Confederation of Indian Industry

CEMENT MANUFACTURERS ASSOCIATION

ENERGY BENCHMARKING

For Indian Cement Industry

May 2019

Version 4.0

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audit data.

This data is an attempt to bring out all the best practices adopted and best energy levels achieved by the cement Industry. We have taken utmost care to bring out the best operating data however, there may be sections and some plants may operate at best levels which may be missing our notice.

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Message from Chairman - Green Cementech 2019

MESSAGE

India is the second largest cement producer in the world, ranking next only to China and surpassing developed nations like the USA & Japan in its overall cement manufacture & consumption.

CII-Sohrabji Godrej Green Business Centre, as part of its World Class Energy Efficiency initiative, has been working on several initiatives to Make the Indian Cement Industry World Class in “Green”. One such initiative is to provide latest information regarding energy performance of Indian Cement plants to all stakeholders in the cement industry in the form of “CII Energy Benchmarking for Indian Cement Industry”. The first manual was released in 2014 and later updated in 2015 and 2018.

Under the PAT scheme, the cement industry has performed well, reaching new performance levels with resultant savings of 1.44 Million Ton of Oil Equivalent (TOE). At this juncture, we felt, to support the industry’s relentless efforts in energy conservation, there was a need to update the manual with new benchmark figures. The CII Energy Benchmarking for Cement Industry Version 4.0 showcases the improved levels of specific energy consumption in various sections of a cement plant. This manual also elaborates the benchmarking approach for comparison of plants to reveal hidden opportunities in a cement plant.

I am sure that this benchmarking manual will serve as a useful tool for performance assessment and target setting across the industry. I take this opportunity to thank the cement industry for supporting this initiative. We warmly invite you to share your feedback with us at encon@cii.in

Philip Mathew
Chairman, Green Cementech 2019, CII-Godrej GBC &
Chief Manufacturing Officer, ACC Limited

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ACKNOWLEDGMENT

CII-Sohrabji Godrej Green Business Centre would like to express sincere and special gratitude to the entire Indian cement industry for their continuous support in this initiative by providing the required data for completing this study which makes this manual more useful to all stake holders.

CII-Godrej GBC acknowledges with thanks the co-operation and the support extended by all the suppliers for sharing their technology advancements and case studies implemented in the cement industry.

We would like to place our vote of thanks for the entire national and international cement technical experts and associations for sparing their valuable time in offering inputs and suggestions in bringing out this manual.

The interactions and deliberations with the industry, suppliers and sector experts and the whole exercise was thoroughly a rewarding experience for CII.

Executive Summary

The Indian Cement Industry is a trend setter in the world of cement and has been consistent in adopting the latest technologies for energy conservation. The levels of energy efficiency in some Indian plants are amongst the best in the world, but there is still scope for improvement through the use of energy efficient technologies and practices in new and old plants.

CII - Godrej GBC has prepared this benchmarking manual with the intent of continuing knowledge transfer and facilitating Cement plants to compare their performance with their peers. Such comparisons will help in the identification of potential areas for performance improvement.

CII - Godrej GBC prepared a detailed questionnaire involving all sectional parameters of the cement industry, from crusher to packing plant, to collect the data required for the benchmarking study. This questionnaire was sent to more than 140 cement factories across India. A majority of these factories participated in this study and shared their data with us. All parameters recorded in various sections in this report are based on the data provided by the plants.

The collected data has been classified into different sections in this report, and each individual section has been compared with respect to section-wise specific energy consumption and other parameters.

The following best operating values have been identified through this benchmarking study:

Sr. No.	Section	kWh/T Material
1	Single Stage Crusher	0.70
2	Double Stage Crusher	0.65
3	Raw Mill - VRM	11.1
4	Raw Mill - Ball Mill	16.5
5	Coal Mill - VRM	23.9
7	Five Stage Preheater - Clinkerisation	16.28
8	Six Stage Preheater - Clinkerisation	17.05
9	Five Stage Preheater - Upto Clinkerisation	45.38
10	Six Stage Preheater - Upto Clinkerisation	43.32
11	Cement Mill - VRM	21.92
12	Cement Mill - Ball Mill Closed Circuit	27.07
13	Cement Mill - Ball Mill with HPRG	23.20
14	Packing plant	0.65
15	Compressor upto clinkerzation	0.67
16	Compressor cement grinding and packing	0.89
17	Overall Electrical Specific Energy Consumption	63.91
18	Thermal Specific Energy Consumption for 5 stage Preheater	685
19	Thermal Specific Energy Consumption for 6 stage Preheater	676

Outcome of energy efficiency initiatives in Indian Cement Industry:

- Good reduction achieved in last 20 years (1995-2015)
- 32% reduction in Electrical SEC
- 11% reduction in Thermal SEC
- 10 Plants Operating below 700 kcal/kg clinker
- 7 Plants Operating below 50 kWh/T clinker
- 10 Plants Operating below 70 kWh/T cement

The other important outcomes of this study are more than 300 best practices implemented in national and international cement plants and more than 50 performance indicators in cement industry, all recorded at one place for the benefit of the industry.

Monitoring techniques with the parameter to be monitored and frequency of monitoring is also provided in each section to further aid the stake holders in achieving energy efficiency.

Finally, the benchmarking reveals the best values at which the industry is operating each section and the best practices and technologies to be adopted to become as leader in energy efficiency.

Benchmarking is Dynamic

The best operating numbers mentioned in the *Energy Benchmarking for Indian Cement Industry* are reported by cement plants based on year average values achieved in the year 2016-2017. We understand that the performance numbers improve as part of continuous efforts and technology upgrades by cement industry, thus making the benchmarking dynamic.

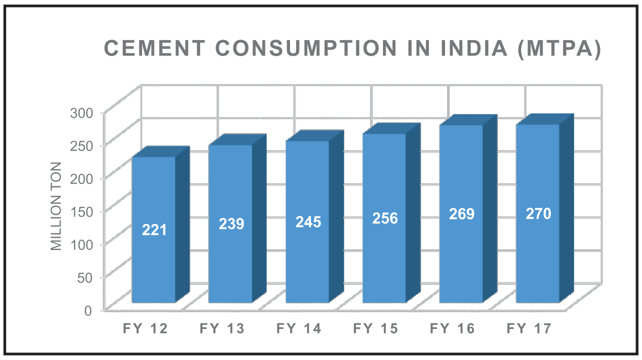
If you feel any cement plant has a better performance number for a section, equipment or overall, please share the details with us at: kiran.ananth@cii.in

CHAPTER-1
INTRODUCTION

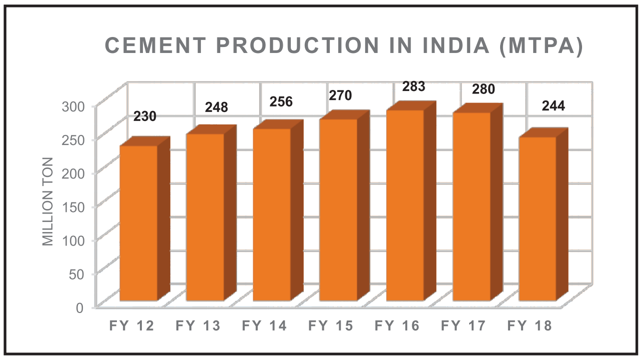
1.0 Indian Cement Industry present scenario

India's cement industry plays a vital role in the growth and development of the nation. The cement industry has been growing due rise in demand for residential buildings and the increasing activities in infrastructure development over the past many years. India's cement production increased by 22.9% in February, 2018 over February, 2017. Its cumulative index (Index of Eight Core Industries*) increased by 5.7 per cent during April to February, 2017-18 over the corresponding period of previous year. The Indian Cement Industry has 210 large integrated cement plants and 350 mini cement plants accounting to a total capacity of 461 million tons.

The Indian cement sector is expected to witness positive growth in coming years, with demand set to increase at CAGR of more than 5% during FY'17 to FY'20. In addition, cement production in India is expected to touch 550 million tonnes (MT) by 2020.



Cement consumption in Indian (milion tonnes)[1]



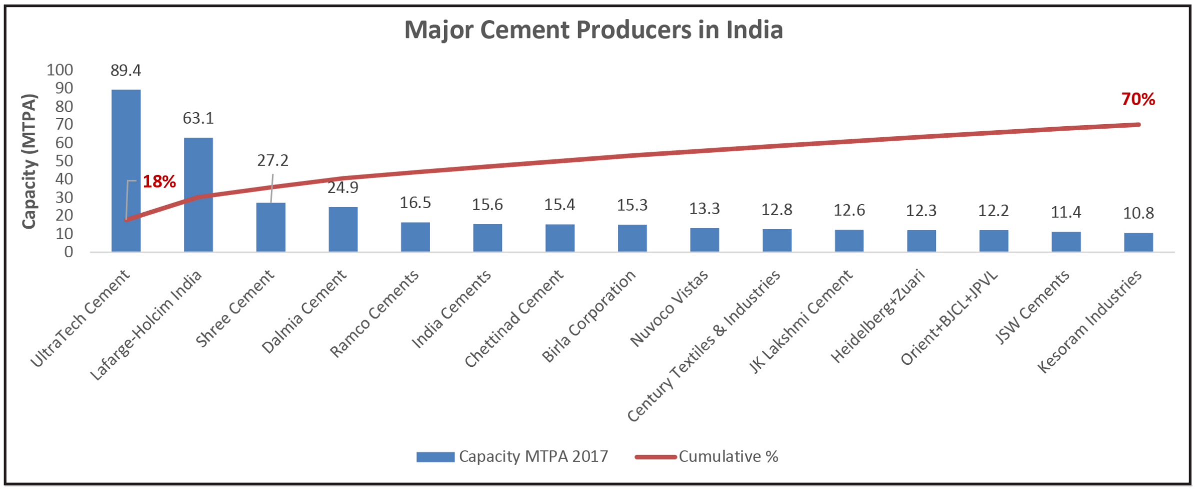
Cement production in Indian (milion tonnes)[2]

1.1 Major Players in Indian Cement Industry

Although the Indian cement industry has some international cement giants such as LafargeHolcim, the Indian cement industry is broadly home developed. UltraTech Cement Limited the country's largest firm in terms of cement capacity, holds around 18% of the production capacity whereas LafargeHolcim (ACC Limited & Ambuja Cements Limited) have 13% share making them two biggest producers of cement in India. The other Indian key players in top 10 (in order of diminishing market share) include Shree Cement Limited (5.4%), Dalmia Cement (Bharat) Limited (5.0%), The Ramco Cements Limited (3.3%), India Cements Limited (3.1%), Chettinad Cement Corporation (3.1%), Birla Corporation Limited (3.0%), Nuvoco Vistas Corporation Limited (2.7%) and Century Textiles and Industries Limited (2.6%).

Cement production giants for the year 2017 are shown below with individual production capacities in million ton per annum (MTPA) and their percentage share of production. Its important to note that UltraTech Cement Limited alone comprises of 18% of the production capacity of India whereas the mentioned 15 Indian cement companies produce more than 70% of total cement produced in India in year 2017.

[1,2] Source: Department of Industrial Policy and Promotion, Aranca Research Notes Estimate, CAGR - Compound Annual Growth Rate

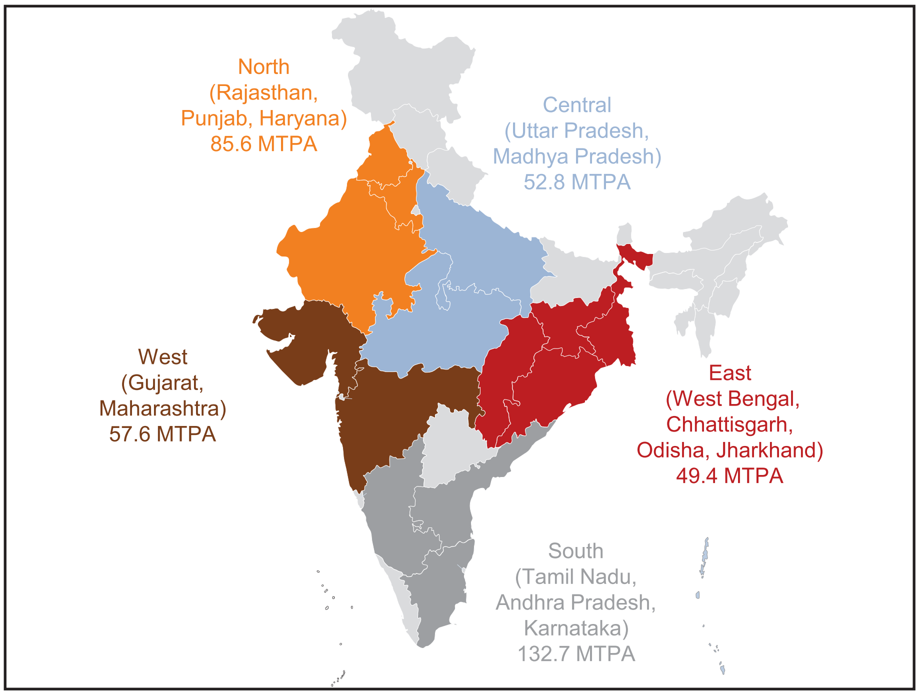


Major Cement Manufacturers in India[3]

1.2 Cluster approach for Indian cement plants

The geology of India is diverse. Different regions of India contain limestone belonging to different geologic periods, dating as far back as the Eoarchean Era. Some of the rocks are very deformed and altered. Other deposits include recently deposited alluvium that has yet to undergo diagenesis. Mineral deposits of great variety are found in the Indian subcontinent in huge quantity. India's limestone belts are also widely spread with different chemical and physical properties in such a way that it impacts the heat of formation and grindability of limestone broadly. Thermal and Electrical Specific Energy Consumption has further impact on location of cement plants due to various favourable conditions like limestone deposit quality, availability and other commercial factors.

A geography wise distribution of major players of Indian cement industry by capacity is as follows:



Location wise cement capacity[4]

[3]Source: Company annual reports - [4]Source : IBEF report March 2018

1.3 Energy Efficiency in Indian Cement Industry

The Indian cement industry is one of the most efficient in the world and continuously adopting the latest technologies for energy conservation. Energy efficiency in the Indian cement industry is already high but still there is a scope for improvement in this area, providing continued use of energy efficient technologies in new plants and old plants. The Indian cement industry should deploy existing state-of-the-art technologies in new cement plants and retrofit existing plants with energy efficient equipment when commercially viable.

A number of plants installed before the 1990s have been modernised to a limited extent by retrofitting with new technologies. However, they need to prioritise bringing specific energy consumption levels closer to the best achieved levels in the Indian industry by further modernization and adoption of best available processes and technologies. The following industry average numbers provide a glimpse of energy efficiency improvement in Indian cement industry in span of 20 years (1995-2015):

- **Improvement in specific electrical energy consumption: 110 kWh/ton cement to 76 kWh/ton cement (32% reduction)**
- **Improvement in specific thermal energy consumption: 807 kCal/kg clinker to 718 kCal/kg clinker (11% reduction)**

The above numbers talk about the overall continuous efforts by the industry, whereas plants with certain efforts has achived next level of performance in terms of energy efficiency.

1.4 Factors favouring Energy Efficiency in Indian cement Industry

Openness in Cement Industry: Cement Industry is known for its technology sharing and openness in the industry. This is benefiting the Industry in replicating the best practices in their organizations without any hesitation.

Positive Market: Cement production accounts for 5.37% of the weight of items included in the Index of Industrial Production (IIP) and is considered in Eight Core Industries comprising 40.27% weightage in the index. Cement production increased by 22.9 per cent in February, 2018 over February, 2017. Its cumulative index increased by 5.7 per cent during April to February, 2017-18 over the corresponding period of previous year indicating a positive growth of the sector on the whole. Thus, making the business more profitable and increasing possibilities for investments in high cost energy efficiency solutions.

Technology Up gradation: The Indian cement industry has been growing at a rapid pace during the late 20th and early 21st centuries; about 50% of Indian cement industry's capacity today is less than ten years old. While building these new cement plants, manufacturers have installed the latest, energy efficient technologies by design. As a result, recent cement plants have achieved high levels of energy efficiency performance.

Increase in Energy Cost: With the electricity tariffs and fuel prices for industry in India being among the highest in the world, implementing such energy efficiency measures at the design stage provides significant advantage to the cement manufacturers by lowering energy and production costs. Increasing energy costs also prompted owners of older manufacturing facilities to adopt gradually the latest energy efficient technologies and improve their energy performance.

Government Policies: Another factor which is enabling energy efficiency movement in India is the Ministry of Power's Bureau of Energy Efficiency (BEE)- Perform achieve and trade scheme. With PAT scheme in place, the cement industry has performed well, reaching new performance levels with resultant savings of 1.44 Million Ton of Oil Equivalent (TOE). The key goal of the scheme is to mandate reduction in specific energy consumption for the most energy-intensive industries and incentivise them to achieve more than their specified specific energy consumption improvement targets. The star rating program for the equipment is also bringing revolutionary changes in the energy consumption levels. New policies towards solid waste management, hazardous waste management and usage of alternate fuels in cement industry has also supported fuel substitution from fossil fuel to greener and efficient fuels.

Technology Suppliers: The most efficient global technologies have been adopted in the major Indian cement plants due to the continuous efforts in bringing the innovation and advancement in the technology. There is good interest shown by international suppliers to enter into Indian market to supply the energy efficient technologies.

Financing Models: Many suppliers are coming up with innovative financing models for higher investment projects and projects with huge replication potential within cement sector. These models are not only limited to BOOT but also ESCO, BOOM, partial profit sharing etc. Best part about these financial models is the high degree of flexibility between buyer and supplier. These models can be worked out on mutual convenience favouring implementation of innovative energy efficiency solutions.

