Energy Efficiency in Small Scale Industries: An Indian Perspective

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ABSTRACT

The small-scale sector occupies a position of prominence in the Indian economy, contributing to more than 50% of the industrial production in value addition terms. The sector accounts for one third of the export revenue and employs the largest manpower next to agriculture. In India's present liberalized economy, the survival and growth of small-scale industry (SSI) largely depends on its ability to innovate, improve operational efficiency and increase productivity. It has been observed that the factories in the small-scale sector in India are generally less efficient in process and utility energy use compared to larger enterprises, as well as to enterprises of equivalent capacity in other countries. There is also a general disregard in small-scale units towards environmental management. The poor energy and environmental performance is directly related to the lack of technical capacity in these enterprises to identify, access, adapt and adopt better technologies and operating practices. Though case studies suggest that enhanced energy management leads to increased productivity as well for these enterprises, yet such win–win potential is actualized in very few instances.

In order to enable small scale enterprises adopt more efficient energy use patterns, it is essential to demonstrate positive impacts of reduced energy use to the entrepreneurs in terms of increased productivity and higher profitability. Thus an effective strategy to promote energy efficiency in small scale industry is to use a cluster based approach wherein energy efficient technologies and practices can be demonstrated to a group of companies located in close geographic proximity. In India, a large portion of the SSI activity is geographically clustered. Within a cluster, there exists a great deal of similarity in the level of technology, the operating practices and even the trade practices among the individual units which means that the potential to develop and implement standard solutions for improving energy efficiency is large.

The paper highlights the importance of the small-scale sector in the Indian economy and the need to improve the energy and environment performance of units operating in the sector. It draws upon the results of a major program that TERI (Tata Energy Research Institute) initiated in 1995 in the small-scale sector with the support of SDC (Swiss Agency for Development and Cooperation). The program aims at finding solutions to the energy problems of the SSI through technology upgradation and human and institutional development in some small scale energy intensive sectors. Three small-scale sectors are presently being covered -foundry, glass and brick manufacture. In each of the three small-scale sectors, demonstration plants have been/are being built to widely disseminate/popularize energy efficient technological options to the cluster. In addition to highlighting the work done in individual cluster/industry, the paper gives details of the benefits that can accrue to the individual units in terms of improving their energy efficiency and improving productivity, if the demonstrated technologies are implemented.

Introduction

India, after her independence in 1947, embarked on the path of industrialization to achieve the much-needed economic growth for development. The government viewed industrial growth as a mode of achieving equitable economic growth in the country. Like many of the developing economies in the post-war period, India opted for rapid industrialization (Lall, S. 1997) in a bid to develop a sound, self-reliant manufacturing base in the country and make rapid progress on the infrastructure development front. Targets were fixed for industrial investments in the five-year Plans that were the backbone of India's planned development. In line with the industrialization policies, many resource-intensive manufacturing facilities, such as iron and steel, oil refineries, cement, and fertilizer were set up with the then available technologies, mostly through public sector investments. In addition to the above energy intensive sectors, which are largely medium to big industries, another important segment that was encouraged by the planners was the small-scale industry (SSI) sector. The small-scale industries[1], besides being instrumental to the economic development of the country, also generated vast employment opportunities. However, in order to meet the increasing demands of the domestic market, the emphasis had been on increasing production capacities rather than operational efficiency and developing indigenous technological capabilities. It is evident now that most of these plants have operated with old technologies and could not keep pace with technological advancements elsewhere for various reasons. Poor management practices along with the declining labor productivity and operating efficiency of manufacturing processes over the years lowered the profitability of many of these plants significantly, resulting in a slowdown of industrial activities. The pursuance of policies that encouraged import-substituting industrialization and the pessimism of planners about exports offered no market incentive for these firms to improve their performance over the long run (Lall, S. 1997). With the gradual integration of the domestic markets with the global economy and growing concerns about the environmental implications of the industrial activities, there is now increasing pressure on domestic industry to improve its performance. The energy shortages coupled with increasing energy prices being witnessed in various states in India is forcing the industries now to look at ways and means for reducing their energy consumption and adopting technologies that result in lowering their energy intensity.

