ENERGY PROFILE

AGRA FOUNDRY CLUSTER

The Energy and Resources Institute

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Promoting Energy Efficiency in SMEs
SAMEEEKSHA

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Certificate of originality

Suggested format for citation

TERI. 2018
Energy Profile: Agra Foundry Cluster
New Delhi: The Energy and Resources Institute; 24pp.
[Project Report No. 2017IE03]

Disclaimer

Published by

TERI Press
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Abbreviations

Abbreviation	Full form
cfm	cubic feet per minute
DI	Development Institute
DIC	District Industries Centre
HT	High Tension
IIF	Institute of Indian Foundrymen
kWh	kilowatt-hour
LT	Low Tension
MSME	Micro Small and Medium Enterprises
NG	Natural Gas
No.	Number
PDB	Power Distribution Board
PMSM	Permanent Magnet Synchronous Motor
PPDC	Process and Product Development Centre
Rs	Indian Rupees
SCM	Standard Cubic Metre
SEC	Specific Energy Consumption
SG iron	Spheroidal Graphite cast iron
SPC	Specific Power Consumption
SPV	Special Purpose Vehicle
t	tonne
T	tonne
toe	tonne of oil equivalent
VFD	Variable Frequency Drive

Acknowledgements

Shakti Sustainable Energy Foundation (SSEF) works to strengthen India's energy security of India by aiding the design and implementation of policies that support renewable energy, energy efficiency and sustainable transport solutions. TERI places on record its sincere thanks to SSEF for supporting the project on Advancing Energy Efficiency in the Micro, Small and Medium Enterprise (MSME) sector in India.

The team at TERI is indebted to MSME-Development Institute (DI), Agra; Institute of Indian Foundrymen (IIF), Agra Chapter, and Agra Iron Founder's Association (AIFA) for providing support, data and information related to foundry units in Agra cluster. TERI extends its sincere thanks to Mr Shashi Kumar Jain, Vice-President, IIF, and Mr Pramod Kumar Agarwal, ex-President, AIFA, for organizing field visits and interactions with unit members during the study for the preparation of this cluster profile report. TERI also places on record the support provided by Mr Gaurav Agarwal, National Council Member IIF during the study. TERI places special thanks to Mr V M Jha, Deputy Director, MSME-Development Institute (DI), Agra for the support.

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

Agra Foundry Cluster

Overview of the cluster

Location of Agra and New Delhi (Source: Google Map)

Agra is located on the banks river Yamuna in the state of Uttar Pradesh. The presence of Taj Mahal has made Agra a major tourist destination. Leather, handicrafts, and garment manufacturing industries flourished across Agra to cater to the tourist population. Subsequently, small foundries were established to support the machinery and spare parts requirement of local industries.

Agra had over 100 foundries, but presently only about 80 of them are in operation. The foundry units are scattered both within and outside the city. The major concentrations of foundry units are in Rambagh, Nunhai and Foundrynagar. Many foundry units in Agra have shifted to induction melting furnace which others are still using natural gas fired cupola furnaces. The smaller cupola-based foundries typically melt once or twice a week.

Product, market, and production capacities

The major raw materials for foundry include pig iron, metal scrap, borings, coke, graphite, limestone and ferroalloys such as ferro-silicon and ferro-manganese. They are procured from distributors and local market. Typical raw material and their cost are given in table.

Raw material and their costs (Rs per tonne)

Raw material	Typical cost
Pig iron	33,000 – 35,000
Scrap	25,000 – 32,000
Borings	20,000 – 22,000
Ferro-silicon	72,000 – 74,000
Ferro-manganese	79,000 – 82,000
Limestone	1,200 – 2,100

Agra foundry units cater to the casting requirements of diesel generator-set, automotive, air compressor and other engineering sectors. Based on their average production levels, categorization of foundry industries in the cluster is given in the following table.