Associations: Industry Associations like CII, CMA and NCCBM are continuously working for the benefit of cement industry. These associations are closely working with government in promoting the growth of the industry.

1.5 CII- Sohrabji Godrej Green Business Centre initiatives for Cement Industry

In the efforts to promote sustainable development of cement sector and demonstrate that green makes good business sense, CII - Sohrabji Godrej Green Business Centre (CII -Godrej GBC) with the support of all the stakeholders is playing a catalytic role in promoting World Class Energy Efficiency initiative in cement industry.

Some of the recent initiatives from CII-Godrej GBC in Indian cement Industry include the following:

1. Development of world class energy efficient cement plants: CII-Godrej GBC has been working with all the major cement plants on the energy efficiency and sustainable front. Significant benefits have been achieved and reported by these units,
2. CII - Godrej GBC is also organizing national and international missions to facilitate the industry to achieve excellence in energy and environment.
3. CII - Godrej GBC is organizing an annual international conference “Green Cementech” to provide the latest information and technology update for the benefit of cement industry.
4. Development of a technology road map to make the Indian cement industry pursue a low carbon growth path by 2050, Eight units are explored for the feasibility of implementation of these technologies and few more expressed their interest in participating this initiative.
5. Facilitating cement plants in pursuing the PAT (Perform Achieve and Trade program of BEE) targets in a cost-effective manner.
6. CII in association with Cement Manufacturers Association (CMA) is working on an initiative to facilitate development of enabling policies and framework by State and Central Pollution Control Boards, to facilitate use of urban & industrial waste as Alternate Fuel & Raw Materials (AFR) in Indian cement industry. The main objective of the project is to accelerate AFR usage in Indian Cement industry.

CHAPTER-2
BENCHMARKING IN CEMENT INDUSTRY

2.0 Purpose of Benchmarking

With the openness and knowledge sharing across the plants Indian cement industry has emerged as a leader in energy efficiency. In an objective to further increase the transfer of knowledge among the industry, CII - Godrej GBC has prepared the benchmarking for the Indian cement Industry. The main intention of the benchmarking study is to continue the knowledge sharing and allow all cement industries to compare their performance with the peers in India, identifying the aspects of their performance which were good, bad or indifferent. This will make the Indian cement plants to perform more in the front of energy efficiency and add momentum to the energy efficiency in the Indian cement industry.

Benchmarking comprises the analysis and reporting of key energy performance Indicators to foster continual energy performance improvements in industry through comparison with internal and external norms and standards. An energy benchmarking analysis generates two important perspectives; it provides an overview of how well a particular industry sector or sub-sector is doing in managing energy performance. Secondly, it enables company participants in a benchmarking exercise to compare the performance of their own plant(s) with the overall industry indicators.

2.1 Approach adopted in benchmarking study

CII - Godrej GBC has prepared a detailed questionnaire involving all sectional parameters starting from crusher to packing plant. While developing questionnaire for the benchmarking the draft format is sent to national and international sector experts for their review and inputs and the same was incorporated in the format. The questionnaire has been sent to more than 140 cement factories for data collection. The majority of plants from all over India have participated in this benchmarking study and different parameters are recorded in various sections from the data provided by plants.

This study describes work with the Indian cement industry to provide a plant-level indicator of energy efficiency and equipment efficiency for assembly plants that produce a variety of products, including ordinary Portland cement (OPC), Portland pozzolana cement (PPC), Portland slag cement (PSC) and other speciality cement products.

Benchmarking provides a more detailed comparison of a particular aspects of operations i.e., energy efficiency, equipment productivity and environmental performance.

The following specific indicators are compared in the benchmarking study:

- Specific thermal energy
- Specific electrical energy in each section
- Clinker to cement factor
- Equipment efficiency
- Equipment productivity
- Equipment reliability
- Auxiliary power consumption in captive power plant
- Environmental performance (GHG emissions)

Greater detail is required to compare the above parameters and to identify the underlying reasons for performance variation between equipment, for e.g., for the variation in thermal energy consumption between cement kilns it is necessary to consider the moisture content of the raw materials, the number of stages of the preheater, the preheater exit temperature etc and lot of other parameters are required to compare the kiln performance.

The cement industries who wish to have an annual or periodic comparison of key performance indicators across the range of cement industry this benchmarking study will be very helpful. The idea of benchmarking study is not only to identify the opportunities to improve energy efficiency but also to understand the underlying factors that impede the implementation of the opportunities.

To address these challenges CII-Godrej GBC has started an innovative and comprehensive benchmarking study. This benchmarking exercise will answer all typical questions which will revolve in the mind of plant team:

- What is my plant's energy performance?
- How do these compare to others in the domestic industry?
- What are the reasons for the differences?
- What opportunities for improvement are available?
- What will be the reductions in emissions possible?
- What is the potential economic advantage that might be realized?

Finally, this report describes the basic concept of benchmarking and the statistical approach employed, more recent experience gained in developing performance-based energy indicators for the Indian cement industry.

CHAPTER-3
BENCHMARKING IN VARIOUS SECTIONS

3.1 SINGLE STAGE CRUSHER

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Overall SEC	kWh / MT Limestone	0.70	0.72	0.73	0.84	0.92	1.02	1.20	1.32	1.33	1.44
Material hardness	-	Soft	Medium	Medium	Hard	Hard	Medium/ Hard	Hard	Hard	Medium/ Hard	Medium
Passing	%	96	89	92		80	95	95	100	92	
Operating output	TPH	500	900	430	909	643	1245	900	1550	1800	1296
Material moisture	%	8	<10	10-12	1	< 1	0.5-1.0	4-6	< 4	0.5-1.0	2-3
Specific power consumption	kWh / MT Limestone	0.70	0.72	0.73	0.84	0.92	1.02	1.20	1.32	1.33	1.44
Crusher Drive	kWh / MT Limestone	0.50	0.36	0.38	0.45	0.44	0.53	0.67	0.46	0.49	0.36
Bag filter Fan	kWh / MT Limestone		0.32			0.10	0.49	0.53	0.85	0.47	1.08
Total (Crusher alone)	kWh / MT Limestone		0.68	0.38							
Pre Blending	kWh / MT Limestone		0.04	0.35							

3.2 DOUBLE STAGE CRUSHER

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
Overall SEC	kWh / MT Limestone	0.65	0.91	0.93	1.23	1.46	2.10	2.30
Material hardness	-	Soft	Medium	Hard	Soft	Hard	Medium/Hard	Medium
Passing	%	85	93	100		100	90	
Operating output	TPH	950	750	716	475	325	800-950	182
Material moisture	%	13	12	1	2	1	4	1
Specific power consumption	kWh / MT Limestone	0.65	0.91	0.93	1.23	1.46	2.10	2.30
Crusher Drive	kWh / MT Limestone	0.45	0.65	0.60	0.87	1.20	1.37	1.70
Bag filter Fan	kWh / MT Limestone				0.05		0.09	0.20
Compressor	kWh / MT Limestone				0.04		0.09	0.15
Total (Crusher alone)	kWh / MT Limestone	0.45	0.26		1.19		1.56	
Pre Blending	kWh / MT Limestone	0.20			0.03			

3.3 RAW MILL - VRM

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Overall SEC	kWh / MT raw meal	12.8	13.3	13.5	13.9	13.8	14.6	14.7	15.0	15.4	15.9
Material hardness	-	Medium		Medium	Medium	Hard		Medium	Soft	Medium	Hard
Residue, 90µ	%	15	20	17	11	12	4	21	18		12
Operating output	TPH	450	320	230	480	290	236	510	400	560	330
Feed Material moisture	%	4		2	2	2	6	4	13	1	2
Mill DP	mmwc	420	740	920	780	750	788	930	600	832	480
Mill model		MPS 5000 B	L38.4+4	LM30.3+3	Loesche	LM 46.4			ATOX42.5	MP 5000	ATOX42.5
Mill fan flow	km^3/hr	540	647	345	835	480	406	810	800	997	765
Cyclone pressure drop	mmwc	60	100	160	70	50	136	80	90	87	50
False air in the circuit	%	11		23	18	20	23	15	25	8	20
SEC											
Mill drive	kWh / MT raw meal	5.9	6.0	3.8	8.1	6.1	6.5	6.8	5.5	8.3	6.3
Mill fan	kWh / MT raw meal	4.1	6.4	6.3	4.5	6.1	6.1	6.4	7.7	6.3	7.7
Aux	kWh / MT raw meal	2.7	0.9	3.3	1.4	1.7	2.1	1.4	1.8	0.9	1.9

3.4 Raw Mill - Ball Mill/HRPG Grinding

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Overall SEC	kWh / MT raw meal	16.5	17.2	17.9	18	19.2	20.6	21.1	23.1	25.1	25.9
Material hardness	-	Hard		Soft	Medium	Hard	Medium			Hard	
Residue, 90µ	%	10	17	14	18	30	21	32	12	14	23
Operating output	TPH	160	295	185	240	145	130	250	70	80	170
Feed Material moisture	%	2	3	2	4	1	1	4	1	7	4
Velocity inside mill	m/sec	1.2		0.6		0.7	1.5	1.9	1.9	1.5	2.8
Mill spec	Dia x length	3 x 10	No ball mill	4.2 x 14.1		4.2 x (4.5 + 2.8)	4.6 x 8.7, 4.6 x 5.1	5.0 x 9.8	3.4 x 12, 3.4 x 7.6	3.8 x 9.5	4.6 x 11.25
Sep fan flow	km^3/hr		585		450	235		125			174
Cyclone pressure drop	mmwc	120	70	70	100	85	35	-		350	300
Sep loading	Kg/m^3				1.1	0.8		0.7		1.1	2.1
Circulating load				2.0	2.3	1.2	1.9	2.6	2.5	1.3	2.5
SEC											
Mill drive	kWh / MT raw meal	6.3		12.7		12.4	18.5	13.5	17.9	18.9	19.3
RP	kWh / MT raw meal	7.6	8.5		10			3.8			2.1
Mill Sep fan	kWh / MT raw meal		5.5	1.4		2.7	1.5	0.7		2.9	4.1
Mill vent fan	kWh / MT raw meal	0.2		1.8		0.3	0.6				
Sept vent fan	kWh / MT raw meal	3.1						1.9			
Sep fan for RP	kWh / MT raw meal				4						

3.5 Coal Mill VRM

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9
Overall SEC	kWh/MT	23.9	26.9	27.2	28.4	29.3	30.2	30.3	37.6	40.9
Mill Type		VRM	VRM	VRM	VRM	VRM	VRM	VRM	VRM	VRM
Coal Composition	%	Imported Coal 100 %	Imported Coal 30 %	Imported Coal 100 %	Indian Coal C & D Grade	Pet coke 40 %, Indian Coal 30 %, Imported coal 30 %	Imported + Indian	Pet coke 100 %	Pet coke	Pet coke 100 %
Mill Output	TPH	34	30	33	75	81	35	25	25	14
SEC										
Mill Drive	kWh/MT	14.5	8.8	10.7	9.9	14.5	13.3	13.1	12.4	15.1
Mill fan	kWh/MT	5.9	8.8	12.7	8.4	11.9	10.9	11.5	19.2	18.4
Aux	kWh/MT	3.5	9.3	3.8	0.8	2.9	5.9	5.7	6.0	7.4

3.6 Comparison of five stages preheaters

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Clinkerisation	kWh/MT Clk	19.6	16.3	18.3	18.1	21.8	22.1	23.0	23.4	24.4	26.1
Upto clinkerisation	kWh/MT Clk	45.1	49.9	46.0	52.3	53.4	55.9	57.2	58.4	69.6	64.5
Kiln output rated	TPD	5500	4500	4000	4000	4000	3200	3850	3800	1200	2800
Kiln output operating	TPD	7140	4700	4600	5000	4800	3500	4400	4300	1300	2800
PH type	ILC / SLC	ILC	ILC	ILC	ILC	ILC	ILC	ILC	ILC	ILC	SLC
No of PH strings		Double	Single	Single	Single	Single	Single	Single	Single	Single	Single
Calciner exit O_2 / CO	%	0.8	1.8		0.9	2.5	1.5/0.00		0.9	1	1.9
PH exit temp	^0C	281	260	335	307	305	333	338	315	318	320
PH exit flow	Nm^3/kg clinker	1.36	1.39	1.46	1.44	1.53	1.58	1.5	1.43	1.78	1.61
PH exit pressure	mmwc	-573	-380	-500	-410	-520	-420	-540	-520		-760
Pressure at PH fan inlet	mmwc	-611	-395	-585	-445	-580	-430	-560	-590	-570	-780
False air across PH	%	9	4		5	5	8	6	13	13	9
Speed control for PH fan		SPRS	VFD	GRR	VFD	GRR/SPRS	VFD	VFD	GRR	GRR	GRR
Speed control for Kiln Bag house fan		SPRS	MV VFD	VFD	VFD	GRR/SPRS	VFD	VFD	GRR	VFD	VFD

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Kiln Bag house fan flow	Nm^3/kg clinker	2.1	2.2	2.0	2.5	1.2	2.0	2.5	2.4	3.3	1.8
Kiln Bag house DP	mmwc	110	100	110	80	110	115	100	125	120	130
Kiln Bag house inlet pressure	mmwc	-50	-55	-60	-60	-70	-50	-60	-55	-60	-65
Kiln Bag house type		RABH	RABH	RABH	Hybrid	RABH	RABH	RABH	RABH	RABH	ESP
Kiln size	Dia x Length	4.75x74	4.35 x67	3.95 x 65		4.15 x 64	3.95 X 62	3.95 x 62	3.95 x 61	3.2 x 48	3.8 X 60.75
Volumetric loading	TPD/m^3	6.1	5.7	5.8	5.5	7.0	5.0	5.7	7.0	4.3	4.5
Thermal loading	$Mkcal/hr/m^2$	3.6	4.3	4.0	4.4	4.8	3.3	5.8	5.0	2.6	2.2
Phase density – PC firing	kg coal / kg air	2.8	2.5	2.0	2.8	4.3	2.7	3.1	5.5	2.5	3.4
Phase density – Kiln firing	kg coal / kg air	2.5	1.2	1.0	3.1	1.2	2.6	2.3	1.2	1.4	1.9
Type of cooler			3rd Gen (SF Cross Bar 4x5)	3rd Gen		SF Cross Bar with static /3rd Gen	CIS/CFG GRATE COOLER	3rd Gen	(3x5)SF-Cross Bar Cooler	Grate Cooler	Grate-With CIS-MFR
Cooling air flow	Nm^3/kg clinker	1.62	1.77	1.72	1.70	1.75	2.20	1.90	1.80	2.20	2.19
Clinker temp	^0C	139	125	165	135	140	120	173	180	170	130
Cooler water spray	m^3/hr	16.9	1.2	5.5			4.5	6.0	1.4	3.7	5.0
Loss in PH gas	kcal / kg clinker	136	126	178	131	162	184	182	140	185	176
Loss in Cooler vent	kcal / kg clinker	74	99	72	105	85	105	73	109	119	87
Loss in clinker	kcal / kg clinker	25	25	31	26	39	27	32	35	33	34
Loss in cooler water spray	kcal / kg clinker	21	5	16	-	0	-	21	2	2	23
Thermal SEC	kcal / kg clinker	680	707	709	707	715	732	729	710	780	770
SEC											
PH fan	kWh/MT Clk	6.4	3.6	6.3	4.4	6.8	6.8	8.2	7.4	8.5	11.6
RABH fan	kWh/MT Clk	2.5	1.7	2.0	0.9	3.1	3.7	3.5	3.9	3.3	2.2
Cooler fans	kWh/MT Clk	3.9	5.4	5.8	5.4	4.8	4.9	5.0	5.1	3.7	6.3
Cooler vent fan	kWh/MT Clk	0.6		0.1	0.4	0.2		0.2	1.1	1.3	0.4
Kiln drive	kWh/MT Clk	1.5	1.4	1.4	1.5	1.7	1.4	1.6	3.9		1.3
Kiln feed	kWh/MT Clk	1.2	1.6	2.6	1.1	1.4		2.9	0.7	0.6	1.3
Aux	kWh/MT Clk		0.4			3.8	5.1		0.8	1.8	3.1

