Confederation of Indian Industry

ENERGY BENCHMARKING

for the Indian Cement Industry

May 2021

VERSION - 5.0

DISCLAIMER

While every care has been taken in compiling this manual, CII- Godrej GBC does not accept any compensation claim, if any entry is wrong, abbreviated, omitted, or inserted incorrectly either as to the wording space or position in the *Energy Benchmarking for Indian Cement Industry*. *Energy Benchmarking for Indian Cement Industry* is a store of information so that it will be useful to the plant personnel involved in production, operations, energy conservation and can be used by them readily. The source bank for *Energy Benchmarking for Indian Cement Industry* is based on a questionnaire submitted by participating cement plants, energy award data, case studies shared by suppliers in our conferences, and through our detailed and preliminary energy 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 the best levels which may be missing our notice.

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CII - Sohrabji Godrej Green Business Centre

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FOREWORD

Message from Chairman - Green Cementech 2021

CII-Sohrabji Godrej Green Business Centre (CII-GBC) has been at the forefront of actions related to industrial energy efficiency in the country. CII-GBC, as part of its "World Class Energy Efficiency" program, is working closely with the Indian cement industry on several initiatives. One such initiative is to develop and make available to the cement industry, energy performance indicators for the sector. This activity has taken the form of a publication titled "CII Energy Benchmarking for Indian Cement Industry". The first version of this manual was released in 2014, and it has been updated on a regular basis.

The Indian cement industry is one of the best performers among its peers in the world. This is made possible by the cement plants achieving milestones such as electrical SEC 43 kWh/MT clinker, thermal SEC of 676 kcal/kg clinker, the pressure drop of 300 mmwg across 6 stage PH, cooling airflow of 1.54 Nm^3/kg clinker, fines below 10% in separator reject and GHG emissions of 285 kg CO_2/t Cement.

However, there is still significant potential to improve the average energy efficiency at the sector level. Viewing this potential through the lens of voluntary carbon targets and other commitments recently made by many in the cement industry, we felt the time was opportune to release this latest version of the manual.

The CII Energy Benchmarking for Cement Industry Version 5.0, in addition to showcasing the improved levels of specific energy consumption in various sections of a cement plant, also provides information related to carbon emissions of the sector and its various products. This manual also features a chapter on thumb rules to help cement plants explore and evaluate different energy-efficient opportunities. We are confident that this manual will support the industry in identifying several hidden opportunities for improvements.

I am sure that this benchmarking manual, being released during the 17th CII "Green Cementech" conference in 2021, 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.

I warmly invite you to share your feedback with us at encon@cii.in

Philip Mathew
Chairman, Green Cementech 2021, CII-Godrej GBC &
Head Cement Manufacturing Excellence, Asia (CEM Asia), LafargeHolcim

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 stakeholders.

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 were thoroughly a rewarding experience for CII.

EXECUTIVE SUMMARY

The Indian cement industry is a trendsetter in environmental sustainability and has been consistently adopting the latest technologies for energy efficiency improvements. The levels of energy efficiency in some Indian cement plants are amongst the best in the world. Despite this, there is still significant scope for improvement through the use of energy-efficient technologies and practices in new and old plants. Energy benchmarking is an effective tool for improving the energy efficiency of any industry. It helps plants to analyse the level of their performance as compared to the best performing plants in their sector. Benchmarking also identifies industry best practices and best available technologies.

CII Sohrabji Godrej Green Business Centre has developed this "Energy Benchmarking Manual for Indian Cement Industry" to provide the latest information regarding the energy performance of Indian cement plants to all the stakeholders in the cement industry. This publication is the fifth version of the manual. The earlier versions of the energy benchmarking manual have been recognized as a useful tool for performance assessment, energy efficiency improvement, and target setting across the cement industry, helping cement plants achieve the status of world-class units. Over the last 6 years, since the development of the first version, there has been consistent improvement in many areas and parameters resulting in improved energy efficiency levels among the Indian cement plants. The intention behind updating the benchmarking manual is to ensure that the most updated information and analysis is available to the sector, thereby facilitating cement plants to continually compare themselves against their peers. Such comparisons will help in the identification of potential areas for performance improvement, and subsequent improvements.

The first step in developing the manual was to collect data from the sector. A detailed questionnaire was prepared, covering all sectional parameters in a cement plant, from crusher to packing plant; the questionnaire was sent to more than 110 cement plants across India for their inputs. The majority of Indian cement plants have participated in this benchmarking study by sharing their data. The collected data was then extensively analysed by section. The report itself is structured around the different sections in a cement plant to enable easy reference and comparison; for each section, the parameters contributing to achieving the best specific energy consumption (SEC) are listed.

The Indian cement industry has seen drastic changes in overall specific energy consumption (SEC) over the last seven years. The average cement power consumption has fallen from 88 kWh/ton of cement in 2014 to 76 kWh/ton of cement in 2021; average clinkerization power has reduced from 65 kWh/ton of clinker to 55 kWh/ton of clinker. The important factors that have contributed to this fall in SEC include reduction in clinker factor, installation of waste heat recovery systems (WHRS doubled over the period, from 240 MW to 500 MW), increase in thermal substitution rate (average increased from 2% to 6% over the period), with 30% being the best achievement), Industry 4.0, and reduction in system resistance of fans by using the latest energy-efficient mills, preheaters & coolers.

The best thermal and electrical energy consumption presently achieved in Indian cement plants are 676 kcal/kg clinker and 56.14 kWh/MT cement, respectively. The average thermal and electrical energy consumption in the Indian cement sector is 740 kcal/kg clinker and 76 kWh/MT cement[1].

[1] *Low carbon technology roadmap for Indian Cement sector: Status review 2018*

There are significant opportunities in most of the cement plants to improve their energy efficiency as the gap between the best performing plant and the other plants is still large (difference of 10-12 kWh/MT cement and 50-80 kcal/kg clinker).

This benchmarking manual will help cement plants to understand the extent of difference in their performance as compared to the best performing plants, as well as the root cause for the differences.

The best-operating values and the outcome of the benchmarking study are as follows

BENCHMARKING NUMBERS			
Sr. No.	Section	Unit	Specific Energy Consumption (SEC)
1	Crusher	kWh/MT Limestone	0.58
2	Raw Mill - VRM	kWh/MT raw meal	10.64
3	Raw Mill – Roller Press	kWh/MT raw meal	12.99
4	Coal Mill – VRM-Pet Coke Grinding	kWh/MT Pet Coke	36.00
5	Six Stage Preheater-kiln SEC	kWh/MT Clinker	15.45
6	Six Stage Preheater – Clinkerization	kWh/MT Clinker	42.59
7	Thermal SEC (6 Stages)	kcal/kg clinker	676
8	Overall SEC upto Cement	kWh/MT Cement	56.10
9	Cement Mill – VRM(PPC)	kWh/MT cement	18.80
10	Cement Mill – VRM(OPC)	kWh/MT cement	24.00
11	Cement Mill VRM (PSC)	kWh/MT cement	31.90
12	Ball Mill(PPC)	kWh/MT cement	27.00
13	Ball Mill +RP(PPC)	kWh/MT cement	20.39
14	Packing Section	kWh/MT cement	0.58

BEST ACHIEVED VALUES			
S.No	Parameters	Unit	Benchmarking numbers
1	RABH Fan Power	kWh/ton clinker	1.22
2	Preheater Outlet temperature(6 stage)	^{0}C	230
3	Preheater losses	kcal/kg clinker	110
4	Temperature Drop Across TAD	^{0}C	30
5	Phase density in pet coke	kg petcoke/kg air	5.90
6	Volumetric loading	TPD/m^3	7.80
7	Cooler Loading	TPD/m^2	56
8	Overall WHRS efficiency	%	21
9	Maximum AFR Consumption (TSR)	%	30
10	Preheater Fan power with WHRS	kWh/ton clinker	6.60
11	Specific power of preheater fan	kWh/ton clinker	3.40
12	Lowest specific power of Cooler Vent fan(Without WHRS)	kWh/ton clinker	0.25
13	Lowest Specific power of cooler fans	kWh/ton clinker	3.10
14	Lowest Specific Power of Fan - Raw mill(VRM)	kWh/ton material	3.86
15	Lowest 5 Stage Preheater – Thermal SEC	kcal/kg clinker	690
16	Lowest 5 Stage Preheater upto clinkerization	kWh/ton clinker	48.92

BEST ACHIEVED VALUES			
S.No	Parameters	Unit	Benchmarking numbers
17	Five Stage Preheater – Clinkerization	kWh/ton clinker	16.28
18	Lowest Single Stage SEC of Crusher	kWh/ton material	0.58
19	Lowest Double Stage SEC of Crusher	kWh/ton material	0.65
20	Maximum Output from normal coal to pet coke (Conversion)	%	65

OVERALL IMPROVEMENT JOURNEY OF INDIAN CEMENT INDUSTRY FROM LAST 7 YEARS					
S.No	Plant Section	Unit	Benchmarking 2014	Benchmarking 2021	Improvement (%)
1	Crusher SEC(single stage)	kwh/ton of Limestone	0.70	0.58	17
2	Raw mill VRM(SEC)	kwh/ton of Msterial-raw meal	13.30	10.64	20
3	Coal mill-VRM (Normal Coal)	kwh/ton of material-coal	23.90	15.50	35
4	Thermal SEC-5 Stage	kcal/kg clinker	707	690	2.4
5	Thermal SEC-6 Stage	kcal/kg clinker	686	676	1.5
6	Average Cooler Vent Fan SEC	kWh/ton of Clinker	0.50	0.25	50.0
7	SEC of RABH Fan	kWh/ton of Clinker	1.65	1.22	26.10
8	Overall SEC up to clinkerization-6 Stage	kWh/ton of Clinker	46	42.59	7.40

OVERALL IMPROVEMENT JOURNEY OF INDIAN CEMENT INDUSTRY FROM LAST 7 YEARS					
S.No	Plant Section	Unit	Benchmarking 2014	Benchmarking 2021	Improvement (%)
9	Preheater exit temperature	^{0}C	245	230	6.10
10	Pressure drop across 6 stage preheater	mmwg	450	350	22.20
11	Cement mill VRM(PPC)	kWh/ton of cement	21	18.6	11.40
12	Compressor SEC up to clinkerization	kWh/ton of clinker	0.90	0.80	11.1
13	Compressor SEC -Cement grinding & packing	kWh/ton of cement	0.80	0.75	6.30
14	Overall reduction in average SEC up to clinkerization	kWh/ton of clinker	60.5	50	17.40
15	Overall reduction in average SEC up to cement	kWh/ton of cement	88	76	13.60
16	Increase in thermal substitution(TSR)	%	4	6	100.0
17	AFR improvement in best-achieved values in terms of TSR	%	21	30	450.0

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1. INTRODUCTION

India is the second largest producer of cement in the world. Cement production reached 329 million tonnes (MT) in FY20 and is projected to reach 381 MT by FY22. However, the consumption stood at 327 MT in FY20 and will reach 379 MT by FY22. The cement production capacity is estimated to touch 550 MT by 2025. India has a lot of potential for development in the infrastructure and construction sector and the cement sector is expected to largely benefit from it. Some of the recent initiatives, such as development of 100[2] smart cities, is expected to provide a major boost to the sector. Growth in infrastructure and real estate sector, post-COVID-19 pandemic, is likely to augment the demand for cement in 2022. The industry is likely to add around 8 MTPA capacity in cement production by year 2022.

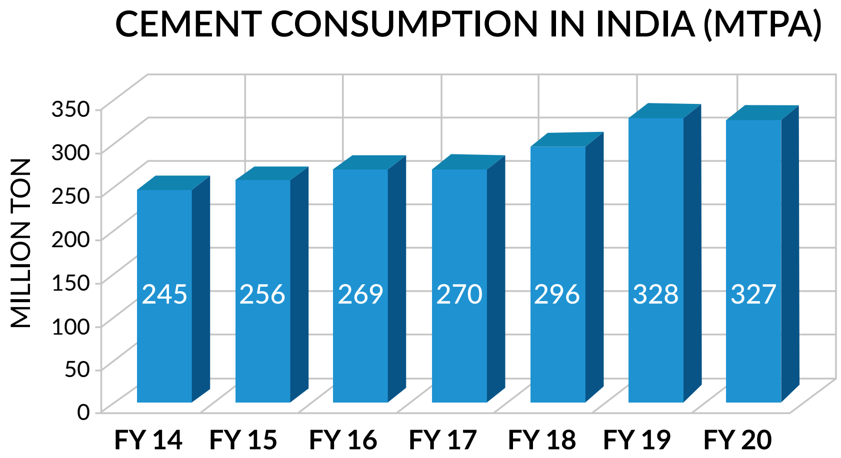


Figure 1: Cement consumption in India (million tonnes)[3]

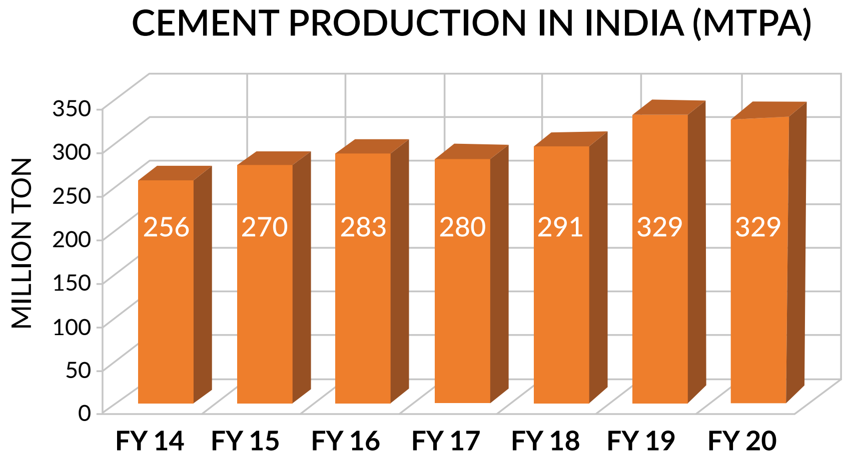


Figure 2: Cement production in India (million tonnes)[4]

[2] *Source: Making a city smart: Report by Ministry of Housing and Urban Affairs*
[3] *Source: Ibef January 2021 report*
[4] *Source: Ibef January 2021 report*

1.1 MAJOR PLAYERS IN INDIAN CEMENT INDUSTRY

The Indian cement industry is mostly domestically developed, with the presence of a few global groups. UltraTech Cement Limited and Lafarge-Holcim (ACC Limited & Ambuja Cements Limited) are the two largest producers of cement in India, with 20% and 12.5% share in the domestic market. The other Indian key players in top 10 include Shree Cement Limited (7.4%), Dalmia Cement (Bharat) Limited (5.6%), Nuvoco Vistas Corp. Ltd. (4.6%), The Ramco Cements Limited (3.2%), India Cements Limited (3.0%), Chettinad Cement Corporation (3.0%), Birla Corporation Limited (3.0%), and Century Textiles and Industries Limited (2.5%). Individual production capacities of the largest cement companies in India for the year 2020 is shown in million tonnes per annum in figure 3. 14 cement companies produce more than 55% of total cement produced in India in year 2020.

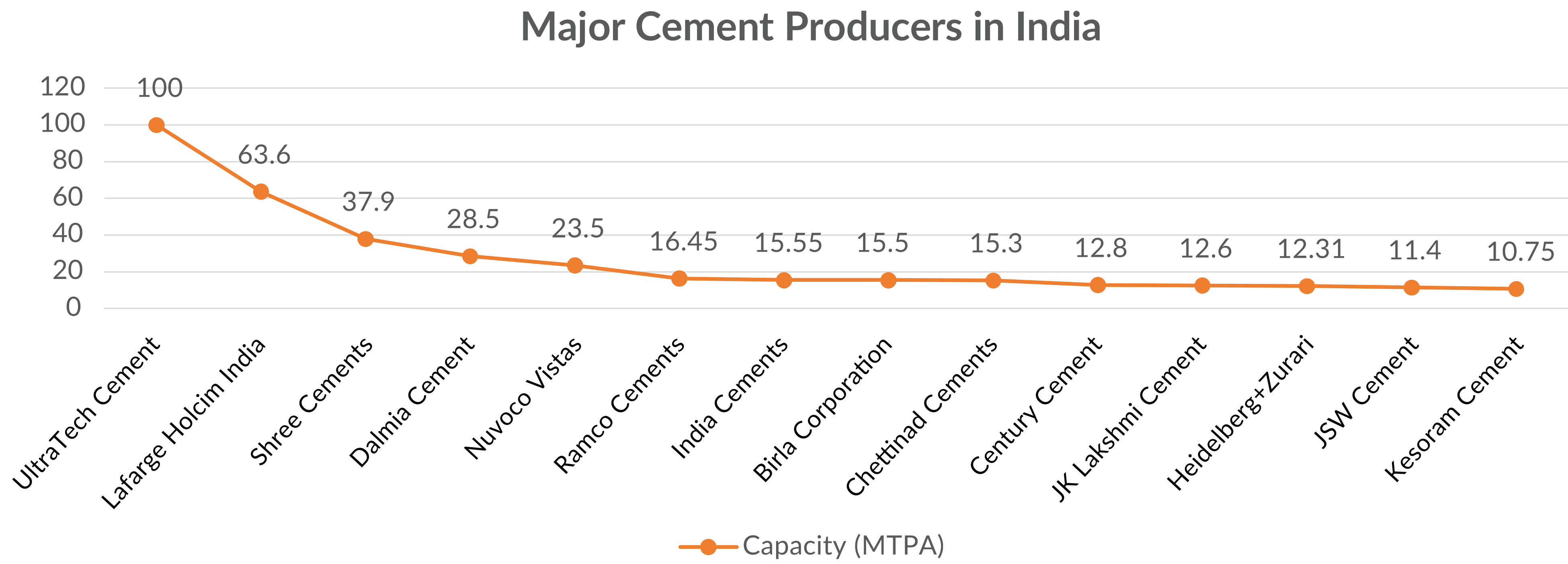


Figure 3: Major Cement Producers in India[5]

[5] *Source: Company annual reports*

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. 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 which impacts the heat of formation and grindability of limestone broadly. This 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 cement manufacturing in India by capacity is as follows:

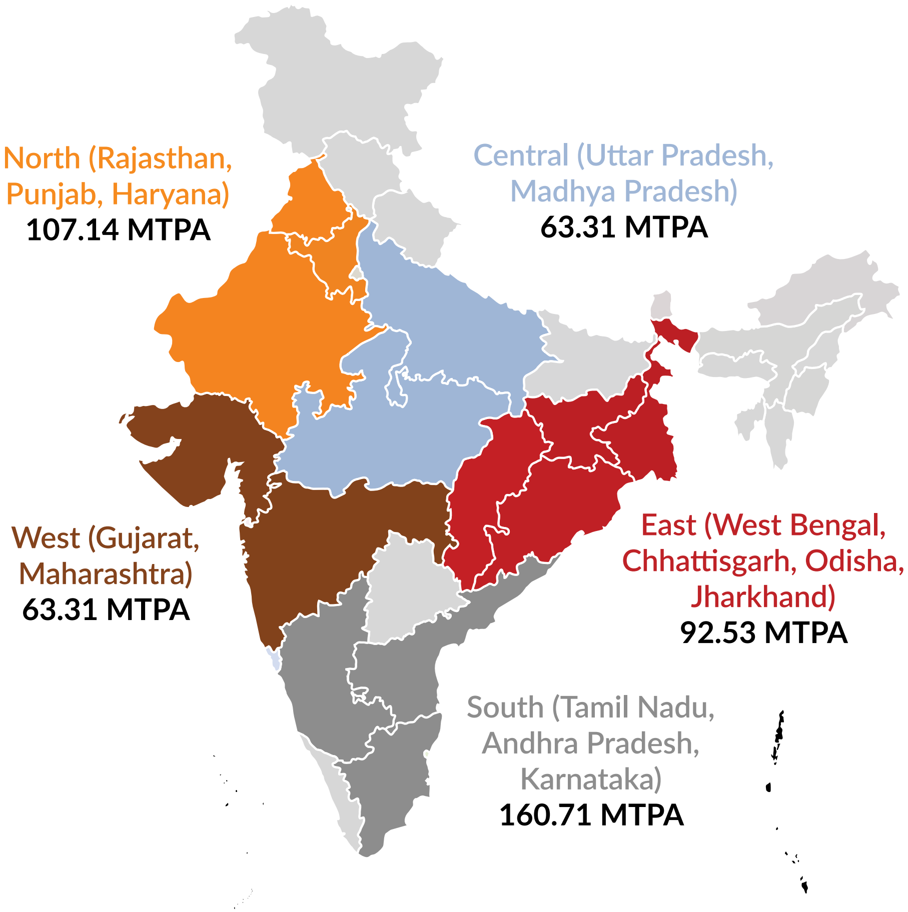


Figure 4: Geographical distribution of Cement Manufacturing[6]

[6] *Ibef January 2021 report*

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. Figure 5 & 6 shows the comparison and between the global average and the Indian average Electrical and thermal SEC from year 2010 and estimates the average electrical and thermal SEC of the Indian cement industry and that of the global average. 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.

