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B20 India Secretariat
CII
Confederation of Indian Industry

ENERGY BENCHMARKING

for the Indian Cement Industry

May 2023

Version 6.0

B20 India Secretariat

Confederation of Indian Industry

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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 sourcebank 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.

Published by

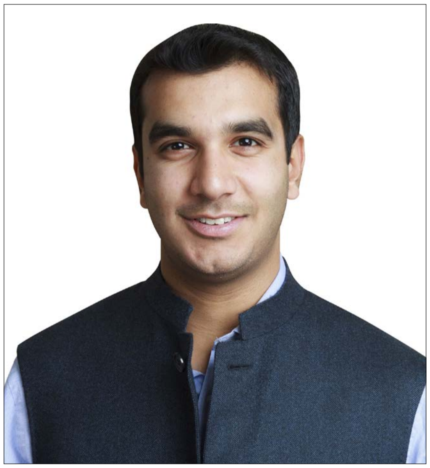
Confederation of Indian Industry

CII - Sohrabji Godrej Green Business Centre

Survey No 64, Kothaguda Post, Hyderabad 500 084

Foreword

Message from Chairman – Green Cementech 2023



It has become a climate imperative for businesses to address energy use, reduce greenhouse gas emissions and transition to more sustainable practices. One way to do this is by improving energy efficiency, which not only reduces emissions but also lowers costs and increases competitiveness. Energy benchmarking plays a critical role in this endeavour by providing a means to measure, track and compare energy usage across various sections and equipment in the industry.

CII Sohrabji Godrej Green Business Centre (CII-GBC), as part of its World Class Energy Efficiency initiative in the cement sector, has been publishing various manuals, case study booklets, etc. on a regular basis to disseminate information on the latest trends and technologies available to the industry.

It is my pleasure to introduce this publication on 'Energy Benchmarking for Cement Industry' (version 6.0). With updated energy consumption numbers and best practices, this publication will serve as an important resource for cement industries worldwide seeking to improve their energy efficiency and reduce their environmental impact.

The Indian cement industry is one of the best performers among its peers in the world. The top 10 Indian cement plants have electrical specific energy consumption less than 70 kWh/MT cement and thermal specific energy consumption less than 690 kCal/kg clinker. The best achieved energy consumption by an Indian cement plant is 56.1 kWh/MT cement and 675 kCal/kg clinker. Considering the commitments recently made by many Indian and international cement companies to achieve net-zero, we felt the time was opportune to release this latest version of the manual.

This publication will serve as valuable resource for the cement industry to establish baseline metrics and identify areas for improvement and will enable organizations to make informed decisions and implement targeted strategies to optimize their energy performance.

I would like to express my appreciation to all the cement plants who have shared their plant performance details and best practices, making this publication possible. Let us continue to work together for a sustainable future and make the cement sector net-zero.

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

Madhavkrishna

Madhavkrishna Singhania
Chairman, Green Cementech 2023 and
Deputy Managing Director & CEO, JK Cement Ltd.

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Acknowledgment

CII-Sohrabji Godrej Green Business Centre would like to express sincere and special gratitude to the entire Indian cement industry for their continuous support in this initiative by providing the required data for completing this study which makes this manual more useful to all 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 stakeholders in the cement industry. This publication is the sixth 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 Indian cement plants achieve world-class status. Over the last 8 years, since the development of the first version, there has been consistent improvement in many areas and parameters levels in Indian cement plants, resulting in improved energy efficiency. The intention behind updating the benchmarking manual is to ensure that the most latest 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 this 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. Majority of these plants have participated in this benchmarking study by sharing their data. The collected data was then extensively analysed section-wise. The report itself is structured around the different operations 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 nine years. The average cement power consumption has fallen from 88 kWh/MT of cement in 2014 to 73.75 kWh/MT of cement in 2023; average clinkersiation power has reduced from 65 kWh/MT of clinker to 51.5 kWh/MT of clinker. The top 10 Indian cement plants have electrical specific energy consumption less than 70 kWh/MT cement and thermal specific energy consumption less than 690 kCal/kg clinker. The important factors that have contributed to this fall in SEC include adoption of energy efficient technologies like Vertical Roller Mill (VRM), High Pressure Roller Grinding (HPRG), high efficiency separators, low pressure cyclones, energy efficient fans, reduction in clinker factor, increased installation of Waste Heat Recovery systems (from 240 MW to 840 MW), increase in thermal substitution rate (average increased from 2% to 7% 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 675 kCal/kg clinker and 56.14 kWh/MT cement, respectively. The average thermal and electrical energy consumption in the Indian cement sector is 726 kCal/kg clinker and 73.75 kWh/MT cement. 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 and the root cause for the differences.

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

Table 1: Benchmarking numbers

Sr. No.	Section	Unit	Specific Energy Consumption (SEC)
1	Crusher	kWh/MT Limestone	0.57
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	33.89
5	Coal Mill – VRM Coal Grinding	kWh/MT Coal	22.2
6	Six Stage Preheater - Kiln SEC	kWh/MT Clinker	15.45
7	Six Stage Preheater Upto Clinkersiation	kWh/MT Clinker	42.6
8	Thermal SEC (6 Stages)	kCal/kg Clinker	675
9	Five Stage Preheater- Kiln SEC	kWh/MT Clinker	16.3
10	Five Stage Preheater Upto Clinkersiation	kWh/MT Clinker	45.3
11	Thermal SEC (5 Stages)	kCal/kg Clinker	683
12	Cement Mill – VRM (PPC Grinding)	kWh/MT Cement	18.80
13	Cement Mill – VRM (OPC Grinding)	kWh/MT Cement	24.00
14	Cement Mill VRM (PSC Grinding)	kWh/MT Cement	31.90
15	Ball Mill (PPC Grinding)	kWh/MT Cement	27.00
16	Ball Mill + HPRG (PPC Grinding)	kWh/MT Cement	18.62
17	Packing Section	kWh/MT Cement	0.7
18	Overall SEC	kWh/MT Cement	56.10

Table 2: Best achieved values

S.No	Parameters	Unit	Benchmarking numbers
1	Single Stage SEC of Crusher	kWh/MT Limestone	0.57
2	Double Stage SEC of Crusher	kWh/MT Limestone	0.62
3	Preheater Outlet temperature (6 stage)	°C	230
4	Preheater losses (Excluding radiation and dust loss)	kCal/kg Clinker	110
5	Temperature Drop Across TAD	°C	20
6	Phase density in Pet Coke	kg Pet Coke/kg Air	5.9
7	Volumetric loading	TPD/m^3	7.8
8	Cooler Loading	TPD/m^2	52
9	Overall WHRS efficiency (Maximum)	%	21
10	Maximum AF Consumption (TSR)	%	30
11	Preheater Fan Specific Power with WHRS (Six Stage)	kWh/MT Clinker	6.24
12	Preheater Fan Specific Power without WHRS (Six Stage)	kWh/MT Clinker	3.4
13	Cooler Vent Fan Specific Power with WHRS	kWh/MT Clinker	0.4
14	Cooler Vent Fan Specific Power without WHRS	kWh/MT Clinker	0.2
15	Specific Power of cooler fans	kWh/MT Clinker	3.1
16	Reverse Air Bag House (RABH) Fan Specific Power	kWh/MT Clinker	1.22
17	Specific Power of Fan - Raw mill (VRM)	kWh/MT Raw Meal	3.8
18	Renewable Energy Installed Capacity (on site)	MW	23
19	Emission Intensity for PSC	kg CO_2/MT Cement	285
20	Emission Intensity for PPC	kg CO_2/MT Cement	493

Table 3: Overall Improvement Journey of Indian Cement Industry in last 9 years

S.No	Plant Section	Unit	Benchmarking 2014	Benchmarking 2023	Improvement (%)
1	Crusher (Single stage) SEC	kWh/MT Limestone	0.70	0.57	19
2	Raw Mill (VRM) SEC	kWh/MT Raw Meal	13.30	10.64	20
3	Coal mill (VRM) SEC -coal grinding	kWh/MT Coal	23.90	15.50	36
4	Thermal SEC - 5 stage PH	kCal/kg Clinker	707.00	683.00	4
5	Thermal SEC - 6 stage PH	kCal/kg Clinker	686.00	675.00	2
6	Cooler vent fan SEC (avg)	kWh/MT Clinker	0.50	0.25	50
7	RABH fan SEC	kWh/MT Clinker	1.65	1.22	26
8	SEC up to Clinkersiation-6 Stage	kWh/MT Clinker	46.00	42.60	8
9	Preheater Exit Gas Temperature	°C	245.00	230.00	7
10	Pressure drop across 6 stage preheater	mmwc	450.00	350.00	23
11	Cement mill VRM(PPC)	kWh/MT Cement	21.00	18.60	12
12	Compressor SEC up to Clinkersiation	kWh/MT Clinker	0.90	0.75	17
13	Compressor SEC - Cement grinding & packing	kWh/MT Cement	0.80	0.70	13
14	SEC up to Clinkersiation	kWh/MT Clinker	60.50	50.00	18
15	Overall SEC	kWh/MT Cement	88.00	73.75	17
16	AF Thermal Substitution Rate (TSR) Indian Cement sector average valve	%	3.00	7.00	133
17	Highest achieved AF TSR in a Cement plant	%	21.00	30.00	43
18	Total WHRS installation in India	MW	240.00	840.00	250

Chapter 01
Introduction

1.1 Indian Cement Industry- Growth prospectus

The Indian Cement industry is the second largest producer of cement in the world, with a production capacity of around 590[1] million tonnes per annum as of FY22 and accounts for 8% of the global installed capacity. In FY22, the country produced 360[1] million tonnes of cement. Cement consumption in India is around 260 kg per capita against a global average of 540[1] kg per capita, which shows significant potential for the growth of the industry. The consumption is expected to increase, driven by increased government spending on infrastructure development, housing for all, smart city initiatives and rural housing schemes. India's cement demand is expected to reach 550-600 Million Tonnes per annum by 2025[1].

Table 4: Cement production in last 4 Financial years[1]

Financial Year	Production of Cement in Million Tonnes
2019-20	334.37
2020-21	299.94
2021-22	360.19
2022-23 (up to December 2022)	283.61

The Indian government has been taking various initiatives to support the growth of the cement industry. The government has allocated INR 1.7 trillion for infrastructure development in FY22, which includes the development of highways, railways, airports and urban infrastructure. The National Infrastructure Pipeline (NIP) envisages an investment of INR 111 trillion in infrastructure projects over the next five years, providing a significant boost to the cement industry. The NIP will provide opportunities for the construction of highways, railways, ports, airports and urban infrastructure, thereby driving the demand for cement[2].

Cement is one of the most technologically advanced industries in the country. The modern Indian Cement plants are state-of-the-art plants and are comparable to the best in the world. The Indian Cement Industry has managed to keep pace with the global technological advancement. The induction of advanced technology has helped the industry immensely to improve its efficiency by conserving energy, fuel and addressing the environmental risks. The Indian Cement industry has always been focusing on energy efficiency and sustainability measures to reduce the fossil fuel consumption and carbon emissions. The Indian cement industry has taken several initiatives to improve energy efficiency through adoption of advanced technologies, Waste Heat Recovery systems, implementation of energy management system etc. Many cement plants in India have started using alternative fuels like biomass, hazardous and non-hazardous wastes and refuse-derived fuels to reduce their dependence on fossil fuels and lower their carbon footprint. The Indian cement industry comprises about 150 integrated large cement plants, about 116 grinding units, 5 Clinkersiation units and few mini cement plants[1].

The Indian cement industry is poised for significant growth in the coming years, driven by increased government spending on infrastructure and housing, the push for sustainable and energy-efficient technologies and the adoption of alternative fuels. With a strong focus on sustainability and innovation, the industry is well-positioned to maintain its position as a major global cement producer.

[1] https://dpiit.gov.in/sites/default/files/DPIIT_AnnualReportE_03March2023.pdf
[2] https://indiainvestmentgrid.gov.in/national-infrastructure-pipeline

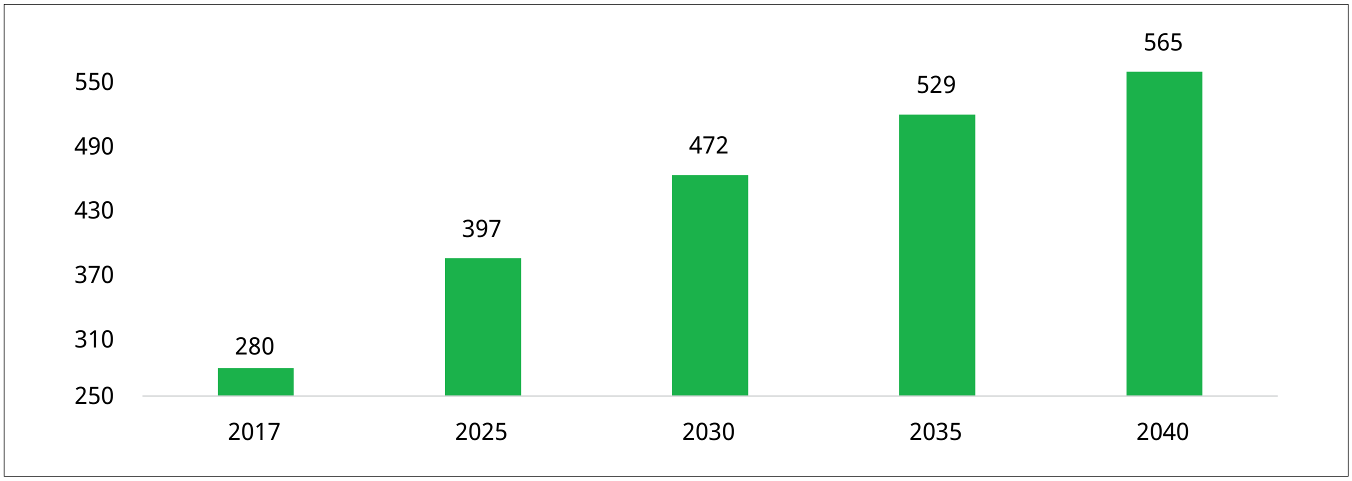


Figure 1: **Estimated projections: cement production (million tons)**

Cement production : CII Estimates

1.2 Major Players in Indian Cement Industry

As of April 2023, the Indian cement industry continues to be mostly domestically developed, with the presence of a few global groups. There are more than 60 cement companies operating in India (excluding mini cement plants). The top 10 Indian cement companies account for around 67% of total cement installed capacity in the country. UltraTech Cement Limited and Adani (ACC Limited & Ambuja Cements Limited) remain the two largest producers of cement in India, with a combined market share of over 30%. The other major players in the top 10 include Shree Cement Limited, Dalmia Cement (Bharat) Limited, Nuvoco Vistas Corp. Ltd., Birla Corporation Limited, Chettinad Cement Corporation Pvt. Ltd., The Ramco Cements Limited, JSW Cement and India Cements Limited

Major players and their carbon reduction initiatives :

- ACC aimed to contribute towards creating a carbon neutral society by 2050. 21.3% Reduction in Scope 1 GHG emissions per tonne of cementitious material by 2030 from a 2018 base year, 48.4% Reduction in Scope 2 GHG emissions per tonne of cementitious material by 2030 from a 2018 base year[10].
- Ambuja Cements Ltd. has committed to reduce Scope 1 and Scope 2 GHG emissions by 21% per ton of cementitious materials by 2030 from a 2020 base year. Ambuja Cements Limited develops Science Based Targets in line with its Net Zero emission ambition. With these targets, Ambuja Cement commits to reduce its CO_2 intensity in cement operations from 531 kg in 2020 to 453 kg net CO_2 per ton of cementitious material by 2030 (excluding emissions from Captive Power Plant)[3].
- Dalmia Cement has committed to becoming carbon negative by 2040 and committed to EP 100 and RE100 by 2030[4].
- JK Cement committed to Science Based Targets to reduce Greenhouse gas emissions from 553 kgCO_2/tonne cementitious in 2021-22 to 465 kgCO_2/tonne cementitious by 2030[5].
- JK Lakshmi Cement has committed to EP100 and RE100 by 2040[6].
- Shree Cement committed to reduce Scope 1 GHG emissions 12.7% per ton of cementitious materials by 2030, from a 2019 base year. SCL also committed to reduce Scope 2 GHG emissions 27.1% per ton of cementitious materials within the same time-frame[7].

[3] https://www.constructionworld.in/cement-news/ambuja-cements-plans-net-zero-emissions-target-through-sbti/30459
[4] https://www.unescap.org/sites/default/files/ESBN%20Slides%20Keynote%20Mr%20Singhi.pdf
[5] www.jkcement.com/frontTheme/pdf/JKCL-sustainability-report-21-22.pdf
[6] https://www.cemnet.com/News/story/174593/jk-lakshmi-cement-joins-re100-and-ep100-climate-initiatives.html
[10] https://www.acclimited.com/AnnualReport-2021-22/net-zero-pathway.html
[7] www.shreecement.com/uploads/cleanupload/16th-sustainability-report-shree-cement-2019-20.pdf

- UltraTech Cement has set a target to reduce its CO_2 emissions intensity by 25% by 2030, 100% of its electricity requirement through renewables sources by 2050 and carbon neutral concrete by 2050 [8,9].

1.3 Energy Efficiency in Indian Cement Industry

The Indian cement industry is a significant energy consumer and contributor to the country's economy. Therefore, improving energy efficiency in the cement industry is crucial for both environmental sustainability and economic reasons. There are several factors that affect the energy efficiency of the Indian cement industry, including technological availability, economic feasibility, government policies, associations and financing models.

India is a country with diverse geology and rich mineral deposits, including vast limestone belts with varying chemical and physical properties that impact the heat of formation and grindability of limestone. The location of cement plants in India is influenced by a range of factors, including the availability and quality of limestone deposits, logistics and energy efficiency.

India's cement industry is organized into clusters based on favourable conditions like availability of raw materials and logistics. The clusters have varying cement production capacities, energy efficiency numbers and alternative fuel usage, with some clusters being more efficient in some parameters than others. The industry's focus on energy efficiency and alternative fuels is expected to continue, leading to a more sustainable and profitable cement industry in India. Some major cement clusters are Ariyalur cluster, Chittorgarh-Udaipur cluster, Guntur-Nalgonda cluster, Gulbargah cluster, Kadapa-Kurnool cluster, Satna cluster, Raipur cluster etc.

Energy efficiency is a key focus area for the Indian cement industry and several Indian cement plants have taken significant steps in this regard. The Indian cement industry is known for its technology sharing and openness, which has allowed for the replication of best practices across organizations. Furthermore, new cement plants have been built with the latest energy-efficient technologies, resulting in high levels of energy efficiency performance. The adoption of new technologies and the upgrade of older facilities to the latest energy-efficient technologies have also contributed to improved energy efficiency.

Table 5: The performance of top 10 plants in Specific heat consumption

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**	675	676	682	682	683	683	685	686	688	689
2	**No of Stages**	**No**	6	6	6	6	6	5	6	6	6	6

Table 6: The performance of top 10 plants in Specific Electricity consumption up to Clinkerisation

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	**Total SEC up to Clinkersiation**	**kWh/MT Clinker**	42.59	43.18	43.81	43.96	45.40	45.60	45.78	46.81	47.51	47.60

8 www.ultratechcement.com/about-us/media/press-releases/ultratech-commits-to-net-zero-concrete-roadmap-announced-by-GCCA

9 www.ultratechcement.com/about-us/media/press-releases/ultratech-cement-joins-re-100-commits-to-100-renewable-energy-usage-by-2050

Table 7: The performance of top 10 plants in overall cement Specific Electricity consumption

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	**Overall Cement SEC**	**kWh/MT Cement**	56.14	60.82	61.40	61.65	61.90	64.56	65.85	66.52	67.96	72.85

With increase in fuel prices, the cost of energy is increasing, making it necessary for manufacturers to implement energy-efficient measures to reduce energy and production costs. Bureau of Energy Efficiency (BEE) under the Ministry of Power has mandated the reduction of specific energy consumption in the most energy-intensive industries, including the cement industry. This has incentivized manufacturers to achieve more than their specified specific energy consumption improvement targets.

The clinker factor is another significant factor affecting the energy efficiency of the cement industry. Clinker is the main component of cement and its production requires a considerable amount of energy. Therefore, reducing the clinker factor is critical in improving the energy efficiency, reducing emissions and cost. Industry have also been adopting alternative fuels to reduce dependence on fossil fuels and alternative raw materials to reduce the clinker factor. In addition, Waste Heat Recovery (WHR) is a crucial technology for improving the energy efficiency of the cement industry. WHR systems capture waste heat from kiln and cooler exhaust gases and convert it into electricity or useful heat, reducing the energy consumption of the plant.

Several new technologies are emerging for reducing the carbon emissions from the cement industry, such as carbon capture and storage, carbon dioxide mineralization and electric vehicles.

The decarbonization study conducted by CII-GBC for the Indian cement sector indicates that the sector can reduce the overall emission intensity by 30% by 2040 as compared to baseline of 2017. Energy efficiency Circularity and Material Efficiency measures like improving clinker factor, increasing additives in overall cement manufacturing will play a huge role in decarbonization efforts for Cement Sector.