3.7 Comparison of six stages preheaters

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Clinkerisation	kWh/MT Clk	17.1	19.9	23.7	24.3	24.7	19.6	25.8	26.2	26.9	27.5
Upto clinkerisation	kWh/MT Clk	51.6	66.3	53.7	63.2	61.3	50.9	70.7	54.5	58.5	74.2
Kiln output rated	TPD	7000	4500	3800	5500	3300	4500	6500	4200	7600	8000
Kiln output operating	TPD	7000	5000	4700	5750	3700	5000	7810	4350	6800	9558
PH type	ILC / SLC	ILC	ILC	ILC	ILC	ILC	ILC	SLC	ILC	SLC	Pyroclone, KHD
No of PH strings		Double	Single	Single	Two string	Single	Single	Double	Single	Double	Double
Calciner exit O_2 / CO	%	2.1-2.9	3.2	2.1	1.5-2.5	2.8	2.2	1.5-2.0	2.0	1.5 -2.0	1.5-2.0
PH exit temp	^0C	303, 310	295	274	270	290	260	290-310	290	300 - 315	255-260
PH exit flow	Nm^3/kg clinker	1.39	1.44	1.62	1.60	1.50	1.42	1.47	1.46	1.57	1.45
PH exit pressure	mmwc	-390, -385	-840	-605	-480,-550	-510	-410	-600	-450	-670, -740	-840
Pressure at PH fan inlet	mmwc	-465, -470	-940	-675	-600	-555	-475	-670	-465	-690, -760	-950
False air across PH	%	10	7	9	12	11	9	8	8	9	8
Speed control for PH fan		VFD	SPRS	VFD	VFD	GRR	VFD	SPRS	VFD	SPRS & GRR	SPRS
Speed control for Kiln Bag house fan		VFD	SPRS	VFD	VFD	SPRS	VFD	SPRS	VFD	SPRS & GRR	SPRS
Kiln Bag house fan flow	Nm^3/kg clinker	2.4	1.8	2.4	2.2	2.1	1.8	2.5	2.2		2.0
Kiln Bag house DP	mmwc	-	90	110	130	120	90	110	120	70	110
Kiln Bag house inlet pressure	mmwc	-40	-50	-70	-60	-55	-60	-65	-50	-50	-55
Kiln Bag house type		RABH	RABH	RABH	Pulse jet	RABH	RABH	RABH	RABH	Pulse jet	RABH
Kiln size		5.5 x 86	4.4 x 65	4.55 x 56	4.75 x 74	4.15 x 64	4.35 x 67	4.75 x 75	4.15 x 64	5.5 x 75.3	5.8 x 85
Volumetric loading	TPD/ m^3	3.6	6.1	6.2	5.4	5.2		7.1	5.5	6.7	5.0
Thermal loading	Mkcal / hr /m^2	3.6	4.6	4.3	4.2	3.9	4.4	3.9	4.2	4.7	3.0
Phase density – PC firing	kg coal / kg air	4.2	2.6	2.7	3.5		2.7	3.0	5.7	2.1	2.5
Phase density – Kiln firing	kg coal / kg air	2.3	1.1	1.6	2.9		1.9	2.0	2.8	2.2	1.5
Type of cooler		Crossbar SF 5 x 6	Poly Track hydraulic 3rd Gen	Crossbar SF	3rd Gen	Grate with static	Crossbar SF	Grate	Crossbar SF	Polytrack	Pyrofloor
Cooling air flow	Nm^3/kg clinker	1.53	1.82	1.80	1.65	2.19	1.78	1.72	1.95	1.65	1.75
Clinker temp	^0C	171	110	170	120	120	150	130	120	140	150

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Cooler water spray	m^3/hr	15	10	9	3	12	0	7	7	1	18
Loss in PH gas	kcal / kg clinker	155	140	138	145	155	134	135	155	155	127
Loss in Cooler vent	kcal / kg clinker	73	100	98	100	103	120	110	108	105	110
Loss in clinker	kcal / kg clinker	32	21	24	23	23	27	24	27	26	23
Loss in cooler water spray	kcal / kg clinker	7		6	7	13			6		
Thermal SEC	kcal / kg clinker	683	698	705	718	705	685	686	705	718	695
SEC											
PH fan	kWh/MT Clk	4.1	5.5	7.9	3.4	9.0	4.7	3.7	5.4	3.1	4.3
Calciner Fan	kWh/MT Clk				3.4			5.9		7.7	4.3
RABH fan	kWh/MT Clk	1.5	2.6	2.7	3.9	2.1	1.5	2.7	1.7	2.1	2.6
Cooler fans	kWh/MT Clk	3.8	5.4	13.2	3.5	6.2	5.1	5.8	5.1	6.1	9.8
Cooler vent fan	kWh/MT Clk	0.3	0.2	0.5	1.2	1.0	0.6	1.1	0.5	0.4	0.7
Kiln drive	kWh/MT Clk	1.9	1.7	1.9	1.7	1.3	1.4	2.5	1.7	2.1	2.0
Kiln feed	kWh/MT Clk	0.4		0.4	0.6		1.8	3.9	0.9		3.1
Aux	kWh/MT Clk	2.7	4.8		6.2	5.2	6.1			5.8	

3.8 Cement Mill - VRM

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Overall SEC	kWh/MT Cement	29.9	25.0	25.9	25.3	28.0	29.1	29.2	29.9	33.2	31.9
Mill model		LM 56.3+3	LM 56.3+3	MP5600 BC	LOESCHE 56.3+3	LM 53.3.3	OK 36.4	OK 36.4	LOESCHE 56.3 + 3	OK 42.4	LM 56.3+3
Product Variety		PPC / OPC	PPC	OPC/PPC	OPC/PPC	OPC/ PPC / PSC	OPC/ PPC / PSC	OPC/ PPC / PSC	OPC/PPC	PSC/PPC	PSC
Rated output	TPH	250 in PPC With 4000 Blaine	250	300 @ 3600 blaine	285 in PPC With 3800 Blaine	170 OPC/ 135 PSC/ 215 PPC	185 OPC /190 PSC/150 PPC	170	270 /305	215 TPH PSC	220 TPH PSC
Operating output	TPH	285 TPH-PPC 260 TPH-OPC	260	305 @ 3550 Blaine	220 OPC 285 PPC	215 OPC/ 179 PSC/ 177 PPC	178 OPC /183 PSC/ 126 PPC	160	245 /310	230 PSC 330 PPC	260 with 3680 blaine

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Mill DP	mmwc	550	500	200 to 220/ 150 to 160	395 OPC 390 PPC	300	280	5 50	580	475 PSC 490 PPC	373
Mill fan flow	km³/hr	650	617	900	548 OPC 560 PPC	630	570-580	487	763	715 PSC 800 PPC	594
Bag filter DP	mmwc	100	80	175	125	110	125	155	100	105	140
Mill fan head	mmwc	730	700	600	610	810	660	800	780	670	650
% Fly ash / % slag	%	33	35	32	26	31/42	28/40	26/45	31	33/66	62
SEC											
Mill drive	kWh/MT Cement	17.4	13.9	16.3	17.6 OPC 14.5 PPC	16.1	16.2	16.5	16.6	21.0 PSC 15.5 PPC	21.2
Mill fan	kWh/MT Cement	7.1	8.7	6.8	6.1 OPC 4.9 PPC	6.3	8.0	8.5	8.7	8.1 PSC 7.2 PPC	6.1
Aux	kWh/MT Cement	5.2	2.4	2.8	1.8	5.7	5.1	4.2	4.6	4.5	5.2

3.9 Cement Mill - Ball Mills (Closed Circuit)

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Overall	kWh/MT Cement	27.1	27.2	27.6	28.5	28.8	29.2	29.4	30.5	31.8	29.1
Rated capacity	TPH	150	133	200	105	105			200	115	80/90
Operating capacity	OPC/PPC TPH	203 PPC	143/186	225	116/122	116/120	195	205	200	105	110
Ball mill dimension		4.6 x 17.1	4.4 x 13.5	5 x 15	4 x 11.5	4.2 x 13.5			4.8 x 15	3 x 10	3.8 x 14.65
Product Variety		PPC	OPC/PPC	PPC	OPC/PPC	OPC/PPC	PPC	PPC	OPC	OPC / PPC	PPC
Mill ventilation velocity	m/sec	1.4	1.1	1.2		1.4			1.1	1.2	0.4
Product Blaine	cm²/gm	3200	2800/ 3800	3200	3000 /3300	3000 /3300			2700	3000	4100
Product residue, +45µ	%	15	OPC : 24 PPC: 22	19 - 20	<25.0	<20.0			+45 micron: 14.5%	15.6	+45 micron: 9.7%
Mill discharge residue, +45µ	%	39	OPC : 55 PPC: 45	45 - 50	<35-40	<35-40	46.4	36.2	+45 micron: 40%	60.5	+45 micron: 44.3%
Mill discharge Blaine	cm²/ gm	200	240/305	2000	1800 to 2200 /1800 to 2400	1800 to 2200 /1800 to 2400			2040	130	1990
Circulating load	%	2.01	1.5 to 1.8	1.0 – 1.5	1.2-1.5	1.2-1.5			1.6		2.8

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Cyclone pressure drop	mmwc		170	200	200			90		130	70
% fly ash / % slag	%	35	30	30	28	28	35	35	-	26	30
Sep fan flow	km^3/hr	418	160	275		155	241	255	248	210	140
Sep reject residue, +45μ	%	63	87	77			81	88	85		65
SEC											
Mill drive	kWh/MT Cement	21.9	21.6	22.6	24.5	25.0	21.2	21.2	25.1	9.1	25.4
Sep fan	kWh/MT Cement	1.3	2.2	2.2	1.5	1.5	2.1	1.9	2.4	4.8	2.2
Mill vent fan	kWh/MT Cement	0.2	-	0.2	0.4	0.3	0.3	0.2	0.1	0.3	0.2
Sep vent fan	kWh/MT Cement	0.7	2.6	0.2			0.2	0.1	0.4		0.4
Dry fly ash unloading	kWh/MT Cement		1.0	0.1	1.9	1.9	2.8	3.1	0.5		0.4

3.10 Cement Mill - Ball Mill with Pregrinder

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
Overall	kWh/MT Cement	23.70	24.70	25.30	25.30	25.40	26.30	30.10
Rated capacity	TPH	225	161	170	225	225	225	165
Operating capacity	TPH	250	201	185/ 210	250	250	250	165-175
Ball mill dimension		4.6 x 14.5	4.2 x 11	3.8 x 11.6	4.6 x 14.5	4.6 x14.5	4.4 x 16	3.8 x 11.5
Product Variety		OPC / PPC	OPC/PPC	OPC/PPC	OPC / PPC	OPC / PPC	OPC / PPC	OPC/PPC
Mill ventilation velocity	m/sec		1.0	0.9				0.6
Product Blaine	cm^2/gm	2600/3500	2850	2800/3800	2600/3500	2600/3500	2600/3500	2750/3300
Mill discharge residue, +45μ	%		20	29				24
Mill discharge Blaine	cm^2/gm	2300	2500	OPC 1682 PPC 1921	2300	2400	2300	2500
Circulating load	%	2.5	2.0	3.0	2.5	2.4	2.4	1.5
% fly ash / % slag	%	32	31	28	32	32	32	32

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
Sep fan flow	km^3/hr		251	165				108/244
Sep reject residue, +45µ	%		35	22				18
SEC								
Mill drive	kWh/MT Cement	11.2	11.2	8.3	10.7	11.0	12.2	12.5
HRGS	kWh/MT Cement	1.53	4.92	8.95	1.58	2.19	1.50	7.50
Sep fan	kWh/MT Cement	1.68	2.84	1.45	1.80	1.88	1.60	2.60
Mill vent fan	kWh/MT Cement	0.38	0.82	0.28	0.31	0.15	0.30	0.30
Sep vent fan	kWh/MT Cement			0.70				0.40
Dry fly ash unloading	kWh/MT Cement			0.50				

3.11 Packing Plant

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
SEC	kWh/MT Cement	0.7	1.2	1.2	1.2	1.3	1.4	1.4	1.4	1.9	1.9
Rated output	TPH	180	240	80	90	3x180	320	4x90	2x120	265	220
Operating output			140	80	89	200	200			250	200
No of spouts		12	16	6	6	3 x 12	8	6	12	16	16
Bag filter fan volume (m^3/hr)		18,100	44,000	16,700	19,500	34,600	12,000			38,400	
BF fan	kWh / spout		4.7	1.7	3.0	3.7		3.5	2.4	1.5	
Compressor pressure	bar		6.0	6.7	6.0	6.7	5.0	5.7	5.8	5.0	

3.12 Utilities

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Kiln capacity	TPD	4000	9558	7810	3800	1200	3250	2800	2800	3600	11250
Grinding capacity	TPH	270	565	402	200	40	210				510
Upto clinkerisation	kWh / MT Clk	0.4	0.9	1.3	1.3	1.3	1.9	2.1	2.2	2.2	2.7
Cement grinding & packing	kWh / MT Clk	0.5			1	1.2	0.7	1.4		0.8	1.1
Avg op pressure for HP compr	bar	6.0	6.0	6.0	6.7	6.7	6.0			6.7	5.8
Comp pr for fly ash unloading	bar	2.0		2.5	0.4	0.4	3.5			3.0	2.5
Fly ash unloading SEC	kWh / MT Clk				0.2	0.2	0.5				0.5
Aux BF - pyro section	Nos	5	11	9	27	11	10	6	4	6	
Aux BF - cement section	Nos	14	32	22	16	5	12	10	10	9	
Aux BF - pyro section	kWh / MT Clk	0.4			1.5	2.2	0.5	0.7	0.2	0.3	
Aux BF - cement section	kWh / MT Cement	0.7			1.1	1.6	1.2	1.2	0.6	0.6	

3.13 Waste Heat Recovery Boiler

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant 3
1	Installed capacity	MW	5	5	5
2	Operating capacity	MW	4	5	5
3	Type of technology		Rankine cycle	Rankine cycle	Rankine cycle
4	Clinker production	TPD	4600	5060	5060
5	Waste heat source (PH/Cooler/Both)		Both	Both	PH
6	Boiler type		Water tube	Water tube	Water tube
7	PH boiler inlet gas temperture	^{o}C	302	306	308
8	PH boiler outlet gas temperture	^{o}C	209	203	200
9	AQC boiler inlet gas temperture	^{o}C	400	430	-
10	AQC boiler outlet gas temperture	^{o}C	180	120	-
11	Condenser type (Water/Air cooled)	%	Air cooled	Air cooled	Air cooled
12	Pressure drop across PH boiler	mmWc	145±5	100±5	110±5
13	Pressure drop across AQC boiler	mmWc	105±5	45±5	-
14	Auxiliary power consumption (APC) by WHR plant	%	7.6	7.2	7.4
15	Average power generation per ton clinker	kWh/MT clinker	18.58	17.9	18.3
16	Water consumption	m^3/MW	0.15	0.21	0.17
17	False air across PH boiler	%	4	5	7

3.14 Captive Power Plants

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
APC	%	7.9	8.5	8.9	9.1	9.3	9.5	9.5	9.6	9.6	9.7
Heat rate	Kcal /kWh	3250	3327	3040	3348	3018	3490	2932	3495	3035	3074
Installed capacity	MW	15.0	30.0	9.0	15.0	17.5	12.5	25 x 2	15.0	17.5	17.5
Type		AFBC	AFBC	AFBC	AFBC	AFBC	AFBC	CFBC	AFBC	AFBC	AFBC
PLF	%	82.3	68.5	88.5	65.0	84.0	88.0	97.4	64.0	77.8	85.0
Coal CV	Kcal / kg	5270	5500	3200	4060	3210	4940	6475	4980	3175	3205
LOI - Bed ash	%	20.1	19.4		5.1		0.5	3.7	14.2		
Inst header pressure	Kg/cm^2	5.5	5.5	6.0	5.2	6.0	6.0	6.4	5.5	6.0	6.0
Fly ash tpt pressure	Kg/cm^2	4.5	4.0	5.0	3.5	5.0	4.5	5.2	4.0	5.0	5.0

3.15 Alternate Fuel and Raw Material

Sr. No.	Plant	Installed Capacity		Thermal Substitution Rate	Specific Heat
		Clinker (MTPA)	Cement (MTPA)	%	Kcal/kg of clinker
1	Plant 1	2.0	2.8	26.4	703
2	Plant 2	3.3	5.0	22.4	714
3	Plant 3	1.6	2.5	21.3	704
4	Plant 4	3.1	4.5	17.5	769
5	Plant 5	2.3	3.4	13.7	797
6	Plant 6	1.1	1.3	13.7	853
7	Plant 7	1.0	1.4	13.6	734
8	Plant 8	1.2	1.9	10.8	714
9	Plant 9	1.0	1.7	8.3	745
10	Plant 10	4.3	5.4	8.2	718
11	Plant 11	2.0	2.8	8.1	713
12	Plant 12	5.4	5.8	8.0	736
13	Plant 13	2.8	4.5	8.0	712
14	Plant 14	4.6	4.6	6.8	704
15	Plant 15	1.0	1.5	6.3	725
16	Plant 16	8.4	8.0	6.2	701
17	Plant 17	2.0	1.6	6.1	707
18	Plant 18	1.3	1.9	5.6	708
19	Plant 19	3.1	4.0	5.4	688
20	Plant 20	3.3	3.5	5.0	710

CHAPTER-4
EXTRACT & OUTCOME OF THE STUDY

The ultimate objective of the study is to identify the best specific energy consumption levels where the best plants are operating and the same was compared in the earlier sessions. The outcomes of the study are recorded in the tables below:

4.1 SEC Upto Clinkerization

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Plant Capacity Cement	MTPA	1.86	2.25	3.30	4.65	3.40	3.00	2.50	3.20	3.05	6.10
Upto clinkerisation	kWh/TClinker	43.3	45.4	47.7	47.7	48.4	50.3	50.9	51.2	52.8	53.7

4.2 Overall Best SEC

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Plant Capacity Cement	MTPA	1.60	2.25	3.00	3.40	3.05	1.86	3.80	2.50	1.20	5.00
Overall SEC	kWh/T Cement	63.9	65.7	66.1	66.3	67.7	68.7	69.8	70.6	71.4	71.9

4.3 Five Stage Preheater Thermal SEC

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Plant Capacity	MTPA	3.00	1.92	1.70	3.07	8.60	5.50	2.10	1.30	1.00	1.40
Thermal SEC	Kcal/kg Cl	682	709	710	710	714	715	725	729	732	735

4.4 Six Stage Preheater Thermal

Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
Plant Capacity	MTPA	3.00	3.80	2.25	3.50	6.10	1.86	3.20	4.65	3.05	2.50
Thermal SEC	Kcal/kg Cl	676	677	682	685	688	690	695	699	699	701

4.5 Best Figures from all sections

The best figures which are operating in different sections in different plants is summarized below:

