, for example, foundation bed, support arms, pillar, slides and guide ways, tailstocks, etc. In metal-forming machine manufacturing industries, main raw material is metal plate used for fabrication of machine bed and support frame. Other raw materials, such as bearings, shafts, chucks, belt, fasteners, lead screw, ball screw, box nut, gears and gear box along with motors, CNC/Programmable Logic Controller (PLC) control panels are procured from external accessory suppliers and vendors. Raw material cost forms 60% of total production cost.

Machining and heat treatment

Machining of castings and rough machining of spare parts, such as shafts, gears, bushes, and pulleys are outsourced. Finishing operation of these components is done in-house to ensure level of accuracy and close tolerance. Some of the components requiring heat treatment processes, such as normalizing, hardening, and stress relieving are also outsourced as the machine tool units generally do not have such facilities.

Painting, sub-assembly, and assembly

After machining of components, painting is done using spray guns. Sub-assembly of metal components is done separately. At the time of assembly, 'blue match' (i.e. mating of two or more components using highly pigmented paste) between two sliding components is done to avoid any high point in sliding motion through scraping of high points on surfaces. In case of metal-forming machine assembly, welding and fabrication of metal plates are carried out to fabricate bed and frame of machine. Once all moving slides are assembled and all mechanical accessories along with electrical components, such as motor, CNC/PLC control panel, and proper cabling and complete lubrication systems are fitted, machine is ready for inspection and testing.

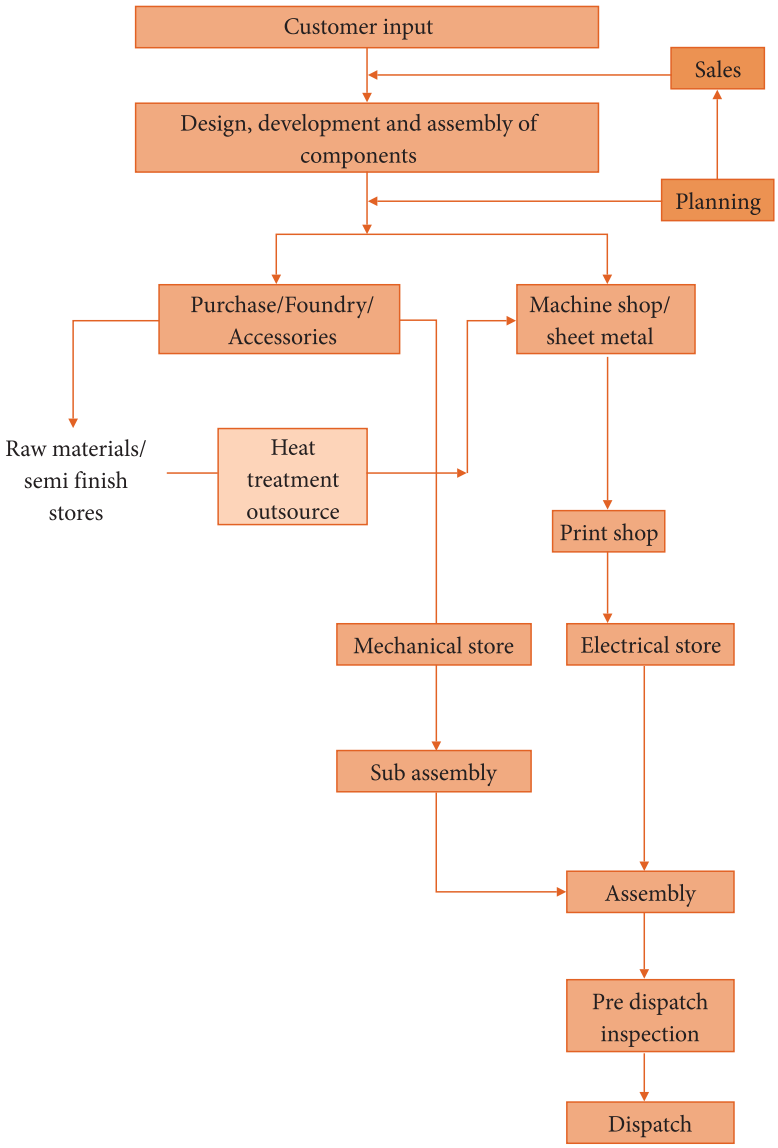
Inspection and testing

Inspection of 'fully assembled' machine is done to ensure quality. Testing of machine is carried out as per standards. In some cases, testing is also carried out with actual job work on machine to check and ensure precision and accuracy of machining.

