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SHAKTI
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ENERGY IS LIFE
BEE
CONSERVE IT

Technology Compendium

on

Energy Saving Opportunities

Cement Sector

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Disclaimer

This report is part of Shakti Sustainable Energy Foundation (SSEF) and CII – Godrej GBC's effort to assist the Indian industry achieve greater energy efficiency levels and to facilitate designated consumers meet their Perform, Achieve & Trade (PAT) targets set by Bureau of Energy Efficiency (BEE), Government of India.

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Foreword by Director General – Bureau of Energy Efficiency

With the growth of economy, the demand for energy has grown substantially. Further, the high level of energy intensity in certain major industrial sectors, and more so, the variation between the most & least efficient facility within them is a matter of concern. In such scenario, efficient use of energy resources and their conservation assume tremendous significance and become imperative for sustainable growth of the industrial economy and the country at large.

Considering the fact that, the efficient use of energy and its conservation is the best option to meet the increasing energy demand, Government of India has enacted the Energy Conservation Act, 2001. The Act provides for institutionalizing and strengthening delivery mechanism for energy efficiency services in the country and the much-needed coordination between the various entities.

The Ministry of Power and Bureau of Energy Efficiency (BEE) are entrusted with the task of preparing the implementation for the National Mission on Enhanced Energy Efficiency (NMEEE) under National Action Plan on Climate Change (NAPCC). This mission has a component which deals with the market based mechanism to improve the energy efficiency in energy intensive large industries and facilities by certification of energy savings which could be traded.

This scheme known as Perform, Achieve and Trade (PAT) is expected to save about 6.686 million metric tonne of oil equivalent (mMtoe) by 2014-15. Eight industrial sectors namely Power, Iron & Steel, Fertilizer, Cement, Aluminium, Pulp & Paper, Textile and Chlor-alkali have been included in this scheme wherein about 478 industries known as Designated Consumers (DCs) are covered. In the ensuing PAT scheme, all the DCs will be required to achieve a reduction in Specific Energy Consumption (SEC) from their baseline SEC within 3 years time (2012-13 to 2014-15).

These industry specific technology compendiums will provide ready-to-use information on national & international energy conservation opportunities, Best Operating Practices (BOP), Best Available Technologies (BAT), with their techno-economic considerations. These compendiums will be helpful for DCs to prepare their energy efficiency action plans and to achieve their SEC reduction targets set by BEE.

I am sure that this Technology Compendium manual will receive an overwhelming response across the industry. I take this opportunity to thank Shakti Sustainable Energy Foundation (a part of Climate Works Foundation) for supporting this initiative.

(Ajay Mathur)

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EXECUTIVE SUMMARY

Indian cement industry is one of the highly energy intensive industry which has a robust growth trajectory over the past decade. Indian cement industry is the 2nd largest producer of cement in the world with a total capacity of 277.46 million MTPA[1]. The per-capita consumption of cement has increased from 28 kg in 1980-81 to 176 kg in 2010[2], led by the growth in sectors like real estate and construction.

Economic growth is contingent upon the growth of cement industry. Consumption of cement is taken to be an indicator of economic development. The greater the infrastructure growth of a country, greater will be the consumption of cement.

The Ministry of Power (MoP) has notified industrial units and other establishments consuming energy more than the threshold in 9 sectors in March, 2007 as Designated Consumers. Designated Consumers, as notified under the Energy Conservation Act, 2001, account for 25% of the national gross domestic product (GDP) and about 45% of commercial energy use in India. In order to further accelerate and incentivize energy efficiency, the Perform Achieve and Trade (PAT) mechanism has been designed.

PAT is a market based mechanism to enhance cost effectiveness of energy efficiency improvements in large energy intensive industries and facilities, through certification of energy savings that could be traded. In the first PAT cycle 8 sectors are covered, namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron & Steel and Aluminum.

The threshold limit of 30,000 MTOE has been defined in PAT for cement sector, and 85 nos. of designated consumers have been identified from various States. The Indian cement industry consumes 14.5 million MTOE which accounts to 6.26% of total energy consumption (231.6 million MTOE) of all eight sectors.

By the end of the first PAT cycle, the energy savings of 0.816 million MTOE /year is expected to be achieved, which is around 12% of total national energy saving targets projected under PAT.

With this background, this Technology Compendium, comprising of various technologies and best practices to save energy is prepared. This compendium is expected to assist the designated consumers to improve their energy efficiency levels and finally to achieve the targets under PAT scheme.

However, implementation of these technologies calls for a sustained effort from the designated consumers. Some of the technologies mentioned in this report are capital intensive and time consuming to implement. But implementation of these projects can surely be beneficial in a long term perspective for the sector.

[1] Cement Manufactures' Association (CMA)
[2] ACC Limited Presentation 2011

METHODOLOGY

Formation of technology advisory group:

A Technology Advisory Group consisting of the following key industrial experts from Cement Sector have been identified.

1. Mr C K Jain (Vasavadatta Cement)
2. Mr M Srinivasan (Madras Cement)
3. Mr D Sivagurunathan (India Cements)

The Technology Advisory Group (TAG) reviewed the project methodology and approach during the inception phase and the project findings during the implementation phase.

Secondary Research:

Secondary research formed an important activity in this project. This was conducted for gathering sectoral information, identification of international best practices and the major technological advancement in the sector. The following were some of the sources that were referred

1. Existing and Potential Technologies for Carbon Emissions Reductions in the Indian Cement Industry-A set of technical papers produced for Low Carbon Technology Roadmap for the Indian Cement Industry- CII, NCBM, IEA, WBCSD
2. Cement Statistics 2011, Cement Manufactures' Association (CMA)
3. Ninety fifth report on Performance of cement industry submitted to Rajya Sabha- 2011
4. Cement Sector Program in SSA: Barriers Analysis to CDM and Solutions- World Bank Assist
5. Detailed Energy Audits Carried out by CII
6. CII- Godrej GBC- Green Cementech Conferences

Stakeholder Interactions:

The team has interacted with CII Godrej GBC's Cement working group members to understand their present levels of technology competence and usage, processes and sub-processes, energy efficiency commitments, etc.

The team also interacted with several technology service providers to seek their opinion on the best available energy efficient technology and to identify existing and in-development technologies to assess their utility.

Best operating practices were identified during the national and international conferences in Cement sector. During the course of the conference, best operating practices were shared by the performing plants to other participants.

Review and Analysis:

Inputs that were received from the Technology Advisory Group, Secondary research and Stakeholder interactions have been compiled and were arrived at the following;

- Mapping of Technologies/Process and Sub-Processes in the Cement sector
- Understanding energy trends from the past and adaptation of technology and its influence on energy performance in the Cement sector
- Identification of clean technologies available in Cement sector
- Identification of best operating practices in Cement sector which also includes
  - Energy savings
  - Environmental benefits
  - Investment required
  - Payback period
  - Technology providers

Draft report on Cement Sector Technology compendium had been prepared to seek inputs from the multi stakeholder group. The Draft report consists of

- Overview of Indian cement industry
- Energy consumption trend
- Environmental issues faced by the sector
- Favourable and non favourable policy / regulations to Indian cement sector
- List of best practices
- Proposed technologies

1.0 INDIAN CEMENT INDUSTRY

Indian cement industry is one of the highly energy intensive industry which has a robust growth trajectory over the past decade. Indian cement industry is the 2nd largest producer of cement in the world with a total capacity of 277.46 million MTPA[3]. The per-capita consumption of cement has increased from 28kg in 1980-81 to 176kg in 2010[4], led by the resilience in sectors like real estate and construction.

Background of Indian Cement Industry

The real foundation of Indian Cement industry was laid in 1914, when a Cement plant was set-up at Porbandar. The company went off well in terms of production as well as economy. The prosperity of the company tempted other industrialists to enter into the sector. Since then, several groups have made inroads into the industry, thereby increasing the industry's capacity.

By the end of 1981, the total installed capacity was 28.87 million MTPA and through a period of 10 years it had shown a growth rate of 100% to reach the level of 58.31 million MTPA. As on December 2010, the total installed capacity was 277.46 million MTPA with 165 plants[5]. Now the industry has transformed itself in to being the second largest in the world, next to China. Today, Indian Cement Industry is regarded as one of the best in the world in terms of technology, quality, efficiency and productivity parameters.

Capacity

India is the 2nd largest producer in the world with a total installed capacity of 277.46 million MTPA as on 31st December 2010. The industry has seen a growth rate in the installed capacity of more than 10-20% over the past 3 years (2007 to 2010). There are 165 large plants and 365 mini cement plants operated by 32 cement manufacturing companies in India contributing to 96% of the total production. Indian cement industry comprises of both private and public sector ownership, but it is predominantly dominated by private companies. The private sector cement companies contribute over 97% of total cement production in the country.

[3] Cement Manufactures' Association (CMA)
[4] IBEF Cement 2011
[5] Cement Manufactures' Association (CMA) & Company Annual Reports

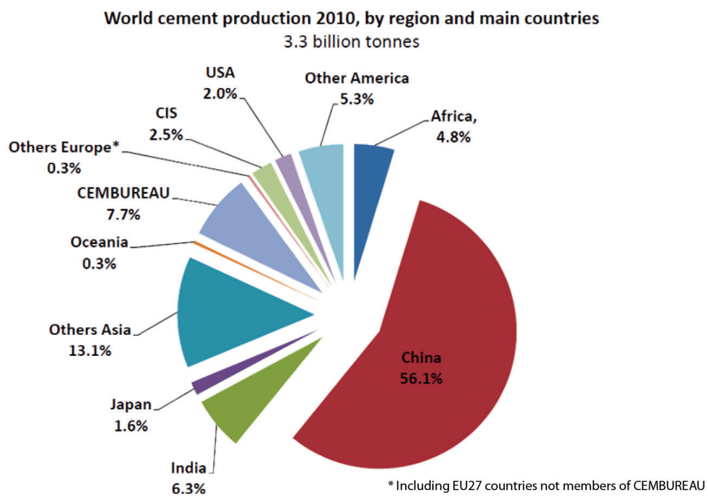

Figure 1-World cement production

As on 31st December 2010 the total installed capacity in India constitutes to 277.46 million MTPA with a production of 207.84 million MTPA from 165 cement plants[7]. The following table shows the breakdown of the production capacity among the different cement plants.

Table 1-Capacity share of major cement plants (2010)

Sl. No	Company	Capacity (million MTPA)
1	Ultratech Cement	48.75
2	ACC Limited	30.21
3	Ambuja Cement Limited	25.00
4	Jaypee Cement	17.15
5	India Cements Limited	15.85
6	Madras Cements Limited	12.72
7	J K Cement Limited	12.27
8	Shree Cement Limited	12.00
9	Dalmia Cement Bharat Limited	9.00
10	Chettinad Cement Corporation Limited	8.20
11	Century Cement	7.80
12	Kesoram Cement & Vasavadatta Cement	7.25
13	Lafarge India Private Limited	6.55
14	Others	64.72
	Total	277.46

[6] CEMBUREAU Activity Report 2010
[7] Cement Manufactures' Association (CMA) & Company Annual Reports

India produces variety of cement such as Ordinary Portland cement (OPC), Portland Pozzolana cement (PPC), Portland Blast Furnace Slag cement (PBFSC), white cement and specialised cement. Cement in India is produced as per the Bureau of Indian Standards (BIS) specifications and the quality is comparable with the best in the world. The chart below shows the various types of cement manufactured in India as on December 2010.

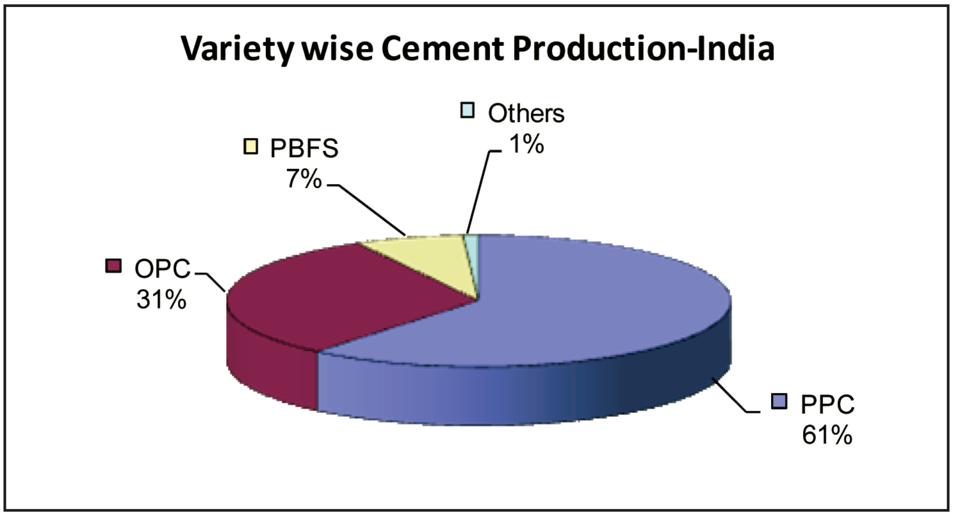

Figure 2- Variety wise cement production in India

1.1 GEOGRAPHICAL SPREAD OF INDIAN CEMENT INDUSTRY

Primarily, the concentration of cement plant depends on the limestone reserves. India has an abundant resource of limestone. As on 31st March 2006, the estimated gross reserve of cement grade limestone in India is 97430.45 million MTPA. Out of the total reserve of cement grade limestone in India, about 45% is in Southern region, 21.84% is in Northern region, 12.34% is in Western region, 15.82% is in Eastern region and the rest 3.64% in the central region.

Cement industry is the largest consumer of limestone in India, accounting for over 75-80% of total limestone. Limestone is the basic raw material needed for the manufacture of cement. To prepare cement, limestone with a minimum CaO content of 44% is necessary. Typically, 1.4-1.5 MT (Metric Tonne) of Limestone is required for producing one tonne of clinker. Thus, for a 1 million MTPA cement plant, assured availability of cement grade limestone reserves of the order of 50-60 million MTPA in the close vicinity is important[9].

The location of limestone reserves in particular States has resulted, in the formation of clusters. The proximity of these clusters is essential for the plants to have a reliable source of raw material and to bring down the transportation cost of raw material.

[8] Cement Manufactures' Association (CMA)

[9] Final report on Application of Surface Miner in Nongtrai Limestone Mine by Central Institute of Mining & Research

As per CMA, there are 7 clusters of limestone in India spread over various geographical location of India. The major clusters constitute to around 40% of the total production of cement in India. The concentration of cement plants in various clusters is shown in the map below[10].

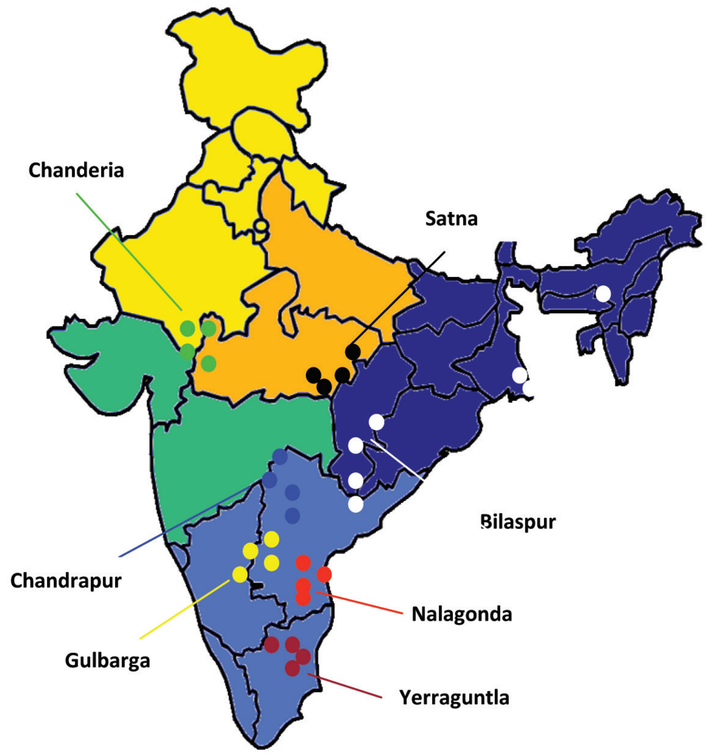

Figure 3-Concentration of cement plants in India

The percentage share of the cement plants in various clusters is illustrated in the table given below.

