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Table of Contents

List of Tables

List of Figures

1 Background

Indian economy is growing at a steady pace over the last few years and is in transition towards development. Much of this growth has been fuelled by the industrial sector. The rising energy requirement and consequent GHG emissions from the sector have emerged as a major threat to climate change. Industrial growth is important for a developing country like India, considering the enormous employment and income opportunities it offers to the ever growing population of India. The challenge, however, is to grow in a manner that is resource-efficient and addresses sustainability considerations from all perspectives – social, economic, and environmental.

1.1 Industry and Economy

The industry sector plays an important role in the Indian economy in terms of its contribution to economic growth, trade, and as a provider of employment. The sector is a mixture of large-scale state-of-the-art plants as well as traditional micro, small and medium enterprises (MSMEs) who primarily deploy out-dated technologies. India's gross domestic product (GDP) figure crossed (USD 2 trillion in 2014 out of which over 26% was contributed by industry.

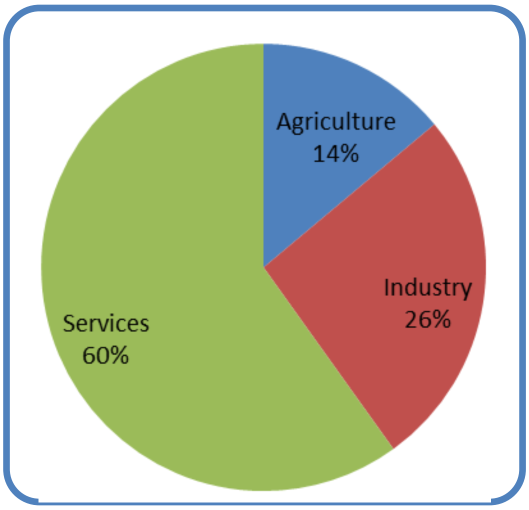

Figure 1 Sectoral contribution to India's GDP (2014)

Source: Planning Commission, 2014

The economy slowed down during the global financial crisis, but recovered to around the 8% mark soon after. In 2011-12, real GDP growth fell to a low of 6.5% (Figure 1), with the slowdown being most pronounced in the industrial sector, which was instrumental in leading the recovery after the global financial slump. According to recent studies, India's manufacturing industry will touch USD 1 trillion by 2025 (McKinsey & Co, 2012). The rising demand within the country and the shifting of labour intensive operations to India by multinational companies will contribute to this growth. Up to 90 million jobs could be generated by that time, with the sector contributing to about 25–30 per cent of GDP.

Some of the major energy-intensive large-scale industrial sectors in India include cement, textiles, iron & steel, fertilizers, aluminum, pulp & paper, and chlor-alkali. One sector where Indian industry is relatively efficient even by international standards is the cement industry. India is the second largest manufacturer of cement in the world, accounting for about 5% of the world cement production. However, the per capita consumption of cement in India still remains as one of the lowest in the world (about 130 kg) whereas the global figure is 260 kg.

The per capita consumption trends in India of other manufactured products are also very similar. The total installed capacity of cement in India is 184 million tonne (mt). The Indian cement industry comprises 165 large cement plants with an installed capacity of 277 (mt). In addition, there are more than 350 mini-cement plants in the country. The best thermal and electrical energy consumption presently achieved by the Indian cement industry is about 663 kcal/kg clinker and 59 kWh/t cement which are comparable to the best reported figures of 660 kcal/kg clinker and 65 kWh/t cement in a developed country like Japan.

Textiles account for about 14% of India's industrial production, 4% of GDP, 11% of total exports and is the second largest employer after agriculture employing nearly 45 million people. Out of the 3,300 textile mills in India, just 90 are in the large-scale sector (classified as designated energy consumers by Ministry of Power). Indian textile mills are relatively energy inefficient compared to international standards. Hence there is a good scope to improve their energy efficiency through introduction of latest technology.

The MSME sector is an important segment of the industry in India as is evident from its contribution to country's income, employment and output. MSMEs are also complementary to large industries as ancillary units. According to the Ministry of MSME, there are about 44 million MSMEs in India employing over 100 million people. The sector is the biggest employer in India outside the agriculture. Additionally, the contribution of MSMEs to the nation's overall industrial production as well as GDP has shown a rising trend in recent years; at present, the MSME sector accounts for close to 45% of India's manufacturing output, 40% of total exports, and over 8% of GDP. There are over 6000 products, ranging from traditional to high-tech, that are manufactured by Indian MSMEs. Many of the MSME units producing similar products exist as clusters located within a small geographical region. There are over 400 such manufacturing clusters across the country of which nearly half comprise of energy intensive sectors such as metallurgy, ceramics, glass, brick, textiles and so on. Most of these MSMEs function in isolation and are constrained in being able to access and make gainful use of knowledge, processes and mechanisms that allow technological progress.

Post liberalization, Indian economy in general and industry sector in particular witnessed rapid growth and progress. High growth rates in the industrial sector have helped achieve significant development gains. The high growth can only be sustained if resource constraints and environmental issues related to industrial growth are adequately addressed. To do so, industries have to embrace a new growth strategy that can turn the trade-off between economic development and environmental protection into a win-win synergy in which "going green" drives economic growth.

The manufacturing sector is expected to grow steadily at 8-10% per annum for the next few decades. A National Manufacturing Policy, 2011 has been formulated by the government with the objective of increasing the manufacturing sector growth rate to over 12% per annum, so that its contribution to GDP is increased to 25% by the 2025 (Planning Commission, 2012). The policy is based on principle of industrial growth in partnership with the states. The Government is providing incentives for infrastructure development to states under the Public Private Partnership (PPP) mode. Maintaining a high growth rate is essential for the Indian industry. This is even more important to provide job opportunities to an ever growing workforce of India and increasing the living standard of the large population. Industrial growth will lead to economic benefits, but simultaneously may pose environmental challenges if sustainability issues are not addressed. For example, India will need to expand its power infrastructure substantially to meet the increasing industrial demand, which could increase GHG emissions, if the increased demand is met from fossil based power plants.

In this context, there is a need to promote green/environment friendly technologies for sustainable development of the industrial sector. One of the least cost proven strategies for achieving sustainable growth of the industrial sector is to improve the end-use energy efficiency of industrial equipment/processes. Energy efficiency improvements in industry can be achieved through adoption of energy efficient technologies and best operating practices (BOPs). Improving energy efficiency will not only promote developmental objectives, but also has significant co-benefits. These co-benefits include lower GHG emissions, increased productivity, better working conditions, reduced health risks and growth in green jobs (IPCC, 2007).

1.2 Rationale for Green Growth

The industry sector accounts for about 45% of the commercial energy consumption of India. The final commercial energy consumption in India reached 353 million tonnes of oil equivalent (MTOE) in 2011-12 (TERI 2015). Fossil fuels accounted for about 90% of the commercial energy supplied in India during 2011-12.