Packing and dispatch

The inspected and tested machine is packed and sent for dispatch.

At each stage, industries either opt for in-house or outsource. Large capacity manufacturers, for example, Jyoti CNC have in-house casting and heat treatment facilities. The Capacity A and Capacity B units procure 60% of raw material from outside supplier/vendors.



Process flow diagram of a machine tool unit

Technologies employed

Some of the major processes/equipment used in machine tool manufacturing units are described below.

Conventional machining

The Capacity A and Capacity B units use conventional manual machining units. Conventional machining includes power-driven machine tools, such as lathes, milling, shaping, planing, grinding, and drilling machines that are used for rough as well as finish machining of foundation bed, gears, shaft, key ways, pulleys, saddle, etc.

Milling machine

Lathe machine

Shaping machine

Cylindrical grinding machine

CNC/VMC/HMC machining

The large and medium units use CNC, HMC, and VMC machines. Employing CNC machines can help in reducing costs, lead times and tooling, and improve quality and productivity. Even today, CNC machines are more expensive than manually operated machines, although their costs are slowly coming down. CNC comes in different orientations—horizontal and vertical. The selection and use of CNC is based on type of applications.

5-Axis CNC machine

HMC machine

Manual assembly

Most of the units in the cluster follow manual assembly process. Assembly work is modified depending on machine and customization requirements. In some cases, customized automation assembly of electronic components such as PLC and CNC panels is also done. The duration required for assembly varies based on type and customization of the machine.

Manual assembly area

Air compressor

Compressed air is used in pneumatic grinders, burr cleaning, and painting and for other miscellaneous uses in a machine tool manufacturing unit. The connected load of compressed air system may vary from a few kilowatts (single air compressor) for a small/ micro scale unit to 22 kW for a medium-scale manufacturer. The pressure requirement for majority of applications is kept below 5 kg/cm^2.

Reciprocating air compressors

Screw air compressor

Energy scenario in the cluster

Electricity is the major source of energy used in machine tool manufacturing. Electricity is supplied by Paschim Gujarat Vij Company Limited (PGVCL). Diesel is used in diesel generator (DG) sets to generate electricity to meet requirements during unscheduled power outage. Diesel is procured from local market. The power outage is very minimal in the cluster, and hence, diesel consumption is insignificant at cluster level. The details of major energy sources and tariffs are given in the following table.

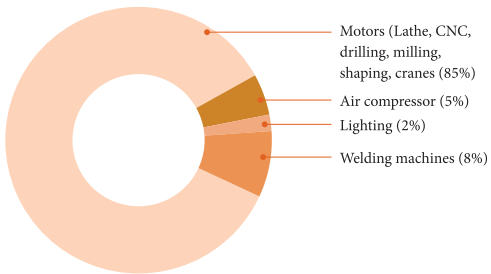
Prices of major energy sources

Source	Remarks	Price
Electricity	High Tension connection (HT)	₹ 8.5 per kWh (inclusive of energy, demand charges, other penalty/ rebate and electricity duty)
	Low Tension connection (LT)	₹ 9 per kWh (inclusive of energy, demand charges and electricity duty)
Diesel	From local market	₹ 50 per litre (price subjected to market fluctuations)
Natural Gas	BPCL, HPCL, IOCL	₹ 32 /SCM (price subjected to market fluctuations)

Energy consumption

Unit level consumption

Electricity is used to run all machinery. Most of the units in the machine tool cluster have LT connections with exceptions of large-scale industries, like Jyoti CNC, Singhal Power Press, and Macpower Manufacturing, which have HT connections. The power supplied at 11 kV is stepped down to 433 V using common transformer of PGVCL and fed to respective power distribution board through LT switchgear located at main distribution. Diesel is used in DG sets only in case of unscheduled power outage.



Share of energy use in machine tool manufacturing

The major energy consuming areas in machine tool manufacturing are motors used in various applications, such as

lathe, CNC, drilling, cranes, etc., which are operated for longer durations. Machining and crane motors account for about 85% of total energy consumption followed by welding machines (8%) and compressed air system (5%). The motor driven presses in most units are operated without any control mechanism. The share of energy usage in a typical small and medium machine tool manufacturer is given in the figure.

The specific energy consumption (SEC) of machine tool units varies considerably depending on type of machines being manufactured. It may be noted that the share of energy cost in final product accounts for only 1–2%. Typical energy consumption based on manufacturing capacity is given in table.