Table 2-Installed capacity of cement plants in various cement clusters

Sl. No.	Cluster	No. of Plants	Installed Capacity (million MTPA)	% Share
1	Gulbarga	7	20.4	7.35%
2	Yerraguntla	8	18.59	6.70%
3	Satna	9	17.82	6.42%
4	Chanderia	7	14.45	5.21%
5	Nalgonda	9	14.36	5.18%
6	Bilaspur	9	12.84	4.63%
7	Chandrapur	6	11.51	4.15%
	Clusters (7)	55	109.97	39.63%
	Others	110	167.49	60.37%

[10] Cement Manufactures' Association (CMA)

Andra Pradesh, Rajasthan and Tamil Nadu constitute the major share of cement plants in India, accounting to 16%, 15.48% and 14.65% respectively of the cement production.

1.2 MAJOR PLAYERS IN INDIAN CEMENT SECTOR[11]

The major share of the cement production in India is from the strong major players in the industry which constitute 74% of the total installed capacity of cement in India. The following table illustrates the capacity share of the major players in India.

Table 3- Capacity share of major cement industries in India

Sl. No	Company	Installed Capacity (million MTPA) Dec 2010	% Share
1	Ultratech Cement Limited	48.75	17.57%
2	ACC Limited	30.21	10.89%
3	Ambuja Cement Ltd.	25.00	9.01%
4	Jaypee Cement	17.15	6.18%
5	India Cements Ltd.	15.85	5.71%
6	Madras cements Ltd.	12.72	4.58%
7	JK Cement Ltd.	12.27	4.42%
8	Shree Cement Ltd.	12.00	4.32%
9	Dalmia Cement Ltd.	9.00	3.24%
10	Chettinad Cement Corporation Limited	8.20	2.96%
11	Century Cement	7.80	2.81%
12	Lafarge India Pvt Ltd.	6.55	2.36%
13	Others	71.96	25.94%

The 12 major players hold 103 plants out of the total 165 cement plants in India. Rest of the 62 plants has its own production share less than 2% of the total cement production. [12]The total cement production in the year 2010 accounts to 207.84 million MTPA from 165 cement plants out of the installed capacity of 277.46 million MTPA.

[11] Cement Manufactures' Association (CMA) & Company Annual Reports
[12] Cement Manufactures' Association (CMA) & Company Annual Reports

The capacity utilisation of the Indian Cement Industry over the past three decades is shown in the graph below.

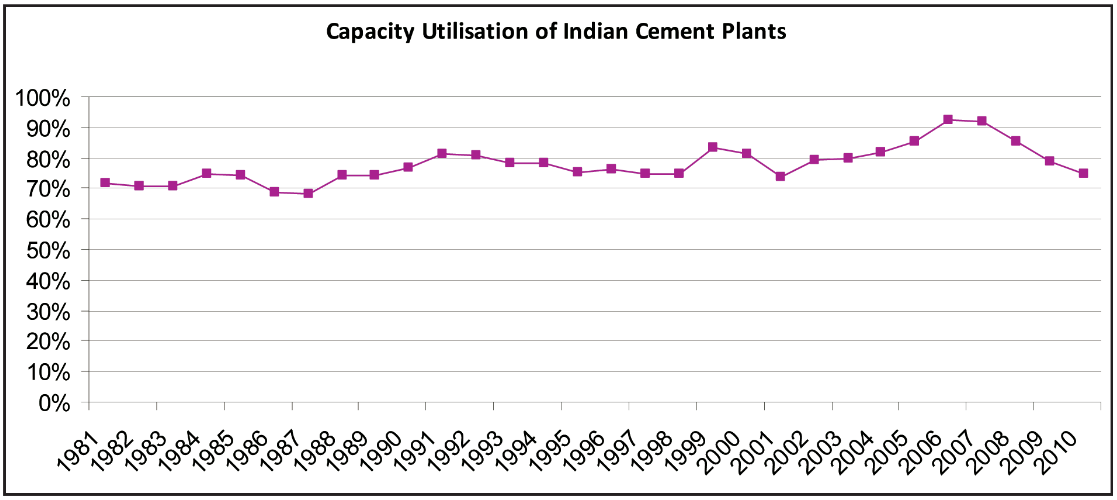

Figure 4-Capacity utilization of Indian cement plants

UltraTech Cement

UltraTech, an Aditya Birla Group Company and a 51 per cent subsidiary of Grasim, has a consolidated capacity of 48.75 million MTPA. In fact, it is the single largest cement producer in the country. The company has its presence in western, eastern and southern regions. The company has 22 manufacturing units in India and five terminals — four in India and one in Sri Lanka. UltraTech Cement is the country's largest exporter of cement clinker. The export markets span countries around the Indian Ocean, Africa, Europe and the Middle East.

ACC Limited (ACC)

ACC Ltd is one of the India's largest cement manufacturer with installed capacity of 30.21 million MTPA and power generating capacity of 355MW including the thermal power and wind power. ACC's operations are spread throughout the country with 15 modern cement factories and more than 40 ready mix concrete plants. Holcim world's premier cement producer has a major stake in this company.

Ambuja Cement Ltd (ACL)

Ambuja Cement Ltd., is the third largest cement producer in the country. It commenced its operation in 1986 with an a installed capacity of 0.7 million MTPA. As on December 2010 the company has 13 manufacturing plants with an installed capacity of 25 million MTPA. Ambuja Cement Ltd has a strong foothold in the northern and western markets. Holcim world's premier cement producer has a major stake in this company.

1.3 ENERGY CONSUMPTION TREND

Cement industry is an energy intensive industry and third largest coal consumer in the country after power and steel industry[13] requiring both electrical and thermal energy for its operation.

Cement industry accounts for around 10% of the coal and 6% of the electricity consumed by the Indian industrial sector. On an average, cement plants are spending about 35-50% of the total manufacturing cost of cement to meet their energy demands. In fact, energy cost is considered as a major factor in pricing of the cement. The breakup of manufacturing cost of cement is shown below. Around 25% of the manufacturing cost is spent on raw materials for cement manufacturing. The rest of the cost is shared among the manpower and factory overheads.

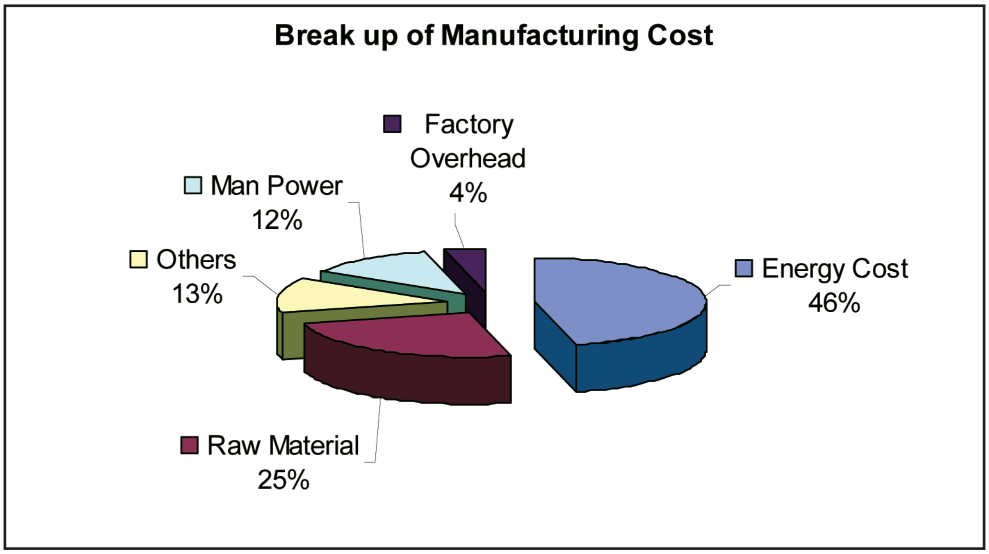

Figure 5-Cost break-up in cement manufacturing

Electrical Energy

Modern cement plants on an average consume about 65-75 kWh of electrical energy[14] for producing one ton of cement. Cement plant requires electrical energy to run its Mill drives, Fans, Conveyors, Packers and for Lighting systems. Kiln and mills are major electrical power consuming areas of the cement plant. In fact, they are consuming about 60 % of total electrical energy requirement. When it comes to old plants due to the old technologies and some inherent barriers, the energy consumption will be in the range of 80-100 kWh[15] per ton of cement. The section wise electrical energy consumption is shown in the graph below.

[13] Indian Coal Sector by IIFL

[14] Average of Cement Manufactures' Association (CMA) and CII- Energy Award Questionnaire

[15] Cement Manufactures' Association (CMA) and CII- Energy Award Questionnaire

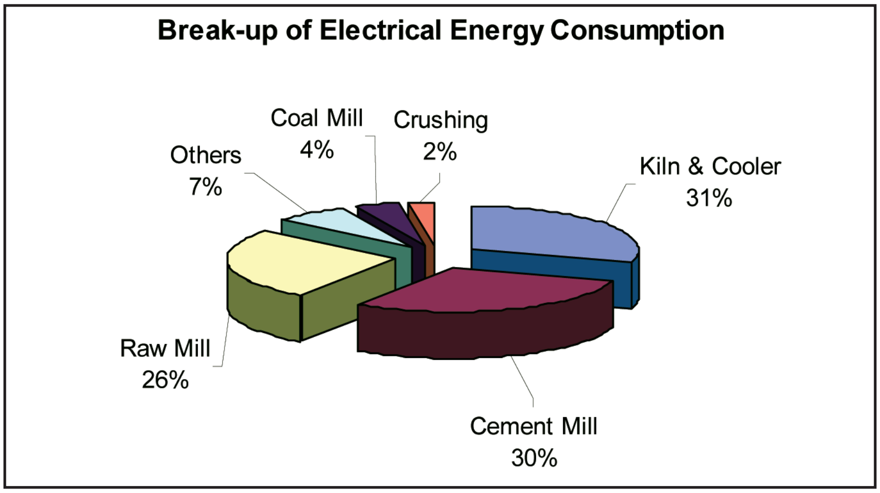

Figure 6- Breakup of electrical energy consumption

Indian cement industry as a whole has a total installed capacity of 2430.64MW of coal fired captive power plants. On an average 50-55% of the Indian cement plants has its share of power from the captive power plant. Cement industry has also explored an additional revenue which they can get by exporting the excess produced power to the grid.

Indian cement industry has taken a good initiative in setting up renewable energy sources such as wind power to offset its part of the energy consumption from the grid and its own captive power plant. As on 31st December 2010 the Indian Cement industry has an installed wind power capacity of 256.25MW. Government of India has also introduced the Renewable Energy Certificate (REC) mechanism, a market-based instrument policy to promote renewable energy and facilitate renewable energy purchase obligations amongst various stakeholders. RECs are applicable to those companies which are connected to grid and exporting power.

Thermal Energy

On an average, Indian cement plants require 723 kCal[16] of thermal energy for producing one kg of clinker. The major use of thermal energy is in the kiln and pre-calciner systems. Thermal energy is needed for the raw meal processing specifically for converting the raw mix to Clinker. Clinker production is the most energy-concentrated stage in cement production. The number of stages in the pre-heater system has a major bearing on the thermal energy consumption in Kiln system.

Continuous technological upgradation and assimilation of latest technologies have been steadily increasing in the cement industry. Today, 98% of the plants use dry process technology compared to 6% in 1960[17].

[16] Average value of Indian cement industry from CMA & CII- Energy Award Questionnaire
[17] Cement Sector Program in SSA: Barriers Analysis to CDM and Solutions- World Bank Assist

Indian cement industry has always been a trend setter for adopting the best available energy efficient technologies. The best thermal and electrical energy consumption presently achieved in India is 663 kcal/kg clinker and 59 kWh/T cement which are comparable to the best figures of 650 kcal/kg clinker and 65kWh/T cement in a developed country like Japan.

The specific energy consumption of the Indian Cement Plants has been reducing with continuous up-gradation of technologies and the change in process technologies. The table given below shows the progressive reduction in specific energy consumption by Indian cement industry[18].

Table 4- Energy consumption trend of Indian cement industry

Parameter	Year				
	1950-60	1970s	1980s	1990s	Post 2000
Heat Consumption (kCal/kg Clinker)	1300-1600	900-1000	800-900	650-750	650-750
Power Consumption (kWh/T of cement)	115-130	110-125	105-115	95-105	80-100

1.4 GROWTH TREND OF INDIAN CEMENT INDUSTRY[19]

Cement industry has always seen an increase in capacity and production over the past three decades. The production and capacity trend of the Indian cement industry is shown in the graph below.

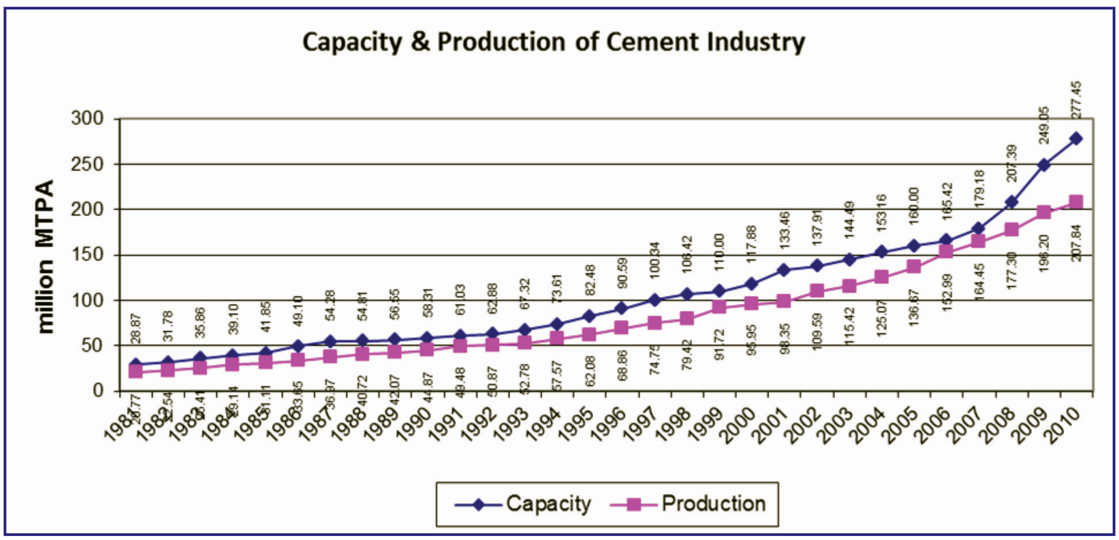

Figure 7-Capacity & production trend in Indian cement industry

Cement industry has continued its growth trajectory over the past years supported by the rising demands from the housing sector, increased activity in infrastructure and construction recovery.

