Technology Transfer of Low Carbon Energy-efficient Technologies – A study of SME Sector in India

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Abstract

The small- and medium-sized enterprises (SME)1 sector plays a vital role in the Indian economy, contributing around 45 per cent of manufacturing output and 40 per cent of exports, and employing an estimated 59.7 million people spread over 26.1 million enterprises according to recent estimates. SMEs today account for almost 90 per cent of the total number of industrial units in the country (Government of India, 2011). In order to promote small industries, a large number of items were reserved to be produced exclusively in small sector during the 1970s and 1980s. However, having functioned for five decades within an overly protective economic and industrial framework, a substantial proportion of Indian SMEs remain isolated from modern technological developments. Apart from certain new-age sectors such as information technology, biotechnology, pharmaceuticals, etc.), SMEs in traditional manufacturing sectors such as castings, forgings, glass and ceramics, food processing, textile processing and so on use obsolete, inefficient technologies to burn commercial fuels (coal, oil and gas), leading to wastage of fuel as well as the release of high volumes of greenhouse gases (GHGs) and particulate emissions that are harmful to health and damage the atmosphere. A large number of energy-intensive SME clusters (around 178 clusters manufacturing about 15 product categories) are energy intensive, with fuel costs making up 2 per cent to 50 per cent of the total cost of production (TERI, 2009). While individual SME units are relatively small in size, their sheer numbers, coupled with the fact that they depend on low-efficiency fuel burning technologies, make the SME sector a sizeable source of carbon emissions. Hence, there is a clear and urgent need for SMEs to adopt EE (energy-efficient) technologies that will help them reduce both fuel consumption and carbon emissions.

This study summarizes two successful low carbon technology transfer projects to promote energy efficient technologies in two energy-intensive SME sub-sectors: small-scale foundries and small-scale glass industries. The technology development and demonstrations were undertaken during the period of 2000 to 2019.

Key words – Carbon footprint, GHG, C02, Climate change, Sustainable technology.

Small-scale foundries

Profile

Foundries make iron castings from molten iron. Castings find diverse applications, such as in the manufacture of sanitary pipes and fittings, automotive parts and engineering equipment (e.g. pumps, compressors and electric motors). There are about 5000 small-scale foundry units in India, with a collective annual output of about 6 million tonnes of castings. While their output predominantly caters to domestic markets, a small percentage is exported. The foundry sub-sector is growing at 8 to 9 per cent annually and provides direct employment to an estimated 0.5 million people.

The Indian foundry industry had its roots in the 19th century, when industrialization and rapid expansion of railways provided an assured and growing market for castings. After Independence, the steel and coal-mining sectors largely remained under government control, hence the foundry industry was assured about both the availability and prices of its primary raw materials, pig iron and coke. In this scenario, energy efficiency was not a major concern for foundries. However, the situation changed following the opening up of the Indian economy during the early 1990s. Competition has forced the large integrated steel plants to reduce pig iron production, leading to a rise in the price of pig iron. In addition, with the removal of licences and permits to obtain coke, small-scale foundries are no longer assured of coke supplies at steady prices. Hence, energy efficiency has become of vital concern for small-scale foundries as a means of reducing fuel consumption and costs and thereby increaeing profitability and competitiveness.

Foundries are mainly located in clusters across the country. The clusters vary in size: some have less than 50 units, while others have over 500 units. Typically, each cluster specializes in producing castings for specific end-use markets. For instance, the Howrah cluster in eastern India has around 300 foundries that mainly produce low value-added castings such as manhole covers and pipes; while the Rajkot cluster in western India has around 500 foundries that mainly produce grey iron castings for the local diesel engine industry.

Mirroring the different products they make and the diverse markets to which they cater, foundry clusters differ from one another in terms of technology, operating practice, and commercial dealings. Within a cluster, foundry units usually operate in isolation; there is little sharing among them of information related to technology, operating practice, and so on. The units may form loose associations; but these are primarily for the purpose of obtaining fuel (coke) at favourable prices from suppliers and for other trade-related issues.