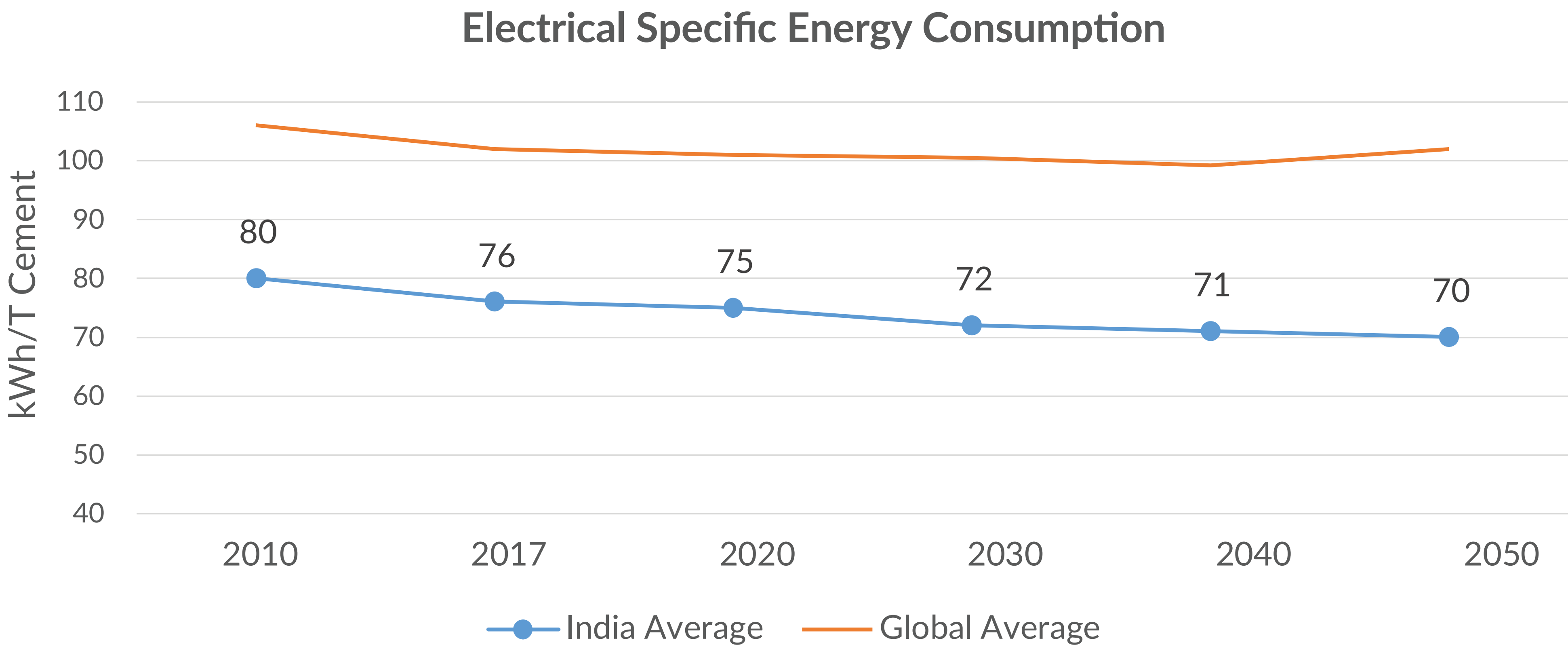


Figure 5: Electrical Specific Energy Consumption trend[7]

[7] *Source: Low carbon technology for the Indian cement industry*

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.

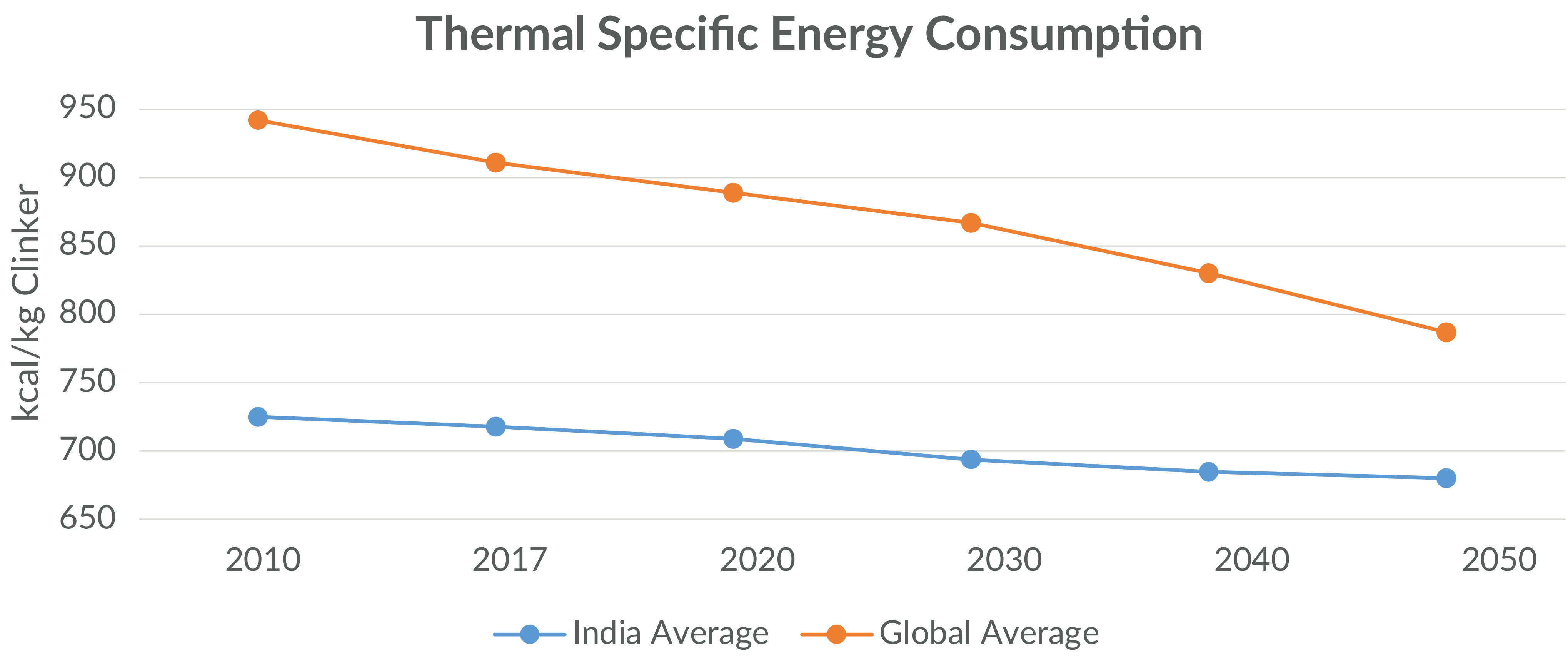


Figure 6: Thermal Specific Energy Consumption trend[8]

[8] *Source: Low carbon technology for the Indian cement industry*

1.4 FACTORS FAVOURING ENERGY EFFICIENCY IN INDIAN CEMENT INDUSTRY

The two main factors that affect the energy efficiency of any industry are technological availability and economic feasibility. Rest all the factors are directly or indirectly related with these two factors. The factors that affect the energy efficiency of cement industry are:

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.

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. The key goal of the scheme is to mandate reduction in specific energy consumption for the most energy-intensive industries and incentivize 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 EESO, 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

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

Some of the initiatives by CII-Godrej GBC to support the 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 a platform for information and technology updates 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; seven units have explored for the feasibility of implementation of these technologies and few more expressed their interest in participating this initiative.
5. Facilitating cement plants in achieving PAT (Perform, Achieve and Trade program of BEE) targets in a cost-effective manner.

2. SPECIFIC ENERGY CONSUMPTION — TOP 10 CEMENT PLANTS IN INDIA

2.1 ELECTRICAL SPECIFIC ENERGY CONSUMPTION

Table 1: Electrical Wise SEC-Top 10 plants

Sr.No.	Section	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant7	Plant 8	Plant 9	Plant 10
•	Overall SEC	kWh/MT cement	56.14	61.40	61.65	64.56	65.85	67.96	72.85	73.02	73.04	76.09
1	Crusher	kWh/MT limestone	1.8	0.65	1.51	0.74	0.74	0.84	1.63	0.75	0.76	0.86
2	Raw mill	kWh/MT raw meal	15.80	12.41	12.99	12.23	14.11	11.19	14.03	14.5	18.84	10.80
3	WHRS	MW	16	NA	NA	NA	NA	NA	-	7.5	9.5	9
4	Kiln	kWh/MT Clinker	19.10	20.06	15.45	18.39	20.06	23.07	19.04	22	21.77	21
5	Coal mill	kWh/MT Coal	29.85	38.27	33.45	15.63	39.63	55.53	40.18	48.50	50.84	34.50
6	Auxiliaries	kWh/ton clinker	1.30	-	3.91	-	2.39	-	-	1.0	-	-
	Total SEC up to Clinkerization	kWh/ton clinker	49.93	43.18	45.60	43.96	48.92	49.47	45.78	50.62	57.67	42.59
7	Cement mill	kWh/MT cement(OPC)	-	28.56	24.50	-	29.85	27.36	-	27	24.47	31.1
		KWh/MT Cement(PPC)	20.39	22.55	20.45	-	22.33	24.39	-	25	18.79	29.0
		kWh/MT Cement(PSC)	-	35.48	-	-	-	-	-	32.68	-	-
		KWh/MT Cement (others)	28.50	29.38	29.52	25.12	39.34	29.61	-	-	30.18	48
		Overall Clinker Factor	0.63	0.71	0.78	-	-	0.81	-	0.85	0.80	0.86

Sr.No.	Section	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant7	Plant 8	Plant 9	Plant 10
8	Packing plant	kWh/MT cement	1.30	0.81	1.52	0.65	1.02	1.29	1.50	1.30	1.62	1.17
9	Utilities & others	kWh/MT cement	-	0.71	4.70	3.22	2.66	3.0	1.43	2.0	2.07	3.34
10	Overall SEC	kWh/MT cement	56.14	61.40	61.65	64.56	65.85	67.96	72.85	73.02	73.04	76.09

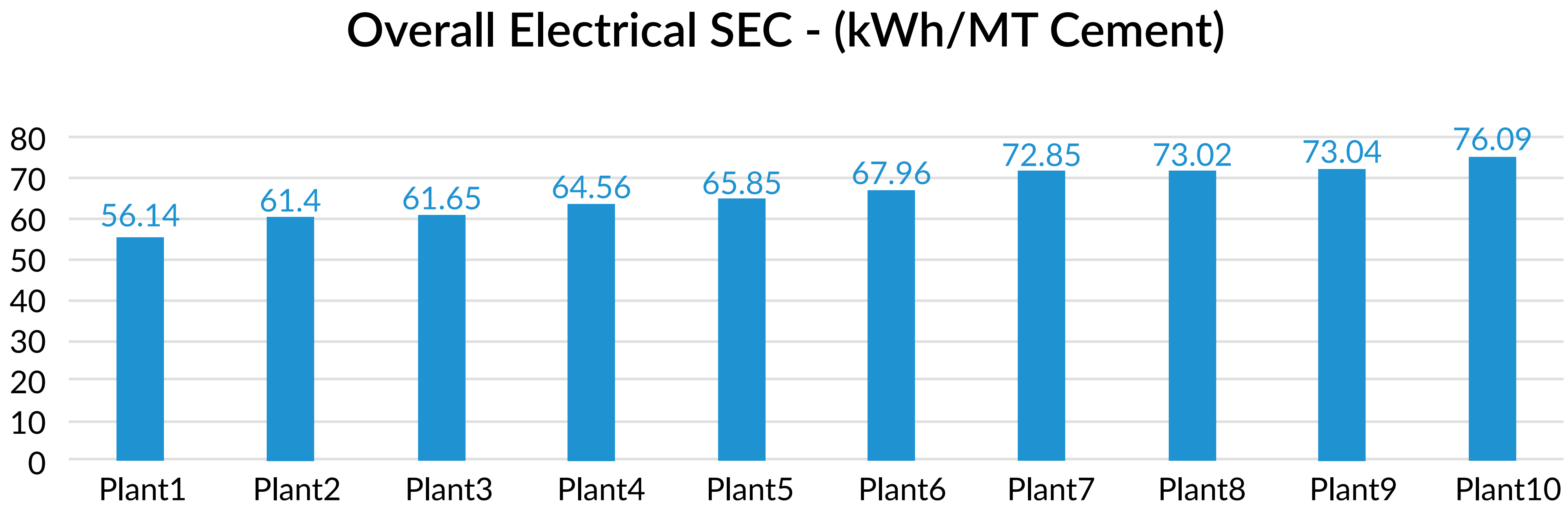


Figure 7: Overall Electrical SEC

2.1.1 SPECIFIC ELECTRICAL ENERGY CONSUMPTION — CLINKERIZATION

Table 2: Top 10 Plants Up to Clinkerization

Sr.No.	Section	Unit	Plant1 (L2)	Plant 2	Plant 3	Plant 4	Plant 5 (L3)	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
*	SEC UPTO Clinkerization	kWh/ton clinker	42.59	43.18	43.96	45.6	45.78	48.92	49.47	49.93	50.62	50.78
1	Crusher	kWh/ton clinker	1.18	0.91	1.11	2.14	2.28	1.06	1.22	2.70	1.11	0.68
2	Raw mill	kWh/ton clinker	15.77	18.86	19.05	19.71	21.04	21.45	17.01	23.70	22.1	18.21
3	Kiln	kWh/ton clinker	21	20.06	18.39	15.45	19.04	20.1	23.07	19.10	22	23.99
4	Coal mill	kWh/ton clinker	4.64	3.22	1.96	4.35	3.41	4.0	5.17	3.13	4.41	4.34
5	Miscellaneous	kWh/ton clinker	-	-	3.46	3.9	-	2.39	-	1.3	1	3.55
6	Total SEC up to clinkerization	kWh/ton clinker	42.59	43.18	43.96	45.6	45.78	48.92	49.47	49.93	50.62	50.78

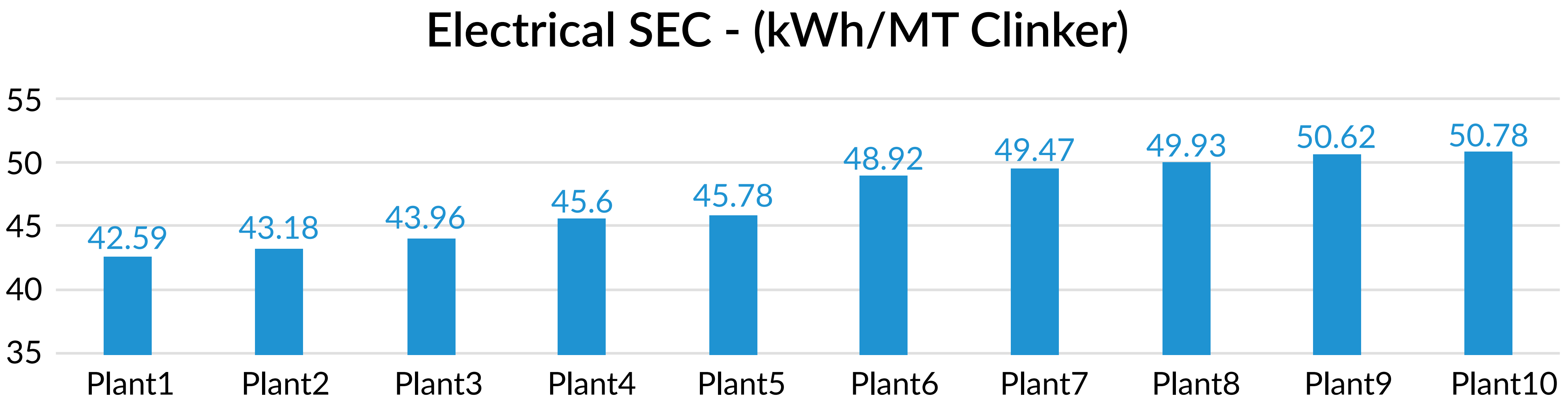


Figure 8: SEC of top Cement plants in India

2.1.2 SPECIFIC ELECTRICAL ENERGY CONSUMPTION BREAKUP

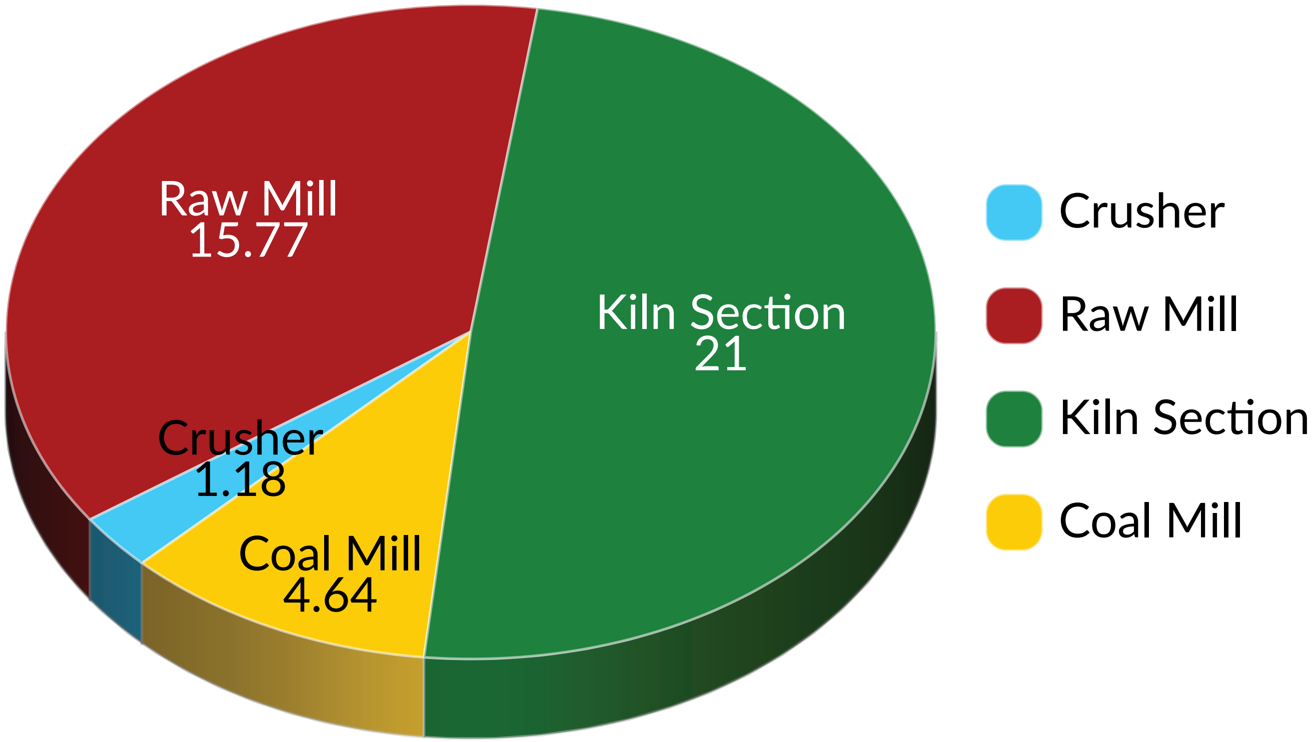


Figure 9: Specific Electrical Energy Consumption of Best plant (kWh/ton of Clinker))

2.2 THERMAL SPECIFIC ENERGY CONSUMPTION

Table 3: Heat Consumption of top 10 plants

Sr.No.	Section	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
1	Thermal SEC	kcal/kg Clinker	676	682	682	683	683	685	690	696	698	702
2	Clinker Output	TPD	9,500	7,215	7,200	4,500	5,000	5,000	4,622	5,175	4,900	3,150
3	No of Stages	No	6	6	6	6	6	6	6	6	6	6

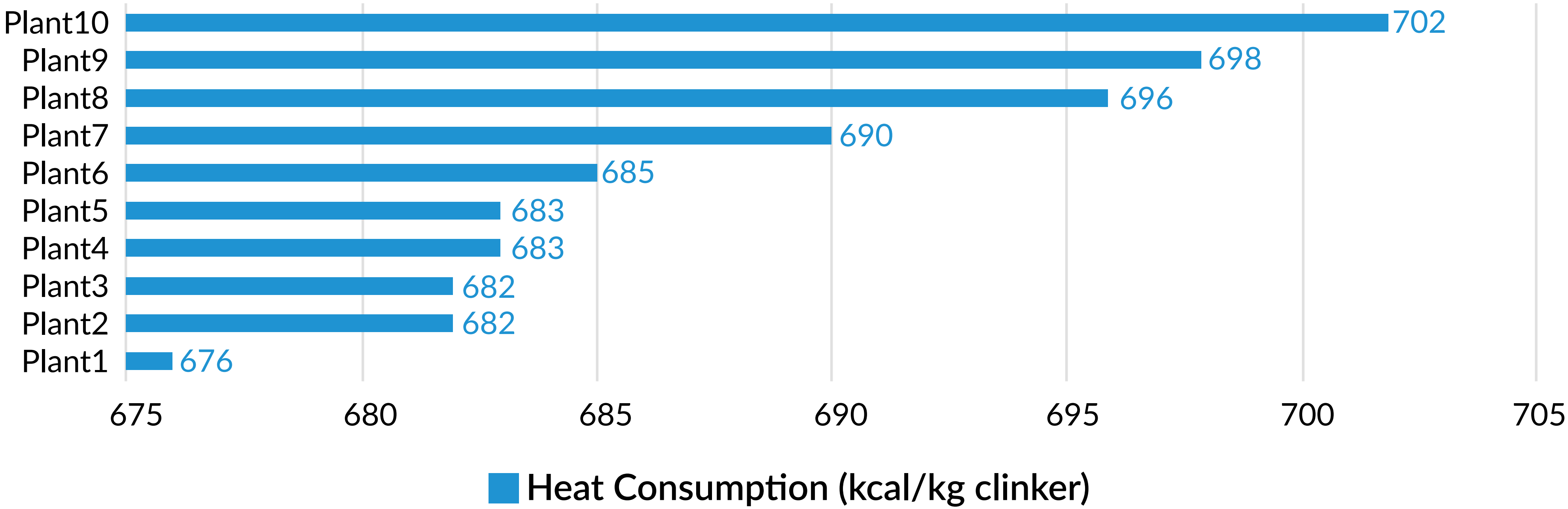


Figure 10: Thermal SEC of top cement plants in India

2.3 AFR UTILIZATION

Table 4: Thermal Substitution rate(%) of different cement plants in India

Sr.No.	Type of alternative fuels (AF)	Thermal Substitution	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9
*	Overall thermal substitution	%	30	15.15	15.11	13.30	12.74	10.40	8.63	4.65	1.58
*	Clinker Production	TPD	7,600	7,200	6,000	5,665	5,175	6,000	4,300	6,050	8,000
1	MSW (RDF)	%	2.5	1.23	0.09	2.7	-	4.96	0.18	0.13	-
2	Tyre chip	%	-	-	0.01	0	-	0.13	5.34	-	-
3	Paint sludge	%	-	-	4.43	0	-	0.28	0.01	-	-
4	Rice husk	%	2.5	-	1.91	1.1	-	-	0.08	0.78	0.06
5	Carbon black	%	14	-	7.33	8.5	-	-	-	0.45	0.01
6	Plastic	%	-	-	-	-	-	3.73	0.32	-	0.03
7	Solid waste	%	1.0	4.55	-	-	-	0.32	-	-	-
9	Cotton waste	%	-	-	-	-	-	0.29	1.65	-	-
10	Dolachar	%	8	2.08	-	-	-	-	-	-	-
11	Others (Biomass, SC, waste, liquid & Organic)	%	2.0	7.20	1.34	0.9	12.74-	0.51	1.0	3.29	1.42