Sr. No.	Section	kWh/MT
1	Single Stage Crusher	0.70
2	Double Stage Crusher	0.65
3	Raw Mill - VRM	11.10
4	Raw Mill - Ball Mill	16.50
5	Coal Mill - VRM	23.90
7	Five Stage Preheater - Clinkerisation	16.28
8	Six Stage Preheater - Clinkerisation	17.05
9	Five Stage Preheater - Upto Clinkerisation	45.38
10	Six Stage Preheater - Upto Clinkerisation	43.32
11	Cement Mill - VRM	21.92
12	Cement Mill - Ball Mill Closed Circuit	27.07
13	Cement Mill - Ball Mill with HPRG	23.20
14	Packing plant	0.65
15	Utilities	0.40
16	Overall Electrical Specific Energy Consumption	63.91

Sr. No.	Section	kcal/kg Clinker
17	Thermal Specific Energy Consumption for 5 stage Preheater	682
18	Thermal Specific Energy Consumption for 6 stage Preheater	676

4.6 Best Available Technology

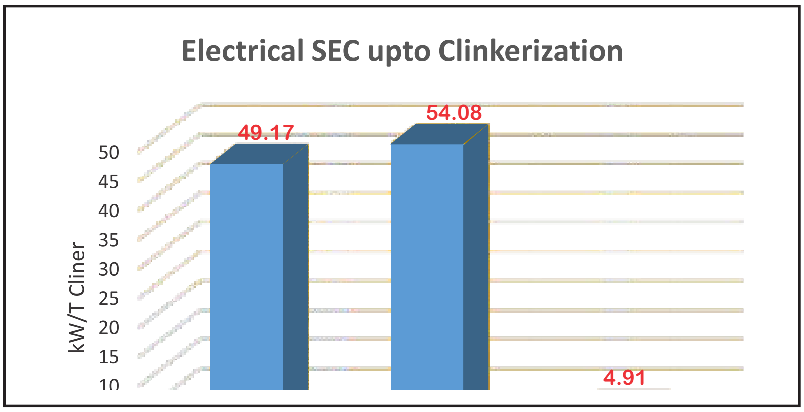
If any of the single plant is operating with all these best figures by adopting all possible latest technology in all sections then the typical energy levels will be at par compared to the peers in the industry:

Section	5 Stage Preheater		6 Stage Preheater	
	kWh/Ton of material	kWh/Ton of cement	kWh/Ton of material	kWh/Ton of cement
Crusher	0.65	0.96	0.65	0.96
Raw mill-VRM	12.8	18.2	12.8	18.2
Coal mill-VRM	23.9	3.1	23.9	3.1
Pyro	16.3	15.5	17.1	16.2
Up to clinkerisation (kWh/MT of Clinker)		37.8		38.5
Cement - VRM	21.9	21.9	21.9	21.9
Packing Plant		0.65		0.65
Utilities & Others		0.85		0.85
Up to cement (kWh/MT of cement)		61.2		62.1

4.7 Gap Analysis and Potential for Viable Improvements

Electrical SEC Analysis up to clinkerisation

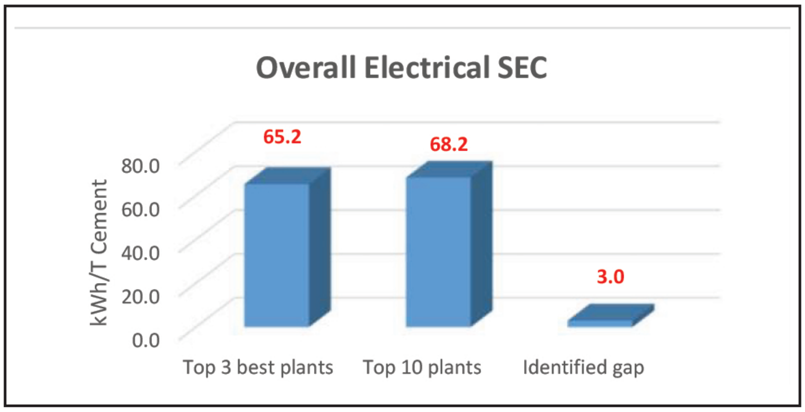
Plant composition	Average SEC kWh/MT Clinker
Top 3 plants	49.17
Top 10 plants	54.08
Identified gap	4.91
Total potential available in 7 plants	3.53 per plant



Saving Potential & Scope for investment	
Power Cost (INR/kWh)	4.5
Annual Operation (hrs/yr)	8000
Gap (kWh/T Clinker)	3.53
Potential @80%	2.82
Clinker Production (4500 TPD)	187.5
Annual Saving Potential (INR Lakh)	191
Target Payback Period (Years)	2
Scope for Investment (INR Lakh)	381

Overall Electrical SEC Analysis

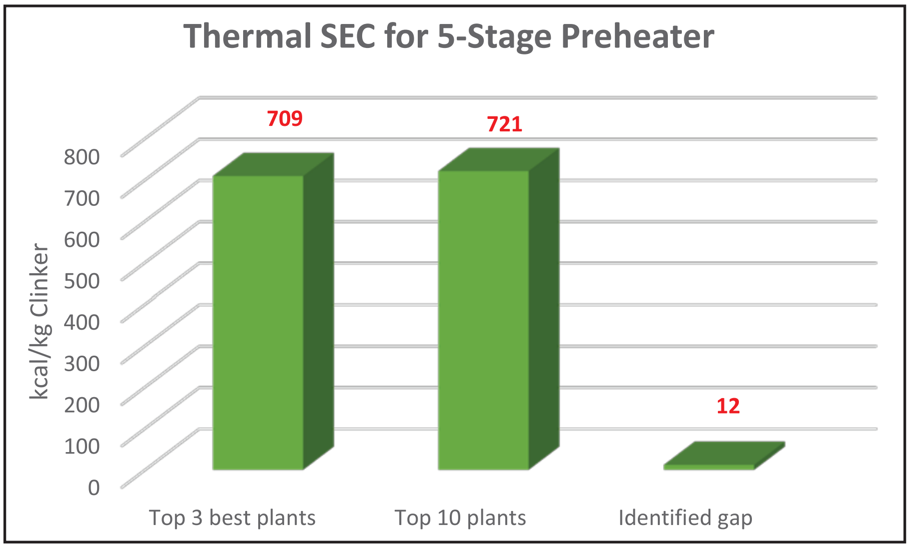
Plant composition	Average SEC kWh/MT Cement
Top 3 plants	65.22
Top 10 plants	68.21
Identified gap	2.99
Total potential available in 7 plants	3.0 per plant



Saving Potential & Scope for investment	
Power Cost (INR/kWh)	4.5
Annual Operation (hrs/yr)	7200
Gap (kWh/T Cement)	2.99
Potential @80%	2.39
Cement Production (6000 TPD)	250
Annual Saving Potential (INR Lakh)	194
Target Payback Period (Years)	2
Scope for Investment (INR Lakh)	388

Thermal SEC analysis for 5-Stage Preheater

Plant composition	Average SEC kcal/kg Clinker
Top 3 plants	709
Top 10 plants	721
Identified gap	12
Total potential available in 7 plants	12 per plant

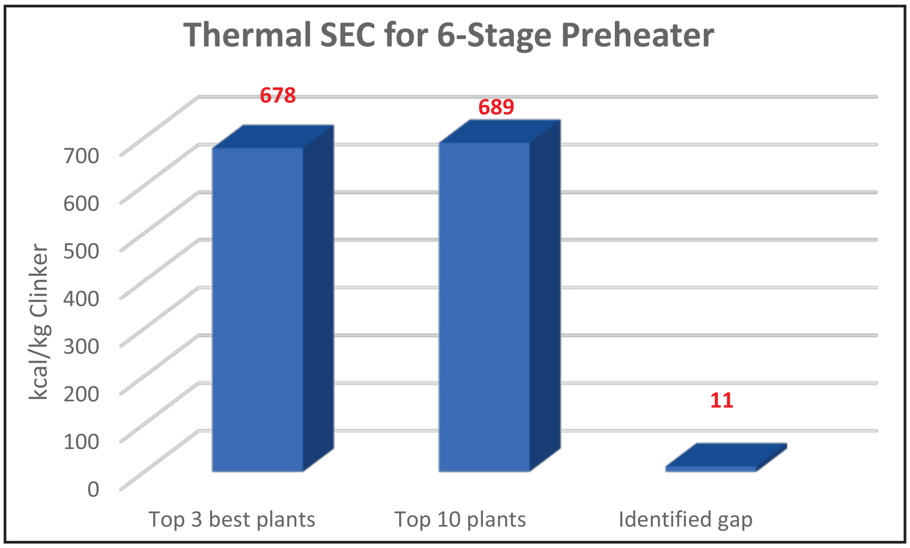


Saving Potential & Scope for investment	
Thermal Cost (INR/Million kcal)	950
Annual Operation (hrs/yr)	8000
Gap (kcal/kg Clinker)	12
Clinker Production (4500 TPD)	187.5
Savings from 1 kcal/kg Clinker improvement (INR Lakh)	14.25
Annual Saving Potential (INR Lakh)	171
Target Payback Period (Years)	3

Scope for Investment (INR Lakh)	513

Thermal SEC analysis for 6-Stage Preheater

Plant composition	Average SEC kCal/kg Clinker
Top 3 best plants	678
Top 10 plants	689
Identified gap	11
Total potential available in 7 plants	11 per plant



Saving Potential & Scope for investment	
Thermal Cost (INR/Million kcal)	950
Annual Operation (hrs/yr)	8000
Gap (kcal/kg Clinker)	11
Clinker Production (4500 TPD)	187.5
Savings from 1 kcal/kg Clinker improvement (INR Lakh)	14.25
Annual Saving Potential (INR Lakh)	157
Target Payback Period (Year)	3
Scope for Investment (INR Lakh)	470

CASE STUDY
USING BENCHMARKING STUDY TO REVEAL HIDDEN OPPORTUNITIES

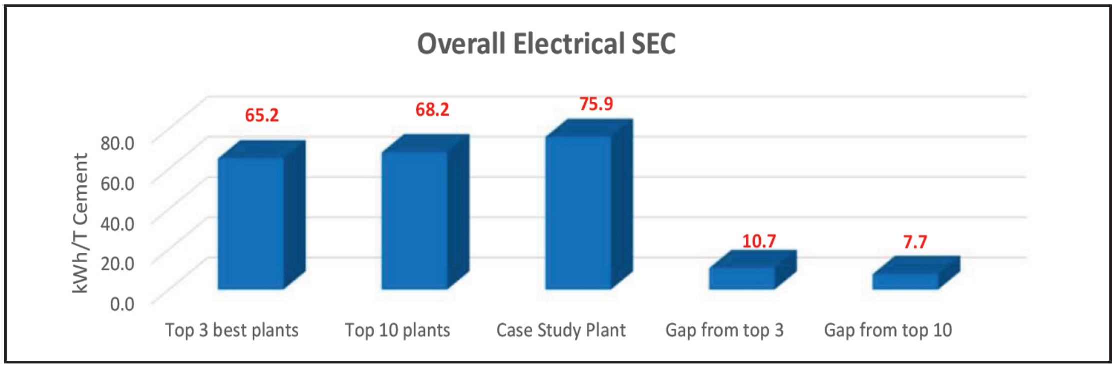
Details of Case study plant

Cement Production Capacity	: 4.60 MTPA
Electrical Specific Energy Consumption	: 76 kWh/T Cement
Electrical Specific Energy Consumption upto Clinkerization	: 47 kWh/T Cinker
Product Mix	: 60% PPC & 40% OPC
Raw Material	: Hard
Technology	: Crusher (Single Stage) Raw Mill (VRM) Pet coke Mill (Ball Mill) Preheater (6-Stage) Cement Mill (Ball Mill)

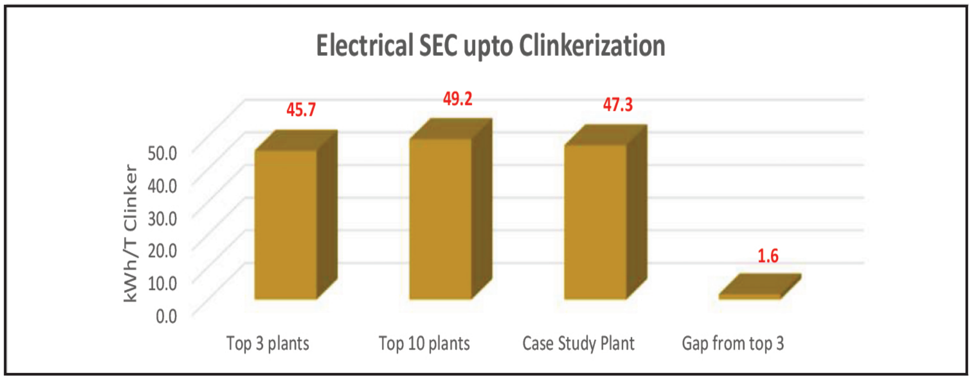
Objective of Study

1. Assess plants' energy performance
2. Comparison with peers
3. Identify gaps and possible solutions
4. Formulate the strategies

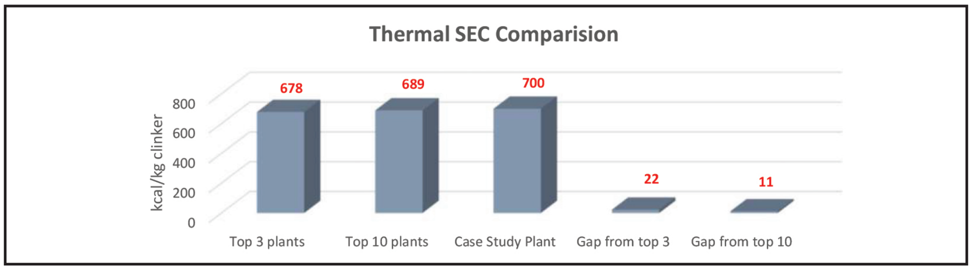
Comparison of Case Study Plant with Top 10 Best plants in India - Overall Electrical SEC



Comparison of Case Study Plant with Top 10 Best plants in India - Electrical SEC up to clinkerization



Comparison of Case Study Plant with Top 10 Best plants in India - Thermal SEC for 6-Stage Preheater system



Section wise comparison of Case Study Plant with Cluster Best and National Best Plants

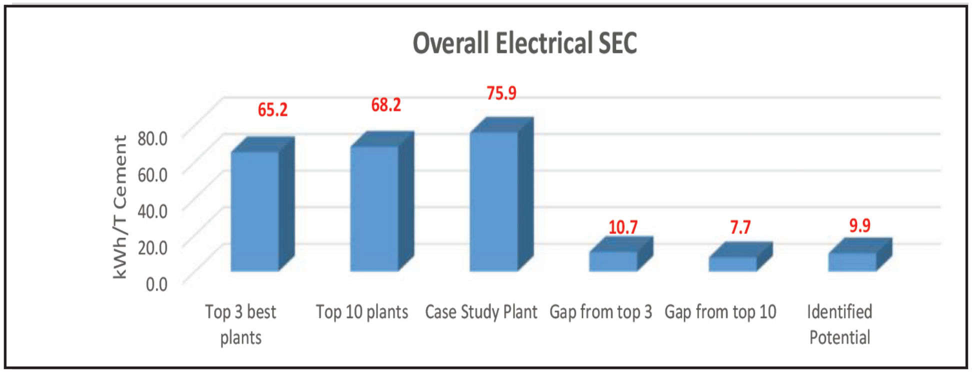
Sr. No.	Parameter	Unit	Case Study Plant	Cluster -1	Cluster -2	Country Best
1	Crusher	kWh/ Ton Material	1.50	1.15	1.30	0.72
2	Raw mill (VRM) (MD+MF+CL+RE)	kWh/ Ton Material	12.20	12.50	14.6	13.3
3	Kiln (6 stage) (including RABH fan power)	kWh/ Ton Clinker	22.30	24.50	26.22	16.92
4	Coal mill	kWh/ Ton Material	37.60	33.40	36.90	32.07
5	Up to clinkerization (including crusher power)	kWh/ Ton Clinker	47.30	45.60	62.40	44.23
6	Cement mill - Ball mill PPC with HRC	kWh/ Ton Cement	23.70	28.10	23.20	23.20
7	Cement mill - Ball mill OPC 53	kWh/ Ton Cement	36.70	33.80	34.70	27.9
8	Packing	kWh/ Ton Cement	1.70	1.45	1.80	0.65
9	Utilities	kWh/ Ton Clinker	3.50	2.10	2.90	0.67
10	Utilities	kWh/ Ton Cement	2.60	1.20	1.40	0.89

Detailed study of parameters mentioned in Chapter-7 of this benchmarking manual reveals that there are many opportunities that can be tapped in each section. A brief of these opportunities and subsequent saving potential is as follows:

Sr. No.	Opportunity	Saving Potential (kWh/T Material)	Annual Saving (INR Lakhs)	Type of investment
1	Reduce the pressure drop from mill outlet to fan inlet	0.2	19.44	Medium
2	Reduce false air in the circuit	0.2	19.44	Low
3	Install latest generation classifier in raw mill	1	97.20	High
4	Improve the fan efficiency in identified fans (70 % efficiency)	0.25	24.30	Medium
5	Reduce the pressure drop across identified bag filters	0.4	38.88	Medium
6	Install high efficiency blower in place of PD blowers	0.5	48.60	Medium
7	Reduce the preheater fan inlet pressure by at least 50 mmWC	0.5	30.38	Medium
8	Improve preheater fan efficiency by 5%	0.5	30.38	High
9	Improve coal conveying phase density in PC & kiln coal systems	0.1	6.08	Low
10	Improve the top cyclone efficiency in preheater	3 kcal/kg cl	37.50	Medium
11	Opportunity in PID loop fine tuning for identified loops	2 kcal/kg cl	25.00	Low
12	Reduce radiation losses in kiln and preheater system	2 kcal/kg cl	25.00	Medium
13	Install Kiln shell radiation heat recovery system	Thermal	37.50	High
14	Reduce the fines in the reject in identified mill	1.2	101	Medium
15	Improve the grinding media surface area and reduce the grinding media weight in the second chamber of identified mill	0.9	75.82	Low
16	Improve the efficiency of circulating air fan in identified mill	0.2	16.85	Medium
17	Install new high efficiency separator and reduce the fines in the reject to <15%	4	337	High
18	Improve the separator loading in identified mill	0.3	25.27	Medium
20	Improve the grinding media surface area and reduce the grinding media wt in the second chamber	0.9	76	Low
22	Reduce the pressure drop from cyclone outlet to CA fan inlet atleast 50mmWC potential available	0.2	16.85	Low
23	Reduce the specific power of packer bag house fan (kWh/Spout)	1	5.18	Low
24	Reduce the compressed air generation pressure	0.2	16.85	Low
25	Optimize compressor operation in clinkerisation section	0.5	42.12	Medium
26	Improve SEC of identified compressors in cement mill section	0.5	42.12	Medium
	Total Potential identified	10 kWh/T Cement	1120 INR Lakh per year	