Industry had the highest share of contribution in India's final commercial energy consumption, amounting to 160 MTOE in 2011-12 (TERI 2015) (Figure 2). Some of the large energy-intensive industries in India have been classified as Designated Consumers (DCs) under the Perform, Achieve and Trade (PAT) mechanism, under the National Mission on Enhanced Energy Efficiency, which was launched by Ministry of Power in June 2008. A total of 478 large-scale industries have been identified as DCs from across eight key energy intensive sectors thermal power plants, iron and steel, cement, textile, fertilizer, aluminium, pulp and paper and chlor-alkali. These energy-intensive sectors account for about 60% of the total energy use in the industry sector (BEE, 2012). In addition, the energy consumption of energy-intensive sub-sectors within the MSME sector in India is significant. MSMEs are typically concentrated in geographical clusters. There are more than 200 energy-intensive MSME clusters in India covering industries like foundry and forging, glass and ceramics, textiles, pulp and paper, chemicals, food processing and so on.

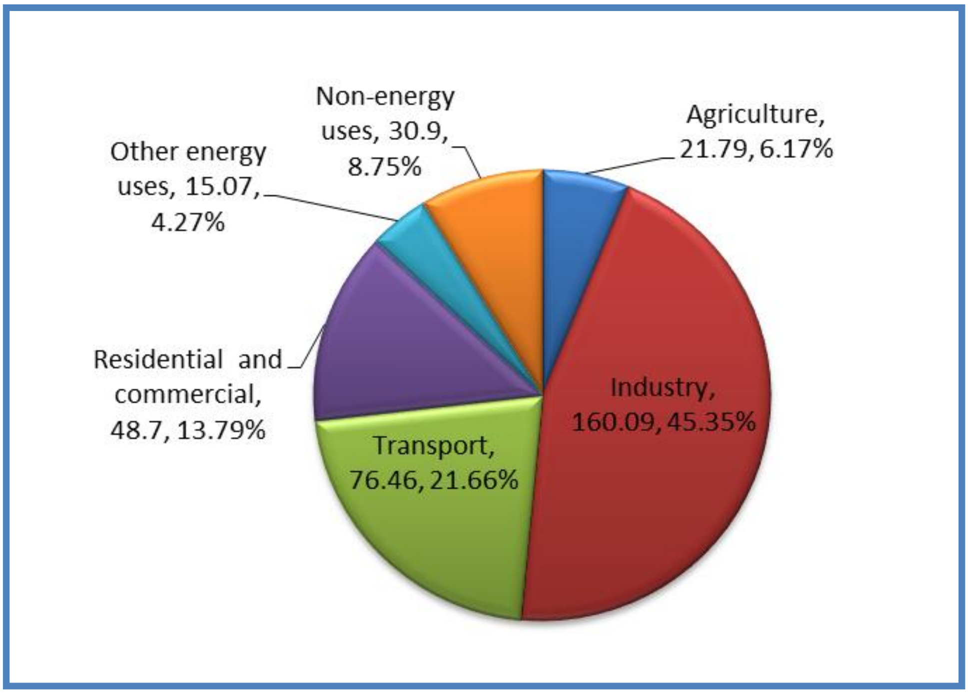

Figure 2 Final commercial energy consumption (in MTOE) across various sectors in India in 2011-12

Source: TERI 2015

India is largely dependent on fossil fuels to meet its energy needs. Coal contributed to over 32% of the total commercial energy supply in the country (TERI 2014). Crude oil and natural gas contributed about 60 % or so while nuclear, renewable and hydro accounted for the remaining percentage (Figure 3).

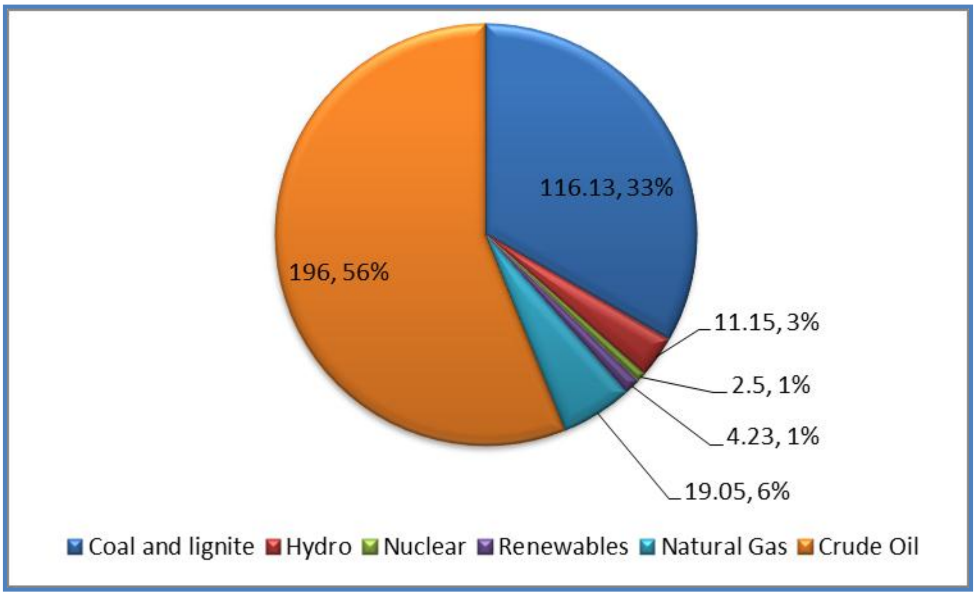

Figure 3 Sources of commercial energy supply (in MT) (2011-12)

Source: TERI 2015

Coal and lignite account for the major share of energy consumed in industries. Figure 4 shows the percentage of energy sources of the industry sector in India.

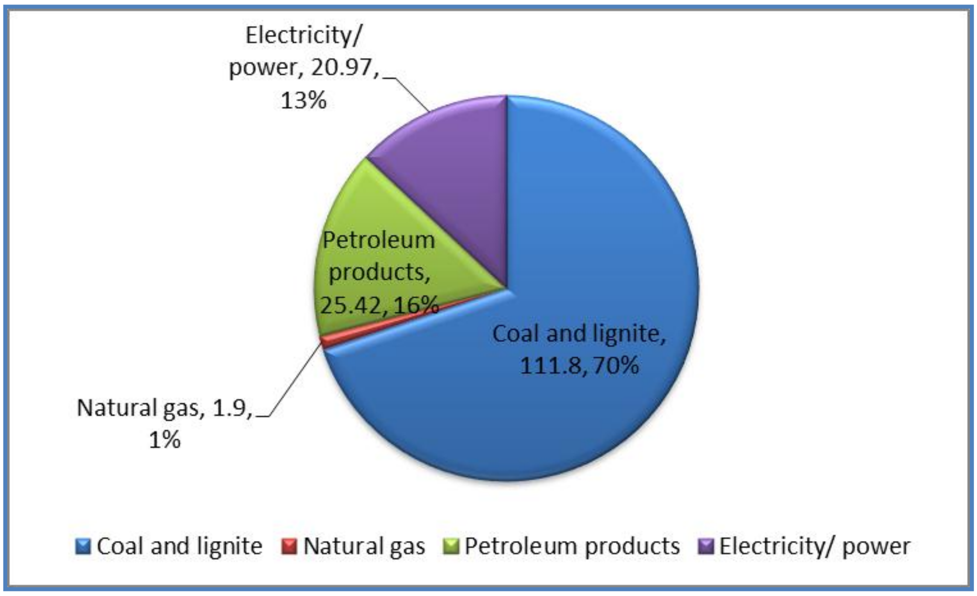

Figure 4 Energy sources (%) in the industry sector (2011-12)

Source: TERI 2015

The increase in energy usage has led to a consequent increase in GHG emissions; in 2007, India's GHG emissions reached 1,728 million tons of CO_2 eq, (MoEF 2010). Because of the high energy consumption, the industry sector is one of the largest emitters of GHG as well. According to the national greenhouse inventory data compiled by Ministry of Environment and Forests (MoEF) the direct CO_2 emissions from industrial sources accounted for nearly 22% of the total CO_2 emissions from the country (MOEF 2010). Industrial activities together emitted 412 million tons of CO_2 eq of GHG in 2007. These emissions include fossil fuel combustion related emissions as well as the process based emissions.

