

ENERGY PROFILE

KARNAL RICE MILL CLUSTER

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SHAKTI
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Promoting Energy Efficiency in SMEs
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The Energy and Resources Institute
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi 110 003
India

For more information

Project Monitoring Cell
T E R I
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail pmc@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delhi (0)11

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Abbreviations

Abbreviation	Full form
DI	Development Institute
DIC	District Industries Centre
ETP	Effluent Treatment Plant
HT	High Tension
kWh	kilowatt-hour
LT	Low Tension
MSME	Micro Small and Medium Enterprise
SEC	Specific Energy Consumption
t	tonne
UHBVNL	Uttar Haryana Bijli Vitran Nigam Limited
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VFD	Variable Frequency Drive
VFD	Variable Frequency Drive
WHR	Waste Heat Recovery
WHR	Waste Heat Recovery
toe	tonne of oil equivalent
tph	tonnes per hour
tpy	tonnes per year

Acknowledgements

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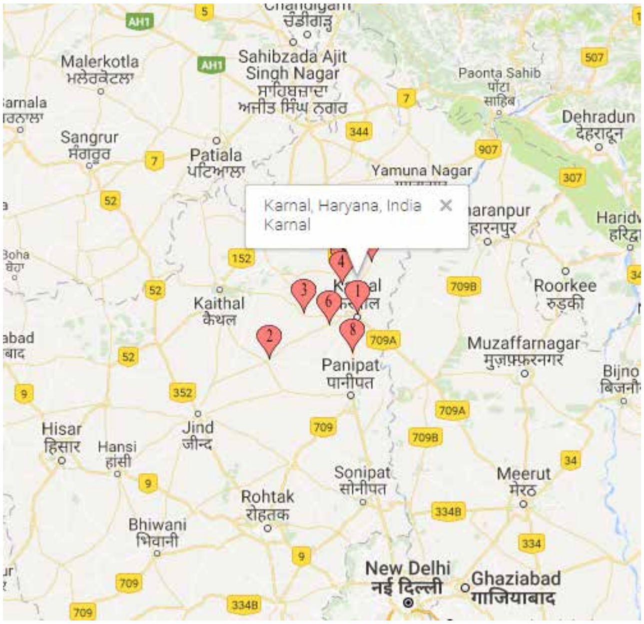
Last but not least, our sincere thanks to the MSME entrepreneurs and other key stakeholders in the cluster for providing valuable data and inputs that helped in the cluster analysis.

Karnal Rice Mill Cluster

Overview of the cluster

Karnal is located north of Delhi in the state of Haryana. Rice milling is one of the major industries in Karnal as well as in rest of Haryana. Karnal is called the rice bowl of India and is famous for the production of the long-grain, aromatic basmati rice.

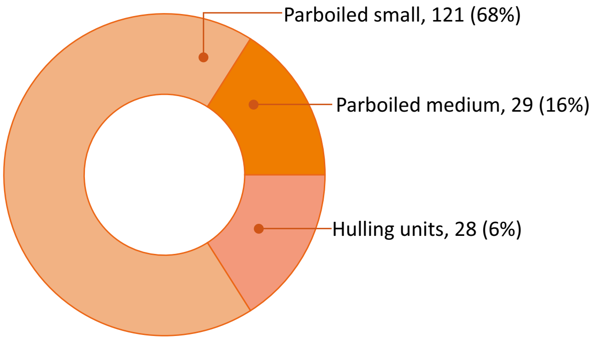
The cluster has about 178 rice mills in operation. Most of the rice mills are located in the periphery of Karnal city. Apart from the Karnal city, the major concentration of mills are in Taraori Assandh, Nissing, Jundla, Indri, Gharounda and Nilokhadi.



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

Product, market, and production capacities

The major raw material used in the rice mills is paddy mainly procured from farmers or local market. The cluster processes about 4.45 million tonnes of paddy producing about 2.88 million tonnes of rice comprising both par-boiled rice and raw rice. The production of par-boiled the rice is about 89% from the cluster and rest 11% of raw rice is produced. The average yield ratio of the local paddy is about 65%, which, however varies based on the quality of grains and contaminants present in raw paddy.