Assumptions : Power cost 4.5 Rs/kWh; Fuel Cost : 900 Rs per Million kcal; Operating TPH 300; Factor 1.6; Blending 30%; Annual Operation 300 days x 24 hrs

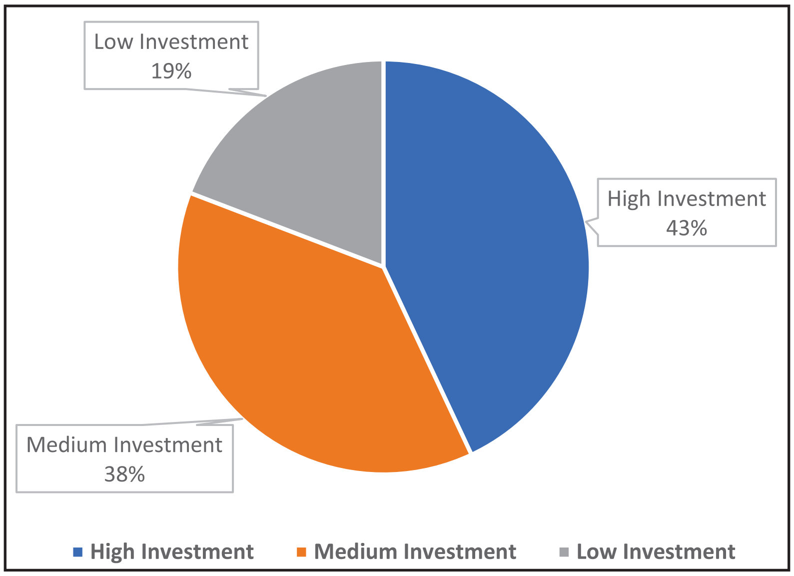
Benefit analysis for Case Study Plant



Identified opportunities in each category of Investment

Category of Investment	Savings (kWh/T Cement)	%	Savings (INR Lakh)	Investment (INR Lakh)
High Investment	4.3	43	502	970
Medium Investment	3.8	38	451	440
Low Investment	1.9	19	165	75

% Savings Identified in each Category of Investment



CHAPTER-5
ENERGY INDICATORS IN CEMENT INDUSTRY

Sr. No.	Parameter	Unit	Indicator
1	WHR least pressure drop	mm WC	50
2	WHR least false air	%	6
3	Lowest Preheater pressure drop	mm WC	-390
4	Lowest Preheater exit O_2	%	2.3
5	Lowest Preheater exit CO	ppm	50.6
6	Fine coal conveying phase density in PC string	Coal/Kg of air	5.8
7	Fine coal conveying phase density in Kiln string	Coal/Kg of air	5.8
8	Specific surface area Cement mill 1st chamber and 2nd chamber:		
	1.6 Piece weight Chamber -1	m^2/Ton	10.2
	1.6 Piece weight Chamber -2	m^2/Ton	40.2
9	TAD temperature drop	^{0}C	30
10	Highest cooler bed height	mm WC	650
11	Lowest lime stone size from crusher	mm	<40
12	Lowest raw mill cyclone pressure drop	mm WC	50
13	Highest separator loading	gm/m^3	548
14	Lowest DP across RABH	mm WC	80
15	Lowest CA fan power in Cement Mill	kWh/MT	1.3
16	Highest AFR Substitution	%	26
17	Lowest Raw mill silo top fan power for 3300 TPD kiln	kW	6
18	Lowest cooler loss	Kcal/kg clinker	98.4
19	Lowest cooling air with respect to cooler loss	Nm^3/kg clinker	1.62 @ 98.4 kcal/kg
20	Highest cooler loading	TPD/m^2	63
21	Highest kiln Thermal loading	kcal /hr / m^2	5.7
22	Highest kiln volumetric loading	TPD /m^3	7.0
23	Highest draught at chimney bottom	mmwc	-60
24	Preheater fan highest efficiency	%	90.5
25	Raw Mill fan highest efficiency	%	87.4
26	Cement Mill fan highest efficiency	%	88.0
27	Highest Fly Ash addition	%	35
28	Highest slag addition	%	70
29	Best top cyclone efficiency	%	97
30	Lowest VRM false air		
	Subtracting feed moisture evaporation, water spray evaporation, seal air fan	%	7.21
	Raw Mill VRM	%	12
	Cement Mill VRM	%	13.20
31	Lowest Preheater fan specific power	kWh/MT Clinker	3.64
32	Lowest electric distribution losses	%	3.2
33	Lowest Capacitor power loss	w/KVAR	3

34	Optimum voltage for lamps	V	210
35	Lowest frequency maintained for CPP operating in island mode	Hz	48.8
36	Best efficiency of motors in LT & HT	%	97.1
37	Lowest VFD loss and SPRS loss	%	3, 4
38	Lowest lighting load (kW) or SEC	kWh/MT cement	0.5
39	Lowest harmonic distortion in Cooler fans (V, I)	%	2, 8
40	Highest capacity of Renewable energy in onsite installation	MW	5.75
41	Highest power factor in CPP in Island mode	-	0.97
42	Lowest compressor air generation pressure	bar	4.5
43	Lowest pressure drop in compressed air distribution system	bar	0.1
44	Lowest pressure drop across dryer	bar	0.1
45	Lowest CPP auxiliary power consumption		
	AFBC	%	5.36
	CFBC	%	6.53
46	Lowest Conveying pressure from ESP hopper to bunker in CPP	bar	3
47	Lowest SEC for blower @1 bar	kWh/MT coal	1.1
48	Lowest compressor air load Cement mill, CPP and Pyro for 4200 TPD plant	CFM	2450
49	Lowest excess air in CPP		
	Indian Coal	O_2 %	2.5
	Pet Coke	O_2 %	2.8
	Lowest heat rate in CPP < 30 MW	kcal/Mwh	3007
50	Lowest primary air		
	Indian Coal	%	19.74
	Pet Coke	%	12.94
51	Lowest pressure drop between BFP and drum pressure	Bar	10
52	Lowest pressure drop in flue gas path	mm WC	64
53	Lowest Cooling water circulation SEC	m^3/MW	239
54	Lowest auxiliary cooling water circulation	m^3/MW	10.5

OPERATING PARAMETERS FOR BEST PLANTS IN COUNTRY

Crusher Section

Sr. No.	Parameter	Country Best #1	Country Best #2	Country Best #3
1	SEC , kWh/ MT	0.72	0.85	0.92
2	Output, TPH	900	900	650
3	No of stages	Single	Single	Single
4	Product size, passing % on 75 mm	90%	95%	95%
5	Crusher main drive SEC, kWh/MT	0.38	0.45	0.44
6	Bag filter fan kWh/ MT	0.10	0.07	0.10
7	Compressor kWh/MT	0.21	0.19	0.23

Raw Mill Section

Sr. No.	Parameter	Country Best #1	Country Best #2	Country Best #3
1	Raw mill (VRM) (MD+MF+CL+RE) Total SEC kW /MT	11.81	13.3	15.0
2	Output TPH, Material Hardness	230, Hard	320	400
3	Type	VRM ATOX 32.5	L38/44	Pfeiffer
4	Mill fan SEC, kWh/Ton of material	5.21	6.4	7.7
5	Mill drive SEC, kWh/Ton of material	5.41	6.0	5.5
6	False air level , %(Mill IL to Mill fan outlet)	16	15	15
7	Mill O/L – Fan I/L pressure drop, mmWc	170	140	145
8	Mill DP, mmwc	430	420	450
9	Cyclone DP, mmwc	60	60	65
10	Separator Loading, kg /m^3	0.62	0.549	0.66
11	Mill fan inlet pressure, mmwc	-955	-840	-1078
12	Mill fan efficiency, % & Control	79%, GRR	81% / VFD	76% / GRR

Coal Mill Section

Sr. No.	Parameter	Country Best #1	Country Best #2	Country Best #1	Country Best #2
1	Total SEC , kWh/ MT	33.26	36.5	26.7	27.40
2	Output TPH, Type of Coal	35 (IMP)	17 (IMP)	29, 100% Pet coke	25, 100% Pet coke
3	Type of mill	Ball Mill	Ball Mill	VRM ATOX	VRM Pfeiffer
4	Mill fan SEC, kWh/Ton of material	4.57	5.00	10.48	8.20
5	Mill drive SEC, kWh/Ton of material			14.53	17.75
6	False air level , % (Mill inlet to Mill fan outlet)	10	30	26	29
7	Mill outlet pressure, mmwc			229	310
8	Pressure drop across BF, mmWC	90-110	90-110	120-130	110-130
9	Mill fan inlet pressure, mmwc	580	590	590	480
10	Mill fan efficiency, % & Control	75%, VFD	81%, VFD	56%, SPRS	72%, VFD

Pyro Section

Sr. No.	Parameter	Country best#1	Country best#2
1	Output, TPD	7624	5231
2	No of PH strings & Stages	DOUBLE, 6	SINGLE,6
3	PH fan inlet pressure mmWC	-470	-506
4	False air across PH, %	8	8
5	PH fan flow, Nm^3/kg clinker & Temp, ^{O}C	1.37 , 295	1.36 , 265
6	PH fan efficiency %, Control	90% & VFD	85% & VFD
7	PH fan SPC, kWh/Ton of clinker	4.45	4.88
8	Cooler vent air Nm^3 /kg clinker, temp	0.82 , 284	1.12 , 280
9	Cooler vent fan SPC, kW/Ton of clinker	0.23	0.55
10	Top cyclone efficiency %	92	97
11	Kiln baghouse flow Nm^3/kg clinker		1.8
12	Kiln baghouse fan efficiency %, Control	81% & VFD	77% & VFD
13	Kiln baghouse pressure drop mmWC	-	50
14	Kiln baghouse fan inlet pressure mmwc	-200	-122
15	False air in the circuit (PH fan O/L to BH fan OL), %		24
16	Cooler fan SPC, kWh/Ton clinker	4.3	4.3
17	Cooling air flow, $Nm^{3/}$kg clinker		
18	Clinker temp at cooler exit, ^{O}C	168	180
19	Kiln thermal SEC, kcal/kg clinker	694	684

Major Process Fans

Sr. No.	Major pyro fans	Country best#1	Country best#2
1	Major pyro fans total SEC	13.3	12.6
2	Pre-heater fan	5.8	6.3
3	Cooler fans	4.3	4.3
4	Cooler vent fan	0.2	0.6
5	Kiln bag house fan	3.0	1.5

Cement Mill Section

Sl no	Parameter	Country Best	Country Best #2
1	Total SEC , kWh/ MT	27.93	28.55
2	Output TPH, Type of material	103.9	103
3	Blaine of product, cm^2/gm	3000	3000
4	Product residue on 45 µ, %	16	15
5	Type of mill	Ball Mill Closed Circuit	Ball Mill Closed Circuit
6	Mill drive SEC, kWh/Ton of cement	24.76	25
7	Separator fan SEC, kWh/Ton of cement	1.77	1.8
8	Mill vent fan SEC, kWh/MT cement	0.41	0.43
9	Mill ventilation velocity, m/s	1.01	0.95
10	Grinding media specific surface area in chamber II, m^2/MT	38	38
11	Separator vent fan volume, % of separator volume	9.8	10.0
12	Separator fan efficiency, % & Control	VFD	VFD
13	Separator fan inlet pressure, mmWc	-358	-290
14	Fines in Separator reject at -45µ, %	9	9
15	Separator loading, kg/m^3	0.85	0.84
16	Separator pressure drop, mmwc	270	260
17	Pressure drop across cyclone, mmWc	95	90
18	Pressure drop from cyclone outlet to CA fan inlet, mmwc	45	30

Packing Plant and Utilities

Sr. No.	Parameter	Country Best #1	Country Best #2	Country Best #3
1	No of spouts	12	12	12
2	Output, TPH	120	120	120
3	SEC , kWh/MT	0.65	1.15	1.2
4	Fan SEC kWh/Spout	1.9	3.5	2.4
5	Compressor pressure average, bar	5.5	5.5	5.8
6	Compressor SEC upto clinkerization, kWh/MT clinker	0.67	0.67	0.99
7	Compressor SEC,, Cement grinding and packing, kWh/MT cement	0.90	0.89	

CHAPTER-6
BEST PRACTICES IN CEMENT INDUSTRY

MINES

1. Using CAP for reducing the fly rock and improving Powder factor
2. Using automation for improving the truck performance
3. Using software to enhance mines life
4. Using mines land for RE installation
5. Using mines land for Energy Plantation
6. By changing blasting technology from top initiation system to bottom initiation system through Nonel shock tubes, crusher input size reduced and output increased from 7 ton to 10 ton per kg of blasting.
7. By the compaction of the floor of the benches diesel consumption of the transport equipment had been reduced from 22ltr/hr to 18ltr/hr.
8. Surface Mining by use of Surface Miner for soft and medium hard materials
9. Use of Mega Rock Breaker
10. Reducing Moisture content of materials by trench cutting and de watering

CRUSHER & PRE BLENDING

11. Utilizing beneficiation plant for processing low grade limestone
12. Using wobbler for to by pass under size through the crusher
13. Using VFD for crusher bag filter fan
14. Installing VFD for crusher compressor
15. Installation of Cross Belt Analyzer for optimizing the mines life
16. Interlock Crusher fan speed with crusher feed belt RPM
17. Crusher output size reduction to get benefit in VRM & Crusher
18. Interlocking crusher feeder rpm with crusher load to optimize loading
19. Installation of Material starvation switch in belt conveyors to avoid idle running
20. Installation of Light pipe for Stacker
21. Installation of Cross Belt analyzer for Coal
22. Power saved by pile changeover in online (without stopping the crusher). Due to this avoided idle run hours during stop seq.+ idle run hours of stacker during pile change over + idle run hours of stacker & transport during start up.
23. Power saved by Stacker hydraulic pump through logic modification.
24. P&V motor switching off after the end of “B” shift due to no “C “shift operation at Crusher-1 & 2.
25. Providing heating system and hydraulic scrapper at wobblers to increase crusher productivity.
26. To operate Limestone crusher from Central control room to facilitate people development- Earlier there was local control for crusher operation and one operator per shift was required for the same. The area was also having high level of noise. To carry out proposed improvements/changes a team was formed, which carried out all the concerned activities in house without the support of any consultant. First an optical fiber cable from LS crusher to CCR was laid and HMI of Control system and the weighbridge was given to CCR. IP cameras were installed at all the three locations to monitor Apron feeder, Dump hopper and weighbridge from CCR.

BENEFITS:

a. The LS crusher operator’s who were operating the crusher in high sound area were shifted to CCR and now they have learnt other operations of the main plant and improved their knowledge.
b. The LS crusher operators are now able to operate Cement mills and Raw mills independently.
c. Operation of complete plant from single location.
d. Availability of the data at single location.

