Confederation of Indian Industry

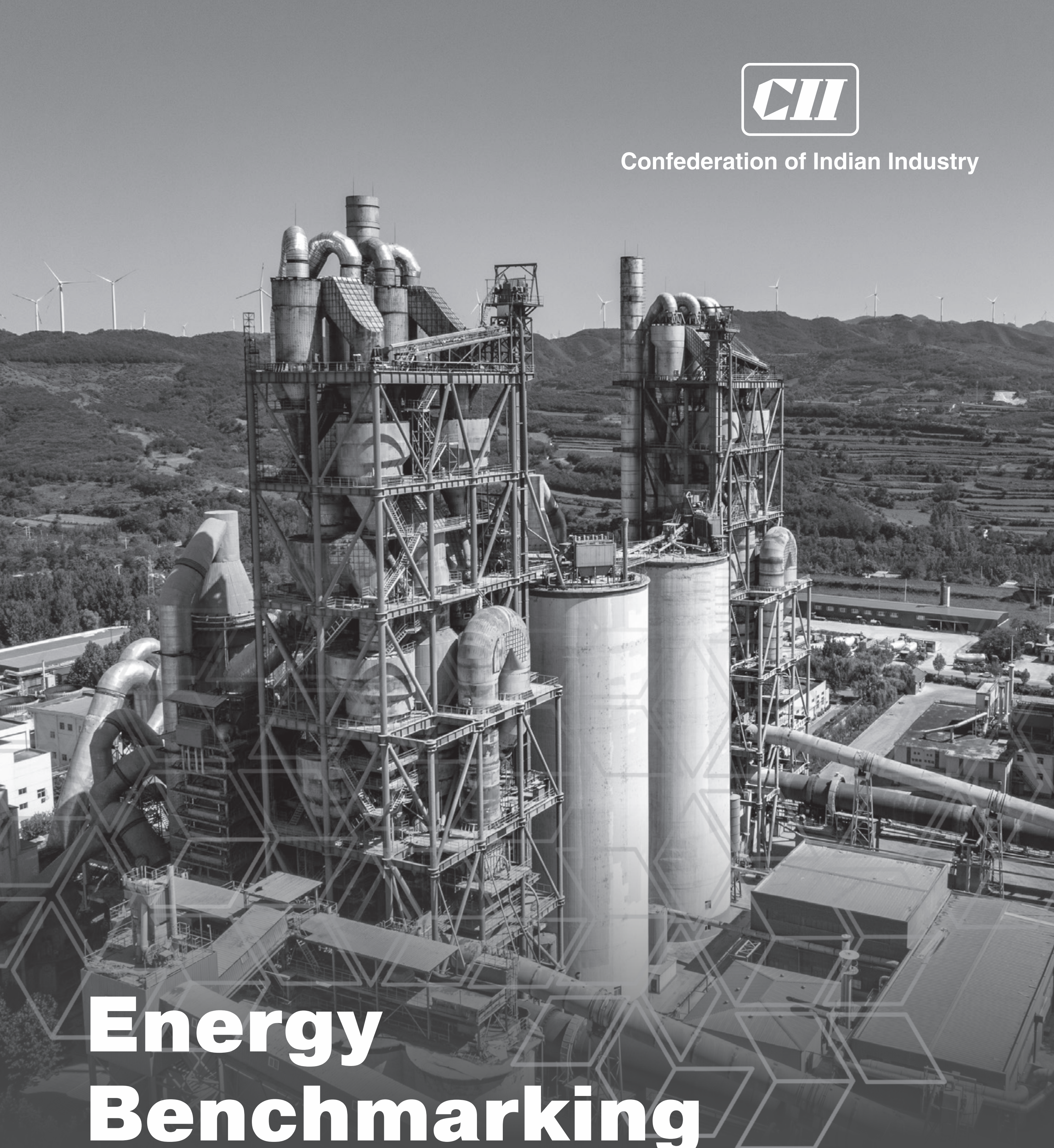
Energy Benchmarking

for the Indian Cement Industry

May 2025

Version 7.0

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.

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CII - Sohrabji Godrej Green Business Centre

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FOREWORD

As the climate crisis intensifies, it has become imperative for businesses to address their energy consumption, reduce greenhouse gas emissions, and transition toward more sustainable operations. Improving energy efficiency is a key strategy in this transition—it not only helps cut emissions but also reduces operational costs and enhances competitiveness.