Technology

A foundry makes iron castings by melting a variety of iron-containing materials such as pig iron and cast iron scrap in a furnace called a cupola. The resulting molten iron is then poured into moulds to make castings of desired shapes. Usually, cupolas burn coke as fuel. Melting is by far the most energy-intensive stage of a foundry's operations.

Until the early 1990s, most Indian foundries were using the conventional 'cold blast' cupola. As described later, TERI partnered with the UK-based BCIRA (now known as BCIRA Cast Metals Technology Centre)2 to identify, transfer and adapt a more energy-efficient melting technology for small-scale Indian foundries – the DBC (divided blast cupola).

Scope for reducing carbon emissions

The total coke consumption by the foundry sub-sector is estimated to be around 600,000 tonnes per year (equivalent to around 1,640,000 tonnes CO_2). There is considerable scope for saving 20 to 40 per cent fuel and reducing carbon emissions in this sector by switching to the energy-efficient DBC technology.

Small-scale glass industries

Profile

Almost the entire small-scale glass industry in India is located in a single cluster in Firozabad, about 4 km from Agra. According to a TERI estimate, each day, glass units in Firozabad produce around 2000 tonnes of glass products, including 50 million bangles, and provide direct employment to an estimated 150,000 people.

Besides having a near-monopoly in the production of bangles, the Firozabad glass cluster also produces popular low-value glass products (bowls, tumblers, lamp shades and so on). There is a steady demand for such products across India. However, with very little to distinguish the glass products made by one unit from another, and in the absence of direct linkages with consumers or retail markets, units sell their products at prices dictated by dealers and middlemen. As a result, competition is vicious among units, and profit margins are thin and unpredictable.

During the early 1990s, glass entrepreneurs had very few options to increase returns. There was no room to reduce manpower or wages. Fuel (coal) costs were beyond their control. The only way to reduce fuel costs was by increasing the energy efficiency of the glass melting furnace; but this task required technical knowledge and skills that neither the entrepreneur nor the traditional furnace builders (mistrys) possessed.

Technology

Glass is made by melting silica sand (which contains about 96 per cent, by weight, silicon dioxide – SiO_2) together with chemicals that reduce melting temperature and give strength and colour to the end-product. The molten glass is drawn from the furnace, blown or formed into desired shapes, and then annealed (heated and cooled in a controlled manner) to impart hardness to the glass. Depending upon their nature, the products are then subjected to various cutting and finishing operations. The glass industry is highly energy-intensive, with fuel cost accounting for over 40 per cent of product cost.

In Firozabad, three basic kinds of melting furnaces are used to make glass: tank furnaces, open-pot furnace, and closed-pot furnaces. Glass for making bangles is melted almost exclusively in open-pot furnaces. Until the early 1990s, almost all of these furnaces operated on coal. By 1996, most tank furnaces in the cluster (about 55 in number) had switched from coal firing to oil firing, but pot furnaces (about 100 numbers) were still being fired by coal. As described later, TERI worked with British Glass and other in partners to transfer know-how for the development and promotion of a more energy-efficient melting technology for small-scale glass melting units in Firozabad – the gas-fired recuperative pot furnace. The fuel switch from coal to natural gas was mandated by the Supreme Court of India in December 1996 with the Taj Trapezium Zone (TTZ), an area of 10,400 square kilometre^2 around the Taj Mahal, within which Firozabad is located.

Scope for reducing carbon emissions

According to a study by TERI (1995), the pot furnace units in the Firozabad glass cluster consumed around 100,000 tonnes of coal annually. As a result, there was considerable potential to reduce coal consumption and decrease carbon emissions in this sector by shifting to more energy-efficient technologies for producing molten glass.