Distribution of rice mills

The majority of the rice mills falls under Micro, Small, and Medium Enterprises (MSME), as defined by the Ministry of MSME. About 150 rice mills are engaged in the production of par-boiled rice. The mills also produce small quantities (about 10%) of raw rice. About 28 hulling units (i.e., units engaged only in removal of husk and polishing activities) produce only raw rice. Apart from rice, the important by-products from rice mills include husk (23%) and bran (9%). Husk in par-boiled rice mills is used in-house as boiler fuel and the bran is sold for further processing.

The installed capacity of rice mills in the cluster typically range between 2–25 tonnes per hour (tph) of paddy processing. The medium mills operate round the clock for about 25 days per month (270 days per year) while shall par-boiled units operate for about 12–16 hours per day (200–250 days). The hulling units operate for about 12 hours per day for about 3–4 months in a year.

Categorization of the rice mills and estimated production

Category	Installed Capacity (tph)	Number of Units	Paddy Processed	
			Million tonnes/year	Share (%)
Parboiled rice mill—Medium	> 10	29	2.1	48
Parboiled rice mill—Small	2-10	121	2.3	51
Raw Rice - Micro	< 2	28	0.05	1
	Total	178	4.45	

Production process

Most of the mills generally produce both par boiled and white (raw) rice using separate production lines. The majority of the micro-scale units produce white (raw) rice. The raw material—paddy—undergoes various processes before reaching rice yard for bagging. The production process to produce par boiled rice from paddy could be grouped into the following major steps:

Paddy preparation

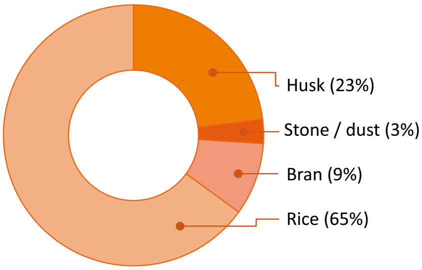
The various contaminants, namely, rice straw, dust, stone, sand, and seedless paddy are removed from paddy using an air blower and series a of vibrating screens with different cut off sizes. The cleaning of raw paddy, equivalent to one batch capacity, takes around 1-2 hours depending on the production capacity and technology employed. The cleaned paddy after preparation is stored in vertical silos for further processing.

Soaking

The cleaned paddy is transferred by a conveyor belt from the storage silos to the soaking pits/silos. Typically, there are two soaking pits, each having a holding capacity between 4–10 tonnes of cleaned paddy. Paddy is soaked in raw water at ambient temperature for about 4 hours. The water is drained out by gravity after the soaking. The process of draining water takes about an hour for one complete batch of soaked paddy. The entire soaking cycle takes about 10–14 hours for one batch.

Steaming

In the par boiled rice manufacturing process, the soaked paddy is heated using steam from the in-house boiler. In case of raw rice, the steaming operation is not required. Soaked paddy from the soaking pits is transferred to a steaming vessel by gravity. During the steaming stage, two steaming vessels are operated alternately for steaming 600–800 kg of soaked paddy in a batch for about 10–20 minutes until steam starts coming out from the vessel indicating it has reached the top surface of the steaming bowl and steaming is completed. The entire batch of soaked paddy from the two bins takes around 4 hours for complete steaming.