Unit level energy consumption of machine tool manufacturers

Typical unit level	Electricity (kWh/yr)	Diesel (litre/yr)	Total energy (toe/yr)	Total CO_2 emissions (tonne CO_2/yr)	Annual energy bill (₹ in million)
Metal cutting	22,686	50	2.0	22.4	0.18
Metal forming	20,005	36	1.8	19.7	0.17
Machine tool accessories	15,836	15	1.4	15.6	0.13
** Except energy consumption for heat treatment for 'components' which is 100% outsourced.*					

Cluster level consumption

The overall energy consumption of cluster is about 2,374 tonnes of oil equivalent per annum leading to carbon emissions of 21,331 tonnes of CO_2. The overall energy bill of cluster is Rs 68 million, which is about 1–2% of cluster turnover. The energy consumption pattern in the cluster is given in the table.

Energy consumption of machine tool cluster (2015–16)

Energy type	Annual consumption	Equivalent energy (toe)	Equivalent emissions (tonne CO_2)	Annual energy bill (Million INR)
Electricity (Million kWh)	20.5	1,760	20,061	167.0
Thermal				
Diesel (Lit/yr)	8,845	8	23	0.4
Natural gas (SCM/yr)	712,500	606	1,247	21.0
Total		**2,374**	**21,331**	**188.4**

Potential energy-efficient technologies

Some of the major energy efficient (EE) technologies relevant for the machine tool units in the cluster are discussed below.

Energy Efficient IE3 standard motors

All the units in the cluster are using lathe machines, hydraulic press machines, drilling machines etc., which use

electrical motors. The ratings of these motors vary from 0.5 HP to 5 HP depending on the capacity of machine and operations to be performed. Most of these motors operate on low loads except during cutting or drilling operation. The power factor of these motors was observed to be generally lower than 0.87.

Due to presence of significant variable and jerk loading pattern observed in motors used in machines, failure rates are also observed to be high. Further, no load losses of these motors are high, which increases the overall energy consumption. There is a lack of awareness about efficiency standards of motors. It was observed that most of the units use low-efficiency standard motors. There is a significant potential for energy savings by replacing low-efficiency motors with energy efficient IE3 standard motors. Depending on the operation period of the machines, payback period for EE motors can vary between 10 months to two years. Energy saving of 3% can be achieved on replacement of old IE2 motor with IE3 motor and savings upto 7% can be achieved on replacement of old IE1 standard motor with IE3 motor.

IE1 and IE2 motors used in the cluster

IE3 motor

Cost-benefit analysis for IE3 motors

Parameter	Unit	3 HP motor	5 HP motor
Power consumption of existing lathe motor	kW/hr	2.4	4.1
Efficiency of existing motor	%	79.7	86.3
Efficiency of IE3 standard motor	%	86.7	88.4
Estimated power consumption of IE3 motor	kW/hr	2.21	3.8
Annual energy cost savings	₹/yr	5,232	8,100
Investment required	₹	4,000	10,000
Simple payback period	Yr	0.8	1.2

Inverter-based welding machines

Inverter based power sources allow delivery of more power output from new power electronics technology, resulting in a better performance-to-size ratio. These models also deliver smooth operation with greater efficiency than many older, conventional welding power sources. Old transformer rectifier based welding machines have efficiency of 67% while inverter based machines can perform with 87% efficiency with better power factor. Inverter based welding power sources offer following advantages:

- Lightweight and portable
- Able to obtain superior stick welding performance with all electrode types

- Multi process welding output without sacrificing arc performance in any mode
- Quick response to changing arc conditions (e.g., maintains steady weld output)
- Superior control over pulsed welding processes
- Line voltage independent-uses single or three phase input power and multiple input voltages without any manual relinking mechanism
- Better power factor (more efficient use of power from the utility)
- Less susceptibility to primary voltage fluctuations

Transformer coil type welding machine

Inverter type welding machine

Cost-benefit analysis for inverter-based welding machines

Parameter	Unit	Value
Power consumption of transformer rectifier welding machine (for 160 Amps)	kW/hr	4.04
Power consumption of inverter welding machine	kW/hr	3.1
Annual energy cost savings	₹/yr	15,228
Investment required	₹	20,000
Simple payback period	yr	1.3

Inverter-based welding power sources can perform high as well as low amperage flux cored, stick, TIG, and MIG welding. The inverter-based models deliver multi-process welding capabilities, offering faster arc response, smoother arc action, and a more consistent bead appearance.