Collaborative research, development, demonstration and diffusion (RDD&D)

In 1992, the SDC initiated a macro-level study by TERI of energy consumption patterns in the Indian SME sector. Based on this study, the SDC partnered with Indian non-governmental organizations (NGOs)/research institutions and international consultants to initiate a programme aimed at introducing clea, energyefficient technologies in four energy-intensive SME sub-sectors. Two of these sub-sectors – namely, the foundry and glass industries – are discussed in this case study. The other two sub-sectors identified were the small-scale brick industry and small/micro enterprises that burn biomass fuels. The overall goals of the SDC programme were to:

• help SMEs achieve energy savings and thereby improve profitability of operations'

• bring about reduction in CO2 and other emissions and thereby address environmental concerns at both local and global levels.

Technology transfer process

In the case of both small-scale foundries and small-scale glass industries, energy efficient technologies were identified, transferred and adapted to local conditions and requirements in the following broad stages:

• conducting energy audits to identify areas in which to improve energy efficiency (needs assessment);

• identification, design, development and adaptation of energy-efficient technological solutions in collaboration with international experts, industry associations and local experts;

• demonstration and fine-tuning of the improved technologies through unit-level demonstration/pilot projects;

• strengthening the knowledge and skills of local entrepreneurs and building their confidence and capabilities in the new/improved energy-efficient technologies through on-going capacity building programmes (thus preparing the ground for dissemination and mainstreaming of the demonstrated technologies).

During the technology transfer processes, TERI obtained strategic support and inputs from Sorane SA, Switzerland. Sorane SA provided advice in energy management and systems integration, helped to identify and coordinate activities with international energy and environmental consultants, and assisted by way of technical support.

Energy audits

During 1993 to 1994, TERI conducted detailed energy audits of representative units in the Agra foundry cluster. The audits revealed that the 'coke feed ratio', or CFR3 (a measure of cupola efficiency), ranged between 31 and 19 per cent in the existing cupolas, compared with the best CFR levels achieved within India and abroad of about 10 per cent. This indicated large potential for improving energy efficiency by introducing optimally designed cupolas and adopting best operating practices (BOPs). TERI also conducted energy audits of representative glass units in the Firozabad glass cluster in 1994. These audits revealed that the energy efficiency of the coal-fired open pot furnace was as low as 10 per cent, with flue gases escaping from the furnace at a temperature of around 950°C. These findings indicated considerable potential to increase energy efficiency in pot furnaces through heat recovery from flue gases.

Identifying technologies for transfer

Having identified the areas in which to introduce energy-efficient technologies – namely, the cupola furnace in foundry units and coal-fired open pot furnace in glass units – TERI teamed up with international partners to select appropriate technologies which could be transferred and adapted to the local industry needs.

In each case, the first step was to evaluate existing technologies to identify those that could be adapted or modified to meet the standards set for better energy efficiency and environmental performance. Thereafter, from among the available options, the most appropriate one – that is, the one most suited to adaptation to meet local needs and conditions – was selected through a bottom-up participatory process and transferred for further development to meet the needs of the industry concerned.

Divided-blast cupola

In the case of foundries, the results of the Agra cluster energy audits were discussed and validated by experts from Cast Metals Development Limited, UK, a group company of BCIRA. The discussions also focused on finding ways to improve the efficiency of the melting furnace. Based on its consultations with the British partners, TERI chose the divided-blast cupola or DBC as the best option to improve energy efficiency in small-scale foundries at a modest investment. The DBC offered the following advantages over the conventional cupola:

• coke consumption reduced by about 25 per cent; • tapping temperature increased by about 50º C; and

• melting rate increased.

Gas-fired recuperative pot furnace

The identification of EE technology options for the open pot furnace in Firozabad presented a unique challenge, primarily because a pot furnace is intrinsically inefficient in design. Pot furnaces had been used in countries such as the UK and Germany; but these burned better-quality coal to make very high-value products such as crystal ware, as a result of which the proportion of fuel cost in the product cost (i.e. the energy intensity) remained low, making operations profitable. In contrast, the pot furnaces in Firozabad burned medium-grade coal to make relatively low-value items hence the fuel cost made up a substantial portion of the product cost. The result: low profitability of operations.