2.4 CARBON EMISSION INTENSITY

Table 5: Carbon Emission Intensity – Top Plants in India

CARBON EMISSION INTENSITY – TOP PLANTS IN INDIA			
Sr. No.	Plant Reference	GHG emission (kg CO_2/T cement)	Remarks
1	Plant 1	285	100% PSC
2	Plant 2	361	100% PSC
3	Plant 3	369	79% PSC and 21% PPC
4	Plant 4	379	100% PSC
5	Plant 5	409	82% PSC, 17% PPC and 1% OPC
6	Plant 6	421	83% PSC, 17% PPC and 1% OPC
7	Plant 7	493	100% PPC
8	Plant 8	494	83% PSC and 17% OPC
9	Plant 9	496	54% PSC, 42% PPC and 3% OPC
10	Plant 10	502	100% PPC
11	Plant 11	506	100% PPC
12	Group 1	543	Overall Group
13	Group 2	618	Overall Group

Table 6: Carbon emission intensity targets-Indian & Global Cement Companies

VOLUNTARY CARBON EMISSION INTENSITY TARGETS – INDIAN & GLOBAL CEMENT COMPANIES									
Sr. No	Cement Company	Target Types	Overall GHG Intensity Reduction	Scope 1 Intensity Reduction	Scope 2 Intensity Reduction	Target Year	Baseline Year	Target GHG Intensity	SBTi
1	ACC Limited	Intensity	40%	-	-	2030	1990	-	Yes
2	Ambuja Cement	Intensity	40%	-	-	2030	1990	-	Yes
3	Dalima Cement	Carbon Negative	-	-	-	2040	-	463	-
4	Lafarge Holicim (Global)	Intensity	-	-	-	2040	-	475	Yes
5	Shree Cement	Intensity	-	12.70%	27.10%	2030	2019	-	Yes
6	Ultratech Cement	Intensity	-	27.00%	69.00%	2032	2017	462	Yes

3. SECTION WISE BENCHMARKING NUMBERS

3.1 CRUSHER SECTION

Sr.No.	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	0.58	0.63	0.74	0.75	0.86	1.04	1.22	1.32	1.44	1.51
1	Crusher type (Gyratory/Jaw/ Impact / Roller etc)	-	Impact	Impact	Roll Crusher	Impact	Impact	Impact	Roller Crusher	Roller	Impact	Impact
2	No. of stages (Eg. Single/Two)		1	1	2	1	1	1	1	1	2	2
3	Material hardness (For Eg. Hard/ Soft/Medium)	-	-	Medium	Medium	Soft	Soft	Hard	Hard	Medium	medium	Medium
4	Product size (% oversize on 75 mm)	%	0	8	5	<50 mm (90%)	5	8	≤80mm (95%)	6	80mm/ 40 - 1.5%max	0
5	Design output	TPH	500	900	1,000	1,200	850	1,300	900	1,200	1,100	1,200
6	Operating output	TPH	463	905	750	1,150	750	1,600	943	967	1,155	1,033
7	Material moisture	%	6.5	<1	13.5	-	5	2.0	0.2	2	2.0	0.5
8	Specific power consumption:	kWh/MT Limestone	0.58	0.63	0.74	0.75	0.86	1.04	1.22	1.32	1.44	1.51
a	Crusher Main Drive	kWh/MT Limestone	0.20	0.34	-	0.40	0.46	0.33	0.54	-	-	0.99
b	Other auxiliaries	kWh/MT Limestone	0.38	0.29	-	0.35	0.40	0.715	0.62	-	-	0.52
c	Total Crusher section SEC	kWh/MT Limestone	0.58	0.63	0.74	0.75	0.86	1.04	1.22	1.32	1.44	1.51

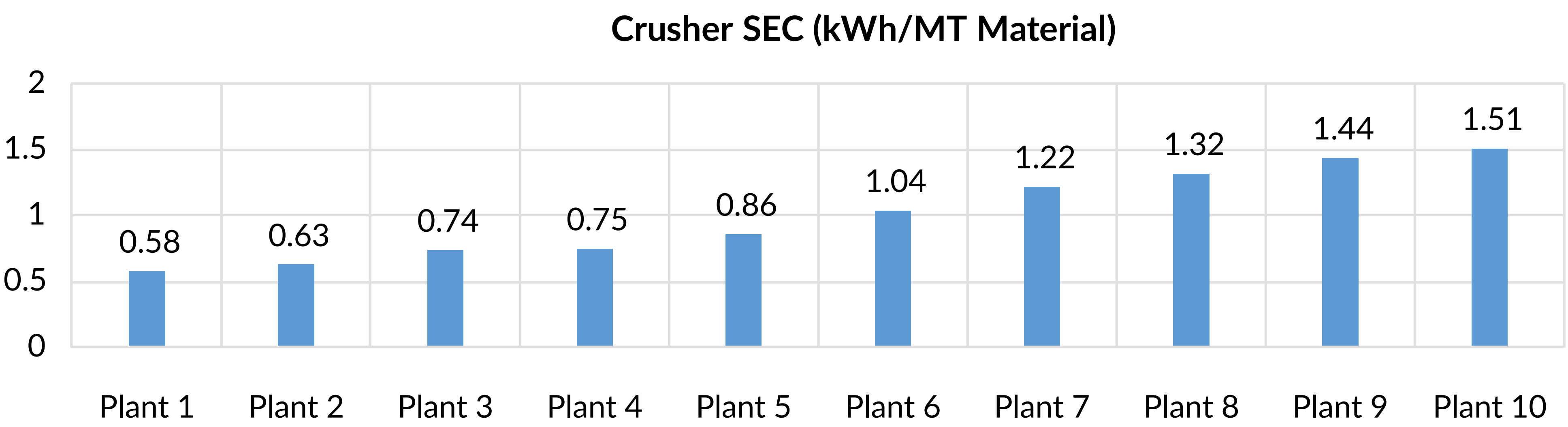


Figure 11: Overall SEC of Crusher – Top 10 plants

3.2 RAW MILL SECTION

3.2.1 RAW MILL SECTION – VRM CIRCUIT

Sr.No.	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	10.64	10.80	11.19	12.14	12.51	13.5	14.11	15.70	16.56	17.7
1	Make	-	Pfeiffer	FLS	Loesche	Loesche	FLS	Loesche	Pfeiffer	Pfeiffer	FLS	Pfeiffer
2	Type / Model	-	MPS 5000 B	ATOX 32.5	LM 46.4	LM 36.41	Atox 52.5	LM 34.4	MPS 5000 B	MPS 5000 B	ATOX-45	5300B
3	Material Hardness(Bond index)	kWh/short ton	8	10	9	-	-	14	8.5	-	-	14
4	Material hardness	-	Soft	Medium	Soft	Soft	Medium	Hard	Soft	Medium	Medium	Hard
5	Design output	TPH	500	180	320	250	540	225	400	420	225	420
6	Operating output	TPH	506	245	312	260	462	336	410	460	275	400
7	Feed input size	%	21% above 60mm& rest below 40 mm	12 % on +53 micron	<75 mm	<50 mm	8-10% in 80 mm	95% passing on 60 mm sieve	90%<70 , MAX 90 MM	90%<75 mm	+5-8% on 75mm	≤80mm (95%)
8	Product size (% residue on 90 mic)	%	15	17	19.3	14.15	11.8-12.3%	Less than 2% on 212 mic.	<16	20	19	18.0
9	Feed Material moisture	%	1-2	5	1	6.2	1-1.4	6% max	13.5	4.0	1.5-2.0	≤0.5%
10	Pressure drop across Nozzle	mmwg	-	-	-	450	410	-	530	-	300	-
11	Mill DP	mmwg	494	464	-	550	530	835	565	500	420	500

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
12	Pressure drop across Separator	mmwg	-	-	-	180	150	-	120	-	170	-
13	Cyclone pressure drop	mmwg	110	100	110	140	100	120	122	-	90	40
14	No. of cyclones	Nos.	2	2	4	8	4	4	4	4	4	4
15	Mill fan operating flow	m^3/hr	7,45,226	2,94,000	5,90,000	4,50,000	8,45,000	4,5,2000	7,65,673	8,50,00	5,80,000	8,40,000
16	Mill fan speed control type (GRR/SPRS/ VFD)	-	VFD	GRR	VFD	SPRS	SPRS	SPRS	VFD	GRR	SPRS	VFD
17	Mill fan inlet damper open position	%	NA	100	NA	NA	100	NA	NA	NA	100	NA
18	Mill fan operating efficiency	%	69	90	83	81	82	86	81	-	81	75
19	Mill Fan inlet pressure (before & after damper)	mmwg	-721	-960	-920	NA	-888 &-893	-1,045	-1,040	-	-695	-930
20	False air in the circuit	%	23	17	15	15	17	19	10	14	16	11
21	Separator loading	gm/m^3	679	833		649	610	720	535	-	474	476
22	Rotor Case velocity	m/s	-	4	-	2.85	5	-	4	-	3	-
23	Separator type	-	-	RAR 35	LSKS 73	LKS 67	RAR-LVT 55	-	SLS 4250 B, LAMELLA WHEEL	-	RAR-45	-
24	Nozzle ring velocity	m/s	40	51	49	54	55	-	42	40	48	52

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
25	Dam ring height	mm	-	120	90	95	200	-	70	40	160	-
26	Table Diameter	Mm	-	3,250	4,600	3,600	5,250	3,400	5,000	5,000	4,500	5,300
27	Electrical SEC											
a	Mill drive	kWh/MT raw meal	5.13	4.60	4.44	5.73	6.88	4.45	5.89	7.60	9.18	8.29
b	Mill fan	kWh/MT raw meal	3.86	5.00	4.95	5.11	4.38	4.82	6.11	6.50	5.49	7.39
c	Auxiliary*	kWh/MT raw meal	1.63	1.20	1.75	1.30	1.25	1.69	2.10	1.60	1.87	1.10
d	Overall SEC	kWh/MT raw meal	10.64	10.80	11.19	12.14	12.51	13.5	14.11	15.70	16.56	17.70

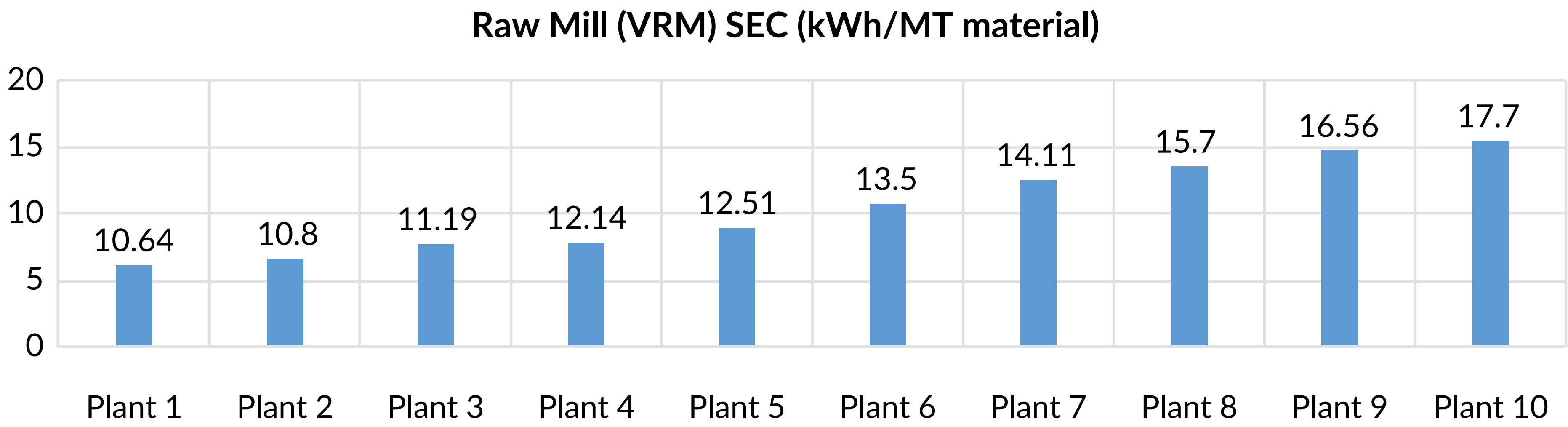


Figure 12: Top 10 VRM SEC in India

3.2.2 RAW MILL SECTION – ROLLER PRESS CIRCUIT

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4
*	Overall SEC	kWh/ton material	12.99	14.5	15.50	17
1	Roller Press Make	-	FLS HRP 3.0	Polysius	KHD	KHD
2	Bond index	kWh/ ton	12.1	8	13	13
3	Design output	TPH	250	256	275	300
4	Operating output	TPH	310	255	260	302
5	Feed input size	mm	Below 50 mm	-	>63 mm -3%	+40, (1.42%)
6	Product size (% residue on 90 mic)	%	19.0	16	17	3.8
7	Feed Material moisture	%	1.25%	-	-	0.5-2.0
8	Separator type/model	-	RARL 40	-	-	SKS
9	Separator loading	gm/m^3	654	722	556	700
10	Pressure drop across separator	mmwg	NA	-	630(V sep)	385
11	Cyclone pressure drop	mmwg	50	258	164	120
12	No. of cyclones	Nos.	4	2	2	4
13	Separator fan operating flow	m^3/hr	4,81,772	3,54,639	4,67,585	5,42,867
14	Separator fan speed control type (GRR/SPRS/VFD)	-	VFD	VFD	VFD	GRR
15	Separator fan inlet damper open position	%	100	NA	NA	100

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4
16	Separator fan operating efficiency	%	75	66	76	83
17	Separator Fan inlet pressure	mmwg	-400	-	-834	-805
18	False air in the circuit	%	17	14	12	10
a	Main drive	kWh/MT raw meal	6.40	10.00	8.40	8.76
b	Mill separator fan	kWh/MT raw meal	2.20	2.40	4.60	5.17
c	Separator vent fan	kWh/MT raw meal	1.11	-	-	-
d	Auxiliary*	kWh/MT raw meal	3.23	2.00	3.00	1.92
e	Overall SEC	kWh/MT raw meal	12.99	14.50	15.50	17.00

3.3 COAL MILL SECTION

3.3.1 COAL MILL SECTION – MIX COAL (VRM)

Sr.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4
*	Overall SEC	kWh/Ton material	33.89	39.49	39.63	43.90
1	Make	-	FLS	FLS	Pfeiffer	CEMTECK
2	Type / Model		Atox 27.50	Atox 27.5	MPS 2800 BK	TRMC31.3
3	Coal type/variety to be grinded (Pet coke / Indian coal /Imported coal)	-	pet coke: 51.98%, Imported coal: 45.98%, Indian coal: 2.05%	Indonesian coal	Pet coke (60 %)/ Imported coal (40%)	Pet coke / Imported coal
4	Design output (normal coal)	TPH	65	60	40	45
5	Operating output (pet coke)	TPH	30	-	25	33
6	Operating output (normal Coal)	TPH	65	32	24	40
7	Product size (% residue on 90 mics)-Pet coke	%	3.0		2	5-7%
8	Feed Material moisture	%	7.0	14.4	5	10
9	Mill DP	mmwg	380	420	425	520
10	Pressure drop across the nozzle ring	mmwg	NA	280	-	-
11	Separator type/model	Dynamic	RAKM-30	RAKM – 27.5	SLS 2450 BK,	SC-3000
12	Circumferential Velocity inside rotor case	m/s	25-27	-	-	-

Sr.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4
13	Static Vanes gap of Separator	mm	30	66	-	-
14	Pressure drop across bag filter/ cyclone+BH	mmwg	80	95	100	95
15	Mill fan operating flow	m^3/hr	2,16,160	1,17,000	1,23,000	1,55,000
16	Mill fan speed control type (GRR/SPRS/VFD)	-	VFD	VFD	VFD	VFD
17	Mill fan inlet damper open position	%	100	100	NA	NA
18	Mill fan operating efficiency	%	80	69	73	65
19	Mill Fan inlet pressure	mmwg	-560	-	-616	-950
20	False air in the circuit	%	11	15	20	14
21	Nozzle ring velocity	m/s	44	63	38	58
22	Dam ring height	mm	150	155	120	70
23	Table Diameter	mm	2,750	2,750	2800	3100
A	Mill drive	kWh/MT coal	15.89	18.17	19.71	12.1
B	Mill vent fan / Bag filter fan	kWh/MT coal	12.27	12.23	9.45	18.4
C	Booster fan	kWh/MT coal	1.98	-	NA	NA
D	Auxiliary*	kWh/MT coal	3.75	9.09	10.48	7.4
E	Overall SEC	kWh/MT coal	33.89	39.49	39.63	43.9

3.3.2 COAL MILL PET COKE GRINDING (VRM)

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
*	Overall SEC	kWh/Ton material	36.18	38.27	39.78	40.94	44.77	48.5	50.8
1	Make	-	Polysius	FLS	LOESCHE	Pfeiffer	FLS	FLS	Pfeiffer
2	Type / Model	-	-	Atox 25	LM 26.3D	(MPS 3550 BK)	Atox 27.5	Atox 32.50	3550 MBPS
3	Coal type	-	Pet coke	Pet coke	Pet coke	Pet coke	Pet coke	Pet coke	Pet coke
4	Design output (normal coal)	TPH	38	50	45	90	65	78	80
5	Operating output (petcoke)	TPH	18	26	16	58	30	35	60
6	Product size (% residue on 90 mics)-Petcoke	%	3.0	2.5-4.5	<4.0	<1.5	<2.0	2.5	1.5
7	Feed Material moisture	%	6	5	6	5	5	5	9
8	Coal mill type Circuit (Inert/ Non-Inert)	-	Inert	-	Inert	Inert	Non-Inert	Inert	Inert
9	Mill DP	mmwg	420		355	550	570	430	400
10	Separator type/model	-	-	RAKM-LVT-27.5	LSKS (Dynamic)	-	RAKM-30	-	-
11	Circumferential Velocity inside rotor case	m/s	18	26	-	27	27	26-27	-
12	Static Vanes gap of Separator	mm	-	40	-	-	30	30	-
13	Pressure drop across bag filter/cyclone+BH	mmwg	110	130	220	164	110	126	-
14	Mill fan operating flow	m^3/hr	1,11,371	1,13,000	1,45,000	3,19,387	1,77,000	1,66,352	2,75,000

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
15	Mill fan speed control type (GRR/SPRS/VFD)	-	VFD	SPRS	VFD	VFD	GRR	VFD	VFD
16	Mill fan inlet damper open position	%	NA	100	NA	NA	100	NA	NA
17	Mill fan operating efficiency	%	75	70	81	76	66	56	80
18	Mill Fan inlet pressure	mmwg	-580	-495	-795	-834	-820	-	-
19	False air in the circuit	%	13	19	40	13	18	20	17
20	Nozzle ring velocity	m/s	51	55	42	42	52	-	45
21	Dam ring height	mm	56	160	105	110	140	-	60
22	Table Diameter	mm	2,500	2,500	2,600	3,500	2,750	3,250	3,500
23	Electrical SEC								
a	Mill drive	kWh/MT pet coke	18.90	17.22	16.90	20.37	16.49	17.00	19.90
b	Mill vent fan / Bag filter fan	kWh/MT pet coke	12.30	10.71	16.70	16.09	16.27	15.00	19.20
c	Auxiliary*	kWh/MT pet coke	4.98	8.42	6.00	4.48	12.01	16.50	11.50
d	Overall SEC	kWh/MT pet coke	36.18	38.27	39.78	40.94	44.77	48.50	50.80

3.4 PYROSECTION

3.4.1 PYROSECTION – WITHOUT WHRS CIRCUIT

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
1	Kiln Clinkerization	kWh/MT clinker	20.16	15.45	20.80	20.05	23.07	23.99	18.50
2	Electrical SEC	kWh/MT clinker	43.18	45.60	48.80	48.92	49.47	50.78	51.00
3	Thermal SEC	kcal/kg clinker	682	682	690	722	790	760	710
4	Kiln output rated	TPD	5,500	6,600	4,200	4,500	3,800	4,400	10,000
5	Kiln output operating	TPD	7,200	7,215	4,622	6,000	4,500	4,300	9,000
PREHEATER SECTION									
1	PH type (ILC/SLC)	-	ILC	ILC	ILC	ILC	ILC	ILC	ILC
2	No of PH strings	Nos.	2	2	1	1	1	1	4
3	No of stages (mention for each string)	Nos.	6	6	6	5	5	4	6
4	PH / Calciner exit O_2 & CO	%	Calciner exit O_2-1% PH exit O_2 3.3%	O_2-1.9%, CO- 60 ppm	2.2-2.8	Calciner-1% PH Exit -2.5%	1.5	3.8	2
5	PH exit/top cyclone outlet temp	^{0}C	275	230	272	300	315	368	257
6	PH exit/top cyclone outlet pressure	mmwg	-565	-350	-545	-630	-610	-565	-468
7	PH top cyclone efficiency	%	95	95	95	94	92	90	95
8	PH fan inlet flow	Nm^3/kg clinker	1.42	1.50	1.41	1.55	1.70	1.38	1.35
9	PH fan speed control type (GRR/SPRS/VFD)	-	SPRS	VFD	VFD	VFD	VFD	SPRS	VFD

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
10	PH fan inlet damper open position	%	100	100	100	NA	NA	100	NA
11	PH fan operating efficiency	%	85	82	85	77	79	61	75
12	PH Fan inlet pressure	mmwg	-596	-360	-545	-667	-685	-602/-611	-480
13	False air across PH	%	-	8	7	5	6	8	9
KILN SECTION									
14	Kiln inlet pressure	mmwg	-	-21	-35	-45	-45	-25	-30
15	Kiln Bag house	Nm^3/kg clinker	1.82	1.26	1.58	2.58	2.40	1.75	1.83
16	Kiln Bag house speed control type (GRR/ SPRS/VFD)	-	SPRS	VFD	VFD	VFD	VFD	VFD	VFD
17	Kiln Bag house damper open position	%	100	100	100	NA	-	100	NA
18	Kiln Bag house fan operating efficiency	%	67	77	67	66	62	65	75
19	Kiln Bag house Fan inlet pressure	mmwg	-195	-167	-	-160	-160	-178	-154
20	Kiln Bag house Pressure drop	mmwg	105	110	100	120	90	90	110
21	Kiln size	Dia x length(m)	4.75 x 74	5 x 78	4.15 x 64	4.35 x 67	3.95 x 63	4.57 x 67.07	5.80 x 85
22	Kiln Volumetric loading	TPD/ m^3	6.5	5.6	6.8	7.3	7.5	4.8	4.5
23	Kiln Thermal loading	Mkcal / hr /m^2	4.8	4.6	5.1	5.9	3.4	3.3	4.7
24	Kiln percentage filling	%	15	12	15	15	16	13	14
COOLER SECTION									
1	Cooling air flow	Nm^3/kg clinker	1.54	1.73	1.60	1.59	1.95	1.65	1.76
2	Cooler vent flow	Nm^3/kg clinker	0.74	0.94	0.72	1.08	1.15	0.9	1.11
3	Pressure Drop Across Cooler ESP	mmwg	50	50	15	40	40	10	40