Percentage yield of rice and by-products

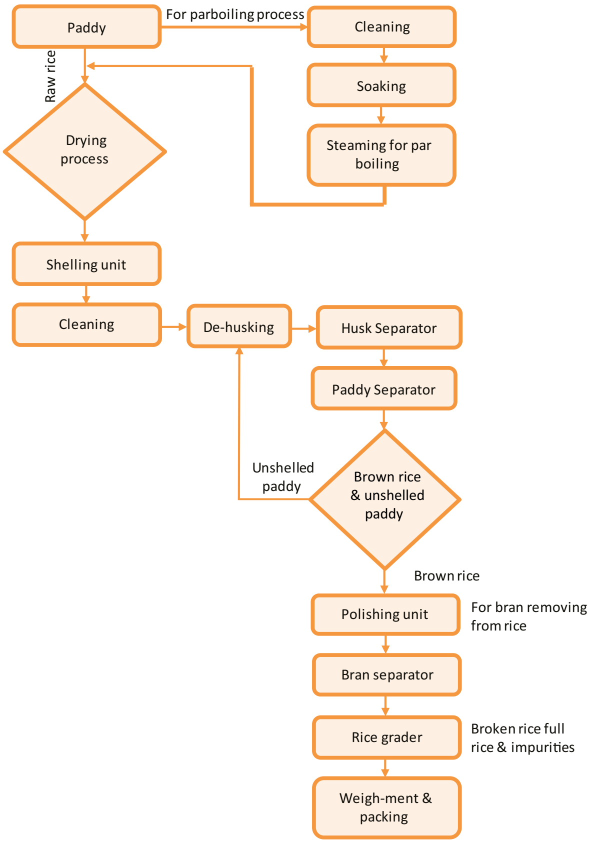
Drying

The steamed paddy is dried by a continuous process in mechanical dryers using hot air. Steamed paddy with around 30–45% of moisture is first transferred to dryer where moisture is reduced to 22%. The hot air is generated in a steam-based heat exchanger with automatic temperature controller to maintain hot air temperature to around 700 °C. Partially dried paddy is then transferred to a second dryer for final moisture reduction to the level of 10–14%. Dried paddy is stored in silos before being transferred to the milling section.

Milling

In the milling section, dried paddy passes through processes like screening, dehusking, separation, cone polishing, separation and grading, silky polishing, and so on, depending upon the existing facilities in the rice mill, before it is transferred to a bagging yard for manual or automatic packing of the final polished rice. Husk, the by-product in rice milling, is primarily used as fuel in the boiler. The other by-product, bran, accounting for about 8% by the weight of paddy is sold. The milling section consists of various motive loads connected to operate either single drive or multiple drives with a common shaft using different pulleys and belts .

Few new mills have automated the milling section by employing latest imported technologies. The investment in automation has helped to increase the production capacity and product quality.



Raw/parboiled rice processing flow chart

Technologies employed

The processing of paddy into par boiled rice involves the following technologies/equipment:

Boiler

Boiler is used for the generation of steam required for par boiling. The capacity of boilers used in rice mills vary in the range of 2.5–20 tph. Steam is generated at a pressure of about 7–10 kg/cm^2 (g). Condensate from indirect use points (like mechanical dryers) is recovered and sent back to the boiler feed tanks to utilize the sensible heat. Husk firing leads to a significant generation of suspended particulates in the flue gases, and hence, pollution control systems such as cyclones are needed to trap the suspended particulates. Few units have installed large settling chambers through which flue gases are passed. While particulates are trapped and collected from the bottom of the chamber, the water kept at a tank above the chamber gets preheated in the process. A majority of the boilers do not have any waste heat recovery (WHR) system for preheating the boiler feedwater. A forced draught fan is used both for combustion air as well as husk feeding simultaneously. The medium-sized units use basic boiler instrumentation. However, most rice mills do not have any instrumentation apart from pressure gauge to monitor the operating parameters of the boiler and steam -distribution system.

Husk fired boiler

Steaming vessel

Upon the completion of raw water soaking in the soaking tanks, paddy is loaded into the steaming vessels in batches through gravity. Steam is directly injected at the bottom of the vessels by opening a valve till it starts coming out from top. The entire steaming cycles is based on the type of paddy being used. The condensed steam is drained out.

Steaming vessel

Dryer

Traditionally, rice mills were using sun drying. However, sun drying does not support operation, especially during the rainy season. Most mills in the Karnal cluster have adopted mechanical dryers for the drying of steamed paddy. The par-boiled paddy is fed to the dryer. Steam from the boiler exchanges heat with the forced air blown across the heat exchanger to generate hot air. The temperature of the hot air is maintained manually by controlling the opening of the steam valve. Steam traps are used to remove the condensate formed in the steam lines.