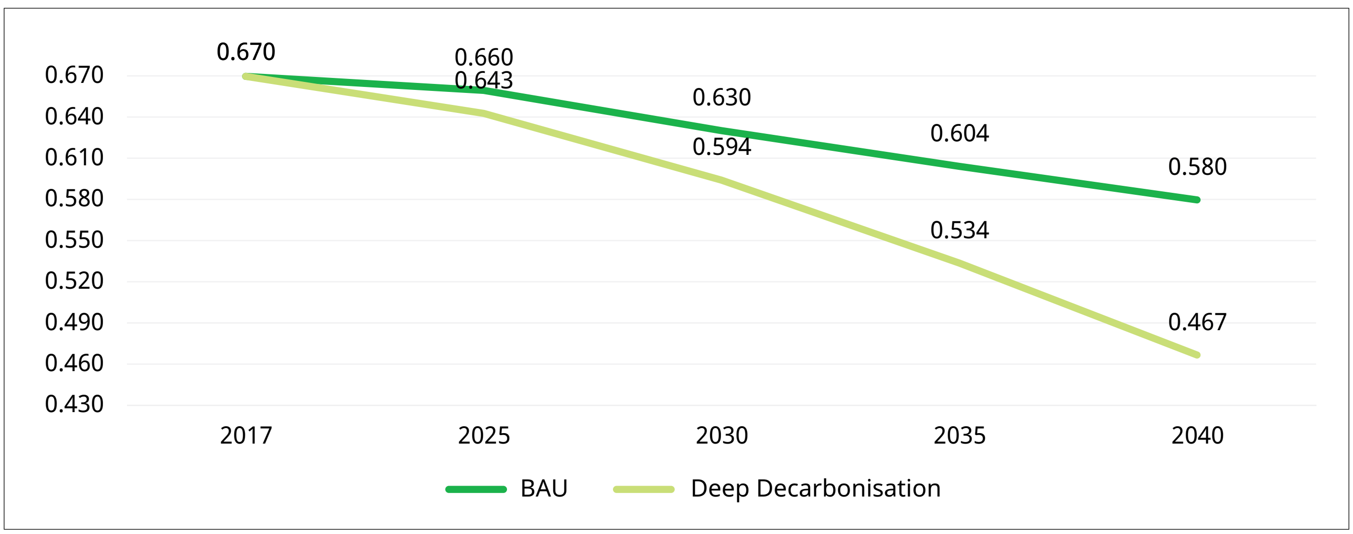


Figure 2: Estimated projections: emission intensity (MT CO_2/ MT Cement)

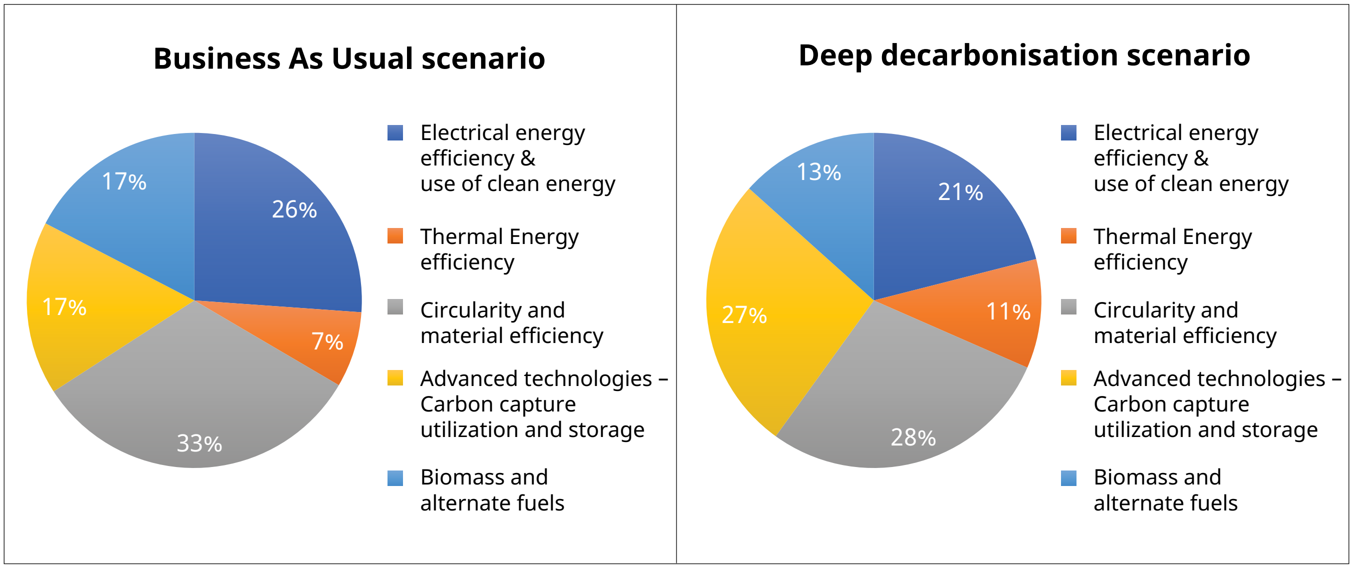
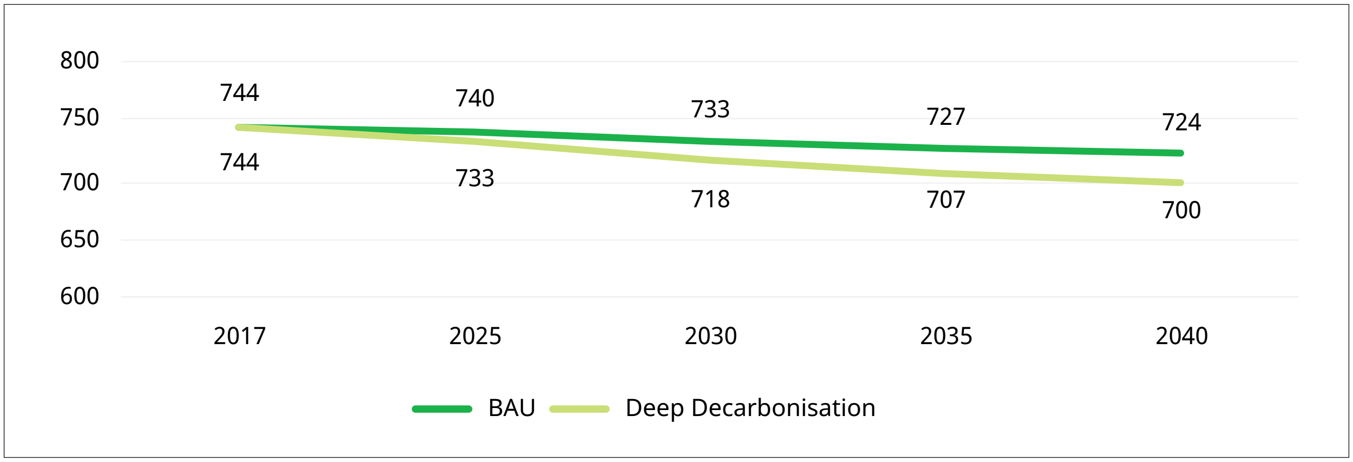


Figure 3: Business As Usual scenario and Deep decarbonisation scenario

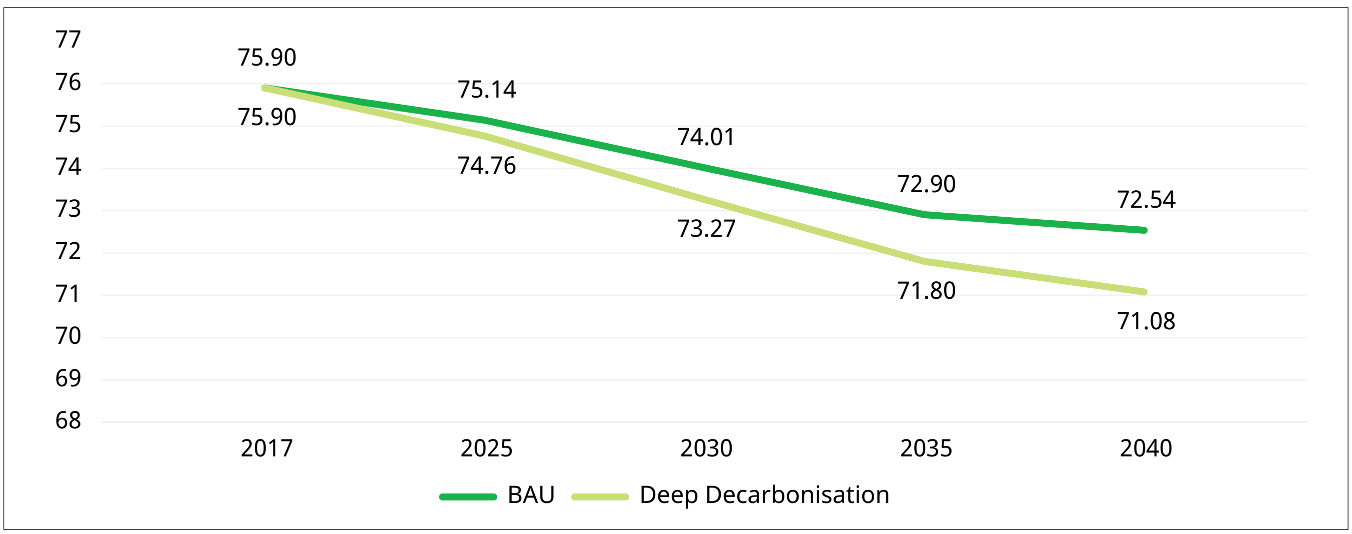
The decarbonization study findings are as below:

- Advanced technologies remain to play an important role in the overall cement sector decarbonization but would need a bigger push from various stakeholders for deeper penetration.
- Circularity and Material Efficiency Measures like clinker factor improvement, increasing additives in overall cement manufacturing will play a huge role in decarbonization efforts (33% in BAU and 28% in Deep Decarbonization Pathways).
- Electrification and use of Renewable Energy will contribute to around 26% in BAU and 21% in Deep Decarbonization pathways. This would include utilization more clean energy from Solar PV plants and Wind based plants for reducing and offsetting fossil based power generations. The sector has already progressed well in the Alternative Fuels department by increased utilization of MSW, RDF and other hazardous wastes and hence, biomass and Alternative Fuels will contribute to 17% in BAU and 13% in Deep Decarbonization Pathways.



Thermal SEC (kCal/kg Clinker)

Figure 4: Estimated projections of Thermal SEC



Electrical SEC (kWh/MT Cement)

Figure 5: Estimated projections of Electrical SEC

Chapter 02

Benchmarking In Cement Industry

2.1 Objective of Benchmarking

Benchmarking is an essential tool for any industry seeking to improve its energy efficiency and overall performance. In recent years, the Indian cement industry has emerged as a leader in energy efficiency, thanks to its openness and willingness to share knowledge across plants. To further enhance this knowledge sharing and promote greater energy efficiency, the CII - Godrej GBC has prepared a benchmarking study for the Indian cement industry.

The purpose of the benchmarking study is to provide a platform for cement industries in India to compare their performance with their peers and identify areas for improvement. Through this process, the Indian cement plants can improve their performance and add momentum to the energy efficiency drive in the Indian cement industry.

Benchmarking involves analysing and reporting key energy performance indicators to foster continual energy performance improvements in the industry through comparison with internal and external norms and standards. The benchmarking analysis provides two important perspectives: first, it provides an overview of how well a particular industry sector or sub-sector is doing in managing energy performance. Second, it enables participants in a benchmarking exercise to compare the performance of their plant(s) with the overall industry indicators.

The benefits of benchmarking in the cement industry are many. Firstly, benchmarking helps identify areas for improvement and provides a roadmap for achieving greater energy efficiency. Secondly, it helps to create a culture of continuous improvement, where companies strive to outperform their peers and stay ahead of the competition. Thirdly, benchmarking enables companies to learn from each other's best practices, thereby promoting knowledge sharing and innovation.

In an international context, benchmarking can be a powerful tool for promoting energy efficiency and sustainability in the global cement industry, benchmarking has becoming increasingly important, as countries seek to reduce their carbon footprint and meet their climate change commitments. By sharing knowledge and best practices across industries and borders, benchmarking can help to accelerate the adoption of energy-efficient technologies and practices. In the cement industry, benchmarking can help to reduce greenhouse gas emissions, improve productivity and sustainability in their operations.

Moreover, the cement industry is a significant contributor to global greenhouse gas emissions, accounting for about 7% of the world's carbon dioxide emissions. Therefore, benchmarking can play a critical role in helping the industry to reduce its carbon footprint and achieve sustainability goals. By comparing their performance with others in the industry, cement companies can identify areas for improvement, adopt best practices and reduce their energy consumption and emissions.

2.2 Approach and Methodology Adopted In Benchmarking

The benchmarking study conducted by CII-Sohrabji Godrej Green Business Centre in the Indian cement industry provides an indicator of energy efficiency and equipment efficiency for plants that produce various types of cement products.

The following specific indicators were compared in the benchmarking study: specific thermal energy, specific electrical energy in each section, clinker to cement factor, equipment efficiency, equipment productivity, equipment reliability, auxiliary power consumption in captive power plants and environmental performance (GHG emissions).

The approach adopted for the benchmarking study involved developing a questionnaire involving all sectional parameters starting from the crusher to the packing plant. The draft format was sent to national and international sector experts for their review and input and the same was incorporated into the format. The questionnaire was then sent to many cement factories for data collection. The majority of plants from all over India participated in this benchmarking study and different parameters were recorded in various sections from the data provided by plants.

The benchmarking study also analysed international scenario benchmarking and lever-wise top 10 cement plants in India. The study compared specific indicators such as electrical and thermal specific energy consumption, AF utilization, carbon emission intensity, clinker factor, WHR and renewable energy. The study analysed each section of the cement plant, such as the crusher section, raw mill section, coal mill section, pyro section, cement mill section, packing section and utility section and provided benchmarking numbers.

The study also covered new and emerging technologies in grinding, pyro section, compressor, fans, WHR, renewable energy, electrical motors, distribution systems, new types of cement and other areas like stacker and reclaimer, elevators, conveyors and magnetic separators. The study provided important thumb rules for raw mill and coal mill, pyro section, cement mill, bag filter optimization, compressed air, electrical equipment and captive power plants.

The study also identified islands of excellence and factors that affect SEC in a particular section and identified the best available technology to design new cement plants. The study also highlights the underlying potential in all the equipment, the gap present amongst the top 10 plants, optimizing equipment based on benchmarking numbers and the contribution of the latest technology. It provided an analysis of national and international best practices and identified the best available technology to design new cement plants. The study provided a detailed comparison of specific aspects of operations, identified areas for improvement and highlighted new and emerging technologies. The study is an important tool for the Indian cement industry to improve its performance and achieve greater energy efficiency and environmental sustainability.

Chapter 03

Energy Performance of International Cement Plants

3.1 Global Cement Production Scenario

The global cement production in 2021 was approximately 4270 million MT[1]. The largest contributor to global cement production was China (55%), followed by India at 8%. The other major producers are the European countries with 5.4%. Cement production is expected to continue growing in the coming years, driven by population growth, urbanization and increasing infrastructure investments in developing countries. However, the cement industry also faces significant challenges related to environmental sustainability, including greenhouse gas emissions, energy consumption and waste generation. The International Energy Agency (IEA) estimates that the global cement industry consumed about 7%[1] of the world's total industrial energy consumption.

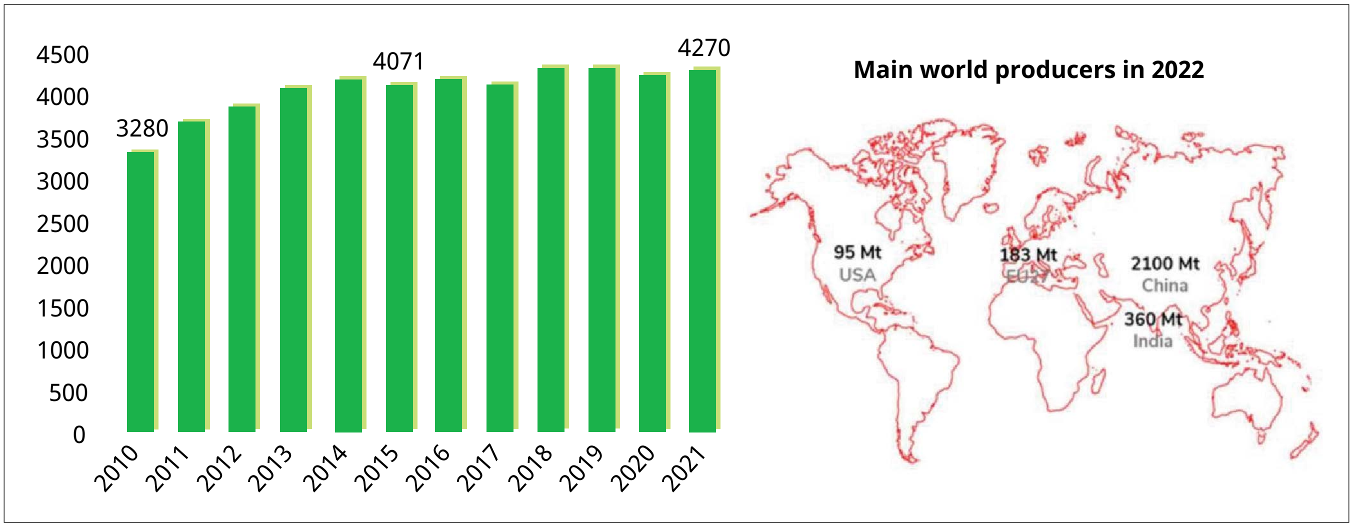


Figure 6: Global Cement production (Million MT) & main producer countries[2]

3.2 Energy Intensity Scenario :

Due to the manufacturing process & high energy intensity, the cement industry faces significant challenges related to environmental sustainability, including greenhouse gas emissions, energy consumption and waste generation. As a result, many companies in the cement industry are exploring innovative technologies and processes to reduce their environmental impact and improve sustainability.

The thermal energy and electricity intensities of cement production have gradually declined over the past decades through dry-process kilns – including staged preheaters and pre calciners (considered state-of-the-art technology), technological evolution in Grinding systems and other best class energy efficient technologies.

Based on the GCCA database, the global average electric energy demand for cement manufacturing was reported around 102 kWh/MT[3] Cement for the years 2014 to 2019. These figures are from 23% of plants worldwide and all technologies and clinker and cement types. The variations due to different technologies & product types are significant.

[1] https://www.iea.org/fuels-and-technologies/cement
[2] https://www.iea.org/fuels-and-technologies/cement, https://cembureau.eu/about-our-industry/key-facts-figures/
[3] THE ECRA TECHNOLOGY PAPERS 2022

The 10% best in class show figures of 83 kWh/MT Cement and below, while the 90% percentile amounted to 140 kWh/MT Cement.[4]

Based on these assumptions, the specific electric energy demand of cement production without carbon capture may decrease from 102 kWh/MT Cement in 2019 to a level of about 100 kWh/MT Cement in 2030 and to 90-95 kWh/MT Cement in 2050 on average. But this strongly depends on market developments and the required product fineness.[4]

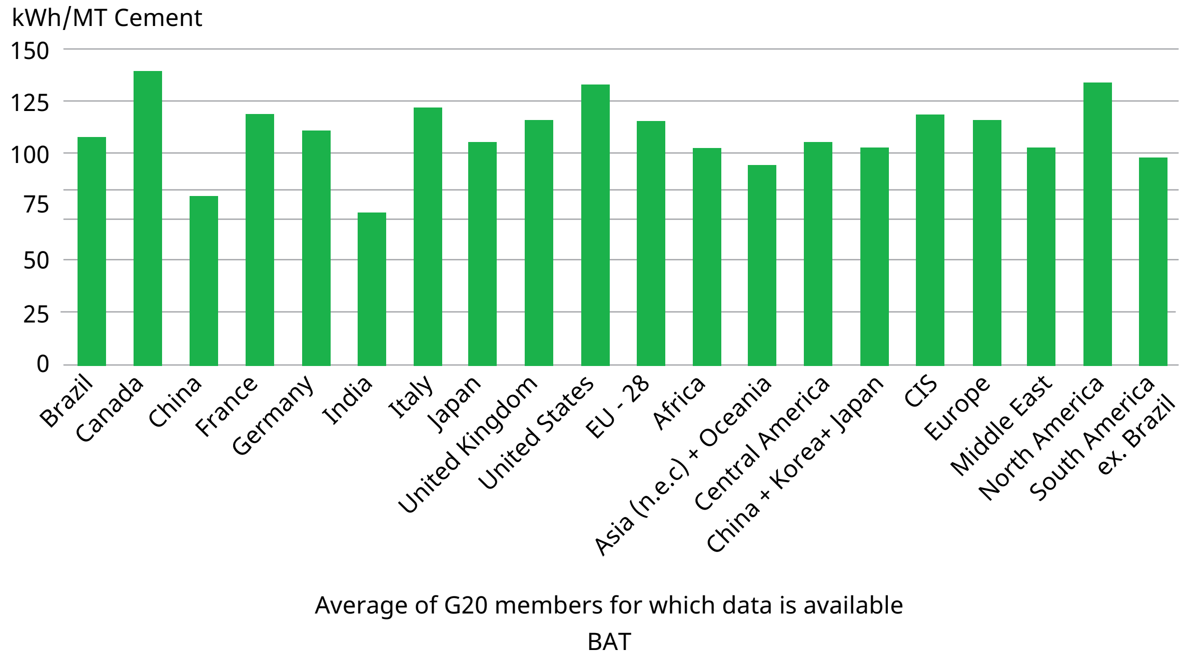


Figure 7: Electricity use per tonne of cement in selected countries and regions, 2018[5]

Based on the GCCA database from 2019, the global weighted average thermal energy consumption for cement clinker manufacturing was 3,460 MJ/MT (827 kCal/kg) Clinker. This is from 22% of the cement producing plants worldwide from all technologies. The variations due to different technologies are significant[4].

The 10% best in class show figures of 3,000 MJ/MT (714 kCal/kg) Cement and below, while the 90% percentile amounted to 4,000 MJ/MT (952 kCal/kg) Cement[4].

[4] THE ECRA TECHNOLOGY PAPERS 2022
[5] https://www.iea.org/data-and-statistics/charts/electricity-use-per-tonne-of-cement-in-selected-countries-and-regions-2018

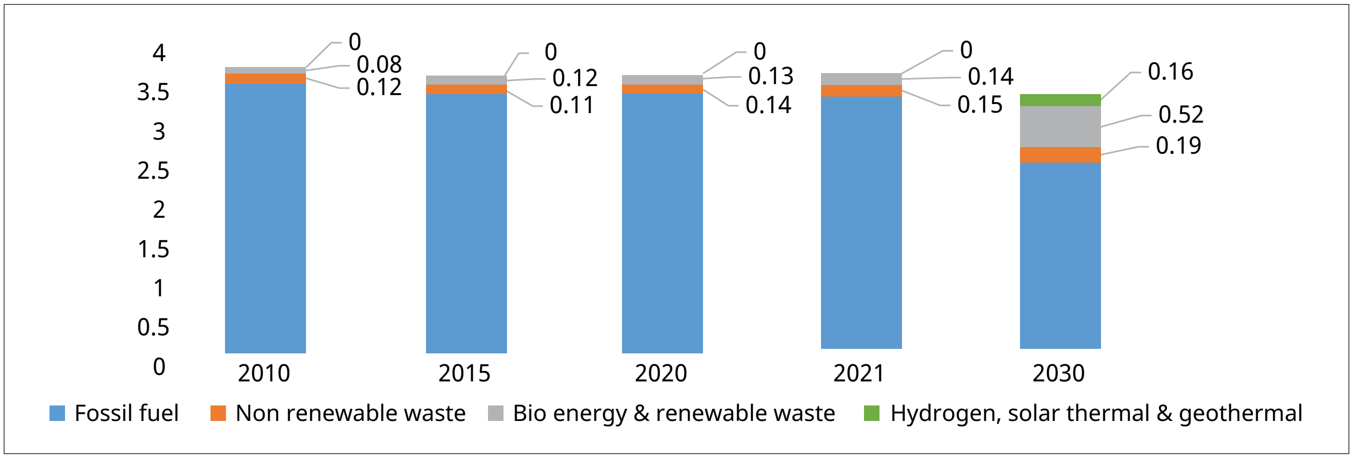


Figure 8: Thermal energy consumption (GJ/MT) & Energy sources[6]

A study carried out by VDZ, Germany, in the context of the European BAT process has determined the ranges for the average yearly fuel energy requirement of state-of-the-art cement kilns based on theoretical modelling and empirical data. These data take all criteria and impacts into account. The number of cyclone stages reflects the need for Specific thermal energy:

3 cyclone stages: 3,400 to 3,800 MJ/MT Clinker (812 to 908 kCal/kg Clinker)

4 cyclone stages: 3,200 to 3,600 MJ/MT Clinker (764 to 860 kCal/kg Clinker)

5 cyclone stages: 3,100 to 3,500 MJ/MT Clinker (740 to 836 kCal/kg Clinker)

6 cyclone stages: 3,000 to 3,400 MJ/MT Clinker (717 to 812 kCal/kg Clinker)

Based on these assumptions, the specific fuel energy demand of clinker burning (as a global weighted yearly average) may decrease from 3,460 MJ/MT (827 kCal/kg) Clinker in 2019 to a level of 3,300 (788 kCal/kg) to 3,400 (812 kCal/kg) MJ/MT Clinker in 2030.