Indian Industrial Sector – Energy Performance

The use of energy from commercial sources (fossil fuels and electricity generation) in India has increased ten folds in fifty years since independence; and the total energy consumption from commercial sources was around 200 million tones of oil equivalent (mtoe) for the year 1998/99. An analysis of the share of commercial energy use by different sectors indicate that the industry is the most dominant sector, accounting for more than half of the total commercial energy use in the country (TERI. 2000c). In general, the Indian industry is highly energy intensive and the energy efficiency is well below that of other industrialized

[1] Small scale industry in India is defined in terms of maximum investment in fixed assets in plant and machinery in a particular unit. The investment ceiling has been subject to revisions from time to time and was increased to Rs 30 million in 1997. However, it has recently been reduced to Rs 10 million on the request of various small scale industry associations. (1 US \$ = Rs 46 approximately).

countries and presents an ideal case where substantial reduction in energy consumption is possible through rational use of energy.

It has been estimated through various studies that 5 - 10% energy saving is possible simply by better housekeeping measures. Another 10-15% is possible with small investments like low cost retrofits, use of energy efficient devices and controls etc. (TERI. 1996, Bhattacharjee, S. 2000). The quantum of saving is much higher if high cost measures like major retrofit, process modifications etc. are considered.

Small Scale Industries – A Broad Overview

The small-scale sector occupies a position of prominence in the Indian economy. It contributes to around 50% of industrial production in value addition terms, 7% of the GNP, and employs the largest manpower next to agriculture (Gulati, M.1997). Over the past five decades, various government policies have been formulated for the growth and development of small-scale industries. A series of six Industrial Policy Resolutions/ Statements have been formulated by the Union Government since independence and all these statements have stressed, in various forms, the need to promote the SSI sector in the country. The underlying feature here is the important role that the SSI sector plays in providing employment opportunities, mobilizing local skills and capital resources, and in the process ensuring development of the rural areas and small towns.

The measures taken by the Government, from time to time, to protect the interests of SSIs and to improve their viability, include reservations of certain items for exclusive manufacture in small-scale and various fiscal measures. More than 800 items are currently reserved for exclusive manufacture in the SSI sector. The overwhelming consideration for reservation of an item is its suitability and feasibility for being made in the small-scale sector without compromising quality aspects. The reservation of products for exclusive manufacture by SSIs is reviewed regularly. Other policy measures undertaken by the Government address the basic requirements of the SSIs, such as, credit, marketing, technology, entrepreneurship development, fiscal, financial and infrastructural support. The Government has also been extending preferences in respect of purchase of items manufactured by SSIs. To focus on planned development of SSI sector, a separate ministry was created by the Government of India in 1999, namely the Ministry of Small Scale Industries & Agro and Rural Industries to act as a nodal ministry for policy formulation, promotion, development and protection of small-scale industries. As a result of the policy measures taken by the various Governments from time to time, the small and medium enterprises have today become the backbone of the Indian manufacturing sector. This can also be gauged from the fact that the direct exports from the SSI Sector account for 35% of the total exports.

Small Scale Industries – Energy Performance

In spite of the emphasis of the Government to promote SSIs, this end-use sector is now faced with a number of challenges. With the new Industrial Policy of 1991, which has paved the way for the liberalization of the Indian economy, the protective framework is slowly giving way to a greater degree of competition from the larger sector as well as from imports. The small-scale units are suffering from deficiencies like technological obsolescence, lower levels of productivity, non-availability of information, poor management practices and non-availability of credits for modernization. They are generally less efficient in process and utility energy use compared to larger enterprises, as well as to enterprises of equivalent capacity in other countries. Environmental management in these enterprises is also poor. The poor energy and environmental performance is directly related to the lack of technical capacity in these enterprises to identify, access, adapt and adopt better technologies and operating practices. Though case studies suggest that enhanced energy management leads to increased productivity as well for these enterprises, yet such win–win potential is actualized in very few instances. There are many energy intensive subsectors operating under the small scale where energy cost accounts for a major share of the operating cost, which means that to remain competitive, it is absolutely essential for them to improve the energy performance. Some of the examples of energy intensive small-scale industries are ceramic and glass industry, foundry, forging, brick manufacture, food-processing etc.