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
4	Cooler ESP Fan efficiency	%	70-75	40	52	55	50	72.85	40
5	Clinker temp at cooler exit	-	150	120	185	168	80	175	-
6	Cooler Grate Loading	TPD/m^2	50	47	46	51	38	41	-
7	TAD temperature	^0C	950	920	1,025	931	990	871	945
8	Temperature Drop Across TAD	^0C	25	30	20	80	60	80	75
9	Cooler water spray	m^3/hr	20	10	8.5	7	-	4.8	-
10	Coal Phase density – PC firing	kg coal / kg air	4.5	2.98	1.62	3	2.75	3.93	3.0
11	Coal Phase density – Kiln firing	kg coal / kg air	4.8	1.96	2.76	2	1.72	3.25	1.60
12	Kiln Thermal SEC	kcal/kg clinker	682	685	690	722	790	760	705
13	Loss in PH gas	kcal/kg clinker	142	105.1	132	161	178	171.8	121
14	Loss in Cooler vent	kcal/kg clinker	87	105.3	78	96	132	92.6	94
15	Loss in clinker	kcal/kg clinker	33	42.7	38	31	18	37.4	33.1
16	Loss in cooler water spray	kcal/kg clinker	-	19.5	21	19.6	0	19.2	29.3
17	Heat of formation	kcal/kg clinker	412	408	399	412	412	406.4	410.4
18	Radiation loss	kcal / kg clinker	38	55	50	48	50	52.8	54
19	Type of burner	-	KHD Pyrojet low NO_x burner	Duoflex	Duoflex	Pyro-Jet BURNER	-	PyroJet -BS-1	Pyrojet
20	Burner Capacity	MW	98	119	73.64	89	58.9	61	-
21	ELECTRICAL SEC								
A	KS fan/PH Fan	kWh/MT clinker	NA	3.4	5.16	6.45	8.82	8.88	5.1
B	Calciner fan/PH Fan	kWh/MT clinker	6.93	NA	-	NA	-	-	-

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
C	RABH/ESP fan	kWh/MT clinker	2.97	1.22	1.69	2.49	2.76	2.12	1.6
D	Cooler fans	kWh/MT clinker	3.98	3.53	3.91	5.49	3.66	6.16	5.2
E	Cooler vent fan	kWh/MT clinker	0.31	0.89	-		1.05	-	0.25
F	Kiln drive	kWh/MT clinker	1.31	1.59	1.74	1.55	1.31	1.67	2.1
G	Kiln feed	kWh/MT clinker	-	0.68	-	1.95	-	-	-
H	Auxiliary*	kWh/MT clinker	4.66	4.14	5.54	2.13	5.13	5.16	4.5
I	Overall SEC of Clinkerisation section	kWh/MT clinker	20.16	15.45	20.8	20.05	23.07	23.99	18.50
J	Total SEC Upto clinkerization	kWh/MT clinker	43.18	45.6	48.8	48.92	49.47	50.78	51.0

3.4.2 PYROSECTION – WITH WHRS

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
1	Overall SEC	kWh/ MT clinker	42.59	46.12	50.68	50.80	54.10	56.57	57.50
2	KILN SEC	kWh/ MT clinker	21.00	19.98	22.00	19.90	21.30	22.60	21.27
3	Thermal SEC	kcal/kg clinker	702	696	729	765	711	720	710
4	Kiln output rated	TPD	2,750	5,000	6,000	10,000	5,000	5,500	6,000
5	Kiln output operating	TPD	3,150	5,175	7,600	12,000	5,665	8,000	5,981
PREHEATER SECTION									
1	PH type (ILC/SLC)	-	ILC	SLC	ILC	ILC	ILC	SLC	ILC
2	No of PH strings	Nos.	1	2	2	4	2	2	1
3	No of stages (mention for each string)	Nos.	6	6	6	6	5	5	6
4	PH / Calciner exit O_2 & CO	%	2.0	3	3	3	2.0	2.60	1.90
5	PH exit/top cyclone outlet temp	^0C	300	310 &315	289 &275	293&294	295	325 &320	282
6	PH exit/top cyclone outlet pressure	mmwg	-565	-605	-605 & -550	-632	-540	-630 & -880	-615
7	PH top cyclone efficiency	%	96	93	95	95	94	91	97
8	PH fan inlet flow	Nm^3/kg clinker	1.38	1.42	1.45	1.59	1.50	1.64	1.62
9	PH fan speed control type (GRR/SPRS/ VFD)	-	VFD	SPRS	VFD	VFD	VFD	SPRS	VFD
10	PH fan inlet damper open position	%	100	NA	NA	NA	NA	100	100
11	PH fan operating efficiency	%	91	80	71 & 65	79 & 83	78	76	90

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
12	PH Fan inlet pressure	mmwg	-680 & -690	-820	-688 & -747	-731	-700	-700 & -720; -960 & -980	-725
13	False air across PH	%	6	6	8	9	12	9	15
KILN SECTION									
14	Kiln inlet pressure	mmwg	-25	-80	-	-30	-	-50	-30
15	Kiln Bag house /ESP	Nm^3/kg clinker	2.00	2.19	2.11	-	-	2.60	-
16	Kiln Bag house speed control type (GRR/ SPRS/VFD)	-	VFD	VFD	VFD	VFD	VFD	SPRS	VFD
17	Kiln Bag house damper open position	%	100	NA	NA	-	-	100	NA
18	Kiln Bag house fan operating efficiency	%	84	78	68	-	75	77	78
19	Kiln Bag house Fan inlet pressure	mmwg	-160	-215	-192	-	-170	-275	-158
20	Kiln Bag house Pressure drop	mmwg	100	120	-	-	130	-	80 (ESP)
21	Kiln size	Dia x length	3.6 x 54	-	4.8 x74	6 x 86	4.80 x 72	4.75 x 75	4.35 x 67
22	Kiln Volumetric loading	TPD/ m^3	7.0	7.22	5.40	6.55	5.30	7.20	7.80
23	Kiln Thermal loading	Mkcal / hr /m^2	3.3	4.6	-	-	5.2	4.9	6.1
24	Kiln percentage filling	%	18.5	14.8	17.0	13.5	15.2	17.5	16.2
COOLER SECTION									
1	Cooling air flow	Nm^3/kg clinker	1.72	1.54	1.82	1.89	1.80	1.78	1.71
2	Cooler vent flow	Nm^3/kg clinker	0.98	-	0.95	1.10	-	-	1.10
3	Cooler Recuperation Efficiency (with WHR/without WHR in operation)	%	66	65	54	55	65	65 &70	57
4	Pressure Drop Across Cooler ESP	mmwg	50	-	-	40	100	50	80

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
5	Cooler ESP Fan efficiency (with WHR/ without WHR in operation)	%	60/90	-	56	59	74	65 &73	78
6	Clinker temp at cooler exit	-	120	155	200	130	120	135	160
7	Cooler Grate Loading	TPD/m^2	51.14	46	56	-	48	43	44
8	WHR Tapping (Mid tap/End tap)-Cooler	-	End Tap	Mid tap	Mid Tap	Mid Tap	Mid Tap	Mid Tap	Mid Tap
9	TAD temperature	^{0}C	900	940	960	930	950	990	990
10	Temperature Drop Across TAD	^{0}C	35	35	80	100	60	-	-
11	Cooler water spray	m^3/hr	NA	NA	NA	NA	NA	NA	-
12	Coal Phase density – PC firing	kg coal / kg air	3.2	3.3	1.8	1.3	-	-	1.0
13	Coal Phase density – Kiln firing	kg coal / kg air	2.6	-	1.0	2.8	-	-	1.4
14	Kiln Thermal SEC	kcal/kg clinker	702	696	729	785	711	720	710
15	Loss in PH gas	kcal/kg clinker	146	141	139	172	150	202	150
16	Loss in Cooler vent	kcal/kg clinker	102	117	144	147	120	119	140
17	Loss in clinker	kcal/kg clinker	22	31	36	25	20	24	27
18	Heat of formation of clinker	kcal/kg clinker	420	416	414	408	408	399	406
19	Radiation loss	kcal / kg clinker	42	45	44	55	57	43	40
20	Type of burner	-	KHD Pyrojet	-	Duoflex	-	-	KHD-Pyrojet	Duoflex
21	Burner Capacity	MW	40	-	89	-	-		86
22	Electrical SEC:	-	-	-	-	-	-	-	-
a	KS fan/PH Fan	kWh/MT clinker	6.70	8.67	8.00	7.75	7.54	2.11	7.24
b	Calciner fan/PH Fan	kWh/MT clinker	-	-	-	-	-	6.42	-

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
c	RABH/ESP fan	kWh/MT clinker	2.60	-	2.90	1.75	1.82	3.04	1.84
d	Cooler fans	kWh/MT clinker	4.30	3.43	4.80	3.52	1.21	4.44	5.00
e	Cooler vent fan	kWh/MT clinker	1.00	1.16	0.50	0.86	-	1.71	1.73
f	Kiln drive	kWh/MT clinker	1.10	1.54	1.30	1.81	2.09	1.46	1.59
g	Kiln feed	kWh/MT clinker	-	1.00	1.50	-	-	-	1.54
h	Auxiliary	kWh/MT clinker	5.30	-	-	4.25	7.37	3.42	2.33
i	Overall SEC of Clinkerisation section	kWh/MT clinker	21.00	19.98	22.00	19.9	21.30	22.60	21.27
j	Total SEC up to clinkerization	kWh/MT clinker	42.59	46.12	50.68	49.93	54.10	56.57	57.50

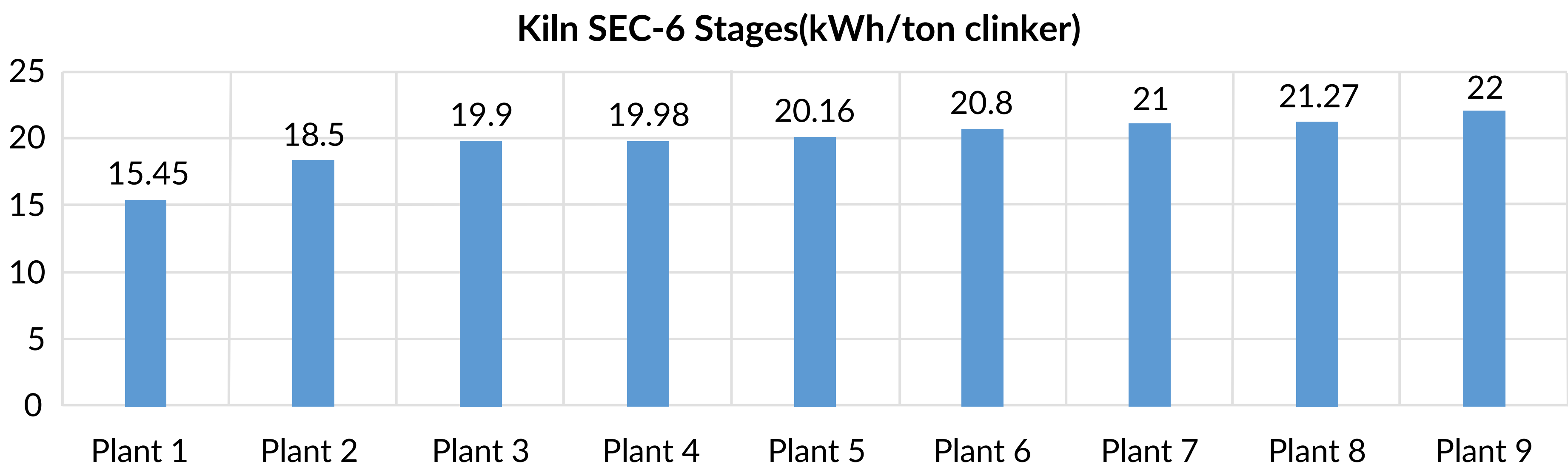


Figure 13: Overall SEC of Kiln Clinkerization (6 Stage)

3.5 CEMENT MILL SECTION

3.5.1 CEMENT MILL – BALL MILL

3.5.1.1 PPC

S.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
	Overall SEC	kWh/MT cement	27.07	27.16	27.59	27.80	28.49	28.8	29	29.13	29.37	29.8
1	Type of circuit	-	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mill
2	Design output	TPH	150	133	200	-	105	105	90	-	-	50
3	Operating output	TPH	203	186	225	192	122	120	110	195	205	68
4	Product variety (OPC/PPC/ PSC/Composite cement/ others)	-	PPC	PPC	PPC	PPC	PPC	PPC	PPC	PPC	PPC	PPC
5	Clinker feed size	mm	-	-	-	25mm to 2mm	-	-	-	-	-	<6.7 mm
6	C_2S & C_3S Content in the clinker	%	-	-	-	26 & 48	-	-	-	-	-	28 & 48
7	Final Product Blaine	m^2/kg	320	380	320	330	330	330	410	-	-	350
8	Final Product residue (% residue on 45 mics)	%	15	22	19 to 20	20.4	<25.0	<20	9.7	-	-	18
9	Fly ash qty	%	34.50	30	30	34.49	28	28	30	-	-	32
10	Clinker factor	-	0.63	-	-	0.62	-	-	-	-	-	-
11	Mill specification (Dia x Length)	-	4.6 X 17.11	4.4 x 13.5	5 x 15	4.4 x 13.5	4 x 11.5	4.2 x 13.5	3.8 x 14.65	-	-	3.4 X 12.3
12	Gas Velocity across the mill	m/s	-	1	1 to 1.2	1.2	1.2 to 1.4	1.2 to 1.4	0.4	-	-	1

S.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
13	Mill outlet draft	mmwg	-	-	-	60-70	-	-	-	-	-	118
14	Separator type/model	-	-	-	-	CM-1 -Dynamic-Sepax, CM-2-Dynamic LNVT	-	-	-	-	-	Dynamic/ Classifier-HEC-2800
15	Pressure drop across separator	mmwg	-	-	-	140-160	-	-	-	-	-	300
16	Separator loading	kg/m³	-	-	-	1.38	-	-	-	-	-	1.22
17	Rotor Case Velocity inside Separator	m/s	-	-	-	4.63(CM-1) & 3.75 (CM-2)	-	-	-	-	-	210
18	Circulating load		2.01	1.8	1.5	1.7	1.5	1.5	2.8	-	-	1.22
19	Separator reject residue (on 45 microns)	%	63	85 to 88	75 to 80	75	-	-	65	-	-	86
20	Separator rejects Blaine	m²/kg	200	-	-	-	-	-	-	-	-	74
21	Separator product (cyclone fines) residue (on 45 microns)	%	15	-	-	19	-	-	-	19	12	16.4
22	Separator product (cyclone fines) blaine	m²/kg		-	-	330	-	-	-	-	-	358
23	Mill discharge residue (on 45 microns)	%	39	45	45 to 50	45	<35	<35	44.3	46.4	36.2	55
24	Mill discharge Blaine	m²/kg	200	305	200	120	240	240	199	-	-	186
25	Cyclone pressure drop	mmwg	-	170	200	100	200	-	70	-	90	
26	No. of cyclones	Nos.	-	-	-	4nos in CM1 & 2nos in CM2	-	-	-	-	-	2
27	Mill vent fan operating flow	m³/hr	-	-	-	45,000	-	-	-	-	-	26,000

S.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
28	Mill vent fan speed control type (GRR/SPRS/VFD)	-	VFD	-	-	VFD	-	-	-	-	-	VFD
29	Mill vent fan operating efficiency	%	-	-	-	72	-	-	-	-	-	88
30	Separator fan operating flow	m^3/hr	4,18,000	1,60,000	2,75,000	1,80,000 & 3,50,000	-	1,60,000	1,40,000	2,41,000	2,55,000	1,09,000
31	Separator fan speed control type (GRR/SPRS/VFD)	-	-	-	-	GRR	-	-	-	-	-	VFD
32	Separator fan operating efficiency	%	-	-	-	72 & 80	-	-	-	-	-	90
33	Separator vent fan operating volume	m^3/hr	-	-	-	12,500 for CM1 & 45,000 for CM2	-	-	-	-	-	18,260
34	Grinding media piece weight in the first chamber	-	-	-	-	1540 & 1560	-	-	-	-	-	1486
35	Grinding media-specific surface area in the second chamber	m^2/MT	-	-	-	40.5 & 42	-	-	-	-	-	37.21
Electrical SEC												
A	Mill drive (Ball mill)	kWh/MT cement	21.90	21.61	22.63	21.1	24.5	25	25.4	21.24	21.17	23
B	Mill vent fan	kWh/MT cement	0.20	-	0.17	0.42	0.35	0.35	0.02	0.3	0.2	0.12
C	Mill separator fan	kWh/MT cement	1.29	2.2	2.24	2.75	1.5	1.5	2.2	2.1	1.9	1.92
D	Separator vent fan	kWh/MT cement	0.70	2.65	0.23		-	-	0.43	0.16	0.12	-
E	Dry Fly ash unloading	kWh/MT cement	-	1	0.07	1.89	1.95	1.95	0.42	2.83	3.12	0.12
F	Overall SEC	kWh/MT cement	27.07	27.16	27.59	27.8	28.49	28.8	29	29.13	29.37	29.8

3.5.1.2 BALL MILL – OPC

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
	Overall SEC	kWh/MT cement	29.79	29.90	30.50	31.8	31.41	31.10	35.22	37.00
1	Type of circuit (Ball mill / Ball mill with HPRG)	-	Ball Mill	Ball Mill	Ball Mill	Ball Mill	Ball Mil	Ball Mil	Ball Mill	Ball Mill
2	Design output	TPH	105	105	200	115	58	110	133	50
3	Operating output	TPH	116	116	200	105	55	120	135-140	54
4	Product variety	-	OPC	OPC	OPC	OPC	OPC-53	OPC	OPC	OPC
5	Clinker feed size	mm	-	-	-	-	40+ mm - 3.74	<25	25mm to 2mm	<6.7
6	C_2S & C_3S Content in the clinker	%	-	-	-	-	46.8 & 27.1	58 &19	26 & 48	28 & 40
7	Final Product Blaine	m^2/kg	300	300	270	300	300	300	285	320
8	Final Product residue (% residue on 45 mics)	%	<20	<25	14.5	15.6	23.12	18	21.5	19
9	Clinker factor	-	-	-	-	-	0.90	0.91	0.91	1.07
12	Ball Mill Make	-	-	-	-	-	Walchandnagar Ind. Ltd	FLS	FLS	Promac
13	Mill specification (Dia x Length)	-	4.2x13.5	4 x 11.5	4.81 x 15	3 X 10	3.2 x 12.07	4.2 x 14.5	4.4 x 13.5	3.4 x 12.3
14	No. of chambers - Ball mill	Nos.	2	2	2	2	2	2	2	2
15	Type of liners (both compartments)	-	-	-	-	-	Universal wave	Double wave liners	Step Liners in First Chamber; Dragpeb liners in the Second chamber	Wave liner & Classifying
16	Gas Velocity across the mill	m/s	1.2	1.2	1	1.1	0.75	0.8	1.2	1.2
17	Mill outlet draft	mmwg	-	-	-	-	-48	70	50-60	125

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
18	Separator type/model	-	-	-	-	-	SD-80	O-Sepa	CM-1 -Dynamic- Sepax, CM-2- Dynamic- LNVT	Dynamic/ Classifier- HEC-2800
19	Pressure drop across separator	mmwg	-	-	-	-	354	90	140-160	300
20	Separator loading	kg/m³	-	-	-	-	0.78	1.2	1.39	-
21	Rotor Case Velocity inside Separator	m/s	-	-	-	-	-	-	4.63(CM-1) & 3.75 (CM-2)	210
22	Circulating load	-	1.2	1.2	1.6	-	0.9	1.8	1.7	1
23	Separator reject residue (on 45 microns)	%	-	-	15	-	75.5	85	78	89
24	Separator rejects Blaine	m^2/kg	-	-	-	-	186	70	75	60
25	Separator product (cyclone fines) residue (on 45 microns)	%	-	-	-	-	25.6	16	22	18
26	Separator product (cyclone fines) blaine	m^2/kg	-	-	-	-	296	298	285	330
27	Mill discharge residue (on 45 microns)	%	<35 - 40	<35 - 40	40	60.5	46.4	45	50	58
28	Mill discharge Blaine	m^2/kg	180 to 220	180 to 220	204	130	225	180	190	150
29	Cyclone pressure drop	mmwg	200	200	-	130	25	90	100	-
30	No. of cyclones	Nos.	-	-	-	-	3	2	4nos in CM1 & 2nos in CM2	2
31	Mill vent fan operating flow	m^3/hr	-	-	-	-	-	37,282	45,000	26,900
32	Mill vent fan speed control type (GRR/SPRS/VFD)	-	-	-	-	-	VFD	GRR	VFD	VFD
33	Mill vent fan inlet damper open position	%	-	-	-	-	100	100	NA	NA
34	Mill vent fan operating efficiency	%	-	-	-	-	28	85	72	88

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
35	Mill vent Fan inlet pressure (before & after damper)	mmwg	-	-	-	-	-65&-68	-300	NA	NA
36	Separator fan operating flow	m^3/hr	145,000	-	248,000	210,000	82,150	1,54,449	1,80,000 & 3,50,000	109,000
37	Separator fan speed control type (GRR/SPRS/VFD)	-	-	-	-	-	VFD	GRR	GRR	VFD
38	Separator fan inlet damper open position	%	-	-	-	-	100	100	NA	NA
39	Separator fan operating efficiency	%	-	-	-	-	77.10	76	72 & 80	90
40	Separator Fan inlet pressure (before & after damper)	mmwg	-	-	-	-	-490	-380	NA	NA
41	Separator vent fan operating volume	m^3/hr	-	-	-	-	10,500	38,171	12,500 for CM1 & 45,000 for CM2	18,000
42	Grinding media piece weight in the first chamber	gm per unit piece	-	-	-	-	-	1610	1540 & 1560	1486
43	Grinding media-specific surface area in the second chamber	m^2/MT	-	-	-	-	42.4	40.31	40.5 & 42	37.21
Electrical SEC										
a	Mill drive (Ball mill)	kWh/MT cement	25.00	24.50	25.10	24.30	24.86	26.27	29.45	28.6
b	Mill vent fan	kWh/MT cement	0.35	0.35	0.11	0.30	1.75	-	0.46	0.15
c	Mill separator fan	kWh/MT cement	1.50	1.50	2.40	4.80	-	2.40	3.20	2.37
d	Auxiliary*	kWh/MT cement	-	-	-	-	4.80	2.43	2.10	5.31
e	Overall SEC	kWh/MT cement	29.79	29.90	30.50	31.80	31.41	31.10	35.22	37.0