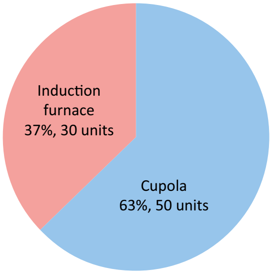
Categorization of units and estimated production

Category	Production (tonne/month)	Employment (Nos.)	Turnover (million Rs/year)
A — Micro	35	15	15
B — Small	75	35	50
C — Medium	250	80	150
D — Large	1000	150	750

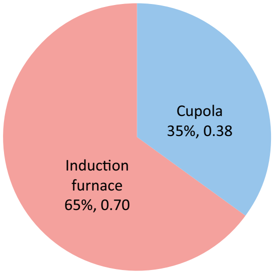
A majority of the foundry units fall under micro and small category: 40 and 23 respectively. About 15 units are medium category while just 2 units are under large category. The estimated production of the cluster is 360 tonnes per day (~0.11 million tonnes per annum). The foundries employ close to 3,000 direct employees. The estimated annual turnover of the foundry cluster is nearly Rs 550 crore. Some of important products produced in the cluster are shown in the figure.

Major products from Agra foundries

Of the foundry units operating in Agra cluster, about 35% production is accounted by cupola furnace-based units (50 foundries). The balance 65% production comes from induction furnace based units (30 foundries). The foundry units mostly use green sand moulding technique which some others use the cold box process for core making.



Number of units



Annual production in lakh tonne

Production process

The major steps in foundry production process are mould sand preparation, charge preparation followed by melting, pouring, knockout, and finishing. A simplified process flow diagram of a typical green sand moulding unit is given in figure. The process steps are explained below.

Mould sand preparation

Fresh sand is mixed with bentonite and other additives and mixed in muller to make green sand. Plants in general use sand mixers and sieves for mould sand preparation. Category A and Category B foundry units have 250–350 kg capacity sand mixers; Category C foundries have bigger sand mixers, with typical size of about 500–800 kg capacity. The large foundries have sand plants.

Moulding

The mould sand is pressed manually or using pneumatic machines on the pattern to prepare moulds. The mould is divided into two sections, namely upper half (cope) and bottom half (drag) which meet along a parting line. Both mould halves are enclosed inside a box, called flask, which is also divided along parting line. The mould cavity is formed by packing sand around the pattern (which is a replica of the external shape of the casting) in each half of the flask. The sand can be packed manually, but moulding machines that use pressure to pack sand are also commonly used. About 50% of foundries use hand moulding technique which the remaining use pneumatic moulding lines. A few units have installed high pressure moulding lines.

Charging of raw material

The raw material such as pig iron, scrap, foundry returns, and other alloys are weighed in proper proportion and charged in the melting furnace. Both manual charging and mechanical charging is adopted by cupola units. The material is charged manually in induction furnaces.

Melting

In induction furnace, metal is charged in batches. Typical sizes of melting furnaces used in the cluster are 300 kg, 500 kg, and 1000 kg. Typical melting time for each batch is about 60 minutes. The cupola furnaces melt metal continuously for upto 8 hours. Typical size (internal diameter) of cupolas used in the cluster are 2 tonnes per hour (25 inch) and 3.5 tonnes per hour (36 inch). The initial chill metal from cupola is pigged and recycled. The condition of molten metal is visually verified by the operator, after which pouring of molten metal begins. The metallics, coke, and limestone are charged in a systematic manner during the cupola operation.