Following extensive consultations between TERI, its British partners and Sorane SA, a new pot furnace design was evolved through research, development and demonstration in the Firozabad glass cluster: a gas-fired pot furnace with its burner mounted on the crown, and with a recuperator to recover and reuse waste heat from flue gases.

Technology development and demonstration

Divided blast cupola

TERI developed and demonstrated the DBC at a foundry unit in the Howrah cluster. In setting up the demonstration plant, the project brought together local and international experts in many disciplines – project management, foundry technology, energy management, cupola operation, and environmental technology.

In particular, Cast Metals Development Limited, UK, provided crucial support and expertise in transferring technical know-how related to the DBC, and at every stage during the design and commissioning of the demonstration plant. The British partner assisted the TERI team in conducting an energy audit of the existing cupola in the demonstration unit; in analysing the results of the audit so as to evolve design parameters for the new DBC; in ensuring that quality and design norms were adhered to during the fabrication of various components of the DBC; and in finetuning various sub-systems during the trial runs.

The demonstration DBC was successfully commissioned in mid-July 1998. The DBC showed a marked improvement in energy efficiency (CFR 8 per cent) compared with the existing cupola (CFR 13.3 per cent). In effect, the new plant yielded an energy saving of about 40 per cent compared to the earlier cupola. The DBC also yielded additional benefits in terms of an increase in metal temperature and a substantial reduction in silicon and manganese losses. On an average monthly melting of 430 tonnes, the demonstration DBC yielded an annual saving in coke of 270 tonnes. The payback period worked out to less than two years on the investment in the DBC alone.

Although the new DBC had proved itself to be far more energy-efficient than the existing cupola, proper operating practices had to be followed to reap the full benefits of its improved design. Hence, following the demonstration, TERI and its British partners worked for several weeks in training the furnace operators and maintenance personnel to follow BOPs in the day-to-day running of the plant.

Recuperative pot furnace

In designing, developing and demonstrating the new gas-fired pot furnace, TERI worked closely with a number of British partners whose key roles are summarized as follows.

• British Glass, UK, provided expertise in glass technology. Along with other partners, British Glass also finalized the conceptual and detailed designs of the new pot furnace.

• AIC (Abbeville Instrument Control Ltd), UK, helped in developing the concept and design of the new furnace, including its heat recovery unit (recuperator).

• Chapman and Brack, UK, provided guidance in constructing the crown of the furnace.

• TECO (Toledo Engineering Co Inc), UK, provided expertise in commissioning the recuperator for the furnace.

• NU-WAY, UK, supplied the burners for the furnace.

The gas-fired recuperative pot furnace was successfully commissioned in February 2000. Following the demonstration, TERI and its British partners trained furnace operators and other workers in monitoring and operating the new system. The British partners continued to provide support for a few years after demonstration in trouble-shooting the furnace system and in fine-tuning its performance parameters.

The energy consumption of the gas-fired recuperative furnace was measured at 16.5 gram calories per day (Gcal/day), against 39.4 Gcal/day in the traditional coalfired pot furnace. This represented a 58 per cent reduction in energy consumption, of which around 28 per cent came from heat recovery alone. Estimates by the project team indicated that the recuperative furnace was also 34 to 38 per cent more energy efficient than the retrofitted gas-fired furnaces being used by other pot furnace units in the Firozabad cluster.4 Because of its increased fuel efficiency, the recuperative furnace promised a payback within two years.

Technology dissemination and results

Following the successful demonstration of the two EE technologies – the DBC and the recuperative pot furnace – TERI focused its efforts on disseminating these technologies through:

• providing customized design solutions and installation/commissioning support to other entrepreneurs on the new energy-efficient technologies;

• awareness generation among industry stakeholders at both policy and cluster levels;

• capacity-building programmes involving entrepreneurs, fabricators, local consultants, masons and other stakeholders.

The Swiss and British partners continued to provide technical support to the project in order to facilitate replication of the EE technologies.