[6] https://www.iea.org/reports/cement

3.3 Benchmarking of SEC & SHC among countries:

Table 8: Benchmarking of SEC & SHC among countries

Sl. No.	Section	Unit	Country 1	Country 2	Country 3	Country 4	Country 5	Country 6	Country 7	Country 8	Country 9
	Overall SEC	**kWh/MT Cement**	104.2	103.4	98.9	98.6	95.3	89.5	84.8	68.3	66.4
1	**Crusher**	**kWh/MT Limestone**	1.7	2.1	1.8	2.2	1.4	1.7	1.6	-	1.1
2	**Raw mill**	**kWh/MT Raw meal**	19.0	28.3	16.0	26.2	15.6	14.9	15.5	13.0	13.5
4	**Kiln**	**kWh/MT Clinker**	21.1	25.8	19.3	24.6	37.8	32.1	28.4	24.2	19.6
5	**Coal mill**	**kWh/MT Coal**	32.5	29.8	20.2	28.2	31.2	43.9	60.0	30.4	39.8
6	**Auxiliaries**	**kWh/MT Clinker**	7.9	4.6	7.4	5.6	5.6	6.4	4.6	3.0	2.1
	Total SEC up to Clinkersiation	**kWh/MT Clinker**	84.3	92.0	76.3	78.6	73.8	73.7	68.6	52.0	47.9
7	**Cement mill**	**kWh/MT Cement**	45.2	39.0	45.5	43.6	43.6	37.9	36.8	29.9	27.0
8	**SHC**	**kCal/kg**	805	884	780	880	855	840	885	775	730
9	**TSR**	**%**	-	-	-	21.0	25.0	38.0	38.0	-	7.0
Kiln			5 stage Double string 4525 TPD	4 stage, Double string ILC 3600 TPD	5 stage Single string 2470 TPD	4 stage single stringILC 3800 TPD	5 stage double string ILC 5500 TPD	4 stage Double string SLC 4400 TPD	4 stage, Double string ILC 3192 TPD	4 stage double string 5026 TPD	6 stage ILC
Coal mill			VRM	VRM	VRM	VRM	VRM	VRM	VRM	VRM	VRM
Raw mill			VRM	ball mill	VRM	Ball mill	VRM	VRM	VRM	VRM	VRM
Cement mill			Ballmill +HPRG	Ballmill +HPRG	Ball mill	Ball mill	Ball mill	4 ball mill & 1 roller press	Ball mill	Ball mill	Ball mill/ VRM/HPRG
Cooler			Grate	Planetary	Grate	Grate	Grate	Grate	Planetory	3rd generation cooler high efficiency static grate	3rd generation cooler high efficiency static grate

These numbers are from few plants / typical numbers for other countries through CII interaction and do not represent country as a whole. Technology wise cement plants across all countries adopt and implement latest technologies. Other country plants do not focus as hard on SEC reduction because power is more affordable and readily available. They operate nearly at the design level or little higher, compared to continuous increase in productivity seen in Indian plants. Indian plants can learn / adopt the following best practices from other country plants like higher Thermal Substitution Rate (TSR), lower fugitive emission, higher limestone addition in final cement as filler etc. another difference is the Blaine / fineness at which the product is made and application specific concrete products.

Chapter 04

Specific Energy Consumption of Top 10 Cement Plants in India

4.1 ELECTRICAL SPECIFIC ENERGY CONSUMPTION (SEC)

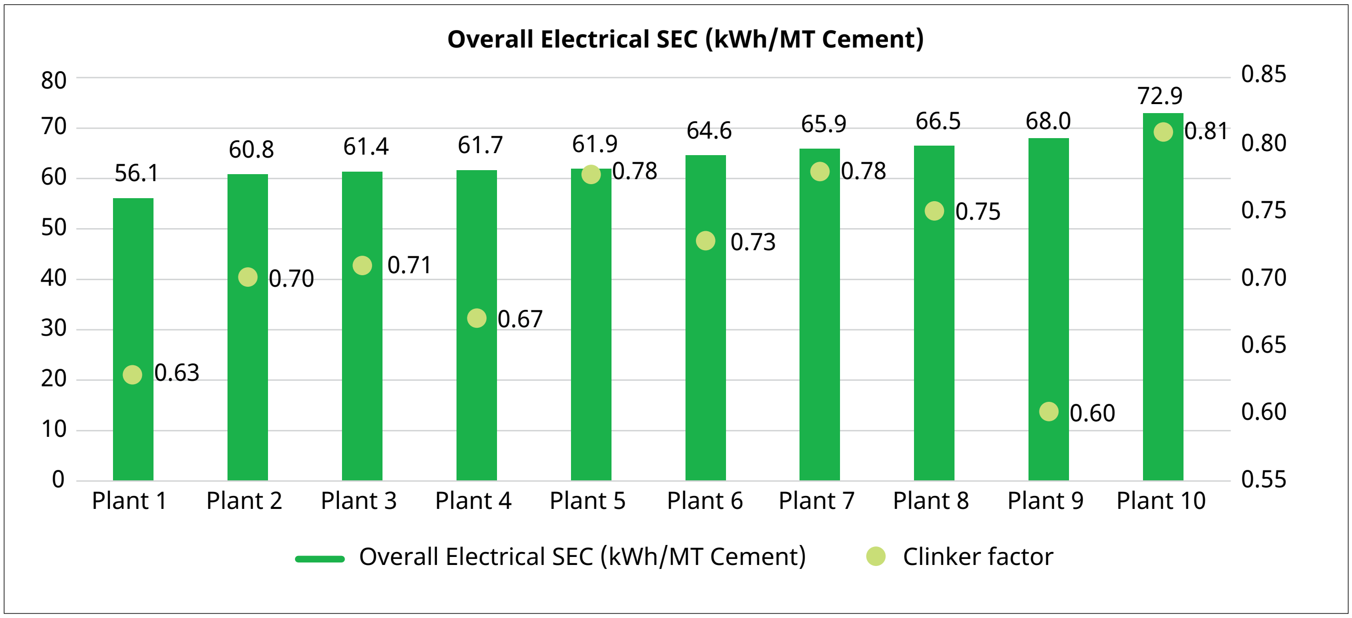


Figure 9: Overall Electrical SEC-Top 10 cement plants

Table 9: Overall Electrical SEC-Top 10 cement 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
	Overall SEC	kWh/MT Cement	56.1	60.8	61.4	61.7	61.9	64.6	65.9	66.5	68.0	72.9
1	Crusher	kWh/MT Limestone	1.8	1.4	0.7	1.5	0.9	0.7	0.7	1.1	0.8	1.6
2	Raw mill	kWh/MT Raw meal	15.8	12.8	12.4	13.0	11.7	12.2	14.1	12.6	11.2	14.0
3	Kiln	kWh/MT Clinker	19.1	15.5	20.1	15.5	22.3	18.4	20.1	21.0	23.1	19.0
4	Coal mill	kWh/MT Coal	29.9	33.9	38.3	33.5	46.5	27.6	39.6	54.1	55.5	40.2
5	Auxiliaries	kWh/MT Clinker	1.3	1.4	-	3.9	-	-	2.4	2.3	-	-
	Total SEC up to Clinkersiation	kWh/MT Clinker	49.9	43.8	43.2	45.6	51.5	44.0	48.9	45.4	49.5	45.8
6	Cement mill	kWh/MT Cement(OPC)	-	24.7	28.6	24.5	-	-	29.9	-	27.4	28.0
		KWh/MT Cement(PPC)	20.4	20.2	22.6	20.5	23.1	-	22.3	28.0	24.4	-
		kWh/MT Cement(PSC)	-	29.8	35.5	-	-	-	-	-	-	-
		KWh/MT Cement (others)	28.5	-	29.4	29.5	-	25.1	39.3	-	29.6	-
		Overall Clinker Factor	0.63	0.70	0.71	0.70	0.67	0.78	0.73	0.75	0.60	0.81
7	Packing plant	kWh/MT Cement	1.3	0.9	0.8	1.5	1.1	0.7	1.0	1.5	1.3	1.5
8	Utilities & others	kWh/MT Cement	0.7	2.0	0.7	4.7	2.3	3.2	2.7	1.7	3.0	1.4

4.1.1 SPECIFIC ELECTRICAL ENERGY CONSUMPTION-Clinkersiation

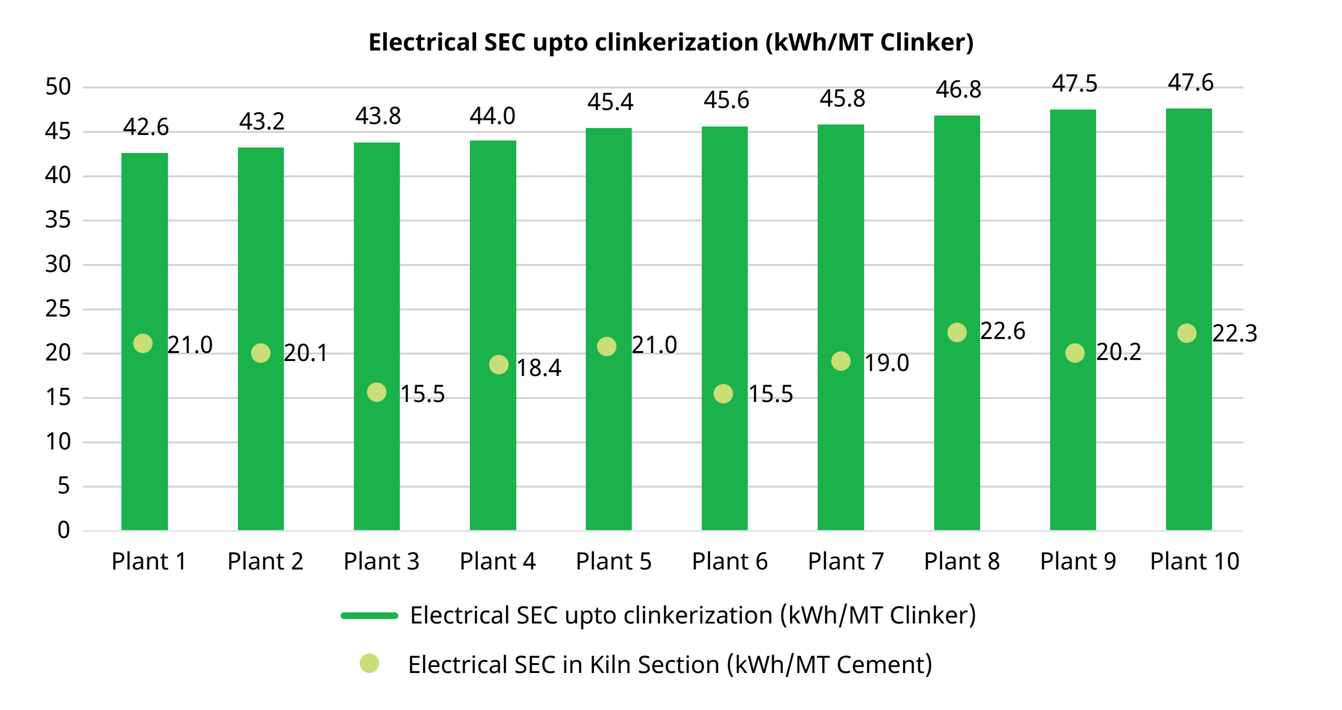


Figure 10: SEC upto Clinkersiation of top Cement plants in India

Table 10: Electrical SEC upto Clinkersiation-Top 10 cement plants

Sr. No.	Section	kWh/MT Clinker	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
	SEC upto Clinkersiation	kWh/MT Clinker	42.6	43.2	43.8	44.0	45.4	45.6	45.8	46.8	47.5	47.6
1	Crusher	kWh/MT Clinker	1.2	0.9	1.4	1.1	1.1	2.1	2.3	0.8	1.1	0.9
2	Raw mill	kWh/MT Clinker	15.8	18.9	12.8	19.1	12.6	19.7	21.0	12.4	14.6	11.3
3	Kiln	kWh/MT Clinker	21.0	20.1	15.5	18.4	21.0	15.5	19.0	22.6	20.2	22.3
4	Coal mill	kWh/MT Clinker	4.6	3.2	3.4	2.4	4.1	4.4	3.4	4.0	3.4	4.6
5	Auxillaries	kWh/MT Clinker	-	1.0	1.4	3.5	2.2	3.9	-	1.0	1.6	2.1
6	Electrical SEC upto Clinkersiation	kWh/MT Clinker	42.6	43.2	43.8	44.0	45.4	45.6	45.8	46.8	47.5	47.6

4.2 THERMAL SPECIFIC ENERGY CONSUMPTION

Table 11: Specific heat consumption-Top 10 cement 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	675	676	682	682	683	683	685	686	688	689
2	No of Stages	No	6	6	6	6	6	5	6	6	6	6

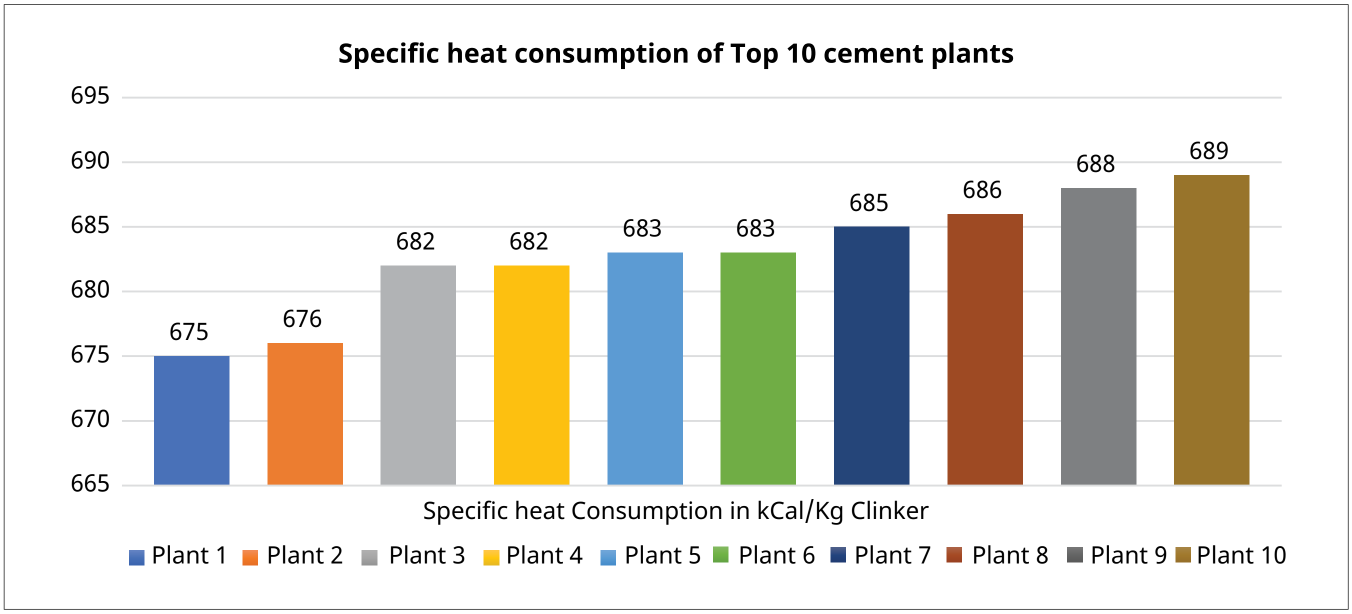


Figure 11: Thermal SEC of top cement plants in India

4.2.1 SPECIFIC HEAT CONSUMPTION BREAKUP FOR PLANT 1 (675 kCal/kg Clinker)

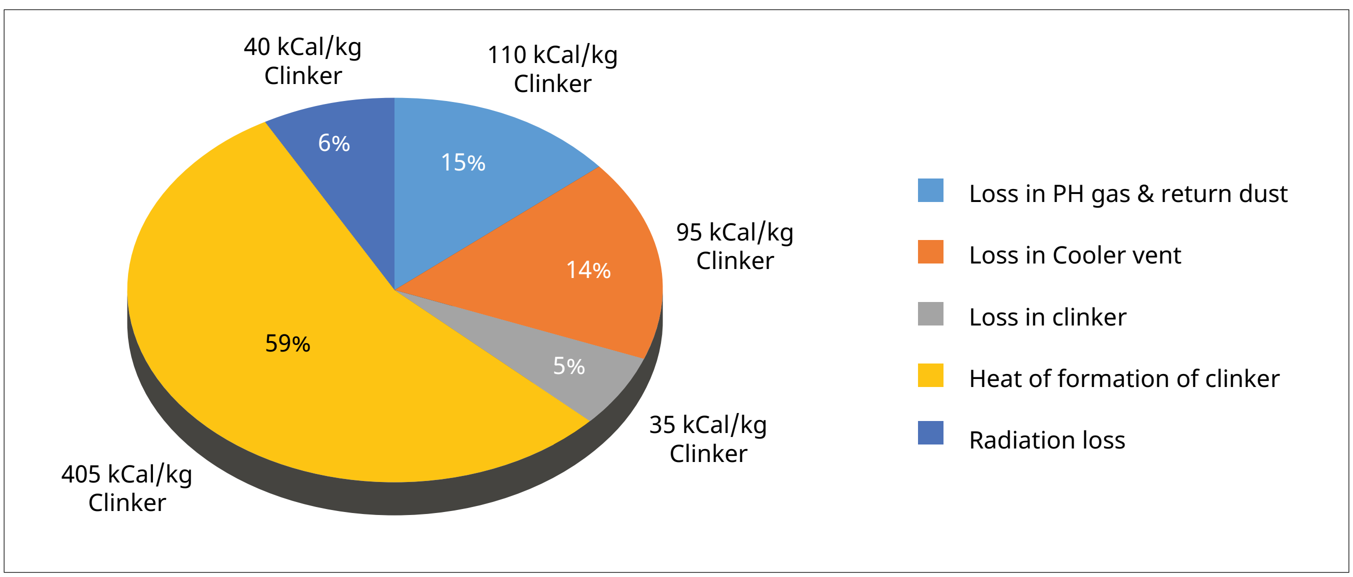


Figure 12: Specific heat consumption Breakup for plant 1

4.3 ALTERNATIVE FUEL UTILIZATION

Table 12: Alternative Fuel Utilization of Top 10 cement plants

Sr. No.	Type of alternative fuels (AF)	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
	Overall thermal substitution%	30.0	21.0	19.6	19.0	16.6	15.4	15.3	15.1	15.1	14.0
1	MSW (RDF)	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
2	Paint sludge	-	-	-	-	✓	-	-	-	✓	-
3	Rice husk	✓	-	-	-	-	✓	-	-	✓	-
4	Carbon black	✓	✓	✓	✓	✓	-	✓	-	✓	-
5	Plastic	-	✓	✓	✓	✓	✓	-	-	-	✓
6	Solid waste	✓	-	✓	✓	✓	-	-	✓	-	-
7	Dolachar	✓	-	-	-	-	-	-	✓	-	-
8	Liquid Waste	-	-	✓	✓	-	✓	✓	✓	-	✓
9	Others (Biomass, waste, & Organic)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

4.4 CARBON EMISSION INTENSITY

Table 13: Carbon Emission Intensity of Top plants with 100% PSC

Sr. No.	Plant reference	Carbon Emission Intensity of Top plants with 100% PSC (kg CO_2/MT cement)
1	PLANT 1	285
2	PLANT 2	361
3	PLANT 3	379

Table 14: Carbon Emission Intensity of Top plants with 100% PPC

Sr. No.	Plant reference	Carbon Emission Intensity of Top plants with 100% PPC (kg CO_2/MT cement)
1	PLANT 1	493
2	PLANT 2	502
3	PLANT 3	506
4	PLANT 4	517
5	PLANT 5	577
6	PLANT 6	578

Table 15: Carbon Emission Intensity of Top plants with varied product mix

Sr. No.	Plant reference	Carbon Emission Intensity of Top plants	
		(kg CO_2/MT cement)	Product Mix
1	PLANT 1	369	79% PSC and 21% PPC
2	PLANT 2	409	82% PSC, 17% PPC and 1% OPC
3	PLANT 3	421	82% PSC, 17% PPC and 1% OPC
4	PLANT 4	494	83% PSC and 17% OPC
5	PLANT 5	496	55% PSC, 42% PPC and 3% OPC
6	PLANT 6	517	90% PPC 10% OPC
7	PLANT 7	544	32% OPC 30% PPC 38% CC
8	PLANT 8	550	30% OPC 60% PPC 10% PSC

Chapter 05

Section Wise Benchmarking Numbers

5.1 CRUSHER SECTION

Table 16: Benchmarking of 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	0.57	0.63	0.74	0.75	0.80	0.83	0.86	0.90	0.92	0.96
1	Crusher type (Gyratory/ Jaw/Impact / Roller etc)		Impact	Impact	Roll Crusher	Impact	Impact	Impact	Impact	Impact	Impact	Hammer
2	No. of stages (Eg. Single/ Two)		1	1	2	1	1	1	1	1	1	1
3	Material hardness (For Eg. Hard/Soft/ Medium)		-	Medium	Medium	Soft	Medium	Hard	Soft	Hard	Medium	Medium
4	Product size (% oversize on 75 mm)	%	0.8	8	5	5	5	10	5	5	10	12
5	Design output	TPH	500	900	1000	1200	700	950	850	1200	1000	600
6	Operating output	TPH	463	905	750	1150	738	890	750	1400	890	341
7	Material moisture	%	6.5	1	13.5	-	5	0.5	5.0	2.0	0.1	3.0
8	**Electrical SEC**											
a	Crusher Main Drive	kWh/MT Limestone	0.20	0.34	-	0.40	0.50	0.47	0.46	0.60	0.43	0.60
b	Other auxiliaries	kWh/MT Limestone	0.37	0.29	-	0.35	0.30	0.36	0.40	0.30	0.49	0.36