Pouring

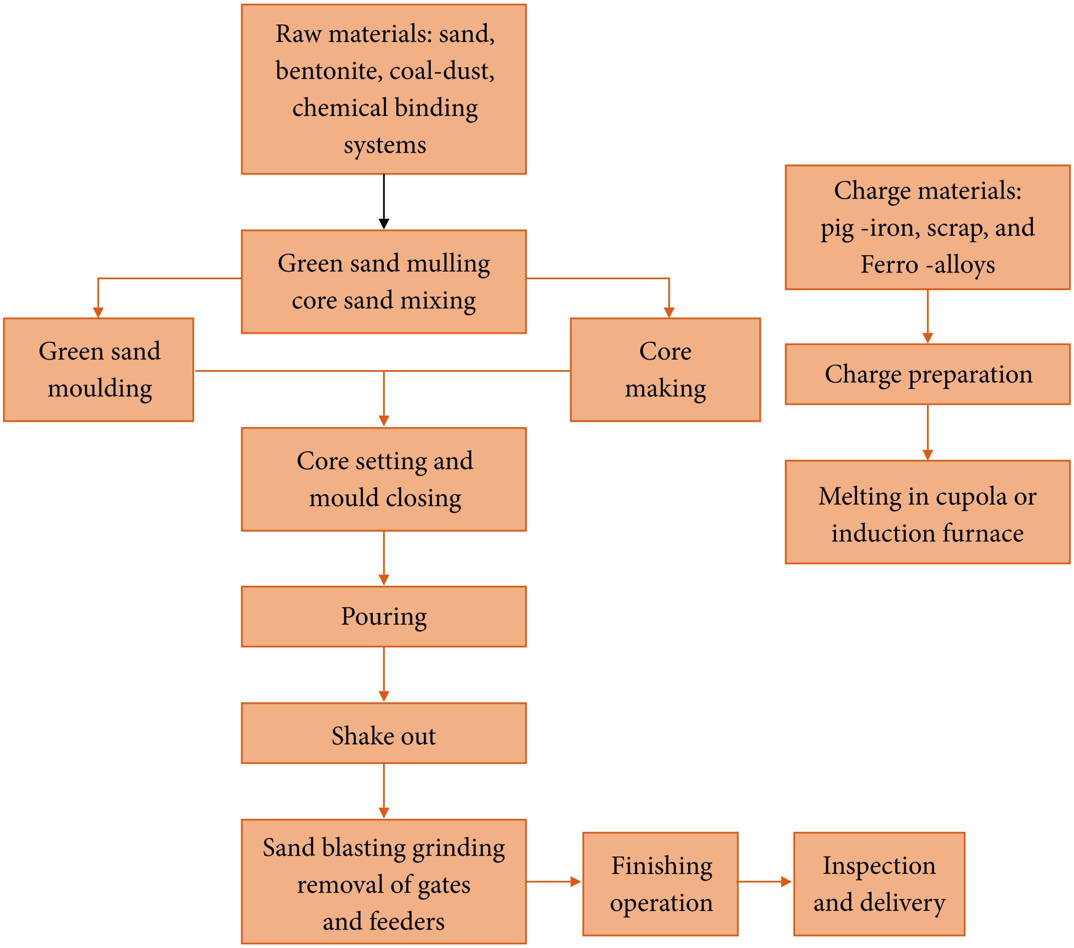
After melting, the molten metal is transferred and poured into the moulds manually using ladles. In some induction furnace-based foundries, molten metal is transferred to moulds using mono-rail system or overhead cranes.

Knocking out of castings

The moulds are left to cool for certain time, after which the castings are knocked out from the mould either manually or using a vibratory knock-out machine.

Finishing

The finishing operation involves removal of runners/risers, shot blasting, and cleaning of castings. This is followed by fettling and machining. In case of steel casting, heat treatment is also an integral part of the finishing operations.



Manufacturing process of foundry

Technologies employed

A number of technologies are employed in the cluster, some of which are elaborated as follows:

Melting

Cupola furnace

The small and micro units use cupola furnace for melting. Majority of units have installed gas-fired cupola. The specific energy consumption (SEC) of the cupolas vary in range of 60 – 70 SCM natural gas per tonne of molten metal. The bed is usually prepared with the graphite procured from steel mills.

Gas-fired cupola

Induction furnace

Most of the induction furnaces are small in size. These furnaces are operated in batch mode, and the typical cycle time and SEC vary considerably depending on the type of metal melted (cast iron, SG iron, steel, etc.) and the size of castings. The SEC varies in range of 650–750 kWh per tonne and batch duration varies between 40 and 80 minutes.

Induction furnace

Sand mixers

Sand preparation is performed using sand mixers and sand sieves. Sand mixers have typical batch size of 100 to 500 kg. The mixers have two motors—mixer motor and blender motor. The connected load of these mixers is about 10–30 kW. These sand mixers operate in batch mode and do not have proper control over the quantity of bentonite and water addition. There is no control of cycle time as well, which typically varies between 6 and 9 minutes.

Sand mixer

Air compressor

Compressed air in the foundries is used mainly in pneumatic grinders, shot blast, pneumatic rammers, and for cleaning. Few units have jolt squeeze pneumatic moulding machines. The connected load of air compressor ranges from a few kW to 45 kW. The pressure requirement for all the applications is below 6.1 kg/cm^2. Typically, smaller a foundries do not use compressed air in the process as they follow hand moulding technique and send casting to third party for fettling and shot blasting.