One of the very effective strategies to promote energy efficiency in the small scale is to use a cluster based approach wherein energy efficient technologies and practices can be demonstrated to a group of units located in close proximity. "Industrial clustering" means existence of a group of factories or units geographically very near to each other and involved in the production of goods and services that have a great deal of commonality. Within a cluster, there exists a great deal of similarity in the level of technology, the operating practices and even the trade practices among the individual units which means that the potential to develop and implement common solutions for improving energy efficiency is high. To enable the small scale enterprises see the benefits of reduced energy consumption, it is essential to demonstrate the positive impacts of lower energy use to a few entrepreneurs in a particular cluster in terms of increased productivity and higher profitability. Once the benefits have been demonstrated to a few units in a cluster, the other units tend to follow and adopt the suggested measures. Since a large portion of the SSI activity in India is geographically clustered, this approach of improving energy efficiency in small-scale units can be very effective.

Small-Scale Industry Clusters in India

The SSI clusters in India are spread throughout the length and breadth of the country. There is no definite figure available on the number and size of these clusters. However, some of the estimates point out the existence of around 2000 clusters, most of which are located in the rural areas. These rural based clusters are artisan-based units that have grown in size with the passage of time. They use very simple manufacturing processes or techniques and the products are manufactured by the local artisans. The skill is transferred from one generation to another without any up-gradation in the methodology of manufacture or improvement in product quality. Some of the examples of products produced in such clusters are textile handicrafts, woodcarving, stone carving, metal ware etc. A perusal of the nature of products in these clusters points out that these clusters are not very energy intensive (Gulati, M.1997).

In addition to these rural artisan-based clusters, there are an estimated 140 clusters that exist predominantly in urban settings and have at least 100 registered units. The size and number of units in these clusters varies significantly from one cluster to another. Some of them are so big that they produce upto 70 to 80% of the total volume of that particular product produced in the country. For example, Ludhiana in the state of Punjab produces 95% of India's woolen hosiery, 85% of sewing machine parts, 60 % of bicycles and its parts and accounts for over half of Punjab's exports. Similarly, Tiruppur, which lies in the middle of TamilNadu's cotton belt in southern India is a home to thousands of small-scale firms involved in spinning, weaving and dying of cotton garments. It accounts for up to 60% of cotton knitwear exports from the country (Albu, M. 1997). Amongst the energy intensive small-scale clusters, a typical example is of the glass-manufacturing cluster in Firozabad, which is around 250 km from New Delhi. It produces nearly 70% of the glass manufactured in the small scale and almost the entire production of glass bangles (colorful bracelets worn by women in India) comes from this small town. Khurja pottery cluster which produces a variety of ceramic products is a highly energy intensive cluster with energy constituting more than 40% of the cost of production. A large number of the beautiful mugs and other tableware that adorn the dining rooms of European homes come from Khurja. There are numerous examples of existence of clusters like these in the Indian small scale manufacturing sector. Some of the other examples of products produced in clusters are sanitary tiles, bricks, foundries, machine parts, leather footwear, brassware, automobile parts, and chemicals.

Energy Efficiency Improvement in the Small-Scale Sector - TERI's Intervention

The intervention by TERI (Tata Energy Research Institute) in the SSI sector aims at finding solutions to the energy and the environment problems of the small units through technology upgradation and increasing productivity in some of the energy intensive sub-sectors. Three small-scale sub-sectors are presently being covered - foundry, glass and brick manufacture. A cluster-based approach is being followed in the three sub-sectors. In each of these sectors, demonstration plants are being/have been built to popularize the technological options to the cluster. Awareness programs and on-site training of the operators are being undertaken simultaneously to familiarize them with the new technologies. Over the long run, appropriate mechanisms (to support the preparation, financing, and implementation of replicable projects) will be developed with an effort to try and make this program sustainable beyond TERI's intervention.