5.2 RAW MILL SECTION

5.2.1 RAW MILL SECTION-VRM CIRCUIT

Table 17: Benchmarking of 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	12.10	12.14	12.51	12.90	13.70	14.11	14.40
1	Make		Pfeiffer	FLS	Loesche	Loesche	Loesche	FLS	Loesche	Loesche	Pfeiffer	Polbeck/ TKII
2	Type / Model		MPS5000 B	ATOX 32.5	LM 46.4	LM 30.31	LM 36.41	Atox 52.5	LM 34.4	LM 34.4	MPS 5000 B	Vertical roller mill
3	Material Hardness (Bond index)	kWh/ short ton	8	10	9	-	-	-	14	-	8.5	-
4	Material hardness		Soft	Medium	Soft	Medium	Soft	Medium	Hard	Hard	Soft	Hard
5	Design output	TPH	500	180	320	190	250	540	225	225	400	285
6	Operating output	TPH	506	245	312	210	260	462	330	330	410	325
7	Feed input size	%	21% above 60 mm	12% on +53 micron	75 mm	75 mm	50 mm	8-10% in 80 mm	95	80 on 60 mm	90% <70 mm	100 mm
8	Product size (% residue on 90 mic)	%	15.0	17.0	19.3	2.0	14.1	12.1	2.0	2.0	16.0	1.5
9	Feed Material moisture	%	2.0	5.0	1.0	12.0	6.2	1.2	6	6	13.5	6, 10 max
10	Pressure drop across Nozzle	mmwc	-	-	-	-	450	410	-	-	530	-
11	Mill DP	mmwc	494	464	-	960	550	540	835	850	565	750
12	Pressure drop across Separator	mmwc	-	-	-	-	180	150	-	-	120	-
13	Cyclone pressure drop	mmwc	110	100	110	75	140	100	120	110	122	150
14	No. of cyclones	Nos.	2	2	4	2	8	4	4	4	4	2
15	Mill fan operating flow	m^3/hr	7,45,226	2,94,000	5,90,000	3,27,823	4,50,000	8,45,000	4,62,000	4,63,000	7,65,673	6,40,000
16	Mill fan speed control type (GRR/SPRS/VFD)		VFD	GRR	VFD	SPRS	SPRS	SPRS	VFD	VFD	VFD	LRS
17	Mill fan inlet damper open position	%	-	100	-	Nil	-	100	-	-	-	100
18	Mill fan operating efficiency	%	69	90	83	82	81	82	79	81	81	82
19	Mill Fan inlet pressure (before & after damper)	mmwc	-721	-960	-920	-1350	-	-888 & -893	-1145	-1165	-1,040	-940

Table 17: Continued

Table 17: Benchmarking of 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
20	False air in the circuit	%	23	17	15	16	15	17	16	18	10	17
21	Separator loading	gm/m^3	679	683	-	641	649	610	700	650	535	520
22	Rotor Case velocity	m/s	-	4	-	-	3	5	-	-	4	-
23	Separator type		-	RAR 35	LSKS 73	LSKS 52 / Dynamic	LKS 67	RAR-LVT 55	LNVT	LNVT	SLS 4250 B, LAMELLA WHEEL	Dynamic separator/ RMR-400
24	Nozzle ring velocity	m/s	40	51	49	50	54	55	46	47	42	45
25	Dam ring height	mm	-	120	90	80	95	200	70	70	70	50
26	Table Diameter	mm	-	3,250	4,600	-	3,600	5,250	3,400	3,400	5,000	-
27	**Electrical SEC**											
a	Mill drive	kWh/MT Raw meal	5.1	4.6	4.4	4.5	5.7	6.9	4.4	4.3	5.9	5.9
b	Mill fan	kWh/MT Raw meal	3.9	5.0	5.0	5.9	5.1	4.4	4.6	5.0	6.1	6.5
c	Auxiliary	kWh/MT Raw meal	1.6	1.2	1.8	4.5	1.3	1.3	3.9	4.4	2.1	1.9
d	Overall SEC	kWh/MT Raw meal	10.6	10.8	11.2	12.1	12.1	12.5	12.9	13.7	14.1	14.4

5.2.2 RAW MILL SECTION-ROLLER PRESS CIRCUIT

Table 18: Benchmarking of Raw Mill Section-Roller Press Circuit

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4
	Overall SEC	kWh/MT Material	12.99	14.50	15.50	17.00
1	Roller Press Make		FLS HRP 3.0	Polysius	KHD	KHD
2	Bond index	kWh/ ton	12.10	8.00	13.00	13.00
3	Design output	TPH	250	256	275	300
4	Operating output	TPH	310	255	260	302
5	Feed input size	mm	50	-	3% on 63 mm	1.4% on 40 mm
6	Product size (% residue on 90 mic)	%	19.00	16.00	17.00	3.8
7	Feed Material moisture	%	1.25	-	-	1.25
8	Separator type/ model		RARL 40	-	-	SKS
9	Separator loading	g/m³	654	722	556	700
10	Pressure drop across separator	mmwc	-	-	630(V sep)	385
11	Cyclone pressure drop	mmwc	50	258	164	120
12	No. of cyclones	Nos.	4	2	2	4
13	Separator fan operating flow	m³/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	-	-	100
16	Separator fan operating efficiency	%	75	66	76	83
17	Separator Fan inlet pressure	mmwc	-400	-	-834	-805
18	False air in the circuit	%	17	14	12	10
19	**Electrical SEC**					
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

5.3 COAL MILL SECTION

5.3.1 COAL MILL SECTION–MIX COAL (VRM)

Table 19: Benchmarking of Coal Mill Section–Mix Coal (VRM)

Sr. No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
	Overall SEC	kWh/MT Coal	22.2	26.1	33.9	33.9	34.7	39.5	39.6	43.9
1	Make		LOESCHE	Citic	FLS	Polbeck/ TKII	LOESCHE	FLS	Pfeiffer	Cemteck
2	Type / Model		-	GYLM1700	Atox 27.50	-	LM 28.2	Atox 27.5	MPS 2800 BK	TRMC31.3
3	Coal type/variety to be grinded (Pet Coke / Indian coal / Imported coal)		Indian Coal	Indian Coal	Pet Coke: 51.98%, Imported coal: 45.98%, Indian coal: 2.05%	Indian coal, Imported coal	Imported coal/ Pet Coke	Indonesian coal	Pet Coke (60%)/ Imported coal (40%)	Pet Coke / Imported coal
4	Design output (normal coal)	TPH	47	25	65	25	40	60	40	45
5	Operating output (Pet Coke)	TPH	-	-	30	-	39/24	-	25	33
6	Operating output (normal Coal)	TPH	52	26.4	65	28	-	32	24	40
7	Product size (% residue on 90 mics)-Pet Coke	%	5	12.5	3	15	16.5/2.5	-	2	5-7
8	Feed Material moisture	%	10	12	7	10	9	14	5	~10
9	Mill DP	mmwc	410	350	380	520	350	420	425	520
10	Pressure drop across the nozzle ring	mmwc	-	-	-	85	-	280	-	-
11	Separator type/ model		Dynamic	Dynamic	RAKM-30	-	LSKS 43	RAKM – 27.5	SLS 2450 BK	SC-3000
12	Circumferential Velocity inside rotor case	m/s	-	-	26	-	-	-	-	-
13	Static Vanes gap of Separator	mm	-	-	30	-	-	66	-	-
14	Pressure drop across bag filter/ cyclone+BH	mmwc	100	120	80	-	150	95	100	95

Table 19: Continued

Table 19: Benchmarking of Coal Mill Section–Mix Coal (VRM)

Sr. No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
15	Mill fan operating flow	m^3/hr	1,55,000	73,700	2,16,160	82,500	1,25,000	1,17,000	1,23,000	1,55,000
16	Mill fan speed control type (GRR/ SPRS/VFD)		VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD
17	Mill fan inlet damper open position	%	100	-	100	-	100	100	-	-
18	Mill fan operating efficiency	%	76	76	80	72	85	69	73	65
19	Mill Fan inlet pressure	mmwc	-655	-650	-560	-802	-680	-	-616	-950
20	False air in the circuit	%	16	33	11	18	15	15	20	14
21	Nozzle ring velocity	m/s	52	48	44	58	55	63	38	58
22	Dam ring height	mm	-	10	150	25	110	155	120	70
23	Table Diameter	mm	-	-	2,750	-	-	2,750	2,800	3,100
24	**Electrical SEC**									
a	Mill drive	kWh/MT Coal	11.1	12.4	15.9	15.3	19.7	18.2	19.7	12.1
b	Mill vent fan / Bag filter fan	kWh/MT Coal	7.2	7.1	12.3	13.1	15.3	12.2	9.5	18.4
c	Booster fan	kWh/MT Coal	1.1	1.3	2.0	-	4.1	-	-	-
d	Separator/classifier	kWh/MT Coal	-	0.1	-	-	1.4	-	-	-
e	Auxiliary	kWh/MT Coal	2.8	5.3	3.8	5.5	7.9	9.1	10.5	7.4
f	Overall SEC	kWh/MT Coal	22.2	26.1	33.9	33.9	34.7	39.5	39.6	43.9

5.3.2 COAL MILL-PETCOKE GRINDING (VRM)

Table 20: Benchmarking of Coal Mill-Petcoke Grinding (VRM)

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9
	Overall SEC	kWh/MT Pet Coke	33.9	36.2	38.3	39.8	40.9	44.8	46.0	48.5	50.8
1	Make		FLS	Polysius	FLS	Loseche	Pfeiffer	FLS	Loseche	FLS	Pfeiffer
2	Type / Model		Atox 27.50	-	Atox 25	LM 26.3D	MPS 3550 BK	Atox 27.5	LM 28.2	Atox 32.50	MBPS 3550
3	Coal type		Pet Coke								
4	Design output (normal coal)	TPH	65	38	50	45	90	65	22	78	80
5	Operating output (Pet Coke)	TPH	30	18	26	16	58	30	22	35	60
6	Product size (% residue on 90 mics)-Pet Coke	%	2.5	3	3.5	4.0	1.5	2.0	2	2.5	1.5
7	Feed Material moisture	%	7	6	5	6	5	5	5	5	9
8	Coal mill type Circuit (Inert/ Non-Inert)		Inert	-	Inert	Inert	Non-Inert	Inert	Inert	-	-
9	Mill DP	mmwc	160	420	-	355	550	570	200	430	400
10	Separator type/ model		RAKM-30	-	RAKM-LVT-27.5	LSKS (Dynamic)	-	RAKM-30	LKS 47ZD / Dynamic	-	-
11	Circumferential Velocity inside rotor case	m/s	-	18	26	-	27	27	-	26.5	-
12	Static Vanes gap of Separator	mm	-	-	40	-	-	30	-	30	-
13	Pressure drop across bag filter/ cyclone+BH	mmwc	80	110	130	220	164	110	300	126	-
14	Mill fan operating flow	m^3/hr	2,16,160	1,11,371	1,13,000	1,45,000	3,19,387	1,77,000	1,40,000	1,66,352	2,75,000
15	Mill fan speed control type (GRR/SPRS/VFD)		VFD	VFD	SPRS	VFD	VFD	GRR	VFD	VFD	VFD
16	Mill fan inlet damper open position	%	100	-	100	-	-	100	-	-	-
17	Mill fan operating efficiency	%	79	75	70	81	76	66	78	56	80

Table 20: Continued

Table 20: Benchmarking of Coal Mill-Petcoke Grinding (VRM)

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9
18	Mill Fan inlet pressure	mmwc	-550	-580	-495	-795	-834	-820	-500	-	-
19	False air in the circuit	%	9	13	19	40	13	18	15	20	17
20	Nozzle ring velocity	m/s	43	51	55	42	42	52	45	-	45
21	Dam ring height	mm	150	56	160	105	110	140	150	-	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	15.9	18.9	17.2	16.9	20.4	16.5	15.7	17.0	19.9
b	Mill vent fan / Bag filter fan	kWh/MT Pet Coke	12.3	12.3	10.7	16.7	16.1	16.3	15.5	15.0	19.2
c	Auxiliary	kWh/MT Pet Coke	5.7	5.0	8.4	6.0	4.5	12.0	15.0	16.5	11.5
d	Overall SEC	kWh/MT Pet Coke	33.9	36.2	38.3	39.8	40.9	44.8	46.2	48.5	50.8

5.4 PYROSECTION

5.4.1 PYROSECTION-WITHOUT WHRS CIRCUIT

Table 21: Benchmarking of Pyrosection-Without WHRS Circuit

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
1	Kiln section SEC	kWh/MT Clinker	15.5	18.5	20.1	20.2	20.8	22.6	23.1	24.0
2	Thermal SHC	kCal/kg Clinker	675	710	722	682	690	713	790	760
3	Electrical SEC upto Clinkersiation	kWh/MT Clinker	43.8	51.0	48.9	43.2	48.8	46.8	49.5	50.8
4	Kiln output rated	TPD	6,600	10,000	4,500	5,500	4,200	5,500	3,800	4,400
5	Kiln output operating	TPD	6,792	9,000	6,000	7,200	4,622	6,700	4,500	4,300
PREHEATER SECTION										
1	PH type (ILC/SLC)		ILC	ILC	ILC	ILC	ILC	ILC	ILC	ILC
2	No of PH strings	Nos.	2	4	1	2	1	2	1	1
3	No of stages	Nos.	6	6	5	6	6	6	5	5
4	PH / Calciner exit O_2 & CO	%	1.6	2.0	Calciner-1% PH Exit -2.5%	Calciner exit O_2-1% PH exit O_2 3.3%	2.2-2.8	3.5	1.5	3.8
5	PH exit/top cyclone outlet temp	°C	260	257	300	275	272	270/275	315	368
6	PH exit/top cyclone outlet pressure	mmwc	-360	-468	-630	-565	-545	-580/-650	-610	-565
7	PH top cyclone efficiency	%	96	95	94	95	95	93	92	90
8	PH fan inlet flow	Nm^3/kg Clinker	1.5	1.4	1.6	1.4	1.4	0.74/0.75	1.7	1.4
9	PH fan speed control type	GRR/ SPRS/VFD	VFD	VFD	VFD	SPRS	VFD	GRR/SPRS	VFD	SPRS
10	PH fan inlet damper open position	%	100	-	-	100	100	100	-	100
11	PH fan operating efficiency	%	82	75	77	85	85	68/74	79	61
12	PH Fan inlet pressure	mmwc	-375	-480	-667	-596	-545	-650/-700	-685	-985
13	False air across PH	%	8	9	5	-	7	8	6	8
KILN SECTION										
14	Kiln inlet pressure	mmwc	-21	-30	-45	-	-35	-50	-45	-25

Table 21: Continued

Table 21: Benchmarking of Pyrosection-Without WHRS Circuit

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
15	Kiln Bag house flow	Nm^3/kg Clinker	1.7	1.8	2.6	1.8	1.6	1.5	2.4	1.8
16	Kiln Bag house speed control type	GRR/ SPRS/VFD	VFD	VFD	VFD	SPRS	VFD	GRR	VFD	VFD
17	Kiln Bag house damper open position	%	100	-	-	100	100	100	-	100
18	Kiln Bag house fan operating efficiency	%	77	75	66	67	67	50/56	62	65
19	Kiln Bag house Fan inlet pressure	mmwc	-170	-154	-160	-195	-	ESP Fan: -50	-160	-178
20	Kiln Bag house Pressure drop	mmwc	110	110	120	105	100	125	90	90
21	Kiln size	Dia(m) × length(m)	5 × 78	5.80 × 85	4.35 × 67	4.75 × 74	4.15 × 64	4.75 × 74	3.95 × 63	4.57 × 67.07
22	Kiln Volumetric loading	TPD/ m^3	5.6	4.5	7.3	6.5	6.8	6.2	7.5	4.8
23	Kiln Thermal loading	MkCal / hr /m^2	4.6	4.7	5.9	4.8	5.1	4.8	3.4	3.3
24	Kiln percentage filling	%	12	14	15	15	15	-	16	13
COOLER SECTION										
1	Cooling air flow	Nm^3/kg Clinker	1.7	1.8	1.6	1.5	1.6	1.75	2.0	1.7
2	Cooler vent flow	Nm^3/kg Clinker	0.9	1.1	1.1	0.7	0.7	-	1.2	0.9
3	Pressure Drop Across Cooler ESP	mmwc	50	40	40	50	15	-	40	10
4	Cooler ESP Fan efficiency	%	69	40	55	70-75	52	-	50	72
5	Clinker temp at cooler exit	°C	200	-	168	150	185	180	80	175
6	Cooler Grate Loading	TPD/m^2	47	-	51	50	46	-	38	41
7	TAD temperature	°C	920	945	931	950	1,025	900	990	871
8	Temperature Drop Across TAD	°C	30	75	80	25	20	-	60	80
9	Cooler water spray	m^3/hr	10	-	7	20	8.5	19.5	-	4.8
10	Coal Phase density – PC firing	kg Coal / kg Air	3.0	3.0	3.0	4.5	1.6	-	2.8	3.9

Table 21: Continued

Table 21: Benchmarking of Pyrosection-Without WHRS Circuit

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
11	Coal Phase density – Kiln firing	kg Coal / kg Air	2.7	1.6	2.0	4.8	2.7	-	1.7	3.2
12	Kiln Thermal SEC	kCal/kg Clinker	675	705	722	682	690	713	790	760
13	Loss in PH gas	kCal/kg Clinker	140	121	161	142	132	140	178	172
14	Loss in Cooler vent	kCal/kg Clinker	95	94	96	87	78	62	132	93
15	Loss in clinker	kCal/kg Clinker	25	33	31	33	38	22	18	37
16	Loss in cooler water spray	kCal/kg Clinker	0	29	20	20	21	33	0	19
17	Heat of formation	kCal/kg Clinker	405	410	412	412	399	416	412	406
18	Radiation loss	kCal/kg Clinker	40	54	48	38	50	40	50	52
19	Type of burner		Duoflex	Pyrojet	Pyro-Jet BURNER	KHD Pyrojet low NO_x burner	Duoflex	-	-	PyroJet -BS-1
20	Burner Capacity	MW	119	-	89	98	73	-	58	61
21	**ELECTRICAL SEC**									
A	KS fan/PH Fan	kWh/MT Clinker	3.4	5.1	6.4	-	5.2	8.3	8.8	8.8
B	Calciner fan/PH Fan	kWh/MT Clinker	-	-	-	6.9	-	-	-	-
C	RABH/ESP fan	kWh/MT Clinker	1.2	1.6	2.5	3.0	1.7	-	2.8	2.1
D	Cooler fans	kWh/MT Clinker	3.6	5.2	5.5	4.0	3.9	9.1	3.7	6.2
E	Cooler vent fan	kWh/MT Clinker	0.9	0.3	-	0.3	-	0.4	1.1	-
F	Kiln drive	kWh/MT Clinker	1.6	2.1	1.6	1.3	1.7	-	1.3	1.7
G	Kiln feed	kWh/MT Clinker	0.6	-	1.95		-	-	-	-
H	Auxiliary	kWh/MT Clinker	4.1	4.5	2.1	4.7	5.5	1.4	5.1	5.2
I	SEC of Kiln section	kWh/MT Clinker	15.5	18.5	20.1	20.2	20.8	22.6	23.1	24.0
J	Total SEC Upto Clinkersiation	kWh/MT Clinker	43.8	51.0	48.9	43.2	48.8	46.8	49.5	50.8

5.4.2 PYROSECTION–WITH WHRS

Table 22: Benchmarking of Pyrosection–With WHRS

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
1	KILN SEC	kWh/ MT clinker	19.9	20.0	20.2	20.9	21.0	21.0	21.3	22.0	22.3	22.6
2	Thermal SEC	kCal/kg Clinker	765	696	696	726	702	736	711	729	766	720
3	Overall SEC	kWh/ MT clinker	47.9	44.1	45.5	45.7	42.6	43.4	50.1	48.7	45.6	51.6
4	Kiln output rated	TPD	10,000	5,000	6,500	3,400	2,750	2,400	5,000	6,000	3,800	5,500
5	Kiln output operating	TPD	12,000	5,175	5,779	3,995	3,150	3,001	5,665	7,600	4,644	8,000
						PREHEATER SECTION						
1	PH type	(ILC/SLC)	ILC	SLC	ILC	ILC	ILC	ILC	ILC	ILC	Low NO_x ILC	SLC
2	No of PH strings	Nos.	4	2	1	1	1	1	2	2	1	2
3	No of stages	Nos.	6	6	6	5	6	5	5	6	5	5
4	PH / Calciner exit O_2 & CO	%	3.0	3.0	3.2	3.0	2.0	2.7	2.0	3.0	2.3	2.6
5	PH exit/top cyclone outlet temp	°C	293	310-315	270	337	300	305	295	289-275	330	325-320
6	PH exit/top cyclone outlet pressure	mmwc	-632	-605	-605	-525	-565	-666	-540	-605, -550	-610	-630, -880
7	PH top cyclone efficiency	%	95	93	93	95	96	95	94	95	92	91
8	PH fan inlet flow	Nm^3/kg Clinker	1.59	1.42	1.35	1.35	1.38	1.54	1.51	1.45	1.65	1.64
9	PH fan speed control type	GRR/SPRS/ VFD	VFD	SPRS	VFD	GRR	VFD	VFD	VFD	VFD	VFD	SPRS
10	PH fan inlet damper open position	%	-	-	No damper	-	100	100	-	-	-	100
11	PH fan operating efficiency	%	79 & 83	80	81	80	91	80	78	71 & 65	79	76
12	PH Fan inlet pressure	mmwc	-731	-820	-685	-670	-685	-805	-700	-688, -747	-680	-700, -720
13	False air across PH	%	9.7	6.1	7.3	6.1	6.0	8.2	12.4	8.1	5.8	9.2
						KILN SECTION						
14	Kiln inlet pressure	mmwc	-30	-80	-23	-32	-25	-47	-	-	-45	-50
15	Kiln Bag house /ESP	Nm^3/kg Clinker	-	2.2	2.1	1.8	2.0	2.1	-	2.1	2.4	2.6
16	Kiln Bag house speed control type	GRR/SPRS/ VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD	SPRS

Table 22: Continued

Table 22: Benchmarking of Pyrosection–With WHRS

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
17	Kiln Bag house damper open position	%	-	-	No damper	-	100	-	-	-	-	100
18	Kiln Bag house fan operating efficiency	%	-	78	68	65	84	75	75	68	65	77
19	Kiln Bag house Fan inlet pressure	mmwc	-	-215	-185	-120	-160	-20	-170	-192	-180	-275
20	Kiln Bag house Pressure drop	mmwc	-	120	110	80	100	90	130	-	100	-
21	Kiln size	Dia(m) × Length(m)	6 × 86	-	4.4 × 65	3.8/4.2 × 56	3.6 × 54	3.6 × 51	4.80 × 72	4.8 × 74	3.95 × 62.1	4.75 × 75
22	Kiln Volumetric loading	TPD/ m^3	6.60	7.22	7.10	7.70	7.00	6.70	5.30	5.40	7.60	7.20
23	Kiln Thermal loading	MkCal / hr/m^2	-	4.6	3.7	4.1	3.3	4.1	5.2	-	7.8	4.9
24	Kiln percentage filling	%	13.5	14.8	-	-	18.5	-	15.2	17.0	-	17.5
COOLER SECTION												
1	Cooling air flow	Nm^3/kg Clinker	1.89	1.54	1.80	1.66	1.72	1.85	1.80	1.82	-	1.78
2	Cooler vent flow	Nm^3/kg Clinker	1.1	-	-	-	0.98	-	-	0.95	-	-
3	Cooler Recuperation Efficiency (with WHR/ without WHR in operation)	%	55	65	-	-	66	-	65	54	-	67
4	Pressure Drop Across Cooler ESP	mmwc	40	-	170	-	50	135	100	-	310	50
5	Cooler ESP Fan efficiency (with WHR/ without WHR in operation)	%	59	-	-	-	60/90	-	74	56	-	65/73
6	Clinker temp at cooler exit	°C	130	155	-	87+ Ambient	120		120	200	-	135
7	Cooler Grate Loading	TPD/m^2	-	46	-	-	51	-	48	56	-	43
8	WHR Tapping- Cooler	Mid tap/ End tap	Mid Tap	Mid tap	-	Mid Tap	End Tap	-	Mid Tap	Mid Tap	NIL	Mid Tap
9	TAD temperature	°C	930	940	880	918	900	1000	950	960	1020	990
10	Temperature Drop Across TAD	°C	100	35	-	-	35	-	60	80	-	-

