Chapter 12

Cement Industry

12.1 Introduction

India is the world's second largest cement producer after China, accounting for about 6% of the world's production. Annual per-capita consumption of cement in India is around 150 Kg, which is much lower than the global average of 270 kg. Cement is one of the core industries, which plays a vital role in the growth of the nation. Limestone and coal being the basic materials for cement manufacturing, India has the requisite quantity of cement grade limestone deposits, backed by adequate reserves of coal. India also has the requisite technical expertise to produce the best quality of cement with the most energy efficient processes. Many Indian companies have attained high levels of energy efficiency in their plants, which are comparable to international benchmarks.

For a variety of applications, various types and grades of cement are used. The most common types of cement are Ordinary Portland Cement (OPC), Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC). Indian cement industry produces various types of cements such as OPC, PPC, Portland Blast Furnace Slag Cement (PBFSC) or PSC, oil-well cement, rapid hardening - Portland cement, sulphate - resisting portland cement & white cement. In the year 2007-08, OPC production accounted for about 25% of the total production, while the blended cements, PPC & PSC accounted for 66% & 8% of the production respectively.

12.2 Present Capacity & Growth

India has 142 large & 200 mini cement plants. The total installed capacity of large cement plants in India is around 198 million tonnes per year & that of mini cement plants is 11 million tonnes. The cement production from large plants in the year 2007-08 was 168 million tonnes. The capacity utilization of cement plants in India is about 85%.

12.3 Manufacturing Process of Cement

Cement production involves the chemical combination of calcium carbonate (limestone), silica, alumina, iron ore and small amounts of other materials. Cement is produced by burning limestone to make clinker and the clinker is blended with additives and then finely ground to produce different cement types. Desired physical and chemical properties of cement can be obtained by changing the percentages of the basic chemical components i.e. CaO, Al_2O_3, Fe_2O_3, MgO, SiO_2, etc..

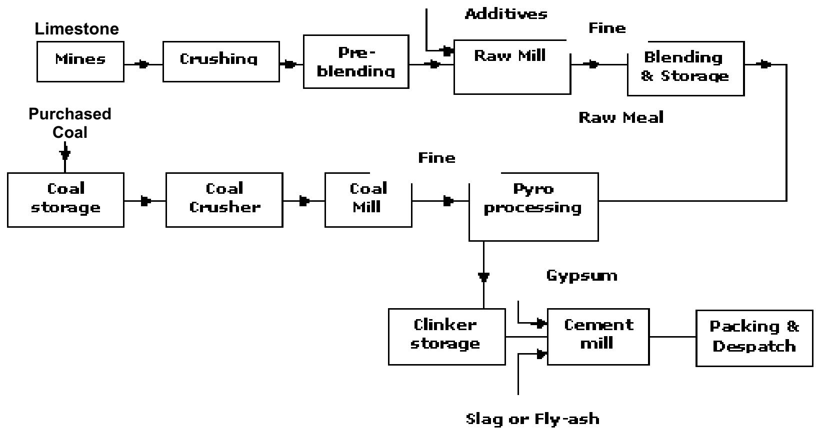
Cement is manufactured from Limestone and involves the following unit operations:

- Mining
- Crushing
- Raw meal grinding
- Pyro-processing
- Cement grinding
- Packing & dispatch

Raw Materials Preparation

Raw material preparation involves crushing of the quarried material, further raw grinding and blending the materials. The specific electrical energy consumption in raw materials preparation accounts for a significant part of overall electrical energy consumption.

Fig 12.1: Block Diagram of Cement Industry - (Dry Process Precalciner Process)



(Source : Investors Manual for Energy Efficieny, EMC, CII & IREDA)

Mining

The major raw material for cement manufacture is limestone, which is mined in open cast mines in the quarry and then transported to the crusher.

Crushing

The mined limestone is conveyed to the crusher through dumpers/ropeways/belt conveyors. The material is then crushed in the crusher to a size of about 25-75 mm. The crushing is done in two stages in the older plants while in the modern plants normally single stage crushing is done. The typical crushers used are jaw crusher and hammer crusher.

Raw meal grinding

The crushed limestone is grounded into fine powder in the dry condition. The Vertical Roller Mill (VRM) is comparatively more energy efficient than ball mill consuming only 65% of the energy consumption of the ball mill. The ball mill along with a pre-grinding system such as roll press is also used in some of the plants with very hard and abrasive limestone.

Pyro-processing

This takes place in the kiln system. The kiln is a major consumer of both the electrical and thermal energy in a cement plant. The calcination of limestone and the conversion into clinker takes place in the precalciner and kiln respectively.

Cement grinding

The clinker which is produced in the kiln is then grounded along with about 5% Gypsum to produce OPC. Ball mills have been generally used for grinding in cement plants in India either alone or in combination with roller press systems. In some of the recently installed plants, the VRM has been installed. The other types of cement such as PPC and PSC are also produced by grinding clinker with fly-ash and blast furnace slag respectively.

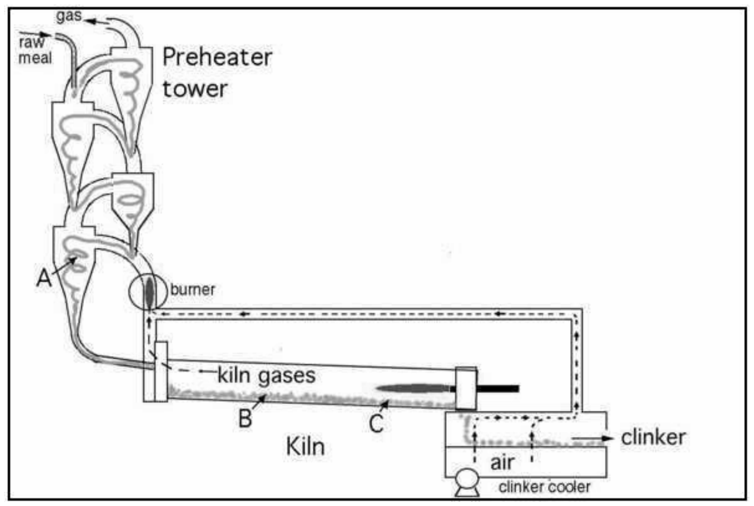
12.3.1 Clinker Production Process Technology

Clinker production is the most energy-intensive step, accounting for more than 80% of the energy used in cement production. Produced by burning a mixture of materials, mainly Limestone ($CaCo_3$), Silicon Oxides (SiO_2), Aluminum, and Iron Oxides, clinker is made through three processes :