Air compressor

Energy scenario in the cluster

Natural gas and electricity are the major sources of energy for the foundry industry. Depending on location of foundry grid electricity is supplied by Torrent Power or Dakshinanchal Vidyut Vitran Nigam Limited (DVVNL) also called Agra Discom. Diesel or natural gas is used in captive generator sets during unscheduled power outages. Natural gas is also used for melting in gas fired cupolas. Piped natural gas is provided by GAIL Gas Ltd, a wholly owned subsidiary of GAIL (India) Limited. The details of major energy sources and tariffs are shown in the table below.

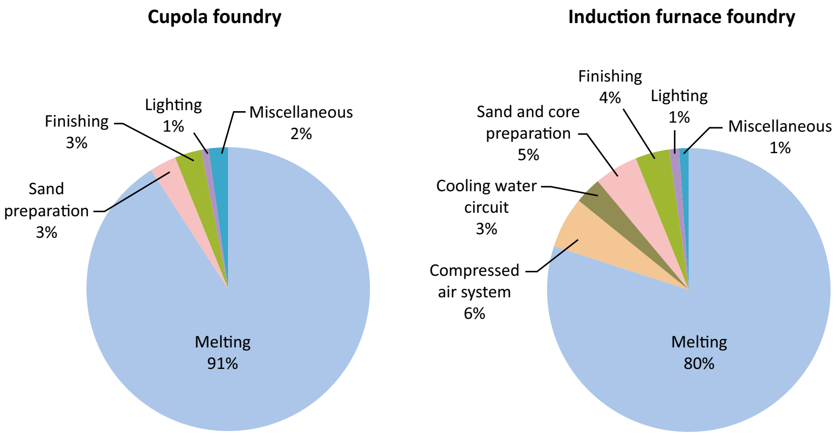
Prices of major energy sources

Source	Remarks	Price
Electricity	Supplier: Torrent Power Connection type: HT	Supply at 11kV Demand charge: Rs.250/kVA/month Energy Charge: Rs.6.65/kVAh
Electricity	Supplier: Torrent Power Connection type: LT	Energy charge: Rs 7.00 per kWh (upto 300 kWh/month) Rs 8.00 per kWh (for 301-1000 kWh/month) Rs 8.30 per kWh (1001 kWh/month onwards) Demand charge: Rs 300 kW/month (upto 2kW) Rs 350 kW/month (from 2kW to 4kW) Rs 430 kW/month (above 4kW)
Electricity	Supplier: DVVNL or Agra Discom Connection type: LT	Energy charge: Rs. 7.00 / kWh (Upto 1000 kWh/month) Rs. 7.35 / kWh (from 1001 to 2000 kWh/month) Rs. 7.60 / kWh (For above 2000 kWh/month) Demand charge: Rs 245 kW/month (upto 4kW) Rs 255 kW/month (from 4kW to 9kW) Rs 275 kW/month (above 9kW)
Electricity	Supplier: DVVNL or Agra Discom Connection type: HT	Supply at 11kV Demand charge: Rs. 250/kVA/month Energy charge: Rs. 6.65/kVAh
Natural gas	Supplier by Gail Gas Ltd	Rs 265.96 per MMBTU
Diesel	From local market	Rs 65 per litre (price subjected to market fluctuations)

Energy consumption

Unit level consumption

The units under Category A and some unit under Category B have LT electricity connections whereas majority of Category C and D units have HT electricity connections. The power supplied at 11 or 33 kV is stepped down to 433 V using transformer and is fed to the respective power distribution board (PDB) via LT switchgear located at the main distribution.



Typical energy use in a foundry

The major energy consuming process in a foundry is melting. In cupola-based units, melting accounts for about 90% of total energy consumption, whereas in induction furnace-based units, it is between 75-80%. In cupola, based foundry other major energy consuming areas include blower, sand and core preparation, finishing and lighting; whereas in induction furnace-based foundry its compressed air system and cooling water system. Compressed air system is an important utility in a category C foundry. It accounts for about 4–10% of total energy depending on how well it is utilized. A typical energy use share in cupola and induction furnace based foundry is given in the figure. The total energy consumption of a foundry unit varies widely based on the size of units (table). The SEC varies considerably in a foundry depending on the type and grade of casting manufactured and degree of mechanisation in unit. On an average, the SEC varies between 99–115 kgoe per tonne.