[18] Cement Manufactures' Association (CMA) & National Council for Cement & Building Materials
[19] Cement Manufactures' Association (CMA) & Company Annual Reports

Domestic cement demand growth has surpassed the economic growth rate of the country for the past couple of years. Thus it has sustained its growth rate even in tough conditions of economic slowdown. The graph below shows the growth in cement capacity addition over the past 5 years. It is evident from the figure that that inspite of adverse conditions that the industry has faced, it has always achieved a growth trajectory in its capacity addition.

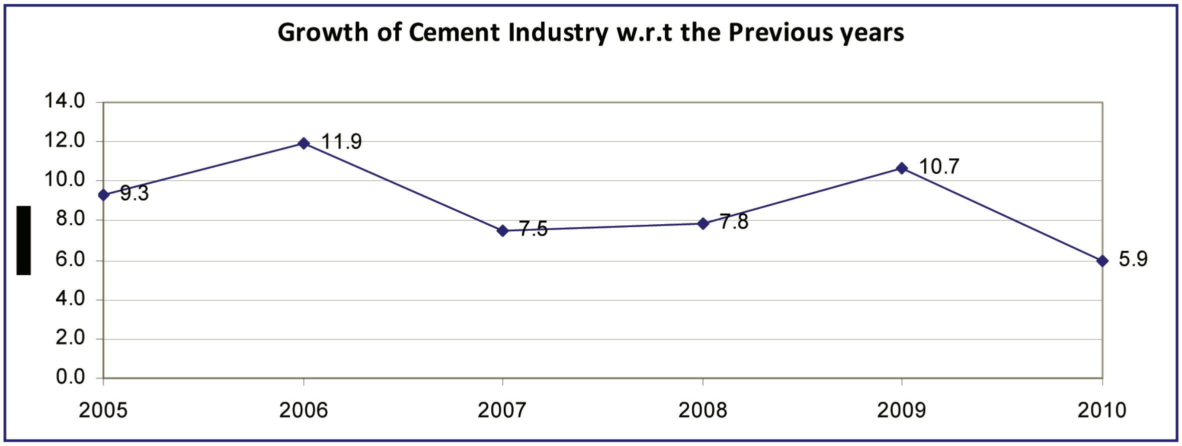

Figure 8-Growth of cement industry w r t previous years

Financial Health of the sector

Cement industry is one of the vital sector for economic development in a country. The total utilization of cement in a year is used as an indicator of economic growth. Cement is a necessary constituent of infrastructure development and a key raw material for the construction industry, especially in the Government's infrastructure development plans in the context of the nation's socioeconomic development. Demand in the cement industry has seen tremendous growth supported by the rising demands from infrastructure, residential and commercial projects.

The industry may be expected to add another 130-135 million TPA of cement capacity in phases over the next three years by 2013 and Cement Manufacturers Association has projected a capacity of 550 million MTPA by 2020. Moreover, total Foreign Direct Investment (FDI) in the cement sector between April 2000 and August 2010 stood at US$ 1.9 billion. Hence, the huge demand of the cement in India will boost the cement industry and will be beneficial for local as well as global cement manufacturers.

1.5 FUTURE GROWTH OPPORTUNITIES

Cement production is expected to grow significantly with the increase in population and per-capita income. The current per capita consumption of 176 kg as compared to the world average of 433 kg and 1210 kg in China underlines the tremendous scope for growth in the Indian cement industry in the long term. The growth of the cement industry will be backed up by the following key drivers.

1. Infrastructure investment
2. Government Initiatives
3. New Investors / players
4. Mergers & Acquisitions
5. Buoyant real estate market
6. Technological change

In past few years, with spurt in infrastructure and real estate demand, Indian cement sector has witnessed robust cement growth. Historically, cement demand to the country's GDP has an average multiplier effect of 1.3x (average of 5 year period).

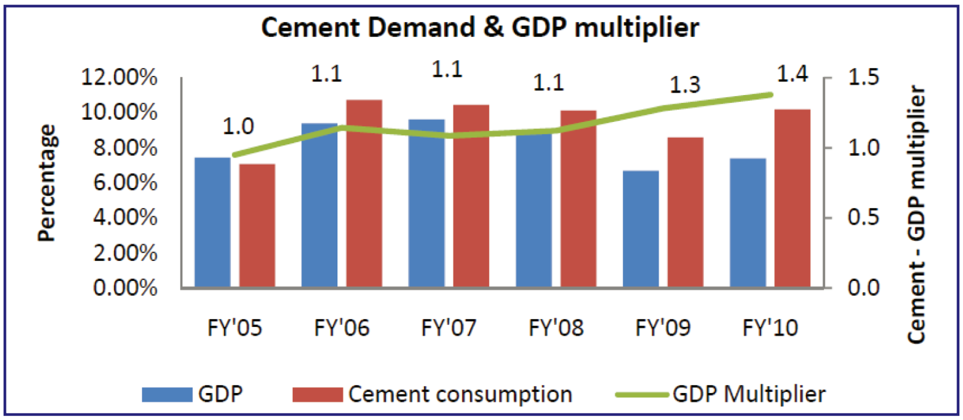

Figure 9- Trend of cement demand & GDP multiplier

The per capita consumption of India is far behind the world average and China is the largest producer of cement in the world. India's per capita consumption is 176kg as on 2010. Lower per capita consumption indicates increased scope for growth.

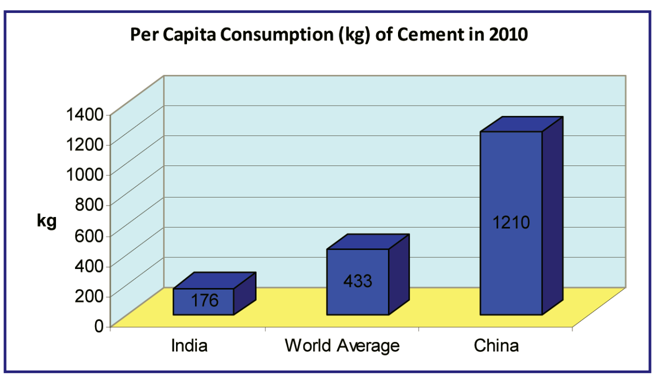

Figure 10- Per Capita consumption (kg) of cement in 2010

India is heading to catch up with the world average of per capita income which will increase the growth of the cement sector. Demand in the cement industry has seen tremendous growth supported by the rising demands from infrastructure, residential and commercial projects. As per

CMA the cement sector capacity is expected to increase to 550 million MTPA by the end of year 2020.

1.6 BARRIERS TO THE GROWTH OF INDIAN CEMENT INDUSTRY

Cement industry in India, after being de-licensed in 1981 has shown remarkable growth. India has emerged as the second largest country in the world after China in the production of cement. The per capita consumption of cement is regarded as an important index of the country's economic growth.

Indian cement industry plays a key role in the national economy by generating substantial revenue for State and Central Governments as well as employment opportunities. The per capita cement consumption in India is 176 kg against the world average of 433 kg. In terms of quality, technology, productivity and efficiency, India compares well with the best in the world. Indian cement sector has adopted new efficient technologies and demonstrated successful technologies.

Though Indian cement sector excels in many aspects, it also faces some barriers in its wide spread development. Major barriers include the following

- High investment cost for adopting WHR and AFR technologies
- Policy Issues related to alternate technologies like AFR

Tax and Levies

As per the National Council for Applied Economic Research (NCAER), Indian cement industry appears to be the highest taxed cement industry among the selected neighboring countries such as China/ Hong Kong, Bangladesh, Bhutan, Indonesia, Pakistan, Nepal, Singapore, Sri Lanka, Thailand and Vietnam. This makes prices of Indian cement non-competitive vis-à-vis other countries in international market.

According to Cement Manufacturers Association (CMA), taxes and levies on cement constitute 60% or more of the ex-factory price. Though excise duty on Cement is levied on the basis of Maximum Retail Price (MRP), no abatement is given to Ordinary Portland Cement (OPC), Pozzlana Portland Cement (PPC) and Slag Cements while white cement has been allowed abatement. The duties imposed on the cement industry are as given below[20].

[20] Ninety fifth report On Performance of cement industry submitted to Rajya Sabha- 2011

Table 5- Various duties imposed on cement industry

Sl. No	Description	Excise Duty
i	For retail sale price of cement not exceeding Rs. 190/- per bag of 50 Kg	Rs. 290 per tonne + (2%+1%) Education cess
ii	For retail sale price of cement exceeding Rs. 190/- per bag of 50 Kg	10% of sale price or Rs. 290 per tonne + (2%+1%) Education cess whichever is higher
iii	For institutional sale of cement	10% of sale price or Rs. 290/- per tonne whichever is higher.
iv	Clinker	Rs. 375/- per tonne

The import duty on the inputs including clinker used in cement production is close to 10% and on coal close to 5%. As a result, the weighted average import duty on various cement inputs is at around 6.8% while the finished product (cement) can be imported duty free. Excise duty levied on the bagged cement and clinker is given below .

Table 6- Excise Duty levied on bagged cement & clinker

Royalty on limestone	Rs. 63/- per tonne
Cess on limestone	Re 1/- per tonne
VAT on Cement & Clinker	12.5% of sale price, 13% + Entry tax @ 1% for MP, 14% for Chhattisgarh, 14.5% for AP and 12.5% + Addl. Tax @ 2.5% for Gujarat
Cess on cement dispatched	Rs. 0.75/- per tonne
BIS marking fees on cement dispatched	Rs.2/- per tonne
CST	2% against C-form

Use of Fly Ash for PPC Manufacturing

In order to reduce the emission of pollutants per tonne of cement production, substitution of clinker by using fly ash and blast furnace slag has been taken into practice by the Indian cement sector. The major problems faced by the sector for increased substitution of clinker are mentioned below[22].

1. Regional availability of clinker-substituting materials
2. Increasing price of substitution materials

[21] Ninety fifth report On Performance of cement industry submitted to Rajya Sabha- 2011
[22] Cement Technology Roadmap 2009

3. Properties of substitution materials and intended application of the cement
4. National standards for Ordinary Portland Cement and composite cements
5. Common practice and acceptance of the composite cement by construction contractors and customers

In India, the total available fly ash generation from power plants is about 130 million MTPA per year and what industry used for production of PPC is around 34 million MTPA per year[23]. Similarly the blast furnace slag available in India is 13 million MTPA per year from steel plants and around 8 million MTPA per year is used for production of blast furnace slag cement.

Environmental issues faced by the sector

Cement industry employs the most modern technology to reduce pollution in various stages of cement production and transportation are not exceptions to causing environment pollution.

As per the Ministry of Environment & Forests and Central Pollution Control Board (CPCB) the industry consumes about 303 million MTPA of lime stone and 30 million MTPA of coal. Dry process of cement manufacturing dominates semi-dry and wet processes due to higher capacity of production and better energy efficiency.

Dust, Oxides of Nitrogen (NO_2) & Carbon Dioxide (CO_2) are major air pollutants emitted in various stages of cement production viz: mining, transportation of material, cement manufacturing process and loading/unloading of cement. Oxidation of sulfur compounds present in raw materials and fuel lead to emission of sulphur dioxide. It also emits carbon dioxide (CO_2) which is the main constituent of Green House Gases. Calcinations of limestone emit 50-55%; combustion of fossil fuel emits 40-50% CO_2; and electricity consumption causes 0-10% CO_2 emission. Overall, 0.85 tonnes CO_2 is emitted during the production of one tonne of cement. An amount of 0.234 kilogram of particulate matter,1.5 kg of sulphur dioxide and 3.00 kg of oxides of nitrogen are emitted for the production one tonne of cement[24].

While the European Union emission standards for large cement plants is 30 mg/Nm^3 the Indian emission standards for existing large cement plants is 50 mg/Nm^3 for cement plants, including grinding units, located in critically polluted or urban areas with a population of one lakh and above and 150 mg/Nm^3 for plants other than those falling under above category. In the case of mini cement plants the standard is 400 mg/Nm^3.

[23] Ninety fifth report On Performance of cement industry submitted to Rajya Sabha- 2011
[24] Ninety fifth report on Performance of Cement Industry submitted to Rajya Sabha- 2011

1.7 POLICY / REGULATIONS FAVOURABLE TO INDIAN CEMENT SECTOR

The Energy Conservation Act 2001 has been the catalyst of energy efficiency in India. Bureau of Energy Efficiency (BEE) which was established under this Act identified cement companies as energy intensive industries and designated energy consumers, requiring them to report periodically on their energy consumption and efficiency levels. In order to increase the competitiveness between the industries BEE is also organizing National Energy Conservation Award every year.

Another framework organized by BEE is the Perform, Achieve and Trade (PAT) for all the energy intensive industries. PAT scheme is involved in order to incentivize industry to achieve better energy efficiency improvements than their specified SEC improvement target in a cost effective manner. The additional certified energy savings can be traded for additional revenue also. All cement industries whose energy consumption is above 30000 MTOE will be considered as designated consumer under PAT scheme. It is estimated that an over all reduction potential of 2-7% is achievable with the implementation of PAT scheme.

Government of India has introduced the Renewable Energy Certificate (REC) mechanism, a market-based instrument to promote renewable energy and facilitate renewable energy purchase obligations amongst various stakeholders.

RECs have been used extensively as a successful market based policy instrument to promote renewable energy in many countries. The REC mechanism entails pricing of two components, namely, electricity component and REC component representing environmental attributes of renewable energy generation. This will promote the generation of renewable energy among various industries which can bring additional revenue or industries can buy the environmental attributes to comply with the sustainability issues.

Clean Development Mechanism (CDM)

CDM is the flexible mechanism in the Kyoto Protocol open to developing-country participation for reduced GHG emissions. CDM has double purpose- assist developing countries in achieving sustainable development and to help industrialized countries cost-effectively reach the emission reduction commitments they assume under the Kyoto Protocol.

Cement industry is playing an active role in the Kyoto Protocol to cut down the sectorial greenhouse gases emissions, particularly in the Clean Development Mechanism (CDM). Indian cement sector has reaped the benefits of CDM through various opportunities like waste heat recovery projects, Alternate Fuel and raw materials use in cement kilns. etc.

1.8 POLICY / REGULATORY ISSUES FACED BY INDIAN CEMENT SECTOR

Though there are many Policies encouraging and incentivising Indian cement sector, there are certain issues which has to be addressed which can bring significant reduction in GHG emissions.

Alternate Fuel Use

Alternative fuel use entails replacing conventional fuels (mainly coal and/or petcoke) which are used for heating the cement kiln raw material, with alternative fuels (like biomass, industrial waste, used tyres, other solid wastes etc). The mixed fuel can be 20-25% less carbon intensive than coal. Cement kilns are particularly well-suited for such fuels mainly because of the high temperature burning and adequate residence time which enables the use of alternate fuel, increasing energy costs and the inorganic components e.g., ashes, are integrated into the clinker product[25].

Although, technically, cement kilns could use upto 100% of alternative fuels, there are some practical limitations. The physical and chemical properties of most alternative fuels differ significantly from those of conventional fuels. It may not be directly used because of low calorific value, high moisture content, or high concentration of chlorine or other trace substances. This means pre-treatment is often needed to ensure a more uniform composition and optimum combustion.