- Dry process ~ 97 % of the production
- Semi-Dry process ~ 1% of the production
- Wet process ~ 2% of the production

The Cement Industry today comprises mostly of Dry Suspension Preheater and Dry-Precalciner plants and a few old wet process and semi-dry process plants. Till late 70's, the Cement Industry had a major share of production through the inefficient wet process technology. The scenario changed to more efficient large size dry process technology since early eighties. In the year 1950, there were, only 33 kilns out of which 32 were based on wet process and only one based on semi-dry process. Today, there are 162 kilns in operation out of which 128 are based on dry process, 26 on wet process and 8 on semi-dry process. Basic principle of precalciner kiln is shown in figure 12.2:

Fig 12.2: Pre-Calciner Kiln



(Source : Understanding Cement; Website : thecementkiln.mhtml)

The energy used in the above three processes is given in table 12.1 below

Table 12.1: Energy Consumption

Item	Wet Process	Dry Suspension Process	Dry Pre - Calciner Process
Heat Consumption (kcal / kg clinker)	1250 –1450	800 – 950	680 – 770
Power Consumption (kWh/tonne of cement)	100 – 115	100 - 105	70 – 95

Source: Handbook of Energy Conservation by H.M. Robert & J.H. Collins

12.3.2 Technology Status of the Industry

A comparison of the status of the modernization in equipment and also the technologies absorbed or implemented by the Indian cement industry alongwith status of Global Technology is as under:

Table 12.2: Status of Technology

	Low Technology Plants	Modern Plants	Global Technology
Plant Size, TPD	300-1800	3000-6000	6000-12000
Mining & Material Handling	Conventional	Computer aided	Computer aided
Crushing	Two stage	Single stage	In-pit crushing & conveying
Conveying of Limestone	Dumpers/Ropeway/ Tippers	Belt conveyors	Pipe conveyors, Belt conveyors
Grinding	Ball Mills with / without conventional classifier	VRM's Roll Presses with dynamic classifier	VRM's, Roll Presses, Horo Mills with dynamic classifier
Pyro Processing	Wet Semi Dry Dry - 4 stage preheater - Conventional cooler - Single channel burner	Dry - 5/6 stage preheater - High Efficiency Cooler - Multi Channel Burner	Dry - 6 stage preheater - High Efficiency Cooler - Multi Channel Burner - Co-processing of WDF - Co-generation of power - Low NO_x/SO_2 emission technologies
Blending & Storage	Batch-Blending Silos	Continuous Blending silos	- Continuous Blending - Multi-Chamber Silos - Dome silos
Packing & Despatch	Bag	- Bag - Bulk	- Bulk - Palletizing & Shrink Wrapping
Process Control	Relay Logic / Hard Wired / PLC	- DDC - Fuzzy Logic expert system	- DDC - Neurofuzzy expert system
Energy consumption level	90-100 kWh/t cem. 900-1000 kcal/kg cl.	75-85 kWh/t cem. 700-800 kcal/kg cl.	70-80 kWh/t cem. 680-725 kcal/kg cl

(Source : NCB)

12.3.3 Upgradation of Technology of Low Technology Cement Plants

The technological spectrum in the industry is very wide. At one end of the spectrum are the old wet process plants, while at the other end, are the new state-of-the-art technology plants presently being built by the Industry. In between these two extremes, are the large number of dry process plants built during the period 1965-90. These plants could not fully modernise or upgrade side by side with advent of

newer technologies and had thus remained at intermediate technology level. Also, the level of technology is not same at all the plants built during the same period.

Majority of the cement plants in the country are in the capacity range of 0.4 to 1.0 MTPA. These were set up more than 15-20 years ago and were based on the latest technology available at that time. Since then, numerous developments have taken place in the cement manufacturing technology.

Though some of the old plants have been modernized to a limited extent by retrofitting the new technologies, substantial scope still exists for adopting state-of-the-art technologies and bringing the old plants at par with world-class plants in terms of productivity, energy efficiency and environment friendliness, leading to cost competitiveness.

Moreover, the emission norms are likely to become more stringent in future and at the same time, the cement plants will be required to utilize waste derived raw materials and fuels to a large extent. The modifications of old plants to comply with these future requirements will also become inevitable. Therefore, there is a need to carry out a comprehensive assessment of all the earlier generation plants in the country to identify the extent of modernization required to improve their all round efficiency and enable them to meet the future criteria of viability, competitiveness and compliance with regard to energy consumption enabling them to comply with the provision of the Energy Conservation Act 2001.

12.3.4 Future Modernization Needs of the Indian Cement Industry

Although the industry has largely set up plants with energy efficient equipment, there are areas which require further improvements

- Appropriate pre-blending facilities for raw materials
- Fully automatic process control and monitoring facilities including auto samplers and controls.
- Appropriate co-processing technologies for use of hazardous and non hazardous wastes
- Interactive standard software expert packages for process and operation control with technical consultancy back-up
- Energy efficient equipment for auxiliary/minor operations
- Mechanized cement loading operations, palletization/shrink wrapping
- Bulk loading and transportation, pneumatic cement transport
- Low NO_x/SO_2 combustion systems and precalciners
- Co-generation of power through cost-effective waste heat recovery system
- Horizontal roller mills (Horo Mills) for raw material and cement grinding
- Advanced computerized kiln control system based on artificial intelligence

12.4 Specific Energy Consumption in Cement Plants

Cement industry is highly energy intensive. The main source of energy is coal, followed by electricity. Energy accounts for almost 40% of the total manufacturing cost in some of the cement plants whereas Coal accounts for 15%-20% of the total cost.

The industry's average consumption in 2006-07 for dry process plants was 730 kcal/kg clinker thermal energy and 77 kWh/tonne cement electrical energy. It is expected that the industry's average thermal energy consumption by the end of 11[th] Five Plan (Year 2011-12) will come down to about 710 kcal/kg clinker and the average electrical energy consumption will come down to 75 kWh/tonne cement.

The best thermal and electrical energy consumption presently achieved in India is 685 kcal/kg clinker and 71 kWh/tonne cement which are comparable to the best figures of 650 kcal/kg clinker and 65 kWh/tonne cement in a developed country like Japan.

The improvements in energy performance of cement plants in the recent past have been possible largely due to

- Retrofitting and adoption of energy efficient equipment
- Better operational control and Optimization
- Upgradation of process control and instrumentation facilities
- Better monitoring and Management Information System
- Active participation of employees and their continued exposure to energy conservation efforts etc.