The intervention in the foundry, glass and brick sub-sectors is a result of a major program that was initiated in 1995 in the small-scale sector with the support of SDC (Swiss Agency for Development and Cooperation). The TERI-SDC projects have sought to develop appropriate packages through the utilization of state-of-the-art knowledge. International experts have worked with local small-scale enterprises, fabricators, and engineers for adapting designs and operating practices to meet local needs. The TERI–SDC knowledge-transfer model can be utilized in other multilateral/ bilateral programs for improving productivity and reducing energy consumption in small scale units in different clusters. It also builds up linkages between engineering and research organizations across countries, which can then collaborate in third countries as well. In fact, off shoots of this initiative are already in the offing in the brick sector with possibilities of partnerships in other neighboring countries like Nepal and Bangladesh. A brief outline of the work done and future plan of action in the three industry segments is given in the following paragraphs.

Foundry Cluster at Howrah

Foundry is one of the most energy intensive small-scale sectors in India. There are about 7000 foundries in the country with a total installed capacity of 3.5 million tones. These units are mostly located in clusters with the cluster size varying from less than 100 to around 500 units. There are around 20 such foundry clusters in the country. Howrah (near Calcutta) is one of the largest foundry clusters in India with around 400 units. Most of the foundries were set-up three to four decades back and are family owned and managed. There has been very little investment towards modernization of plants and machinery after initial commissioning. As the industry had evolved in pre-independence period and at a time when energy was not a major concern, the energy consumption in the sector is relatively high. No off-the-shelf commercial systems have been available to the industry to help it overcome its poor energy and environment performance. The inefficient design of furnaces employed in these foundries is also reflected in lower levels of productivity.

Project Description

The major objective of the foundry project is to demonstrate energy-efficient cupola furnace design and appropriate flue gas cleaning system for the foundries in Howrah cluster. The long-term objective of the intervention in the foundry sector is to initiate a sustainable program leading to energy saving, pollution reduction and improvement in the productivity through technical support, training, and dissemination for a large-scale adoption.

In the energy audits conducted by TERI in various foundries, it was found that most of the foundries in the small-scale sector, have a very low operating efficiency of cupolas, characterized by very high coke feed ratio[2]. It was concluded that by adopting better operating practices and employing furnaces of improved design, energy savings of up to 40% is achievable. Technology upgradation of the cupola furnace leads to reduction in fuel consumption for the same output thus improving the productivity of the units. At the same time, pollution reduction at source reduces the size of the pollution control system necessary to meet the stipulated emission standards. Till 1995, most of the foundries in Howrah cluster had conventional cupola furnaces, that is, had a single row of tuyeres[3]. The divided-blast cupola, having provision for blasting air to the cupola furnace at two levels through a double row of tuyeres, is a well-proven means of obtaining economic operation at a modest investment. However, most small-scale entrepreneurs in Howrah cluster, have not adopted this simple technology because of lack of technical support and apprehension in their ability to cope with the changes in technology and consequent operating practices.

In order to demonstrate the benefits of the improved technology, a full-scale demonstration plant consisting of energy efficient divided-blast cupola and high efficiency venturi scrubber for improving the energy and environment performance was set-up by TERI at a small-scale foundry unit in Howrah. The local industry association, Indian Foundry Association, which is a partner in the project and has been involved since inception of the project, selected the site for the demonstration plant. The demonstration plant, which is operating continuously since September 1998, has been successful in reducing the coke consumption and emission of suspended particulate matter and sulphur dioxide. The coke

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[2] Tones of coke consumed for melting one tone of iron – an index of furnace efficiency