3.5.2 CEMENT MILL – VRM

3.5.2.1 VRM – PPC

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
*	Overall SEC	kWh/MT Cement	18.80	19.70	22.30	22.33	22.55
1	Product variety	PPC	PPC	PPC	PPC	PPC	PPC
2	Make	-	LOESCHE	FLS	Pfeiffer	Pfeiffer	Pfeiffer
3	Type / Model	No	LM 53.3+3S	OK 39.4	MBR 6000 C6	MPS 5600 BC	MPS 5600 BC
4	Design output	TPH	280	265	412	300	230
5	Operating output	TPH	320	300	412	400	324
6	Final Product Blaine	m^2/kg	330	350	360	350	335
7	Final Product residue (% residue on 45 mics)	%	14	14	10	16	12
8	Fly ash Addition	%	32.0	34.5	35.0	35.0	34.9
9	Clinker factor	-	0.66	0.63	0.60	0.63	0.58
10	Pressure drop Across Nozzle ring	mmwg	200	200	-	180	205
11	Pressure drop Across Separator	mmwg	100	150	-	120	83
12	Mill DP (Mill inlet to Mill outlet)	mmwg	350	250	510	200	215
13	Bag house pressure drop	mmwg	140	25	110	130	118

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
14	Mill fan operating flow	m^3/hr	5,55,000	5,85,000	11,20,000	9,28,500	7,95,796
15	Mill fan speed control type (GRR/SPRS/ VFD)	GRR/VFD/SPRS	VFD	VFD	GRR	SPRS	SPRS
16	Mill fan operating efficiency	%	73	78	79	81	78
17	Mill Fan inlet pressure	mmwg	-595	-595	-782	-700	-530
18	Separator type/model	-	-	ROKSH90	-	SLS 5600 BC - Lamella Wheel	Air swept lemella classifier SLS 5000 BC
19	Nozzle ring velocity	m/s	31	44	43	42	31
20	Dam ring height	mm	380	152	275	230	270
21	Table Diameter	mm	5,300	-	6,000	5,600	5,600
22	Grinding Pressure	bar	90	160	185	110	115
23	Thermal in Case of HAG	kcal/MT Cement	-	-	300	-	-
24	Cement mill section electrical SEC	-	-	-	-	-	-
A	Mill drive	kWh/MT cement	11.90	13.00	14.00	13.40	13.06
B	Mill fan	kWh/MT cement	4.20	4.6	6.80	6.24	6.30
C	Separator/classifier	kWh/MT cement	0.20	0.16	0.70	0.43	-
D	Auxiliary*	kWh/MT cement	2.50	2.00	0.80	2.26	2.80
E	Overall SEC	kWh/MT cement	18.80	19.70	22.30	22.33	22.55

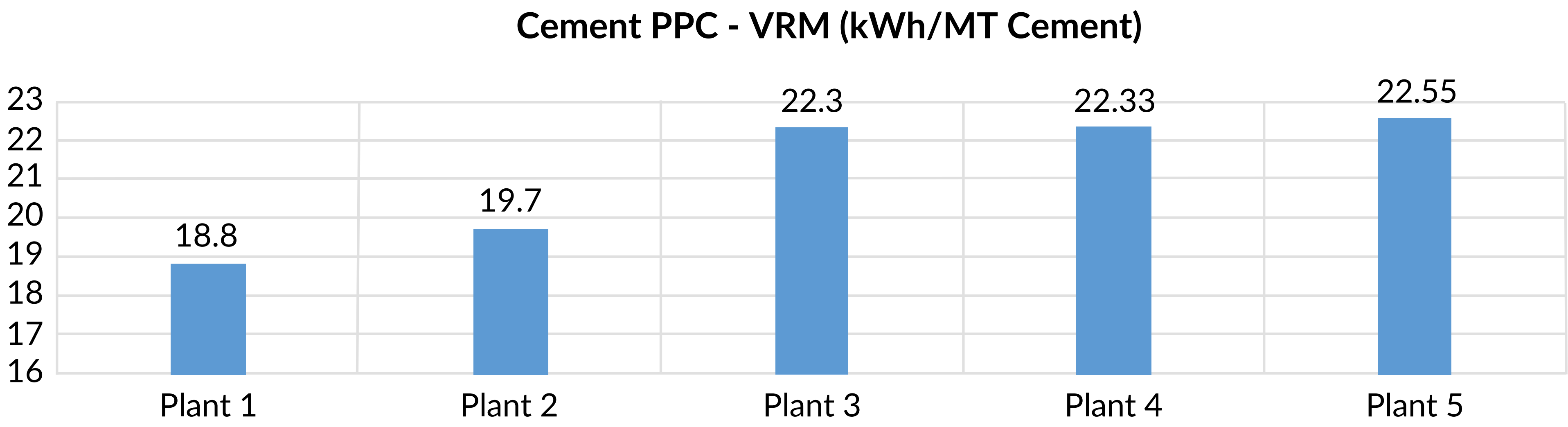


Figure 14: Top 5 Plants in PPC grinding (VRM)

3.5.2.2 VRM OPC

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
*	Overall SEC	kWh/MT Cement	24.00	25.00	28.56	29.50	29.86
1	Product variety	OPC	OPC	OPC	OPC	OPC	OPC
2	Make	-	FLS	LOESCHE	Pfeiffer	Pfeiffer	Pfeiffer
3	Type / Model	-	OK39.4	LM 53.3+3S	MPS 5600 BC	MBR 6000 C6	MPS 5600 BC
4	Design output	TPH	250	210	250	305	300
5	Operating output	TPH	235	230	252	310	270
6	Final Product Blaine	m^2/kg	320	300	305	340	300
7	Final Product residue (% residue on 45 mics)	%	14	15	12-14	9	11
8	Clinker factor	-	0.91	0.93	0.88	0.93	0.97
9	Pressure drop Across Nozzle ring	mmwg	220	200	205	-	200
10	Pressure drop Across Separator	mmwg	168	100	83	-	120
11	Mill DP (Mill inlet to Mill body)	mmwg	-	350	-	510	-
12	Bag house pressure drop	mmwg	100	150	119	110	110
13	Mill fan operating flow	m^3/hr	6,10,000	5,65,240	8,05,796	11,20,000	9,53,100
14	Mill fan speed control type	(GRR/SPRS/VFD)	VFD	VFD	SPRS	GRR	SPRS
15	Mill fan operating efficiency	%	78	74	77-80	79	81.3
16	Mill Fan inlet pressure	mmwg	-610	-580	-550	-782	-725
17	Separator type/model	-	ROKSH90	-	Air swept lemella classifier SLS 5000 BC	-	SLS 5600 BC - Lamella Wheel

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
18	Nozzle ring velocity	m/s	44	32	32	43	42
19	Dam ring height	mm	152	380	270	275	230
20	Table Diameter	mm	3,900	5,300	5,600	6,000	5,600
21	Grinding Pressure	bar	160	90	115	185	130
A	Mill drive	kWh/MT cement	15	16.50	17.40	19	17.92
B	Mill fan	kWh/MT cement	5.8	5.40	7.30	9.0	8.34
C	Separator/classifier	kWh/MT cement	0.212	0.20	-	0.7	0.57
D	Auxiliary*	kWh/MT cement	3	2.80	3.37	0.80	3.03
E	Overall SEC	kWh/MT cement	24	25.0	28.56	29.50	29.86

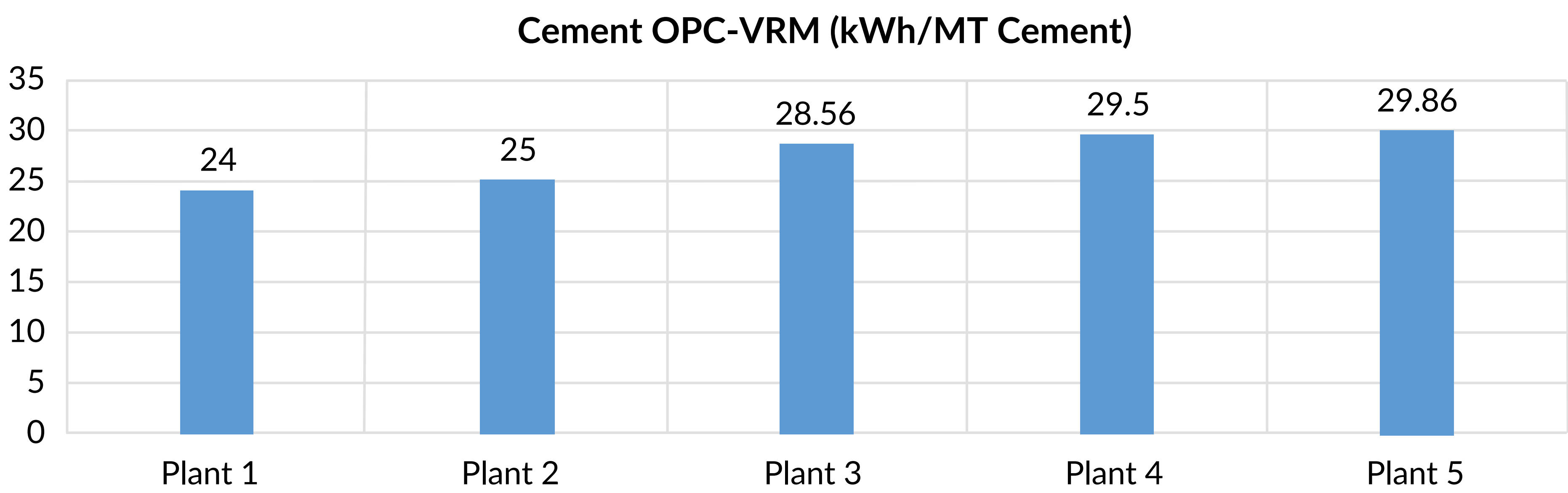


Figure 15: -

3.5.2.3 VRM – PSC

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
*	Overall SEC	kWh/MT Cement	31.90	32.60	33.20	34.80	35.48
1	Product variety	(PSC,Composite & others)	PSC	PSC	PSC	PSC	PSC
2	Make	-	LOESCHE	LOESCHE	OK MILL	Pfeiffer	Pfeiffer
3	Type / Model	-	56.3+3	LM 53.3+3S	42.4	MBR 6000 C6	MPS 5600 BC
4	Design output	TPH	220	150	215	250	150
5	Operating output	TPH	260	170	230	260	197
6	Final Product Blaine	m^2/kg	368	330	-	390	335
7	Final Product residue (% residue on 45 mic)	%	-	15		8	12
8	Slag qty	%	62	58	66	67	70
9	Clinker factor	-	-	0.40	-	0.28	0.23
10	Pressure drop Across Nozzle	mmwg	-	200	-	-	205
11	Pressure drop Across Separator	mmwg	-	100	-	-	83
12	Mill DP (Mill inlet to Mill body)	mmwg	373	320	475	500	-
13	Baghouse pressure drop	mmwg	150	110	110	120	-
14	Mill fan operating flow	m^3/hr	5,74,000	4,90,000	7,15,000	10,45,000	7,25,796
15	Mill fan speed control type (GRR/SPRS/ VFD)	-	VFD	VFD	VFD	GRR	SPRS
16	Mill fan inlet damper open position	%	NA	NA	NA	100	NA
17	Mill fan operating efficiency	%	-	74	-	76	80
18	Mill Fan inlet pressure	mmwg	-	-490	-680	-710	-495

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
19	Nozzle ring velocity	m/s	-	29	-	43	32
20	Dam ring height	mm	-	380	-	275	270
21	Table Diameter	mm	-	5,300	-	6,000	5,600
22	Grinding Pressure	bar	-	90	-	185	115
23	Thermal in Case of HAG	kcal/MT Cement	-	-	-	480	-
a	Mill drive	kWh/MT cement	21.00	21.80	21.00	23.00	21.47
b	Mill fan	kWh/MT cement	6.12	6.00	8.10	11.00	8.70
c	Booster fan	kWh/MT cement	-	1.70	-	-	-
d	Separator/classifier	kWh/MT cement	-	0.60	-	0.90	-
e	Auxiliary	kWh/MT cement	5.20	2.50	4.50	0.90	5.32
f	Overall SEC	kWh/MT cement	31.90	32.60	33.20	34.80	35.48

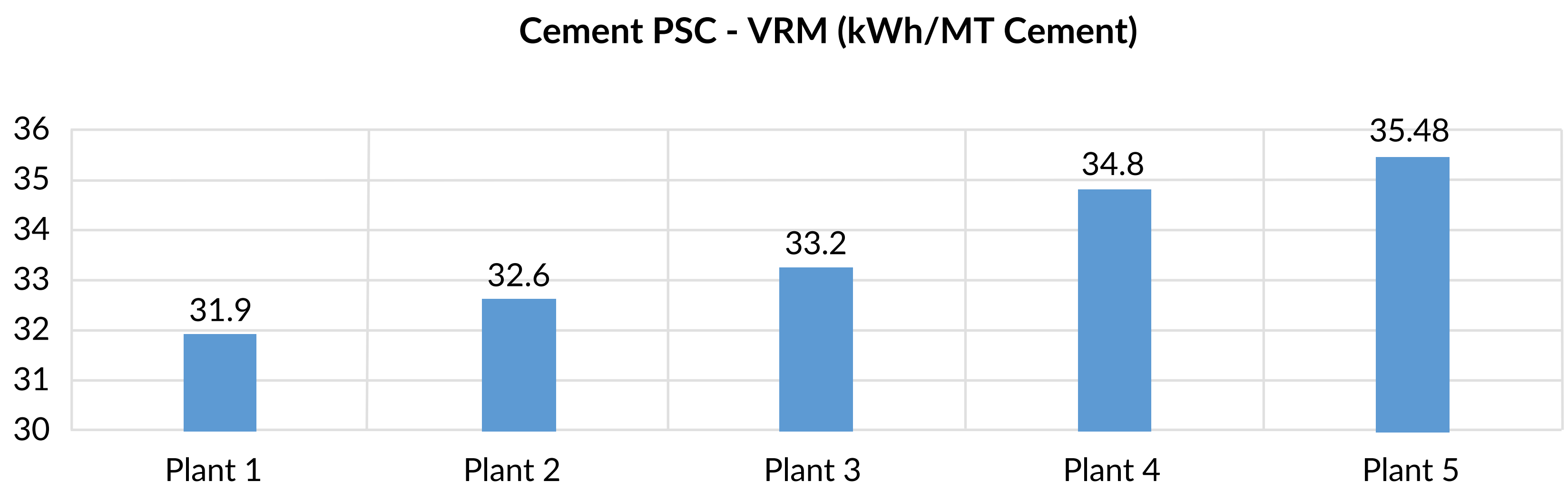


Figure 16: Top 5 plants SEC in PSC grinding (VRM)

3.5.3 CEMENT MILL – BALL MILL + RP

3.5.3.1 PPC

Sr.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4
*	Overall SEC	kWh/MT cement	24.05	24.9	25.7	26.58
1	Type of circuit (Ball mill with HPRG)	-	Ball mill with HPRG	Ball mill with HPRG	Ball mill with HPRG	Ball mill with HPRG
2	Design output	TPH	155	175	225	125
3	Operating output	TPH	180	194	238	135
4	Product variety (OPC/PPC/PSC/Composite cement/others)	-	PPC	PPC	PPC	PPC
5	Clinker feed size	mm	20-26	<25	<25	20-26
6	C_2S & C_3S Content in the clinker	%	-	22 & 52	22 & ,52	-
7	Final Product blaine	m^2/kg	310	320	320	310
8	Final Product residue (% residue on 45 mic)	%	10	8	8	10
9	Fly ash qty	%	34	35	35	34
10	Clinker factor	-	-	0.63	0.63	-
11	Ball Mill Make	-	-	FLS	KHD	-
12	Mill specification (Dia x Length)	-	3.0 x 11	3.8 x 12	4.2 x 13.5	3.6 x 12
13	No. of chambers - Ball mill	Nos.	1	1	1	1
14	Type of liners (both compartments)	-	Semi classifying	UVL & classifying	classifying	Fully Classifying
15	Velocity inside mill	m/s	1	0.7	0.8	0.5

Sr.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4
16	Mill outlet draft	mmwg	155	80	90	70
17	Separator type/model	-	SKS	VSK /Sepol	SKS	Sepol
18	Pressure drop across separator	mmwg	550	180	240	300
19	Separator loading	kg/m^3	0.87	-	-	0.87
20	Circulating load	-	2.86	1.8	1.9	2.58
21	Separator reject residue (on 45 microns)	%	72	85/40	70	67
22	Separator reject blaine	m^2/kg	-	65	70	-
23	Separator product (cyclone fines) residue (on 45 microns)	%	12	17	-	12
24	Separator product (cyclone fines) blaine	m^2/kg	315	220/400	380	310
25	Mill discharge residue (on 45 micron)	%	60	27	65	58
26	Mill discharge blaine	m^2/kg	130	2800	180	115
27	Cyclone pressure drop	mmwg	-	250/100	80	-
28	No. of cyclones	Nos.	2	2/4	4	4
29	Mill vent fan operating flow	m^3/hr	23,000	17,653	24,109	14,000
30	Mill vent fan speed control type (GRR/SPRS/VFD)	-	VFD	VFD	VFD	VFD
31	Mill vent fan inlet damper open position	%	100	100	100	100
32	Mill vent fan operating efficiency	%	80	53	63	45
33	Mill vent Fan inlet pressure (before & after damper)	mmwg	-160 & -170	-153&-159	-161&-168	-170 & -180
34	Separator fan operating flow	m^3/hr	20,000	49,997	51,899	1,78,000
35	Separator fan speed control type (GRR/SPRS/VFD)	-	GRR	VFD	VFD	VFD
36	Separator fan inlet damper open position	%	100	100	100	100

Sr.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4
37	Separator fan operating efficiency	%	82	80	47	78
38	Separator Fan inlet pressure (before & after damper)	mmwg	-619	-110 &-120	-178 & -185	-450
39	Separator vent fan operating volume	m^3/hr	30,000	2,71,283	3,30,647	6,000
40	Grinding media piece weight in first chamber		20	19	18	18
41	Grinding media-specific surface area in the second chamber	m^2/MT	-	42	41	
42	HPRG Make	-	KHD	KHD	KHD	Polysius
43	Type/Model	-	RPZ 13	RP-Z-13-140/140	RP-Z-13-140/141	Polycom 14/06
44	HPRG separator type/model	-	SKS	-	-	Sepol
A	Mill drive (Ball mill)	kWh/MT cement	6.30	8.27	12.6	11.00
B	Mill vent fan	kWh/MT cement	-	0.43	-	-
C	Mill separator fan	kWh/MT cement	-	-	0.39	-
D	Separator vent fan	kWh/MT cement	-	2.90	2.96	-
E	Separator - Ball mill	kWh/MT cement	0.95	-	-	-
F	Booster fan	kWh/MT cement	2.66	-	-	3.20
G	HPRG drive	kWh/MT cement	10.50	6.60	6.68	7.20
H	Dry Fly ash unloading	kWh/MT cement	2.45	-	-	2.45
I	Auxiliary	kWh/MT cement	3.50	3.78	3.17	3.50
J	Overall SEC	kWh/MT cement	24.05	24.9	25.70	26.58

3.6 OVERALL BENCHMARKING NUMBERS OF CEMENT MILL SECTION

Table 7: Summary of cement mill section

Sr.No.	Type of Circuit	Unit	PPC	OPC	PSC
1	Ball Mill	kWh/MT Cement	27.07	29.79	-
2	VRM	kWh/MT Cement	18.80	24	31.90
3	Ball + HPRG	kWh/MT Cement	20.39	28.96	39.01

3.7 PACKING SECTION

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9
*	Overall SEC	kWh/MT cement	0.81	1.02	1.03	1.17	1.41	1.52	1.53	1.61	1.63
1	Design output	TPH	180	200	180	120	180	240	120	180	210
2	Operating output	TPH	130	200	140	90	175	180	120 & 180	126	175
3	No of Packers	Nos.	4	3	6	-	-	5	6	5	8
4	No. of spouts	Nos.	12	16	16	8	12	16	8	12	16
5	Type of discharge (single/double)	-	Double	Double	Double	Single	Double	Double	single	Double	Double
6	Bag filter fan (main & aux) volume	m^3/hr	28,500	38,000	40,000	18,783	-	40,000	13,459	38,000	55,000
7	Bag filter fans operating power	kW	25	-	-	10	39	75	15.2	55	69
8	Compressed air pressure	kg/cm^2	6	6	5	5.5	6	5	5.6	4.8	5
a	Auxiliary*	kWh/MT cement	0.16	-	-	0.91	0.8	-	-	-	-
b	Overall SEC	kWh/MT cement	0.81	1.02	1.03	1.17	1.41	1.52	1.53	1.61	1.63

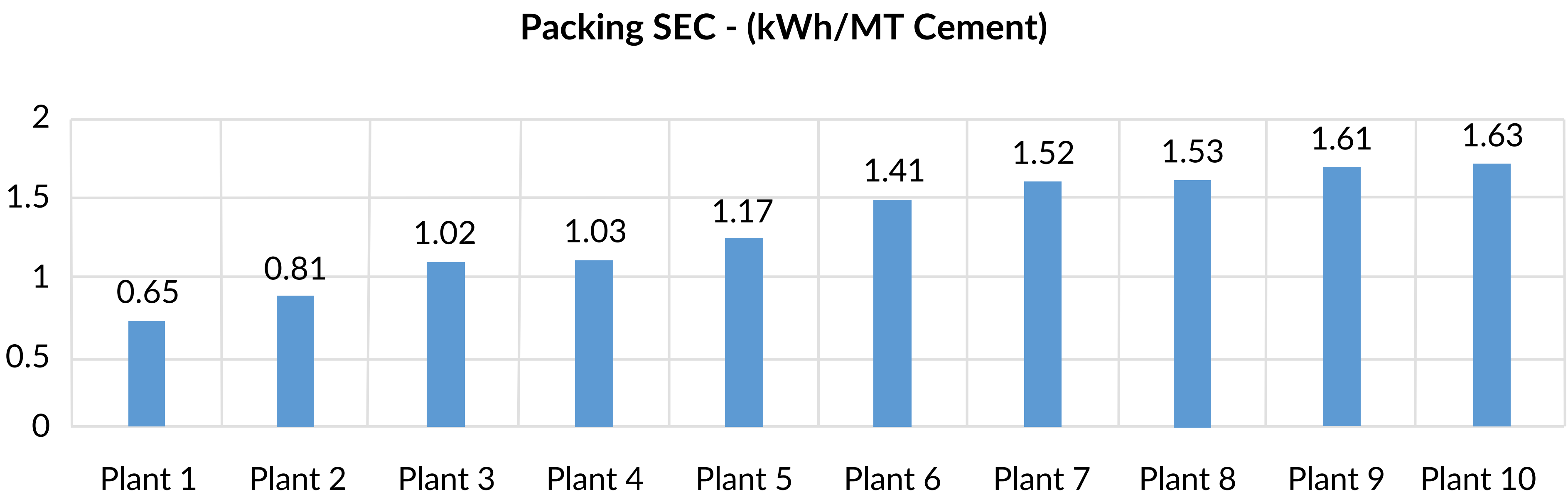


Figure 17: Overall best figures of packing plant section

3.8 UTILITIES SECTION

3.8.1 COMPRESSOR

Sr.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	Clinker production (operating)	TPD	7,100	6,000	6,600	5,040	8,150	3,150
2	Cement production (operating)	TPH	150	302	301	210	190 PPC, 130 OPC	120
*	Clinkerization(SEC)	kWh/MT clinker	0.7 -0.8	1.14	1.34	1.6	1.59	1.69
*	Cement grinding & packing(SEC)	kWh/MT cement	0.8 - 0.9	0.82	0.98	1.3	1.13	0.66
3	COMPRESSOR OPERATING PRESSURE							
a	Main bag house	kg/cm^2	4	NA	NA	4.5-5.0	3	5.5-6
b	Fly ash unloading	kg/cm^2	2.5	6	6	4.5-5.0	2.5	5.5-6
c	Other sessions	kg/cm^2	5.5	5.5	6.5	4.5-5.0	5.5	5.5-6

3.8.2 SPECIFIC WATER CONSUMPTION & AUXILIARY BAG FILTERS

Sr.No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5
1	Cooling water consumption (upto clinkerization)	m^3/MT clinker	0.045	0.063	0.153	0.092	0.076
2	Cooling water consumption (cement grinding & packing)	m^3/MT cement	0.053	0.046	-	0.032	0.055
3	Auxiliary bag filters upto clinkerization (11 kW & above)	Nos.	20	NA	19	8	14
4	Auxiliary bag filters- cement section & packing plant (11 kW & above)	Nos.	21	NA	33	24	5
5	Auxiliary bag filters SEC upto clinkerization (11 kW & above)	kWh/MT clinker	-	NA	1.24	-	0.76
6	Auxiliary bag filters SEC- cement section & packing plant (11 kW & above)	kWh/MT cement	-	NA	1.91	-	0.01

4. BEST AVAILABLE TECHNOLOGY TO DESIGN NEW CEMENT PLANT

4.1 SELECTION OF THE EQUIPMENT ON BASIS OF BENCHMARKING NUMBERS

This chapter is a compilation of information related to best available technology/equipment based on the benchmarking study done to achieve lowest possible energy consumption for an upcoming cement plant.