However, the achievement of higher substitution rates has stronger political and legal barriers than technical ones:

- Material Acquisition: Cement plants face big issues in sourcing the alternate fuel resources. The entire cost for sourcing the material has to be borne by the industry itself. Higher fuel substitution only takes place if local or regional waste legislation restricts land-filling or dedicated incineration, and allows controlled waste collection and treatment of alternative fuels.
- Lack of 'Polluter Pays' Concept.
- The level of social acceptance of co-processing waste fuels in cement plants can strongly affect local uptake. People are often concerned about harmful emissions from co-processing, even though emissions levels from well-managed cement plants are the same with or without alternative fuel use.
- Continuous emission monitoring system required for hazardous waste being used as a raw material which will increase the cost of using AFR in cement kilns

[25] Cement Technology Roadmap 2009, Centre for Science and Environment, New Delhi

Waste Heat Recovery

In order to bring down the cost towards energy, several cost reduction techniques such as using of pet coke and low grade coal, optimization of Indian coal with imported coals are being practiced. In that way, waste heat recovery is an alternative source for captive power generation. Other than reducing energy cost significantly, it can be also a reliable source of power. The concept of waste heat recovery is slowly picking up across the country.

In cement manufacturing, Pyro-processing is the most energy intensive process. Out of the total heat generated in the process, a good potential exists in tapping the waste heat for power generation. There exists a tremendous potential to recover this heat and to utilize for power generation. This cogeneration of power utilizing waste heat in a cement plant can meet 25-30% of total power requirement of the plant.

There are only few cement industries in India with the waste heat recovery technology for power generation. The installed capacity of WHR in Indian cement sector is articulated in the table given below.

Table 7- Waste Heat Recovery share of various cement industries

Sl. No.	Company	Installed Capacity (MW)
1	Shree Cement Ltd.	46.0
2	Birla Cement, Satna	15.0
3	J K Nimbahera	13.2
4	J K Lakshmi, Sirohi	12.0
5	India Cements Ltd., Vishnupuram	7.7
6	Birla Cement, Satna	7.5
7	KCP Ltd., Macherla	2.5
8	Ultratech APCW I	3.8
	Total	**107.7**

The total installed capacity of the Waste Heat Recovery in India as on September 2011 is 107.7MW[26].

It is estimated that Indian Cement Industry has a potential of 500MW through cogeneration of power by waste heat recovery, of which, only about 20% is being tapped. This will not only reduce cost of production of cement but also help in reducing the green house gas (CO2) emissions.

[26] Cement Manufactures' Association (CMA) & Company Annual Reports

Major barriers which hinder the industry in adopting Waste Heat Recovery projects includes:

- High investment cost
- Lesser cycle efficiency
- Non-availability of indigenous suppliers and service providers
- Lack of incentives for waste generation from waste heat

Availability of Coal

Cement industry depends heavily on coal for manufacturing cement. Therefore, adequate and sustained availability of proper quality of coal is of paramount importance for the Indian cement industry.

Coal India Ltd. (CIL) and Singareni Colleries Co. Ltd. (SCCL) are the two indigenous coal suppliers for the cement industry through the system of linkage and Fuel Supply Agreement (FSA). However, the supplies are grossly inadequate from CIL and SCCL. In 2008-09 only 48% of the total requirement is being supplied from them[27]. The additional requirement had to be procured at a huge cost from various other sources like purchase from open market, imports, use of pet coke etc. to supplement the requirement.

Another Policy issue faced by the sector is that as per new coal distribution policy only 75% of the normative requirement will be supplied. Thus, there is an ab-initio shortfall in the allocation of coal to each cement plant against its normative requirement. In order to avoid the problems faced by the sector timely & proper allocation of coal blocks to the core sectors has to be ensured.

[27] Ninety fifth report On Performance of cement industry submitted to Rajya Sabha- 2011

2.0 PRESENT ENERGY EFFICIENCY PRACTICES

Substantial reduction in specific energy consumption levels was observed in the past decade. Improvements in energy performance of cement plants in the recent past have been possible largely due to retrofitting and adoption of energy efficiency equipment, better operation control, better monitoring and management information system, up-gradation of process control and instrumentation facilities. The cement sector has always practiced the sharing of information among them, which has also helped in replication of national and international best practices and cleaner technologies.

National & International Best Practices

1. Optimizing the venting volume in crusher
2. Reducing the feed size of limestone to ball mill / VRM by optimizing crusher gap
3. Reducing the feed size of limestone by installing MMD crusher / Tertiary crusher
4. Replacement of the Air-lift with Bucket Elevator for Raw-meal Transport to the Silo
5. RABH Differential Pressure optimizations by installing VFD for RA fan
6. Reducing quality fluctuation in raw meal by installing CBA
7. Converting the air swept mill to mechanical discharge mill
8. Optimizing the first compartment grinding media size in accordance with feed size in ball mills
9. Optimizing the second compartment grinding media specific surface area
10. Reducing the fines in the classifier reject
11. Converting static separator with dynamic separator for ball mills
12. Reducing false air in the ball mill circuit
13. Replacement of High pressure drop Cyclones with Low Pressure Drop (LP) Cyclones
14. Reduction of pressure drop in the pre-heater down comer duct by introducing flow diverting plates
15. Reducing the oxygen content / excess air in pre-heater
16. Installing VFD for cooler fans
17. Lower dispersion box in raiser ducts of pre-heater cyclones and increase heat transfer
18. Converting the kiln feed system from pneumatic to mechanical
19. Maintaining different coal residue for kiln and calciner
20. Increasing the residence time of calciner

21. Reducing false air in pre-heater
22. Utilizing low thermal conductivity bricks in the kiln
23. Optimizing coal phase density in kiln and pc firing
24. Adding dry fly ash at the outlet of the cement mill
25. Adding mill ventilation collection to cement silo (product)
26. Reducing the fine fraction in separator rejects
27. Conversion of Open Circuit Cement Mills to Closed Circuit by Installing High Efficiency Separator

Cleaner technologies

1. Installation of Waste Heat Recovery Systems for power production from cooler exhaust and pre-heater exit gases
2. Use of Alternate Fuels and Raw Materials
3. Use of Renewable energy resources for power production

3.0 MAPPING STAKEHOLDER INITIATIVES

Indian cement industry is one of the key pioneers in undertaking energy efficiency activities and can be compared globally in terms of its lowest specific energy consumption levels. Several initiatives have been taken by the sector in terms of energy efficiency and GHG emission reduction opportunities with the help of industrial associations and suppliers.

Industry Organizations

In order to facilitate a conducive environment to promote the growth of Indian cement industry there are several national organizations which works closely with Government in terms of various Policy issues, enhancing efficiency, competitiveness, growth and development opportunities for Indian cement industry.

Major industry organizations working closely with the cement industry include the following:

- Cement Manufactures Association (CMA)
- National Council for Cement and Building Materials (NCCBM)
- Confederation of Indian Industry (CII)
- Cement Sustainability Initiative (CSI)

Cement Manufactures Association (CMA)

Cement Manufacturers' Association (CMA), is the apex body of cement manufacturers in India which was established in 1961. The main focus of the association is to work closely with government on policy issues, finding growth and development opportunities for Indian Cement Industry, identifying newer applications of cement usage etc.

It is also involved in dealing with the government bodies for coal allocation for the cement sector and also controls the cement price in India. CMA also provides technical advice, design and specification on concrete roads and thus improving the utilization of cement.

Website: - www.cmaindia.org

National Council for Cement and Building Materials (NCB)

National Council for Cement and Building Materials is a cement research institute working with the Indian Cement Industry for more than 50 years. It works with the cement sector to enhance quality, productivity and cost effectiveness, to improve the management of materials, energy and environmental resources and to develop sectoral competency.

Confederation of Indian Industry (CII) & CII- Sohrabji Godrej Green Business Centre

CII is a non-government, not-for-profit, industry led and industry managed organization founded over 117 years ago plays a proactive role in India's development process. CII works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes.

CII - Sohrabji Godrej Green Business Centre (CII - Godrej GBC) is one of the 10 Centres of Excellences of the Confederation of Indian Industry (CII). CII-Sohrabji Godrej Green Business Centre offers advisory services to the industry in the areas of Green buildings, energy efficiency, water management, environmental management, renewable energy, Green business incubation and climate change activities. The Centre sensitises key stakeholders to embrace Green practices and facilitates market transformation, paving way for India to become one of the global leaders in Green businesses by 2015.

CII – Godrej GBC has been very closely associated with energy efficiency improvement of the Indian industry. CII – Godrej GBC had carried out more than 1100 detailed energy audits till date in different sectors of industries. CII- Godrej GBC has conducted energy efficiency studies across the Indian cement clusters. CII- Godrej GBC has been closely involved with the Indian Cement Sector in analyzing the potential and promotion of Waste Heat Recovery installations, use of Alternate Fuels & Raw Materials in cement kilns.

Website: - www.cii.in and www.greenbusinesscentre.com

World Business Council for Sustainable Development (WBCSD) - Cement Sustainability Initiative (CSI)

The WBCSD is a CEO-led organization of forward-thinking companies that galvanizes the global business community to create a sustainable future for business, society and the environment. Cement Sustainability Initiative (CSI) is a sector project of WBCSD. The Cement Sustainability Initiative (CSI) is a global effort by 22 major cement producers with operations in more than 100 countries. CSI holds the largest data bank of GHG emission reporting from the cement companies.

CSI members from India includes ACC Ltd. (Holcim), Ambuja Cement Ltd. (Holcim), Lafarge India Private Ltd., Shree Cement Ltd., Ultratech Cement, Zuari Cement (Italcementi Group), Digvijay Cement (CIMPOR) and My Home Industries (CRH). Collectively these companies 54% of production of cement in India

Website: - http://www.wbcsdcement.org

The various stakeholders which are actively involved in increasing the energy efficiency levels of the cement sector are given below.

Energy Efficiency

Energy consumption in cement industry constitutes to 35-45% of the total manufacturing cost. The modern cement plants on an average consume about 65-75 kWh of Electrical energy[28] for producing one ton of cement. When it comes to old plants, due to old technologies and some inherent barriers, the energy consumption will be in the range of 80-100 kWh[29] per ton of cement. Indian cement sector has always been a trend setter in adopting the latest technologies and practicing energy efficiency activities. As part of the several initiatives, the industry has seen a decreasing trend in its average energy consumption. It has witnessed reduction in average SEC of 110 units to 82 units per MT of cement over the last two decades. The best thermal and electrical energy consumption presently achieved in India is 663 kcal/kg clinker and 59 kWh/t cement which are comparable to the best figures of 650 kcal/kg clinker and 65kWh/t cement in a developed country like Japan.

The major industry organizations which works closely with the sector in terms of energy efficiency are

- ❖ CII- Sohrabji Godrej Green Business Centre (www.greenbusinesscentre.com)
- ❖ NCB (National Council for Cement and Building Materials) (www.ncbindia.com)
- ❖ TERI (The Energy and Resources Institute) (www.teriin.org)
- ❖ Holtec Consultants (www.holtecnet.com)
- ❖ National Productivity Council (www.npcindia.org)

The energy efficiency improvement opportunities in the cement sector majorly lies in the areas of installation of high efficiency coolers, multi-channel burners and electrical energy efficiency. Supplier plays an important role in providing the newer energy efficient technologies and IIP should partner with them.

[28] Average of Cement Manufactures' Association (CMA) and CII- Energy Award Questionnaire
[29] Cement Manufactures' Association (CMA) and CII- Energy Award Questionnaire

4.0 ENERGY EFFICIENCY IMPROVEMENT OPPORTUNITIES

Cement making process is highly energy intensive accounting for nearly 35-50 % of the production costs. This provides ample opportunities for reducing energy consumption in many of the cement plants. About 30% of electric power is consumed for finish grinding, and a little under 30% is consumed by the clinker burning process. Raw mill circuit is another major consumer accounting for 24% of the energy. The raw mill circuit and finish grinding process mainly consumes electric power for the mill, and the clinker burning process mainly for the fan. The specific energy consumption levels of Indian cement sector are globally comparable values. The range of electrical energy consumption varies from 65-110 kWh/ MT of cement. As per Bureau of Energy Efficiency the thermal energy consumption also varies in the range of 665-900 kCal / kg of clinker.

Indian cement industry is growing at a rapid pace; about 50% of Indian cement industry's capacity is less than 10 years old. While building these new cement plants, cement manufacturers have installed latest, energy efficient technologies by design, and therefore, the recent cement plants have achieved significant levels of energy efficiency performance. With energy costs in India being one of the highest in the world, such energy efficiency measures implemented at design stage have provided significant advantage to the cement manufacturers by lowering energy costs. This recent capacity addition, coupled with old plants consistently improving their energy performance through technology retrofits and continual operational improvements, has also resulted in a gradual, yet significant improvement in country's average energy efficiency performance.

The improvement in the specific energy consumption figures of the Indian cement sector is shown in the table below[30].

Table 8-Improvement of specific energy consumption figures of Indian cement sector

Parameters	Year			
	1950-60	1970s	1980s	2000s
Thermal Energy Consumption kCal/kg of clinker	1300-1600	900-1000	800-900	665-900
Electrical Energy Consumption kWh/MT of cement	115-130	110-125	105-115	65-110

From these data it is evident that there exists a wide gap between the SEC figures across the sector. The huge gap between the specific energy consumption figures across the sector is mainly due to the less focus on operational improvements. Highest energy consumption plant has its SEC 1.25 to 1.50 times the lowest figure of SEC. From the present facts, the sector should focus on reducing the larger gap of SEC figures across the sector by focussing on the operational improvements.

[30] Cement Manufactures' Association (CMA) & CII

Energy efficiency in cement sector is a three pronged approach with the following aspects

1. **Capacity Utilization: -** High capacity utilization is essential for achieving energy efficiency. This brings down the fixed energy loss component of the specific energy consumption. Survey of excellent energy efficient companies show that 80% of the companies attribute capacity utilization as one of the foremost reason for a major drop in specific energy consumption. Atleast 90% capacity utilization is to be ensured for achieving low specific energy consumption. Also, achieving high capacity utilization is under the control of plant personnel. Hence the first and foremost step for an aspiring energy efficient unit should be to increase their capacity utilization and reduce the specific energy consumption.
2. **Fine Tuning of Equipment: -** When high capacity utilisation is acheived, fine tuning of equipment should be taken up by the energy efficient plants. Various energy audit studies reveal that 'Fine-tuning', if efficiently done can yield 3 to 10% energy saving. The greatest incentive for resorting to fine tuning is that it requires only marginal investment.
3. **Technology Up-gradation: -** Quantum jumps in energy efficiency level are possible through new technology or technology up-gradation of existing systems.

   Among the three mentioned approaches the first two options ie capacity utilization and fine tuning of the equipment are more or less fully explored. The major scope of energy reduction can be achieved by focusing on installation of newer technologies and the up gradation of existing technologies.

For each for energy saving approach, it is essential to calculate the reduction potential. For the basis of calculation, a reference plant is taken into consideration with the following parameters.

- Kiln Capacity - 4500TPD
- Clinker Capacity - 1.5 million MTPA
- Cement Capacity - 2.1 million MTPA
- Cooler Type - Reciprocating Grate Cooler
- Thermal SEC - 715kCal/kg of Clinker
- Electrical SEC - 75 kWh/ MT of cement
- AFR usage - 1%
- CO2 Emissions - 720 kg CO2/MT of cementitious product
- Coal Cost - Rs. 1000/million kCal
- Power Cost - Rs 3.5 /kWhr

Energy efficiency in Indian cement sector focuses on the deployment of existing state of the art technologies in new cement plants and retrofit of energy efficiency equipment where economically viable. Indian cement industry has phased out several old technologies in the last 1-2 decades. Out of about 167 larger cement manufacturing facilities in the country, only 2-3 facilities still operate with wet kilns (includes wet, semi-wet & semi-dry). Increasing energy costs has resulted in older cement manufacturing facilities to adopt latest energy efficient technologies and improve their energy performance. Improvement in energy efficiency can be classified into two namely, Thermal Energy Efficiency and Electrical Energy Efficiency.