As of September 2010, around 95 TERI-design DBCs of different capacities (based on local requirements) have been adopted by foundry clusters across the country (Ahmedabad, Rajkot, Coimbatore, Nagpur, etc).5 The adoption of this energy-efficient technology has yielded an estimated cumulative energy savings of 33,000 tonnes of oil equivalent (toe) and a cumulative CO2 savings of about 120,000 tonnes to date. The DBC technology has also been replicated in two foundry units in Bangladesh with technical support from TERI – an example of successful South–South technology transfer. Widespread adoption of the DBC will make it possible to save about 25 per cent of the coke consumed by the Indian foundry industry (i.e. 150,000 tonnes of coke annually). The overall CO2 emissions from conventional cupolas used by the foundry industry are estimated at 2.5 million tonnes per annum. The CO2 emissions could be reduced by around 0.6 million tonnes annually through the widespread adoption of DBC technology.

Similarly, with on-going technical support from TERI, 76 of the 100 odd operating pot furnace units in the Firozabad cluster have since switched over to the TERI-designed recuperative furnace, yielding an estimated cumulative energy savings equivalent to 79,000 toe. Most of the remaining pot furnace units are expected to follow suit in the next few years. These replications have brought about a cumulative reduction in carbon emissions of 245,000 tonnes CO2 . In addition to these 'direct' replications of the TERI-designed furnace, reportedly almost all pot furnace units in Firozabad have adopted the concept of heat recuperation from the TERI-designed furnace. This in itself indicates that the technology transfer process has succeeded; that the entrepreneurs have shed their traditional reluctance to consider changes in their technology, and are becoming increasingly confident in learning from the improved EE technologies and adapting them to suit their individual needs.

Intellectual property rights (IPRs)

Given the fact that SME entrepreneurs in developing countries are generally resource poor (as they operate on thin margins), it is difficult for them to raise the resources to invest in improved technology (which may have elements of IPR), even when they are willing to overcome their intrinsic reluctance to abandon their traditional technologies. Often, therefore, an improved technology that is introduced in the SME sector (which, in most cases, is likely to be costlier) is prone to be reverse-engineered by local manufacturers and sold in cheaper forms. The 'hardware' elements of technology (e.g. specific pieces of imported equipment such as burners, etc.) are particularly prone to be reverse-engineered. The 'software' elements (such as design drawings for a cupola furnace) are less prone to be engineered locally, primarily because they have an intrinsic element of knowledge which requires capacity-building of local stakeholders (from implementing agencies, local consultants, users, etc.). Besides, for each particular industry, the 'software' needs to be adapted to suit local conditions.

It is therefore vital for all project partners and collaborators – including both hardware and software suppliers – to be aware of these ground realities of the SME sector. However, it is important to note that the reverse-engineered models are usually not perfect and therefore perform far less efficiently than the original technologies. For instance, some pot furnace units in Firozabad are using a locally made gas burner that resembles the gas burner imported from NU-WAY, a leading manufacturer of energy-efficient burners in the UK, and costs much less. However, reports indicate that the locally made gas burner reportedly has a much shorter life than the NU-WAY burner, and its performance is unpredictable. Likewise, reports from the foundries in Howrah that have adopted DBCs without reference to the project indicate that their performance is suboptimal.

As a result, although the overall deployment of improved technologies (including original and self-replicated versions) is not hindered by the tendency in the SME sector to reverse-engineered technologies, the overall fuel and carbon savings achievable is reduced to some extent because the performance of these locally engineered technologies is usually suboptimal.

Policy implications

• Small-scale industries manufacturing energy-intensive products form the backbone of many developing country economies. There is an enormous potential to reduce CO2 emissions at lower costs in this sector. This is important considering the fact that SMEs, in general, do not have either the inherent financial capacity or the technical capacity to undertake research or adaptation activities that would help them to improve their energy and environmental performance. It is therefore important to identify such SMEs in developing countries (preferably a group of enterprises having a similar technological base and similar operating practices), and then develop tailormade RDD&D programmes for them (which may be industry/cluster specific), with support from multilateral/bilateral organizations, especially in the context of climate change.