A) Selection of Crusher

The Roller crusher is the most energy-efficient with respect to the other types of crusher that we have studied in this benchmarking study and the SEC of the crusher should be in between **0.7 and 0.90 kWh/ton** of material after including the impact of the bond index.

B) Selection of Raw Mill

In this benchmarking study, it was found that four vertical mills have a power consumption of less than **12.0 kWh/ton** of material, therefore the SEC of the raw mill of the type VRM should be in the range of **10.6-12.0 kWh/ton** of material. The plant can also further reduce power consumption by reducing the feed size to the raw mill, as the power required by impact crushing is less than the power required by attrition.

C) Preheater Section

In this benchmarking study, it was found that in one of the plants the preheater outlet temperature was in the range of **230-240 ^{0}C** which indicates that the heat transfer efficiency of the entire preheater system is excellent. Improved heat transfer and lower pressure drop are resulting in reduction in specific air volume handled and specific power consumption of preheater fan as well as overall thermal losses. The overall preheater losses are around **105-110 kcal/kg clinker** which is the best number in the Indian Cement Industry.

D) Cooler Section

Presently the best energy efficient coolers operate at an efficiency of around 65%. The losses in the cooler section should not be greater than **110-120 kcal/kg clinker**. Also, cooler fan power should not excess **4.0 kWh/ton** of clinker.

E) Overall pyro section

1)	Preheater Fan SEC (6 stages)	:	3.4-4.0 kWh/ton of clinker
2)	Preheater Fan SEC (With WHRS) (6 stages)	:	6.0-7.0 kWh/ton of clinker
3)	RABH Fan SEC	:	1.20-1.50 kWh/ton of clinker
4)	Cooler Fan power	:	3.10-3.40 kWh/ton of clinker
5)	Cooler Vent Fan	:	0.40-1.0 kWh/ton of clinker
6)	Overall thermal SEC (without WHRS)	:	680-690 kcal/kg clinker
7)	Cooler Efficiency	:	>70%
8)	Overall Electrical power	:	15.45-17.50 kWh/ton of clinker

F) Coal mill Section

In the current scenario, many the plants are using vertical roller mills for pet coke grinding and study suggest that the output of coal mills (VRM) grinding pet coke should be more than 50% with product residue less than 2% and the best number is around 65 % of design output. The SEC of VRM grinding pet-coke should be in the range of **36 kWh/ton-40 kWh/ton** of material.

G) Cement mill Section

In this benchmarking study, it was found that the Vertical mill & Ball mill with pre grinder is more energy-efficient as compared to the ball mill for cement grinding. The energy consumption in the top 2 plants was found to be **19 and 19.50 kWh/ton** of material in PPC grinding & for OPC grinding **24-25 kWh/ton** of material.

4.2 OVERALL SUMMARY

Table 8: Recommended Specific power parameters for New Plant

6 Stage Preheater				
Section	kWh/ton of material	kWh/ton of clinker	kWh/Ton of cement(OPC)	kWh/Ton of cement(PPC)
Crusher power	0.58	0.82	0.74	0.52
Raw mill power	10.64	15.96	14.36	10.05
Kiln power	15.45	15.45	13.90	9.73
Coal mill pet coke	36	3.24	2.91	2.04
Utilities	-	0.8	0.72	0.50
Clinkerization	-	36.47	32.65	22.85
Cement mill(OPC)	18.6	-	24	18.6
Overall Clinker factor	-	-	0.9	0.63
Packing Section	-	-	0.65	0.65
Miscellaneous	-	-	1	1
Overall SEC in Cement(kWh/MT)	-	-	58.30	43.10

5. OPTIMIZATION & PRODUCTIVITY IMPROVEMENT MEASURES

5.1 MILL OPTIMIZATION IN PET COKE GRINDING

In the last 5 years, the Indian Cement Industry has seen a drastic change in the quality of fuel, used for making the clinker. The Indian Cement plants have been undergoing major changes in order to shift from high carbon coal (anthracite) to pet coke. One of the major reasons for this shift is the high calorific value (> 7500 kcal/kg) of pet coke, besides, low ash & moisture content. Due to these qualities of the pet coke the cement plants can produce good quality clinker. However, due to its lower volatile matter content and lower HGI, it requires hard fine grinding with Residues as low as < 2 % in a 90-micron sieve. Therefore many Indian cement players have done many modifications to their coal mill circuit.

This section mainly addresses the challenges to convert coal mill (VRM) from normal coal grinding to pet coke grinding. This section also throws light on important process parameters which play an important role in achieving the desired output on pet coke and the methodology through case studies.

5.1.1 IMPORTANT PROCESS PARAMETERS

A. Nozzle Ring Velocity
B. Circumferential Velocity
C. Dust loading (gm/m^3)
D. Dam Ring Height
E. Static Vanes Gap
F. Water spray pattern
G. Mill table speed
H. Seal air gap

A) Nozzle Ring Velocity

The nozzle ring velocity while grinding pet coke should be in the range of 45-60 m/s and the dust loading of the mill should be in the range of **250-300 gm/m³**. Furthermore, due to the abrasive nature of pet coke, the louvers of the mill are severely affected, which leads to a higher pressure drop across the mill. Due to this, regular maintenance is necessary, to keep low wear and tear inside the mill try to maintain as minimum nozzle velocity as possible. This will reduce the pressure drop across the nozzle ring, reducing the static head of the fan. Typically, this can reduce fan SEC by 15-20%.

B) Circumferential Velocity

Rotor circumferential velocity of the majority of the coal mill separators which were commissioned 10 years ago is designed around 18 m/s which is suitable for Anthracite or Semi Anthracite Indian / imported coal. This is not suitable for pet coke grinding as it is required to be ground very fine. For fine grinding higher centripetal force is required, thus the recommended range for pet coke grinding is **27-30 m/s**. The residue for the pet coke should be in the range of 1.5-2.0% on a 90-micron sieve. In this respect, many plants have upgraded their separators with high circumferential velocity.

The Circumferential velocity is calculated by the below formula:

$$CV = \frac{N \times 3.14 \times D}{60} \ (m/s)$$

N = Separator RPM

D = Rotor diameter in Case

C) Dust loading

Dust loading is a crucial factor in mill optimization. Optimizing the dust loading helps in optimizing the residue of the grinded pet coke, which in turn increases the separator efficiency. Dust loading can be optimized by optimizing the fan flow as per the mill feed while ensuring desired nozzle ring velocity. The recommended range of dust loading for pet coke grinding is **250-300 gm/m³**.

D) Dam ring height

The main function of the Dam Ring is to optimize the grinding bed in such a way that the mill remains stable with minimum vibration & optimum main drive load. As **Hard Grove Index (HGI)** of petcoke is on the lower side (< 40) as compared to normal coal, so it's hard to grind, as a result, certain changes are recommended in dam ring height such as increase the height as compared to other types of coal to minimize the vibration on the mill bed and in many cases, the optimum range was found to be **5-6 %** of table diameter and may vary as per supplier specifications.

E) Static Vanes gap

The distance between the static vanes gap in the separator plays a significant role to maintain the proper residue in any type of mills. The main function of static vanes is to give constant centripetal force to the particles. If the static vane gap is non-uniform, it deteriorates the efficiency of the separator, so it is recommended to check the gap once a month and maintain it as per OEM drawings/specifications, moreover, any change in the vanes gap (Atox-30 mm) should be done depending upon the residue condition.

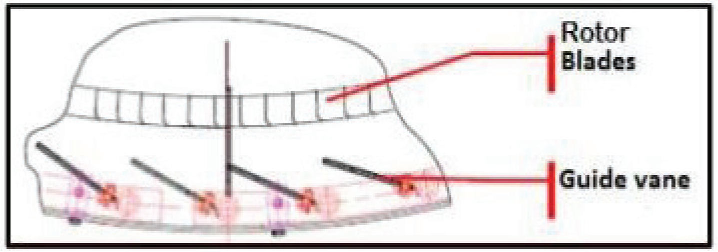


Figure 18: Static Vanes gap in a Separator

F) Water Spray pattern

In VRM grinding, the water spray pattern, which acts as a plasticizer plays a crucial role whether it is pet coke/coal or raw meal grinding. Optimizing the water spray pattern another way to make the grinding bed stable in pet coke grinding. Typically, the water spray nozzle during pet coke grinding is adjusted in such a way that the vertical distance between the table & nozzle should be minimum (**100-500 mm**) at the same time avoid contact of water with a roller to ensure increased life of the roller.

G) Mill table Speed

Due to lower HGI and desired higher fineness, pet coke grinding needs more residence time/contact between the roller and the table. As the mill cannot be operated with full table speed, VFD OR GRR is generally installed in the main drive to reduce the table speed (**70-80%** of maximum speed) to increase the retention time of pet coke in the mill for effective grinding.

H) Seal air Gap

The main function of the seal air gap is to avoid the by-pass / carryover of coarse particles with the product. An effective gap/seal helps to achieve the desired residue in pet coke grinding and the recommended range is **6- 10 mm** which is applicable for both vertical & horizontal gaps.

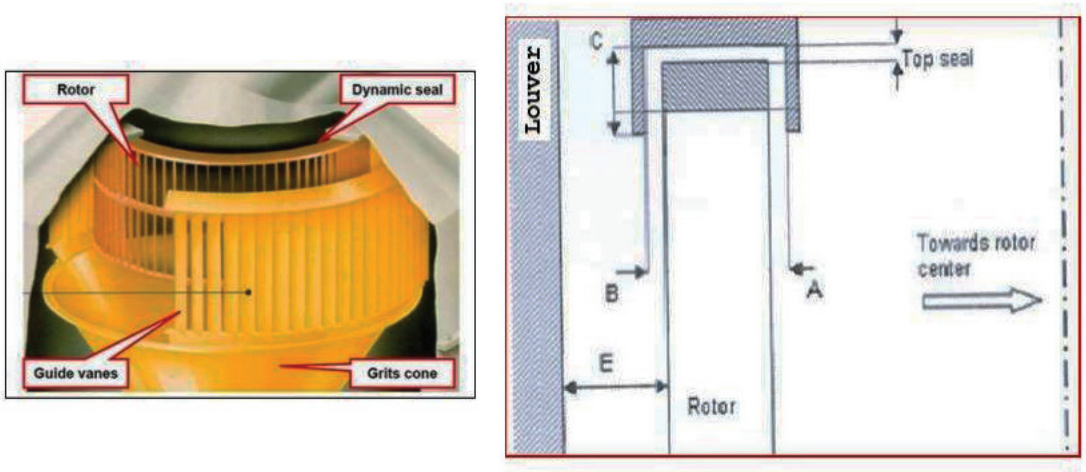


Figure 19: Seal Air Gap details of VRM separator

5.1.2 METHODOLOGY TO CONVERT NORMAL COAL FOR PET COKE GRINDING – CASE STUDY

Before starting any audit of the mill it's better to check all the process parameters which have been discussed in the above section and then take countermeasures as per the deviations and list of process parameters before and after which have been implemented. The following case study is from one of the cement plants in India where the plant team took certain measures which are highlighted in below table

Table 9: Case Study-Atox Coal Mill (22.5)

Parameters	Unit	Before	After	Deviation (%)
Table diameter	mm	2250		
Mill Design	TPH	38 –Normal Coal		
Kiln output	TPH	125	187.5	After improving the coal mill residue which ultimately minimizes the formation of CO at kiln inlet along with optimization of raw mix & recuperation efficiency distribution proper in SA&TA
Mill SEC	kWh/ton of material	43.50	40	-
Mill Output	TPH	18-21	18-21	-
Nozzle Ring Velocity	m/s	42	55	31
Dam ring height	mm	145	120	-17
Seal Air Gap	mm	6	6	0
Dust loading	gm/m^3	170	210	24
Distance between Static Vanes	mm	30-40	30	33
Residue on 90 micron	%	8	2	-75
Water Spray pattern-Nozzle height from table	mm	2000	500	75

Case Study Outcomes

By maintaining all the process parameters which have been discussed in the above table the residue in pet coke grinding has been reduced from 8% to 2% on 90 microns without major investment and the plant team was able to optimize their mill circuit through the above methodology. Ultimately the plant team was able to increase the kiln feed from 200 TPH to 300 TPH through optimizing the petcoke residue, raw mix optimization & increased the volume of secondary air at the kiln inlet by reducing the TAD damper.

5.1.3 COMPARISON OF MILLS IN PETCOKE GRINDING

Table 10: Comparison of Coal mills (different models) in pet coke grinding

Parameters	Unit	Atox	Gebr.Pfeiffer	Polysius	Loesche
Design Capacity	TPH	38	90	38	55
Mill Model	No	ATOX 22.5	MPS 3550 BK	25/12	-
Operating Capacity in Pet Coke	TPH	18-21	54-58	18-20	35
Output Conversion-Normal Coal to Pet Coke	%	55	65	50	63.60
Circumferential Velocity	m/s	27-30	27-30	18	-
Nozzle Velocity	m/s	55-60	50-55	45-50	45-50
Dust loading	gm/m^3	210	-	164	180
Seal Air gap	mm	< 10	< 10	< 10	<10
Residue on 90 micron	%	2	2	2.5	<2
Grinding Pressure	Bar	145	85	130	60
Fan Controlled	VFD/GRR	VFD	VFD	VFD	VFD
Main drive power	kWh/ton material	-	20.36	18.90	13
Fan power	KWh/ton	13	16.20	12.30	20
Total SEC	kWh/ton of material	39	41	36.18	40

5.2 WHRS OPTIMIZATION

The cost of fuel has been increasing day by day which leads to the increase in power generation cost. Stringent government policies regarding reducing NO_x emissions, voluntary commitment towards reduction in carbon emission, and other factors such as PAT benefits, reduction in water consumption compel the cement plants in India to install WHRS setup.

Many companies have taken some initiatives from last 4-5 years such as installation of low NO_x burner, SNCR installation, retrofit of process fans with more efficient fans, energy-efficient grate cooler, enhancing the solar generation capacity, increase the utilization of alternative fuels. Out of these steps, the major step taken by the plants is the installation of the WHRS plant.

Presently, the capacity of power generation by WHRS in the cement industry above 500 MW and more than 200 MW is in pipeline and will be installed in coming years.

The WHRS has enabled the Indian cement industry to reduce its GHG emission and is expected to be one of the major contributors in making the industry to progress towards carbon neutral by 2050.

This section mainly deals with the appropriate measures & steps which everyone should keep in mind while operating the WHRS section such as optimum power generation of WHRS without deteriorating cooler efficiency, the impact of cooler grate loading on cooler vent temperature, the impact of WHRS on preheater & cooler ESP power, the role of hot air recirculation in WHRS system and lastly overall cost analysis.

Table 11: Comparison of WHRS of Cement Plants

Sr.No.	Parameter	Unit	Plant1	Plant2	Plant3	Plant 4	Plant 5
1	Installed capacity	MW	8.8	7	15	9.5	16
2	Operating capacity	MW	8	7	11.3	9.5	13
4	Clinker production	TPD	6,050	5,665	8,150	6,200	12,000
6	WHR Tapping-Cooler(End Tap/Mid Tap)	-	End Tap	Mid Tap	Mid Tap	Mid Tap	Mid tap
7	Mid Tap /End tap Temperature of cooler	^0C	473	350	480	440	Line1:-310 &Line2:-460
8	Heat Consumption With WHR	kcal/kg Clinker	721	711	721	712	765
10	Hot Air Recirculation (Yes/No)	-	NO	YES	Yes	NO	Yes-Line1

Sr.No.	Parameter	Unit	Plant1	Plant2	Plant3	Plant 4	Plant 5
11	Cooler recuperation efficiency (with WHR)	%	66	67	65	58	64 & 58
12	Cooler Grate Loading	TPD/m^2	54	-	45	44	46
13	Boiler type	-	-	Pre Heater & AQC type	WHRB	Water tube	No of Boiler-6
14	PH boiler inlet gas temperature	^0C	315	315	325	272	337,316,293,294
15	PH boiler outlet gas temperature	^0C	227	206	160	161	167,174,166,169
16	AQC boiler inlet gas temperature	^0C	440	400	450	415	403,420
17	AQC boiler outlet gas temperature	^0C	115	100	95	130	201,100
19	Pressure drop across PH boiler	mmwg	100	38	120	51	86
20	Pressure drop across AQC boiler	mmwg	110	60	90	75	74
21	Auxiliary power consumption (APC) by WHR plant	%	3.8	3.5	3.7	5.5	-
22	Average power generation per ton clinker	kWh/MT clinker	31.74	22.37	35.84	35.50	33
23	Water consumption	m^3/MW	-	0.45	0.21	0.14	-
24	False air across PH boiler	%	7	5.0	8.5	15	6
25	Overall WHR efficiency	%	20.4	-	17.0	20.7	13.0

5.2.1 OVERALL WHRS POTENTIAL ASSESSMENT

Calculations:-

Cement Plant details

Plant Capacity	=	5,500 TPD
Kiln Feed to Clinker Factor	=	1.60
Preheater Fan Volume	=	1.50 Nm^3/kg clinker
Preheater Outlet temperature	=	315 ^{0}C
Preheater Dust Concentration	=	80 gm/Nm^3
Cyclone efficiency	=	95%
Density of Flue Gas	=	1.42 kg/Nm^3
Cooler end tap temperature	=	460 ^{0}C
Cooler efficiency	=	65%
Cooler Vent Volume	=	0.75 Nm^3/kg clinker
Specific Heat of Air	=	0.24 kcal/kg ^{0}C
Specific Heat of Flue gas	=	0.25 kcal/kg ^{0}C
Density of Air	=	1.29 kg/Nm^3
Heat available From Preheate	=	3, 43,750 X 1.42 X 0.23 X 320
	=	35.92 Mkcal/hr
Heat available from cooler	=	1, 71,875 X 1.29 X 0.24 X 460
	=	24.47 M kcal/hr.

WHRS details

Overall operating Efficiency	=	22.37%
Maximum Power generation	=	7 MW

PH Boiler

Inlet temperature of APH Boiler	=	320 ^{0}C
Outlet temperature of APH Boiler	=	230 ^{0}C
Heat absorbed	=	3,43,750 X 1.42 X 0.23 X (320-230)
	=	10.104 Mkcal/hr

AQC Boiler

Inlet temperature	=	426 ^{0}C
Outlet temperature	=	110 ^{0}C
Heat absorbed	=	1, 71,875 X 1.29 X 0.24 X (426-110)
	=	16.81 M kcal/hr.
Total Heat Supplied to boiler	=	10.104 + 16.81
	=	26.91 M kcal/hr
Power generation	=	7.0 MW
	=	7.0 X 1000 X 860
	=	6.02 Mkcal/hr
Overall efficiency of WHR	=	Power generation / Heat absorbed in Boilers
	=	6.02/26.91 X 100
	=	**22.37%**

5.2.2 HOW TO SELECT A TAPPING POINT IN THE COOLER?

Before deciding the location of the tapping point in the cooler for WHRS, few factors should be kept in mind; firstly, the cooler null point should be identified to avoid deterioration of the cooler efficiency. Secondly, the grate loading should be optimized, in many plants, it has been found that coolers that are operating on high grate loading facing the problem of high temperature in mid tap as compared to the desired temperature of **450 ^{0}C** which is sufficient for WHRS generation. The difference between excess temperature & the desired temperature was found to be more than **150 ^{0}C**, as a result, cooler efficiency was deteriorated by **5-6 %**, which makes the project infeasible in terms of cost analysis.