Energy benchmarking plays a vital role in this process by enabling organizations to measure, monitor, and compare energy usage across different systems, equipment, and facilities. First introduced in 2014, this manual has been regularly updated to reflect evolving practices and technologies, marking a decade of progress with this latest edition.

CII Sohrabji Godrej Green Business Centre (CII-GBC), under its World Class Energy Efficiency initiative for the cement sector, has been consistently publishing manuals, case study booklets, and other resources to disseminate information on the latest trends, best practices, and emerging technologies relevant to the industry.

It is my pleasure to introduce the seventh edition of the publication Energy Benchmarking for Cement Industry (version 7.0). This updated version includes the latest energy consumption data and highlights best practices across the sector. It is designed to serve as a valuable resource for cement industries around the world striving to enhance energy efficiency and minimize their environmental footprint.

The Indian cement industry stands out as one of the top performers globally. The top 10 cement plants in India demonstrate remarkable energy efficiency, with electrical specific energy consumption below 67 kWh/MT of cement and thermal specific energy consumption below 690 kCal/kg of clinker. The most efficient Indian cement plant has achieved energy consumption levels of 56.1 kWh/MT of cement and 670 kCal/kg of clinker.

This publication will serve as a valuable resource for the cement industry by establishing baseline metrics, identifying areas for improvement, and enabling organizations to make informed decisions and implement targeted strategies to optimize energy performance.

I would like to express my sincere appreciation to all the cement plants that shared their performance data and best practices, making this publication possible. Let us continue to collaborate toward a sustainable future and strive to achieve a net-zero cement sector.

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

Ajay Kapur
Chairman, Green Cementech 2025 and
Managing Director, Ambuja Cements Limited
(Adani Group)

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ACKNOWLEDGEMENT

CII-Sohrabji Godrej Green Business Centre extends its sincere and special gratitude to the entire Indian cement industry for their continuous support in this initiative by providing the necessary data for this study, thereby enhancing the usefulness of this manual for all stakeholders.

We extend our heartfelt thanks to all national cement technical experts and associations for generously contributing their time, inputs, and suggestions toward the developing of this manual. The interactions and deliberations with industry leaders, suppliers, and sector experts made this entire exercise a truly rewarding experience for CII.

EXECUTIVE SUMMARY

The Indian cement industry continues to demonstrate global leadership in environmental stewardship and energy efficiency. The levels of energy efficiency in some Indian cement plants are amongst the best in the world, underscoring the industry's proactive approach to sustainability and adoption of cutting-edge technologies.

Despite this progress, a significant potential for further improvement remains - especially through the deployment of advanced energy-efficient technologies and operational best practices in both new and existing facilities. Energy benchmarking serves as a powerful tool in this journey, enabling plants to assess their current performance, identify gaps, and benchmark themselves against top-performing peers. It also facilitates the identification and replication of best practices and technologies across the sector.

Since the release of the first version in 2014, the benchmarking initiative has played a pivotal role in promoting energy efficiency across the cement industry. Over the past eleven years, Indian cement plants have made significant progress, as evidenced by declining energy consumption and the growing adoption of clean technologies.

This updated version is based on extensive data collected through a detailed questionnaire shared with over 100 cement plants across the country. The data spans all key sections of the cement production process—from raw material handling to clinkerization and cement grinding—enabling comprehensive sectional analysis and benchmarking. For each section, the manual outlines the parameters contributing to achieving the best specific energy consumption (SEC), providing actionable insights for plants to improve their own performance.

Between 2014 and 2025, the sector has achieved remarkable improvements:

- Average electrical SEC has declined from 88 to 73 kWh/MT of cement
- Average clinkerization power reduced from 65 to 50 kWh/MT of clinker
- The top 10 plants now operate at less than 67 kWh/MT (electrical) and under 695 kcal/kg (thermal)
- Best-in-class specific energy consumption has reached 56.1 kWh/MT cement and 670 kcal/kg clinker.
- Higher Thermal Substitution Rates (TSR), averaging 7%, with a best-case of 38%.
- WHR installed capacity increased from 240 MW to 1,289 MW.

Key drivers of this progress include:

- Deployment of energy-efficient technologies such as VRMs, HPRGs, Energy efficient fans, latest generation clinker coolers, hot air recirculation, energy efficient cyclones and high-efficiency separators.
- Reduction in clinker factor
- Installation of pre-processing and co-processing platforms
- Adoption of Industry 4.0 solutions for process optimization.