Table 22: Continued

Table 22: Benchmarking of Pyrosection–With WHRS

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
11	Cooler water spray	m^3/hr	-	-	-	-	-	-	-	-	-	-
12	Coal Phase density – PC firing	kg Coal / kg Air	1.3	3.3	-	-	3.2	-	-	1.8	-	-
13	Coal Phase density – Kiln firing	kg Coal / kg Air	2.8	-	-	-	2.6	-	-	1.0	-	-
14	Kiln Thermal SEC	kCal/kg Clinker	785	696	695	726	702	736	711	729	766	720
15	Loss in PH gas	kCal/kg Clinker	172	141	113	161	146	145	150	139	185	202
16	Loss in Cooler vent	kCal/kg Clinker	147	117	134	104	102	96	120	144	104	119
17	Loss in clinker	kCal/kg Clinker	25.00	31.00	34.80	21.75	22.00	28.00	20.00	36.00	23.00	24.00
18	Heat of formation of clinker	kCal/kg Clinker	408	416	404	403	420	406	408	414	412	399
19	Radiation loss	kCal/kg Clinker	55	45	43	36	42	66	57	44	52	43
20	Type of burner		-	-	-	-	KHD Pyrojet	-	-	Duoflex	-	KHD-Pyrojet
21	Burner Capacity	MW	-	-	-	-	40	95	-	89	87	-
22	**ELECTRICAL SEC**											
a	KS fan/PH Fan	kWh/MT Clinker	7.8	8.6	6.2	7.3	6.7	6.5	7.5	8.0	7.7	2.1
b	Calciner fan/ PH Fan	kWh/MT Clinker	-	-	-	-	-	-	-	-	3.1	6.4
c	RABH/ESP fan	kWh/MT Clinker	1.8		2.8	1.6	2.6	1.4	1.8	2.9		3.0
d	Cooler fans	kWh/MT Clinker	3.5	3.4	3.2	5.4	4.3	-	4.2	4.8	-	4.4
e	Cooler vent fan	kWh/MT Clinker	0.9	1.1	0.9	-	1.0	-	-	0.5	1.0	1.7
f	Kiln drive	kWh/MT Clinker	1.8	1.5	-	1.5	1.1	-	2.1	1.3	-	1.5
g	Kiln feed	kWh/MT Clinker	-	1.0	-	-	-	1.7	-	1.5	1.6	-
h	Auxiliary	kWh/MT Clinker	4.3	-	6.2	5.1	5.3	4.9	6.4	-	5.7	3.4
i	Kiln Section SEC	kWh/MT Clinker	19.9	20.0	20.2	20.9	21.0	21.0	21.3	22.0	22.3	22.6
j	Total SEC up to Clinkersiation	kWh/MT Clinker	49.9	46.1	47.5	47.7	42.6	45.4	54.1	50.7	47.6	56.6

5.5 CEMENT MILL SECTION

5.5.1 CEMENT MILL – BALL MILL

5.5.1.1 Cement Mill Section – Ball Mill – PPC

Table 23: Benchmarking of Cement Mill Section – Ball Mill – PPC

S. 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 Cement	27.07	27.16	27.59	27.80	28.49	28.80	29.00	29.13	29.28	29.37
1	Type of circuit	**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	73	205
4	Product variety	**PPC**										
5	C_2S & C_3S Content in the clinker	%	-	-	-	26 & 48	-	-	-	-	17.5	28 & 48
6	Final Product Blaine	m^2/kg	320	380	320	330	330	330	410	-	350	350
7	Final Product residue (% residue on 45 mics)	%	15	22	19	20	25	20	10	-	-	18
8	Fly ash qty	%	34	30	30	34	28	28	30	32	33	32
9	Clinker factor		0.6	-	-	0.6	-	-	-	-	-	0.6
10	Mill specification (Dia × Length)	m × m	4.6 × 17.1	4.4 × 13.5	5 × 15	4.4 × 13.5	4 × 11.5	4.2 × 13.5	3.8 × 14.6	-	3.4 × 12.3	-
11	Gas Velocity across the mill	m/s	-	1.0	1.1	1.2	1.3	1.3	0.4	-	1.2	1.0
12	Mill outlet draft	mmwc	-	-	-	65	-	-	-	-	-	118
13	Separator type/model	-	-	-	CM-1 - Dynamic-Sepax, CM-2-Dynamic LNVT	-	-	-	-	-	-	-
14	Pressure drop across separator	mmwc	-	-	-	150	-	-	-	-	140	300
15	Separator loading	kg/m^3	-	-	-	1.38	-	-	-	-	1.22	1.22
16	Rotor Case Velocity inside Separator	m/s	-	-	-	4.63 (CM-1) & 3.75 (CM-2)	-	-	-	-	-	-

Table 23: Continued

Table 23: Benchmarking of Cement Mill Section – Ball Mill – PPC

S. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
17	Circulating load		2.01	1.81	1.56	1.73	1.54	1.52	2.81	-	2.05	1.22
18	Separator reject residue (on 45 microns)	%	63	87	77	75	-	-	65	-	-	86
19	Separator rejects Blaine	m²/kg	200	-	-	-	-	-	-	-	77	74
20	Separator product (cyclone fines) residue (on 45 microns)	%	15	-	-	19	-	-	-	19	17	12
21	Separator product (cyclone fines) blaine	m²/kg		-	-	330	-	-	-	-	17	358
22	Mill discharge residue (on 45 microns)	%	39	45	47	45	<35	<35	44	46	57	36
23	Mill discharge Blaine	m²/kg	200	305	200	120	240	240	199	-	220	186
24	Cyclone pressure drop	mmwc	-	170	200	100	200	-	70	-	102	90
25	No. of cyclones	Nos.	-	-	-	4 nos in CM1 & 2 nos in CM2	-	-	-	-	2	2
26	Mill vent fan operating flow	m³/hr	-	-	-	45,000	-	-	-	-	26,900	-
27	Mill vent fan speed control type (GRR/ SPRS/VFD)		VFD	-	VFD	-	-	-	-	VFD	VFD	-
28	Mill vent fan operating efficiency	%	-	-	-	72	-	-	-	-	90.8	88
29	Separator fan operating flow	m³/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	1,08,032	2,55,000
30	Separator fan speed control type (GRR/ SPRS/VFD)	-	-	-	GRR	-	-	-	-	VFD	VFD	-
31	Separator fan operating efficiency	%	-	-	-	72 & 80	-	-	-	-	79	90

Table 23: Continued

Table 23: Benchmarking of Cement Mill Section – Ball Mill – PPC

S. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
32	Separator vent fan operating volume	m^3/hr	-	-	-	12,500 for CM1 & 45,000 for CM2	-	-	-	-	20,255	-
33	Grinding media piece weight in the first chamber	-	-	-	1,540 & 1,560	-	-	-	-	1,680	1,486	-
34	Grinding media-specific surface area in the second chamber	m^2/MT	-	-	-	40.5 & 42	-	-	-	-	32	37.2
Electrical SEC												
a	Mill drive (Ball mill)	kWh/MT Cement	21.9	21.6	22.6	21.1	24.5	25.0	25.4	21.2	29.3	21.2
b	Mill vent fan	kWh/MT Cement	0.20	-	0.20	0.40	0.40	0.40	-	0.30	23.20	0.20
c	Mill separator fan	kWh/MT Cement	1.29	2.20	2.20	2.80	1.50	1.50	2.20	2.10	0.10	1.90
d	Separator vent fan	kWh/MT Cement	0.70	2.65	0.23	-	-	-	0.43	0.16	2.53	0.12
e	Auxillaries	kWh/MT Cement	2.8	1.00	0.07	1.89	1.95	1.95	0.42	2.83	3.44	3.12
f	Overall SEC	kWh/MT Cement	27.07	27.16	27.59	27.80	28.49	28.80	29.00	29.13	29.28	29.37

5.5.1.2 Cement Mill Section Ball Mill-OPC

Table 24: Benchmarking of Cement Mill Section 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	31.80	31.40	31.10	35.20	37.00
1	Type of circuit		**Ball Mill**							
2	Design output	TPH	110	105	200	115	58	110	133	50
3	Operating output	TPH	120	115	200	105	55	120	137	54
4	Product variety		OPC							
5	Clinker feed size	mm	-	-	-	-	40	25	2 to 25	6.7
6	C_2S & C_3S Content in the clinker	%	-	-	-	-	27 & 46	19 & 58	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)	%	20.00	25.00	14.50	15.60	23.12	18.00	21.50	19.00
9	Clinker factor		-	-	-	-	0.90	0.91	0.91	0.93
12	Ball Mill Make		-	-	-	-	WIL	FLS	FLS	Promac
13	Mill specification (Dia × Length)		4.2 × 13.5	4 × 11.5	4.81 × 15	3 × 10	3.2 × 12.07	4.2 × 14.5	4.4 × 13.5	3.4 × 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	1.20	1.20	1.00	1.10	0.75	0.80	1.20	1.20
17	Mill outlet draft	mmwc	-	-	-	-	-48	70	55	125
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	mmwc	-	-	-	-	354	90	140-160	300
20	Separator loading	kg/m^3	-	-	-	-	0.78	1.20	1.39	-
21	Rotor Case Velocity inside Separator	m/s	-	-	-	-	-	-	4.63(CM-1) & 3.75 (CM-2)	-
22	Circulating load		1.2	1.2	1.6	-	0.9	1.8	1.7	1.0

Table 24: Continued

Table 24: Benchmarking of Cement Mill Section Ball Mill-OPC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
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	16	22	18
26	Separator product (cyclone fines) blaine	m^2/kg	-	-	-	-	296	298	285	330
27	Mill discharge residue (on 45 microns)	%	35.0	37.0	40.0	60.5	46.4	45.0	50.0	58.0
28	Mill discharge Blaine	m^2/kg	180 to 220	180 to 220	204	130	225	180	190	150
29	Cyclone pressure drop	mmwc	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	-	-
34	Mill vent fan operating efficiency	%	-	-	-	-	28	85	72	88
35	Mill vent Fan inlet pressure (before & after damper)	mmwc	-	-	-	-	-65&-68	-300	-	-
36	Separator fan operating flow	m^3/hr	1,45,000	-	2,48,000	2,10,000	82,150	1,54,449	1,80,000 & 3,50,000	1,09,000
37	Separator fan speed control type (GRR/ SPRS/VFD)		-	-	-	-	VFD	GRR	GRR	VFD
38	Separator fan inlet damper open position	%	-	-	-	-	100	100	-	-
39	Separator fan operating efficiency	%	-	-	-	-	77.10	76	72 & 80	90
40	Separator Fan inlet pressure (before & after damper)	mmwc	-	-	-	-	-490	-380	-	-

Table 24: Continued

Table 24: Benchmarking of Cement Mill Section Ball Mill-OPC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
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 piece	-	-	-	-	-	1610	1540 & 1560	1486
43	Grinding media-specific surface area in the second chamber	m^2/MT	-	-	-	-	42.40	40.31	40.50 & 42.00	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	28.60
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	2.94	3.55	2.89	2.40	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

5.5.2 CEMENT MILL-VRM

5.5.2.1 Cement Mill Section VRM-PPC

Table 25: Benchmarking of Cement Mill Section VRM-PPC

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 Cement	18.80	19.70	21.18	22.28	22.30	22.33	22.55	24.95	25.85	26.8
1	Type of Circuit and Product variety	**VRM & PPC**										
2	Make	-	Loesche	FLS	Loesche	Peiffer	Pfeiffer	Pfeiffer	Pfeiffer	Loesche	Pfeiffer	Loesche
3	Type / Model	No	LM 53.3+3S	OK 39.4	LM 56.3+3	MPS 5600 BC	MBR 6000 C6	MPS 5600 BC	MPS 5600 BC	LM 46.2+2	MVR 5000C4	LM 56.3 + 3 CS
4	Design output	TPH	280	265	305(OPC)	180 (PSC)	412	300	230	115(OPC)	200	305 (PPC) @ 3400 Blaine
5	Operating output	TPH	320	300	286 - OPC, 342 - PPC	330 (PPC)	412	400	324	147.4 - OPC, 163- PPC	195	290 @ OPC, 373 @ PPC, 270 @ CC
6	Final Product Blaine	m^2/kg	330	350	350/ 300	360	360	350	335	350/ 300/ 300/ 380	350	310/ 360/ 380
7	Final Product residue (% residue on 45 mics)	%	14	14	18-20	-	10	16	12	18-20	34	<15
8	Fly ash Addition	%	32.0	34.5	31.8	32	35.0	35.0	34.9	31.4	0	PPC 34.5%, CC 25.8%
9	Clinker factor		0.66	0.63	-	0.62	0.6	0.63	0.58	-	-	-
10	Pressure drop Across Nozzle ring	mmwc	200	200	-	-	-	180	205	-	-	-
11	Pressure drop Across Separator	mmwc	100	150	-	-	-	120	83	-	-	-
12	Mill DP (Mill inlet to Mill outlet)	mmwc	350	250	540	200	510	200	215	490	85	485
13	Bag house pressure drop	mmwc	140	25	175	-	110	130	118	155	-	130
14	Mill fan operating flow	m^3/hr	5,55,000	5,85,000	7,40,000	9,20,000	11,20,000	9,28,500	7,95,796	3,40,000	7,20,521	8,05,000
15	Mill fan speed control type (GRR/SPRS/ VFD)	GRR/ VFD/ SPRS	VFD	VFD	VFD	GRR/VFD	GRR	SPRS	SPRS	SPRS	VFD	GRR

Table 25: Continued

Table 25: Benchmarking of Cement Mill Section VRM-PPC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
16	Mill fan operating efficiency	%	73	78	78	80	79	81	78	65	68	81
17	Mill Fan inlet pressure	mmwc	-595	-595	-785	-680	-782	-700	-530	-690	-	-770
18	Separator type/model		-	ROKSH90	LSKS 87	SLS 5000 B	-	SLS 5600 BC - Lamella Wheel	Air swept lemella classifier SLS 5000 BC	LSKS 66	SLS 4750BC	LSKS 92
19	Nozzle ring velocity	m/s	31	44	49	32	43	42	31	45	31	42
20	Dam ring height	mm	380	152	290	250	275	230	270	310	310	370
21	Table Diameter	mm	5,300	-	-	-	6,000	5,600	5,600	-	-	8,040
22	Grinding Pressure	bar	90	160	-	-	185	110	115	-	-	-
23	**Electrical SEC**											
a	Mill drive	kWh/MT Cement	11.9	13.0	12.8	12.3	14.0	13.4	13.1	14.2	16.1	15.3
b	Mill fan	kWh/MT Cement	4.2	4.6	5.2	6.5	6.8	6.2	6.3	6.8	6.3	7.8
c	Separator/ classifier	kWh/MT Cement	0.2	0.2	0.1	-	0.7	0.4	-	0.1	0.0	0.7
d	Auxiliary	kWh/MT Cement	2.5	2.0	3.2	3.5	0.8	2.3	2.8	3.8	3.3	3.0
e	Overall SEC	kWh/MT Cement	18.8	19.7	21.2	22.3	22.3	22.3	22.6	25.0	25.9	26.8

5.5.2.2 Cement Mill Section VRM OPC

Table 26: Benchmarking of Cement Mill Section VRM OPC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
	Overall SEC	kWh/MT Cement	24.00	25.00	27.60	28.14	28.56	29.50	29.86
1	Product variety	**OPC**							
2	Make		FLS	Loesche	Pfeiffer	Loesche	Pfeiffer	Pfeiffer	Pfeiffer
3	Type / Model		OK39.4	LM 53.3+3S	MVR 5000C4	VRM LM 56.3 +3 C	MPS 5600 BC	MBR 6000 C6	MPS 5600 BC
4	Design output	TPH	250	210	190	275 OPC and 240 PPC	250	305	300
5	Operating output	TPH	235	230	190	251 OPC and 272 PPC	252	310	270
6	Final Product Blaine	m^2/kg	320	300	310	300	305	340	300
7	Final Product residue (% residue on 45 mics)	%	14	15	18	25	12	9	11
8	Clinker factor		0.91	0.93	-	-	0.88	0.93	0.97
9	Pressure drop Across Nozzle ring	mmwc	220	200	0	-	205	-	200
10	Pressure drop Across Separator	mmwc	168	100	0	-	83	-	120
11	Mill DP (Mill inlet to Mill body)	mmwc	-	350	95	530	-	510	-
12	Bag house pressure drop	mmwc	100	150	110	95	119	110	110
13	Mill fan operating flow	m^3/hr	6,10,000	5,65,240	7,56,109	7,10,000	8,05,796	11,20,000	9,53,100
14	Mill fan speed control type	GRR/ SPRS/ VFD	VFD	VFD	VFD	VFD	SPRS	GRR	SPRS
15	Mill fan operating efficiency	%	78	74	63	75	78	79	81

Table 26: Continued

Table 26: Benchmarking of Cement Mill Section VRM OPC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
16	Mill Fan inlet pressure	mmwc	-610	-580	-457	-730	-550	-782	-725
17	Separator type/model		ROKSH90	-	SLS 4750BC	Dynamic cage wheel with vortex rectifier	Air swept lemella classifier SLS 5000 BC	-	SLS 5600 BC - Lamella Wheel
18	Nozzle ring velocity	m/s	44	32	50	53	32	43	42
19	Dam ring height	mm	152	380	310	450	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
22	**Electrical SEC**								
a	Mill drive	kWh/MT Cement	15.0	16.5	16.6	15.0	17.4	19	17.9
b	Mill fan	kWh/MT Cement	5.8	5.4	7.1	7.4	7.3	9.0	8.3
c	Separator/ classifier	kWh/MT Cement	0.2	0.2	0.5	2.3	-	0.7	0.6
d	Auxiliary	kWh/MT Cement	3.0	2.8	3.4	3.5	3.4	0.8	3.0
e	Overall SEC	kWh/MT Cement	24.0	25.0	27.6	28.1	28.6	29.5	29.9

5.5.2.3 Cement Mill Section VRM - PSC

Table 27: Benchmarking of Cement Mill Section VRM - PSC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
	Overall SEC	kWh/MT Cement	31.9	32.6	33.2	33.9	34.8	35.3	35.5
1	Product variety		**PSC**						
2	Make		Loesche	Loesche	OK Mill	Loesche	Pfeiffer	Pfeiffer	Pfeiffer
3	Type / Model		56.3+3	LM 53.3+3S	42.4	LM 46.2 + 2 CS	MBR 6000 C6	MVR 5000C4	MPS 5600 BC
4	Design output	TPH	220	150	215	75 @ 4500 blaine GGBS	250	160	150
5	Operating output	TPH	260	170	230	96 @ PSC, 130 @CC	260	163	197
6	Final Product Blaine	m^2/kg	368	330	-	380	390	360	335
7	Final Product residue (% residue on 45 mic)	%	-	15	-	-	8	-	12
8	Slag qty	%	62	58	66	61	67	57	70
9	Clinker factor		-	0.4	-	0.4	0.3	0.4	0.3
10	Pressure drop Across Nozzle	mmwc	-	200	-	-	-	-	205
11	Pressure drop Across Separator	mmwc	-	100	-	-	-	80-85	83
12	Mill DP (Mill inlet to Mill body)	mmwc	373	320	475	340	500	-	-
13	Bag house pressure drop	mmwc	150	110	110	110	120	110	-
14	Mill fan operating flow	m^3/hr	5,74,000	4,90,000	7,15,000	3,15,000	10,45,000	6,95,832	7,25,796
15	Mill fan speed control type	GRR/ SPRS/VFD	VFD	VFD	VFD	VFD	GRR	VFD	SPRS
16	Mill fan inlet damper open position	%	-	-	-	No damper	100	100	-

Table 27: Continued

Table 27: Benchmarking of Cement Mill Section VRM - PSC

Sr. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7
17	Mill fan operating efficiency	%	-	74	-	79	76	63	80
18	Mill Fan inlet pressure	mmwc	-	-490	-680	-555	-710	-454	-495
19	Nozzle ring velocity	m/s	-	29	-	46	43	50	32
20	Dam ring height	mm	-	380	-	360	275	310	270
21	Table Diameter	mm	-	5,300	-	4,233	6,000	-	5,600
22	Grinding Pressure	bar	-	90	-	-	185	-	115
23	**Electrical SEC**								
a	Mill drive	kWh/MT Cement	21.00	21.80	21.00	21.22	23.00	24.31	21.47
b	Mill fan	kWh/MT Cement	6.12	6.00	8.10	7.61	11.00	7.70	8.70
c	Booster fan	kWh/MT Cement	-	1.70	-	0.89	-	0.03	-
d	Separator/ Classifier	kWh/MT Cement	-	0.60	-	0.21	0.90	1.12	-
e	Auxiliary	kWh/MT Cement	5.20	2.50	4.50	3.93	0.90	2.11	5.32
f	Overall SEC	kWh/MT Cement	31.90	32.60	33.20	33.86	34.80	35.27	35.48

5.5.3 CEMENT MILL - BALL MILL+HPRG
5.5.3.1 Cement Mill Section - Ball Mill+HPRG - PPC

Table 28: Benchmarking of Cement Mill Section - Ball Mill+HPRG - PPC

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant3	Plant4	Plant5	Plant6	Plant7	Plant8
	Overall SEC	kWh/MT Cement	18.6	24.0	24.9	25.7	25.7	26.6	27.3	28.0
1	Type of circuit	**Ball mill with HPRG**								
2	Design output	TPH	260	155	175	210 (PPC)/ 190 (OPC-53)	225	125	210 (PPC)/ 190 (OPC-53)	140
3	Operating output	TPH	265	180	194	224 (PPC)/ 193 (OPC-53)	238	135	221 (PPC)/ 193 (OPC-53)	142
4	Product variety		PPC	PPC	PPC	PPC/ OPC	PPC	PPC	PPC/OPC	PPC
5	Clinker feed size	mm	-	23	25	26	25	23	26	-
6	C2S & C3S Content in the clinker	%	-	-	22 & 52	47	22 & 52	-	47	-
7	Final Product blaine	m^2/kg	349	310	320	324 (PPC)/ 292 (OPC-53)	320	310	324 (PPC)/ 292 (OPC-53)	3500
8	Final Product residue (% residue on 45 mic)	%	-	10	8	13.1 (PPC)/ 10.1 (OPC-53)	8	10	13.1 (PPC)/ 10.1 (OPC-53)	10
9	Fly ash qty	%	-	34.00	35.00	31.60	35.00	34.00	31.60	35.00
10	Clinker factor		-	-	0.63	0.65 (PPC)/ 0.93 (OPC-53)	0.63	-	0.64 (PPC)/ 0.94 (OPC-53)	-
11	Ball Mill Make		Thyssenkrup	FLS	TCDRI	KHD	-		TCDRI	ACC VICKER BABCOCKS
12	Mill specification	Dia(m) × Length(m)	4.4 × 11.7	3.0 × 11	3.8 × 12	4.2 × 13	4.2 × 13.5	3.6 × 12	4.2 × 13	13.5 × 2.89
13	No. of chambers - Ball mill	Nos.	1	1	1	1	1	1	1	1
14	Type of liners	both compart-ments	Thin Classifying	Semi classifying	UVL & classifying	Clssifying Liners	classifying	Fully Classifying	Classifying Liners	Classfying
15	Velocity inside mill	m/s	1.2	1	0.7	1.2-1.3	0.8	0.5	1.3-1.4	1.4
16	Mill outlet draft	mmwc	-70	-155	-80	-95	-90	-70	-95	-60
17	Separator type/model		Thyssenkrup	SKS	VSK/Sepol	TESu-310	SKS	Sepol	TESu-310	QDK 294/Z