Methodology

- Identification of cooler null point by doing cooler balance so that cooler efficiency could not deteriorate too much
- Secondly, before finalizing the tapping location decide the cooler grate loading for operating the plant as studies suggest that a cooler which operates with high loading should take the tapping from the end tap & vice versa for mid tap.
- Cooler ESP fan retrofication should be done after commissioning the WHRS so that plant knows the system resistance across the AQC boiler.
- The final evaluation of the project is to be evaluated by verifying the impact on cooler efficiency due to WHRS.

5.2.3 METHODOLOGY TO OPTIMIZE COOLER LOSSES IN WHRS SYSTEM THROUGH CASE STUDY

This section mainly emphasizes the relationship between cooler grate loading with mid tap temperature therefore considering two coolers one is Pendulum and another is Cross Bar cooler & application of these coolers in four plants with high & optimum cooler grate loading.

Plant 1 : (Optimum Grate loading) – Pendulum
Plant 2 : (Overloading) – Pendulum
Plant 3 : (Optimum Grate loading) – Cross Bar
Plant 4 : (Overloading) – Cross Bar

Case 1 Pendulum Cooler

During the energy audit study in one of the cement plants (**Plant1**), it has been found that the pendulum cooler was operating with optimum grate loading (**45 TPD/m²**) in which mid tap temperature was coming around **480⁰C** & cooler is also equipped with hot air recirculation but still, the overall efficiency of the cooler has not deteriorated too much & overall efficiency of the cooler is nearly about **65%**.

Another cooler (**Plant2**) which was operating with cooler grate loading (**54 TPD/m²**) on the higher side) but WHRS generation fulfillment is to be done by the end tap-tapping point of the cooler in which cooler vent temperature was found to be around **470⁰C** in that case also cooler efficiency was found to be around in the range of **65-66%** it means cooler grate loading plays an important role for WHRS generation.

Case 2 Cross Bar Cooler

As per energy study data, **Plant 3** which was operating with optimum loading (**44 TPD/m²**) & generate the WHR generation through mid-tap temperature which was found to be around 460 degree C with overall cooler efficiency of around **58%**.

On the other hand, when it was operated with high grate loading(**Plant 4**) (**56 TPD/m²**) a result mid-temperature was found to be around in the range of **600-650⁰C**, as a consequence, the overall cooler efficiency of the cooler has been found only **53%**.

It means that due to high grate loading & corresponding which the tapping point position for WHR generation was not correct as a result the overall efficiency of the cooler has been deteriorated by **4-5%**.

Conclusion

From the above case studies of the plants, the correlation between grate loading with cooler vent temperature (tapping point) plays a very significant role to minimize the impact on cooler efficiency due to WHRS generation it means that through optimization plant can increase the cooler efficiency by **4-5 %** avoiding excess vent heat losses.

5.2.4 SIGNIFICANCE OF HOT AIR RECIRCULATION (HAR)

Another way to increase the WHRS generation in cement plant through Hot Air Recirculation (HAR) concept in which cooler vent air (through Stack) at a temperature of 100 ^{0}C is recirculated to the middle compartments of the cooler which is shown in the below figure, as a result, cooler mid-temperature increases by 40-60 ^{0}C and depends upon the cooler recuperation efficiency. The gain in the available heat is in the range of 20-25% and can vary as per supplier specifications.

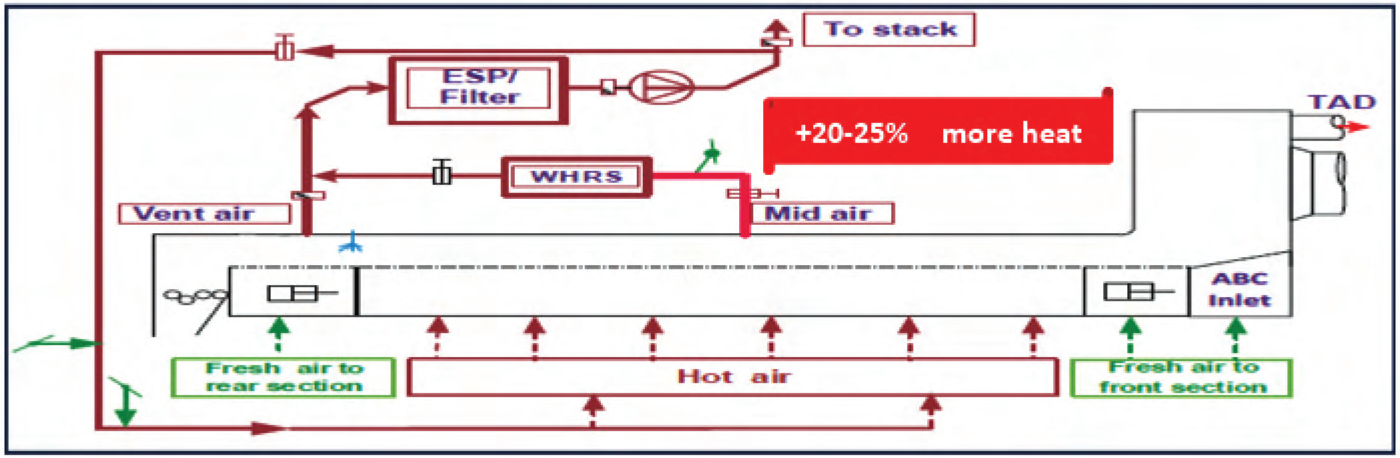


Figure 20: Hot Air Recirculation System of the cooler section

5.2.4.1 FEASIBILITY STUDY OF HAR

Overall power generation through AQC boiler generally contributes around **60 percent** of the total as a result contribution of vent air temperature plays an important role in power and today's scenario maximum suppliers design their WHRS system for AQC boiler inlet around **450 ^{0}C.**

Therefore, maintaining the temperature around it is another challenge to maximizing the power generation in some plants in which coolers are not so efficient and not able to generate the desired temperature for the WHRS system in that case concept of HAR plays a significant role to increase the power generation by **0.3-0.4 MW**.

Another thing to keep in mind where sufficient temperature is available at the cooler vent in that case project economics feasibility should be checked first before implementation because one disadvantage of the HAR system is that it increases the clinker losses& overall SEC of cooler fans, therefore, all these things should be taken in the account before taking any decision regarding it.

5.2.5 IMPACT ON COOLER EFFICIENCY & OVERALL COST ANALYSIS

In energy audit studies it has been found that the overall cooler efficiency is to be deteriorated by **5-6 %** when it is operated with WHR as compared to without WHR for instance in one of the cement plants the overall heat consumption was found to be **712 kcal/kg clinker** with WHR & without it was around **690 kcal/kg clinker**, similarly, in 2-3 cement plants the difference between in heat consumption was found to be around in the range of **20-25 kcal/kg clinker**, therefore cost analysis of the project is a very important parameter to make the project feasible.

Overall Cost analysis Calculation

Heat Consumption with WHR	=	715 kcal/kg clinker
Heat Consumption without WHR	=	692 kcal/kg clinker
Overall difference	=	715-695
	=	20 kcal/kg clinker
Clinker production	=	6,000 TPD
Coal NCV	=	**7,000 kcal/kg Coal**
Total heat	=	20 X 6,000X 1,000
	=	120 Mkcal
Quantity of fuel increased	=	120 X 106/7,000
	=	**17.14 Tonnes in a day**
Cost of fine coal	=	INR 10,000 per ton
Overall cost per day	=	17.14 X 10,000
	=	**INR 1.71 lakhs per day**
Total power generation	=	**8 MW**
Generation of power through AQC Boiler	=	60% X 8
	=	**4.8 MW**
Cost of 1 unit	=	INR 4 per kWh
Total power cost in Rs per day	=	4.8 X1,000X 4 X 24
	=	INR 4.60 lakhs per day
Total net saving per day	=	4.60 - 1.71
	=	**INR 2.89 lakhs per day**

6. IMPORTANT THUMB RULES

6.1 FANS

A) Fans with aerofoil, backward curved blades can operate with an efficiency of more than 85%

B) The optimum margin for pressure is 15 % and flow is 10% while designing a fan

C) Optimum cut off clearance in a centrifugal fan is 8 -12 %

D) Dampers provided at the fan outlet consumes more power than provided at the inlet due to an increase in absolute pressure of gas handled by the fan

E) The difference between suction box velocity & duct Velocity should not be greater than 8 m/s

F) Increase the stack height & temperature of gas for maximizing the natural draft effect

G) Operating parameters of the fan should not be deviated from a design by 10% otherwise it deteriorates the fan efficiency.

H) Safety margin-10% excess volume,15% excess pressure for a new fan

I) In a Vent fan, the volume margin should be around 30% such as a cooler vent fan

J) Allowable pressure loss across multi louver type damper in 100% open condition 10-15 mmwg

6.2 RAW MILL & COAL MILL

A) The circumferential velocity of the rotor inside the pet coke grinding should be in the range of **27-30 m/s** for achieving the product residue.

B) Recommended gas velocity in ducts at cement plant 14-16 m/s

C) Pressure drop in latest generation LP cyclones 50-60 mmwg

D) High false air in Raw mill circuit mainly increase the RABH fan power

E) Conversion from normal coal grinding to petcoke grinding deteriorates the mill output and best figures:-65% of Normal coal

F) Rotary airlocks shall not be composed of more than 6 cells/pockets Cell/pocket filling degree shall not exceed 33 %

G) External material re-circulation shall be designed for around 50-90% of the nominal production rate

H) The specific loading of the rotor of the internal separator shall be <=10 t/h m^2

I) The separator cage shall be capable of achieving 25 m/s circumferential velocity

J) The pressure drop across the cyclones should not exceed **40-100 mmwg**.

K) Air to cloth ratio for raw meal/filter dust:2 m^3/ m^2/min for air slide design

L) Separator venting air quantity (m^3/h) should be more than 10-12 % of the fan inlet air quantity.

M) Maximum Intake velocity at venting hood should be 1.5 m/s for bag filters.

N) The acceptable range of false air in the coal mill VRM circuit should be in the range of **14-15%**

O) The gas temperature of the mill should be greater than dew point by **20^{0}C**

P) Coal mill outlet temperature should be greater than dew point(50-52 ^{0}C) of flue gases by 20 ^{0}C

Q) Maximum particle size(mill feed) should be 5 to 8% of the Roller diameter

R) Ball mill ventilation velocity: 1.3 to 1.5 m/s above the ball charge for the elevator outlet mill and 3 to 5 m/s for the air-swept mill.

S) Ball mill can accommodate input moisture level up to 12 % (Max); whereas Vertical Roller Mill can accommodate moisture level even up to 20 % Max.

T) Wear Rate

Table 12: Standard Wear Rates of VRM parts

Material	Application Wear material	Wear Rate (gm/t)	
		Roller Tire	Table
Raw meal	Ni-hard 4, High Cr	3.1	3.3
Clinker	Cast segments	1	1
Clinker	Hard faced segments	0.5	0.5
Slag	Cast segments	6	9
Slag	Hard faced segments	3	4.5

U) The separator loading should be maintained above 0.6 kg of material/ m^3

V) The seal gap is to be maintained between 6 and 8 mm.

W) The false air in the VRM should be maintained below 15%

Table 13: Important Norms & Guidelines for mills grinding

Section	Unit	Typical Range
Cage Velocity of Classifier rotor		
Raw Mill	m/s	<5
Cement mill	m/s	up to 5
Nozzle Ring Velocity		
Slag Grinding	m/s	35-40
Raw meal grinding	m/s	40-55
Cement grinding	m/s	40-50
Coal grinding	m/s	50-70
Circumferential Velocity inside the Rotor		
Pet Coke grinding	m/s	27-30
Raw mill	m/s	10-25
Cement Mill	m/s	10-35
Operating Dust load at mill Outlet		
Pet Coke grinding	gm/m^3	220-250
Raw mill	gm/m^3	500-700
Cement Mill	gm/m^3	200-400
Slag Grinding	gm/m^3	200-400
Heat Consumption for water Vaporization		
VRM	Kcal/kg Water	900-1000
Ball Mill	Kcal/kg Water	700-800
Specific Rotor Load		
Raw mill	$t/hr/m^2$	9-12
Cement Mill	$t/hr/m^2$	10-12

6.3 PYROSECTION

A) 20 % increase in height of chimney (stack) can save 20 % power consumption of the connected ID fan

B) Latest generation low NO_X burners can operate with a Primary air % as low as 4-6%

C) PID loop optimization will result in savings of 3-5 kcal/kg of clinker

D) Application of refractories

   a. Preheater-Cyclones : 20% to 40% alumina with insulation backup

   b. PC Vessel : 40% to 60% alumina with insulation backup

   c. Smoke Chamber : 40% to 60% alumina or silicon carbide castable for anticoating with insulation backup.

   d. Cooler : 40% to 90% alumina with insulation backup.

   e. TAD : 40% to 60% alumina with insulation backup

E) Types of refractory material for different locations inside the kiln

   a. Cooling zone : High alumina (>70%) bricks or mag-chrome bricks

   b. Burning zone : Dolomite bricks (MgO >96%)

   c. Transition zone : Alumina or high alumina bricks; mag-chrome bricks (MgO > 65%)

   d. Preheating zone : Fireclay brick with Al_2O_3 content decreasing towards feed end; lightweight bricks

F) The temperature drop across TAD should not be greater than 40 ^{0}C

G) Recommended phase density for petcoke should be in the range of 5-6 kg coal/kg air

H) Phase density for normal coal:-4-6 kg coal/kg air

I) The specific consumption of coal firing blowers should be in the range of 0.4-0.7 kW/m^3/min

J) The top cyclone efficiency should be greater than 95 % efficiency

K) Null point for pet coke firing lies between 0.75 -0.80 Nm^3 air per kg clinker.

L) Overall cooler efficiency should be greater than 70% efficiency

M) Cooler losses should not be greater than 120 kcal/kg clinker

N) Overall radiation losses contribute around 6-8% of total heat losses

O) False air across preheater circuit should be less than 8%

P) The kiln should be operated in the oxidizing atmosphere during pet coke firing

Q) Pressure drop across ESP should not be greater than 30 mmwg

R) Down comer duct velocity should be in the range of 15-16 m/s

S) The pressure drop from the top cyclone to the fan inlet in the downcomer duct should not be greater than 30 mmwg

T) The specific volume of preheater fan for pet coke firing should be in the range of 1.45-1.50 Nm^3/kg clinker

6.4 CEMENT MILL

A) Ball mill ventilation velocity – 1.3 to 1.5 m/s above the ball charge

B) The specific surface area of grinding media charge in the second chamber of a ball mill for cement grinding- 38 to 44 m^2/ton

C) Total piece weight in the first compartment should be in the range of 1400-1500 gm per unit piece without pre-grinder & Roller press

D) Recommended piece weight in the first chamber with HPRG lies in the range from 900-1100 gm per unit piece.

E) The specific surface area of grinding media charge in the second chamber of a ball mill for raw material grinding- 24 to 27 m^2/ton

F) Separator dedusting bag filter flow should be 10-12% of the separator airflow

G) Rotor Case velocity inside the separator should be in the range of 4-5 m/s

6.5 BAG FILTER OPTIMIZATION

A) Air to Cloth ratio:-

  a. 1.2 m^3/m^2xmin for Slag, Coal, and Clinker dust

  b. 1.5 m^3/m^2xmin for limestone and Cement dust.

B) The minimum distance between the bags should be 50 mm.

C) The maximum number of bags per row should not be more than 16 bags

D) Maximum 6-8 dust sources to vent should be connected to one dust collector.

E) Duct Slope:-

a. Max 30 degree for limestone, cement, slag de-dusting

b. Max 45 degree for clinker de-dusting

F) At material discharge chute, drop height must be not more than 2 m if it is more than 2 m then baffle plates are provided.

G) Velocity Vent Norms:-

a. 10 m/s for non-explosive dust like clinker, slag and fly ash

b. 20 m/s for explosive dust like coal.

H) Static pressure below Rotary Air Lock should not be more than 10 mmwg else false air through RAV will increase.

I) Optimum pressure drop across filter 80-120 mmwg indicates efficient utilization of bag filter capacity.

J) Recommended air pressure for purging is 4.5-5.5 kg/cm^2 and above there is loss of energy.

K) Clean air velocity is generally in the range of 16-18 m/s.

L) Velocity profile should be even in sub-branches for effective utilization of bag filters.

M) Dedusting air requirement in CF or blending Silo is to be depended upon aeration as well as air slides blower.

N) Dedusting of airtight clinker silo is to be determined by following formula Q silo = $D^2 \times 0.055$, where D is the diameter of silo in m

O) In drag chain and screw conveyors, the velocity through the ventilation flap is 4-6 m/s.

6.6 COMPRESSED AIR

A) 1 bar reduction in compressed air pressure will save 8 % power

B) Recommended compressed air velocity in the pipeline is 6 - 8 m/sec

C) Reduction in Cooling tower fan speed by 50 % by VFD can save power by 75%

D) The 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

E) Maintaining intercooler performance can save 7 % power on the compressor

F) Reduction of 10°C in the combustion air of DG will save 1.5 gm of Fuel / kWh of power generated

G) 150 sq ft of room area needs 1 TR Air Conditioning load in a conventional building.

H) The optimum approach (Difference between Coldwell temperature and wet bulb temperature) in a cooling tower is 2- 4°C

I) Recommended increase in temperature of water (Delta T – Cooling water outlet – inlet temperature) for condenser and compressor is 10°C and for process heat exchanger 5°C

J) FRB Blades in an axial cooling fan can save up to 20 - 40 % power compared with metal blades

K) Every 4°C rise in inlet air temperature of the compressor results in higher energy consumption by 1 % to achieve equivalent output".

L) Recommended compressed air outlet temperature after intercooler is ambient temperature + 20 °C

M) The 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

N) Trans vector nozzles can reduce power and save compressed air up to 50%

O) 3 mm diameter hole in a compressed air pipeline with 7 kg/cm^2 air pressure would result in a power loss of 5 kW (equivalent to INR 1.5 Lakhs per annum)

P) Compressed air leakage quantity to be as low as 10%

Q) In 800 m length compressed air pipeline, pressure drop should not be more than 0.3 kg/cm^2

R) Centrifugal and Screw blowers can save up to 40 % power when compared with PD blowers for the same application (pressure and volume)

S) Flat belt pulley can save 3 – 5 % compared with V pulley

T) The typical power consumption of a conventional vapor compression refrigeration system is 1.2 kW / TR

U) Typical power consumption of Screw chiller system is 0.35 kW / TR for 10 °C chilled water & 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

V) Evaporative cooling can reduce the compressor or chiller load by 20 - 40%

W) Ceramic coating can save up to 8 – 20% radiation loss in furnaces and hot surfaces

6.7 ELECTRICAL EQUIPMENT

A) 4 % reduction in voltage will result in a 1 % reduction in power

B) 10 % reduction in speed will save 27 % power in centrifugal equipment

C) LED can save power consumption by nearly 50 %

D) Power transformer efficiency will be maximum in the range of 60 - 80 % Loading

E) Distribution transformer efficiency will be maximum in the range 40 – 60 % Loading

F) Motor life doubles for every 10^{0}C reductions in operating temperature

6.8 CAPTIVE POWER PLANT

A) 22^{0}C Drop-in Boiler flue gas temperature will increase efficiency by 1%

B) A 10% blowdown in a 15 kg/cm^2 boiler results in 3% efficiency loss

C) 3 mm of soot can cause an increase in fuel consumption by 2.5% due to increased flue gas temperatures.

D) Optimum efficiency of boilers occurs at 65–85% of full load,

E) Reducing the frequency by 1 Hz at the main TG / DG (in Island mode) will reduce the power consumption of Centrifugal equipment by 3 %

F) A 1 mm thick scale (deposit) on the waterside could increase fuel consumption by 5 to 8%

G) The optimum excess air for a coal-based boiler is 15 -20%

H) With every 1% reduction in excess air in the boiler, there is an approximately 0.6% rise in inefficiency.

I) 6^{0}C raise in feed water temperature by economizer/condensate recovery corresponds to a 1% saving in fuel consumption, in the boiler

J) Heat available in DG exhaust is close to 33 %, the cooling medium is 24 % and this can be recovered by WHR with VAM and other techniques

K) A 3-mm diameter hole on a pipeline carrying 7 kg/cm^2 steam would waste 33 Kilo liters of fuel oil per year

L) 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)

M) 1 mm thick air film in steam piping offers the same resistance as a wall of copper of 15 meters thick!

N) Every 4.8 kg/cm^2 drop in generation pressure of steam will result in a 1% increase in efficiency

7. FACTORS WHICH AFFECTS SEC IN PARTICULAR SECTION

7.1 RAW MILL SECTION

7.1.1 BOND INDEX

The bond index indicates the grindability of limestone and in mechanical terms, the intensity of energy required to minimize from an initial size of mass up to ultimate product size and the higher value represents that the particular characteristic of limestone material is hard to grind. Specific power of main drive mainly depends upon the bond index and it has been found that due to high bond index the same mill takes higher power on different bond indexes and the overall difference in power vary in the range between 10-40 % depending upon the hardness of the material.

Table 14: Bond Index Values of limestone

Bond Work Index(kWh/ton)	7-9	9-14	14-20	20
Material Property(Limestone)	Soft	Medium	Hard	Very Hard

7.1.2 RAW MATERIAL MOISTURE

Heat requirement of the mill is directly proportional to moisture in the material as the moisture in the material increases which results the increase in overall heat consumption.

Table 15: Heat Consumption requirement values in VRM

Heat Consumption for water Vaporization		
VRM	kcal/kg Water	900-1000
Ball Mill	kcal/kg Water	700-800

7.1.3 PRESSURE DROP PROFILING

System resistance plays an important role to decide the overall consumption of the fan power, therefore, pressure profiling across raw mill circuit is a very necessary task in a cement plant from a process point of view to reduce the overall energy consumption of the mill.