[3] Provision for fresh air intrusion into the furnace

savings achieved have been 35% compared to the best operating foundry unit in the cluster and at least 65% compared to the highly energy inefficient foundries. These results are based on the energy audits carried out in the demonstration plant and in various other foundries existing in the cluster. The comparison is shown in figure 1. Better combustion efficiency in the demonstration unit has also led to an increase in production rate of at least 20% compared to traditional cupola of the same size. To maintain a tighter control on the raw material and fuel input, the feed materials are charged into the cupola by a mechanical charging system. This has led to an increase in labor productivity, better control on quality of castings produced and improved working conditions in the factory. Adoption of the demonstrated technology by foundries planning modernization or expansion of their operations is a win-win option - an increase in production rates and also energy saving in melting operation. To widely disseminate/popularize the demonstrated technology within the Howrah cluster as well as in other foundry clusters in the country, awareness programs are presently being carried out for the benefit of all entrepreneurs and supervisors. A few other entrepreneurs have already shown interest in replicating the demonstrated technology and are in the process of setting up the energy efficient plants (TERI.1998).

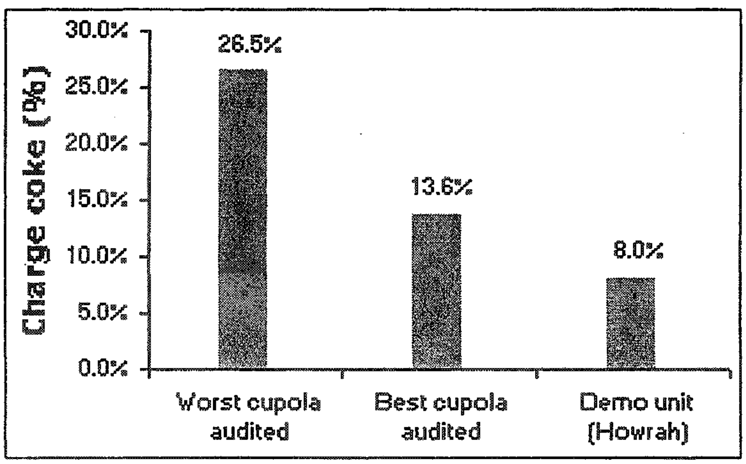

Figure 1. Comparison of Charge Coke Consumption

Glass Industry Cluster at Firozabad

Firozabad, also called the glass capital of India, is a small town in the state of Uttar Pradesh. It is 40 km from Agra, which is famous world over for the historical monument, Taj Mahal. The glass industries located at Firozabad account for roughly 70% of the total glass production in the small-scale sector. A preliminary diagnostic study of the glass cluster was carried out by TERI in 1995, to identify the areas where technological intervention would make maximum impact in terms of reducing the energy intensity. Table 1 shows the major furnace types existing in Firozabad along with a summary of the results pertaining to their energy efficiency.

Table 1. Summary of Results from the Diagnostic Study

Furnace type	Units operating (approx.)	Capacity (tons per day)	Specific energy consumption (Gcal/t of melt)	Fuel to melt ratio(kg/kg)	Thermal efficiency (%)
Tank furnace (coal)	15	15-25	3.6	0.6	12.7
Tank furnace (oil)	6	15-25	2.1	0.2	21.3
Open pot furnace	50	4.8- 6.7	5.5	1.0	9.8
Closed pot furnace	30	2-4	9.5	1.7	4.7
Muffle furnace (baking units)	400	-	-	-	3.1

In 1996, in response to a public interest litigation for protection of Taj Mahal from air pollution, the Supreme Court of India passed a landmark judgement, that had wide ranging implications for the industries located in the vicinity of the Taj. The verdict banned use of coal/ coke within the Taj Trapezium Zone (TTZ) – an area of 10,400 sq. km. around the Taj. Affected industries were asked to convert to natural gas (to be supplied by GAIL[4]), relocate outside the TTZ or shut down.

At this juncture, TERI decided to intervene in pot furnace segment (both of open and closed types), by deciding to set up an energy efficient gas based furnace in one of the functioning units. The major reasons for choosing the pot furnace segment was the non-availability of any "off-the-shelf" energy efficient solution for these enterprises to switch over to natural gas to comply with the Supreme Court mandate. This sector had the largest amount of coal usage and the factories were operating at very low levels of efficiency. For setting up the demonstration furnace, TERI requested the local industry association to nominate an industrial unit where the demonstration furnace could be installed. It was also decided to intervene in the muffle furnace segment at a later date as this area also offered tremendous scope for energy conservation and productivity improvement.