Table 28: Continued

Table 28: Benchmarking of Cement Mill Section - Ball Mill+HPRG - PPC

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant3	Plant4	Plant5	Plant6	Plant7	Plant8
18	Pressure drop across separator	mmwc	300	550	180	-	240	300	-	220
19	Separator loading	kg/m³	-	0.87	-	-	-	0.87	-	0.80
20	Circulating load		2.3	2.9	1.8	2.3 (PPC)/ 2.06 (OPC-53)	1.9	2.6	2.76	1.8
21	Separator reject residue (on 45 microns)	%	80	72	85	62	70	67	62	78
22	Separator reject blaine	m²/kg	120	-	65	92	70	-	92	85
23	Separator product (cyclone fines) residue (on 45 microns)	%	12	12	17	-	-	12	-	12
24	Separator product (cyclone fines) blaine	m²/kg	350	315	400	-	380	310	-	341
25	Mill discharge residue (on 45 micron)	%	50	60	27	55	65	58	58	60
26	Mill discharge blaine	m²/kg	192	130	280	138	180	115	145	190
27	Cyclone pressure drop	mmwc	50	-	250/100	-	80	-	-	90
28	No. of cyclones	Nos.		2	2 & 4	-	4	4	-	2
29	Mill vent fan operating flow	m³/hr	60,000	23,000	17,653	40,000	24,109	14,000	45,000	22,000
30	Mill vent fan speed control type	GRR/SPRS/ VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD
31	Mill vent fan inlet damper open position	%	-	100	100	-	100	100	-	-
32	Mill vent fan operating efficiency	%	81	80	53	72-76	63	45	70-76	78

Table 28: Continued

Table 28: Benchmarking of Cement Mill Section - Ball Mill+HPRG - PPC

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant3	Plant4	Plant5	Plant6	Plant7	Plant8
33	Mill vent Fan inlet pressure (before & after damper)	mmwc	100	-160 & -170	-153 & -159	-180	-161 & -168	-170 & -180	-190	-190
34	Separator fan operating flow	m³/hr	5,00,000	20,000	49,997	3,00,000	51,899	1,78,000	3,20,000	3,00,000
35	Separator fan speed control type	GRR/SPRS/ VFD	VFD	GRR	VFD	VFD	VFD	VFD	VFD	VFD
36	Separator fan inlet damper open position	%	-	100	100	-	100	100	-	-
37	Separator fan operating efficiency	%	42	82	80	76	47	78	73	75
38	Separator Fan inlet pressure (before & after damper)	mmwc		-619	-110 & -120	-650	-178 & -185	-450	-700	-360
39	Separator vent fan operating volume	m³/hr	-	30,000	2,71,283	-	3,30,647	6,000	-	20,000
40	Grinding media-specific surface area in the second chamber	m²/MT	-	-	42	-	41	-	-	38
41	HPRG Make		KHD	KHD	TCDRI	-	KHD	Polysius	TCDRI	KHD
42	Type/Model		RPZ 13	RP-Z-13-140/140	TRP140-160	-	RP-Z-13-140/141	Polycom 14/06	TRP140-160	RP15 140/120 Z
43	HPRG separator type/model		Thyssenkrup	SKS	-	-	-	Sepol	-	SKS 210/4
44	HPRG separator Fan volume	m³/hr	5,00,000		-	-			-	1,80,000
45	HPRG separator Fan control		VFD		-	-			-	VFD

Table 28: Continued

Table 28: Benchmarking of Cement Mill Section - Ball Mill+HPRG - PPC

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant3	Plant4	Plant5	Plant6	Plant7	Plant8
46	**Electrical SEC**									
a	Mill drive (Ball mill)	kWh/MT Cement	6.4	6.3	8.3	11.8	12.6	11.0	13.0	15
b	Mill vent fan	kWh/MT Cement	0.40	-	0.43	3.59	-	-	3.60	3.0
c	Mill separator fan	kWh/MT Cement	-	-	-	-	0.39	-	-	-
d	Separator vent fan	kWh/MT Cement	-	-	2.90	-	2.96	-	-	7.83
e	Separator - Ball mill	kWh/MT Cement	-	1	-	-	-	-	-	-
f	Booster fan	kWh/MT Cement	-	2.7	-	-	-	3.2	-	3.9
g	HPRG drive	kWh/MT Cement	6.93	10.50	6.60	6.68	6.68	7.20	7.10	7.70
h	Dry Fly ash unloading	kWh/MT Cement	2.5	2.5	-	0.1	-	2.5	0.2	1.4
I	Auxiliary	kWh/MT Cement	2.4	3.5	3.8	3.1	3.2	3.5	2.9	7.3
J	Overall SEC	kWh/MT Cement	18.6	24.0	24.9	25.7	25.7	26.6	27.3	28.0

5.6 OVERALL BENCHMARKING NUMBERS OF CEMENT MILL SECTION

Table 29: Benchmarking of Cement Mill Section

Sr. No.	Type of Circuit	Unit	PPC	OPC	PSC
1	Ball Mill	kWh/MT Cement	27.0	29.8	-
2	VRM	kWh/MT Cement	18.8	24.0	31.9
3	Ball + HPRG	kWh/MT Cement	18.6	24.8	39.0

5.7 PACKING SECTION

Table 30: Benchmarking of Packing 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 Cement	0.70	0.80	0.80	0.80	0.90	1.02	1.00	1.00	1.10	1.10
1	Design output	TPH	120	90	90	180	240	200	240	180	240	120
2	Operating output	TPH	105	71	67	130	170	200	180	140	175	90
3	No of Packers	Nos.	4	2	2	4	4	3	3	6	4	-
4	No. of Spouts	Nos.	8	6	6	12	16	16	12	16	16	8
5	Type of discharge	Single/ Double	Single	Single	Single	Double	Double	Double	Double	Double	Double	Single
6	Bag filter fan (main & aux) volume	m^3/hr	-	-	-	28,500	-	38,000	-	40,000	-	18,783
7	Bag filter fans operating power	kW	55	27	29	25	75	-	71	-	90	-
8	Compressed air pressure	kg/cm^2	4.5	5.5	5.5	6.0	5.0	6.0	5.0	5.0	6.0	5.5
9	**ELECTRICAL SEC**											
a	Auxiliary	kWh/MT Cement	0.3	0.4	0.4	0.2	0.2	-	-	-	-	0.9
b	Overall SEC	kWh/MT Cement	0.70	0.76	0.80	0.81	0.90	1.02	1.03	1.03	1.10	1.17

5.8 UTILITIES SECTION

5.8.1 COMPRESSOR

Table 31: Benchmarking of 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
3	SEC of Compressors for Clinkersiation	kWh/MT Clinker	0.7	1.1	1.3	1.6	1.6	1.7
4	SEC of Compressors for Cement grinding & packing (SEC)	kWh/MT Cement	0.82	0.80	1.00	1.30	1.10	0.98
5	**COMPRESSOR OPERATING PRESSURE**							
a	Main bag house	kg/cm^2	4	-	-	4.5	4.8	5.5
b	Fly ash unloading	kg/cm^2	2.5	3	3.2	3	2.5	3
c	Other sections	kg/cm^2	5.5	5.5	5	5	5.5	5.5

5.8.2 SPECIFIC WATER CONSUMPTION

Table 32: Benchmarking Water Consumption

Sr. No.	Parameter	Unit	Plant1	Plant 2	Plant 3	Plant 4	Plant 5
1	Cooling water consumption (upto Clinkersiation)	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

5.9 WHRS OPTIMIZATION

Presently, the overall capacity of power generation by WHRS in the Indian Cement Industry is about 837 MW and may further increase in upcoming years to reduce overall GHG emission and also give a contribution to make industry carbon neutral by 2040.

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 too much 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 33: Comparison of WHRS of Cement Plants

Sr. No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	Installed capacity	MW	6.31	13.20	12.50	11.60	6.45	9.50
2	Operating capacity	MW	6.20	11.30	9.70	7.80	6.65	9.00
3	Clinker production	TPD	3,450	8,200	8,700	6,050	4,450	6,139
4	WHR Tapping-Cooler(End Tap/Mid Tap)		End Tap	Mid Tap	End Tap	Mid Tap	End Tap	Mid tap
5	Heat Consumption With WHR	kCal/kg Clinker	770	735		724	730	720
6	Hot Air Recirculation		No	Yes	No	Yes	No	-
7	Cooler recuperation efficiency (with WHR)	%	49	63.71	-	73	60	57
8	Cooler Grate Loading	TPD/m^2	>50				57	
10	Boiler type		Pre Heater & AQC type	Pre Heater & AQC type	Pre Heater & AQC type	Pre Heater & AQC type	Pre Heater & AQC type	Pre Heater & AQC type
11	PH boiler inlet gas temperature	°C	308	408	351	325	313	278
12	PH boiler outlet gas temperature	°C	198	227	221	169	187	168
13	AQC boiler inlet gas temperature	°C	395	450	338	380	395	422
14	AQC boiler outlet gas temperature	°C	91	149	125	110	90	135
15	Pressure drop across PH boiler	mmwc	100	37	120	-	-	-
16	Pressure drop across AQC boiler	mmwc	37	-	54	44	40	40
17	Auxiliary power consumption (APC) by WHR plant	%	7.0	5.7	5.7	4.1	5	4.7

Table 33: Continued

Table 33: Comparison of WHRS of Cement Plants

Sr. No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
19	Average power generation per ton clinker	kWh/MT Clinker	43.00	33.01	26.78	30.94	35.87	35.18
20	Average power generation per million kCal	kWh/ MkCal	132.5	125.6	111.3	120.3	135.6	137.7
21	Water consumption	DM & Raw Water m^3/MW	0.25 & 0.795	0.07 & 0.317	0.24 & 0.686	0.25 & 0.92	0.13 & 0.470	0.06 & 0.4
22	False air across PH boiler	%	1.14	3.49	-	-	1.71	7.10
23	Overall WHR efficiency	%	20	22	21	18	21	20

Chapter 06

Best Practices and Important Thumb Rules

6.1 FANS

1) Fans with aerofoil, backward curved blades can operate with an efficiency of more than 85%.
2) The optimum margin for pressure is 15% and flow is 10% over the required capacity while designing a fan.
3) Optimum cut off clearance in a centrifugal fan is 8-12%.
4) 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.
5) The difference between inlet suction box velocity & duct velocity should not be greater than 8 m/s.
6) Increase in the cooler chimney height will increase the natural draft effect and reduce the cooler vent fan power.
7) Efficiency losses due to faults in
   a. Cone condition or cone gap : 3-4%.
   (Worn out or damaged cone condition or deviation in cone gap compared to design)
   b. Absence of inlet flow guide : 2-5%.
   c. Build up on impellor : 4-6%.
8) Allowable pressure loss across multi louver type damper in 100% open condition is 10-15 mmwc.
9) In a closed circuit loop fan, Outlet pressure should be with in -10 to -20 mmwc, irrespective of the flow to the mill.
10) Suction at cooler fan inlet should not be more than -30 mm wc.
11) Reduction in Cooling Tower fan speed by 50% by VFD can save power by 75%.
12) Flat belt pulley can save 3 – 5% compared to V belt pulley.

6.2 RAWMILL & COAL MILL

1) For Pet Coke grinding, the circumferential velocity of the rotor should be in the range of 27-30 m/s for achieving the product residue.
2) Recommended gas velocity in ducts 14-16 m/s.
3) Pressure drop in latest generation LP cyclones is 50-60 mmwc.
4) High false air in Raw Mill circuit mainly increases the RABH or Bag House Fan Power.
5) Conversion from normal coal grinding to Pet Coke grinding deteriorates the mill output and it can achieve best figure of 65% of normal coal capacity.
6) Rotary airlocks shall not be composed of more than 6 cells/pockets. Cell/pocket filling degree shall not exceed 33%.
7) External material re-circulation shall be designed for around 50-90% of the nominal production rate.
8) The specific loading of the rotor of the internal separator shall be <=10 t/h m^2.
9) Optimum dam-ring height is usually between 2.5% to 4% of table dia.
10) For Pet Coke grinding optimum dam-ring height is usually between 5-6% of table dia.

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

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

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

14) The false air in the VRM circuit should be maintained below 15%.

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

16) The gas temperature of the flue gas at the stack should be greater than dew point by 20 °C.

17) Dew point range in coal mill from flue gases (50-52 °C).

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

19) Ball mill ventilation velocity: 1.2 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.

20) Ball mill can accommodate input moisture level up to 5% (Max); whereas Vertical Roller Mill can accommodate moisture level even up to 20% ; Roller Press with V separator combination can accommodate up to 15% input moisture level.

21) The separator loading should be maintained between 0.6 to 0.7 kg of material/m^3.

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

Table 34: Important Norms for wear rate

Material	Application Wear material	Roller tire wear (gm/T)	Table wear (gm/T)
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

Table 35: 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
Casing Velocity at separator		
Raw Mill	m/s	7.5
Cement Mill	m/s	7
Coal Mill	m/s	7
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	45-60
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	500-680
Cement Mill	gm/m^3	200-400
Slag Grinding	gm/m^3	200-400
Heat Consumption for water Vaporization		
VRM	kCal/kg Water	800-1,000
Ball Mill	kCal/kg Water	700-800
Roller press	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

1) Latest generation low NO_x burners can operate with a Primary air percentage as low as 4-6%.
2) PID loop optimization will result in savings of 3-5 kCal/kg of clinker.
3) The temperature drop across TAD should not be greater than 30 °C.
4) Recommended phase density for Pet Coke should be in the range of 5-6 kg Coal/kg Air.
5) Phase density for normal coal: 4-6 kg Coal/kg Air.
6) The specific consumption of coal firing blowers should be in the range of 0.4-0.7 kW/m^3/min.
7) 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.
8) 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.
9) The top cyclone efficiency should be greater than 95%
10) Null point for Pet Coke firing lies between 0.75-0.80 Nm^3 Air / kg Clinker.
11) Overall cooler efficiency should be greater than 70%.
12) Cooler losses should not be greater than 120 kCal/kg Clinker.
13) Overall radiation losses contribute around 6-8% of total heat losses.
14) False air across preheater circuit should be less than 6%.
15) An increase in specific exit gas amount (example change of fuel, etc.) by 0.1 Nm^3/kg increases the preheater exit gas temperature by 17°C.
16) The kiln should be operated in the oxidizing atmosphere during Pet Coke firing.
17) Pressure drop across ESP should not be greater than 30 mmwc.
18) Down comer duct velocity should be in the range of 14-16 m/s.
19) The pressure drop from the top cyclone to the fan inlet in the downcomer duct should not be greater than 30 mmwc.
20) The specific volume of preheater fan for Pet Coke firing should be in the range of 1.45-1.50 Nm^3/kg Clinker.
21) Ceramic coating can save up to 8%-15% radiation loss in furnaces and hot surfaces.

6.4 CEMENT MILL

1) Ball mill ventilation velocity – 1.3 to 1.5 m/s above the ball charge.
2) Recommended velocities at other mill areas:
   - Inside the trunion: 22-25 m/s.
   - Partitions: 8-14 m/s (<20 m/s).
   - Hood: <5 m/s to prevent dust from being sucked up (dust pick-up is proportional to speed^2).
   - Dropout box: <2 m/s.
3) 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.
4) The optimum volume loading of grinding media for minimum power consumption mode is 26-28% in 1^{st} chamber & 28-30% in 2^{nd} chamber.
5) The volume loading of media for maximum productivity mode is 32-34% in 1^{st} chamber & 34-36% in 2^{nd} chamber.
6) One metric tonne of balls increases the mill power draw by 10 kW.
7) In practical terms, material level should equal ball level in the first chamber.
8) In practical terms, material level should be higher than ball level in the second chamber.
9) The expansion of the ball charge due to the material in between would not exceed 3% in an optimised mill (measurement of the ball charge level of the empty and the filled mill).
10) Fineness norms in the first compartment before intermediate diaphragm.
    - 95% passing of 2.365 mm for the material leaving the first compartment.
    - Particle size distribution recommended on other sieves:
      - 86-92% passing 1.0 mm
      - 80-90% passing 0.6 mm
      - 75-85% passing 0.5 mm
11) Fineness norms in the second compartment before discharge diaphragm.
    - 95% passing 0.5 mm
    - 70-80% passing 0.2 mm (212 μm)
12) Total piece weight in the first compartment should be in the range of 1400-1500 gm/piece without pre-grinder & Roller press.
13) Recommended piece weight in the first chamber with HPRG lies in the range from 900-1100 gm/piece.
14) 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.
15) The maximum size of outlet discharge diaphragm slot should be more than half of the lower size grinding media in mill.
16) Lifting liners should be replaced when effective lifting height has worn out more than 60%.
17) Worn out liners (>60%) can reduce 8-10% production.
18) Rotor Cage velocity inside the separator should be in the range of 4-5 m/s.

6.5 BAG FILTER OPTIMIZATION

1) Air to Cloth ratio:
   a. 1.2 m^3/m^2/min for Slag, Coal and Clinker dust.
   b. 1.5 m^3/m^2/min for limestone and Cement dust.
2) The minimum distance between the bags should be 50 mm.
3) The maximum number of bags per row should not be more than 16 bags.
4) Maximum 6-8 dust sources to vent should be connected to one dust collector.
5) Duct Slope:
   a. Max 30 degree for limestone, cement, slag de-dusting
   b. Max 45 degree for clinker de-dusting
6) At material discharge chute, drop height must not be more than 2 meters. If it is more than 2 meters, then baffle plates to be provided.
7) The ideal height of discharge hood is 1200 mm from belt top.
8) The skirtboard should be min of 5 meters length for each transfer points.
9) 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.
10) Static pressure below Rotary Air Lock should not be more than 6 mmwc else there is false air in the circuit.
11) Optimum pressure drop across filter 80-120 mmwc indicates efficient utilization of bag filter capacity.
12) Recommended air pressure for purging is 4.5-5 kg/cm^2.
13) Clean air velocity is generally in the range of 16-18 m/s.
14) Velocity profile should be even in sub-branches for effective utilization of bag filters.
15) Dedusting air requirement in CF or blending Silo is to be depended upon aeration as well as air slides blower.
16) 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.
17) In drag chain and screw conveyors, the velocity through the ventilation flap is 4-6 m/s.

6.6 COMPRESSED AIR AND OTHER UTILITIES

1) 1 bar reduction in compressed air pressure will save 7-8% power.
2) Recommended compressed air velocity in the pipeline is 6-8 m/sec.
3) 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.
4) Maintaining intercooler performance can save 7% power on the compressor.
5) Every 4 °C rise in inlet air temperature of the compressor results in higher energy consumption by 1% to achieve equivalent output.
6) Recommended compressed air outlet temperature after intercooler is ambient temperature plus 20 °C.
7) Transvector nozzles can reduce power and save compressed air for cleaning application up to 50%.
8) 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).
9) Compressed air leakage quantity to be as low as 10%.
10) In 800 m length compressed air pipeline, pressure drop should not be more than 0.3 kg/cm^2.
11) Centrifugal and Screw blowers can save up to 40% power when compared with PD blowers for the same application (pressure and volume).
12) The typical power consumption of a conventional vapor compression refrigeration system is 1.2 kW/TR.
13) 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.
14) Evaporative cooling can reduce the compressor or chiller load by 20-40%.

6.7 COOLING TOWER

1) 150 sq ft of room area needs 1 TR Air Conditioning load in a conventional building.
2) The optimum approach (difference between coldwell temperature and wet bulb temperature) in a cooling tower is 2-4 °C.
3) Recommended increase in temperature of water (ΔT = Cooling water outlet – Inlet temperature) for condenser and compressor is 10 °C and for process heat exchanger 5 °C.
4) FRP Blades in an axial cooling fan can save up to 15-40% power compared with metal blades.

6.8 ELECTRICAL EQUIPMENT

1) 4% reduction in voltage will result in 1% reduction in power.
2) 10% reduction in speed will save 27% power in centrifugal equipment.
3) LED can save power consumption by nearly 50%.
4) Power transformer efficiency will be maximum in the range of 60-80% Loading.
5) Distribution transformer efficiency will be maximum in the range 40-60% Loading.
6) Motor life doubles for every 10°C reductions in operating temperature.
7) The problem with excessive harmonics can be poor power factor, High heating of neutral conductor, high heating in IM, damage to capacitor banks, noise from transformer etc.
8) For Low voltage distribution the individual voltage harmonics is limited to 5% and VTHD is limited to 8%.
9) The total demand distortion of 5% and 8% is limited for Isc/Il <20 and 20<Isc/Il<50 respectively.

6.9 CAPTIVE POWER PLANT

1) 22°C Drop-in Boiler flue gas temperature will increase boiler efficiency by 1%.
2) A 10% blowdown in a 15 kg/cm^2 boiler results in 3% efficiency loss.
3) 3 mm of soot can cause an increase in fuel consumption by 2.5% due to increased flue gas temperatures.
4) Optimum efficiency of boilers occurs at 65–85% of full load.
5) Reducing the frequency by 1 Hz at the main TG/DG (in Island mode) will reduce the power consumption of Centrifugal equipment by 3%.
6) A 1 mm thick scale (deposit) on the waterside could increase fuel consumption by 5-8%.
7) The optimum excess air for a coal-based boiler is 15-20%.
8) With every 1% reduction in excess air in the boiler, there is an approximately 0.6% rise in inefficiency.
9) 6 °C raise in feed water temperature by economizer/condensate recovery corresponds to a 1% saving in fuel consumption, in the boiler.
10) 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.
11) A 3-mm diameter hole on a pipeline carrying 7 kg/cm^2 steam would waste 33 kilo Liters(kL) of fuel oil per year.
12) 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).
13) 1 mm thick air film in steam piping offers the same resistance as a wall of copper of 15 meters thick.
14) Every 4.8 kg/cm^2 drop in generation pressure of steam will result in a 1% increase in efficiency.