4.1 THERMAL ENERGY EFFICIENCY IMPROVEMENT OPPORTUNITIES

Kiln and preheater system in Indian cement industry has achieved very high levels of technology adoption and energy efficiency levels. With significantly higher productivity levels and installation of latest energy efficiency and automation control devices, these systems are operating at one of the best performance measures in the world. India's modern cement plant is equipped with six stage (or five stage in certain clusters having higher moisture levels in limestone) preheater with in-line or separate-line calciner (depending on the rated kiln output), kilns with volumetric loading of about 5--6.5 tpd/cu.m and advanced automation systems. Continuous Emission Monitoring Systems (CEMS) are also being increasingly adopted in new as well as existing kilns.

Technology 1: Installation of High Efficiency Clinker Coolers

The Indian cement industry, over the last several years, has increasingly adopted reciprocating grate coolers with great success. While rotary coolers have been completely phased out, several installations with planetary coolers are still in vogue. With more than 50% of cement produced from kilns less than 10 years old, reciprocating grate coolers have become common practice in the industry today, with cooler loading of about 45–50 TPD/square metre (m^2) of cooler area. A conventional grate cooler operates at a recuperation efficiency of 50-65%, depending upon the mechanical condition and process operation of the coolers. This corresponds to a heat loss of about 120-150 kCal/kg of clinker from the cooler. Quite a large number of cement kilns in India, as a result higher capacity utilization operates at significantly higher cooler loading range than rated, with a range of 50-65 TPD/m^2 of cooler area in-spite of the design range of 45-50 TPD/m^2. This has also resulted in increased heat losses from the kiln.

The reciprocating cooler has under gone significant design development and the latest generation coolers have better clinker properties with significantly lower exit gas and clinker temperatures. As a direct consequence, secondary and tertiary air temperatures offered by latest generation coolers have also increased to about 1250^{o}C and 1000^{o}C respectively.

The cooling air requirements of such coolers have gradually reduced to about 2.2-2.4 kg/kg of clinker. The total heat loss of latest generation clinker coolers is less than 100kCal/kg of clinker and has a recuperation efficiency of 75-80%.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs.37.50 million	Rs. 37.50 million
MTOE equivalent	3750	3750
PAT benefit[31]	--	Rs. 38.07 million
Total benefit	Rs. 37.50 million	Rs. 75.57 million
Investment	Rs. 300 million	Rs. 300 million
Payback period	8 Years	4 Years
Replication Potential		
Number of plants	50% of the plants	
MTOE savings	**181860**	

[31] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 2: Installation of Cross Belt Analyzers

Sampling of crushed limestone or raw meal (input to the kiln) is essential to maintain stockpile quality and control chemistry of raw mix, thereby maintaining homogeneous clinker composition to meet quality requirements.

Currently, several plants are adopting conventional sampling and quality control methods where sampling of a fixed quantity of material is collected at frequent intervals. These samples are analyzed for its chemical composition through X-ray techniques. Collection of samples and its analysis results in time delay for correction and manual error in analysis. This in turn affects clinker quantity and increases energy consumption.

Cross belt analyzers analyze the chemical properties of the materials instantaneously and direct corrective actions much quicker compared to conventional sampling and quality control methods. Cross Belt Analyzers (CBA) can be installed either in upstream of the stock pile or before the raw mill. Former option helps to track the cumulative chemistry of the pile thus allowing the operator to direct haul trucks to various sections of the quarry to maintain target elemental composition of the pile. Installation of CBA before the raw mill can monitor the chemistry of the raw mix and automatically trigger adjustment in proportions of reclaimed stockpile and take corrective actions in varying the quantity of additives. The cross belt analyzers are needed in cases of heterogeneous deposits of limestone is present or the limestone is received from more than one mines. The advantage of cross belt analyzers in each stage is as below.

- Upstream of Stock Pile
    1. Increase in mines life and conservation of natural resources
    2. Reduces raw material cost by minimizing the % addition of other raw material additives
    3. Maintains good limestone deposit for a longer time
- Before Raw Mill
    1. Maintain lower standard deviation in kiln feed and thereby reduces the specific energy consumption
    2. Stable kiln operation
    3. Consistent good clinker quality
    4. Reduces the cement grinding power
    5. Achieve higher blending levels of fly ash/slag in cement
    6. Maintain productivity levels in the kiln

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs.7.50 million	Rs. 7.50 million
MTOE equivalent	750	750
PAT benefit[32]	--	Rs. 7.60 million
Total benefit	Rs. 7.50 million	Rs. 15.10 million
Investment	Rs. 30 million	Rs. 30 million
Payback period	4 Years	2 Years
Replication Potential		
Number of plants	50% of the plants	
MTOE savings	**36372**	

[32] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 3: Retrofit mono-channel burner with advanced multi-channel burner

Increased focus on energy efficiency and preparedness for increased alternate fuel utilization has resulted in the Indian cement industry gradually shifting from uni-flow (or mono-channel) burners to multi-channel burners. Some of the plants still in India use conventional straight pipe mono channel burners. Mono-channel burners are basically a refractory-lined single pipe with a nozzle. Primary air and fuel are conveyed together through the mono-channel for combustion into the rotary kiln. A mono-channel burner also has some operational disadvantages; their exit velocities at the tip of the burner cannot be varied according to the changing fuel feed rate. Modern multi-channel burners offer much better possibilities than mono channel burners for flame shape control, high momentum, flexibility to use different types of fuels like liquid, solid and bio-mass. If mono-channel burners are replaced by modern multi-channel burners, fuel energy can be saved because the latter require significantly lower primary (burner) air volume flow. Therefore the efficiency of the clinker cooler, in which the combustion air is pre-heated. While mono-channel burners need primary air ratios of 20-25% (often the burners are in direct compound operation with the coal mill), modern multi-channel burners are operated with around 10-12%.

Advanced burners reduce the loss in production during kiln disturbances and also reduce NO_x in the burning zone as the primary air ratio is low. NO_x emissions can be reduced as much as 30–35% over emissions from a typical direct fired, uni-flow burner. Better flame properties with the multi-channel burner improve combustion efficiency and eliminate flame impingement on refractory. Alternate fuel utilization is still lower in India with an average Thermal Substitution Rate (TSR) of less than 1%. However, several cement facilities have gradually increased the TSR in cement manufacture, some plants recording a peak TSR of up to 12%.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs.7.50 million	Rs. 7.50 million
MTOE equivalent	750	750
PAT benefit[33]	--	Rs. 7.60 million
Total benefit	Rs. 7.50 million	Rs. 15.10 million
Investment	Rs. 20 million	Rs. 20 million
Payback period	2.7 Years	1.3 Years
Replication Potential		
Number of plants	30% of the plants	
MTOE savings	**21823**	

[33] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 4: Increase the number of pre-heater cyclone stages

The pre-heater cyclone is designed for heat transfer between hot gases leaving the kiln system and incoming kiln feed material. Energy savings can be achieved by reducing the temperature of the hot gas through heat recovery with additional cyclone stage. The kiln exhaust gas from pre-heater is being used for drying moisture in raw materials during grinding. Therefore the number of pre-heater stage is determined by the heat requirement in raw mill for raw material drying. The moisture in-turn depends on the properties of the raw materials, geographical location and the season. The temperature and therefore the enthalpy in the hot gas depend on the number of pre-heater cyclone stages. The thermal energy consumption decreases with the increase in number of pre-heater stages.

- 4 stage - 725 kCal/kg of clinker
- 5 stage - 700 kCal/kg of clinker
- 6 stage - 685 kCal/kg of clinker

However the number of pre-heater stages depends on moisture content in raw meal. For 15% moisture content in the raw mill, the temperature required for drying purpose stands in the range of 280-300^{o}C. The addition of cyclone stage is feasible only if the original design offers potential after meeting the raw material drying requirement. Apart from requirement of hot gases for drying of the raw materials, increase in number of pre-heater stages is possible only if the existing civil structure can withstand an additional load on it.

In many cases, addition of preheater stage also competes with WHR systems. Facilities would have to decide either to recover additional heat availability by increasing a preheater stage or by installing waste heat recovery system. In facilities where a stage addition is feasible (after considering raw material drying requirement and civil structure), energy saving potential could be significant.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs.22.50 million	Rs. 22.50 million
MTOE equivalent	2250	2250
PAT benefit[34]	--	Rs. 22.80 million
Total benefit	Rs. 22.50 million	Rs. 45.30 million
Investment	Rs. 75 million	Rs. 75 million
Payback period	3.3 Years	1.6 Years
Replication Potential		
Number of plants	20% of the plants	
MTOE savings	**43646**	

[34] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 5: Installation of Waste Heat Recovery Systems

Hot gas from pre-heater exit is used for drying of raw materials. Depending on the humidity of the raw materials and the cooler technology, additional waste heat is available from the kiln gases and cooler exhaust air. Heat recovery from the preheater exit hot gases for production of power is limited if the moisture content in the raw materials is very high. Power production requires a heat recovery boiler and turbine. The technologies available for waste heat recovery include Rankine Cycle, Organic Rankine Cycle and Kalina Cycle.

Based on the chosen process and kiln technology, 8–10 kWh/t clinker can be produced from cooler exhaust air and 9–12 kWh/t clinker from the preheater gases, if the moisture content in the raw material is low and it requires only little hot gas/air for drying. So in total up to 22 kWh/t clinker or about 20% of the power consumption of a cement plant can be met by using currently available waste heat recovery technologies without significant changes in kiln operation. Power generation can further be increased by additional co-firing in the boiler or by by-passing the cyclone stages. WHR system availability can be considered as 7000 hrs per annum.

The adoption of waste heat recovery systems in Indian cement manufacturing facilities has been relatively slower compared to its global peers. Out of over 167 large cement plants in the country, only about 8-10 cement plants have adopted WHR systems. Estimates indicate that the waste heat recovery potential in Indian cement industry is close to 500 MW while the installed capacity till date is only about 107.7 MW. This indicates the huge opportunity for adoption of waste heat recovery in Indian cement industry.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs.101 million	Rs. 101 million
MTOE equivalent	9263	9263
PAT benefit[35]	--	Rs. 94 million
Total benefit	Rs. 101 million	Rs. 195 million
Investment	Rs. 500 million	Rs. 500 million
Payback period	5 Years	2.5 Years
Replication Potential		
Number of plants	30% of the plants	
MTOE savings	**269534**	

[35] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 6: Increasing the Thermal Substitution Rates in Cement Plants

Alternative fuel use in the Indian cement industry is at very low levels; the country's average stands at less than 1% of Thermal Substitution Rate (TSR). Several nations globally have utilized cement kilns as an effective option for their country's industrial, municipal and hazardous waste disposal. This creates a win-win situation for both the local administration and the cement plants: the administration utilizes the infrastructure already available at cement kilns, thereby spending less on waste management, and the cement kilns are paid by the polluter for safe waste disposal, as well as having their fuel requirements partly met.

Cement kilns can theoretically operate with 100% TSR, thereby completely off-setting the need for primary fossil fuels. However, several other enabling factors, such as the installation of adequate pre-processing and blending facilities, and the availability of alternative fuels without technical limitations (heat content, larger proportion of detrimental trace elements, chlorine, sulfur and so on) should be considered. Cement kilns can exhibit significantly varying behavior depending on the type of alternative fuel substituted, and hence the technical competence of the industry should be adequate to face these challenges which come alongside a TSR increase. With extensive national and global expertise available, the Indian cement industry today is technically ready for adopting higher TSR rates.

Increased TSR in the cement industry would be possible if the waste legislation in the country progresses in line with the industry's increased need for alternative fuels. First and foremost, a change in perspective amongst policy makers is required to explore cement kiln utilization of waste disposal. Secondly, stringent waste legislation is needed which will enable high heat content waste to be co-processed in cement kilns rather than in incinerators where the heat content goes largely unutilized. It is important that the legislation related to cement kilns is as stringent as for dedicated waste facilities. Thirdly, to ensure availability and consistency of alternative fuel quantity and quality, waste legislation in the country should enable effective waste collection, treatment and processing by introducing a new service sector which works as an effective intermediary between waste generators and the cement industry. The pricing of waste is also a key factor to ensure waste minimization at source (to reduce disposal costs for waste generators) and to ensure zero or negative cost to cement manufacturers (encouraging them to install the expensive handling, storage and firing facilities at their premises) for increased TSR. The fifth key factor is the social acceptance of using wastes as alternative fuels in cement kilns by the society and consumers.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs.17 million	Rs. 17 million
MTOE equivalent	8,580	8,580
PAT benefit[36]	--	Rs. 87 million
Total benefit	Rs. 17 million	Rs. 104 million
Investment	Rs. 300 million	Rs. 300 million
Payback period	17.5 Years	3 Years
Replication Potential		
Number of plants	30% of the plants	
MTOE savings	**665,753**	

[36] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 7: Utilization of Advanced Automation systems in Cement Manufacturing

An effective advanced automation and control system can bring substantial improvements in overall performance of the kiln, increased material throughput, better heat recovery and reliable control of free lime content in clinker. Furthering the scope of automation in process control, quality is also maintained by continuous monitoring of the raw mix composition with the help of x-ray analyzer and automatic proportioning of raw mix components. New types of on-line bulk material analyzers have also been developed based on Prompt-Gamma-ray Neutron Activation Analysis (PGNAA) to give maximum control over the raw mix. The analyzer quickly and reliably analyzes the entire flow online providing real time results. The latest trends in online quality control include computers and industrial robots for complete elemental analysis by x-ray fluorescence, x-ray diffraction techniques, online free lime detection, and particle size analysis by latest instrumental methods.

The control and operation of kiln systems today is extremely complex, with properties of input fuel and feed materials varying greatly and with product standards becoming increasingly stringent. Cement kiln operators today encounter such sudden variations that dynamic control of the kiln is vital to achieve optimum results and lower manufacturing costs.

Some of the proven control systems employed for optimal performance and quality are:

- Adaptive predictive control system
- Online shell scanner and refractory management
- Online NOx control
- Online flame control
- Online free lime control
- Flow measurement with advanced techniques
- Online measurement of kiln health
- Online Energy Management System (EMS) for drives and power generation
- Remote monitoring and operation for split location plants

Grinding systems are also undergoing significant improvements, more from their operations since the grinding technology has been witnessing only incremental improvements over the last several years. Automation and control systems can significantly improve the performance of grinding systems by reducing the variations, maintaining precise particle size distribution and increasing throughput.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 3 million	Rs. 3 million
MTOE equivalent	300	300
PAT benefit[37]	--	Rs. 3 million
Total benefit	Rs. 3 million	Rs. 6 million
Investment	Rs. 10 million	Rs. 10 million
Payback period	3.3 Years	1.6 Years
Replication Potential		
Number of plants	50% of the plants	
MTOE savings	**14,549**	

[37] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 8: Installation of Rotor Weigh Feeder for Coal Feeding

Coal is used as major fuel for clinker manufacturing in the kiln. While feeding coal to the kiln for firing, maintaining precise control of quantity of coal fired is essential for stable operation of kiln. Usually conventional impact type solid flow meters are used for the quantity measurement of coal by mass flow analysis. As this analysis is not accurate and can result in errors of more than ±10%, it may cause unstable operation or kiln upset.