Cement and iron and steel are amongst the highest CO_2 emitting sectors accounting for about 60% of the total GHG emissions from the industrial sector (excluding power plants) in 2007. The break-up of GHG emissions from the industrial sector is given in Figure 5.

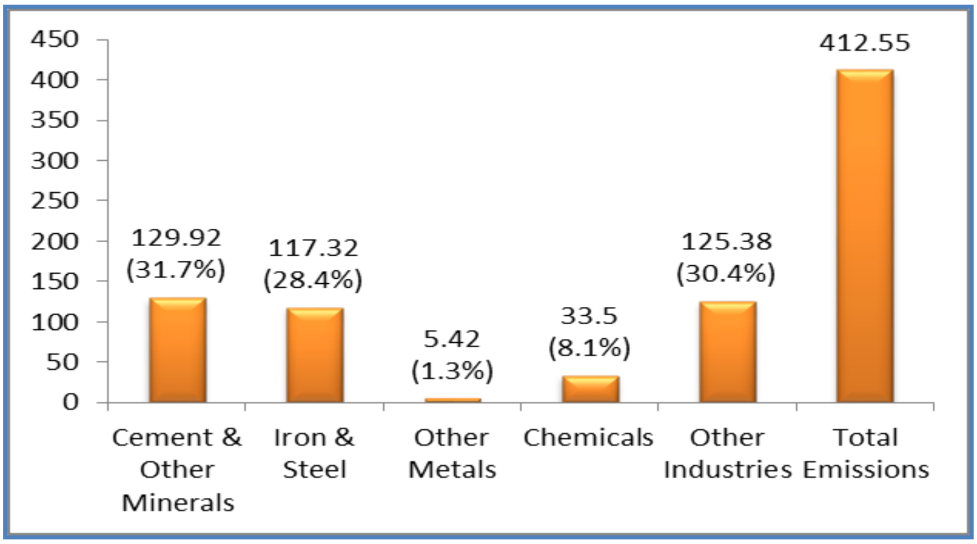

Figure 5 GHG emissions from Industry Sector (million tons of CO_2 eq).

Source: National greenhouse inventory data (MoEF 2010)

2 Policies and Institutional Framework

Over the past few years, the government has taken several important steps to promote energy efficiency in the industry sector. This section discusses some of the major government initiatives with regard to promoting energy efficiency among large, medium and small-scale industrial enterprises in India.

Energy Conservation Act, 2001 was the first major step to promote energy efficiency in India. The Act provides for the legal framework, institutional arrangement and a regulatory mechanism at the Central and State level to embark upon an energy efficiency drive in the country (ECA. 2001). The Bureau of Energy Efficiency (BEE) is the nodal agency for implementation of EC Act in India (see box 1). The EC Act defines powers and functions of the Bureau for this purpose. India prepared a National Action Plan on Climate Change (NAPCC) in 2008. As recommended in the plan, eight missions were set-up to undertake activities including National Mission for Enhanced Energy Efficiency (NMEEE). The Perform, Achieve, and Trade (PAT) mechanism was launched under the NMEEE (see box 2). Various new initiatives were undertaken within this mission; including identification of designated consumers (DCs), standard and labelling of appliances, energy conservation building codes, and establishment of an energy conservation fund. The DCs consume about 45% of energy used in the industrial sector in India. By the end of the first PAT Phase-1 (2012-15), energy savings of 6.7 MTOE per year is expected to be achieved.

Box 1: Bureau of Energy Efficiency (BEE)

BEE is the nodal agency for promoting energy efficiency in industry and other economic sectors of India, Under the provisions of the E.C. Act 2001, BEE was established in March, 2002 by merging into it, the erstwhile Energy Management Centre, being a society registered under the Societies Registration Act, 1860, under the Ministry of Power.

Functions of BEE

The major functions of BEE include:

- Develop and recommend to the Central Government the norms for processes and energy consumption standards.
- Recommend the Central Government for notifying any user or class of users of energy as a designated consumer.
- Develop and recommend to the Central Government minimum energy consumption standards and labeling design for equipment and appliances.
- Develop and recommend to the Central Government specific energy conservation building codes.
- Take necessary measures to create awareness and disseminate information for efficient use of energy and its conservation.

BEE implemented many schemes and programs to promote energy efficiency in the industry sector. The major programs initiated include- PAT scheme for large industries, BEE-SME program for SMEs, professional certification and accreditation of energy professionals and so on.

Source: (BEE 2008)

Box 2: Perform Achieve and Trade (PAT)

The PAT mechanism covers 478 designated consumers under 8 energy intensive industrial sectors - (aluminum, cement, chlor-alkali, fertilizer, iron & steel, pulp & paper, textile and thermal power plants) each of which consume around 165 mtoe energy per annum. Each designated consumers is mandated to reduce their specific energy consumption (SEC) by a specified percentage. The percentage reduction for a facility would depend on its current level of efficiency; with the most efficient facility in a sector having a lower percentage reduction requirement, and the less efficient facility having a larger percentage reduction requirement.

In order to enhance the cost effectiveness of this mechanism, facilities which achieve savings in excess of their mandated reduction would be issued Energy Savings Certificates (ESCerts) for the savings which are in excess of their mandated target. These certificates can be used by other facilities for compliance if they find it expensive to meet their own reduction target. The targets are plant specific with a lower target for the efficient units and a higher target for the inefficient ones. The scheme under its 1st cycle aims to achieve about 6.6 MTOE (5.5% collective SEC reduction) in the first commitment period of 3 years (ending in 2015).

Source: (BEE 2012)

Increasing energy efficiency among MSMEs has also received a high priority in National Action Plan on Climate Change and the recent five year plans of the Indian government. Energy efficiency in the MSME sector is being spearheaded at the central level by two government ministries/ agencies, viz., BEE and Ministry of Micro, Small and Medium Enterprises (MoMSME). The major focus of BEE in the industry sector remains large industries. To address the small-scale industries BEE has formulated the "BEE-SME Program". The program aims to accelerate the adoption of energy efficient technologies and practices in a few chosen industry clusters through focused studies, knowledge sharing, preparation of detailed project reports and facilitating in the process of developing innovative financing mechanisms (see Box 3). The Ministry of MSME also has programs that promote energy efficiency in MSME clusters.