Table 16: Recommended Values for VRM pressure profiling

Parameters	Unit	Optimum Value	Remarks
Mill inlet Pressure	mmwg	40-50	Nozzle Ring Velocity-40-50 m/s
Pressure Drop Across nozzle	mmwg	350-500	Reference Feed-400 TPH
Pressure Drop Across Separator	mmwg	90-100	Feed-300-400 TPH
Pressure drop across cyclone	mmwg	40-100	-
Duct Velocity	m/s	15-17	-
Suction box velocity at fan inlet	m/s	25-28	The difference between the duct & suction box velocity should not be greater than 8 m/s.
False air across VRM Circuit	%	12-15	Should be less than 15%

7.1.4 FAN EFFICIENCY

After optimizing the system resistance in the mill then check the fan efficiency which indicates the overall performance of the fan and factors which are responsible for the low efficiency of the fan are as follow:

1) A mismatch between design condition with operating condition (deviation should not be greater than 15%)
2) The problem in impeller cone gap
3) The physical condition of the impeller
4) Low efficiency by design
5) High internal recirculation

7.2 PYROSECTION

7.2.1 PRESSURE PROFILING ACROSS PREHEATER

Overall pressure drop across preheater mainly affects the fan static pressure at fan inlet and factors which are responsible for high system resistance in the preheater system are as follows:

1) Riser duct velocity
2) Type of cyclone whether its low-pressure type or high-pressure cyclone
3) Velocity in the downcomer duct
4) Excess false air across the system
5) Higher production against the design
6) Higher specific consumption resulting in higher specific air flow,
7) Pressure drop across WHR
8) False air across WHR

Table 17: Important norms for the preheater section

Parameters	Unit	Optimum Value	Remarks
Pressure drop across cyclone for each stage (LP Cyclone)	mmwg	50-60	-
Riser duct velocity	m/s	10-15	Design at minimum velocity
Downcomer duct Velocity	m/s	14-16	-
Pressure drop across downcomer duct	mmwg	30-40	-
Total pressure drop across 5 stage	mmwg	300-350	
Total pressure drop across 6 stage	mmwg	360-400	-
The gas temperature difference between in each cyclone	^0C	240-260	Important to check the heat transfer rate in each cyclone by measuring the gas temperature of each cyclone
False air across the preheater	%	6-8	-
Top cyclone efficiency	%	95-97	To improve heat transfer rate with material & gas
Pressure drop across APH boiler in case of WHRS	mmwg	80-100	-

7.2.2 PREHEATER & COOLER VENT FAN EFFICIENCY

Preheater & cooler vent fan efficiency plays an important role to decide the overall specific energy consumption of the fan and typical values of fan efficiency in the pyro section are as shown in the below table

Table 18: Important guidelines for pyro-section

Parameters	Unit	Optimum Value	Remarks
Preheater Fan Efficiency	%	>80%	Should be greater than 75%
Cooler vent fan (without WHRS)	%	>70%	At least 55 %
Cooler Vent Fan(WHRS)	%	>70%	Design it at WHRS condition
Preheater Specific Volume(Normal Coal)	Nm^3/kg Clinker	1.35-1.50	For normal & mix coal
Preheater Specific Volume(Pet coke)	Nm^3/kg Clinker	1.40-1.50	Pet coke
Null point inside the cooler-Normal Coal	Nm^3/kg clinker	0.75	Reduce the volume of cooler fans after the null point
Null point inside the cooler-Petcoke	Nm^3/kg clinker	0.75-0.80	Vent volume should not be greater than 1 Nm^3/kg Clinker

7.2.3 THERMAL LOSSES

Table 19: Thermal Losses Norms

Parameters	Unit	Optimum Value	Remarks
Cooler Efficiency	%	>70	At least should be greater than 65% to reduce overall cooler losses
Temperature drop across TAD	^{0}C	30-40	Optimize the radiation losses & false air in the TAD circuit to achieve the desired range
Total Radiation Loss in pyrosection	%	6-8% of total heat losses in the system	The standard value for Radiation loss-45 kcal/kg clinker
Phase density in normal coal	kg coal/kg air	4-6	Maintain the transport velocity for coal conveying inside the pipeline:>25 m/s
Phase density in pet coke	kg coal/kg air	4-6	Maintain the transport velocity for coal conveying inside the pipeline:-->25 m/s
Cooler losses(include clinker)	kcal/kg clinker	110-120	Optimum cooler vent temperature-250 ^{0}C
Preheater losses	kcal/kg clinker	110-125	-
Preheater outlet temperature	^{0}C	240-260	Improve it by optimizing the heat losses in the pyro section
Cooler vent temperature	^{0}C	230-260	-
Cooler grate loading	TPD/m^2	45-50	High cooler grate loading increases the heat losses & ultimately reduce the cooler efficiency

7.3 COAL MILL SECTION

7.3.1 HGI

The grinding ability of coal & pet coke is indicated by the Hard grove index (HGI) and the lower the value, the harder is the material to grind.

Table 20: HGI data of coal & Petcoke

HGI	kWh/MT		
	10%	15%	20%
30	11.8	10.6	9.9
40	11	9.8	9.3
50	10.3	9.4	8.9
60	9.8	9	8.6

HGI	kWh/MT	
	2%	5%
35	18	14
45	16.8	13

7.4 CEMENT MILL

Table 21: Important Norms for Cement Mill section

Parameters	Unit	Optimum Value	Remarks
Separator Fan Efficiency	%	>75	Should be greater than 75%
Air Velocity inside the mill(open circuit)	m/s	0.8-1.2	High velocity jams the diaphragm slots
Air Velocity inside the mill(closed circuit)	m/s	1.2-1.5	-
Velocity inside the rotor case	m/s	4-5	Operate the separator fan as per rotor case velocity
Pressure drop cyclone	mmwg	<90	-
Separator efficiency	%	75-80	-
Circulation factor	-	2-3	-
Cut size (d50)	micron	Depend upon rotor speed & fineness level	-
Sharpness(d25/d75)	-	0.5	-
Bypass	%	5-15	-
Separator load	kg/m^3	1.8-2.5	-
Product load(fines)	kg/m^3	0.75	-
Optimum loading inside the mill	%	25-26%	At this loading SEC consumption of mill is minimum
Grinding media Piece weight-1st Compartment	gm/piece	1500-1600	Applicable in double chamber mill
The average Surface area in 2nd Compartment	m^2/MT	40-44	Increase the surface area to increase the production rate
Grinding media Piece weight in Case of RP(Double Chamber)	gm/piece	1000-1200	Clinker feed size is smaller in the case of RP that automatically reduces the piece weight requirement in 1st chamber.

7.5 UTILITIES & PACKING

7.5.1 COMPRESSED AIR

Table 22: Important norms for compressed air usage in cement plant

Parameters	Unit	Optimum Value	Remarks
Bag filter air volume per spout	m^3/min per spout	<22,00	Includes auxiliary as well as main bag filter
Compressed air leakage	%	10-12	-
Compressed air pressure for conveying	kg/cm^2	2-3	Fly ash loading & unloading
Operating pressure in instrumentation	kg/cm^2	4.5-5.5	-
SEC in Screw compressor	kWh/CFM	0.16-0.17	-

7.5.2 AUXILLARY BAG FILTERS

Table 23: Important Norms for Bag filters

Parameters	Unit	Optimum Value	Remarks
Vent velocity at bag filter inlet(Non-Explosive dust)	m/s	9-12	Applicable:-Clinker dust, Raw meal, limestone, Cement
The velocity of clean air after bag filter	m/s	16-17	-
Vent velocity at bag filter inlet(explosive dust)	m/s	19-20	Applicable in case of coal meal
Pressure drop across bag filter	mmwg	80-130	-
Pressure below rotary airlock	mmwg	0-10	Indicator for false air infiltration
Compressed air pressure	kg/cm^2	4.5-5.0	-

7.6 CAPTIVE POWER PLANT

Table 24: Important norms for Captive power plant

Parameters	Unit	Optimum Value	Remarks
Auxiliary Power consumption-AFBC	%	5.5-6.0	Depends on the plant load and operation
Auxiliary Power consumption-CFBC	%	6.5-7.0	Depends on the plant load and operation
PLF	%	80-90	Indicator of the consistent power requirement of cement plant.
Conveying pressure from ESP hopper to bunker	bar	3-4	Minimum 3 bar
Excess air requirement- Indian coal	O_2 %	Minimum 2.5	-
Excess air requirement- Pet coke	O_2 %	Minimum 2.8	-
Heat rate (<30 MW)	kCal/kWh	2950-3100	-
BFP & CEP efficiency	%	70-80	Should be above 75%

8. ISLANDS OF EXCELLENCE

Sr.No.	Parameter	Unit	Indicator
CRUSHER			
1	Lowest crusher specific power consumption	kWh/MT limestone	0.58
RAW MILL			
2	Lowest raw mill specific power consumption- VRM	kWh/MT limestone	10.64
3	Lowest raw mill fan specific power consumption- VRM	kWh/MT limestone	3.86
4	Lowest raw mill main drive specific power consumption- VRM	kWh/MT limestone	4.44
5	Lowest raw mill specific power consumption- Roller Press	kWh/MT limestone	12.99
6	Lowest pressure drop across Nozzle-VRM(400 TPH)	mmwg	300
7	Lowest pressure drop across VRM	mmwg	464
8	Lowest pressure drop across Separator-VRM	mmwg	100
9	Lowest false air infiltration across VRM Circuit	%	12
10	Highest raw mill fan efficiency-VRM	%	90
11	Maximum separator loading-VRM	gm/m^3	720
COAL MILL			
12	Lowest coal mill specific power consumption- VRM (Coal)	kWh/MT coal	15.31
13	Lowest coal mill specific power consumption- VRM (Pet coke)	kWh/MT pet coke	36
14	Maximum output rate from normal to pet coke	%	65
15	Highest dust loading in pet coke grinding	gm/m^3	220
16	Minimum false air infiltration across the circuit	%	13

Sr.No.	Parameter	Unit	Indicator
PYRO SECTION			
17	Lowest electrical SEC-KILN(6-Stage)	kWh/MT clinker	15.45
18	Lowest electrical SEC up to clinkerization(6 stage)	kWh/MT clinker	42.59
19	Lowest thermal SEC-5 Stage	kcal/kg clinker	690
20	Lowest thermal SEC-6 Stage	kcal/kg clinker	676
21	Lowest preheater fan SEC(With WHRS)	kWh/MT clinker	6.6
22	Lowest cooler fans SEC(without WHRS)	kWh/MT clinker	3.10
23	Lowest cooler ID fan SEC	kWh/MT clinker	0.13
24	Minimum radiation loss from kiln & preheater	%	5
25	Minimum Preheater loss excluding dust	kcal/kg clinker	110
26	Minimum Preheater outlet temperature	^{0}C	230
27	Lowest preheater fan SEC(Without WHRS)	kWh/MT clinker	3.40
28	Fine coal conveying phase density in PC string	kg coal/kg air	5.9
29	Fine coal conveying phase density in kiln string	kg coal per kg air	5.0
30	Minimum temperature drop across TAD observed	^{0}C	30
31	Highest Preheater fan efficiency	%	90
32	Highest Cooler Recuperation Efficiency (with WHR/without WHR in operation)	%	65&70
33	Best cooler ESP Fan efficiency	%	78
34	Minimum Cooler Vent losses	kcal/kg clinker	120
35	Highest cooler loading	TPD/m^2	63
36	Highest kiln volumetric loading	TPD/m^3	7.80

Sr.No.	Parameter	Unit	Indicator
37	Lowest clinker temp at cooler exit	^0C	95
38	Minimum preheater fan flow	Nm^3/kg clinker	1.35
39	Minimum air infiltration across preheater	%	5.34
40	Highest preheater top cyclone efficiency	%	97
41	Minimum pressure drop across RABH	mmwg	80
WHR			
42	Maximum power generation per clinker production (6 stage)	kWh/ton clinker	38
43	WHR least pressure drop	mmwg	50
44	WHR least false air	%	6
CEMENT MILL			
45	Lowest cement mill specific power consumption- Ball Mill+RP-PPC	kWh/MT Cement	20.39
46	Lowest cement mill specific power consumption- Ball Mill+RP-OPC	kWh/MT Cement	28
47	Lowest cement mill specific power consumption- VRM-PPC	kWh/MT Cement	18.8
48	Lowest cement mill specific power consumption- VRM-OPC	kWh/MT Cement	24
49	Lowest cement mill specific power consumption- VRM-PPC	kWh/MT Cement	31.9
50	Highest cement mill fan efficiency(VRM)	%	81
51	Highest fly ash addition	%	35
52	Highest slag addition	%	70

Sr.No.	Parameter	Unit	Indicator
ELECTRICAL			
54	Lowest electrical distribution losses	%	3.2
55	Lowest capacitor power loss	w/KVAR	3
56	Optimum voltage for lighting	V	210
57	Best efficiency of motors in LT & HT	%	97.1
58	Lowest VFD loss and SPRS loss	%	3,4
59	Lowest harmonic distortion in cooler fans (V,I)	%	2,8
60	Highest capacity of renewable energy in onsite installation	MW	5.75
COMPRESSOR			
61	Lowest compressor air generation pressure	Bar	4.5
62	Lowest pressure drop in compressed air distribution system	Bar	0.1
63	Lowest pressure drop across dryer	Bar	0.1
64	Lowest SEC for blower @1 bar	kWh/MT coal	1.1
65	Lowest compressor air load Cement mill, CPP, and Pyro for 4200 TPD plant	CFM	2450
AFR			
66	Highest thermal substitution rate-7650 TPD	%	30
CPP			
67	Lowest heat rate in CPP < 30 MW	kcal/Mwh	3006
68	Lowest CPP auxiliary power consumption-AFBC	%	5.36
69	Lowest CPP auxiliary power consumption-CFBC	%	6.53
70	Lowest Conveying pressure from ESP hopper to bunker in CPP	bar	3

Sr.No.	Parameter	Unit	Indicator
71	Lowest excess air in CPP-Indian Coal	O_2%	2.5
72	Lowest excess air in CPP-Pet coke	O_2%	2.8
73	The lowest pressure drop between BFP and drum	bar	10
74	Lowest pressure drop in flue gas path(Boiler O/L –FD fan I/L)	mm WC	64
75	circulation rate for water cooled condenser	m^3/MW	239
76	Lowest auxiliary cooling water circulation	m^3/MW	10.5

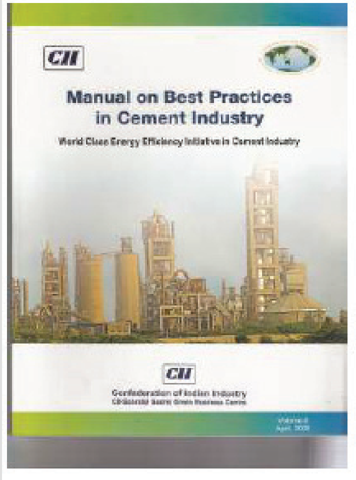
ABBREVIATION

AC-Alternating Current	FA- False Air	PPM- Parts Per Million
ACC-Air Cooled Condenser	FD- Forced Draft	RABH- Reverse Air Bag House
ACWP- Auxiliary Cooling Water Pump	GCT- Gas Conditioning Tower	RE- Renewable Energy
AFR- Alternate fuel & Raw Material	GI- Galvanized iron	RPM- Revolutions per Minute
BDP- Best Demonstrated Practice	GRR- Grid Rotor Resistance	SEC- Specific Energy Consumption
BEE- Bureau of Energy Efficiency	HAR-Hot Air Recirculation	SLC- Separate Line Calciner
BFP-Boiler Feedwater pump	HPRG- High-Pressure Roller Grinding	SPRS- Slip Power Recovery System
BH-Bag House	ILC-Inline Calciner	STP- Sewage Treatment Plant
CA-Circulating Air	LDR- Light Dependent Resistor	TAD- Tertiary Air Duct
CAGR- Compound Annual Growth Rate	LOI- Loss on Ignition	TG- Turbo Generator
CCR- Central Control Room	LRR- Liquid Rotor Resistance	TPH- Tonnes per Hour
CEP- Condensate Extraction pump	LSF- Lime Saturation Factor	TSR- Thermal Substitution Rate
CFC- Chlorofluorocarbon	MTPA- Million Tons per Annum	VRM- Vertical Roller Mill
CFD- Computational Fluid Dynamics	NCCBM- National Council for Cement and Building Materials	VFD-Variable frequency drive
CMA- Cement Manufacturers Association	NCV- Net Calorific Value	WHR-Waste Heat Recovery
CO- Carbon monoxide	OPC- Ordinary Portland cement	
COC- Cycle of concentration	PAT- Perform Achieve and Trade	
CWP- Cooling Water Pump	PPC- Portland Pozzolana Cement	
DP- Differential Pressure	PSC- Portland Slag Cement	
EOT- Electric Overhead Travelling	PH- Pre Heater	
ESP- Electrostatic Precipitator	PLC- Programmable Logic Controller	

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

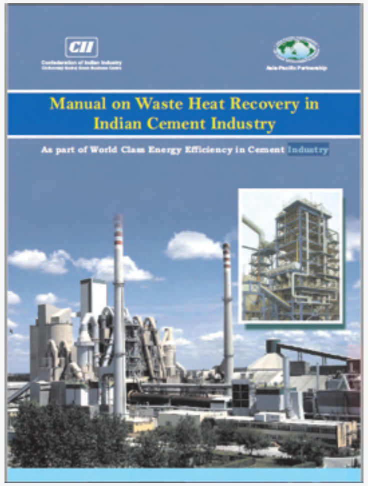
Manual on Best Practices in Cement Industry

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



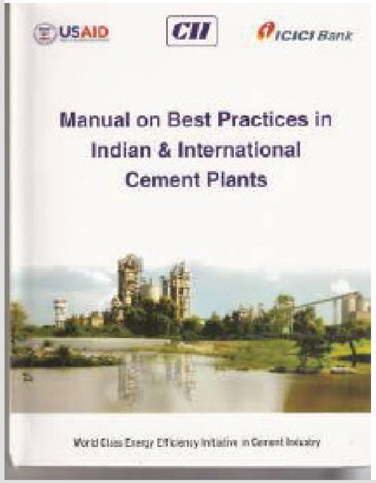
Manual on Waste Heat Recovery in Indian Cement Industry

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



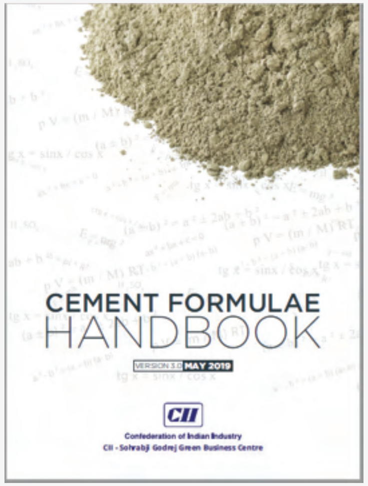
Manual on Best Practices in Indian & International Cement Plants

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.



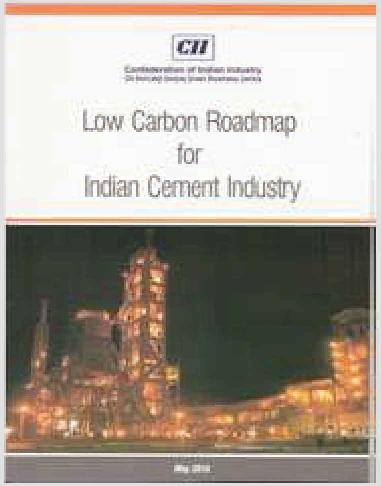
Cement Formulae Handbook

The formula book is a compilation of useful formulas, norms available at various sources, intended as a store of information that acts as a quick reference for the plant personnel. This was very well accepted by the Indian cement plants and the third edition was released during the annual conference in 2019.



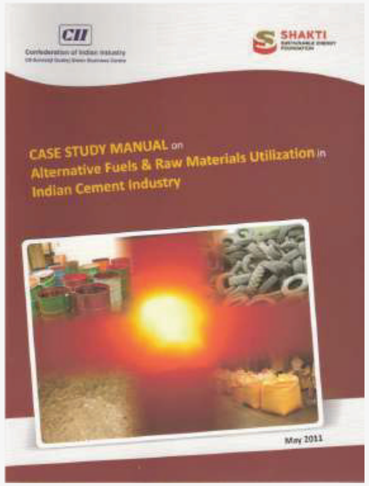
Low Carbon Roadmap for Indian Cement Industry

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 low carbon growth.



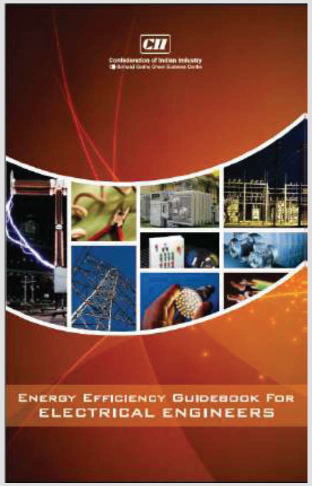
Case study Manual on Alternative Fuels & Raw Materials Utilization in Indian Cement Industry

The purpose of this manual is to act as a catalyst for promoting increased use of alternate fuel & raw materials in the Indian Cement Industry through co-processing of wastes and reducing the cost of clinker production, thereby improving the 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 equipment and provides the latest information on electrical systems such as motors and their control, transformers, lighting systems, etc. It also throws light on the possible energy-saving opportunities and newest trends in electrical and lighting systems.

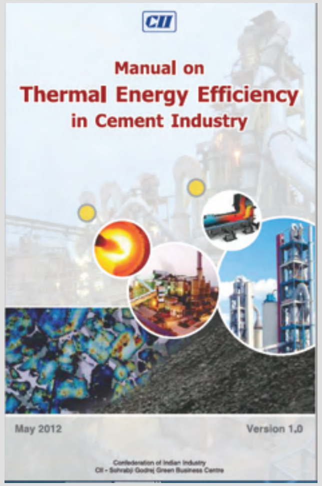


Low Carbon Technology Roadmap for the Indian Cement Industry

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 the Indian Cement Industry. The technology papers are developed by the Confederation of Indian Industry (CII) & NCCBM in partnership with International Energy Agency (IEA) and WBCSD's Cement Sustainability Initiative (CSI).

Manual on Thermal Energy Efficiency in Cement Industry

The Government of India in consultation with the 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. The 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 the latest norms and best practices to reduce thermal Specific Energy Consumption.



ABOUT CII — GODREJ GBC

CII-Sohrabji Godrej Green Business Centre (CII-Godrej GBC) was established in the year 2004, as CII's Developmental Institute on Green Practices & Businesses, aimed at offering world-class advisory services on the conservation of natural resources. The Green Business Centre in Hyderabad is housed in one of the greenest buildings in the world and through Indian Green Building Council (IGBC) is spearheading the Green Building movement in the country. The Green Business Centre was inaugurated by His Excellency Dr. A. P. J. Abdul Kalam, the then President of India on 14 July 2004.

The Services of Green Business Centre include- Energy Management, Green Buildings, Green Companies, Renewable Energy, GHG Inventorization, Green Product Certification, Waste Management, and Cleaner Production Process. CII-Godrej GBC works closely with the stakeholders in facilitating India to emerge as one of the global leaders in Green Business by the year 2022.

Conclusion

We feel that this Energy Benchmarking Version 5.0 for Cement Industry would have given you useful tips/ information and helpful for you in your day-to-day energy conservation activities. We invite your valuable feedback for any corrections /suggestions to be added for updating the details in the future version of this handbook.

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