Air compressor

Some of the units in Capacity B and Capacity C types in the cluster use compressed air for various pneumatic utilities and cleaning purpose. Electrical rating of these compressors ranges from 5 HP to 30 HP. Larger units use screw compressors whereas smaller units use reciprocating compressors. Screw compressors are designed to operate on more than 80% load for efficient performance. There is a huge potential for energy saving by adopting variable

Reciprocating compressor (in smaller units)

Screw compressor with VFD (in larger units)

frequency drive (VFD) based screw air compressors and permanent magnet motor (PMM) based air compressors having higher CFM to power ratio. Energy savings can range from 15 to 40% compared with the existing system.

Cost-benefit of VFD screw air compressor

Parameter	Unit	Value
Annual power consumption of existing screw compressor (30 HP)	kW/CFM	0.23
Estimated power consumption with PMM- and VFD-based screw air compressors	kW/CFM	0.15
Annual energy cost savings	₹/yr	295,773
Investment required	₹	500,000
Simple payback period	yr	1.7

Cranes and hoists

Cranes and hoists are widely used in machine tool industry to enable movement of heavy parts and components. Cranes and hoists have two motors for horizontal and vertical movement with rating of 7.5 HP to 75 HP depending on crane capacity. As these motors go under frequent on/off cycles along with jerk loading, application of VFD in crane operation may lead to an energy saving of about 15%. VFDs will also facilitate soft start thereby avoiding jerk starts, which will further help in increasing motor life.

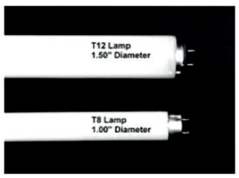
VFDs installed in cranes and hoists

Cost benefit of VFDs in cranes

Particular	Unit	Value
Power consumption of conventional hoist motor	kW/hr	22
Power consumption of hoist motor with VFD	kW/hr	18
Annual energy cost savings	Rs/yr	43,200
Investment required	Rs	60,000
Simple payback period	yr	1.4

Lighting

T-12 tube lights (of 52 W including choke) and halogen lamps (150W and 250W) are generally used by machine tool units in the cluster. These inefficient lightings can be replaced with energy efficient LED lighting (LED tube lights of 10W and 20W) and flood lamps and high bay lamps (20 W, 40 W, and 80 W), which would provide better illumination and energy savings. Since a large number of lamps are used in the units, the existing lighting may be replaced with EE lighting in a phased manner.



T12 and T8 FTL


T5 FTL


High bay HPMV lamp


High bay Magnetic induction lamp

Cost-benefit analysis of EE lighting

Particular	Unit	Value
Power consumption with 52W T-12 FTLs	Watt/hr	52
Power consumption with EE LED tube light of 20 W	Watt/hr	20
Annual energy cost savings	₹/year	864
Investment required	₹	1,000
Simple payback period	year	1.2

Heat treatment furnace

All the Capacity A and Capacity B units in the cluster outsource heat treatment operation of components. The heat treatment furnaces use natural gas (NG) as fuel. The exit flue gas temperatures of furnaces used in these units are in the range of 500–750oC. These furnaces have not been equipped with any heat recovery systems. The waste heat available with high temperature flue gases can be recovered in a metallic recuperating system to preheat combustion air that can result in significant improvement in furnace efficiency (over 10%) substantial reduction in fuel consumption.

Cost-benefit analysis of heat treatment furnace

Particular	Unit	Value
Flue gas exit temperature from furnace	°C	550
Present temperature of combustion air at burner inlet	°C	38
Temperature of preheated combustion air	°C	200
Annual energy cost savings	₹/yr	160,000
Investment required	₹	3
Simple payback period	year	1.9

Major cluster actors and cluster development activities

Industry associations

There are several industry associations in Rajkot Machine Tool Cluster. The major industry associations that are active in the cluster are briefed below.

Machine Tools Manufacturers Association, Rajkot

Machine Tools Manufacturers Association (MTMA), Rajkot, was established in 1983 and was involved in activities pertaining to common issues of machine tools industries and strongly represents their hindrances. Major activities of MTMA include technology upgradation programme, participation in various domestic and international exhibitions, and technology exposure visit.