The average thermal and electrical energy consumption in the Indian cement sector is 740 kcal/kg clinker and 73 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 understand the extent of difference in their performance as compared to the best-performing plants, as well as the root cause for the differences.

Section wise best identified numbers are as below:

Table 1: Benchmarking numbers

S.No.	Section	Unit	Specific Energy Consumption (SEC)
1	Crusher	kWh/MT Limestone	0.6
2	Raw Mill – VRM	kWh/MT Raw Meal	10.6
3	Raw Mill – Roller Press	kWh/MT Raw Meal	10.4
4	Coal Mill – VRM-Pet Coke Grinding	kWh/MT Pet Coke	33.9
5	Coal Mill – VRM Coal Grinding	kWh/MT Coal	21.2
6	Six Stage Preheater - Kiln SEC (with WHRS)	kWh/MT Clinker	16.8
7	Six Stage Preheater Up to Clinkerization	kWh/MT Clinker	41.4
8	Thermal SEC (6 Stages without TSR)	kCal/kg Clinker	670
9	Thermal SEC (6 Stages with 13% TSR)	kCal/kg Clinker	682
9	Five Stage Preheater- Kiln SEC	kWh/MT Clinker	20.1
10	Thermal SEC (5 Stages without TSR)	kCal/kg Clinker	694
11	Cement Mill – VRM (PPC Grinding)	kWh/MT Cement	18.8
12	Cement Mill – VRM (OPC Grinding)	kWh/MT Cement	22.3
13	Cement Mill VRM (PSC Grinding)	kWh/MT Cement	31.1
14	Ball Mill (PPC Grinding)	kWh/MT Cement	25.3
15	Ball Mill + HPRG (PPC Grinding)	kWh/MT Cement	18.6
16	Packing Section	kWh/MT Cement	0.7
17	Overall SEC	kWh/MT Cement	56.1

Table 2 : Best achieved values

S.No	Parameters	Unit	Benchmarking numbers
1	Preheater outlet temperature (6 stage)	˚C	230
2	Preheater losses (excluding radiation and dust loss)	kCal/kg Clinker	110
3	Temperature drop across TAD	˚C	20
4	Phase density in Pet coke	kg Pet coke/kg Air	5.9
5	Kiln Volumetric loading	TPD/m^3	7.8
6	Overall WHRS efficiency (maximum)	%	21.3
7	Maximum AF Consumption (TSR)	%	38
8	Preheater fan specific power with WHRS (Six Stage)	kWh/MT Clinker	4.6
9	Preheater fan specific power without WHRS (Six Stage)	kWh/MT Clinker	3.4
10	Cooler vent fan specific power with WHRS	kWh/MT Clinker	0.5
11	Cooler vent fan specific power without WHRS	kWh/MT Clinker	0. 2
12	Specific power of cooler fans	kWh/MT Clinker	3.1
13	Reverse Air Bag House (RABH) fan specific power	kWh/MT Clinker	1.1
14	Specific Power of Raw mill fan (VRM)	kWh/MT Raw Meal	3.6
15	Renewable energy installed capacity (on site)	MW	29
16	Specific power generation from WHR	kWh/MT clinker	43

Table 3 : Overall Improvement Journey of Indian Cement Industry in last 10 years

S. No	Plant Section	Unit	Benchmarking 2014	Benchmarking 2025	Improvement (%)
1	Crusher (Single stage) SEC	kWh/MT Limestone	0.7	0.6	19
2	Raw Mill (VRM) SEC	kWh/MT Raw Meal	13.3	10.6	20
3	Coal mill (VRM) SEC -coal grinding	kWh/MT Coal	23.9	21.2	11
4	Thermal SEC - 5 stage PH	kCal/kg Clinker	707	694	2
5	Thermal SEC - 6 stage PH	kCal/kg Clinker	686	670	2
6	Cooler vent fan SEC	kWh/MT Clinker	0.5	0.20	60
7	RABH fan SEC	kWh/MT Clinker	1.6	1.1	33
8	SEC up to Clinkersiation-6 Stage	kWh/MT Clinker	46	41.4	10
9	Preheater exit gas temperature	˚C	245	230	6
10	Pressure drop across 6 stage preheater	mmWC	450	350	22
11	Cement mill VRM (PPC)	kWh/MT Cement	21	18.6	11
12	Compressor SEC up to Clinkerization	kWh/MT Clinker	0.9	0.7	17
13	Compressor SEC - Cement grinding & packing	kWh/MT Cement	0.8	0.7	13
14	Overall SEC Average	kWh/MT Cement	88	73	17
15	AF Thermal Substitution Rate (TSR) Indian Cement sector average value	%	3	7	133
16	Highest achieved AF TSR in a Cement plant	%	21	38	81
17	Total WHRS installation in Indian cement plants	MW	240	1,289	437