Typical energy consumption of a foundry

Production category	Electricity	Natural gas	Graphite (t/yr)	Total energy	Total CO_2 emissions	Annual energy bill
	(kWh/yr)	(SCM/yr)		(toe/yr)	(t CO_2/yr)	(Rs million)
Gas fired cupola based foundry						
A	14,000	24,000	16	34	100	0.7
B	30,000	51,000	34	72	213	1.4
Induction furnace based foundry						
C	3,750,000	4,800	-	320	3,080	31.9
D	13,800,000	12,000	-	1,200	11,300	110.6

Cluster level consumption

Electrical energy consumption of foundry units at cluster level is estimated to be 85 million kWh per annum. The natural gas consumption of the cluster is about 2.23 million SCM. In addition, it is estimated that about 1,422 tonne of graphite is consumed in the cluster. The overall energy consumption of the cluster is estimated to be 10,310 tonne of oil equivalent (toe) per annum equivalent to greenhouse gas (GHG) emissions of 77,743 tonnes of CO_2. The overall energy bill of cluster is estimated to be Rs 940 million, which is about 17% of cluster turnover.

Energy consumption of the Agra foundry cluster (2017-18)

Energy type	Annual consumption	Equivalent energy (toe)	Equivalent CO_2 emissions (tonne)	Annual energy bill (million Rs)
Electricity	85 million kWh	7,319	69,700	706
Natural Gas	2.229 million SCM	1,832	3,902	28
Graphite	1422 tonne	1,159	4,141	21
	Total	10,310	77,743	755

Potential energy efficient technologies

Some of the major energy-efficient technologies for the foundry units in the cluster are discussed below.

(i) Induction furnace

Replacement by IGBT type induction furnace

About 30 foundries in the cluster use induction furnace for melting. Of these 95% use silicon-controlled rectifier (SCR) type furnace and are about a decade old. The typical SEC of SCR type furnace is about 680 kWh per tonne for metal. The units do not follow standards operating procedures and are operated crudely.

Replacing SCR-based induction furnace with insulated-gate bipolar transistor (IGBT) type induction furnace would help in reducing SEC level to about 540 kWh per tonne of metal. The potential energy saving is about 15–25%. The investment for IGBT furnace is expected to pay back within one year on account of energy saving alone (as is visible in the table below).

IGBT induction furnace

Cost benefit analysis of IGBT induction furnace

Particular	Unit	Value
Investments in IGBT furnace	Rs	4,000,000
SEC of existing induction furnace	kWh/t	680
New SEC of proposed furnace	kWh/t	540
Electricity saving	kWh/t	140
Total annual monetary saving (@ 250 t/m)	Rs/year	3,528,000
Simple payback period	year	1.1

Retrofit of lid mechanism for furnace crucible

All induction furnaces use crucibles for melting with crucible size varying between 300 and 1,000 kg. In all units, the mouth of crucible is kept open during operation, resulting in substantial radiation losses (6-8% of total energy input). Retrofitting induction furnace crucible with lid mechanism will lead to an energy saving of up to 3%. The saving would depend on size of crucible and operating practices. The investment for lid mechanism is expected to pay back within few months. The cost benefit analysis of lid mechanism is given in the following table.

Lid mechanism

Cost-benefit analysis of lid mechanism

Particular	Unit	Value
Investments in lid mechanism	Rs	300,000
Radiation loss without lid mechanism	kWh/t	40
Losses with lid mechanism	kWh/t	21
Electricity saving	kWh/t	19
Total annual monetary saving (@ 280 t/m)	Rs/year	478,800
Simple payback period	year	0.6

Sand mixer:

Sand mixer

A typical sand mixer used in category A and category B foundries is of 250 kg capacity. In mixer, 11 kW (15 hp) motor is used for mixing and 3.7 kW (5 hp) motor for blending. The mixer is manually operated with the cycle time varying between 6 and 9 minutes.