As in case of rotor weigh feeder the coal quantity measurement is done on volumetric basis and with this technology it can control coal feeding rate with an accuracy of ±1%. The rotor weigh feeder actively compensates changes in material characteristics and supplies a constant stream of coal to the burning process. It supplies high short-term and long-term accuracy in deviation of set-feed rate and actual-feed rate.

The stable feeding results out of the pro-active control strategy and permanent gravimetric weighing and dosing. Installation of rotor weigh feeder for the coal feeding to the kiln has the following advantages over the normal weigh feeder.

- Optimal flame control
- Stable operation of kiln
- Instantaneously adjustable feed rate
- Reliable feeding
- Consistent good clinker quality

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 3 million	Rs. 3 million
MTOE equivalent	300	300
PAT benefit[38]	--	Rs. 3 million
Total benefit	Rs. 3 million	Rs. 6 million
Investment	Rs. 30 million	Rs. 30 million
Payback period	10 Years	5 Years
Replication Potential		
Number of plants	50% of the plants	
MTOE savings	**14,549**	

[38] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.2 ELECTRICAL ENERGY EFFICIENCY IMPROVEMENT OPPORTUNITIES

Technology 1: Installation of High Efficiency Separators

Separators are used in material grinding for the purpose of separating the fine particles from the coarse material coming out from the ball mill thus increasing its grinding efficiency. The fine particles are collected as product while the coarse particles are sent back to the mill for further grinding.

A good separator should ensure that the stream of coarse material generally referred to as reject should contain very little fine particles as possible (less than 10-15% retained over 45 micron sieve) and the stream of fine material should contain very low quantities of coarse material. An efficient separator improves the mill performance by avoiding the over grinding of the material and thereby reduces the grinding power consumption. By efficiently separating the coarse particles from the fine particles, it maintains the required product fineness, avoids over-grinding, thereby saving mill power consumption.

High-efficiency separator / classifier improve the grain size distribution of the finished cement and reduce grinding power requirements. The high separation efficiency results in higher proportion of classifier fines which results in decline of the number of circulations of the mill feed and hence the throughput rises by up to 10 -15%. This result in reduction of the specific energy demand compared to grinding circuits with standard separators. High efficiency separators contribute to the energy demand for grinding with about 5 to 8%.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 5.9 million	Rs. 5.9 million
MTOE equivalent	543	543
PAT benefit[39]	--	Rs. 5.5 million
Total benefit	Rs. 5.9 million	Rs. 11.4 million
Investment	Rs. 20 million	Rs. 20 million
Payback period	3.4 Years	1.75 Years
Replication Potential		
Number of plants	75% of the plants	
MTOE savings	**40,328**	

[39] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 2: Installation of HT VFD/ SPRS in place of GRR for Speed Control

Large slip ring induction motors are used for driving major fans (Pre-heater fan, cooler vent fan, Mill fans etc) in cement industry where they have the advantage of controlled starting characteristics and adjustable speed capability. The rotor has a 3-phase winding, with the three terminals connected to separate slip rings, which are normally connected to a liquid rheostat or resistor bank. The rheostat is used for starting, and can be disconnected once the motor is up to speed. By changing rotor resistance with the rheostat (Grid Rotor Resistance, GRR), the motor speed can be changed. The speed control of slip ring induction motor by varying the resistance in the rotor circuit results in power loss across the rotor circuit. The amount of power lost across the GRR depends on the speed at which the fan is operating which in turn depends on the operating step of GRR.

The power dissipated in the resistances of GRR is lost as heat. However, by using a variable speed drive or by installing a Slip Power Recovery System (SPRS), the power which is lost can be avoided or recovered. In case of HT VFD's the speed of the motor is controlled by varying the frequency of the supply voltage and the speed of the motor can be controlled in the range of 0-100% of the rated speed of the motor. While installing VFD for slip ring induction motor, care has to taken that the rotor terminals has to be short circuited.

Installation of Slip Power Recovery Systems in the rotor circuit controls the rotor voltage by the power converter, which in turn controls the speed of motor. The SPRS provides speed and torque control like the resistors, but can also recover the power taken off from the rotor and feed it back into the power system. SPRS can control the speed of the motor in the range of 60-95%. SPRS has a power recovery potential up to 95% of rated speed of motor. Hence it is advisable to install SPRS only when the operating speed is less than 95% of the rated speed.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 4.5 million	Rs. 4.5 million
MTOE equivalent	416	416
PAT benefit[40]	--	Rs. 4.2 million
Total benefit	Rs. 4.5 million	Rs. 8.7 million
Investment	Rs. 22 million	Rs. 22 million
Payback period	4.8 Years	2.5 Years
Replication Potential		
Number of plants	65% of the plants	
MTOE savings	**26,746**	

[40] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 3: Installation of Fly Ash Dryer

Increase in manufacture of blended cement and quantity of addition of fly ash in cement results in reduced energy consumption and lowers carbon emission intensity. This increase has resulted in a short fall of availability of dry fly ash in some of the cement manufacturing clusters. This project of installation of fly ash dryer is applicable to plants which are forced to use wet fly ash for production of PPC cement due to non availability of dry fly ash.

Considerable quantity of fly ash with moisture content in the range of 15-20% is available in the fly ash dykes of old thermal power plants. The cement plants located near these power plants can utilize the fly ash, provided if they have systems like Vertical Roller mills where feed material with high moisture content is acceptable (up to 15%) or having hot air generators and dryers which can dry this material so that it can be used in ball mill.

Higher percentage addition of fly ash in PPC is possible by installing fly ash dryer to reduce the moisture content in wet fly ash. The fly ash can be dried either by taking the hot gases from the cooler exit (or from the pre-heater exit) or by installing fly ash drier. Based on the wet fly ash transportation distance from its source, it becomes economical to install a fly ash dryer and get the benefit of increased addition of fly ash in PPC manufacturing. Installation of fly ash dryers results in the following advantages.

- Reduced power consumption in cement grinding
- Increased throughput from the mill
- Higher clinker substitution rates hence lower operating cost
- Reduced energy consumption for clinkerisation due to higher substitution
- Conservation of natural resources like limestone, coal

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 2.4 million	Rs. 2.4 million
MTOE equivalent	225	225
PAT benefit[41]	--	Rs. 2.2 million
Total benefit	Rs. 2.4 million	Rs. 4.6 million
Investment	Rs. 30 million	Rs. 30 million
Payback period	12.5 Years	6.5 Years
Replication Potential		
Number of plants	15% of the plants	
MTOE savings	**3,334**	

[41] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 4: Installing Particle Size Distribution (PSD) Analyzer for Cement Quality Improvement

Traditional quality control in cement manufacturing plant has been practiced by collecting samples from different processing points at regular intervals and analyzing them in a central laboratory, either manually, or in some cases automatically. In case of cement manufacturing, the main parameters that determine the physical and chemical qualities are.

a. Gypsum additions: – measured by SO_3 content of the finished cement

b. Limestone addition: –measuring the carbon content in the finished cement

c. Blaine analysis: –uses air permeability to characterize the fineness of the cement. Traditionally, analysis is done for 5 g of cement every hour in an air-permeability apparatus to estimate a Blaine number.

While the quality team endeavors to maintain testing and control parameters as precise as possible, inherent errors do occur in manual measurements, including:

- Losing some of the sample when transferring the cement from the scale to the permeability cell
- Failure to compress the sample sufficiently
- Temperature fluctuations
- Humidity
- Losing manometer fluid

Experimental studies also prove that Blaine do not indicate the nature of the particle size of the cement. Controlling cement quality with blaine alone can lead to poor quality and higher specific power consumption for cement grinding.

As an alternate, Particle Size Distribution (PSD) analysis gives a complete grain size distribution of the finished cement and has now replaced Blaine measurement. Using an online PSD analyzer giving a real time continuous measurement, it is possible to dynamically control the speed of the separators at the finish grinding mill and therefore optimize the fineness, maintain quality requirements and save energy cost of grinding.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 3.6 million	Rs. 3.6 million
MTOE equivalent	337	337
PAT benefit[42]	--	Rs. 3.4 million
Total benefit	Rs. 3.6 million	Rs. 7.0 million
Investment	Rs. 5 million	Rs. 5 million
Payback period	1.4 Years	0.7 Years
Replication Potential		
Number of plants	80% of the plants	
MTOE savings	**26,670**	

PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 5: Increase the PPC Production / % addition of Fly Ash in PPC Manufacturing

Clinker when ground and mixed with 4-5% gypsum, reacts with water and hardens. Several constituents are available for mixing with clinker for production of blended cement. Clinker when mixed with fly ash (from thermal power plants) will produce Portland Pozzolana Cement (PPC). Increased use of blending materials in clinker has direct impact on reduction in clinker factor (% of clinker content by mass in cement) in cement, thereby reducing fuel combustion and reduced limestone calcinations.

Fly ash conforming to standard IS: 3812 (1) 2003 can be used (up to 35% maximum) in the manufacture of PPC as per IS: 1489 (part 1) 1991. The role of fly ash in PPC is attributed to the pozzolanic action leading to a contribution to strength development. Studies carried out on the Indian fly ash samples have indicated that the range of glass content varies between 15% and 45% and the Lime Reactivity (LR) between 2.0 mpa and 7.0 mpa. The fine fraction of fly ash below 45 micron is a major portion, and contributes predominantly to the performance of PPC. This particular aspect of fly ash is very important with a view to enhance the percentage use of fly ash in PPC and concrete, and needs further thorough and systematic investigations to arrive at adoptable methodologies of using finer fly ash at higher levels. The quality of the clinker, suitable and adequate admixture addition, will improve the fly ash absorption. The addition of plasticizers will help in fly ash absorption in concrete applications.

The average fly ash % utilisation in Indian cement industry is around 27%. The savings for increase in fly ash addition percentage by 2% is shown below.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 30 million	Rs. 30 million
MTOE equivalent	3003	3003
PAT benefit[43]	--	Rs. 30.45 million
Total benefit	Rs. 30 million	Rs. 60.45 million
Investment	Rs. 35 million	Rs. 35 million
Payback period	1.2 Years	0.6 Years
Replication Potential		
Number of plants	60% of the plants	
MTOE savings	**178327**	

[43] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 6: Installation of Pre-grinder along with Ball Mill for Material Grinding

Material grinding is the largest electrical energy consumer in cement manufacture. Ball mills are used for grinding application of raw materials containing moderate moisture content. The size of the balls in the mill chamber determines the degree of fineness of the finished product. In a ball mill majority of the grinding takes place by attrition force produced by the cascading effect rather than the coarse grinding happening by impact in the first chamber. By design ball mills are efficient in fine grinding than coarse grinding.

Installation of Roller press in the upstream of ball mill can avoid the inefficient coarse grinding from ball mill, reduce and maintain the feed size to mill hence making the system more efficient. The roller press grinds the material by immense pressure and thus gives a much finer product to the ball mill. Roller press can produce the product with size less than a micron. Reduced feed size of the material to the ball mill results in reduced power consumption for grinding needs. Many plants have installed the roller press along with the ball mills and achieved reduction in specific energy consumption. Installation of roller press along with separator can result in reduction of power consumption in the range of 25-30%.

Installation of roller crusher along with the ball mills can also reduce the power consumption for grinding the ball mills. Roller crushers are used for primary crushing or secondary crushing of easily fractured materials such as lime stone or clinker. Lumps of materials are reduced to sizes ranging from one third to one fifth of the original size. Crushing is achieved by passing the material between rollers. Typically the installation of roller crusher can result in reduction of power consumption in the range of 5-10%.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 51.4 million	Rs. 51.4 million
MTOE equivalent	4716	4716
PAT benefit[44]	--	Rs. 47.8 million
Total benefit	Rs. 51.4 million	Rs. 99.2 million
Investment	Rs. 300 million	Rs. 300 million
Payback period	5.8 Years	3 Years
Replication Potential		
Number of plants	75% of the plants	
MTOE savings	**350044**	

[44] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

Technology 7: Installation of Tertiary Crusher for Raw Mill Production Increase

Raw mill is used to grind raw materials in the process of cement manufacturing. The size reduction of the raw material is carried out in the raw mill either by the use of ball mill or most commonly, the Vertical Roller Mills (VRM). Raw material grinding consumes around 30% of the total electrical power consumption during cement manufacturing.

Typical grinding efficiency of ball mill is in the range of 10% and that of VRM is between 14-15%. Grinding power requirement of a mill depends on the input material feed size. By installing a tertiary crusher in the upstream of raw mill will result in reduced power consumption along with increased mill output.

Reference Plant		
	Without PAT	With PAT benefit
Energy savings	Rs. 3.6 million	Rs. 3.6 million
MTOE equivalent	337	337
PAT benefit[45]	--	Rs. 3.4 million
Total benefit	Rs. 3.6 million	Rs. 7.0 million
Investment	Rs. 30 million	Rs. 30 million
Payback period	8.2 Years	4.3 Years
Replication Potential		
Number of plants	75% of the plants	
MTOE savings	**25003**	

[45] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.3 HEAT RATE OPTIMIZATION IN CAPTIVE POWER PLANT

In Indian cement industry 50-55% of its power is from its own Captive Power generation. The need of Captive Power Plant (CPP) has also become the need of the hour with the increased cost of grid power. The average auxiliary power consumption in the CPPs of Indian cement industry ranges between 10-13%, whereas the best operating CPPs in the Indian cement sector has its auxiliary power consumption ranging from 5.8-6%. In case of CPP heat rate, the average value stands at about 3200kCal/kWh when compared to the best operating value of 2550-2575 kCal/kWh.

With such a large share of cement plants operating with CPP and leading to such a wide variation in auxiliary power consumption and heat rate values, this serves as an excellent lever for energy efficiency improvement. Energy efficiency improvement opportunities in CPPs of cement sector can be achieved by focusing on optimization of operations and technology up-gradation.

4.3.1 Installation of Variable Frequency Drives (VFDs) for major Fans

Fans are one of the main auxiliary equipment which consumes the major power for captive power plant operation. Inherently this equipment will have a good margin in design values for its operation under emergency conditions or during the capacity up-gradation. With the higher margin of design, it is being forced to provide various types of control technologies for its normal operation. In order to control the flow of an over designed fan, it is inevitable to use the capacity control methods like dampers or speed control mechanisms like Grid Rotor Resistance (GRR) control. This type of control mechanisms are inefficient ways of controlling the capacity of equipment when compared to the latest technologies available. The major equipment in a power plant includes Primary air fans, FD fans and ID fans.

The capacity control of these equipment can be done by installing Variable Frequency Drives (VFDs). By installing VFDs for the major fans, the flow can be controlled by controlling the speed of the driven motor by changing the frequency. One of the major advantages of VFD is the closed loop operation of the system which is possible with a feedback from the process parameters. This enables the automated operation of the system with fine controls.

Reference CPP (15MW)		
	Without PAT	With PAT benefit
Energy savings	Rs. 1.6 million	Rs. 1.6 million
MTOE equivalent	154	154
PAT benefit[46]	--	Rs. 1.5 million
Total benefit	Rs. 1.6 million	Rs. 3.1 million
Investment	Rs. 2.4 million	Rs. 2.4 million
Payback period	1.4 Years	0.7 Years
Replication Potential		
Number of plants	60% of the CPPs	
MTOE savings	**14968**	

[46] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.3.2 Install Vacuum Pump in lieu of Steam Ejector

Steam ejectors are widely used for maintaining a vacuum inside the condenser by removing the un-condensable gases in the condenser outlet. For the operation of steam ejector, steam is required at a particular pressure, which is normally taken from the main steam line of the boiler. Pressure Reducing and De-superheating System (PRDS) is used to reduce the main steam pressure to the operating pressure of the ejector. But by doing so, motive steam, that has the potential to generate more power is lost.