1

Introduction

INTRODUCTION

1.1 Indian Cement Industry- Paving the Way Forward

India is the world's second-largest cement producer, accounting for over 8% of the global installed capacity. With a critical role in supporting national infrastructure, housing, and industrial development, cement remains a vital material in India's growth story. The sector is also globally significant, ranking as the second-largest producer of cement in the world, after China.

As of 2024, the total installed cement production capacity in India stands at approximately 690 million tonnes per annum (MTPA). This capacity is spread across more than 200 large cement plants and numerous mini plants. The actual cement production in FY 2023-24 was around 420–430 million tonnes. The top 10 cement companies account for around 70% of the total cement production in India.

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

Financial Year	Production of Cement in Million Tonnes
2021-22	360.2
2022-23	391.4
2023-24	426.3
2024-25 (up to November 2024)	282.6

The Indian cement sector is expected to witness robust growth over the coming decade, driven by:

- Massive infrastructure development under government schemes such as PM Gati Shakti, Bharat Mala, Smart Cities Mission, and AMRUT.
- Rapid urbanization and increasing demand for affordable housing, especially under the Pradhan Mantri Awas Yojana (PMAY).
- Industrial growth and rising investment in commercial and logistics parks, data centres, and transport infrastructure.

The Indian cement sector's capacity is expected to expand at a compound annual growth rate (CAGR) of 4-5% over the four-year period up to the end of FY27. Cement consumption is expected to reach 450.78 million tonnes by the end of FY27. India's cement production for FY25 is expected to grow by 7-8% driven by infrastructure-led investment and mass residential projects[2]

While growth prospects remain strong, the industry faces increasing pressure to operate sustainably. With rising input costs, decarbonization imperatives, and energy intensity being key challenges, the Indian cement sector must continue to adopt best-in-class technologies and practices to remain competitive. Energy benchmarking emerges as a crucial tool in this context—helping plants improve operational efficiency, reduce costs, and align with global sustainability goals.

This seventh edition of the Energy Benchmarking Manual is designed to support this journey, offering stakeholders valuable insights into energy performance trends, best practices, and emerging technologies that can guide future improvements.

1 https://dpiit.gov.in/sites/default/files/annualReport_English_21February2025.pdf
2 Indian Cement Industry Analysis | IBEF

The cement industry has seen significant technological advancements in the areas of quality assurance, process control, and production, driving improvements in efficiency, sustainability, and profitability.

With a strong commitment to sustainability and innovation, the industry is well-equipped to sustain its status as a leading global producer of cement.

1.2 Decarbonization commitments by Indian Cement Companies

The Indian cement sector is undergoing transformative changes, emphasizing product innovation and sustainable practices. Leading cement companies are focusing on product innovation through the development of specialized cement variants, such as water-resistant, high-strength, and eco-friendly formulations, to meet evolving construction requirements. A notable focus is on energy efficiency, with advancements in preheater cyclones and calciners aimed at reducing thermal energy consumption. The industry is swiftly transitioning to blended cements to significantly cut CO_2 emissions. Ongoing modernization of existing plants further enhances operational efficiency and minimizes the carbon footprint.

Major players and their carbon reduction initiatives:

Table 5 : Major players and their carbon reduction initiatives

Company	Scope 1 GHG Emission Reduction Target	Scope 2 GHG Emission Reduction Target	Base Year	Target Year	Additional Commitments
UltraTech Cement[3]	27% per ton of cementitious material	69% per ton of cementitious material	2017	2032	Includes biogenic emissions/ removals from bioenergy feedstocks
ACC[4]	21.3% per ton of cementitious material	48.4% per ton of cementitious material	2018	2030	Aims for carbon neutrality by 2050
Ambuja Cements[5]	21% per ton of cementitious material	21% per ton of cementitious material	2020	2030	CO_2 intensity reduction from 531 kg to 453 kg/ton; Science Based Targets aligned with Net Zero ambition
Dalmia Cement[6]	32% reduction per tonne of cementitious material	61.9% reduction per tonne of cementitious material	2019	2034	Committed to becoming carbon negative by 2040; EP100 & RE100 by 2030. 100% TSR by 2035