Rajkot Engineering Association (REA)

Rajkot Engineering Association (REA) is the apex industry association for engineering industry in Rajkot and has membership of over 1,600 industrial units. The association was incorporated in 1963 with an objective of providing support for its members on promotion and development of its manufacturing activities.

The Institute of Indian Foundrymen, Rajkot Chapter

The Rajkot chapter of Institute of Indian Foundrymen (IIF) is one of the most vibrant chapters in the Western Region. The chapter organizes meetings on monthly basis and discusses new initiatives to be taken and other activities such as participation in various exhibitions, technology upgradation, seminars, and workshops. IIF has been progressive and has started implementing lean manufacturing by forming lean cluster of few foundries.

District Industries Centre

The District Industries Centre (DIC), Rajkot, provides several incentives to MSMEs such as capital investment subsidy, interest subsidy, venture capital quality certification, energy and water audits, and so on. DIC is very active in creating awareness about trade information, import–export, and financial rules and regulations for MSMEs.

Cluster development activities

The United Nations Industrial Development Organization (UNIDO) had undertaken a technology upgradation program among machine tool units in Rajkot. Rajkot cluster has been adopted by UNIDO for cluster development program for machine tools industries. Under this program, MTMA and UNIDO had organized various programmes for their members. A testing laboratory has been set up as a Common Facility Centre (CFC) in the campus of National Small Industries Corporation (NSIC) with the help of Indian Machine Tools Association, Bengaluru.

Abbreviations

Abbreviation	Full form
CFC	Common Facility Centre
CFM	Cubic feet per minute
CNC	Computer Numerical Control
DG	Diesel Generator
DIC	District Industries Centre
EE	Energy Efficient
GIDC	Gujarat Industrial Development Corporation
HMC	Horizontal Machining Centre
HT	High Tension
IIF	Institute of Indian Foundrymen
kL	Kilolitre
kW	Kilowatt
kWh	Kilowatt-hour
Lit	Litre
LT	Low Tension
MSME	Micro, Small, and Medium Enterprise
MTMA	Machine Tools Manufacturers Association
NG	Natural Gas
NSIC	National Small Industries Corporation
PGVCL	Paschim Gujarat Vij Company Limited
PLC	Programmable Logic Controller
PMM	Permanent Magnet Motor
REA	Rajkot Engineering Association
SEC	Specific Energy Consumption
SME	Small and Medium Enterprise
SPM	Special Purpose Machine
SSEF	Shakti Sustainable Energy Foundation
t	tonne
TERI	The Energy and Resources Institute
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive
VMC	Vertical Machining Centre

Note

Note

About TERI

A dynamic and flexible not-for-profit organization with a global vision and a local focus, TERI (The Energy and Resources Institute) is deeply committed to every aspect of sustainable development. From providing environment-friendly solutions to rural energy problems to tackling issues of global climate change across many continents and advancing solutions to growing urban transport and air pollution problems, TERI's activities range from formulating local and national level strategies to suggesting global solutions to critical energy and environmental issues.

The Industrial Energy Efficiency Division of TERI works closely with both large industries and energy intensive Micro Small and Medium Enterprises (MSMEs) to improve their energy and environmental performance.

About SSEF

Shakti Sustainable Energy Foundation (SSEF), established in 2009, is a section-25 not-for-profit company, which aids design and implementation of clean energy policies that support promotion of air quality, energy efficiency, energy access, renewable energy and sustainable transportation solutions. The energy choices that India makes in the coming years will be of profound importance. Meaningful policy action on India's energy challenges will strengthen national security, stimulate economic and social development, and keep the environment clean.

Apart from this, SSEF actively partners with industry and key industry associations on subsector specific interventions towards energy conservation and improvements in industrial energy efficiency.

About SAMEEEKSHA

SAMEEEKSHA (Small and Medium Enterprises: Energy Efficiency Knowledge Sharing) is a collaborative platform set up with the aim of pooling knowledge and synergizing the efforts of various organizations and institutions – Indian and international, public and private – that are working towards the development of the MSME sector in India through the promotion and adoption of clean, energy-efficient technologies and practices. The key partners of SAMEEEKSHA platform are: (i) Swiss Agency for Development and Cooperation: (ii) Bureau of Energy Efficiency: (iii) Ministry of MSME, Government of India and: (iv) The Energy and Resources Institute.

As part of its activities, SAMEEEKSHA collates energy consumption and related information from various energy intensive MSME sub-sectors in India. For further details about SAMEEEKSHA, visit **http://www.sameeeksha.org**

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