Project Description

Keeping the Supreme Court directions in mind, the major goals of the glass project were set as follows:

- To design an energy efficient gas fired pot furnace with minimum modifications in the existing operating practices for glass drawing
- To demonstrate energy savings by setting up a demonstration furnace in one of the units in the Firozabad glass industry cluster
- To design a sustainable program leading to energy savings through technical support, training and dissemination for large scale adoption of the demonstrated technology within the cluster

The pot furnaces in Firozabad, chiefly making bangles and decorative items, are all based on the same design. The conventional pot furnaces are downdraft, bottom fired using coal and wood as fuel. They have a life of 10-12 months. In view of the low energy

[4] GAIL (Gas Authority of India Limited) is a Public Limited Company that has put up India's first major in-country gas pipeline for supplying natural gas to industrial enterprises in North India.

efficiency of the conventional furnaces, it was decided to minimize energy wastage in the demonstration furnace by combustion air preheating (to reduce flue gas loss), by installing efficient combustion system (to reduce loss due to unburnt fuel) and by using better refractory and insulating material (to reduce structural loss).

The demonstration open pot furnace, using natural gas as fuel was commissioned in February 2000. Results over a period of around 10 months since the plant was commissioned have been very promising. The thermal energy consumption of the gas fired demonstration unit is 17 Gcal/day as against 39 Gcal/day in the conventional coal fired furnace of equivalent capacity. This represents a reduction of 56% over a coal-fired furnace (TERI. 2000a).

With the long-term objective of improving the energy efficiency of furnaces in Firozabad, TERI has plans to undertake the following activities in the area.

- Dissemination of the demonstrated technology and assistance (including on the job training) to other units willing to adopt TERI design
- Publications in local language about basics of savings energy and safety
- Demonstration of improvement in production rates and reduction in energy conservation by setting up a muffle furnace based upon newer innovative design.
- Imparting training to the local operators working in pot and muffle furnaces on the basics of operation so as to ensure energy efficient operation of the furnaces.

Brick Industry Cluster

Brick remains one of the most important building materials for construction activities in India. Brick making is a traditional industry, generally confined to rural and semi-urban areas. The Indian brick industry, which is the second largest producer in the world next to China, has more than 60,000 operating units, producing about 100 billion bricks annually. Brick industry is located in clusters in different parts of the country where raw materials are available. Establishing and operating brick-works have low requirements in terms of capital investment and labor skills. Most of the brick-works are small-scale units (production capacity – 1 million to 10 million bricks per year). Brick industry has an annual gross revenue of about Rs 100 billion and employs millions of workers. However, brick making is an energy intensive process as fuel costs alone accounts for almost 30% of the production cost. Thus it comes as no surprise that the annual coal consumption in the sector is estimated to be in the range of 15 – 20 million tons, placing brick industry as third largest consumer of coal in the country next to thermal power plants and steel industry.

Project Description

A two-pronged strategy was adopted for promoting energy efficiency in the brick sector. It involved demonstration of Vertical Shaft Brick Kiln (VSBK) technology in different brick kiln clusters in the country and incremental efficiency improvement in traditional Bulls Trench Kilns (BTKs).

VSBK technology demonstration, adaptation and dissemination. An energy efficient and sustainable alternative to the traditional kilns is the Vertical Shaft Brick Kiln. This technology which originated in China has a promising future in India as it is suitable for small-scale brick manufacturing. The major advantages of VSBK technology are:

- *Highly energy efficient method for firing bricks.* VSBK technology results in an energy saving of more than 50% compared to clamps[5] and 30% compared to BTKs.
- *Increase in productivity.* Because of proper control on the combustion conditions, it is possible to drastically reduce the production of improperly fired bricks. It is thus possible to increase productivity by almost 15 - 30% compared to traditional kilns.
- *Compact nature of kiln.* This kiln is very compact, requiring a small area of land. For the same production capacity, the land requirement is about 1/4th compared to BTK.
- *Operation.* Easy to operate and does not require electricity for functioning.
- *Investment.* The construction cost, though slightly higher compared to BTK, is still reasonably low.
- *Capacity utilization.* Since VSBK can be operated during monsoons, which means protection from rain and year-round operations (other brick kilns are able to operate only for 5–6 months in a year), it helps in better capacity utilization and consequently increase in production volumes.