Various energy audit studies have estimated that at least 5 to 10% energy saving is possible in both thermal & electrical consumption through adoption of various energy conservation measures. It is estimated that the saving of 5 kcal/kg of thermal energy and 1 kWh/t cement of electrical energy will result in total savings of about Rs 6 Million per annum in a 1 Million tonne plant. The average energy consumption values by process for Indian cement plants vs the best world practice is given in Table 12.3 below:

Table 12.3 : Average and Best Practice Energy Consumption Values for Indian Cement Plants by Process.

Process	Unit	India Average	World Best Practice
Raw Materials Preparation			
Coal mill	kWh/t clinker	8	2
Crushing	kWh/t clinker	2	1
Raw mill	kWh/t clinker	2	2
Clinker Production			
Kiln & cooler	kcal/kg of clinker	77	6
Kiln & cooler	kWh/t clinker	2	2
Finish Grinding			
Cement mill	kWh/t cement	3	2
Miscellaneous			
Utilities: mining & transportation	kWh/t clinker	1 6	1 .
Utilities: packing house	kWh/t cement	1	1
Utilities: misc.	kWh/t cement	2	1
Total Electric	kWh/t cement	9	7

(Source: Cement Manufacturer's Association 2003; Worrell 2004)

12.5 Energy Efficiency measures adopted by Indian Cement Industry

12.5.1 General Measures

The Indian Cement Plants have achieved a high level of energy efficiency. The escalating costs of cement manufacturing over the years and increasing competitiveness have resulted in a focused approach by the cement industry in India to maximise the operational efficiency with respect to retrofitting of energy efficient equipment/systems, technology upgradation, process optimisation, effective maintenance management and above all, energy management including energy monitoring and energy audit. The comprehensive approach adopted by the Govt. of India, the National Council for Cement and Building Materials (NCB) and Cement Manufacturers Association (CMA) has resulted in significant reduction in specific energy consumption levels in cement plants.

NCB energy audit studies carried out in 36 Cement Plants during last five years indicated potential savings ranging from 4 to 210 kcal/kg clinker and 0.78 to 27 kWh/tonne cement. The estimated cost savings ranges between Rs 47 lakhs for 600 tpd plant to Rs 945 lakhs per annum for 4300 tpd for plant.

Major factors identified for higher energy consumption are

- High preheater exit gas temperature (25-50°C higher)
- High preheater exit gas volume (0.1-0.4 NM^3/kg cl. higher)
- High pressure drop across preheater (upto 200 mmWG higher)
- High moisture in fine coal (upto 5.8%)
- Incomplete combustion of coal (CO - upto 1630 ppm)
- False air infiltration in kiln and mill circuits (upto 20%)
- Low heat recuperation efficiency of grate cooler (55-60%)
- High cooler air exhaust temperature (upto 100°C higher)
- High clinker temperature (upto 175°C against 90-100°C)
- Low efficiency of major process & cooler fans (<65%)
- Under-loading (<50% kW loading) of motors resulting in low operating efficiency

The potential savings identified in few plants are given in table-12.3 below :

Table 12.3: Potential Savings Identified

Plant	Kiln(s) capacity (tpd) and process (kwh/ton clinker)	Potential savings Thermal energy kcal/kg cl	Electrical Energy kWh/t CEM	Annual Savings Rs Lakhs
1	1200 tpd, 6-ST, RSP Calciner	35	0.78	98
2	3800 tpd, 4-ST, PH & ILC	13	4.43	269
3	3225 tpd, 5-ST, Double String Precal (Pyroclone)	38	2.11	289
4	300 tpd, 4-ST Preheater	210	27	239
5	6000 tpd, 6-ST, Double String Precal	32	1.30	445
6	1800 tpd, 5-ST, PH & ILC	60	6.50	408
7	2500 tpd, 4-ST, SLC Calciner (F L SMIDTH)	40	9.56*	512
8	1215 tpd, 4-ST Preheater	45	14	350
9	2400 tpd, 6-ST, Double String Preheater & Precalciner (Pyroclone)	22	5.68*	295
10	3850 tpd, 5-ST PRECALCINER	68	5.98	588
11	4000 tpd, 4-ST ILC Precalciner	11	5.52	336
13	3700 tpd, 5-ST, PC	70	5.40	895
14	2400 tpd, 5-ST, ILC PC	36	4.95	287

- kWh/t Clinker

(Source : NCB)

Some of the energy efficiency measures implemented in different cement plants in India are:

(i) Operational Control and Optimisation

Process optimisation, load management and operational improvement generally involve marginal financial investment and yet found to have produced encouraging results in energy saving. The different aspects explored in this direction are :

- Plugging of leakages in kiln and preheater circuit, raw mill and coal mill circuits
- Reducing idle running of equipments
- Installation of Improved insulating bricks/blocks in kilns and preheaters
- Effective utilisation of hot exit gases
- Optimisation of cooler operation
- Optimum loading of grinding media/grinding mill optimisation
- Rationalisation of compressed air utilization
- Redesigning of raw mix
- Installation of capacitor banks for power factor improvement
- Replacement of over-rated motors with optimally rated motors
- Optimisation of kiln operation
- Changing from V-belt to flat belt

(ii) Energy Efficient Equipment

Use of energy efficient equipment gives very encouraging results even at the cost of some capital investment. More and more plants are now going for these available energy saving equipment to improve the energy performance of the units. The energy efficient equipment being used by the cement industry are :

- Slip Power Recovery System
- Variable Voltage & Frequency Drive
- Grid Rotor Resistance
- Soft Starter for Motors
- High Efficiency Fans
- High Efficiency Separators
- Vertical Roller Mill
- Pre-Grinder/Roller Press
- Low Pressure Preheater Cyclones
- Multi-channel Burner
- Bucket Elevator in place of pneumatic conveying
- Fuzzy Logic/Expert Kiln Control System
- Improved Ball Mill Internals
- High Efficiency Grate Cooler

(iii) Waste heat recovery for cogeneration of power

In case of dry process cement plants, nearly 40 percent of the total heat input is rejected as waste heat from exit gases of preheater and cooler. The quantity of heat lost from preheater exit gases ranges from 180 to 250 kcal/kg clinker at a temperature range of 300 to 400°C. In addition, 80 to 130 kcal/kg clinker heat is lost at a temperature range of 200 to 300°C from grate cooler exhaust. The waste heat has various applications such as drying of raw materials and coal, but even after covering the need for drying energy, there is still waste heat available which can be utilized for electrical power generation thereby making additional power available and reducing CO_2 emission.