3 Case Study - UltraTech Cement Limited - Science Based Targets Initiative
4 ACC - Annual Report 2021-22
5 Ambuja Cements plans net zero emissions target through SBTi
6 https://www.unescap.org/sites/default/files/ESBN%20Slides%20Keynote%20Mr%20Singhi.pdf

JK Cement[7]	From 553 $kgCO_2$/ton to 465 $kgCO_2$/ton (16% reduction)	21.7% reduction	2021-22	2030	Committed to Science Based Targets Clinker factor reduction 65% by FY2023-Q2 Green energy mix 75% by FY2030
JK Lakshmi Cement[8]	586 kg CO_2 per ton of cement equivalent (down from 599 kg in FY2022-23)		—	2047	Committed to EP100 and RE100 by 2040
Shree Cement[9]	12.7% per ton of cementitious material	27.1% per ton of cementitious material	2019	2030	—

1.3 Energy Efficiency - Indian Cement Industry

With the adoption of massive modernisation and assimilation of state-of-the-art technology, Indian cement plants are today the most energy-efficient and environment-friendly and are comparable to the best in the world in all respects, whether it is kiln size, technology, energy consumption, or environment-friendliness.

The cement industry contributes to environmental cleanliness by consuming hazardous wastes like Fly Ash from Thermal Power Plants and the granulated Slag produced by Steel manufacturing units, and using alternative fuels and raw materials, using advanced and environment-friendly technologies. Numerous factors influence the energy efficiency of the Indian cement industry, including the availability of technology, economic feasibility, governmental policies, associations, and financing models.

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, Gulbarga 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. Adopting new technologies and upgrading older facilities to the latest energy-efficient technologies have also contributed to improved energy efficiency.

7 jkcement.com/frontTheme/pdf/JKCL-sustainability-report-21-22.pdf
8 JK Lakshmi Cement joins RE100 and EP100 climate initiatives from International Cement Review
9 16th-sustainability-report-shree-cement-2019-20.pdf

Table 6 : The performance of top 10 plants in Specific heat consumption

S.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	670	671	682	682	688	688	691	692	693	694
2	No of Stages	No	6	6	6	6	6	6	6	6	6	5
3	TSR	%	0	0.8	12.8	1.3	9	8.8	6.5	9	10.4	0

Table 7 : The performance of top 10 plants in Specific Electricity consumption up to Clinkerization

S.No.	Section	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
1	SEC up to Clinkerization	kWh/ MT clinker	41.4	43.1	43.3	43.5	45.2	45.3	45.5	46.1	46.7	46.9

Table 8 : The performance of top 10 plants in overall cement Specific Electricity consumption

S.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	56.1	60.3	60.7	62.5	64.7	64.9	66.1	66.2	67.5	66.7

With the rise in fuel prices, energy costs are also increasing, making it essential for manufacturers to implement energy-efficient measures to reduce both energy and production costs. The Bureau of Energy Efficiency (BEE), under the Ministry of Power, has mandated a reduction in specific energy consumption for the most energy-intensive industries, including the cement industry. This mandate has encouraged manufacturers to exceed their specific energy consumption improvement targets.

Following are the levers identified in low carbon technology roadmap to reduce the specific emission intensity:

1) Thermal and electrical energy efficiency improvement
2) Increasing alternative fuel and raw material utilization
3) Reducing the clinker factor
4) Installation of WHR and RE
5) Adoption of new technologies like – oxygen enrichment and CCUS

One of the key factors influencing energy efficiency and emissions in the cement industry is the clinker factor. Clinker, the main component of cement, requires a significant amount of energy to produce. Therefore, reducing the clinker factor is crucial for improving energy efficiency, cutting emissions, and lowering production costs.

The industry is also increasingly adopting alternative fuels to reduce reliance on fossil fuels, as well as using alternative raw materials to preserve the limestone reserves.

Additionally, Waste Heat Recovery (WHR) is a vital technology for enhancing the energy consumption of cement plants. WHR systems capture waste heat from kiln and cooler exhaust gases and convert it into electricity or useful heat, thereby reducing overall energy consumption.