Dryer

Milling section

The dried paddy is transferred to the milling section and is stored in silos. The milling section comprises the following areas:

Milling section

a. **Destoning:** In this pre-cleaning area, the contaminants carried-over along with paddy, such as stones, are removed through vibrating sieves.
b. **Dehusking:** Husk is removed from the paddy to produce brown rice. The husk generated is used as fuel in the boiler for steam generation.
c. **Whitening and polishing:** The product from dehusking has a brownish layer called bran. The bran is removed from the brown rice in the polishing area to produce white rice. Bran, which is rich in protein contents, is sold as a by-product for the production of rice bran oil and poultry products.

The utilities used in the rice mills include electric motors, material conveying systems, water pumping systems.

Energy scenario in the cluster

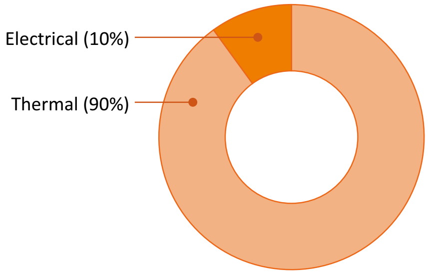
The rice mills mainly use by-product husk for meeting the fuel needs of the boiler. Electricity, sourced from grids, is used for operating the electrical loads. Grid electricity is supplied by Uttar Haryana Bijli Vitran Nigam Limited (UHBVNL). The details of the major energy sources and tariffs are shown in the following table.

Prices of major energy sources

Source	Remarks	Price
Electricity	HT industry (above 50 kW)	Demand charges: Rs 170 per kVA Energy charges: @11 kV—Rs 6.65 per kVAh @33 kV—Rs 6.55 per kVAh @66/132 kV—Rs 6.45 per kVAh
	LT industry (up to 50 kW)	Demand Charges: Rs 185 per kW Energy Charges: @up to 10 kW—Rs 6.35 per kVAh @10–20 kW—Rs 6.65 per kVAh @20–50 kW—Rs 6.40 per kVAh
Rice husk	By-product	Nil (Selling price of excess husk: Rs 2,500 per tonne)
HSD	Distributors	Rs 62.5 per litre (price subjected to market fluctuations)

Energy consumption

The major energy forms used by par-boiled rice mills in the cluster include husk and electricity. Electricity from the grid is used for different motive loads in the processing sections, water pumping, and blowers. Thermal energy in the form of steam is used for soaking of paddy and subsequent drying. Husk, a by-product, is used as a fuel in boiler for generating steam. Generally, 85% of husk generated is used in-house for steam generation and the balance 15% is sold. However, some mills, using old boilers, procure additional husk from local market.



Energy share in parboiled rice mills

Unit-level consumption

The major energy forms in a rice mill are rice husk and electricity. The hulling units, which do not require soaking and steaming of paddy, and only have husk removal and polishing operations use only electricity.

In a par boiled unit, internally generated rice husk constitutes about 90% of the total energy requirement. The balance 10% of the energy is met through grid electricity. The average 'specific energy consumption' (SEC) of parboiled units in the cluster is 0.061–0.062 toe per tonne; the SEC of a hulling unit is estimated to be 37–45 kWh per tonne of the rice processing production (equivalent to 0.004 toe per tonne). The typical energy consumption of the different capacities of rice mills are shown in the following table.

Typical energy consumption of typical rice mills

Type of unit	Husk (tpy)	Electricity (kWh/year)	Total energy (toe/year)
Par boiled—Medium	13,414	5,485,716	4,496
Par boiled—Small	3,450	1,257,600	1,143
Hulling unit	–	90,000	8

Cluster level consumption

The annual energy consumption of the cluster is estimated to be about 268,920 toe. The estimated 'greenhouse gas' (GHG) emissions from rice mills at the cluster level is 256, 660 tonne of CO_2 per annum. The overall energy bill of cluster is estimated to be Rs 3,809 million. Husk is the by-product from paddy processing; hence the selling price of husk from the rice mills is considered for estimating the energy bill.