The cement industry is yet to adopt the cogeneration technology due to various technical, financial and institutional barriers. Recently, a model demonstration project has been jointly implemented by New Energy and Industrial Technology Development Organisation of Japan (NEDO), and Govt. of India under Green Aid Plan (GAP). The system has been installed on a kiln of 4550 tpd clinker capacity with 4 stage suspension preheater and precalciner. The exhaust gas flow through preheater (PH) boiler is of the order of 3,60,750 Nm^3/hr at 340°C whereas through Air Quench Cooler (AQC) boiler, it is 1,96,000 Nm^3/hr at 360°C. The power generated is of the order of 7700 kW at 6.6 KV. The installation cost of the system is around Rs 84 crores. The economic efficiency analysis indicates reduction of :

- 56.07×10^6 kWh of power purchased - Rs 24 crores
- Fossil fuel consumption of 14517 tonnes/year
- CO_2 emission of about 45098 tonnes/year

Case Study 1 : Installation of High Efficiency Dynamic Separator for Raw Mill

Brief

In a million tonne dry process pre-calciner plant, the existing static separator of the VRM was replaced with a new cage type dynamic high efficiency separator.

There was an increase in the output of the Mill, finer product and reduction in the specific power consumption of the Mill. Additionally, the Mill vibration also got reduced resulting in trouble free operation.

The Power Saving amounted to 2.5 units/tonne of Raw meal or 3.0 units/tonne of cement

Energy Saving

Annual Energy saving	:	*Rs 1.8 Million kWh*
Annual Savings	:	*Rs 270 Million*
Investment	:	*Rs 300 Million*
Simple payback	:	*13 months*

Case Study No. 2: Savings in Electrical Energy by increasing Kiln String Cyclone Diameter from 5.4 Mts to 6.6mts

Brief

Parameter	*Before Implementation*	*After Implementation*	*Saving/Improvement*
Cyclone dia. (m)	*5.4*	*6.6*	
Pressure drop (MMwg)	*115*	*86*	*(-) 29*
Energy consumption kWh	*750*	*722*	*(+) 28*
Kiln output (TPD)	*6281*	*6597*	*(+) 316*

Energy Saving

Energy Savings	:	28 kWh
Annual Savings	:	Rs 0.88 Million
Investment	:	Rs 2.2 Million
Payback period	:	2.5 years

Case Study No. 3: Optimisation of Crusher Output

Brief

The average output of Crusher is 205 TPH. The major constraints were the capacities of belt conveyor from Primary crusher to secondary Crusher.

The feed was restricted due to spillage taking place at the belts. It was possible to increase the width of the belt and speed after changing the gear boxes.

The capacity of belt was increased from 200 TPH by enlarging the belt size and gearbox.

Energy Saving

Parameter	Before Implementation	After Implementation	Saving/Improvement
Output of crusher (TPH)	205	235	(+) 30
Energy consumption kW h / tonne	2.1	1.8	(-) 0.3
Annual saving (Rs.)	-	-	(+) 66000

Case Study No.4: Replacement of the Air-lift with Bucket Elevator for Raw-meal transport to the Silo

Brief

The air-lift was replaced with a bucket elevator. The air-lift was retained to meet the stand-by requirements.

The implementation of this project resulted in reduction of power from 140 units for the air-lift to 40 units for the Bucket elevator. The air to be ventilated from the silo also got reduced with the installation of the mechanical conveying system. The silo top fan was downsized to tap this saving potential.

Low energy consumption (25 - 30% of Pneumatic conveying)
Reduction in power consumption of silo top dedusting system

Energy Saving

Annual Energy Saving	:	0.68 Million kwh
Annual Savings	:	Rs 2.24 Million
Investment	:	Rs 5.4 Million
Simple payback	:	29 months

Case Study No.5: Installation of new correct head pump for raw mill slurry transfer to Silo

Brief

Suppose that there are 3 raw mills, out of which 2 to 3 are in normal operation. Limestone slurry from the raw-mill section is pumped to the low-grade silos. There are two slurry pumps of different capacities to meet the carrying capacity requirements.

The specifications of the two slurry pumps are as follows

Description	Head	Capacity
Smaller capacity pump	20 m	-
Larger pump capacity(54 KW)	40 m	$175\ m^3/h$

The large pump is operated, when 2 raw mills are in operation, while the smaller pump is in operation, when for 1 raw mill is in operation. On comparing the two pumps, it is evident that the larger pump is designed with a higher head. The maximum head required for the slurry pump is :

Silo Height	:	16 m
Pit Height	:	4 m
Line loss	:	3 m
Additional height	:	2 m

It is recommended to install new correct head pump for slurry transfer from raw mill to LG silos, using the existing pump as standby.

Actual head required for pump : 4 m (Pit height) + 16 m (Silo height) + 2 m (Additional height) + 3 m (Line loss)
= 25 m (Say 30 m)

With one mill in operation & smaller pump started - head is only 20m. With 2 or 3 mills, bigger pump is operated & here the head is very high.

Capacity required with 3 mill Operation = $175\ m^3/h$ (Same as existing)

Maximum power consumption $= \dfrac{175\ m^3/h \times 30m \times 1.69\ kg/m^3}{102 \times 3.6 \times 0.70\ \text{pump} \times 0.85\ \text{motor}}$
= 40.61 (Say 41 kW)

Annual Savings = (54-41) kW x 8000 kWh x Rs. 2.26/kWh
= Rs 0.235 Million

Energy Saving

Annual savings	:	0.235 Million
Investment required (for new pump & motor)	:	0.120 Million
Pay back period	:	6 months

Case Study No.6 : Replacement of Existing Cyclones with Low Pressure Drop (LP) Cyclones

Brief

Implementation methodology & time frame: The top cyclone was at a height of nearly 106 metres. The implementation of this project involved removal of the existing cyclone and fixing of the new LP cyclone.