Presently, in order to avoid the use of motive steam for the steam ejector, it is advisable to install a vacuum pump which is capable of creating the vacuum inside the condensor. Many plants have explored possibility of installation of vacuum pump with subsequent reduction in the use of motive steam. The extra electrical energy requirement for the operation of vacuum pump is offset by the significant thermal savings achieved by avoiding the use of motive steam for the operation of steam ejector.

Reference CPP (15MW)		
	Without PAT	With PAT benefit
Energy savings	Rs. 1.8 million	Rs. 1.8 million
MTOE equivalent	173	173
PAT benefit[47]	--	Rs. 1.7 million
Total benefit	Rs. 1.8 million	Rs. 3.5 million
Investment	Rs. 0.7 million	Rs. 0.7 million
Payback period	0.4 Years	0.2 Years
Replication Potential		
Number of plants	75% of the CPPs	
MTOE savings	**19618**	

[47] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.3.3 Installation of VFD for Major Pumps

The major auxiliary pumps such as Boiler feed water pump, condensate extraction pump will have enough margin by design. Higher design margins will result in capacity control for the normal operation of the pump with the help of throttling. The mismatch between the design and operating heads of the pump will result in inefficiency. Valve throttling is not an efficient method of controlling the capacity of the pump as the total pressure developed by the pump will be lost across the control valve, resulting in energy loss. Moreover the flow requirement of the pump is varying in nature depending on the load on the turbine. At lower loads, the valve is further throttled to get the required flow.

In view of higher design margins and varying flow requirements, there is a good opportunity to save energy by installing Variable Frequency Drive (VFD) for the major pumps. By using VFD's the pump speed can be varied to match the capacity to match the actual requirement.

Reference CPP (15MW)		
	Without PAT	With PAT benefit
Energy savings	Rs. 2.1 million	Rs. 2.1 million
MTOE equivalent	195	195
PAT benefit[48]	--	Rs. 1.9 million
Total benefit	Rs. 1.8 million	Rs. 4 million
Investment	Rs. 2 million	Rs. 2 million
Payback period	1.2 Years	0.5 Years
Replication Potential		
Number of plants	60% of the CPPs	
MTOE savings	**18954**	

[48] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.3.4 Segregate High Pressure and Low Pressure Compressed Air Users

Compressed air plays a vital role in the operation of Captive Power Plant. Compressed air is required for the instrument air application and also for conveying the fly ash from the ESP bottom to the hopper in CPP. The operating pressure of the compressor is set in such a way that the maximum pressure requirement in the plant can be met. The instrument air application in the plant requires compressed air at a maximum pressure of 5.5 bar while fly ash conveying requires the compressed air at maximum 3 bar.

Some of the plants have installed high pressure (HP) compressors for the entire compressed air applications in their CPPs. With compressed air generated at high pressure it is required to install air regulators to reduce the compressed air pressure for the use of low pressure applications like fly ash conveying.

In compressors, the power consumption is proportional to the operating pressure. The loading power consumption reduces with reduction in operating pressure and vice versa. Hence energy saving can be achieved by segregating high pressure and low pressure compressed air users and compressors can be dedicated for low pressure applications supplying compressed air at lower pressure matching with the requirement.

Reference CPP (15MW)		
	Without PAT	With PAT benefit
Energy savings	Rs. 0.8 million	Rs. 0.8 million
MTOE equivalent	79	79
PAT benefit[49]	--	Rs. 0.8 million
Total benefit	Rs. 0.8 million	Rs. 1.6 million
Investment	Marginal	Marginal
Payback period	-	-
Replication Potential		
Number of plants	50% of the CPPs	
MTOE savings	**6399**	

[49] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.3.5 Apply Hydraulic Coating for bigger pumps and improve the operating efficiency

Energy loss or the hydraulic loss is one of the major factors for the reduction in operating efficiency of the pump. The surface condition of the pump plays an important role in hydraulic losses of a pump. Corrosion, erosion and cavitation also add to the hydraulic losses in the pumps. All these parameters affect the power consumption of the pump and increases lifetime running cost. Over a period of time, due to natural erosion and corrosion, the design efficiency of the pump decreases by about 1% per year. There is an excellent opportunity to enhance the efficiency of the pump and retain the efficiency for longer period.

One effective way to reduce the hydraulic loss is to protect the pumping systems using corrosion resistant coatings. The coating material has low electronic affinity for water molecules (hydrophobic material). This can delay the onset of turbulent flow and reduce skin friction.

Advantages of hydraulic coating:

- Improves design efficiency and is anti corrosive in nature
- Reduces surface roughness
- Hydrophobic in nature

In case of aqueous media, materials which have low surface attraction are hydrophobic & repel water, will result in lower frictional losses than surface which are highly attractive to water molecules. Hydraulic coating can improve the efficiency of the pumps by 5-8% with respect to the present operating efficiency.

Reference CPP (15MW)		
	Without PAT	With PAT benefit
Energy savings	Rs. 0.3 million	Rs. 0.3 million
MTOE equivalent	31	31
PAT benefit[50]	--	Rs. 0.3 million
Total benefit	Rs. 0.3 million	Rs. 0.6 million
Investment	Rs. 0.1 million	Rs. 0.1 million
Payback period	0.3 Years	0.1 Years
Replication Potential		
Number of plants	50% of the CPPs	
MTOE savings	**2511**	

[50] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

4.3.6 Minimize the Air Infiltration in the Flue Gas Path

The flue gas path including Air Preheater (APH) and ESP are vulnerable to air ingress. The performance of APH and ESP can be analyzed based on the oxygen level in the flue gas at various points of APH and ESP. If there is significant air ingress in the flue gas path, then certainly the oxygen levels in the flue gas path will increase. This air leakage into the flue gas path leads to further reduction in flue gas temperature. The reduction in flue gas temperature further increases the low temperature end corrosion and further increases the leakage level. The air leakage leads to reduction in heat recovery in the air preheater and hence results in increased fuel consumption. The air infiltration also leads to increased load on the ID fan and hence increases ID fan power consumption.

Significant reduction in heat rate can be achieved by minimizing the air ingress in the flue gas path of a boiler. It is always preferable to have a portable oxygen analyzer to regularly monitor the oxygen levels across the APH and ESP and do the corrective actions in arresting the leakages. It is always preferable to maintain the oxygen levels in the flue gas path less than 4-5%.

Reference CPP (15MW)		
	Without PAT	With PAT benefit
Energy savings	Rs. 1.1 million	Rs. 1.1 million
MTOE equivalent	103	103
PAT benefit[51]	--	Rs. 1.0 million
Total benefit	Rs. 1.1 million	Rs. 2.1 million
Investment	Rs. 0.1 million	Rs. 0.1 million
Payback period	0.1 Years	Immediate
Replication Potential		
Number of plants	60% of the CPPs	
MTOE savings	**10011**	

[51] PAT benefits calculated based on the MTOE Savings. One MTOE equals Rs.10154 for the year 2011-12 as per the PAT notification

5.0 FUTURE ENERGY SAVING OPPORTUNITIES

Indian cement industry is under the global focus in terms of its energy efficiency activities which is comparable with its global peers. Indian cement sector is one of the world's energy efficient industries. Higher energy cost and increased competitiveness are the key reasons which have made the Indian cement sector one fof the world's best in adopting all the latest technologies. Indian cement consumer market is in an increasing trend and the sector has doubled its installed capacity. It is inevitable at the present situation that, focus should be there on newer cement manufacturing technologies and newer types of cements. The major thrust areas in terms of energy efficiency improvements should be in the following areas.

5.1 Use of Nano-technology in Cement Manufacturing

Nanotechnology is the study and manipulation of the properties and structure of matter at nanoscale. Nano-cements are being developed as cements containing well dispersed nano-sized particles of cement and mineral admixtures. The nanoparticles would be evenly distributed among the larger particles of mineral admixtures and with such fine dispersion that even a lower content of cement should be able to provide the desired binding of aggregates and admixture particles generating required strength and performance. In such systems the mineral additives can be utilized in larger quantity. Nano-cements therefore have the potential to provide significant saving of cement and lower CO_2 emissions.

Mechano-chemical activation of raw materials and cements may provide enhanced reactivity during clinkerization and hydration, respectively. The most studied and well-reported area is the use of nanoparticles, such as nano-silica in cement mortar and concrete. The health hazards associated with handling and use of nanoparticles need to be studied and solutions to be found. As this technology is in the pilot stage and not yet commercialised, the figures of potential savings are not published.

5.2 Manufacturing of Geo-polymer Cement

Geopolymer cement utilises waste materials from the power industry (fly ash, bottom ash), the steel industry (slag), and from concrete waste, to make alkali-activated cements. The performance of such a system is dependent on the chemical composition of the source materials, the concentration of sodium hydroxide (NaOH) and potassium hydroxide (KOH) chemical activators, and the concentration of soluble silicates. Geopolymer cements have been commercialised in small-scale facilities, but have not yet been used in large-scale applications where strength is critical. This process was developed in the 1950s. Geopolymeric cements set quickly and as strong as Portland cements, last longer and are more resistant to fires[52]. They can be cheaply made, based on several types of clay and industrial waste and a few common sedimentary rocks, and they can be formed at much lower temperatures than Portland cement (750 degrees C). This also results in resulting in 3/5 less energy assumption than portland cement.

5.3 Carbon capture through algal growth and use of bio fuels

Carbon capture through algal growth and use either as fuel or converting to bio fuels is one of the most actively pursued measures of carbon capture in India. Photosynthesis of algae which reduces carbon in the gas stream by converting it to biomass, which can be carried out either in open pond or closed bioreactor system in presence of light. It has been concluded that open pond system is not commercially viable; hence various researchers have designed different bioreactors with varying efficiencies. This will be one of the promising modes of carbon capture and reuse for Indian cement industry to pursue. Implementation of this project can result thermal savings in terms of substitution of fossil fuels in the range of 1 to 2%.

[52] Development of Sustainable Cementitious Materials', in Proceedings of the International Workshop on Sustainable Development and Concrete Technologies, Beijing

6.0 COST ABATEMENT CURVE

Table 9-MTOE reduction opportunities

	Description of proposal	Investment, Rs/MTOE	MTOE Savings
A	Increase the PPC Production / % addition of Fly Ash in PPC Manufacturing	11655	3003
B	Installing Particle Size Distribution (PSD) Analyzer For Cement Quality Improvement	14837	337
C	Retrofit mono-channel burner with advanced multi-channel burner	26667	750
D	Increase the number of pre-heater cyclone stages	33333	2250
E	Utilization of Advanced Automation systems in Cement Manufacturing	33333	300
F	Increasing the Thermal Substitution Rates in Cement Plants	34965	8580
G	Installation of High Efficiency Separators	36832	543
H	Installation of Cross Belt Analyzers	40000	750
I	Installation of HT VFD/ SPRS in place of GRR for Speed Control	52885	416
J	Installation of Waste Heat Recovery Systems	53978	9263
K	Installation of Pre-grinder along with Ball Mill for Material Grinding	63613	4716
L	Installation of High Efficiency Clinker Coolers	80000	3750
M	Installation of Tertiary Crusher for Raw Mill Production Increase	89021	337
N	Installation of Rotor Weigh Feeder for Coal Feeding	100000	300
O	Installation of Fly Ash Dryer	133333	225

COST ABATEMENT CURVE

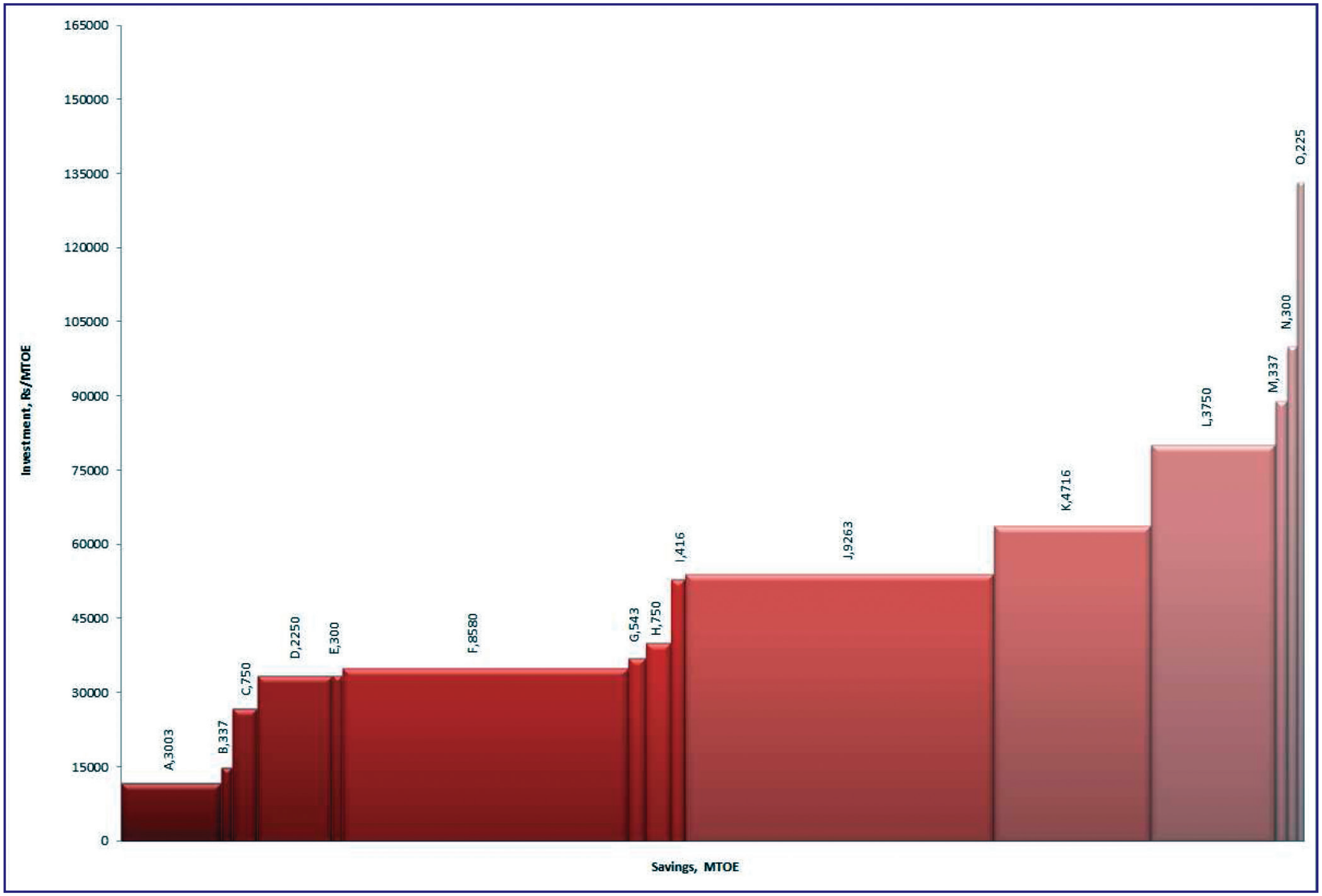

Figure 11-Cost abatement curve

A	Increase the PPC Production / % addition of Fly Ash in PPC Manufacturing
B	Installing Particle Size Distribution (PSD) Analyzer For Cement Quality Improvement
C	Retrofit mono-channel burner with advanced multi-channel burner
D	Increase the number of pre-heater cyclone stages
E	Utilization of Advanced Automation systems in Cement Manufacturing
F	Increasing the Thermal Substitution Rates in Cement Plants
G	Installation of High Efficiency Separators
H	Installation of Cross Belt Analyzers
I	Installation of HT VFD/ SPRS in place of GRR for Speed Control
J	Installation of Waste Heat Recovery Systems
K	Installation of Pre-grinder along with Ball Mill for Material Grinding
L	Installation of High Efficiency Clinker Coolers
M	Installation of Tertiary Crusher for Raw Mill Production Increase
N	Installation of Rotor Weigh Feeder for Coal Feeding
O	Installation of Fly Ash Dryer

7.0 CONCLUSION

The technologies and best practices presented here is an effort to help the designated consumers to achieve the PAT targets. The technologies provided in this compendium can result in enormous amount of energy savings. Apart for this, several other routine energy saving activities like reducing the pressure drop across ducts, cyclones etc., reducing the air infiltration and operating the pumps and fans at the best efficiency point can also bring in good amount of energy savings.