27. Automation of Mines weighbridge by installation of RF ID card reader system.
28. Installation of Radar level monitoring system in Crusher Dump Hopper
29. Installed VFD to reclaimer.
30. All additives belts are covered with GI sheets to feed moisture free material in rainy season.
31. Crusher Productivity has been improved by maintaining the constant bed level, an interlock is provided to stop the crusher apron feeder based on the apron feeder current
32. Ensuring sufficient amount of material availability before starting the crusher for continuous operation
33. Use of Compound Impactor (Two Stage Crushing) to achieve lowest power consumption with best size reduction ratio suitable for Vertical Roller Mill for Raw grinding.
34. Use of Sizer type Crushers for Soft and medium Hard materials

RAW MILL-BALL MILL

35. Installation of Tertiary crusher for increasing the mill output
36. Installation of Cross Belt Analyzer for on line quality control
37. Installation of Boltless Classifying liner
38. Mill level control system based on vibrations instead of acoustic control
39. Shorter length of drying chamber to increase output
40. Mono chamber for mills with HPRG
41. HPRG in finishing mode
42. High separator loading
43. Bucket type belt conveyor in place of metallic conveyor
44. VFD for Raw meal silo top bag filter fan
45. Adaptive predictive control system for mill operation
46. VFD for Separator fan, mill vent fan, sept vent fan
47. Air slide fans with pressure less than 250 mmwg for fine material air slide and 350 mmwg for separator reject air slide
48. Low pressure drop cyclones
49. Rotary Air Lock for mill feed to reduce false air
50. Reject sample analysis on 90 micron daily basis to optimize sep performance
51. Plant stopped Nib trap blower and air is taken from air slide blower and thus plant saved 2 kW power per hour in raw mill.
52. Optimized the silo dust collector by introducing VFD for bag filter fan
53. Use of filter bags with moisture and Oil repellent finish

RAW MILL - VRM

54. Mill Louvre velocity in the optimum range 45 -55 m/sec
55. Maximum Sep Loading gm / m^3 of air
56. Low pressure drop cyclones
57. Rotary Air Valve for mill feed to reduce false air
58. Blocking the louvre below the rollers and optimizing the flow
59. Vera bar for flow measurement in place of orifice and venturi
60. VFD for raw mill fan
61. Cross belt analyzer at mill feed belt for online quality control
62. Low false air across mill circuit
63. Reducing feed size in line with crusher for total power reduction
64. Adaptive Predictive control system for mill
65. Minimum continuous recirculation in Mill rejects (10 - 30%)

66. Vortex rectifier for reducing the pressure drop across the classifier
67. Carrying out CFD for optimum pressure drop in the ducts
68. Interlock has been made Seal air fan STOP with 1 hr delay after mill stop of Raw mill
69. Air slide blowers 12 number optimized in phase II raw meal transport system.
70. Process optimization done by reducing raw mill dam ring height & mill feed size.
71. In belt discharge chutes provided self cleaning spring loaded plates provided to avoid coating/jamming
72. Reduction in false air by 3% by replacing of rubber dampers in VRM circuit.
73. Installation of air blasters, SS chute, polymer liners in limestone hopper and reclaimer discharge chute to avoid jamming
74. Usage of Feldspar in raw mix grinding to mitigate the effect of sulfur from pet coke
75. Installation of Sinter cast liners for Table & Roller to increase the life and to reduce the Downtime hours.
76. Mill Reject system running based on Reject Chute Level & Timer switch instead of continuous operation.
77. Expert Optimizer had been installed to reduce the standard deviation in the product results and for consistency in output.
78. Low pressure off line Pulse jet cleaning – especially suitable for Glass fibre bags(bag specific weight 750gms/m^2) to get lower pres-sure drop & longer life without loss in performance
79. Fully welded cast steel table liner and roller tyres for low wear rate and longer mill availability

COAL MILL

80. Installation of additional crusher for reducing the size
81. Vibration based control system for mill filling
82. Optimum drying chamber for reducing the output
83. VFD for Mill fan and booster fan
84. Rotary Air Lock for mill feed to reduce the pressure drop
85. Optimum phase density in fine coal conveying
86. Energy efficient blower instead of PD blower
87. Reject sample analysis on 90µ daily basis to optimize sep performance
88. Vera bar in place of venturi and orifice
89. High residue for calciner firing compared with kiln firing
90. GRR introduced for Coal Mill-drive to control speed to grind Pet coke
91. High efficiency dynamic classifier in place of Static Vane Grit Separator (for ball mill circuit)

PYRO PROCESSING

92. Optimum excess air at preheater outlet
93. Lowest false air across pre heater circuit
94. VFD for preheater fan, Cooler vent fan and cooler fans
95. Low pressure drop cyclones
96. Low pressure drop across down comer duct
97. High efficiency cyclone in the top stage
98. Low thermal conductivity bricks in the kiln inlet and calcining zone
99. High momentum burner with AFR usage
100. Low suction loss in cooler fans
101. Optimum clinker bed height for improved cooler efficiency
102. Optimum charge ratio for ESP for better emission control
103. Chimney draught for reducing the cooler vent fan power consumption
104. Adaptive Predictive control system to improve efficiency
105. Installation of WHR for utilizing waste heat

106. Installation of VFD for shell cooling fan and auto control with shell temperature
107. Installation of Graphite sealing system for kiln inlet and outlet seal
108. Installation of slide gate instead of multi Louvre damper in pre heater fans with SPRS / GRR
109. CFD analysis of cyclones to improve heat transfer, cyclone efficiency
110. Optimum feeder box height for better heat transfer in riser ducts
111. Low temperature drop in Tertiary Air Duct
112. Better sealing arrangement for camera , pyrometer in kiln hood
113. Timer based operation for Screw conveyors below Cooler ESP, RABH
114. Increasing chimney height to reduce power consumption
115. Optimizing RA fan with VFD for reducing RABH fan power consumption
116. Use of Effluent water for cooler spray
117. Low capacity pump for GCT and cooler to avoid recirculation
118. Low pressure drop and false air across WHR boiler
119. Low pressure drop across cooler fans silencer
120. Installed VFD for kiln feed aeration blower to operate in required pressure & speed.
121. Coal conveying pipe size reduced to getting required velocity
122. 5th Cyclone inlet area reduced (at bottom entrance) for both strings to increase inlet velocity and to avoid material surges from this cyclone.
123. To reduce the pressure drop across PH down comer, installed baffle plates at PH top of DC duct.
124. Substitution of Industrial waste as Alternate fuel.(Highest consumption in TSR basis in India)
125. Provided C3 clearance Bearings in F.K Pump for avoiding abnormal sound and vibration
126. Grease distributer is provided for uniform grease spray throughout the width of the gear/pinion and proximity is provided at distributor plunger to sense its operation. If there is no flow proximity will sense thereby avoid girth gear running without grease
127. Cooler Mid hot air connected to raw mill to dry limestone.
128. Addition of Horicon (cyclone) in top stage to reduce pressure drop and minimize dust loss.
129. Kiln feed LSF standard deviation has been achieved up to 1.4 through optimization of blending silo extraction cycle
130. Used the un burnt fly ash as fuel
131. Silo extraction standard deviation of Cao is <0.15.
132. Installed with a Knock out chamber in TAD take off to reduce the Clinker fine dust re entrainment into the Preheater
133. Belt Bucket Elevator with Steel chord
134. PH down comer duct sizing : Duct inside gas velocity can be kept at <10 m/sec to minimize the pressure drop and to save PH fan power(applicable where the power cost is > 10 US Cents per kwh
135. Use of Natural Pozzolona like Riyolite, Pumice and Basaltic Scoria as Silica Substitute in Raw mix for Clinkerisation to reduce the energy consumption and increase production
136. Recirculation of cooler air for higher power generation in WHR.

CEMENT MILL

136. HPRG for pre grinding
137. Separator for HPRG for overall performance
138. Diverting HPRG sep reject for another mill to optimize overall circuit
139. VFD For separator, mill vent and sep vent fans
140. Dry fly ash bin at 20 m near mill for optimizing power and use of energy efficient blower for fly ash unloading
141. Fly ash feeding at mill outlet
142. Air seal / felt seal in separator to reduce fines in reject
143. Sep vent in the range of 10 -15 % of separator fan flow

144. Low pressure drop across separator circuit (cyclone, separator, duct)
145. CFD for ducts and cyclones for optimizing pressure drop
146. Adaptive predictive control system
147. Lower size grinding media in second chamber
148. Mill fill control system using vibration measurement
149. Residue control instead of Blaine control
150. Hydraulic pressure of roller press reduced from L1-130 to 90 & L2-140-100bar to avoiding initial tripping
151. Interlock has been made RP motor cooling fans stop 1hr time delay after RP stop.
152. Interlock has been made Bag house heaters automatically stop 1hr delay after the mill stops.
153. Cement VRM support to run without hot gas by replacement of hydro-pneumatic spring type HSLM in place of conventional hydraulic type HSLM. Thermal Energy saving achieved.
154. Mill de-dusting discharge material directly goes with mill fresh feed in CM3.It has been observed that mill running with unstable and tripping 2-3 times in a day. Redirected de-dusting discharge material to classifier. Benefits,(i) Mill tripping avoided (ii) Initial startup & Aux power saving.
155. Provided auto skewing adjustment arrangement for Roller Press.
156. Cement Mill slide shoe bearing interlock modification. If any LP Pump trip, automatically HP Pump should run to avoid tripping of Mill.
157. Use of problem solving tools (six sigma, RCM etc) for elimination of chronic problems.
158. Elevator installed in place of pneumatic conveying system for fly ash unloading.
159. Every 45 days roller profiling is done for both rollers of Roller press in CM-1 & 2 circuits.
160. Grinding media makeup charge as per requirement (Blaine /residue graphs).
161. Auto reversal of mill feed rotary air lock to avoid stoppage due to rotary air lock stalling
162. No Preheating before start up of mill (No Hot gas generator used)
163. Online monitoring of Nitrogen pressure in accumulators
164. Separate grinding and Blending of additive materials

PACKING HOUSE

165. Air slide fans for silo extraction instead of compressed air / blower
166. Blower for packing machine feed bin (surge hopper) extraction instead of compressed air
167. Packer fan volume 2000m^3/ hr per spout consuming 1.9 kWh/ spout
168. Low false air across packer bag filter
169. VFD for packer fan and interlock with machine operation
170. Material starvation switch in belt conveyors to avoid idle running
171. Open wagon loading
172. Packer upgradation with EEL packers to reduce the weight variation.
173. Truck loading de-dusting system interlock is provided whenever truck loading is stop.
174. Auto flushing system provided for bag printing machine.
175. Zero velocity chute provided in Packing Plant vibrating screen to increase the life.
176. Cleaning compressor, 18.5 kW stopped in packing plant & 2.2 kW blower arranged for cleaning purposes and saved Rs. 8.39 Lakhs annually.
177. Online branding system to reduce man power.
178. Installation of VFD for compressors & an interlock is provided with no. of packers running for reduction of Specific power consumption
179. All discharge chutes are lined with ceramic pad to reduce the bag burstage
180. Conversion of truck loader inclined belt from rough top to fish bone type belt to reduce bag burstage
181. Regular cleaning of spouts in every shift.

182. Installation of electronic bag counting mechanism before truck loading machine.
183. Use of small capacity compressor for single plant operation.
184. Floor Sweeper for Spillage Cement collection
185. Vacuum Cleaning System for Spillage Recovery

COMPRESSOR

186. Generation pressure at 5.5 bar irrespective of the section
187. Screw compressor with VFD instead of reciprocating compressor
188. LP compressor for fly ash unloading
189. Dedicated compressor operating at 4.0 bar for Pulse jet kiln bag house
190. Red tag system for minimizing and reducing leakages
191. Level based drain valve instead of timer
192. Demand side / supply side controller to optimize power
193. Centrifugal compressor for base load in multiple kiln in single location
194. HOC dryer instead of refrigerant dryer
195. Energy efficient blower at 0.8 bar for fly ash unloading
196. Optimized the ideal running of ELGI compressor's dryer through interlock and saved 3kW per hour.
197. Reduced the pressure drop across filter and optimized the pressure setting of compressors and saved 25 kW per hour.
198. Waste heate recovery from compresser
199. Decentralized Compressed air generation according to consumer capacity

PUMPS

200. Level based auto control instead of manual control
201. Booster pump for high head low volume users like separator Gear box
202. Sand filter recirculation based on online turbidity measurement
203. High Energy efficient pumps
204. Online water flow meter
205. Submersible pumps for mines dewatering
206. Optimized the operation of cooling tower during winter and stoppages of cement mill and saved 2 kW power per hour.
207. Installed smaller water pump (18 kW) for usage during plant shutdown instead of 60 kW water pump (during kiln running)
208. Gas conditioning in Cooler & Raw mill is being done with the Treated STP water.
209. Water treatment plant's rejects, Boiler Blow down & cooling tower blow down water is being used for Gas conditioning in Cooler, Raw mill & Dust Suppression
210. Reducing the specific water consumption from the level of 0.22 m^3 per ton of cement to 0.18 m^3 per ton of cement

ELECTRICAL DISTRIBUTION

211. Installation of lighting transformer and maintaining optimum lighting voltage
212. Install Auto power factor controller and maintain unity power factor
213. Optimize the frequency of turbo generator (In island mode only)
214. Install LED lamps with Solar PV for colony and remote street lighting
215. Replace the old rewound motors with Energy Efficient IE3 motors
216. Install Intelligent MCC Controls
217. Speed control through GRR with 20 – 100% speed variation where VFD is not available
218. Interlock the GRR cooling fans operation with GRR panel temperature
219. Replace the T12 or T8 lamps with T5 lamps

220. Install Magnetic induction lamps for high bay areas in place of HPMV lamps
221. Replace the Mercury vapor lamps with Metal halide/Sodium vapor lamps/CFL/Magnetic Induction Lamps
222. Convert Delta to permanent Star connection for lightly loaded motors (<35%)
223. Install auto star delta converter for lightly loaded motors (variable loads)
224. Minimize unbalance in Voltage by equally loading the transformer
225. Using Soft Starters to avoid higher initial currents to larger size motors
226. Replace Cooler vent fan and Kiln main drive motors with AC drives
227. Install Harmonic filters
228. Installation of Energy Monitoring system
229. Installation of Light pipe in place of high discharge lamps for day lighting
230. Replace 85W incandescent lamps with 45W LED
231. Replace 70 W Sodium vapor lamps replaced with 45W LED
232. Interlock the transformer cooling with temperature of the winding
233. Optimize ESP heaters operation from 110 to 80 ^{O}C.
234. Commissioning of Energy monitoring system to control the power consumption
235. In-house overhauling of all HT motors rating from 250kw to 5300kw.
236. Plant lights ON&OFF optimization through PLC timer
237. Use Astronomical switches/ LDR's for lighting controls
238. Install maximum demand controller to avoid demand charges
239. Conducting Thermography survey on electrical system to avoid breakdowns
240. Power distribution at 11KV for to minimize distribution losses
241. Selected white metal bearing motors with forced lubrication to minimize breakdowns on bearings failures
242. Upgrading of old SPSR with IGBT based SPRS to increase availability of SPRS
243. Upgrading old SPRS controllers (Bin card system) with new controller to increase availability of SPRS.
244. Replacement of reciprocating chiller with high efficiency screw chiller for air condition
245. Scheduling of mill operation to reduce TOD consumption resulting in cost saving
246. Use of Passive infrared sensors for lighting system
247. Intelligent relay for reducing the LT motor failures
248. Optimization of distribution Transformer losses by loading the transformer between (40%-60%)
249. Isolate the primary of transformer also to avoid no load losses
250. Increase the radiators size of Power transformers to improve cooling
251. Reduce the tap setting of Power/Distribution transformer to optimize the system voltage
252. Install energy efficient amorphous transformer for new installations
253. Optimize the Charge Ratio of ESP Transformer
254. Install Medium Voltage VFD in place of GRR/LRR
255. Install magna drive for variable speed applications
256. Replace the Panel incandescent indication lamps with LED lamps
257. Replace halogen lamps with metal halide lamps
258. Optimize the operation of lighting in MCC rooms with door interlock/entrance switch/movement sensors
259. Install neutral Compensator in lighting circuit to compensate neutral current
260. Provide more transparent sheet instead of asbestos sheets to use natural light
261. Replace the turbine hall exhaust fans with turbo ventilators
262. Providing of Insulated Wall Panels for the MCC Rooms to reduce Air conditioning load

CAPTIVE POWER PLANT

263. VFD for Pumps (BFP, CEP, CWP,ACWP) and fans
264. Optimum pressure drop across condenser and HE
265. Optimum frequency and power factor
266. IGBT control system for furnace control
267. Optimum excess air
268. Optimum false air in flue gas circuit
269. Desulphurization & Gypsum production for reducing flue gas loss
270. Low pressure compressed air for fly ash and bed ash transport
271. VFD for instrument and fly ash compressor
272. Low pressure drop in FD fan
273. Multi stage drag reduction valve in place of ARC
274. Turbo ventilator for turbine hall
275. Low pressure drop in flue gas circuit
276. VFD for cooling tower fans
277. Vacuum pump in place of ejector
278. Adaptive Predictive control system for operation
279. Low compressed air leakage
280. Sep lubrication oil pump for generator cooling and governor
281. Optimum charge ratio for better ESP performance
282. Changing Evaporator coils once in every two years to achieve maximum performance
283. Monitoring tube thickness in every shutdown
284. Introduction primary screen in coal belt to avoid fines
285. Predictive and Preventive Maintenance Practice
    a. Tripping Analysis.
    b. Thickness checking of Acid tanks & Chimneys.
    c. Committee for steam leakage detection.
    d. Ultrasonic leak detection for vacuum.
    e. Wear Debris Analysis for TG oil.
    f. Checking of thermal insulation.
    g. Condition monitoring of all equipment.
    h. Maintenance is being done through EAM system.
    i. Coal sieve analysis.
    j. Chemicals are being used on first come, first out basis.
    k. Half yearly checking of compressed air vessels.
    l. Yearly checking of slings, chain blocks, D-shackles & EOT Crane
    m. Replacement of Boiler Bed coils, once in Two years.
    n. Chemical followed by bullet shot Cleaning of condenser tubes once in two years.
    o. Monitoring the condition of major equipments as per check list.
    p. Over-hauling of TG sets – once in 5 years
286. Dual speed for Cooling Tower fan.
287. Installed Energy efficient Air Conditioners in plant.
288. TPP ACC-1 chamber lighting circuit modified with ON/OFF switch.
289. TPP ESP top lighting circuit modified with ON/OFF switch
290. Installation of steam heaters to maintain Lube oil temperature of DG, thereby stop use of electric heater and save energy.