The replacement lead to an increase in the output of the Kiln, reduction in pressure drop of the pre-heater, reduction in Kiln section power consumption and reduction in Kiln specific thermal energy consumption. The comparison of the conditions and the energy consumption before and after installation of the LP cyclones are as below:

Energy Saving

Parameter	Before Implementation	After Implementation	Benefits
Clinker Production (TPD)	2650	2850	(+) 200
DP across Top Cyclone (mmWg)	100 – 125	70 – 90	(-) 30-35
Kiln section Power (kWh/T)	30	28.5	(-) 1.5
Heat Consumption (kcal/kg)	830	810	(-) 20

Annual Savings : Rs 2.4 Million
Investment : Rs 2.2 Million
Payback period : 11 months

Case Study 7: Derating Compressors to optimize the unload power consumption

Brief

The Filteration plant instrument compressor is observed to unload for 22% of time. Power consumption measurements indicate that the load power consumption is 22 kW and the unload power consumption is 7 kW.

The cement mill D-pump compressor was found to unload for 17% of time. The load and unload power consumption was measured to be 111 kW and 24kW.

It was recommended to derate cement mill D-Pump compressor & filtration plant instrument compressor by 10%. The compressor drives were belt driven and derating was carried out by changing the pulley size suitably.

Compressor	Timings		Power consumption	
	Load (S)	Unload (S)	Load (kW)	Unload (kW)
Filtration plant Instrumentation Compressor	69	17		
	71	23	22	7
Average Unload = 22 %				

Compressor	Timings		Power consumption	
	Load (S)	Unload (S)	Load (kW)	Unload (kW)
Cement Mill D-Pump	90	16	111	24
	72	18		
Average unload = 17 %				

Energy Saving

Savings in power consumption : 3.1 kWh
Annual savings : Rs 0.1 Million
Investment : Negligible
Payback period : Immediate

Case Study 8 : Variable Speed Fluid Coupling for Cooler ID Fan and replacement with lower capacity motor

Brief

A Variable Fluid Coupling (VFC) was installed for the Cooler ID fan. The hood draught was maintained by varying the speed through the VFC. The existing 315 kW, 750 rpm & 6.6 kV motor was replaced with a 230 kW, 750 rpm & 6.6 kV motor.

There was a drastic reduction in the power consumed by the Cooler ID fan. The comparison of the conditions and the power consumption before and after installation of the VFC are as below:

Energy Saving

Power consumption with damper control : 123 kW
Power consumption with VFC : 76 kW
Energy saving : 47 kW
Annual Energy saving : 0.384 Million kWh
Annual Savings : Rs 1.15 Million
Investment : Rs 0.5 Million
Payback period : 5 months

Case Study 9: Delta Start Star Run Operation of Dust Collector

Brief

i) The Dust Collectors are installed in the cement plant for collection of dust emission. The dust collector is provided with the filter bags and blower motor. The dust is collected in the bags and prevented from going in the air to control air pollution.

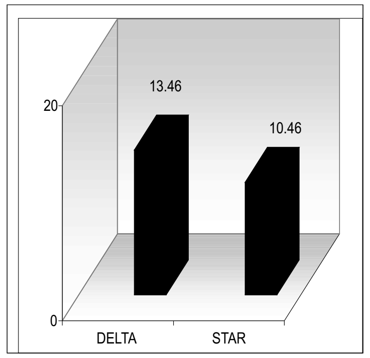
ii) It was observed during analysis of drive loading that the Dust Collector motor was operating below 50% loading. The loading on the motor has been reduced due to optimization of dust collector and pipelines bends. The starting torque requirement of the equipment is high hence ***Delta start and star run*** *arrangement was suggested to reduce the power consumption.*

iii) The Delta start and star run operation of the motor was technically viable, as the motor will operate in equipment safe operation and energy saving mode. The star operation of the drive will reduce the loading of the motor with reduction in copper losses and improvement in the efficiency of the motor. The PLC logic was prepared to start the motor in delta mode and shifting to star mode when full speed was pick up by the motor. The financial implications are nil, as no capital investment needed.

Energy Saving

Sno.	Perticulars	Before Modification	After Modification (A)	Saving
1	**Operation**	**Delta mode**	**Star mode**	
2	Power Intake /Hr. a) Load Current b) Power Factor c) Voltage d) Power (1.73 xVxIxP.F)	 20.9 AMPs 0.93 400 Volts 13.46 kWH	 15.4 AMPs 0.98 400 Volts 10.46 kWH	
3	Saving in KW	**13.46**	**10.46**	3 kw

kW SAVING



Case Study 10 : Variable Frequency Drives for Cooler Fans

Brief

Four cooler fans were installed with Variable Frequency Drives (VFDs). There was a drastic reduction in the power consumed by the Cooler fans. The power saving in the fans is on account of

- *Saving in the energy lost across the dampers*
- *Increase in the operating efficiency of the motor. The efficiency of the motor depends on the V/f ratio. In the case of the VFD, the voltage is varied to maintain the V/f ratio at the designed value. Hence, the efficiency of the motor is maintained at a higher level even at lower loading of the motor.*

The comparison of the conditions and the power consumption before and after installation of the VFDs are as below:

Equipment	Rating (kW)	Power consumption beforeVFD	Power consumption after VFD	Saving through VFD
Fan – IA (kW)	75	45	32	13
Fan – IB (kW)	75	44	30	14
Fan – IC (kW)	110	68	54	14
Fan – IC (kW)	110	59	44	15
Total Saving (kW)	-			**57**

Energy Saving

Annual energy saving	:	*0.46 Million kWh*
Annual Savings	:	*Rs 1.5 Million*
Investment	:	*Rs 2.5 Million*
Payback period	:	*20 months*

Case Study 11: Installation of Variable Frequency Drive for MFC Fluidizing Air Blower

Brief

The Blower used for fludisation air is of the following specifications - 165 m^3/hr flow, 1000 mm WC pressure rise and 40kW motor rating - for supplying fluidizing air. The actual power consumption of the fan is 37 kW.

The suction area of the fan is about 70% closed and the inlet guide vane is controlled to the extent of 70% open. This indicates that the rated flow is much higher that actual requirement.