• The RDD&D programmes should focus on cleaner production, which means conservation of resources and energy use in the production processes through improved technologies. The industry associations at the local/state levels can play an important role by identifying suitable locations for initiating such programmes, while multilateral agencies can help in facilitating inter-governmental partnerships and bringing international technical experts together in such programmes.

• The technology demonstrations could focus on 'incremental' technological improvements, which would be easily adopted by the SME sector. By their very nature, SME units find it hard to absorb rapid change; they are inhibited by factors such as lack of technical knowledge, resource constraints, low productivity, and so on. A step-wise incremental approach in TT allows them to adopt and absorb better technology/operating practices, and based on their own unique (unit-specific) requirements; all that they require is the necessary technical back-up support to be able to do so. The incremental approach also imparts a growing confidence in the entrepreneurs to experiment with, evolve and adopt their own cost-effective technological solutions.

• In order to ensure their sustainability in the long term, RDD&D programmes in the SME sector should have a strong partnership element and involve local actors right from the initial stages. Local actors can take over once the consultants and expert R&D organizations have helped the SMEs to identify and demonstrate the benefits of cleaner technologies.

• It is equally important for funding agencies to have a long-term commitment and a flexible approach in RDD&D programmes; change is invariably a slow process at the small-scale industry level. A prime factor that has contributed to the success of the TT project highlighted in this case study is the flexibility and long-term engagement with the project shown by the SDC, and the unique partnership arrangement that exists among the project partners at different levels: between the funding organization (SDC), implementing agency (TERI), local consultants, international consultants, industry associations at cluster level and grassroots-level agencies. There is a need to develop and replicate similar innovative partnership arrangements on a much larger scale for interventions in the SME sector.

• For a collaborative RDD&D venture in the small-scale sector to be effective in bringing about sustainable change, technology transfer should not take place directly between technology supplier(s) and end users. Rather, it should be routed through an intermediary institution (such as an R&D establishment or consultancy organization), which can act as a facilitator to disseminate the improved technology on a large scale. An example is the TT project described above, in which TERI as an intermediary institution was able to absorb two improved EE technologies and then transfer and adapt them for dissemination among a large number of SMEs across India.

• One of the financial mechanisms available for promoting low-carbon technologies under international climate change protocol is the Clean Development Mechanism (CDM). However, high transaction costs act as a barrier in initiating small CDM projects in the SME sector. For CDM projects to be workable in the SME sector, there is a need to revisit the CDM implementation cycle – specifically, the documentation and verification formalities. A simplified CDM project cycle for SMEs holds promise of reducing millions of tonnes of GHG emissions in diverse SME sectors in developing countries.

Notes

1 The manufacturing enterprises are defined in terms of investment in plant and machinery. They are classified as small scale if the investment does not exceed 50 million Indian rupees and medium scale if the investment is below 100 million Indian rupees. US$1 is about 45 Indian rupees.

2 BCIRA is the UK's leading organization involved in research and development within the field of cast metals.

3 The energy efficiency of a cupola is measured in terms of the amount of coke consumed per tonne of metal charged. Known as CFR, or coke feed ratio, this is usually denoted as a ratio or as a percentage. The lower the CFR, the more efficient is the cupola.

4 By December 2001, almost all pot furnace units in Firozabad had adopted a 'retrofitted' gas-fired furnace design, which provided some improvement in energy efficiency compared to coal firing. However, the recuperative furnace designed by TERI and its partners proved far superior in terms of energy efficiency, as described.

5 The number of replications needs to be viewed in light of the fact that they focused on a limited number of foundry clusters in India. An external review of the project conducted in July 2011 mentioned that a much larger number of cupolas have adopted certain innovative design features introduced under the project, if not the entire cupola. Hence, there are spin-offs of the innovation. Some factors which have inhibited quicker replication are the slow pace of change typical among small-scale industries, the higher capital cost, the lack of life-cycle costing by SMEs, and limited capacity for and availability of the DBC technology at the cluster level.

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