Lately, energy efficiency improvement among MSMEs is gaining attention of government bodies and multilateral organizations. The government, through BEE and Ministry of MSME has launched programs/schemes to promote ener gy efficiency among MSMEs. GEF has also initiated projects focusing on the MSME sector through United Nations Industrial Development Organization (UNIDO) and World Bank. These projects are primarily being implemented in clusters through BEE and Small Industries Development Bank of India (SIDBI). The Energy and Resources Institute (TERI), with the support of SDC (Swiss Agency for Development and Cooperation), initiated activities more than a decade ago to provide support to three energy-intensive industry clusters/sectors (viz. foundry, glass and brick) by developing, demonstrating and disseminating energy efficient technologies. The project has successfully replicated the demonstrated energy efficient technologies and practices in six clusters: Firozabad glass industry cluster, Eastern Uttar Pradesh brick industry cluster and Ahmedabad, Howrah, Rajkot, and Coimbatore foundry clusters. The pioneering knowledge sharing platform, launched in 2010, 'SAMEEEKSHA' (Small and Medium Enterprises: Energy Efficiency Knowledge Sharing) has gained acceptance by a large number of organizations.

Box 3: Achievements under BEE-SME program

- 1250 comprehensive Energy Audits conducted and cluster specific energy conservation manuals prepared for around 25 clusters.
- 386 Detailed Project Reports on energy efficient technologies prepared and shared with project stakeholders
- Total energy consumption in selected 25 clusters is estimated to be about 5.6 MTOE.
- Energy saving potential of 0.82 MTOE in 25 SMEs clusters, which is 15% of the total energy consumption.
- Total energy saving potential is estimated to be Rs.1400 Cr in 25 SMEs clusters with total investment requirement of Rs. 3388 Cr.
- Average simple payback period is estimated to be 2 to 3 years only.

Source: Dhingra, Upinder et al (editors). (2013).

3 Barriers to green growth in industry

As per an assessment by the BEE, the total potential for saving electricity in the industrial sector, including the MSME sector and large industries, stands at close to 18 billion units annually (NPC 2010). This can be achieved by accelerating adoption of energy efficiency measures in industry. Despite the government's active involvement through various interventions towards increasing penetration of energy efficiency measures in India, the major challenge is to translate government policies into actual action at the ground levels. The barriers to green growth in the industry sector have been discussed within the four broad categories: (1) awareness (2) technology (including operation practices) (3) financing and (4) support services.

3.1 Lack of awareness on and access to improved EE technology

Most of the energy-intensive (EE) industries were set-up several decades back at a time when energy costs were not a major concern. These units had installed outmoded resource inefficient technologies which they still continue to use. Although a few progressive units may have adopted a new EE technology, the benefits are usually not shared with other units. Most industries are either unaware about the energy-efficient technologies/equipment or their energy saving potential.

3.2 Few programs to support technology development of EE technologies

Although industries are often told about the virtues of adopting cleaner production process, in most cases there are no off-the-shelf cleaner technological solutions which they can adopt. Added to this, industries often depend on in-house technical expertise or engage local technical consultants who provide sub-optimal solutions. Lack of off-the-shelf technological solutions coupled with poor quality of local service providers has resulted in a high degree of scepticism towards new technologies and ideas. Since new technologies are usually more expensive than conventional technologies, the industry wants to be absolutely certain before they invest in new technologies. Few programmes have targeted development and demonstration of cleaner technologies in the industry sector. While technology transfer is also considered as a potential solution, it is not very effective considering the size and scale of the industry (including MSMEs) sector in India. There has to be a significant effort at the national level to develop cost-effective technological solutions customized to local conditions. However, if we take a technology from outside, it should not be merely a 'black-box', but should be accompanied by know-how of the technology. Hence, there is a need to focus greater attention on technology development and demonstration in the industrial sector. Research Development, Demonstration and Dissemination (RDD&D) has proven to be successful in terms of increasing the capabilities of the manufacturing sector.

3.3 Absence or paucity of skills to deploy EE technologies

Successful implementation of EE technologies depend to a large extent on the in-house capacity at the unit level. This is because many of these technologies have a substantial component of best operating practices. For example, the operators need training on monitoring and control of important process parameters like volume and pressure of the combustion air, quality and composition of raw materials and operational trouble-shooting. Lack of skilled manpower to deploy EE at the unit level is a major barrier to their implementation. There is at present few specialised institutions for providing training on energy efficient technologies and practices for the operational level staff of industry.

3.4 Lack of awareness on and access to financial schemes for obtaining EE technologies

One of the important factors influencing uptake of new technologies is financing. However, in general, the MSMEs are perceived to be high risk sectors for lending by commercial banks and financial institutions. There is also a lack of awareness among MSMEs about the various financial schemes which are available with specialized financial institutions like SIDBI for EE technologies. There is a need for reaching out to the MSMEs about various financial schemes. Innovative financing schemes for the sector need to be established. Local financial counsellors can play a major role in terms of bridging the gap between financial institutions and MSMEs.

3.5 Absence or paucity of local service providers to sustain energy efficiency

Local service providers (LSPs)/institutions play a key role in sustaining innovations. Unfortunately, very few existing institutions at the regional level have the technical and managerial capacities to initiate and support technological innovations. Thus LSPs at the regional level like consultants, fabricators, masons and so on need to be strengthened so that they can act as the local node for dissemination of cleaner technologies beyond the project period. Specialized training programmes of LSPs on best operation practices and maintenance of the equipment's need to be organized.

4 Ways Forward

Energy efficiency improvements can yield huge technical and economic benefits and has proven to be the most cost-effective means to bring about reductions in GHG emissions. Adoption of best available technologies (BATs) and best operating practices (BOPs) would significantly reduce the energy consumption and CO_2 emissions in the industrial sector in the short and the medium term. In the long run, development of new energy efficient technologies could address the dual problems of growing resource scarcity and environmental degradation. New and emerging technologies that consume resources more efficiently, such as low temperature waste heat recovery and high energy efficient electric motors, promises to further boost the energy efficiency of the industrial sector in the long run.

Some of the key strategies that could be adopted (in the short, medium and long term) towards improving the energy efficiency and greening the industry sector are mentioned below:

Short term

Promote energy audits

Effective management of energy-consuming systems can lead to significant cost and energy savings as well as lower maintenance costs, and extended equipment life, all in a short span of time. A successful energy management program begins with a thorough energy audit. In order to improve the energy efficiency of an industry, it is necessary first to examine the existing industrial process and identify the patterns of energy use in various stages – this exercise is known as energy audit. It helps identify the areas where energy saving measures might be taken. Energy audits provide the basis on which energy-efficient technological options can be developed for the industry concerned. Typically, an energy audit examines major energy-consuming systems and equipment such as motors, furnaces, boilers, pumps and blowers, HVAC (heating, ventilation and air cooling) systems, and the load and demand management of the plant.