A major step in bringing this technology to India was taken by TERI along with the other project partners, by setting up four VSBK pilot plants in diverse climatic and socio-economic regions. These plants have been operational for the past three years and are now poised to act as models for other brick kiln clusters elsewhere in the country. They have generated widespread interest among all the concerned stakeholders and have also been found to be commercially viable. Presently there are 10 VSBKs operating in India and another 10 are under various stages of construction.

TERI has recently finalized a plan to disseminate the technology on a much wider scale in the country. Different organizations would be involved in this process that would cover different regions of the country. Large-scale dissemination of VSBK technology would require a decentralized approach. Hence there are plans to develop a pool of entrepreneurs who would serve as technology providers in different brick industry clusters in the country.

Improvements in BTKs. BTK technology is about 125 year old. However, during its long lifetime it has not witnessed any considerable changes. The production capacities of BTKs are generally large (varies from 15,000 to 50,000 bricks per day). They are highly polluting, affecting not just the flora and fauna, but also posing severe threats to human health. The productivity in these kilns is extremely low with a large number of bricks being discarded either due to over-firing or under-firing.

TERI studied in detail the emissions as well as energy use in BTKs. It included detailed measurements of air pollution in kiln stacks; heat loss to ground; and heat loss from kiln surface. These studies provided better scientific understanding of the functioning of kilns and in identifying measures that reduce fuel consumption and emissions. A reduction of upto 20% in energy consumption and 50% in emissions (suspended particulate matter) were demonstrated in fixed chimney BTKs. The improvement in performance was achieved through controlled fuel feeding practices, provision of larger chimneys, better insulation of kilns, and provision of pollution control systems such as gravity settling chamber. During the studies, it was found that by adopting better operating practices in fuel feeding, a reduction of

[5] Traditional brick manufacturing technology that exists in certain clusters. It differs from BTKs in terms of stacking and firing methodology.

5-10% in rejects (with a corresponding increase in productivity) has been achieved. The efforts clearly demonstrated that enhanced energy management in brick production leads to increased productivity for the kiln owners (TERI. 2000b)

Conclusion

Small-scale industry sector is a very important segment in the Indian industrial sector and would continue to play a crucial role in the Indian economy in the future. It has also been observed that many of the units in the SSI sector are today plagued with technological stagnation and their quality, efficiency and productivity have actually declined over the years. Except for a few progressive units that have incrementally improved their performance over the years, most of them can be classified as "passive users of technology". In addition, in view of the opening up of the Indian economy, many new players are coming into the field and the sector is now facing increasing competition from imports as well as from larger units. To remain competitive, the units, therefore, need to adopt newer and innovative approaches to upgrade their technological capabilities and thus remain competitive. The small-scale units, however, have limited capacity and resources to invest in the technological capability development. Unlike the large firms, which might have in-house capability to improve the technology and undertake energy conservation and productivity improvement projects, the small-scale industry is more dependent on external sources of skills and knowledge. This calls for active involvement of a technology developer who should interact and work together with the local industry associations and other stakeholders in developing energy efficient and environmentally sound technological solutions that are appropriate for that SSI segment. The case studies in the three energy intensive small-scale sectors (foundries, glass and brick) clearly brought out the benefits of looking at SSIs by using the concept of "collective efficiency". This basically meant looking at the combined advantages the SSI units would experience as a result of gains from joint action. Thus it can be said that a cluster-based approach is one of most effective means for demonstrating the benefits of energy conservation and productivity improvement in small-scale industries. The learning occurs fairly fast at a cluster level and is embedded in the formal and informal organization structures existing in the clusters.

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