Energy consumption of the Karnal rice mill cluster (2017-18)

Energy type	Annual consumption	Equivalent energy (toe)	Equivalent CO_2 emissions (t CO_2)	Annual energy bill (million Rs)
Husk	806,456 tonne	241,936	–	1,612
Electricity	313 million kWh	26,985	256,660	2,196
	Total	268,921	256,660	3,808

Potential energy-efficient technologies

Par boiled rice mills, offer significant scope for energy-efficiency improvements in both thermal and electrical areas. These options are discussed below.

Energy efficiency in steam boilers

The majority of the boilers do not have proper automation and control for maintaining the optimum air-fuel ratio. The temperature of the exhaust flue gases from the boiler is high (180 °C–220 °C). Proper WHR systems to recover the heat from the hot flue gases are not available in most boilers.

The majority of rice mills in the Karnal cluster do not recover the condensate fully. Many of the units have open loop condensate recovery system, resulting in contamination of the water. Even in units that have installed condensate recovery, mainly in the dryer section, the condensate lines are not insulated, thus loading to a loss in the heat availability.

There is possibility to improve the control on husk feed rate to the boiler based on steam demand or controlling the air-fuel ratio. The existing boilers may be retrofitted with control and automation to maintain optimum air-fuel ratio. Monitoring and control of the flue gas temperature and periodic maintenance of the boiler are needed. The units may also maintain a proper record (logbook) for key the operating parameters such as steam pressure and temperature, water consumption, fuel consumption, water properties, and blow, down frequency.

Some of the recommended actions for improving the energy efficiency of the boiler are as follows:

a. Three-pass boiler construction for better heat-transfer efficiency.
b. Appropriate size of smoke tubes for a smooth passage of flue gases and minimize choking/clinkering problems.
c. Air-fuel ratio controller with a closed-loop control mechanism (installation of variable frequency drive for induced draft fans and forced draft fans) with flue gas parameters (O_2 level and temperature).
d. Variable control option in induced draft fan to optimize gas velocities for minimum pressure drop on the gas side and the most effective heat transfer.
e. Appropriate selection of refractory (based on the furnace temperature) and surface insulation material.

Cost-benefit analysis in a boiler

Energy-saving Measure	Existing Scenario	Proposed Scenario	Energy Saving Potential (%)	Simple Payback Period
Installation of energy-efficient boiler	Single pass boiler of efficiency 48–60 %	Three pass boiler with WHR mechanism	15–27	up to 18 months
Installation of economizer in boilers	Flue gas temperature: 220–310 °C Boiler feed water temperature: 30–35 °C	Economizer for preheating of boiler feed water to 75 °C	5–8	up to 8 months
Air-fuel ratio controller	Estimated excess air: 110%–160% (based on design) No control on air combustion	Air-fuel ratio controller with closed-loop feedback of flue gas parameters	8–14	8–12 months
Use of appropriate surface insulation	Non-insulated surfaces Surface temperature with insulation: 80–110 °C Ambient temperature: 30 °C	Use of appropriate insulation at front and back faces	1.5–2	up to 3 months
Condensate recovery from indirect steam use application	Condensate not being recovered Condensate is having impurities Condensate temperature downs by 30–40 °C during transfer	Installation of condensate pumps	5-8%	up to 10 months

Compressed air system

Compressed air is a continuous operating utility in rice mills in the Karnal cluster. It is also one of the highest energy intensive utilities. Different factors influence the performance of compressed air system, such as the intake air temperature and quality, generation pressure, capacity utilization, type of technology used, design of distribution network, and so on.

In the cluster, the maximum pressure requirement at the utilization end is 5.5 bar; whereas, the set generation pressure in the air compressors was observed to be in the range of 7.5–10 bar. As a thumb rule, 1 bar of increased air pressure leads to a 7% additional consumption of electricity. For the optimum utilization of compressed air, it is recommended to keep the set pressure of compressed air at about 1 bar above the pressure requirement at the point of utilization.

The temperature of intake air to compressors was observed to be 8 °C–10 °C higher than ambient temperature in some units. An increase in intake air temperature by 4 °C increases the electricity consumption by 1%. Hence, it is important that the intake air to compressor must be taken from a clean, cool location.

The capacity utilization of many screw compressors were low (45–65%). Use of VFD air compressors or the retrofit of VFD in the existing screw type air compressor will lead to reduction in the electricity consumption.