Support financing of EE technologies

Energy efficiency in any industry has two dimensions i.e. Technology and Financing. Technologies are available in different stages of commercialization (Pre commercial, Semi commercial and fully commercial). Financing has to adapt itself to meet the requirement at each stage for scaling-up energy efficiency among the industries, given that energy efficient technologies are more expensive in comparison to conventional technologies. Therefore, energy efficiency financing models need to be customized to the specific financing needs of technologies in different stages of commercialization.

Public finance through the government and low cost finance from bilateral /multilateral agencies has a crucial role in supporting research and development (R&D) and innovation of new technological solutions for pre-commercial technologies, especially in the MSME sector in context of climate change. Bank finance is important for developing the market for commercially available technologies. It is important to note that most new technologies are more efficient compared to existing ones, and it is essential to ensure that the financial assistance for energy efficiency promotion gets channelized properly for correct technologies. One such criterion which has been adopted internationally is to calculate the financial returns (e.g. payback period, internal rate of return) on capital investment fully from energy saving only. The energy saved from the technology needs to be estimated by certified energy professionals or from clearly defined measurement & verification (M&V) techniques. The financing can then be made flexible to decide on the amount and terms of lending for such technologies.

Benchmarking

Benchmarking of specific energy consumption (SEC) is an important tool to access and compare present status of performance, technologies and processes in selected industrial sectors with those of others, to industry average and to best technologies and practices world-wide. This can help industries to compare with their peers and determine the potential of energy efficiency improvement within their plant.

Utility technologies such as boilers, pumps and compressors are large energy guzzlers and those produced in India offer immense scope for improvement in energy efficiency when compared to those manufactured in more advanced economies. However, no comprehensive benchmarking studies have been carried out for industry to assess the performance of these equipment. In order to create awareness of energy efficient pumps among consumers, BEE has launched a voluntary star labeling of pump sets in India. The scheme covers electric mono set pumps, submersible pump sets and open well submersible pump sets. No such ratings have yet been developed for boilers or compressors. However, even the existing pump ratings are only applicable for 3-phase pump sets from 1.1 kW (1.5 HP) to 15 kW (or 20 HP). Furthermore, these values are mainly to guide consumers on energy savings but do not provide any specific industry benchmarks. The PAT scheme has shown that benchmarking is an effective tool to set energy reduction targets for DCs.

Several developed countries such as Canada, Belgium, the Netherlands, Norway and the USA have supported the development of benchmarking programs in various forms. As part of its energy and climate policy the Dutch government has reached an agreement with its energy intensive industry that is explicitly based on industry's energy efficiency performance relative to that of comparable industries worldwide. Industry is required to achieve world best practice in terms of energy efficiency. In return, the government refrains from implementing additional climate policies. In the USA, EPA's Energy STAR for Industry program has developed a benchmarking system for selected industries, like automotive assembly plants and cement. The system is used by industries to evaluate the performance of their individual plants against a distribution of the energy performance of US peers. (IPCC-Bernstein, L. et al 2007).

Adoption of best operating practices (BOPs)

Cross-sectoral best practices offer immense potential to conserve energy across a variety of industrial segments irrespective of the type of manufacturing process. Particular emphasis needs to be placed on BOP as such practices improve energy efficiency without major investments. Such practices are also relatively easier to adopt and they can be implemented without major investments. Typically, the energy saving potential by adoption of improved practices is in the range of 5–20%. According to an IPCC study (IPC 2007), application of housekeeping and general maintenance on less-efficient plants can yield energy savings of 10–20%. Low-cost capital measures (combustion efficiency optimization, recovery and use of exhaust gases, use of correctly sized, high efficiency electric motors and insulation) show energy savings of 20–30%. More emphasis needs to be placed on documentation and promotion of BOPs through benchmarking and capacity building programmes. Some of these best practices are elaborated below:

Reduce, recycle and reuse

Reduction of rejections in industries could lead to significant material and energy savings. The culture of continuous quality improvement needs to be promoted in a systematic manner among industries. Simple measures such as monitoring and analysis of defectives, identifying the root causes and initiating corrective actions in the process hold great promise among Indian industries. Recycling of used materials like aluminium and paper is less energy–intensive than processing the primary raw materials. For example, steel recycling is a well-established practice and recycling of paper is also increasing worldwide– waste paper recovery in Austria and the Netherlands is more than 60%. Recycling of steel in electric arc furnaces accounts about a third of world production and typically uses 60–70% less energy (ILO 2012).

In the cement sector, it is further possible to increase the use of blended cements, which would result in reducing the usage of limestone per tonne of cement produced. Since process emissions from cement production is one of the major sources of CO_2 emission in the cement sector, systemic shift to higher proportions of blended cements would not only help in reducing the CO2 emissions, it would also help reducing the exploitation of cement grade limestone deposits in the country. Materials substitution, for example the addition of wastes (blast furnace slag and fly ash) and geo-polymers to clinker helps reduce CO_2 emissions from cement manufacture significantly (IPCC 2007). A fantastic Brazilian example of recycling waste os provided in Box 4.

Box 4: Recycling and Waste— An Example from Brazil

Brazil has a tradition of recycling with recovery levels for many materials matching or exceeding those in industrialized countries. Some 95% of all aluminum cans and 55% of all polyethylene bottles are recycled. About half of all paper and glass is recovered. Recycling in Brazil generates a value of almost USD 2 billion and avoids 10 million tons of GHG emissions. At the initiative of local governments, some 60,000 recycling workers have been organized into cooperatives or associations and work in formal employment and service contracts. Their income has increased doubled than that of individual waste pickers, lifting families out of poverty. The National Solid Waste Policy (PNRS) – established by law on 2 August 2010 – aims to build on this potential. It provides for the collection, final disposal and treatment of urban, hazardous and industrial waste in Brazil.

Source: UNEP 2011

System optimisation

Most of the industries in India (especially in the MSME sector), persist with out-dated and inefficient technologies and there is not much focus on system optimization. As in other countries, both markets and policy makers in India tend to focus more on individual components despite the larger energy savings potential in a system optimization approach especially for steam, pumping and compressed air systems.

Plant equipment is discarded only after it has completed its entire life cycle and even when the equipment is upgraded, the focus is on the component and not on the entire system in place. For example, an out-dated reciprocating compressor may be replaced with a modern screw compressor, but no effort is made to evaluate the piping systems, pressure controls and supporting equipment for the compressor. Similarly, factors such as pipes, cables, panel boards and the quality of power impact the performance of pumps.

A large share of the energy efficiency benefit is lost when such auxiliaries and practices are ignored. Hence, it is important to also focus on the practice of system optimization amongst industries. Considering the expanse of industry in India, there is immense potential for energy savings and consequent reductions in its GHG emission levels. Experience shows that while efficient energy components, such as pump, steam and compressed air systems, can raise average efficiency 2–5 %, whereas system optimization measures can yield 20–30 % gains– with a payback period of less than two years.

Use of ICTs to enhance energy efficiency

Achieving industrial energy efficiency is a multifarious task and involves access to information, financing, human resources and technology, improved decision making processes, and the ability to measure and verify the achieved energy savings. One of the best technological options is the adoption of Information and Communication Technologies (ICT). Application of ICT tools in critical processes and equipment of industries would help in its optimization and also maintain the operating parameters close to the design level. Close control of various operating parameters in production processes may be achieved through advanced control, metering and feedback information.