Table 36: Important Norms for Captive power

Parameters	Unit	Optimum Value	Remarks
Auxiliary Power consumption-AFBC	%	5.5-6	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	2.8-3.5	Minimum 2.8 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%

Chapter 07

Low Carbon Technologies

Calcination and Energy use are the two primary sources of CO_2 emission in the cement manufacturing process. The use of fuels, most frequently coal, in the pre-calciner and rotary kiln results in energy-related emissions, which account for 30–40% of direct CO_2 emissions. In the pre-calciner, where limestone (mostly calcite and aragonite, with the chemical formula $CaCO_3$) is broken down into lime (CaO) and carbon dioxide (CO_2), a chemical reaction occurs that results in the other main source of direct CO_2 emissions (process emissions). While lime is processed to produce clinker, one of the primary ingredients of cement, the CO_2 is released into the environment. Cement production has substantial environmental impacts. Globally, cement is responsible for 8% of GHG emissions and 2–3% of energy demand. Further, the selection of fuels for cement kilns and in part the kiln materials used, currently lead to notable air pollutant emissions. At the same time cement kilns can help to recover energy and dispose of hazardous wastes, chemicals, and MSW from the existing landfills and the wastes that are to be disposed off in the most environmentally sustainable manner. It is critical to select mitigation strategies that can contribute to reduced CO_2 emissions while lowering other environmental impacts. These factors must be taken into consideration when evaluating strategies to decarbonize cement production, one of the most difficult industries to decarbonize, due to the need for high temperatures, the generation of CO_2 process emissions, and the large quantity of cement demanded globally. Research indicates that a mix of many efforts can be done to reduce CO_2 emissions across the industry value chain. The aim is to assist global cement industry in minimizing the environmental impact of cement manufacturing by reducing its CO_2 emissions. This chapter evaluates strategies or levers such as

1. Improving Energy Efficiency in the cement production
   1.1 Electrical
   1.2 Thermal
2. Reducing Clinker factor in the cement and concrete by using more blending material
3. Use of Alternative fuels and Raw materials
4. Waste Heat Recovery and Adoption of Renewable Energy
5. New and Emerging Technologies such as Nano particles, Geo polymer etc including Carbon Capture Utilisation and Storage

1. Energy Efficiency

Research suggests the cement industry could cut three-quarters of its CO_2 emissions by 2050 and 7% of overall emissions can be reduced by implementation of existing energy efficient technologies i.e, 0.2 $GtCO_2$ annually.[1]

1.1 Reducing Carbon Footprint of Electrical Energy:

Enhancing energy performance levels by installing cutting-edge technologies in new cement plants and retrofitting old facilities, Improving efficiency through energy efficient equipment, Digitization, and Industry 4.0. The technologies listed below have a payback period of nearly 3 years.

[1] https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement#/

Potential CO_2 emissions and reductions, $GtCO_2$ anually[1]

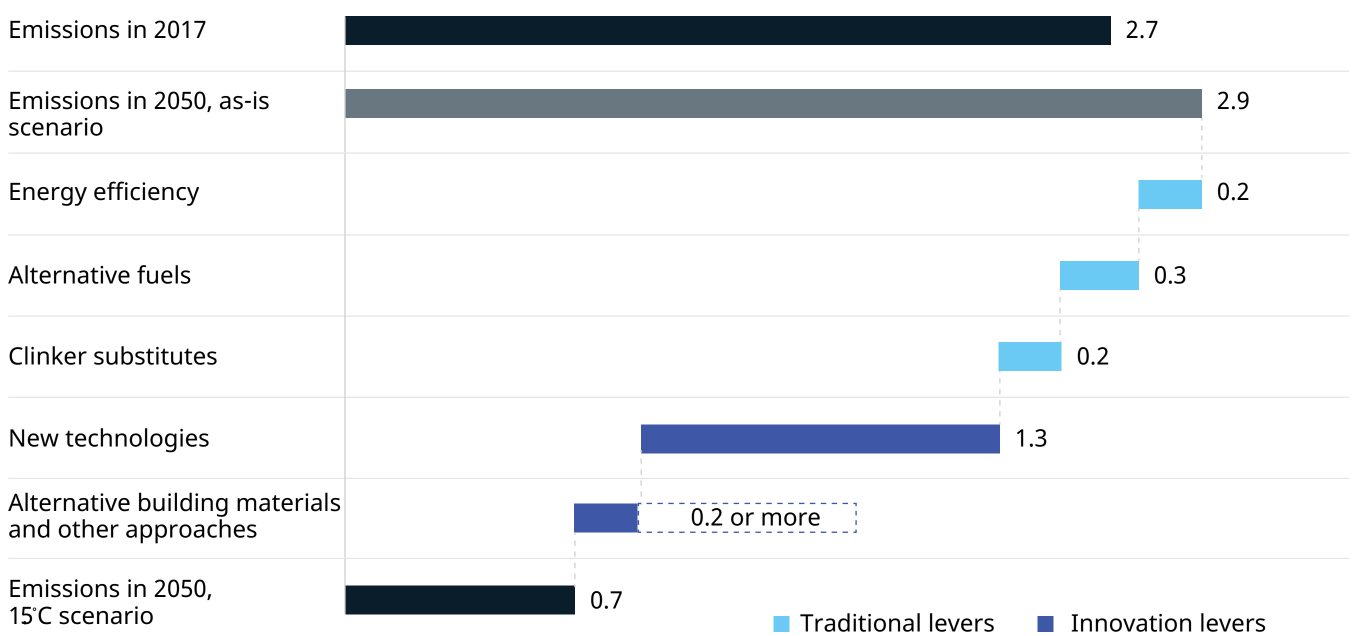


Table 37: Low carbon Technologies to enhance Electrical Energy Efficiency

LEVER: 1.1 ELECTRICAL ENERGY EFFICIENCY		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
1	Low Pressure drop cyclones	· Due to the optimum flow dynamic design, the pressure drop of the pre heater system is small, minimising the electrical energy requirement for the exhaust gas fan. The high collection efficiency of the cyclones ensures that the exhaust gas has a low dust content.
2	High Pressure Grinding Roller (HPGR) for material grinding	· Improved productivity, reliability, and product quality, at lower cost. This cutting-edge technology can be linked with advanced digital functionality that enables continued process optimization and predictive maintenance. · >50% more throughput for up to 15% lower energy consumption
3	4th Generation Separators- High Efficiency separators	· 4th generation Separator is fitted with an integrated cyclone and recirculation fan inside body, a perfect combination between the compactness of a 1st generation and the efficiency of a 3rd generation separator. · Increase production, · Improve cement quality , clinker factor, · Reduce power consumption, · Reduce maintenance costs
4	Vortex rectifier for classifiers in vertical roller mills	· A new arrangement of diverter blades at separator to reduce turbulence and pressure drop. · Installing vortex rectifier will result in reduction in separator pressure and reduces the SEC of Mill fan. · At least 10% reduction in SEC · At least 10% increase in mill throughput
5	Ceramic grinding media	· Ceramic grinding media for fine and ultra-fine grinding application · Reduction in wear · Reduction in Mill Specific power
6	Reducing raw mill feed size by installing secondary / Tertiary crusher	· Secondary/ Tertiary crusher will help to reduce Raw mill SEC. · It has been seen that many plants have reduced their specific power consumption in raw mill VRM by maintaining 100% feed size below 40mm size. · 2% SEC reduction.
7	Smart monitoring & control of compressed air - Wise Air 4.0	· Wise Air 4.0 smart control technology is designed to curb all the drawbacks in present control systems. It monitors critical parameters from all major sections in a compressor unit and can precisely predict the supply-demand with its machine learning capabilities. · Elimination of artificial demand, Avoids excess generation, Real time insights on the compressed air, IoT enabled platform. · Up to 15% Electrical energy saving.

Table 37: Continued

Table 37: Low carbon Technologies to enhance Electrical Energy Efficiency

LEVER: 1.1 ELECTRICAL ENERGY EFFICIENCY		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
8	Waste Heat Recovery from compressed air before intercooler & aftercooler	· Air to water heater exchanger, which will extract the heat of compression which is rejected to cooling tower (in case of water-cooled compressors) & ambient atmosphere (in case of air-cooled compressors). Here an Air to water heater exchanger will be installed before Intercooler and after-cooler where waste heat from the compressed air is getting transferred to the water and the generated hot water will be used in the Waste Heat Recovery Boiler. · Increases the output of the Waste Heat Recovery Boiler as waste heat is recovered from air compressors. The Waste Heat Recovery will be to the tune of around 60% of the Air compressor input power. (Oil screw compressor).
9	Automatic star-delta-star converter for conveyor belt	· When the load on the motor is less than 50% of the full load, it switches the motor to operate in a star mode to save energy. · When the load increases beyond 50%, it automatically switches the motor to operate in Delta without disturbing the working of the motor. · Reduce the losses in low load conditions and result in energy savings of up to 10%.
10	Energy Efficiency EC fans in place of conventional blowers in Air handling units (AHU)	· AHUs are belt driven with conventional Induction Motors. BLDC system is a combination of all the conventional Motor functions : Fan, Motor, Pulley and Belts, VFD etc., · Reduces the input electrical energy. There will be about 25 to 30% savings.
11	IE4 and IE5 class motors	· The efficiency of these motors are high and have better operation under VFD application. · 5-10 % Energy savings possible.
12	Installation of Fly Ash Dryer	· Blending of cement with fly ash reduces energy consumption and lowers the carbon emission intensity. This led to increase in consumption of fly ash in cement blending. Most of the fly ash available reclaimed from old ash ponds / wet ash collection systems contain 15-20% of moisture hence known as wet fly ash. Using fly ash dryer will reduce the moisture content in the fly ash and heat requirement. Use of Fly ash driver · Reduces power consumption in cement grinding. · Throughput of the mill increases. · Due to higher clinker substitution, it reduces energy consumption for clinkerization and operating costs.
13	Particle Size Distribution (PSD) Analyzer for Cement quality improvement	· By utilizing Particle Size Distribution (PSD) analysis, it becomes feasible to continuously measure and analyze the complete grain size distribution in real time. This analysis enables dynamic adjustment of the separator speed at the finish grinding mill, optimizing the fineness of cement particles to meet specific requirements. This will enhance the product cement quality while conserving electrical energy by avoiding over grinding and achieving higher cement mill productivity

1.2 Thermal Energy :

Table 38: Low carbon Technologies to enhance Thermal Energy Efficiency

LEVER: 1.2 THERMAL ENERGY EFFICIENCY		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
1	Installation of High Efficiency Clinker Coolers	· Latest generation coolers have better clinker properties with significantly lower exit gas and clinker temperatures The total heat loss of latest generation clinker coolers is less than 100 kCal/kg of clinker and has a recuperation efficiency of >75%.
2	Improving the burnability of raw mix by use of mineralizer	· The potential use of mineralizers to improve clinker quality. There are two overlapping terms, namely fluxes and mineralizers, 'flux' is an additive that decreases the melting point whereas a 'mineralizer' is a substance that accelerates the reaction rates. · Thermal savings: Reduction in clinkering temperature by around 30 °C. · Electrical savings: Reduction in power consumption up to 1 kWh/MT.
3	optiMAKX - PID Loop optimization	· A smart tool with Artificial Intelligence and Machine Learning features that optimizes the PIC loop by reduces their Average Absolute Controller Error (AACE) · Optimization of process operating parameters Error correction in PID loops · Lesser energy consumption by reducing AACE in PID loops. · 2-3 kCal/kg Clinker and · 2-10% Electrical energy saving
4	Total Burner Solutions	· Total Burner Solutions (TBS) is a cutting-edge energy efficient burner solution with advanced thermal design performed in state of art computational modelling produced by additive manufacturing. It comes a wholesome solution covering three major areas – burner leg, exhaust leg and recuperator. · Improved fuel efficiency · 5-10% fuel savings
5	Coomtech clean technologies- Drying	· Coomtech has developed a low energy, low cost drying technology using managed turbulent air, creating kinetic energy to remove moisture. revolutionizing a 100-year-old process, a single Coomtech-enabled plant can cut CO_2 emissions by the equivalent of more than 600,000 mature trees per year and is 75% cheaper to operate. · Increasing production optimisation and improving customer service,75% reduction in CO_2 emissions and energy costs.
6	Improve the heat transfer in preheater cyclones by conducting a CFD	· Exhaust temperature of hot gases leaving the pre-heater can be reduced by improving heat transfer in cyclones · By CFD study, we can identify and analyze the reason for low heat transfer. · Thermal energy savings of 4-5 kCal/kg Clinker.
7	Apply thermal insulation paint in kiln shell & reduce radiation loss	· Reducing the radiation losses from these hot surfaces of Kiln, Preheater and cooler by Lithophone sodium silicate paint, Heat resistant aluminium paint. · Thermal energy savings of 4-5 kCal/kg Clinker.

Table 38: Continued

Table 38: Low carbon Technologies to enhance Thermal Energy Efficiency

LEVER: 1.2 THERMAL ENERGY EFFICIENCY		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
8	Advanced multi-channel burner	· Lower primary air percentage (4-6%) in burner · Reduced fuel Consumption · Thermal energy savings of 2-3 kCal/kg Clinker. · NOx emissions can be reduced as much as 30–35% over emissions from a typical direct fired, uni-flow burner
9	Cross-belt analyser	· Cross-belt analysers will analyse the chemical properties of the materials instantaneously and direct corrective actions much quicker compared to conventional sampling and quality control methods. · Increase in mines life and conserves natural resource. · Consistent material quality, reduced heat consumption
10	Hot air Recirculation	· The recirculation of hot cooling air from the cooler exhaust back into the cooler will improve WHR generation

Some of the Low carbon technologies in a cement plant from crusher to packers are listed:

- Crusher discharge:
  - A cross belt analyzer can be installed to ensure the quality and to enhance the mine's life.
  - Stacker and reclaimer with higher blending ratio (of 10:1) can be adopted by design.
- Raw Mill:
  - For limestone with a moisture content of more than 5% and hardness classified as medium to soft, Vertical Roller Mills (VRM) with the latest generation classifier are being installed with the following: Mechanical recirculation system, High efficiency fans with High Tension (HT) Variable Frequency Drive (VFD), Automatic sampler and cross-belt analyzer in the mill feed for better quality control, Adaptive predictive control for mill operation,
  - For limestone with low moisture content (less than 3%), a roller press with a separator in finished mode can be installed with the following: High efficiency separators and cyclones, Automatic sampler and cross-belt analyzer in the mill feeding for better quality control, Adaptive predictive control for mill operation.
- Silo:
  - Continuous blending silo with high blending ratio (10:1), Mechanical conveying system for all material transport,
  - For silo extraction, gravimetric feeding system for all fine material with an accuracy of over 1%
- Pyro-processing
  - Preheater: A six stage or seven stage preheater can be used wherever the heat from preheater and cooler is sufficient to dry fuel and raw material
  - Cyclones with high efficiency and low pressure drop.
  - Low NOx calciner with adequate residence time for increased Alternative Fuels and Raw materials (AFR) use in calciner
  - Computational Fluid Dynamics (CFD) studies to reduce the pressure drop, enhance heat transfer and improve energy efficiency,
  - VFD for preheater fans
  - Kiln: Multi-channel burner for improved thermal efficiency, flexibility of firing AFR, better flame control and low NOx emissions
  - High strength insulation bricks in kiln inlet and calcining zones for minimizing radiation loss in kiln and preheater sections.
  - Kilns operating with high peripheral speed (up to 6 – 7 RPM)
  - VFD control for shell cooling fans
  - Coolers: Latest generation coolers with a total loss of less than 110 kCal/kg Clinker, and a recuperation efficiency of above 75%
  - High efficiency aero foil bladed cooler fans with VFD
- Control system
  - Adaptive predictive control system
  - Online NOx control
  - Online flame control, Online free lime control, Flow measurement with advanced techniques
  - Online thermograph scanning and triggering corrective action to reduce kiln heat loss.
- Coal mill
  - Stacker and reclaimer with high blending efficiency to use different coal grades with alternative fuel.
  - Vertical roller mill for grinding
  - Gravimetric feeding system

- Hot gas source from preheater to ensure safety and coal drying
- Coal mill fans with VFD and high efficiency
- High pressure blowers for fine coal transportation with increased phase density

- Cement mill
  - Preferred options for cement grinding could be among
  - Vertical roller mill for grinding using cooler vent air as the hot gas source
  - Roller press and ball mill combination with high efficiency separator
  - Roller press in finish mode
- Packing plant
  - Cement silo extraction with air slide and blower
  - Electronic packers
  - Double-decker wagon loader
  - Provision for bulk dispatch and bag dispatch, depending on plant context Minimal Waste Heat Concept

2. Alternative Fuels and Raw Materials:

Indian Alternative fuel usage stands at 7% (on a country average) Thermal Substitution Rate (TSR). Utilizing biomass and waste products as fuels in cement kilns can help counterbalance the use of carbon-intensive fossil fuels by encouraging the use of alternative fuels (fuels with less carbon footprint than conventional fuels). Alternative fuels have a scope to reduce 0.3 $GtCO_2$ annually i.e, 10 % of overall GHG emissions.

Table 39: Low carbon Technologies to enhance Alternative fuel usage.

LEVER-2: ALTERNATE FUELS AND RAW MATERIALS		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
1	Advanced Calciners	· High retention time · Ability to co-process low grade Alternative fuels · Mixing Chamber to enhance fuel burn-out · Uniform kiln operation, thanks to extensive pre-calcination of the raw meal, · Intensive mixing of gas, fuel and meal inside the calciner · for enhanced burnout. · Minimal coating formation in the preheater, due to the low circulation of alkalis, · Low pressure drop in the preheater because of the optimum flow-dynamic design of the calciner, · Superior economy of operation thanks to the high fuel flexibility · Low NOx
2	Chlorine bypass system	· The presence of low volatile / coating forming substances such as Chlorine in kiln gases is a growing challenge as more alternative fuels and raw materials are being utilized. Kiln bypasses, which remove these elements, are therefore becoming increasingly important. The bypass is designed to offer optimal removal of unwanted materials, improving the reliability and availability of the kiln system · Helps in achieving a High TSR %
3	Complete AF infrastructure along with pre-processing platform	· Increasing Thermal Substitution Rate · TSR is basically on two fronts: first, biomass-based alternative fuels and second alternative fuels reduces the use of primary fossil fuel (coal, petroleum coke, and so on). · Alternative fuel stands at 7% Thermal Substitution Rate (TSR) · Shredder, Screens, Feeding machinery, Conveying systems, blasters and appropriate feeding points are needed to increase TSR levels. · CO_2 reduction (PPC): 70 - 150 kg CO_2/tonne of cement
4	Pyro rotor	· Advanced technology for utilizing alternative fuels, with very high thermal substitution rates with almost no fuel pre-processing, even when dealing with low-quality alternative fuels. · Reduction in fuel cost

3. Clinker factor

Clinker substitutes have a potential to reduce 7% of overall emissions i..e, 0.2 GtCO_2 annually. Enhancing use of supplementary cementitious materials, Increasing the use of blended materials and the market deployment of blended cements to decrease the amount of clinker required per tonne produced. Some of the low carbon-based cements are

- o Fly ash based Cements,
- o GGBF Slag Cements,
- o Limestone Calcined Clay Cement - LC3,
- o Limestone based Cements,
- o Calcined clay/Natural Pozzolana based Cements,
- o Multi-blend Cements

Table 40: Low carbon Technologies to enhance Clinker substitutes in Cement.

LEVER-3: CLINKER FACTOR		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
1	Reducing clinker factor by using low grade limestone	· Reducing clinker factor by using low grade limestone to reduce the Greenhouse Gas (GHG) emissions. · Various other materials, such as limestone, low grade/dolomitic limestone. · Reducing energy consumption · Reducing GHG Emission
2	Use of Nano-technology in Cement Manufacturing	· The nanoparticles would be evenly distributed among the larger particles of mineral admixtures and with such fine dispersion that even a lower content of cement should be able to provide the desired binding of aggregates and admixture particles generating required strength and performance. In such systems the mineral additives can be utilized in larger quantity. · Nano Cements provide significant saving of cement and lower CO_2 emissions. · Nano Cements may provide enhanced reactivity during clinkerization and hydration.
3	Limestone Calcined Clay Cement (LC3)	· LC3 is a mixture of 50% clinker, 30% low-grade kaolinite clay, 15% limestone and 5% gypsum. Because less usage of fuel and limestone for clinker needs to burn with a temperature in the range between 1400-1500 °C. Where calcined clays require only in the range between 700-800 °C. · 40% reduction of CO_2 emissions when comparing with OPC.
4	Reducing Clinker Factor by using other blending materials	· Copper industry, lead-zinc smelters, refineries, mineral processing industries generate industrial wastes that are unutilized posing serious environmental and health hazards. · Cement manufacturing offers to gainfully utilize industrial wastes to be used as blending materials. · Reduce heat consumption · Mitigate CO_2 emission

Table 40: Continued

LEVER-3: CLINKER FACTOR		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
5	Geo-polymer Cement	· Geo-polymer cement utilises waste materials from the power industry (fly ash, bottom ash), the steel industry (slag), and from concrete waste, to make alkali-activated cements. · Geo-polymeric cements set quickly and as strong as Portland cements, last longer and are more resistant to fires as they can be formed at much lower temperatures than Portland cement (750 °C) also they consume less energy assumption than Portland cement.
6	Cinder recovery	· Utilises unburnt carbon in the fly ash by re-firing it in the boiler, which is conveyed through the primary air. · Fly ash with a Loss of Ignition less than 8% can be utilised in cement mills. · Reduction of the LOI from 15-17% to 6-8% · Boiler efficiency improvement by 0.5%
7	TernoCem	· This technology(Heidelberg) works on an altered chemical composition and lower burning temperatures · CO_2 output is 30% lower in comparison with conventional clinker and energy consumption. · CO_2 can be reduced by around 15%.
8	Low Emissions Intensity Lime and Cement	· The project is focused on developing a calciner that can directly separate and capture about 95% of the CO_2 released from limestone
9	Novel Cement (Cemex)	· It can reduce carbon emissions by 15% to 20%. · The product uses clinker with around 20% natural pozzolanic material after it has been treated mechanically and chemically.
10	Alternative de-carbonated raw materials for clinker production	· The utilization of alternative raw materials containing calcium, which are either de-carbonated or contain calcium as non-carbonate minerals reducing Greenhouse Gas (GHG) emissions. · Raw materials are fly ash, blast furnace slag, steel slag, carbide sludge, lime sludge from paper plants, lime from shaft kilns, phosphor-gypsum, Pb-Zn slag contain some of the deleterious oxides in the form of Na_2O, K_2O, sulphur and chlorides. · CO_2 reduction (direct): for every 1% of conventional limestone. · CO_2 reduction shall be up to 5.25 kg/MT clinker or up to 8.0 kg/mt Cement.

4. WHR AND RENEWABLE ENERGY:

Table 41: Some of the technologies in Waste Heat Recovery and Renewable Energy

LEVER-4: WHR AND RENEWABLE ENERGY		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
1	Installation of Waste Heat Recovery Systems	· The adoption of Waste Heat Recovery systems in Indian cement manufacturing facilities has gained a good pace. · The technologies available for Waste Heat Recovery include Rankine Cycle, Organic Rankine Cycle and Kalina Cycle. · Estimates indicate that the Installed Waste Heat Recovery capacity in Indian cement industry is close to 840 MW. Has a further potential to adopt 500 MW
2	Roof top Solar	· Cement plants can harness the power of solar energy by installing rooftop solar panels in various locations such as silo tops, material storage sheds, workshops, office buildings, CCR, colony and admin office. Several plants have already installed more than 2 MW of solar rooftop capacity. This initiative can not only reduce stack and fugitive emissions but also provide a sustainable source of energy for the plant operations. Therefore, cement plants should consider rooftop solar installations as a viable option for their energy needs. · Cement plants consume a significant amount of energy, and installing solar panels can help reduce the electricity bills by generating electricity from a renewable source. · Reduction in Energy costs, reduced carbon foot print and increased operational flexibility are other benefits.
3	Electric Vehicle for i) Underground electric loaders and ii) Mining trucks	· Unlike internal combustion technology—which uses combustion and pressure to propel a vehicle—electric vehicles, or EVs, are propelled by electromagnetism. These vehicles use electricity, typically stored in a battery, to power an electric motor. · Zero Tailpipe Emissions · Reducing greenhouse gas emission from the Environment if the EV is charged by RE.