After installing the VFD, open the suction area fully and gradually reduce the rpm till the discharge pressure is the same as before. Subsequently, open the IGVcompletely to 100% open position and further reduce the speed of the blower till the pressure difference across the blower is maintained at present values.
Blower specification (WC) : 165 m^3/h, 1000 mm
Motor Rating (kW) : 40

Energy Saving

Energy savings	:	*0.3 x 37 kW = 11.1 kW*
Annual savings	:	*Rs 0.37 Million*
Investment	:	*Rs 0.35 Million*
Payback period	:	*11 months*

Case Study 12 : Replacement of Existing Cooler I Grate with High Efficiency Cooler System

Brief

The plant replaced the I grate with high efficiency cooler system. This was done to increase the capacity of the Cooler and also improve the thermal efficiency of the system. Additionally the following capacity upgradation measures were also implemented simultaneously :

- *Increasing the height of the Calciner*
- *Installation of high efficiency classifier for both Raw mill and Coal Mill*
- *Conversion of the existing two fan system to three fan system*
- *Installation of high efficiency nozzles for GCT*

On account of the capacity upgradation projects the capacity of the Kiln increased from 2800 TPD to 3000 TPD. The installation of the high efficiency Cooler resulted in reduction in the Cooler air quantity and cooler exhaust air quantity. There was also an improvement in the steady operation of the Kiln, better quality and lower temperature Clinker. The over-all benefits achieved are as below:

Energy Saving

Parameter	Before Implementation	After Implementation	Savings/Improvement
Clinker Production TPD	2800	3000	(+) 200
Cooler air Nm^3/kg	2.6	2.1	(-) 0.5
PH outlet air Nm^3/kg	1.475	1.444	(-) 0.031
Clinker Temperature ° C	180	120	(-) 60
PH outlet Temperature ° C	370	336	(-) 34
PH loss kCal/kg	217	19	(-) 26
Cooler & Clinker loss kCal/kg	131	120	(-) 11
Radiation loss kCal/kg	69	65	(-) 4
Heat Consumption kCal/kg	780	745	(-) 35

Annual Savings : Rs 12 Million
Investment : Rs 29 Million
Payback period : 30 months

Case Study 13: Usage of High Efficiency Crusher as a Pre-grinder before the Cement Mill

Brief

The plant installed a Horizontal Impact Crusher (HIC) of 300 TPH capacity (including recirculation). The HIC was to act as a pre-grinder and perform the initial size reduction before the Mill. The HIC had a three deck-vibrating screen to separate and return the coarse material back to the HIC. The coarse was sent to the HIC back by gravity while the fines were conveyed to the hopper through a belt conveyor. The fines from the hopper can be later fed to the Mill through a belt conveyor. Thus the HIC and the Mill were made independent so that the operation of one does not affect the other.

Energy Saving

Increase in capacity from 125 TPH to 175 TPH
Reduction in power consumption from 29.0 units to 25.7 units per tonne of O P C - 4 3

Annual Savings : Rs 15 Million
Investment : Rs 40 Million
Simple payback : 32 months

Case Study 14: Installation of Grid Rotor Resistance (GRR) Control and varying the Speed of the Recirculation Fan

Brief

The Cement mill is a close circuit mill. The recirculation fan in the cement mill draws air from Separator through Cyclone. The recirculation fan is rated for 3800

m^3/min of flow 500 mm pressure rise with a motor rating of 470 kW. The measured power consumption of this fan is 270 kW.

The Recirculation fan flow was controlled by damper . This indicated the excess capacity/head availed in the fan. The damper opening was observed to vary from 45% to 80% depending on the separator output.

At 80% of the damper opening (the normal maximum damper opening), the damper is observed to offer a pressure drop of 18.9%. This indicates that 18.9% of the power consumed by the fan is lost across the damper.

The capacity of the fan cannot be permanently derated because the capacity of the fan needs to be varied with time.

It was concluded that good energy saving potential exists by installing a speed control device and varying the speed of the fan.

Hence, it was required to install a Grid Rotor Resistance (GRR) control to the recirculating fan and vary the capacity as required. The damper must be fully opened once the GRR is installed to the recirculating fan. Damper position of recirculation fan varies from 45% to 80% opening based on the separator output.

At 80% damper opening, damper loss is calculated

$$\text{Damper loss} = \frac{-320 - (-390)}{-20 - (-390)} = 18.9\%$$

Actual power consumption = 270 kW

Install a GRR and vary the speed of the fan instead of the damper position. Measured Savings, after considering GRR's power consumption (kW) : 51.

Energy Saving

Savings in power consumption (kW) : 30
Annual savings : Rs 0.64 Million
Investment : Rs 0.5 Million
Payback period : 10 months

Case Study 15: Reducing the Speed of Cement Mill's Dust Collection Fan

Brief

A Cement Mill's dust collection fan was observed to operate with damper control. The damper was open to the extent of about 40%. Pressure measurements before and after the damper and at the fan delivery indicated that the pressure drop across the damper is about 73%. The motor rating of this fan is 22 kW and the measured power consumption of the fan is 17 kW.

The pressure loss of 73% across the damper indicates that nearly three-fourth of the power consumption of the fan is lost across the damper.

Good potential for energy saving exists by reducing the speed of the fan.

Reduce the speed of the fan by 30%. *The speed reduction should be done in stages of 10% each. This fan being a belt driven equipment, the speed reduction could be carried out by pulley size reduction.*

Loss across damper = -48-(-175) / -1-(-175) (All measurements in mmWC) = 73 %
Energy loss = 0.73 x 17 kW = 12.4kW

By reducing the speed of the fan by 30%, 50% savings in energy Consumption is possible.

Energy Saving

Savings in energy consumption	:	*8.5 kW*
Annual savings	:	*Rs. 66,000*
Investment	:	*Rs. 10,000/-*
Payback period	:	*2 months*

12.6 Energy Consumption in Cement Plants - World's Best Practice

The specific energy consumption of cement plants in developed countries like Japan is 650 kcal/kg of clinker as thermal energy and 65 kwh / tonne of cement as electrical energy. This is mainly because of advanced technologies, process designs and best energy efficiency practices adopted. The 'World's Best Practices represent the most energy efficient processes that are in commercial use in at least in one location, worldwide. The Energy Intensity values are defined as:

(i) "Final Energy Intensity Values", i.e. the energy used at the production facility

(ii) "Primary Energy Intensity Values" i.e. the sum of energy used at the production facility, plus the energy used to produce electricity consumed at the facility.

The process in cement plant based on the energy consumption can be divided into following parts: -

a) Raw materials preparation (limestone & fuels).
b) Clinker making (fuel use & electricity use)
c) Additive drying
d) Cement drying
e) Other energy uses (quarrying, auxiliaries, conveyers and packing)

The World Best Practice Values based on the above processes for 'Final Energy' and 'Primary Energy' are given in tables 12.4 & 12.5 for Portland Cement, Fly Ash Cement and Blast Furnace Slag Cement respectively.

Table 12.4: 'Final Energy Intensity Values' for Cement Plants following World Best Practice.