291. Utilization of waste hot gases from TPP to reduce moisture content in lignite.
292. Modification of fluidizing & pushing air line in air slide to opti-mize & control high bed temperature to increase Boiler efficiency.
293. Modification in ACC condensate drain line resulting in improved vacuum, reduced heat rate & auxiliary consumption of 0.48%.
294. Avoiding steam dumping
295. Mist/Sprinkler cooling for Air Cooled Condenser Operation.
296. Optimization of Ash conveying time and eliminate empty line purging.
297. Installation of mechanical transport system in place of pneumatic transport for fly ash handling

GENERAL

298. Compressed air purging based on DP across bag filter
299. VFD for bag filter fans and interlocking speed with suction
300. Cooling tower fans speed reduction in stead of on /OFF control
301. Optimum delta T across heat exchangers
302. Installation of Evaporative condenser for improving AC plant performance
303. Installation of Vapor Absorption Refrigeration system
304. Installation of Building Management system for reducing AC load
305. Construction / Retro fit to Green Building to reduce power consumption
306. Installation of Hybrid (Solar / Wind) power generation systems
307. Installation of Solar thermal systems for steam generation for canteen
308. Daily monitoring and analysis of key parameters
309. Daily power consumption report sent all management cadre employees for their information and control action
310. Celebration of National Energy conservation week celebrations to educate all persons
311. Rain water harvesting done for every individual bore well to recharge ground water table.
312. Installation of Transparent sheet at workshop to avoid lighting during day time.
313. Replacement of tube type heat exchanger with plate type heat exchanger to improve efficiency.
314. LOTO for all energy isolation.
315. Carrying out energy audits at regular intervals and adopting necessary energy conservation activities through Zero / Low / high cost investments
316. Robo Lab
317. Torn out switch introduced for Belt Conveyors to identify the belt cut
318. Performing Root Cause Analysis of any failures / breakdowns to avoid recurrence.
319. Formation of energy circle team.
320. Selection of equipments for saving on energy.
321. Implementation of ISO 50001 for effective energy conservation and management
322. Scheduling and Operation of production plants having spare capacities to reduce the peak load requirement.

CHAPTER-7
INVESTMENT AND PAYBACK FOR MAJOR TECHNOLOGY UPGRADES

Sr. No.	Name of the technology	Tentative range of savings of the technology/ equipment	Typical investment (INR Lakhs)	Typical pay back period (years)
1	Install waste heat recovery from preheater and cooler exhaust gases	15 -20%	1000- 1200 per MW	2-4
2	Install HRPG for cement grinding along with ball mill	20 -30%	2000 -3000 pre 100 TPH	1-2
3	Install latest generation energy efficient classifier	15-30%	200- 300	1-2
4	Install latest generation cooler	20 -50 kcal / kg clinker	2000 -3000	2-3
5	Retrofit existing burner with latest generation burner	10 -15 kcal /kg clinker	100 - 300	1
6	Install cross belt analyser for Improving quality and reduce energy	5 -10 kcal / kg clinker	200 - 400	1
7	Increase the top cyclone efficiency	5 -10 kcal / kg clinker	100	1
8	Install low pressure drop cyclones	1 - 2 %	50 - 100	1
9	Install rotary coal feeder (latest generation) for kiln feeding	5 - 10 kcal / kg clinker	200 - 300	1-2
10	Installation of HT VFD in place of SPRS / GRR in major fans	2- 5 %	100-200	1
11	Install WHR to recover waste heat from kiln shell radiation for power generation / VAM to produce Chilled water for AHU	0.2 - 0.5 %	100	2
12	Install Fly ash dryer to increase fly ash addition in PPC	2 -3 %	200-500	1
13	Install tertiary crusher before raw mill to increase raw mill output	1-3 %	100-200	1
14	Install particle size distribution analyser to improve efficiency and output in cement mill	2- 5 %	100	1
15	Install low pressure compressor for fly ash unloading	1-2 %	25-50	2
16	Reduce the false air ingress in various circuits raw mill, coal mill, preheater , cement mill	2- 10%	10-30	1
17	Optimise separator flow (air loading) by benchmarking and installing flow measuring device	2- 5%	5-20	1
18	Co-processing & preprocessing platform for increased alternative fuel utilization	2- 15%	30-8000	1-3

CHAPTER-8
THUMB RULES FOR ENERGY EFFICIENCY

1. 4 % reduction in voltage will result in 1 % reduction in power
2. 10 % reduction in speed will save 27 % power in centrifugal equipment
3. 1 bar reduction in compressed air pressure will save 8 % power
4. 22 deg drop in boiler flue gas temperature will increase efficiency by 1%
5. Reducing steam generation pressure by 4.8 kg/cm^2 will increase efficiency by 1%
6. A 10% blow down in a 15 kg/cm^2 boiler results in 3% efficiency loss
7. 3 mm of soot can cause an increase in fuel consumption by 2.5% due to increased flue gas temperatures
8. Optimum efficiency of boilers occurs at 65-85% of full load
9. Reducing the frequency by 1 Hz at main TG / DG (in Island mode) will reduce power consumption of centrifugal equipment by 3 %
10. A 1 mm thick scale (deposit) on the water side could increase fuel consumption by 5 to 8%
11. LED can save power consumption by nearly 50 % in lighting
12. Reduction in cooling tower fan speed by 50 % by VFD can save power by 75% in fan
13. Maintaining intercooler performance can save 7 % power on compressor
14. Reduction of 10 deg C in the combustion air of DG will save 1.5 gms of fuel/kWh of power generated
15. 150 sq ft of room area needs 1 TR air conditioning load in a conventional building
16. Power transformer efficiency will be maximum in the range of 60 - 80 % loading
17. Distribution transformer efficiency will be maximum in the range 40 - 60 % loading
18. Optimum excess air for a coal based boiler is 15 -20%
19. Every 1% reduction in excess air in boiler there is approximately 0.6% rise in efficiency
20. Optimum approach (Difference between cold well temperature and wet bulb temperature) in cooling tower is 2- 4 Deg C
21. 6°C raise in feed water temperature by economiser/condensate recovery corresponds to a 1% saving in fuel consumption, in boiler
22. Recommended increase in temperature of water (Δ T - cooling water outlet - inlet temperature) for condenser, compressor is 10 deg C, process heat exchanger 5 deg C
23. FRB blades in an axial cooling fan can save up to 20 -40 % power compared with metal blades
24. Every 4°C rise in inlet air temperature of compressor results in a higher energy consumption by 1 % to achieve equivalent output".
25. Recommended compressed air outlet temperature after intercooler is ambient temperature + 20 deg C
26. Minimum quantity of cooling water required (in liters per minute) is 2.85 m^3/min for a single stage compressor operating at 7 bar pressure
27. Trans-vector nozzles can reduce power and save compressed air up to 50%
28. Compressed air leakage quantity to be as low as 10%
29. Optimum pressure drop between generation and end user point can be less than 0.5 bar
30. Heat available in DG exhaust is close to 33%, cooling medium is 24% and this can be recovered by WHR with VAM and other techniques
31. Fans with aero foil, backward curved blades can operate with efficiency more than 85%
32. Optimum margin for pressure is 15% and flow is 10% while designing a fan
33. Optimum cut off clearance in a centrifugal fan is 8-12%
34. Centrifugal and Screw blowers can save up to 40% power when compared with PD blowers for the same application (pressure and volume)
35. 20% increase in height of chimney (stack) can save 20% power consumption of the connected ID fan

36. Flat belt pulley can save 3 - 5% compared with V-pulley
37. Typical power consumption of conventional vapor compressor refrigeration system is 1.2 kW/TR
38. Typical power consumption of screw chiller system is 0.35 kW/TR for 10 deg C chilled water
39. Normally two lower size impellers and one immediate higher size impeller can be used in the same casing in case of centrifugal pumps to avoid throttling and save power in case of over design
40. A 3-mm diameter hole on a pipe line carrying 7 kg/cm^2 steam would waste 33 Kilo liters of fuel oil per year
41. Remove air from indirect steam using equipment - (0.25 mm thick air film offers the same resistance to heat transfer as a 330-mm thick copper wall)
42. Recommended compressed air velocity in pipe line is 6 - 8 m/s
43. Dampers provided at the fan outlet consumed more power than provided at inlet due to increase in absolute pressure of gas handled by the fan
44. 1 mm thick air film in steam piping offers same resistance as wall of copper of 15 meter thick
45. Every 4.8 kg/cm^2 drop in generation pressure of steam will result in 1% increase in efficiency
46. Evaporative cooling can reduce the compressor or chiller load by 20 - 40%
47. Ceramic coating can save up to 8 - 20% radiation loss in furnaces and hot surfaces
48. Volume of receiver for compressed air: 1/10th of flow rate in m^3/min to 1/6th of flow rate in m^3/min
49. In 800 m length compressed air pipe line, pressure drop should not be more than 0.3 kg/cm^2
50. 3 mm diameter hole in a compressed air pipe line with 7 kg/cm^2 air pressure would result in power loss of 5 kW (equivalent to INR 1.5 Lakhs per annum)
51. Average power generation from WHR system: 30 kWh/MT clinker
52. Ball mill ventilation velocity: 1.3 to 1.5 m/s above ball charge
53. Specific surface area of grinding media charge in second chamber of a ball mill for cement grinding: 38 to 40 m^2/ton
54. Specific surface area of grinding media charge in second chamber of a ball mill for raw material grinding: 24 to 27 m^2/ton
55. Recommended gas velocity in ducts at cement plant 14-16 m/s
56. Allowable pressure loss across multilouvre type damper in 100% open condition 10-15 mmWC
57. Pressure drop in latest generation low pressure drop cyclones 50-60 mmWC
58. Water pump Best SEC for cement grinding (Ball mill): 0.02 kW/ ton of cement
59. Latest generation burners can operate with a primary air % as low as 4-6%
60. PID loop optimization will result in savings of 3-5 kcal / kg of clinker
61. As per NEMA standards, the exposed conductor resistance units can attain a temperature rise up to 375 Deg C whereas when they are enclosed in a housing the temperature rise must be restricted to 350 Deg C
62. In conductor resistance housing, the temperature rises of the air when measured at a gap of 1 inch from the enclosure should not exceed 175 Deg C
63. The speed of a slip ring motor can be varied by up to 25% of the rated speed. Further reduction in speed will take the motor to a unstable region and may stall as per the speed-torque curve

CHAPTER-9
MONITORING PARAMETERS FOR ACHEIVING ENERGY EFFICIENCY

Monitoring system is an integral part of any cement plant; Energy Monitoring is the process of establishing the existing pattern of energy consumption and explaining deviations from existing system if any.

The following parameters can be used by Energy Manger and the Process engineer for optimizing the output and power consumption in each section:

CRUSHER

S.No	Parameter	Purpose	Preferred monitoring frequency
1	Crusher output size	To ensure crusher and raw mill output	Weekly
2	Crusher feeder speed(rpm) and running hours	To ensure optimum crusher output and loading	Online Daily
3	Crusher output , TPH, BDP and actual	BDP and actual	Daily
4	SEC, BDP and actual	Deviation and improvement	Daily
5	Main Bag filter DP	Optimum venting and power	Online continuous
6	BF venting Specific air flow, m^3 / TPH	Identify excess air flow	Monthly
7	Moisture content of material	Too high wet material adds up to energy consumption. Monitoring and controlling moisture at Crusher product shall be more effective to control energy conservation in mining, transportation & raw grinding sections. To control by mine dewatering program/plan the mine block operation/ surface drying	Daily average sample or Online continuous

RAW MILL -VRM

S.No	Parameter	Purpose	Preferred monitoring frequency
1	False air from mill inlet to mill fan outlet	Optimizing fresh air in RABH / Kiln bag house fan and its power	Monthly
2	Mill fan Inlet pressure	Pressure drop across circuit	Online continuous
3	Mill outlet dust loading gm /m^3	Optimize flow accordance with output	Monthly
4	Cyclone pressure drop	Achieve lowest SEC	Online continuous
5	Pressure drop across Mill fan inlet damper	Damper condition	Monthly
6	Louvre velocity	Optimize Mill DP	Monthly
7	Mill reject %	To optimize Mill fan SEC	Online continuous
8	Mill load (avg kW) to allowable kW	Optimize output	Monthly
	SEC		
9	Mill drive	Monitor and maintain SEC	Online continuous , Daily
10	Mill fan	Monitor and maintain SEC	Online continuous, Daily

11	Mill fan Efficiency	To achieve best tech possible, monitor and maintain	Monthly
12	Mill feed size	Optimize output	Weekly
13	Mill product residue Target and actual	Optimize mill and kiln operation	Hourly
14	Feed moisture	For Mill Efficiency monitoring	Daily average
15	Mill Internal Water Spray rate	For Mill Efficiency monitoring	Daily average

RAW MILL- BALL MILL

S.No	Parameter	Purpose	Preferred monitoring frequency
1	False air from mill inlet to mill fan outlet	Optimizing fresh air RABH / Kiln bag house fan	Monthly
2	Mill fan Inlet pressure	Pressure drop across circuit	Online continuous
3	Sep dust loading	Optimize flow accordance with output	Monthly
	Optimize flow accordance with output	Monthly / Online	Online continuous
4	Cyclone pressure drop	Achieve lowest SEC	Online continuous
5	Pressure drop across Mill fan inlet damper	Damper condition	Monthly
6	Mill Grinding media filling level	To achieve optimum grindability in mill	Online continuous
7	Circulation load	Ensure better separator efficiency	Online Continuous
8	Mill Reject < 90 micron sieve	Monitor separator performance	Shift wise
	SEC		
9	Mill drive	Monitor and maintain SEC	Online continuous , Daily
10	Mill fan	Monitor and maintain SEC	Online continuous , Daily
11	Mill fan Efficiency	To achieve best tech possible, monitor and maintain	Monthly
12	Mill feed size	Optimize output	Weekly
13	Mill product residue Target and actual	Optimize mill and kiln operation	Hourly
14	Mill load (avg kW) to allowable kW	Optimize output and decide on grinding media make up charge	Daily
15	Piece weight in first chamber	To achieve optimum grindability in mill	Monthly
16	Grinding media surface area in second chamber	To achieve optimum grindability in mill	Monthly
17	Size of Slot Opening in the partition wall grates / cleanliness	To achieve optimum material and gas/ air flow through mill	Fortnightly
18	Pressure drop across mill	To monitor the material and air/gas flow and identify the blockages if any in the grates (partition and discharge diaphragm)	On line continuous

PYRO SECTION

S.No	Parameter	Purpose	Preferred monitoring frequency
S.No	Parameter	Purpose	Preferred monitoring frequency
1	Kiln feed LSF SD	Kiln stability, optimum heat of reaction, clinker grindability	Daily
2	Preheater outlet oxygen	To maintain optimum excess air	Online Continuous
3	Preheater outlet CO	To maintain optimum excess air	Online Continuous
4	Preheater outlet pressure and temperature	Maintain and monitor preheater thermal loss	Online Continuous
5	Preheater fan inlet damper pressure drop	Damper condition	Monthly
6	False air across preheater (from kiln inlet to preheater fan outlet)	Optimize electrical and thermal sec	Monthly
7	Kiln inlet Nox level	Burning Zone excess air level	Online Continuous
8	Each cyclone ΔP and ΔT (BDP and actual)	Optimize electrical and thermal sec	Monthly
9	Dust concentration in down comer duct (BDP and actual)	Optimize electrical and thermal sec	Yearly
10	RABH DP	Optimize bag life and fan power	Online Continuous
	Fan efficiency		
11	Preheater fan	To achieve best tech possible, monitor and maintain	Monthly
12	RABH Fan	To achieve best tech possible, monitor and maintain	Monthly
13	Cooler vent fan	To achieve best tech possible, monitor and maintain	Monthly
14	Cooler fans	To achieve best tech possible, monitor and maintain	Monthly
15	Temp drop across TAD	Reduce radiation loss and false air entry	Monthly
16	Cooler fans suction pressure	Optimize fan power	Monthly
17	Pressure drop across silencer in cooler fans	Ensure optimum power	Monthly
18	Damper pressure drop (if any)		Monthly
19	Preheater fan	Damper condition	Monthly
20	Cooler vent fan	Damper condition	Monthly
22	SEC		
	Preheater fan	Monitor and maintain SEC	Online continuous and daily
	Cooler fans	Monitor and maintain SEC	Online continuous and daily
	Cooler vent fan	Monitor and maintain SEC	Online continuous and daily
	RABH fan	Monitor and maintain SEC	Online continuous and daily
	Coal conveying blower	Monitor and maintain SEC	Online continuous and daily

23	Specific air flow		
	Cooling air	Monitor and maintain thermal & Electrical SEC	Monthly
	Cooler vent air	Monitor and maintain thermal & Electrical SEC	Monthly
	Preheater fan flow	Monitor and maintain thermal & Electrical SEC	Monthly
	RABH fan flow	Monitor and maintain thermal & Electrical SEC	Monthly
	Tertiary air flow	Monitor and maintain thermal & Electrical SEC	Monthly
24	Coal phase density		
	Kiln	Optimise blower power and sp heat consumption	Monthly
	PC	Optimise blower power and sp heat consumption	Monthly
25	Primary air %		Monthly
26	Cooler bed height	To achieve cooler recuperation efficiency	Online Continuous
27	Temperatures		BDP and actual
	Cooler vent	Monitor and maintain specific heat consumption	Online Continuous
	Clinker	Monitor and maintain specific heat consumption	Online Continuous
	Preheater outlet	Monitor and maintain specific heat consumption	Online Continuous
	Tertiary Air	Monitor and maintain specific heat consumption	Online Continuous
	Secondary air	Monitor and maintain specific heat consumption	Online Continuous
	Kiln Exit gas	Monitor and maintain specific heat consumption/ Volatile circulation phenomena	Online Continuous
28	Water spray quantity		
	Cooler	Water, energy conservation, specific heat consumption	Online Continuous
	Down comer / Top cyclone	Water, energy conservation, specific heat consumption	Online Continuous
29	Free silica (Quartz) in kiln feed %	Kiln stability, optimum heat of reaction, clinker grindability	Hourly
30	Free lime in clinker %	Kiln stability, optimum heat of reaction, clinker grindability	Hourly
31	Kiln Feed Fineness - Residue on 212 µ sieve	Control of Free Lime and optimize energy consumption	Hourly