Indian cement industry consumes 14.5 million MTOE which accounts to 6.26% of total energy consumption (231.6 million MTOE) of all eight sectors. By the end of the first PAT cycle, the energy savings of 0.816 million MTOE/year is expected to be achieved, which is around 12% of total national energy saving targets assessed under PAT. This compendium is an effort to help the designated consumers in achieving the PAT targets set by Bureau of Energy Efficiency.

Annexure 1: GHG INVENTORISATION AND TREND ANALYSIS

Present Status

Industries accounted for 22 percent of the total GHG emissions or 412.55 million tons of CO_2-eq in 2007[53]. The GHG emissions from industries are both due to fossil fuel combustion as well as due to processes that chemically or physically transform materials. In 2007, the top 2 GHG emitting industries, cement and iron and steel together accounted for about 60 percent of the total GHG emissions from the Industry sector. Around 31.7 percent or 129.92 million tons of CO_2-eq emissions from the industries sector was from cement industries[54].

Emissions of green house gas like CO_2, generated from decomposition of the carbonate raw material (calcination of limestone), burning of fossil or alternate fuel (coal, lignite etc) and use of grid or captive power is a major environmental issue related with cement industry. Indian cement industry has been working on the issue of its GHG emissions and has brought down the CO_2 emission level from 1.04 MT of CO_2 / MT of cement in 1995 to 0.79 MT[55] of CO_2 / tonne of cement in 2007. Decrease in the share of inefficient wet process from 12 percent in 1999 to around 2 percent in 2007 has also contributed to this emissions decrease. The share of blended cement has also increased from less than 30 percent in 1994 to over 60 percent. Since blended cement has a lower clinker percentage and consequently lower emissions intensity, this shift towards blended cement has reduced the overall emissions intensity of cement production in India. [56]The approximate contributions of each of the 3 main sources of CO_2 emissions are calcinations 50 to 55%, fuel combustion 40 to 50% and electricity upto 10%. As on December 2010, GHG emission from the Indian Cement Sector stands at 0.719 MT CO_2/MT[57] of cement.

Future Emissions Scenario

In order to explore strategic options for reducing emission intensity from the cement sector, an analysis of the quantities and trends of GHG emissions is essential. In this regard several independent studies have taken place focusing on the target emission levels in the near and farther future. The following are the major studies carried out in identifying the GHG emission trends.

- Interim Report of the Expert Group on Low Carbon Strategies for Inclusive Growth
- Energy Transition for Industry: India and the Global Context

[53] India: Greenhouse Gas Emissions 2007, MoEF, Government of India
[54] India: Greenhouse Gas Emissions 2007, MoEF, Government of India
[55] Interim Report on Low Carbon Strategies for Inclusive Growth by Planning Commission of India
[56] Working Group on Cement Industry for the Twelfth Five Year Plan
[57] CII Internal Estimate

1. LOW CARBON STRATEGIES FOR INCLUSIVE GROWTH

The report, Low carbon strategies for inclusive growth, by Planning Commission of India projects the growth of the industry for 2020 by considering two scenarios. The growth projections are based on the assumptions that India's GDP grows at 9% each year and the elasticity factor for sectors growth as 1.5%.

a) Determined Effort

Effective implementation of the Determined Effort regime over the next decade with the clinker/cement ratio decreasing to 0.8 by 2020 and a fuel substitution of around 5 percent would lower the emission intensity to 0.67 MT CO_2/MT cement by 2020. Overall emissions from this sector under such a scenario are projected to lie in the range 336 - 383 million MT CO_2 range for 2020[58].

b) Aggressive Effort

In addition to the determined effort it includes implementation of new policies, new technologies and additional finance. Under these efforts it is expected that the emission intensity by 2020 will be 0.59MT CO_2/MT of cement with over all emissions standing at 293.5-335 million MT CO_2[59].

2. ENERGY TRANSITION FOR INDUSTRY: INDIA AND THE GLOBAL CONTEXT

International Energy Agency (IEA) in its publication Energy Transition for Industry: India and the Global Context published in 2011 describe the sector wise (including cement sector) energy consumption trend and the options to reduce the same in pursuit for a low carbon economy. IEA has developed two scenarios to analyze the industrial sector. First one is the Baseline Scenario which reflects developments that are expected on the basis of the energy policies that have been implemented or that have been approved and are to be implemented. Second one is the BLUE Scenario considered by IEA is target-driven and aims to achieve total emissions from the industry that are 24% lower in 2050 than the 2007 level.

Demand for cement in India will be between 3.8 and 9.7 times higher in 2050 than it was in 2007. The production and the emission levels to be the same under the Baseline and BLUE scenarios is shown the table below.

Table 10- Production and GHG emission levels-IEA estimates

	2007	Baseline – 2050			BLUE – 2050		
		low-demand	high-demand	strong growth	low-demand	high-demand	strong growth
Cement production (Mt)	170	646	742	1 656	646	742	1 656
Energy consumption (Mtoe)	13	42	48	105	48	55	126
Direct CO_2 emissions (Mt CO_2)	128	422	483	1 060	275	291	676

[58] Interim Report on Low Carbon Strategies for Inclusive Growth by Planning Commission of India
[59] Interim Report on Low Carbon Strategies for Inclusive Growth by Planning Commission of India

GHG mitigation potential for the projects specified in the report is as follows:

Table 11- Technology wise GHG emission reduction potential

Sl.No.	Description of Proposal	Investment, Rs/MTOE	Savings, MTOE	Million tons of CO_2 Reduction[60]
1	Increase the PPC Production / % addition of Fly Ash in PPC Manufacturing	11655	3003	0.030
2	Installing Particle Size Distribution (PSD) Analyzer For Cement Quality Improvement	14837	337	0.001
3	Retrofit mono-channel burner with advanced multi-channel burner	26667	750	0.003
4	Increase the number of pre-heater cyclone stages	33333	2250	0.008
5	Utilization of Advanced Automation systems in Cement Manufacturing	33333	300	0.001
6	Increasing the Thermal Substitution Rates in Cement Plants	34965	8580	0.031
7	Installation of High Efficiency Separators	36832	543	0.002
8	Installation of Cross Belt Analyzers	40000	750	0.003
9	Installation of HT VFD/ SPRS in place of GRR for Speed Control	52885	416	0.002
10	Installation of Waste Heat Recovery Systems	53978	9263	0.030
11	Installation of Pre-grinder along with Ball Mill for Material Grinding	63613	4716	0.013
12	Installation of High Efficiency Clinker Coolers	80000	3750	0.014
13	Installation of Tertiary Crusher for Raw Mill Production Increase	89021	337	0.001
14	Installation of Rotor Weigh Feeder for Coal Feeding	100000	300	0.001
15	Installation of Fly Ash Dryer	133333	225	0.001

[60] GHG savings indicated is calculated only for the reference plant of 1.5 million MTPA. Projects explained in this compendium should be seen individually for its applicability in a particular plant. The reader is advised not to sum up individual GHG emission savings and extrapolate for the sector as it might be misleading

Annexure 2: BASIS OF SAVINGS ESTIMATIONS/SAMPLE CALCULATION

Basis for calculation:

Operating hours of the plant	=	8000 hrs
Plant size (Clinker Capacity)	=	1.5 million MTPA
Cost of electrical energy	=	Rs. 3.50 / kWh
1 MTOE value	=	Rs. 10,154

Sample Calculation:

Savings without PAT

Energy saved	=	500 kWh
Annual savings	=	500 kWh x Rs. 3.50 / kWh x 8000 hrs
	=	Rs. 14.00 million / annum
Investment	=	Rs. 20.00 million
Payback	=	Rs. 20.00 million x 12 months Rs. 14.00 million
	=	18 months

Savings with PAT

Energy saved	=	500 kWh
Annual savings	=	500 kWh x Rs. 3.50 / kWh x 8000 hrs
	=	Rs. 14.00 million / annum
MTOE saved	=	344
MTOE savings	=	344 X Rs. 10, 154 / MTOE
	=	Rs. 3.40 million
Total savings	=	Rs. 14.00 million + Rs. 3.40 million
	=	Rs. 17.40 million

Investment	=	Rs. 20.00 million
Payback	=	Rs. 20.00 million x 12 months Rs. 17.40 million
	=	14 months

Miscellaneous:

1 kWh	=	860 kCal
1 MTOE	=	10^7 kCal

GHG Emission Savings Calculations

For all electrical energy saving opportunities the emission factor of 0.91kg CO_2 /kWh is considered for GHG emission calculations. Similarly for thermal savings 2.6kg CO_2/MT of cement is considered for every 10kCal/kg clinker reduction in specific energy consumption.

Annexure 3: LIST OF EQUIPMENT/TECHNOLOGY SUPPLIERS

Energy Efficient Cooler Technologies

1.	IKN GmbH	www.ikn.eu
2.	FLSmidth	www.flsmidth.com
3.	KHD Humboldt Wedag	www.khd.com

Multichannel Burners

1.	KHD Humboldt Wedag	www.khd.com
2.	Pillard	www.pillard.de
3.	FLSmidth	www.flsmidth.com

Cross Belt Analyzers

1.	KHD Humboldt Wedag	www.khd.com
2.	Thermo Fisher Scientific	www.thermofisher.com

Grinding Systems

1.	KHD Humboldt Wedag	www.khd.com
2.	FLSmidth	www.flsmidth.com
3.	Loesche	www.loescheindia.com

Tertiary Crusher

1.	MMD Group of Companies	www.mmdsizers.com

Separators

1.	FLSmidth	www.flsmidth.com
2.	KHD Humboldt Wedag	www.khd.com
3.	ThyssenKrupp Polysius	www.polysius.com
4.	LV-Technology	www.lv-technology.com

Automation Systems

1.	FLSmidth	www.flsmidth.com
2.	Ramco Systems	www.ramco.com

Electrical Energy Efficiency

1.	Larsen & Toubro Electrical & Automation	www.larsentoubro.com
2.	Siemens India Limited	www.siemens.co.in
3.	ABB India Limited	www.abb.co.in
4.	Schneider Electric	www.schneider-electric.com
5.	Danfoss India	www.danfoss.com
6.	Bharat Bijlee Ltd.	www.bharatbijlee.com
7.	Kirloskar Electric Company Ltd.	www.kirloskar-electric.com
8.	Crompton Greaves Ltd.	www.cgglobal.com

Vacuum Pump

1.	Nash	www.gdnash.com
2.	Kakati Karshak Industries Pvt. Ltd.	

Hydraulic Coating of Pump

1.	Kirloskar Pumps	www.kirloskarpumps.com

Waste Heat Recovery

1.	Kawasaki plant systems	www.khi.co.jp
2.	Transparent Energy Systems Private Limited	www.heatrecovery-system.com
3.	Dalian East Energy Project corporation limited	www.dleast.cc
4.	Ormat Technologies, Inc	www.ormat.com
5.	Siemens AG	www.siemens.com
6.	Thermax	www.thermaxindia.com
7.	FLSmidth	www.flsmidth.com

Alternate Fuels & Raw Materials (AFR)

1.	Schenck Process	www.schenckprocess.com
2.	FLSmidth	www.flsmidth.com
3.	ATS Conveyors	www.atsconveyors.com
4.	Lindner-Recyclingtech GmbH	www.l-rt.com

ABBREVIATIONS

AFR	-	Alternate Fuels & Raw Materials
CII	-	Confederation of Indian Industry
CMA	-	Cement Manufactures Association
CPCB	-	Central Pollution Control Board
CSI	-	Cement Sustainability Initiative
GoI	-	Government of India
HT	-	High Tension
kCal	-	kilo Calorie
Kg	-	kilogram
kW	-	kilowatt
kWh	-	kilowatt hour
mg/Nm3	-	milli gram/ normal m3
MTOE	-	Metric Tonnes of Oil Equivalent
MTPA	-	Metric Tonnes per Annum
MoEF	-	Ministry of Environment & Forests
MoP	-	Ministry of Power
MT	-	Metric Tonne
MTOE	-	Metric Tonne of Oil Equivalent
MTPA	-	Metric Tonnes Per Annum
MW	-	Mega Watt
NCCBM	-	National Council for Cement & Building Materials
PAT	-	Perform Achieve & Trade
REC	-	Renewable Energy Certificate
SPCB	-	State Pollution Control Board
SRIM	-	Slip Ring Induction Motor
SSEF	-	Shakti Sustainable Energy Foundation
TPD	-	Tonnes Per Day
TSR	-	Thermal Substitution Rate
VFD	-	Variable Frequency Drive
WBCSD	-	World Business Council for Sustainable Development

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25) Report to the People on Environment & Forest 2009-2010, MoEF, GoI
26) India: Greenhouse Gas Emissions 2007, MoEF, 2010

Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy. Based on both energy savings and carbon mitigation potential, it focuses in four broad sectors: Power, Transport, Energy Efficiency and Climate Policy. Shakti acts as a systems integrator, bringing together key stakeholders including government, civil society and business in strategic ways, to enable clean energy policies in these sectors.

Shakti is part of an association of technical and policy experts called the ClimateWorks Network. For more information, please visit http://www.shaktifoundation.in

Bureau of Energy Efficiency (BEE)

The Government of India set up Bureau of Energy Efficiency (BEE) on 1st March 2002 under the provisions of the Energy Conservation Act, 2001. The mission of the Bureau of Energy Efficiency is to assist in developing policies and strategies with a thrust on self-regulation and market principles, within the overall framework of the Energy Conservation Act, 2001 with the primary objective of reducing energy intensity of the Indian economy. This will be achieved with active participation of all stakeholders, resulting in accelerated and sustained adoption of energy efficiency in all sectors. BEE co-ordinates with designated consumers, designated agencies and other organizations and recognize, identify and utilize the existing resources and infrastructure, in performing the functions assigned to it under the Energy Conservation Act. www.beeindia.in

Confederation of Indian Industry (CII)

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering industry, Government, and civil society, through advisory and consultative processes. CII is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has over 7100 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 90,000 enterprises from around 257 national and regional sectoral industry bodies.www.cii.in

CII - Sohrabji Godrej Green Business Centre (CII - Godrej GBC), a division of CII is India's premier developmental institution, offering advisory services to the industry on environmental aspects and works in the areas of green buildings, energy efficiency, water management, environment management, renewable energy, green business incubation and climate change activities. www.greenbusinesscentre.com

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