Cement	Unit	GJ/t	*kgce / t
Portland Cement	t Cement	2.9	100
Fly Ash Cement	t Cement	2.0	70
Blast Furnace Slag Cement	t Cement	1.7	57

**kgce = kg of coal equivalent*
(Source : World Best Practice Energy Intensity Values; LBNL; Worrell E., Price L., Neelisy Galitsky C.)

Table 12.5: 'Primary Energy Intensity Values' for Cement Plants following World Best Practice.

Cement	Unit	GJ/t	Kgce/t
Portland Cement	t Cement	3.4	115
Fly Ash Cement	t Cement	2.5	84
Blast Furnace Slag Cement	t Cement	2.1	73

(Source : World Best Practice Energy Intensity Values; LBNL; Worrell E., Price L., Neelisy Galitsky C.)

12.7 Other Best Practices of Energy Efficiency in Cement Industry

Some of the best ENCON practices being used in cement industry Internationally are:

i) Raw Material Preparation

- Mechanical conveyors, in place of pneumatic conveyers, which consume 2 kwh/t less energy for dry process.
- On line analysers used for raw mix control.
- Gravity type homogenizing silos (or continuous blending & storage silos) reduce power consumption by 0.9 - 2.3 kWh/t raw material.
- Reduction in compressed air losses by plugging of leakages in slurry blending & homogenizing (wet process).
- Replacement of tube mill by a wash mill in wet process leads to reduction in electricity consumption by 5-7 kWh/t.
- High efficiency vertical roller mills in place of balls mills, saves energy of 6-7 kWh/t raw material.
- A multi variable controller in vertical roller mills to maximize the total feed while maintaining a target residue and enforcing a safe range of trip-level vibration. The throughput increases by 6% and SEC reduces by 6% or 0.8 1.0 kwh/t of raw material.
- Using high efficiency classifiers or separators, the material stays longer in the separator, leading to shaper separation, thus reducing over - grinding & saving 8% of electricity.

ii) Fuel Preparation

- Installation of roller presses for coal grinding in place of conventional grinding mills.

iii) Clinker Production

a) Wet Process :

- Wet process conversion to semi-dry process through slurry gas driers. Evaporation energy is reduced to half in this process, reducing fuel consumption by 1 MBtu/t clinker.
- Wet process conversion to semi-wet process by installing filter press to reduce moisture content to about 20% of the slurry and obtain a paste, ready for extrusion into pellets.

- Wet process conversion to dry process production by installing multi - pre heater / pre - calciner. Fuel saving of upto 2.9 MBtu/ ton can be achieved.

b) Dry Process pre-heater Kilns :

- Low pressure drop cyclones for suspension pre - heaters can save 0.6 - 0.7 kWh/t clinker for each 50mm WC (Water column).
- Heat recovery from the kiln exit gases for co-generation, either by installing direct gas turbines that utilize the waste heat (top cycle) or by installing waste heat recovery boiler system that runs a steam turbine system (bottom cycle). Power generation may vary from 10 to 23 kWh/t clinker, saving electrical energy of 20 kWh/t clinker.
- Dry process conversion to multi - stage pre - heater by installing multi stage suspension pre heating (4 or 5 stage) reduces heat loss and thus increases efficiency. Kiln length is also shortened by 20% to 30%, thereby reducing radiation losses.
- Conversion of Long Dry Kilns to multi - stage pre heater / pre calciner kiln can save 1.2 MBtu / tonne clinker.

c) Other measures :

- Advanced process control through online analyzers to recover heat from kilns (e.g. 'fuzzy logic' or 'ABB LINKman' control system) to save 2.5% - 5% energy and reduce NOx emissions by 20%.
- Gyro - thermal technology for kiln construction system improves gas flame quality while reducing NOx emissions.
- Oxygen enrichment in the kiln to increase production capacity.
- Upgradation of pneumatic seals at the kiln inlet and outlet reduces false air penetration as well as heat losses.
- Use of better insulating refractories with high temperature insulating lining reduces kiln shell heat losses thereby saving 0.1 - 0.34 Btu/ton fuel use.
- Use of high efficiency AC variable frequency drives in place of DC drives for rotating the kiln.
- Use of VFD in kiln fan reduces 40% of energy.
- Replacement of rotary or shaft coolers by Reciprocating Grate coolers in the cooling of clinker and efficient heat recovery (almost by 65%) saves about 8% of the fuel consumption in the kiln.
- Optimization of heat recovery by using reciprocating grate coolers for large kilns (upto 10,000 tpd) for recovery of sensible heat upto 1.4 MBtu/t.

iv) Finish Grinding

- Process control and management of Grinding mills.
- Advanced grinding concepts by installing high pressure roller presses.
- Use of high efficiency classifiers increases production by 20% to 25% and reduces 8% electricity.
- Improved wear grinding materials such as chromium steel can be installed for grinding media. Potential savings 5% to 10%.

v) Plant-wide measures

- Preventive maintenance of the plant.
- Use of High - Efficiency Motors & Drives.
- VFDs for clinker fans, fans in kiln, cooler, pre heater, separator and mills.
- Reduction is losses in compressed air system.
- Energy Efficient lighting.

12.7.1 The energy efficiency measures in 'Dry Process Cement Plants' in US

Energy Efficiency Measures in Dry Process Cement Plants are summarized in table 12.6. The estimated savings and payback periods are averages for indication, based on the average performance of the U.S. cement industry (e.g. clinker to cement ratio). The actual savings and payback period may vary by project, based on the specific conditions in the individual plant.

Table 12.6 : Energy Efficiency Measures in Dry Process Cement Plants

Energy Efficiency Measure	Specific Fuel Savings (MBtu/tonne	Specific Electricity Savings (kWh/tonne	Estimated Payback Period (1) (years)
Clinker Making			
Energy Management & Control Systems	0.10 – 0.20	1.2 – 2.6	1 – 3
Seal Replacement			
Combustion System Improvement	0.02	-	< 1
Indirect Firing	0.10 – 0.39	-	2 – 3
Optimize Grate Cooler	0.09 – 0.31	-	1
Conversion to Grate Cooler	0.06- 0.12	0 – (-1.8)	1 – 2
Heat Recovery for Power Generation	0.23	-2.4	1 – 2
Low-pressure Drop Suspension Preheaters	-	18	3
Finish Grinding			
Energy Management & Process Control	-	0.8 – 3.2.6	<1
Improved Grinding Media in Ball Mills	> 0.5	-	1
Plant Wide Measures			
Preventative Maintenance	0.04	0 – 5	< 1
High Efficiency Motors	-	0 – 5	< 1
Adjustable Speed Drives	-	5.5 – 7.0	2- 3
Optimization of Compressed Air Systems	-	0 – 2	< 3
Product Change			
Blended Cement	1.21	-15	< 1
Limestone Portland Cement	0.30	3.0	< 1
Use of Steel Slag in Clinker (CemStar)	0.16	-	< 2
Low Alkali Cement	0.16 – 0.4	N/A	Immediate
Reduced Fineness of Cement for Selected Uses	-	0 – 14	Immediate

Notes: Payback periods are calculated on the basis of energy savings alone.