Application of ICT tools can be either process related or cross-cutting across different industry sub-sectors. Few examples of process related ICT solutions include operating conditions of reformers in fertilizer industry or application in state-of-the-art smelter technology in an aluminium industry. A cross-cutting example of ICT includes the Enterprise Resource Planning (ERP) systems.

A number of Indian industries have acquired the benefits of standardized procedures through adoption of ERP systems. A sector-specific application of ICT is for improving product yields, by making use of three-dimensional Computer Aided Design (CAD) simulation softwares for Indian foundry sector. These softwares can be used to study the actual fluidity and solidification progress of molten steel in the moulds. Better understanding of the solidification structure (i.e. dendrite pattern) of risers and runners of the castings helps in optimum design of the mould and thus improves the overall product yield.

Another example of use of ICT in pulp and paper industry is adoption of Advanced Process Control (APC) technology in conjunction with the existing Distributed Control System (DCS). The technology allows varying of the multiple parameters to achieve the desired outputs of increased productivity and enhanced energy efficiency. The APC takes corrective actions every 30 seconds for disturbances in the unit to maintain excess oxygen close to the minimum allowable limit.

Medium term

Creating an enabling environment

The Indian government needs to play a crucial role in setting the cross-sectoral framework for energy efficiency. This includes implementing enabling policies to cost-effectively increase energy efficiency by establishing market signals to motivate effective action to accelerate the introduction of new technologies. According to IEA, to achieve energy savings in the industrial sector, the national governments need to (a) support industry adoption of energy management protocols; (b) mandate minimum energy performance standards

(MEPS) for electric motors; implement a package of measures to promote energy efficiency in MSMEs. This is relevant in the Indian context as well and the state governments can design their programs on these lines. The Indian government will have to take aggressive steps to stimulate investment in energy efficiency and accelerate implementation through synergies with national level energy efficiency plans.

Additionally, government needs to put in place complementary financial policies that promote energy-efficient investment. This could be done by:

- Reducing energy subsidies and internalizing the external costs of energy through policies
- Encourage investment in energy efficient technologies (EETs) and processes by putting in place targeted financial incentives such as tax incentives for adopting EETs
- Foster private finance of energy efficiency upgrades in industry through risk-sharing or loan guarantees with private financial institutions and enabling the market for energy performance contracting.

In India, the industry energy efficient investment decisions, many of which have long-term consequences, will continue to be driven by consumer preferences, costs, competitiveness and government regulation. A policy environment that encourages the implementation of existing and new mitigation technologies could lead to lower GHG emissions. Reallocation of public and private investments, along with appropriate policy reforms, will substantially reduce the energy intensity of the industrial sector. These 'green' investments will help India achieve its long term GHG emissions goals.

There can be no single instrument to promote industrial energy efficiency effectively amongst different stakeholders and across all levels. The main stakeholders involved in energy efficiency landscape other than the government agencies are (i) energy suppliers (ii) equipment manufacturers and technology suppliers (iii) energy efficiency service providers (consultants) (iv) financial institutions and (v) energy consumers. The equipment manufacturers, the technology providers, financial institutions and energy efficiency service providers who act as intermediaries have a very important role in the energy efficiency market place.

Large companies have greater resources, and usually more incentives, to factor environmental and social considerations into their operations than MSMEs, but MSMEs provide the bulk of employment and manufacturing capacity in India. Government needs to integrate MSME development strategy into the broader national strategies for sustainable development. The concept of 'designated consumers' as in large industries can be extended to MSMEs. High energy intensive clusters can be classified as 'designated clusters' and cluster level programs should be formulated and implemented for them. Donor agencies such as UNIDO, UNDP, World Bank – Global Environment Facility (GEF) who are implementing EE projects in India also need to focus on developing new low-cost clean technological solutions for these energy intensive MSME clusters. Often technological solutions that are available in developed countries cannot be used by MSMEs in developing countries because of their high cost and different scales of operation.

Fuel switch options

Switch over from coal to low carbon fuels like natural gas and biomass offers one of the best opportunities in terms of moving towards a low carbon economy. Waste materials (tyres, plastics, used oils and solvents and sewerage sludge) are being used by a number of industries. Even though many of these materials are derived from fossil fuels, they can reduce CO_2 emissions compared to an alternative in which they were landfilled or burned without energy recovery. In Japan, use of plastics wastes in steel has resulted in a net emissions reduction of 0.6 MtCO_2-eq/yr (IPCC 2007).

In case of certain applications like cement manufacturing, the plants can use municipal solid waste as well as other fuels like used tyres to replace fossil fuels. Industries with low temperature water requirements (around 100°C) such as dairy, textiles and pharmaceuticals also use solar thermal systems. Rational pricing of cleaner fuels like natural gas at the national level will help in encouraging industries to explore switchover to cleaner fuels in a big way.

Adoption of cross-cutting best available technologies (BATs)

Cross-cutting technological options have potential to conserve energy across a variety of industrial segments irrespective of the type of manufacturing process. It has been estimated that in general, in the industries, approximately 50% of the industrial energy use is consumed in cross-cutting areas such as boilers, air compressors, motors, pumps, blowers and so on. Some of the BATs available for realizing energy savings are mentioned below:

Cogeneration (combined heat and power CHP) systems

Cogeneration (also called CHP) involves using energy losses in power production to generate heat for industrial processes and district heating, providing significantly higher system efficiencies. Industrial cogeneration is an important part of power generation in Germany and the Netherlands (IPCC 2007).

Cogeneration is common in many pulp and paper, sugar and chemical industries in India. However, there is a significant scope to improve the efficiencies of the cogeneration plants by adoption of high pressure systems, suitable regulatory framework needs can go a long way in encouraging industries to adopt advanced cogeneration systems and explore surplus power to the grid. Conservative estimates suggest a huge potential of over 20,000 MW from cogeneration units in India. As per the Integrated Energy Policy Report, 2006 prepared by an expert committee constituted by the Planning Commission, renewable sources may contribute to nearly 6% of India's energy mix by 2032

The current availability of biomass in India is estimated at about 500 millions metric tones (MMT) per year. Studies sponsored by the Ministry of New and Renewable Agency (MSRE) have estimated surplus biomass availability at about 120 – 150 MMT per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. This apart, about 5000 MW additional power could be generated through bagasse based cogeneration in the country's 550 sugar mills, if these sugar mills were to adopt technically and economically optimal levels of cogeneration for extracting power from the bagasse produced by them.

Use of energy efficient equipment

Use of energy efficient equipment's such as pumps, motors, and air compressors provide an opportunity to industries save energy. Motors and motor driven systems account for a major share of electricity used by industries in India for operating various machines, fans, pumps, conveyors, and compressors.

These machines find applications in various types of industries like pharmaceuticals, sugar, pulp & paper and cement manufacturing. The electric motor is the main element in a motor-driven system that offers the potential for savings. Replacement of inefficient motors with EE ones such as IE1, IE2 and IE3 can yield a savings of 10-15% with quick payback period and cost-effectiveness.