The conventional sand mixer can be replaced with an automatic sand mixer. The automatic sand mixer will have skip charger, automatic control for water addition, and a timer circuit. These features help in saving energy as well as improving quality of sand processed. The investment on sand mixer is generally paid back in about 2-3 years (table).

Cost-benefit analysis for automatic sand mixer

Particular	Unit	Value
Investment in new sand mixer	Rs	430,000
Average power consumption of old mixer	kW	10.7
Cycle time	Min	7.0
Average power consumption of new mixer	kW	12.3
Cycle time	Min	2.5
Monetary saving (@ 100 cycles per day)	Rs/year	176,600
Simple payback period	Year	2.4

Compressed air system

Air compressor

Compressed air system is one of the important utilities in a foundry. Air compressors are highly energy intensive. The foundry units use fixed speed screw air compressors. State-of-the-art variable frequency drive (VFD) based Permanent Magnet Synchronous Motor (PMSM) screw-type air compressors may replace existing air Compressors in Category B and category C foundries, which are energy efficient. The cost-benefit analysis of VFD PMSM screw air compressor is given in the following table.

Cost-benefit analysis of VFD PMSM screw air compressor

Particular	Unit	Value
Investment	Rs	1,100,000
Base Case: Screw air compressor fixed speed of 45kW/313 cfm Proposed: VFD PMSM screw air compressor of 37Kw/285 cfm		
Present power consumption	kWh/year	200,880
Proposed power consumption	kWh/year	79,050
Annual energy cost saving	Rs/year	8,65,000
Simple payback period	year	1.3

Major cluster actors and cluster development activities

Industry associations

There are a number of industry associations in Agra foundry cluster. The major industry associations, related to foundries, are the following:

Agra Iron Founder's Association

Agra Iron Founder's Association (AIFA) is one of the oldest associations in the cluster with a membership of about 100 foundries. It mainly addresses regulatory issues facing the foundry, such as pollution, taxation, raw material purchases, selling price of castings, and the like.

The Institute of Indian Foundrymen, Agra Chapter

The Institute of Indian Foundrymen (IIF) Agra Chapter, is one of the most vibrant chapters in northern region. The Chapter has a membership of about 25, of which about 15 are foundry units. It organizes awareness workshops and plant visits on a regular basis for its members.

National Chamber of Industries and Commerce

The National Chamber of Industries and Commerce is the nodal association for industries in the state. It has a membership of over 1,000 companies. It is affiliated to bodies like Federatin of Indian Chambers of Commerce and Industry (FICCI), Confederatino of Indian Industry (CII), and the Associated Chambers of Commerce & Industry of India (ASSOCHAM). The association takes up current issues facing the local industries.

Government support institutions

The District Industries Centre (DIC), Agra, provides incentives to MSMEs such as capital investment subsidy, interest subsidy, venture capital quality certification, energy and water audits, and so on. The MSME Development Institute (MSME DI), Agra under the Ministry of MSME, Government of India, provides assistance for the promotion and development of MSMEs. Further, a Process and Product Development Centre (PPDC) was established in 1985 with the assistance of Government of India, Government of Uttar Pradesh, and United Nations Development Programme/United Nations Industrial Development Organization (UNDP/UNIDO) for technological upgradation of small scale castings and forging industries in Agra. The centre offers services such as, testing, product development, and training and consultancy to the foundry industry.

Cluster development activities

Agra has a dedicated industrial estate set-up for the foundry. It is known by name Foundry Nagar. Foundry Nagar is approximately 10 km from Agra cantonment. A number, foundries have relocated from city premises to Foundry Nagar over the past few years. PPDC has undertaken cluster development activities like promoting lean manufacturing practices among foundry units in Agra.

NOTES

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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 established in 2009, is a section-25 not-for-profit company that works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage renewable energy, energy efficiency and sustainable transport solutions. Based on both energy savings and carbon mitigation potential, Shakti focuses on four broad sectors: Power, Transport, Energy Efficiency and Climate Policy. Shakti act as a systems integrator, bringing together key stakeholders including government, civil society and business in strategic ways, to enable clean energy policies in these sectors.

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 (1) Swiss Agency for Development and Cooperation (2) Bureau of Energy Efficiency (3) Ministry of MSME, Government of India (4) Shakti Sustainable Energy Foundation, and (5) 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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