(Source : Energy Efficiency Improvement Opportunities for Cement Making; An Energy Star Guide; LBNL; by Worrell E., Galitsky C.)

12.8 Energy Efficient Technologies being used in Cement Plants in Japan

Case Study 16: Cement clinker burning process

(a) Adoption of suspension preheater (SP)

Brief

This modification represents installation of a facility to effectively dry and preheat the feed previously blended in the raw material blending section using the flue gas stream from the kiln. This improvement has achieved marked energy saving compared with the conventional wet process.

1) *The exhaust gas from the kiln in the dry burning process is about 1050^{0}C. Formerly, the sensible heat of this flue gas was partly recovered by exhaust gas boiler for power generation.*

2) *The new facility represents a modification which instead directly recovers the sensible heat for drying and preheating the kiln feed.*

3) *The Suspension preheater is a multistage cyclone and the temperature of these gas at he outlet of cyclone was 350^0 -380^{0}c.*

Energy Saving

(1) Energy saving effect of the suspension preheater (Production: 4,000 t/D)

	Savings / Improvement	Note
Specific heat recovery kcal/(t-clinker)	400 to 500 x 10^3	Av. 450 x 10^3
Annual total heat recovery kcal/y	594 x 10^9	Operation: 330 D/y
Crude oil equivalent (kL/y)	264,000	

(2) Productivity of burning process will be improved.

Capacity of the kiln: one series of 4,000 tons/day facilities (raw materials preparation through burning to finishing)

Investment : Rs 1.2 Billion

(b) Adoption of vertical roller mill for coal crushing

Brief

Formerly, combination of a tube mill and a separator was used mainly for crushing coal. Nowadays, highly efficient vertical roller mills capable of crushing and drying coal, and classifying crushed coal have been com- mercialized. As a result, significant reduction of specific electric power consumption has been achieved.

1) *Moist coal is fed either from the top or side to the rotating table of the vertical roller mill.*

2) *The roller mill mechanism is primarily to crush coal between the disc table and rolls which are pressed hydraulically onto the table.*
3) *Ground coal is fed upward to the classifier placed above by the hot air blown into the mill from below. Coal is dried while it is being brought upward by the hot air.*

Use of the vertical roller mill can reduce specific consumption of electric power by 20 to 25 percent compared with the conventional combination of tube mill and separator.

Energy Saving

Investment amount : Rs. 250 Million for 20 tonne/hour size
Improvement Effect : Reduction of SEC by 20% - 25%

(c) Adoption of high-efficiency quenching cooler

Brief

This modification represents adoption of a high-efficiency quenching cooler. The high-efficiency quenching cooler rapidly cools burned clinkers from the kiln by air to improve the cement quality. At the same time the air heated by the burned clinkers is used as combustion air for kiln burner to achieve energy saving.

Modification: Modification into high-efficiency cooler with the capacity of 5,000 tonne / day

Energy Saving

Energy saving effect of clinker cooler

	Savings /Improvement
Heat recovery rate	56.9% to 62.3% (Increased)
Specific heat consumption for cement (kcal/kg)	20.5 (Reduced)
Crude oil equivalent (kL/y)	2,240 (reduction)

Equipment modification cost : Rs. 20 - 80 Million
Reduction of SEC : 2.8%

Case Study 18 : Cement production finishing section :

Brief

The present case installs a vertical roll crusher of high grinding efficiency as a pre-grinding crusher in the step previous to the ball mill, the finishing grinder of cement. Crushing clinkers before they are fed into the ball mill of high power consumption, the efficiency of the ball mill was increased because its load was greatly reduced and the specific electric power consumption was significantly saved.

A mixture of clinkers and gypsum was crushed by the compression and shear force between the table and three rollers, the latter being hydraulically pressed onto the former.

Energy Saving

	Before improvement	After improvement	Savings / Improvement
Production capacity(t/hr)	107	160	1.5 times (increase)
Specific electric power consumption (kWh/t)	36	29	7 (19% reduction)
Electric power consumption* (MWh/y)	32,400	26,100	6,300 (reduction)
Crude oil equivalent (kl/y)			1,531 (reduction)

*Note: * Production : 3,000 tonnes/day at 300 days/year operation*

Investment amount : Rs. 250 Million for a 100 tonne / hour grinder
Reduction in SEC : 19%

References

1. IEA, World Energy Outlook 2007.
2. Directory of Energy Conservation Technology in Japan, prepared by New Energy & Industrial Technology Development Organization, The Energy Conservation Centre, Japan.
3. Investors Manual for Energy Efficiency, EMC, CII & IREDA..
4. Bureau of Energy Efficiency.
5. NCCBM (National Council for Cement & Building Materials).
6. Portland Cement Association : Innovations in Portland Cement; Shokil IL, PCA.
7. Energy Management Policy-Guidelines for Energy Intensive Industry in India, Bureau of Energy Efficiency. www.bee-india.com/aboutbee/Action %20 Plan/ 05. tal, html.
8. Energy Efficiency Improvement opportunities for Cement making : An Energy Star Guide for Energy & Plant Managers. Lawrence Berkeley National Laboratory; Ernst Worrell & Christina Galitsky.
9. Assessment of Energy use & Energy Saving Potential in Selected Industrial Sectors in India (Ernest Orland Deptt. Of Environmental Energy Technologies Division; by Jayant Sathaye, Lynn Price, Stephane delaPue can & David Fridley.
10. Energy Efficiency Programmes & Policies in the Industrial Sector in Industrialised Countries, Berkelay, LBNL.
11. Indo-German Energy Efficiency & Environment Project (IGEEP); India.com/aboutsee/implementation/designated/
12. Statistical Pocket Book, India, 45th Edition, 2006-07, Central Statistical Organisation; www.mospi.gov.in.
13. Website : www.ibef.org/artdisprirew.aspx art
14. Handbook of Energy Conservation by H.M.Robert & J.H. Collins.