Energy-efficient lighting

Replacing incandescent and mercury vapour lamps with energy efficient lamps such as CFLs and low pressure sodium lamps could effectively reduce the energy consumption in lighting systems. These lamps would require proper ballasts to operate effectively. However, while replacing the lamps in industry, their suitability in specific areas will have to be seen in view of their colour rendering index.

In general, the electricity savings for switching over to energy-efficient lamps can be of the order of 35–45% from the existing level. According to an Energy Efficiency Services Limited (EESL) study (2014), replacement of a 60W incandescent lamp with 10W LED will result in saving of over 80% energy savings. Lighting controls and voltage stabilization systems would also offer substantial energy savings as well as enhance the life of the lighting systems.

Implementation of ISO 50001 energy management standard

Using energy efficiently helps organizations save money as well as helping to conserve resources and tackle climate change. The International Standards Organization (ISO) has developed ISO 50001 - a standard focusing exclusively on energy management. ISO 50001 supports organizations in all sectors to use energy more efficiently, through the development of an energy management system (EnMS). The Bureau of Indian Standards (BIS), Government of India, has accepted this standard and introduced its own version for the Indian market. ISO 50001 has been successful in many countries including the United States and many European countries and there are several lessons that can be leveraged. While ISO 50001 is fast penetrating the industrial space in global enterprises, it has yet to show such pace in India. Currently, there are only around 30 enterprises in the entire country that have adopted the standard; it is evident that an additional impetus is required to catalyze its widespread adoption.

With regard to the energy management practices followed by industries in India, it is seen that most industries persist with out-dated and inefficient technologies and systems. Revenue generation by increasing production remains at the forefront, while cost savings through energy efficiency is a less sought after method of operation. Promoting ISO 50001 is imperative in this context. Seminars can be organized in association with various chambers of commerce and industry to promote ISO 50001 across the country. Assistance from industry associations will be sought for disseminating information to energy intensive SME clusters.

ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management. ISO 50001 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the policy works, and
- Continually improve energy management

<u>Adoption of sector specific cleaner technological options</u>

Sector specific energy efficient technologies can lead to significant energy savings, sometimes as high as 25-50%. This section discusses some sector specific mitigation options for some major energy intensive sectors viz. cement, textiles, pulp and paper, and iron and steel.

Cement sector

Significant potential for energy savings exist in Indian cement industry. A few major energy-efficient technologies and practices in cement plants are outlined below:

- *Utilization of industrial wastes*: Blended cement can be manufactured from industrial wastes such as slag and fly ash. Other industrial wastes like biomass, petroleum coke, and waste tyres) can also be utilized beneficially during clinker burning process. Various substitute fuels need to be explored depending on their availability locally.
- *Raw material grinding*: The use of vertical roller mill can make a significant contribution to the reduction of power consumption in the raw material grinding process. To dry and grind at the same time makes a large volume of gas through the system, increasing the power consumed by the fan. Therefore, the difference of the facility power of the mill itself is not related to the reduction of electric power but, as compared to the existing process with the ball mill, reduces the power consumption by 10-15%. More reduction can be expected by reducing the volume of gas passing through or circulating in the process.
- *Co-generation by utilizing waste heat*: Sources of waste heat in cement industry include flue gases, vapor streams, convective and radiant heat loss and so on. On an average, Indian cement industry is losing almost 35% of its energy through flue gases and hot air streams. It has been observed that losses through kiln exhaust gases (20%) and hot air from cooler (12.8%) are prominent, and provides the potential areas for the waste heat recovery. Co-generation or waste heat power generation (WHPG) system will utilize the waste heat and produce electricity thereby reducing the overall

energy cost of cement plants. A co-generation system utilizing the waste heat can deliver up to 20% of total electrical energy required for the process.

Textile sector

Textile industry is highly energy intensive. Wet processing or dyeing operation consumes almost 50% of the energy in a composite mill. Thermal energy (steam and hot water) is primarily used to process, dye, print and dry the cloth during wet processing. There is a large scope to save energy in the boilers, steam distribution and drying operation in a textile mill. Some examples of energy conservation measures in a textile mill are the following:

- Energy efficiency improvement in humidification plant
- Conversion of thermic fluid heating system to direct gas firing system in stenters and dryers
- Temperature control system in processing machines
- Recovery of condensate in wet processing plants
- Energy efficiency improvement in cylinder dryer
- Waste heat recovery in stenters, merceriser machines and bleaching system
- Replacing electric heating with thermic fluid heating in polymeriser machine
- Installation of photocells for speed frames

Pulp and paper industry

Process optimization, waste heat recovery, and cogeneration systems offer significant scope for improving the performance of Indian paper mills. Other energy conservation measures, which require marginal or no investments and would resulting 5–10% energy savings, are listed below:

- Excess air control in boilers through ducting design and instrumentation to help in reducing the load on induced draft (ID)/forced draft (FD) fans.
- Proper temperature control in slaking and causticizers to reduce steam consumption.
- Better instrumentation loop in agitators.
- Cascading system for efficient use of steam in the dryer section of the paper machine.
- Vacuum piping with minimum bends in the paper machine section.
- Replacement of beaters by double disc refiners in small paper mills.
- Adoption of bio methanation.
- Use of de-silication technology for silica-rich raw materials such as rice straw, bagasse, and bamboo based raw materials.

Iron & steel industry

- Installation of regenerative burner system
- Hot charging of continuous cast billet
- Top-and-bottom firing system in reheating furnace
- Oxy-fuel combustion system in reheating furnace
- Replacement from lump coal to coal producer gas as fuel
- Installation of high efficiency recuperator with improved furnace design

Long term

Development of new energy efficient technologies

Innovation is clearly central to the idea of green growth in the long run. While existing technologies can significantly reduce industrial GHG emissions, new and lower-cost technologies are needed in the industry sector to meet long-term mitigation objectives of India. Public and private participation is required for RDD&D (Research, Development, Demonstration and Deployment) for clean technologies that can reduce GHG emissions. Especially in the MSME sector in India, where ready technology solutions are not available, the government and the industry needs to invest in R&D solutions. Adequate support from the government would be required to set up incubation centers; and cluster level fabricators would need to be incentivized to develop low cost technological solutions as per local conditions.

Most industrial processes use at least 50% more than the theoretical minimum energy requirement determined by the laws of thermodynamics, suggesting a large potential for energy-efficiency improvement and GHG emission mitigation (IEA, 2006a). RDD&D can help capture these potential efficiency gains and achieve significant GHG emission reductions.

Additionally, to expedite the uptake of energy efficient and clean technologies in the MSME sector, there is a need to go beyond conventional methodologies. Innovation is essential and studies have shown that new technologies offer up to 30% energy savings potential. Experience shows that RDD&D has proven to be successful in terms of increasing the capabilities of the manufacturing sector and the SME workforce as a whole (see box 5). In RDD&D, the focus needs to be on customizing technologies for sub-sectors and clusters/units, extending technical/financial support, and providing units with dedicated assistance on implementation. This model was followed by the Swiss Agency for Development and Cooperation (SDC) in India in selected energy intensive MSME sub-sectors (glass, brick and foundry); and has proven to be very successful. Customization has to be followed by successful demonstration to increase uptake of technologies in the MSME sector. Thereafter, dissemination assumes utmost importance so that other units and clusters can also benefit.