Cost-benefit in air compressor

Energy-saving Measure	Existing Scenario	Proposed Scenario	Energy saving Potential (%)	Payback Period
Optimum setting of compressed air generation pressure	Set pressure: 7.5–10 bar End user pressure requirements: 5.5 bar (max.)	Set pressure: 6.5–7.0 bar End user pressure requirements: 5.5 bar (max.)	10–17	Immediate
Air compressor intake air temperature should be close to the ambient temperature	Intake air temperature: 38 °C–40 °C Ambient temperature: 30 °C	Intake air temperature: 30 °C–32 °C Ambient temperature: 30 °C	1.5–2	UP to 3 months
Installation of VFD on existing screw compressor to avoid unload operation/ installation of VFD enabled air compressor	Capacity utilization: 45-65 % Unload period: 35%–55 %	Unload period is minimised	15–25	UP to 12 months

Energy efficient IE3 standard motors

The electricity consumption in a rice mill takes place mainly in motors associated with boiler (fans and pumps), milling, and other utilities. The ratings of these motors vary from 3 hp to 150 hp depending on the application, capacity, and operations to be performed. Most of these motors operate on low loads except milling and finishing operation. The power factor of these motors was observed to be generally lower than 0.65–0.70.

Most of the installed motors in the cluster are of the standard efficiency class and several have been rewound multiple times. The motor efficiency drops 1% to 5% each time a motor is rewound. Attractive energy savings is possible in motor systems by standard motors with the premium efficiency class (IE3) motors and other system-level improvements. The average improvement in efficiencies is estimated to be 5% by the efficiency upgrades of the electric motors and in the range of 10–15% by including system-level improvements (such as VFDs, soft starters, gear assembly, etc.) which indicate quite an attractive return on investment (ROI).

Cost-benefit analysis for IE3 motors

Energy Saving Measure	Existing Scenario	Proposed Scenario	Energy Saving Potential (%)	Payback Period
Replacement of under loaded motors with optimum capacity IE3 motors	Motor loading was observed in the range of 40% – 65%	Recommended loading 65% – 95% of rated	5% – 7%	18 – 24 months
Replacement of rewound motors with premium efficiency class IE3 motors	Many motors rewound twice or more times	Replacement with IE3 motor	3% – 7%	18 – 24 months

Solar water heater

Both small and medium rice mills in the cluster provide significant scope for the adoption of solar water heaters that can be used for generating of hot water at about 60 °C–70 °C. Hot water is required in the soaking of paddy in steam vessels. Apart from soaking process, hot water can also be used as boiler feedwater that would help in fuel saving. The estimated energy saving potential is 1,800 tonnes per year of husk (equivalent to 540 toe). The equivalent annual monetary saving is Rs 4.5 million.

Others

A significant reduction in energy losses is possible in areas, such as steam distribution (including insulation and steam traps), steaming, vessels, and paddy dryer. Further, as the level of water reuse from the different processes in rice mills is very low, there is potential to improve water recycling. There is a good potential for energy-efficiency improvements in water pumping and belt drives. Further, the monitoring and control of the operating parameters in the different process sections, for example, temperature monitoring in soaking and steam areas, would help in operating the mill close to the design level.

Major cluster actors and cluster developmental activities

Major stakeholders

The major stakeholders of the Karnal cluster are rice millers, paddy and rice merchants, and machinery suppliers. The industry associations, such as All India Rice Exporters Association and Karnal Rice Millers & Dealers Associations are generally engaged with the government on export-related policy issues. The associations are involved in activities related to technology upgradation of the cluster at present. However, the associations have shown keen interest to collaborate in the future activities related to the technology upgradation of rice mills. Other important stakeholders in the cluster are MSME Development Institute (MSME DI), Karnal and state government agencies such as District Industries Centre (DIC).

Cluster development activities

No major cluster developmental activities have been undertaken in the Karnal cluster. With the cluster exhibiting significant potential for energy savings, there is a good potential to undertake interventions on energy-efficiency improvement amongst par boiled rice mills in the Karnal cluster.

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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