5. NEW TECHNOLOGIES:

Developments are underway to manufacture next-generation cement that have significant carbon reductions. Also known as green cement, they are produced by implementing a carbon-negative manufacturing process and using renewable electricity. Advanced carbon capture and storage methods also have the potential to decarbonize the cement industry. These emerging technologies can provide approximately 48% of cumulative CO_2 emission savings by 2050 i.e., to reduce 1.3 $GtCO_2$ annually to reach 1.5 °C by 2050.

The technologies listed below are not in commercial scale as of now and are under R & D.

Table 42: List of New Technologies

LEVER-5: New Technologies		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
1	Carbon Capture Technology	· CarbonOrO's mission is to mitigate climate change by turning landfills or plants into a source of renewable energy or extracting the CO_2 out of flue gas. Carbon capture technology using unique bi-phasic amine with a lower cost of capture. · Less thermal and oxidative degradation than commercial solvents and saves energy usage. Drives operational costs down, bring prices for carbon capture to below 25 €/t CO_2 for large emitting installations. https://www.carbonoro.com/
2	Carbon Upcycling Technologies	· Improves the strength of plastics while sequestering CO_2 at the same time. · Carbon Upcycling Technologies chemically activates and captures CO_2 within solid waste materials to produce a range of supplementary cementitious materials, to create low carbon cement and concrete. · Reduces the carbon footprint of cement, and improves concrete performance. · Improves the strength of industrial plastics by 30% to 200% and reducing the need for resin production. https://carbonupcycling.com/
3	Solar-Thermal Mixed-Media Enhancement and Decarbonization of Clinker Formation	· Synhelion's technology delivers process heat beyond 1,500 degrees Celsius to produce clinker without using fossil fuels. · Few renewable technologies can generate heat at the temperatures needed to process raw cement feedstock, said Nathan Schroeder, Sandia researcher and principal investigator for the Solar MEAD project. · The project is expected to advance understanding of how to use CST to gather and deliver heat to existing cement production facilities. · Techniques could be used in other ore processing industries such as refractory, ceramics, and battery production. https://synhelion.com/

Table 42: Continued

Table 42: List of New Technologies

LEVER-5: New Technologies		
Sr. No	**Name of the Technology**	**Brief Description and Benefits**
4	Oxyfuel combustion	· Oxyfuel combustion creates a flue gas of highly concentrated CO_2 that is relatively easy to capture and process for geological storage or onward use. · Partial oxyfuel capture rates are lower, at 55%-75%, but only requires adaptation of part of the pyro process. This makes it a more economical option and presents the opportunity for staged implementation of oxyfuel technology, mitigating the capital requirements. · At the plant, oxyfuel technology requires the installation of an air separation unit (ASU) to provide the large quantities of oxygen needed to generate oxyfuel conditions, as well as a heat recovery system for the recirculation of flue gases to avoid additional firing and unabated CO_2 emissions. The integration of this equipment more than doubles the amount of electricity required per tonne of clinker, raising the final cost of the production by 40%-50%. · In addition, process and equipment improvements are required to reduce false air leakage into the system. Burner/cooler design also needs adapting
5	Green Hydrogen	· Injecting hydrogen into its cement kilns as a catalyst, plants may optimize the combustion process and increase its use of alternative fuels, decreasing its use of fossil fuels. · There's good reason to consider locating electrolysers right at cement plants. Electrolysers yield both hydrogen and oxygen. The oxygen is also useful at the plants. Oxygen helps to: · Produce higher quality clinker · Reduce emissions · Use low-quality alternative fuels · Increase production rates · Consider a proposed system at an Austrian cement plant. It would capture CO_2 and combine it with hydrogen to produce synthetic fuels. It would also yield needed plastics and chemicals.
6	Physical Solvent based Carbon capture	· Absorption due to CO_2 solubility in the solvent · Governed by Henry's Law · Suitable for gas streams with high partial pressure of CO_2 · Regeneration through low temperature flashing or pressure reduction · High absorption capacity & lower solvent recirculation rates
7	Post-combustion carbon capture by chemical adsorption	· Chemisorbents generally include an active phase, such as amines or carbonates, supported on a porous support. · High capture efficiency of 95% and High specific power consumption

Chapter 08

Islands of Excellence

Table 43: Islands of Excellence

Sr. No.	Parameter	Unit	Indicator
CRUSHER			
1	Crusher specific power consumption	kWh/MT Limestone	0.57
RAW MILL			
2	Raw mill specific power consumption- VRM	kWh/MT Limestone	10.64
3	Raw mill fan specific power consumption- VRM	kWh/MT Limestone	4.3
4	Raw mill main drive specific power consumption- VRM	kWh/MT Limestone	3.86
5	Raw mill specific power consumption- Roller Press	kWh/MT Limestone	12.48
6	Pressure drop across Nozzle ring-VRM (400 TPH)	mmwc	200
7	Pressure drop across VRM	mmwc	464
8	Pressure drop across Separator-VRM	mmwc	100
9	False air infiltration across VRM Circuit (Mill IL to Fan OL)	%	10.4
10	Raw Mill fan efficiency-VRM	%	90
11	Separator loading-VRM	gm/m^3	700
COAL MILL			
12	Coal mill specific power consumption- VRM (Coal)	kWh/MT Coal	22.2
13	Coal mill specific power consumption- VRM (Pet Coke)	kWh/MT Pet Coke	33.8
14	Output rate from normal to Pet Coke	%	65
15	Dust loading in Pet Coke grinding	gm/m^3	220
16	False air infiltration across the circuit - Mill IL to fan OL	%	9
PYRO SECTION			
17	Electrical SEC-KILN (6-Stage)	kWh/MT Clinker	15.45
18	Electrical SEC up to Clinkersiation (6 stage)	kWh/MT Clinker	42.6
19	Thermal SEC-5 Stage	kCal/kg Clinker	683
20	Thermal SEC-6 Stage	kCal/kg Clinker	675
21	Preheater fan SEC (With WHRS)	kWh/MT Clinker	6.6
22	Preheater fan SEC(Without WHRS)	kWh/MT Clinker	3.40

Table 43: Continued

Table 43: Islands of Excellence

Sr. No.	Parameter	Unit	Indicator
23	Cooler fans SEC (without WHRS)	kWh/MT Clinker	3.10
24	Cooler ID fan SEC	kWh/MT Clinker	0.13
25	Radiation loss from kiln & preheater	%	5
26	Preheater loss excluding dust	kCal/kg Clinker	110
27	Preheater outlet temperature	°C	230
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/kg Air	5.0
30	Temperature drop across TAD observed	°C	20
31	Preheater fan efficiency	%	90
32	Cooler Recuperation Efficiency (with WHR/without WHR in operation)	%	65&70
33	Cooler ESP Fan efficiency	%	78
34	Cooler Vent losses	kCal/kg Clinker	110
35	Kiln volumetric loading	TPD/m^3	7.80
36	Clinker temp at cooler exit	°C	95
37	Preheater fan flow	Nm^3/kg Clinker	1.31
38	Air infiltration across preheater	%	5.3
39	Preheater top cyclone efficiency	%	97
40	Pressure drop across RABH	mmwc	80
WHR			
41	Power generation per clinker production (AQC+PH) (Mid-tap)	kWh/MT Clinker	38 @ 700 kCal/kg Clinker- 6 stage 43@740kCal/kg Clinker- 6 stage 43 @ 710 kCal/kg Clinker -5 stage
42	WHR pressure drop	mmwc	39
43	WHR false air	%	5
CEMENT MILL			
44	Cement mill specific power consumption- Ball Mill+HPRG-PPC	kWh/MT Cement	18.6
45	Cement mill specific power consumption- Ball Mill+HPRG-OPC	kWh/MT Cement	28.0
46	Cement mill specific power consumption- VRM-PPC	kWh/MT Cement	18.8
47	Cement mill specific power consumption- VRM-OPC	kWh/MT Cement	21.2

Table 43: Continued

Table 43: Islands of Excellence

Sr. No.	Parameter	Unit	Indicator
48	Cement mill specific power consumption- VRM-PSC	kWh/MT Cement	31.9
49	Cement mill fan efficiency(VRM)	%	82
50	Fly ash addition	%	35
51	Slag addition	%	70
	ELECTRICAL		
52	Electrical distribution losses	%	3.2
53	Capacitor power loss	W/kVAR	3
54	Optimum voltage for lighting	V	210
55	Efficiency of motors in LT & HT	%	97.1
56	VFD loss and SPRS loss	%	3.4
57	Harmonic distortion in cooler fans (V,I)	%	2.8
58	Capacity of renewable energy in onsite installation	MW	8.8
	COMPRESSOR		
59	Compressor air generation pressure	Bar	4.5
60	Pressure drop in compressed air distribution system	Bar	0.1
61	Pressure drop across dryer	Bar	0.1
62	SEC for blower @1 bar	kWh/MT Coal	1.1
63	Compressor air load of Cement mill, CPP and Pyro for 4200 TPD plant	CFM	2450
	AF		
64	Thermal substitution rate-7650 TPD	%	30
	CPP		
65	Heat rate in CPP < 30 MW	kCal/Mwh	3006
66	CPP auxiliary power consumption-AFBC	%	5.36
67	CPP auxiliary power consumption-CFBC	%	6.53
68	Conveying pressure from ESP hopper to bunker in CPP	Bar	3
69	Excess air in CPP-Indian Coal	O_2%	2.5
70	Excess air in CPP-Pet Coke	O_2%	2.8
71	Pressure drop between BFP and drum	Bar	10
72	Pressure drop in flue gas path(Boiler O/L – FD fan I/L)	mmwc	64
73	Circulation rate for water cooled condenser	m^3/MW	239
74	Auxiliary cooling water circulation	m^3/MW	10.5

Chapter 09

Factors Affecting SEC

RAW MILL SECTION

9.1 BOND INDEX

Bond index indicates the grindability of limestone. In terms of the intensity of energy required to minimize from initial size of mass up to and ultimate product size. Higher value represents that the characteristic of limestone is hard to grind.

Specific power of main drive is mainly depend 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 overall difference in power vary in the range between 10-40% depending upon the hardness of the material.

Table 44: Bond Index Values of limestone

Bond Work Index (kWh/ton)	7-9	9-14	14-19	>19
Material Property (Limestone)	Soft	Medium	Hard	Very Hard

9.2 RAW MATERIAL MOISTURE

The largest particle size should be maximum 3-4% of the roller diameter.

Typical feed size distribution: 100% passing 100mm, 95% passing 60mm & 10% passing 1mm.

Reducing feed size can increase production and improve specific energy consumption. But excessive fines can increase mill vibration, especially in case of VRM grinding.

9.3 RAW MATERIAL MOISTURE

Material moisture is directly proportional to the heat consumption requirement of the mill as the moisture in material increases the overall heat consumption.

Table 45: Heat Consumption requirement values in VRM

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

9.4 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 very necessary task in cement plant for process point of view to reduce overall energy consumption of the mill.

Table 46: Recommended Values for VRM pressure profiling

Parameters	Unit	Optimum Value	Remarks
Mill inlet pressure	mmwc	40-50	Nozzle ring velocity 40-50 m/s
Pressure drop across nozzle	mmwc	350-500	Reference Feed 400 TPH
Pressure drop across separator	mmwc	90-100	Feed 300-400 TPH
Pressure drop across cyclone for large	mmwc	80-100	Number of cyclone-2
Pressure drop across cyclone for small	mmwc	40-60	Number of cyclone-4
Duct velocity	m/s	15-17	Laminar flow
Suction box velocity at fan inlet	m/s	25-28	Difference between the duct & suction box velocity should not be greater than 8 m/s.

9.5 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 low efficiency of fan are as follow:

1) Mismatch between design condition with operating condition (deviation should not be greater than 15%).
2) Higher impeller cone gap compare to design.
3) Physical condition of impeller.
4) Low efficiency by design.
5) High internal recirculation which will increase power consumption.
6) Higher Velocity difference between Duct & Inlet box (>8 m/s).

PYRO SECTION

9.6 PRESSURE DROP ACROSS CYCLONE

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) Pressure drop across WHR.
7) False air across WHR.

Table 47: Recommended Values in Preheater

Parameters	Unit	Optimum Value	Remark
Pressure drop across cyclone for each stage (LP Cyclone)	mmwc	50-60	
Riser duct velocity	m/s	10-17	Design at minimum velocity
Downcomer duct velocity	m/s	14-17	
Velocity at TAD	m/s	>25	
Pressure drop across downcomer duct	mmwc	30-40	
Total pressure drop across 5 stage	mmwc	300-350	
Total pressure drop across 6 stage	mmwc	360-400	
The gas temperature difference between in each cyclone	°C	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	mmwc	80-100	

9.7 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 48: Recommended Values for Preheater & Cooler vent fan efficiency

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 (Pet Coke)	Nm^3/kg Clinker	0.75-0.80	Vent volume should not be greater than 1 Nm^3/kg Clinker

9.8 THERMAL LOSSES

Table 49: Recommended Values for Thermal Losses in Kiln

Parameters	Unit	Optimum Value	Remarks
Cooler Efficiency	%	>70	At least should be greater than 65% to reduce overall cooler losses
Temperature drop across TAD	°C	20	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 is 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 is >25 m/s
Phase density in Pet Coke	kg Coal/kg Air	4-6	Maintain the transport velocity for coal conveying inside the pipeline is >25 m/s
Cooler losses(include clinker)	kCal/kg Clinker	110-120	Optimum cooler vent temperature is 250 °C
Preheater losses	kCal/kg Clinker	110-125	-
Preheater outlet temperature	°C	240-260	Improve it by optimizing the heat losses in the pyro section
Cooler vent temperature	°C	230-260	-
Cooler grate loading	TPD/m^2	45-50	High cooler grate loading increases the heat losses & ultimately reduce the cooler efficiency

COAL MILL SECTION

Important factors which play an important to affect overall specific energy consumption in the coal mill section are as follow:

1) HGI of coal
2) Material moisture
3) Fan efficiency
4) Pressure drop across mill circuit
5) False air infiltration

9.9 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 50: HGI vs Grindability

HGI	kWh/MT		
	10%	15%	20%
30	11.8	10.6	9.9
40	11.0	9.8	9.3
50	10.3	9.4	8.9
60	9.8	9.0	8.6

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

9.10 DRYING CAPACITY

1) The air volume required for mill sweep: 1.7 to 2.2 Nm^3/kg fuel
2) Drying capacity: average 1200 kCal/kg of H_2O for a residual moisture of 0.5 to 1.5%

CEMENT MILL SECTION

9.11 CEMENT MILL AND SEPARATOR

Table 51: Recommended Values for Cement mill and Separator

Parameters	Unit	Optimum Value	Remarks
Separator Fan Efficiency	%	>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 cage	m/s	4-5	Operate the separator fan as per rotor cage velocity
Pressure drop cyclone	mmwc	<90	-
Separator efficiency	%	75-85	-
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	%	26-28%	At this loading SEC consumption of mill is optimum
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 HPRG (Double Chamber)	gm/piece	1100-1200	Clinker feed size is smaller in the case of HPRG that automatically reduces the piece weight requirement in 1st chamber.

9.12 Parameters affecting Clinker grindability & energy consumption:

Table 52: Parameters affecting Clinker grindability & energy consumption

1 percent increase of→ Produces a variation of↓ Wx (KWh/T @ × m²/kg blaine)	C_3S	Excess SO_3/Total alkali%	C_2S	D75 alite (µm)	Alite C_3S × 100
W250	-0.3	4	+0.2	0.1	-
W300	-0.5	4	+0.2	0.1	-0.1
W350	-0.6	5	+0.4	0.2	-0.2
W400	-0.7	5	+0.4	0.2	-0.3

UTILITIES & PACKING

Important factors which play an important to affect overall specific energy consumption in the Utilities and packing sections are as follow:

1) Type of compressors
2) Operating & generation pressure of compressed air
3) Compressed air leakages
4) Artificial demand
5) Unwanted usage of compressed air (Example: man cleaning, machine cleaning and bag cleaning)
6) Auxillary bag filters in a packing plant

9.13 COMPRESSED AIR

Table 53: Recommended Values for Compressed Air

Parameters	Unit	Optimum Value	Remarks
Compressed air leakage	%	10-12	-
Compressed air pressure for process bag filters	kg/cm²	5	-
Compressed air pressure for conveying	kg/cm²	2-3	Fly ash loading & unloading
Operating pressure in instrumentation	kg/cm²	4.5-5.5	-
SEC in Screw compressor at 7 kg/cm²	kWh/CFM	0.16-0.17	-

9.14 AUXILLARY BAG FILTERS

Table 54: Recommended Values for Auxillary 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	mmwc	80-130	-
Pressure below rotary airlock	mmwc	0-10	Indicator for false air infiltration
Bag filter air volume per spout	m^3/spout	<2,000	Includes auxiliary as well as main bag filter

Chapter 10

Lowest possible SEC with Best Available Technologies

During the energy benchmarking analysis, it was observed that none of the cement plant have best SEC numbers in all the sections. Few plants have best/lowest SEC in raw mill or kiln section, but not in cement mill and packing plant and vice versa.

The SEC numbers depends majorly on the type of technologies or equipment installed. Below table indicates the lowest possible SEC for a cement plant if all the best technologies or equipment are installed.

10.1 OVERALL SUMMARY

Table 55: Lowest possible specific power consumption for a new plant with all the best technologies and equipment

6 Stage Preheater				
Section	kWh/ton of Material	kWh/ton of Clinker	kWh/Ton of Cement (OPC)	kWh/Ton of Cement (PPC)
Crusher power	0.57	0.80	0.71	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	33.9	3.24	2.916	2.04
Utilities	-	0.80	0.72	0.50
Clinkersiation	-	36.47	32.65	22.85
Cement mill	18.60	-	24.00	18.60
Overall Clinker factor	-	-	0.90	0.63
Packing Section	-	-	0.65	0.65
Miscellaneous	-	-	1.00	1.00
Overall SEC in Cement (kWh/MT)	-	-	58.30	43.10

Abbreviations

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

CII-Sohrabji Godrej Green Business Centre Initiatives

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 stakeholders.

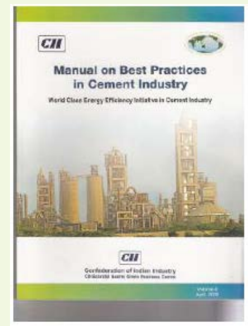
CII-Godrej GBC has been working with all the major cement plants in the country on the energy efficiency and sustainable front, resulting in significant benefits have been achieved and reported by these units. Some of these activities include:

1. Development of a technology roadmap to make the Indian cement industry pursue a low carbon growth path by 2050.
2. Facilitating cement plants in achieving PAT (Perform, Achieve and Trade program of BEE) targets in a cost-effective manner.
3. Developing a website to accelerate net zero transition in the industry.
4. Reducing carbon emissions from the sector by facilitating electrification of trucks used by the sector.
5. Conducting detailed energy audits and energy benchmarking studies to identify the potential and opportunities for improving the performance and reduce the energy consumption.
6. Supporting cement plants in increasing alternative fuel consumption by identifying the waste generators and waste availability.
7. Greenhouse gas (GHG) inventorization and lifecycle assessment (LCA) studies.
8. Green product (GreenPro) certification and green company (GreenCo) assessment services.
9. Organizing national and international missions to facilitate the industry to achieve excellence in energy and environment.
10. Organizing an annual international conference “Green Cementech” to provide a platform for knowledge dissemination for the benefit of the cement industry.

Publications By CII-GBC as Part of World-Class Energy Efficiency in Cement Plants

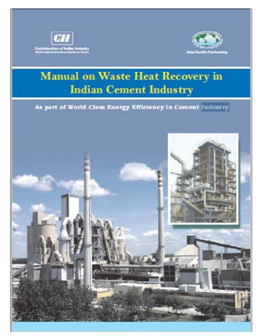
Manual on Best Practices in Cement Industry

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



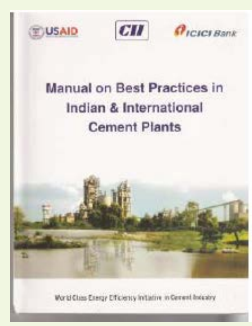
Manual on Waste Heat Recovery in Indian Cement Industry

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.



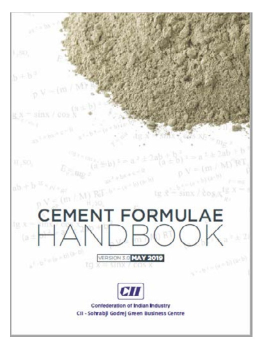
Manual on Best Practices in Indian & International Cement Plants

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.



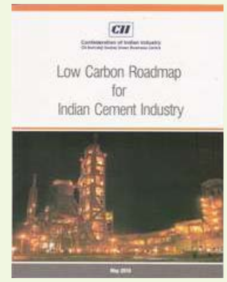
Cement Formulae Handbook

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.



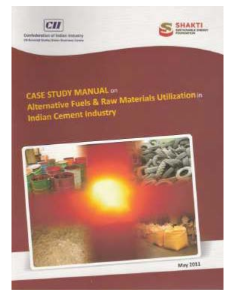
Low Carbon Roadmap for Indian Cement Industry

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.



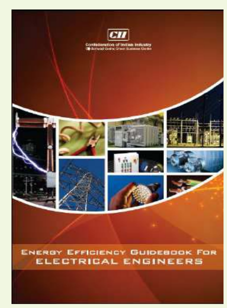
Case study Manual on Alternative Fuels & Raw Materials Utilization in Indian Cement Industry

The purpose of this manual is to act as a catalyst for promoting increased use of alternative fuels & 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.

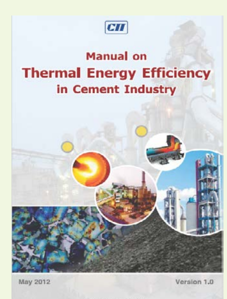


Low Carbon Technology Roadmap for the Indian Cement Industry

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 2024.

Conclusion

We feel that this Energy Benchmarking Version 6.0 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.

Contact Details:

Mr. P. V. Kiran Ananth

Deputy Executive Director
Confederation of Indian Industry
CII-Sohrabji Godrej Green Business Centre
Survey No. 64, Kothaguda Post, near HITEC City
Hyderabad- 500084, India.
Phone : +91 40 4418 5152
e-mail: kiran.ananth@cii.in
W: www.cii.in / www.greenbusinesscentre.com

Notes

B20 India Secretariat

Confederation of Indian Industry

CII - Sohrabji Godrej Green Business Centre
Survey No 64, Kothaguda Post, Hyderabad 500 084
Tel: +91 40 44185152; Fax: +91 40 44185189
Email: kiran.ananth@cii.in / k.muralikrishnan@cii.in
Website: www.greenbusinesscentre.com / ww.cii.in