CEMENT MILL - BALL MILL

S.No	Parameter	Purpose	Preferred monitoring frequency
1	Circulation Load	Optimize separator performance	Online continuous
2	Separator loading(gm/m^3)	Optimize fan power	Online continuous/ monthly / variety wise
3	Velocity inside mill	Avoid over grinding	Mill vent volume can be alternative
4	Specific grinding media weight for first chamber	Optimize grindability	Monthly / regarding half yearly
5	Specific GM surface area for second chamber	Optimize grindability	Monthly / regarding half yearly
6	% filling level	Optimum output	Online continuous
7	Residue on 45µ in the reject	Monitor separator performance	Shift wise
8	Roller press BDP KW and actual loading	Optimum grinding	Online continuous
9	Product residue or Blaine Target and actual	Optimum output and power	Hourly
10	Separator vent flow as % of circulating air flow	Control false air in the circuit, cooling of cement and optimize power	Monthly
11	Pressure drop across cyclone	Optimize fan power	Online continuous
	SEC		
12	Mill , HPRG Drives	Monitor and maintain SEC	Online continuous, Daily
13	CA fan	Monitor and maintain SEC	Online continuous, Daily
14	Mill vent	Monitor and maintain SEC	Online continuous, Daily
15	Sept Vent	Monitor and maintain SEC	Online continuous, Daily
16	Bag filter DP		
	Sept vent	Optimize bag life and fan power	Online Continuous
	Sept fan inlet	Optimize bag life and fan power	Online Continuous
	Mill vent	Optimize bag life and fan power	Online Continuous
17	Fan Efficiency		
	CA fan	To achieve best tech possible, monitor and maintain	Monthly
	Mill vent	To achieve best tech possible, monitor and maintain	Monthly
	Sept Vent	To achieve best tech possible, monitor and maintain	Monthly
18	Feed Composition/Recipe	To monitor consumption of additives and extenders	Online / Continuous
19	Feed moisture	To monitor SEC	Daily
20	Pressure Drop across Mill	To monitor SEC	Online / Continuous
21	Size of Slot Opening in the partition/end wall grates / cleanliness	To achieve optimum material and gas/air flow through mill	Fortnightly

UTILITIES

S.No	Parameter	Purpose	Preferred monitoring frequency
1	Compressor (HP) SEC	Monitor and maintain power	Daily
2	Up to clinkerisation		
3	Cement grinding		
4	Compressed air generation pressure	Optimize power and indication of leakage and pressure drop	Online continuous
5	Compressor loading %	Ensure optimum utilization	Monthly
6	Compressed air leakages %	Unproductive power	During every shutdown
7	Compressor SEC	Condition of compressor	Monthly where stand by is available other wise during stoppages
	Compressor discharge air temperature	Monitor and maintain efficiency of compressor / Cooling system/ FAD Capacity	Daily
	Screw Compressor – Oil Pressure	Monitor and optimize no load power	Periodical
8	Cooling water circulating flow		
	Pyro section	Water consumption and power saving	Monthly
	Cement mill	Water consumption and power saving	Monthly
9	Cooling water inlet and return temp	Effectiveness of heat exchangers ,process heat load and cooling tower effectiveness	Online continuous
10	COC	Water consumption	Monthly
11	Pump efficiency	Optimum power	Monthly
12	Pump discharge pressure	Line condition, requirement and valve throttling	Online continuous in case of common header or monthly
13	Fly ash unloading pressure	Optimize compressor power	daily
14	Air Conditioning SEC (kWh/TR)	Optimize air cooler performance	Daily

CAPTIVE POWER PLANT

S.No	Parameter	Purpose	Preferred monitoring frequency
1	Boiler exit oxygen	Monitor and maintain excess air	Online continuous
2	Id fan inlet oxygen	Monitor and maintain false air	Monthly
3	DP across BFP Flow control valve	BFP power	Online continuous
4	Efficiency		
	BFP	To achieve best tech possible, monitor and maintain	Monthly
	CEP	To achieve best tech possible, monitor and maintain	Monthly
	CWP	To achieve best tech possible, monitor and maintain	Monthly
	ACW	To achieve best tech possible, monitor and maintain	Monthly
5	Compressor SEC	Monitor and maintain power	Daily
6	Inst compressor pressure	Optimize power and indication of leakage and pressure drop	Online continuous
7	Ash conveying pressure	Optimize power and indication of leakage and pressure drop	Online continuous
8	Compressor loading	Ensure optimum utilization	Monthly
9	Cooling tower inlet and outlet temp	Effectiveness of heat exchangers ,process heat load and cooling tower effectiveness	Online continuous
	Approach to Wet bulb temperature	Monitor the efficiency of Cooling tower	Monthly
10	Temp in ARC line (after valve)	Optimize BFP power, identify ARC valve life	Online continuous
11	Id fan inlet pressure	Optimize fan power	Online continuous
12	FD fan suction pressure	Optimize fan power	Online continuous
13	Fan efficiency		
	FD fan	To achieve best tech possible, monitor and maintain	Monthly
	Id fan	To achieve best tech possible, monitor and maintain	Monthly
14	SEC kW / MW (BDP and actual)		
	Pumps	Monitor and maintain SEC	Online continuous, Daily
	Fans	Monitor and maintain SEC	Online continuous, Daily
	compressor	Monitor and maintain SEC	Online continuous, Daily
15	Coal - Moisture	Monitor and Control Parasite consumption	Daily
16	Heat Rate	Monitor the boiler efficiency	Daily
17	Coal – Proximate analysis	Monitor the boiler efficiency	Periodical/Shipment wise
18	Gas Turbine inlet air temperature	Monitor the Turbine efficiency	Hourly

ELECTRICAL

S.No	Parameter	Purpose	Preferred monitoring frequency
1	Transformer Losses	To calculate efficiency	Monthly
2	Transformer winding temperatures	To eliminate or interlock with winding temperature	Online continuous, Daily
3	Transformer Incoming voltage	TO minimize the operation of OLTC by manual/auto mode	Online continuous, Daily
4	Transformer Tap position	To optimize distribution voltage	Monthly
5	Motor Loading	To Improve the efficiency	Monthly
6	Motor Voltage	To reduce the voltage loss and for maintain optimum voltage	Online continuous, Daily
7	Power factor	To reduce the distribution losses and increase the capacity(KVA)	Online continuous, Daily
8	Capacitor Power	To reduce the loss	Monthly
9	Captive Power plant – Frequency in Island Mode	To minimize the frequency and saving power in centrifugal loads	Online continuous, Daily
10	Captive Power plant – Power factor in Island Mode	To improve turbo generator efficiency	Online continuous, Daily
11	Lighting Voltage (210 V)	To save power and increase lamp life	Online continuous, Daily
12	Distribution Losses	To reduce cable losses	Online continuous, Daily
13	Maximum demand	To avoid any penalties	Online continuous, Daily
14	Temperature of major feeders	To avoid any shut downs (using thermograph)	Monthly
15	Voltage drop	To minimize distribution losses	Monthly

ABBREVIATION

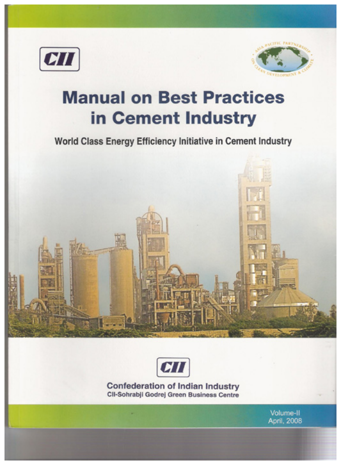
AC	-	Alternating Current
ACC	-	Air Cooled Condenser
ACWP	-	Auxiliary Cooling Water Pump
AFBC	-	Atmospheric Fluidized Bed Combustion
AFR	-	Alternate fuel & Raw Material
BDP	-	Best Demonstrated Practice
BEE	-	Bureau of Energy Efficiency
BF	-	Bag Filter
BFP	-	Boiler Feed water Pump
BH	-	Bag House
CA	-	Circulating Air
CAGR	-	Compound Annual Growth Rate
CAP	-	Capacity
CCR	-	Central Control Room
CEP	-	Condensate Extraction pump
CFC	-	Chlorofluorocarbon
CFD	-	Computational Fluid Dynamics
CKT	-	Circuit
CMA	-	Cement Manufacturers Association
CO	-	Carbon monoxide
COC	-	Cycle Of concentration
CWP	-	Cooling Water Pump
DP	-	Differential Pressure
EOT	-	Electric Overhead Travelling
ESP	-	Electrostatic Precipitator
FA	-	False Air
FD	-	Forced Draft
GCT	-	Gas Conditioning Tower
GI	-	Galvanized iron
GRR	-	Grid Rotor Resistance
HMI	-	Human Machine Interface
HP	-	High Pressure
HPMV	-	High Pressure Mercury Vapor Lamp
HPRG	-	High Pressure Roller Grinding
IGBT	-	Insulated Gate Bypolar Transistor
ILC	-	In Line Calciner
LDR	-	Light Dependent Resistor
LED	-	Light Emitting Diode
LOI	-	Loss on Ignition

LOTO	-	Lock Out Tag Out
LRR	-	Liquid Rotor Resistance
LS	-	Lime stone or Linear Stacker
LSF	-	Lime Saturation Factor
MCC	-	Motor Control Center
MTPA	-	Million Tons per Annum
MV VFD	-	Medium Voltage Variable Frequency Drive
NCBM	-	National Council for Cement and Building Materials
NCV	-	Net Calorific Value
OPC	-	Ordinary Portland cement
P&V	-	Pressurization & Ventilation
PAT	-	Perform Achieve and Trade
PH	-	Pre Heater
PLC	-	Programmable Logic Controller
PLF	-	Plant load factor
PPC	-	Portland Pozzolana Cement
PPM	-	Parts Per Million
PSC	-	Portland Slag Cement
RABH	-	Reverse Air Bag House
RE	-	Renewable Energy
RP	-	Roller Press
RPM	-	Revolutions per Minute
SEC	-	Specific Energy Consumption
SLC	-	Separate Line Calciner
SPRS	-	Slip Power Recovery System
STP	-	Sewage Treatment Plant
TAD	-	Tertiary Air Duct
TG	-	Turbo Generator
TOD	-	Time of Day
TPH	-	Tonnes per Hour
TSR	-	Thermal Substitution Rate
VFD	-	Variable Frequency Drive
VRM	-	Vertical Roller Mill
WC	-	Water Column
WHR	-	Waste Heat Recovery

PUBLICATIONS BY CII-GBC AS PART OF WORLD CLASS ENERGY EFFICIENCY IN CEMENT PLANTS

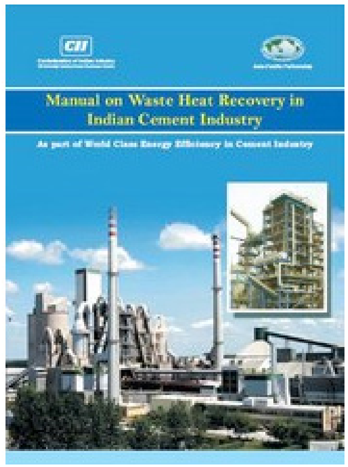
Manual on Best Practices in Cement Industry

The publication details the best practices followed by the Indian plants in the areas of energy efficiency, quality and productivity improvement.



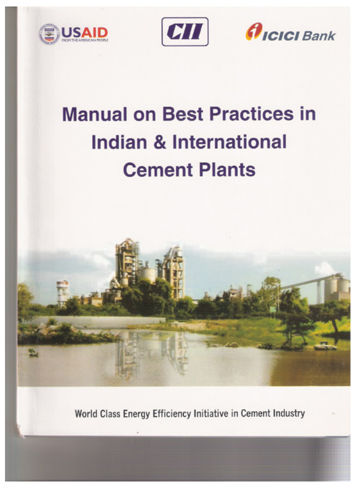
Manual on Waste Heat Recovery in Indian Cement Industry

The manual focuses on description of technologies available for Waste Heat Recovery Potential and installations in the Indian Cement Plants. This also discusses the advantages and also the barriers towards the deployment of WHR Technologies.



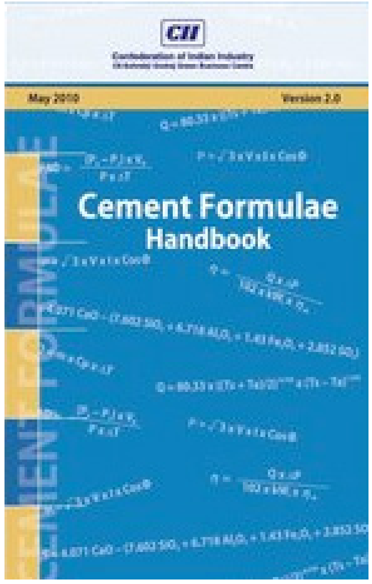
Manual on Best Practices in Indian & International Cement Plants

The publication was brought out as part of world class energy efficiency which covers the energy conservation measures carried out in the six cement plants as part of the mission and the experience and learning on Waste Heat Recovery from international mission carried out in Germany, Belgium, UK, Switzerland and Japan cement plants.



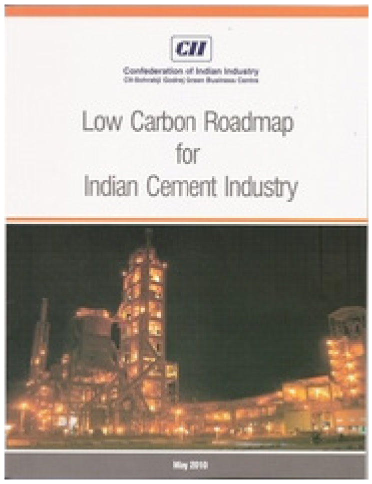
Cement Formulae Handbook

The formula book is a compilation of useful formulas, norms available at various sources, intended as a store of information which acts as a quick reference for the plant personnel. This was very well accepted by the Indian cement plants and subsequently the second edition was released during the annual conference in 2010.



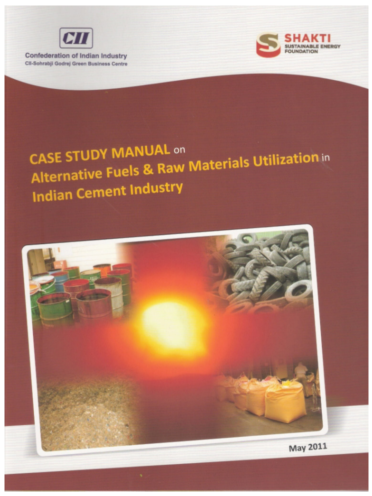
Low Carbon Roadmap for Indian Cement Industry

The report is an effort to create a road map for Indian Cement Industry to achieve the reduction in its Green House gas emission intensity. This is meant for due contemplation, reflection and necessary action from the Indian cement industry in its road map towards a low carbon growth.



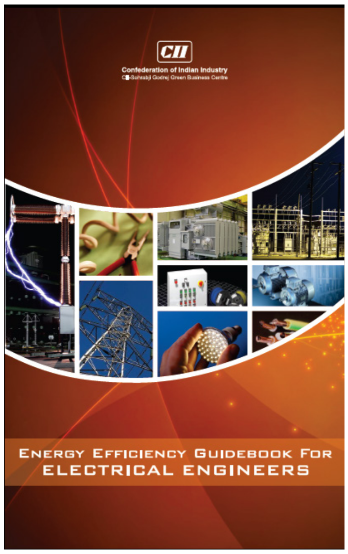
Case study Manual on Alternative Fuels & Raw Materials Utilization in Indian Cement Industry

The purpose of this manual is to act as catalyst for promoting increased use of alternate fuel & raw materials in Indian Cement Industry through co processing of wastes and reducing cost of clinker production, thereby improving performance competitiveness of individual cement plants. The objective also is to promote a much needed ecologically sustaining solution to the waste management problem in the country through co processing in cement kiln.



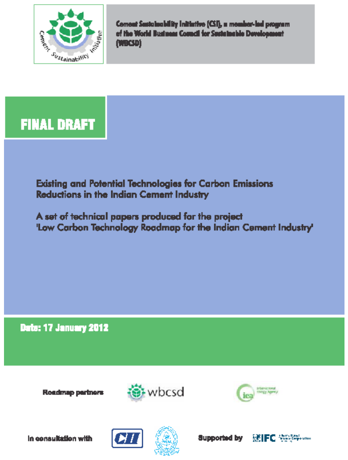
Energy Efficiency Guidebook for Electrical Engineers

The guidebook is a quick reference for electrical engineers that covers the fundamental theory of basic electrical equipments and provides the latest information on electrical systems such as motors and its control, transformers, lighting systems etc. It also throws light on the possible energy saving opportunities and newest trends in electrical and lighting systems.



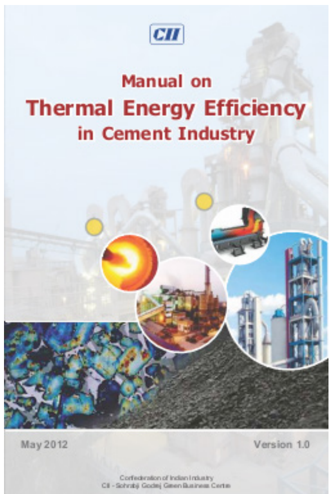
Low Carbon Technology Roadmap for the Indian Cement Industry

The report is a set of technical papers focusing on technologies, policy factors and financing needs for carbon emissions reduction and resource efficiency enhancement in Indian cement Industry. The technology papers are developed by Confederation of Indian Industry (CII) & NCCBM in partnership with International Energy Agency (IEA) and WBCSD's Cement Sustainability Initiative (CSI).



<u>Manual on Thermal Energy Efficiency in Cement Industry</u>

The Government of India in consultation with Bureau of Energy Efficiency (BEE) has released the PAT targets for the period from 2012-13 to 2014-15 in relation to their current level of energy consumption. Cement industry needs to focus more on Thermal Energy Efficiency in its endeavor to achieve the PAT targets. This manual serves as a ready reckoner on thermal energy efficiency including latest norms and best practices to reduce thermal Specific Energy Consumption.



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