Box 5: RDD&D in small scale grey iron foundries in India

An example of one such technology is the energy efficient melting furnace technology called the divided blast cupola (DBC). TERI designed and developed the energy efficient DBC for foundry industries in India. Around 100 DBCs in different units within the foundry clusters like Coimbatore, Ahmedabad, Rajkot, Howrah, etc. have adopted this technology design. TERI successfully strengthened the capabilities of local fabricators to promote and sustain the uptake of DBCs among foundries in various clusters. The intervention enhanced the technological capacities of cluster-level providers and fabricators of DBCs. The DBC typically helps in energy saving of 20%-30% and increases production quality. The successful implementation of the technology in a few units convinced a number of foundries to adopt the DBCs.

Keeping pace with constantly improving technologies is critical for industry competitiveness in a developing country such as India. This requires an enabling environment and infrastructure that nurtures research and development of modern technologies matching the best available worldwide. Technology developers, supply industries and users need to cooperate, brainstorm and discuss market mechanisms to develop suitable technologies. Technology RDD&D has to be carried out by both governments (public sector) and the corporate (private sector). Ideally, the roles of the public and private sectors will be complementary. Many studies have indicated that the technology required to reduce GHG emissions and eventually stabilize their atmospheric concentrations is not currently available in the developing countries (Bernstein, L. et al 2007).

A collaborative R&D and demonstration approach that combines the know-how of local/national and international experts is needed. Such an approach will lead to building the technical capacities of local actors on manufacturing and trouble shooting of the technology and thus promote dissemination of the new technology at a faster pace. In order to create a delivery system for the developed technology it is important to identify and develop a network of local service providers (LSPs). The LSPs who can be consultants, fabricators or consultancy organisations, can play an important intermediary role in hand-holding of the units to successfully implement the technology. The LSPs can be developed as project promoters for providing services such as technical assistance, financial intermediation and ESCO services.

Energy saving potential

The band-width of specific energy consumption varies widely in different industrial sectors. For example, state-of-the-art technologies have been adopted by some industries within every industry sub-sectors. At the same time, there are a large number of plants within the same sub-sectors using conventional technologies and practices. A detailed study of different industry sub-sectors is required for quantifying the energy conservation potential.

Co-benefits of energy efficiency improvements

The energy efficiency interventions in the industry sector will not only provide significant GHG reduction benefits, but also lead to important co-benefits and directly impact the well-being of the workforce. Some of the co-benefits include improved productivity/product quality, cleaner air, improved quality of life, waste reduction and social benefits. The co-benefits, as reported by the Working Group III of the Fourth Assessment Report of the IPCC are highlighted in Table 1.

Table 1 Co-benefits of greenhouse-gas mitigation or energy-efficiency programmes of selected countries

Category of Co-benefit	Examples
Health	Better health of workers, Reduced medical expenses, reduced lost working days, reduced acute and chronic respiratory symptoms, and increased life expectancy.
Emissions	Reduction of dust, CO, CO_2, NO_x and SO_x; reduced environmental compliance costs.
Waste	Reduced use of primary materials; reduction of waste water, hazardous waste, waste materials; reduced waste disposal costs; use of waste fuels, heat and gas.
Production	Increased yield; improved product quality or purity; improved equipment performance and capacity utilization; reduced process cycle times; increased production reliability
Operation and maintenance	Reduced wear on equipment; increased facility reliability; reduced need for engineering controls; lower cooling requirements; lower labour requirements.
Working environment	Improved lighting, temperature control and air quality; reduced noise levels; reduced need for personal protective equipment; increased worker safety.
Other	Decreased liability; improved public image; delayed or reduced capital expenditures; creation of additional space; improved worker morale.

Source: IPCC (2007)

Additionally, economy wide impact studies show that in a developing country, like India, adoption of energy efficient technology can lead to higher employment (particularly green jobs) and income generation (Sathaye et al., 2005; Phadke et al., 2005).

A review of 54 emerging energy-efficient technologies, produced or implemented in the USA, EU, Japan and other industrialized countries for the industrial sector, found that 20 of the technologies had environmental benefits in the areas of 'reduction of wastes' and 'emissions of criteria air pollutants'. The use of such clean technologies is often most compelling when it enables the expansion of incremental production capacity without requiring additional environmental permits. In addition, 35 of the technologies had productivity or product quality benefits (IPCC 2007). The quantification of the co-benefits of industrial technologies is often done on a case-by-case basis. An evaluation of 52 selected projects form the USA, the Netherlands, UK, New Zealand, Canada, Norway and Nigeria that monetized non-energy savings had an average simple payback time of 4.2 years based on energy savings alone. Addition of the quantified co-benefits to this, reduced the simple payback time to 1.9 years (Worrell et al., 2003).

A green industry reduces carbon-footprint by adoption of energy efficient technologies and practices, substitution of fossil fuels with low-carbon fuels thereby addressing climate change, creating green jobs and reducing import dependency. New technologies promoting energy and resource efficiency provide growth opportunity in new directions, offsetting "brown economy" job losses. Resource efficiency–both energy and materials use, becomes a driving proposition in this path towards sustainable development.

Transition to a green growth cannot and will not occur unless there is an active involvement of hundreds of thousands of enterprise managers and millions of workers through appropriate policies that emphasize building of local capacities to absorb, implement and innovate new technology. The industries and their workers must realize the importance of reducing the energy intensity of their unit and government has to make this happen. Much more attention needs to be paid on developing people (capacity building, handholding). Major manufacturing sectors need to respond to the green agenda by focusing on strengthening existing institutions. The industries need to integrate energy efficiency in to their company's mission and growth agenda.

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About TERI

A unique developing country institution, TERI is deeply committed to every aspect of sustainable development. From providing environment-friendly solutions to rural energy problems to helping shape the development of the Indian oil and gas sector; from tackling global climate change issues across many continents to enhancing forest conservation efforts among local communities; from advancing solutions to growing urban transport and air pollution problems to promoting energy efficiency in the Indian industry, the emphasis has always been on finding innovative solutions to make the world a better place to live in. However, while TERI's vision is global, its roots are firmly entrenched in Indian soil. All activities in TERI move from formulating local- and national-level strategies to suggesting global solutions to critical energy and environment-related issues. TERI has grown to establish a presence in not only different corners and regions of India, but is perhaps the only developing country institution to have established a presence in North America and Europe and on the Asian continent in Japan, Malaysia, and the Gulf.

TERI possesses rich and varied experience in the electricity/energy sector in India and abroad, and has been providing assistance on a range of activities to public, private, and international clients. It offers invaluable expertise in the fields of power, coal and hydrocarbons and has extensive experience on regulatory and tariff issues, policy and institutional issues. TERI has been at the forefront in providing expertise and professional services to national and international clients. TERI has been closely working with utilities, regulatory commissions, government, bilateral and multilateral organizations (The World Bank, ADB, JBIC, DFID, and USAID, among many others) in the past. This has been possible since TERI has multidisciplinary expertise comprising of economist, technical, social, environmental, and management.

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