Several emerging technologies aim to further reduce carbon emissions in the cement sector. These include carbon capture and storage (CCS), carbon dioxide mineralization, renewable energy, energy storage, green hydrogen, and the use of electric vehicles.

A decarbonization study conducted by CII-GBC for the Indian cement sector indicates that the industry can reduce its overall emission intensity by 30% by 2040, compared to the 2017 baseline. Measures related to energy efficiency, circularity, and material efficiency—such as improving the clinker factor and increasing the use of additives in cement production—will play a critical role in achieving this goal.

Key Findings from the Decarbonization Study:

- **Role of Advanced Technologies:** Advanced technologies are expected to play a pivotal role in the decarbonization of the cement sector. However, broader adoption will require stronger support and collaboration from various stakeholders to drive deeper market penetration.
- **Circularity and Material Efficiency:** Measures such as reducing the clinker factor and increasing the use of additives in cement manufacturing are projected to significantly contribute to emission reductions—accounting for approximately 33% under the Business-As-Usual (BAU) scenario and 28% under Deep Decarbonization Pathways.
- **Electrification and Renewable Energy Adoption:** The transition to electrification and increased use of renewable energy sources, such as solar photovoltaic and wind power, is estimated to contribute around 26% under the BAU scenario and 21% under Deep Decarbonization Pathways. These efforts aim to reduce and offset emissions from fossil fuel-based power generation.
- **Alternative Fuels and Biomass Utilization:** The sector has made notable progress in utilizing alternative fuels, including municipal solid waste (MSW), refuse-derived fuel (RDF), and other hazardous wastes. As a result, the contribution of biomass and alternative fuels is projected to be 13% under the BAU scenario and 17% under Deep Decarbonization Pathways.

2 Benchmarking In Cement Industry

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 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. Most 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 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 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 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.

CII - Sohrabji Godrej Green Business Centre (CII-GBC) developed a Benchmarking Webtool for the Cement Sector in 2023. Webtool is a digital platform designed to help cement plants assess, compare with the best plant cluster wise and nation wise. Thus improving their both thermal and electrical specific energy consumption. Webtool also has information on latest specific energy consumption, latest renewable energy and WHRS installed capacity numbers.

Version 2 of the webtool was launched in 2024.

- 1st ever country specific net zero roadmap webtool for cement sector
- GHG Emissions Calculator
- Scope 1 & Scope 2 Emissions (Calcination, Coal, AFR, Biomass, CPP, Grid, etc.)
- Role of various levers such as Clinkerization SEC, Thermal SEC, AFR, Clinker factor, WHRS, RE, Grid, CPP, New technologies, etc. in achieving net zero.

3 Specific Energy Consumption Of Top 10 Cement Plants In India

Specific Energy Consumption Of Top 10 Cement Plants In India

3.1 Specific Electrical Energy Consumption- Cement Plant

Table 9 : Overall Electrical SEC-Top 10 cement plants

S.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**	**60.3**	**60.7**	**62.5**	**64.7**	**64.9**	**66.1**	**66.2**	**66.7**	**67.5**
	Overall Clinker Factor	-	0.63	0.61	0.63	0.76	0.77	0.64	0.66	0.81	0.66	0.69
1	Crusher	kWh/MT Limestone	1.8	1.6	1.4	1.5	0.7	1.2	0.7	1.1	1.0	0.8
2	Raw mill	kWh/MT Raw meal	15.8	14.1	16.0	13.9	12.7	10.9	20.7	14.6	18.1	12.9
3	Coal mill	kWh/MT Coal	29.9	51.4	35.1	35.6	25.0	57.7	29.7	30.7	41.7	42.7
4	Kiln	kWh/MT clinker	19.1	26.7	20.5	21.3	18.3	20.5	22.0	23.3	21.7	28.2
5	Total SEC up to Clinkerization	kWh/MT clinker	49.9	58.7	53.2	46.9	43.1	45.0	56.8	51.0	54.0	52.8
6	Cement Mill	OPC - kWh/MT Cement	-	-	-	26.8	29.9		30.8	25.8	-	36.4
		PPC - kWh/MT Cement	20.4	23.0	25.9	20.8	30.8	31.5	26.6	23.6	-	27.8
		PSC - kWh/MT Cement	-	-	-	-	32.6	41.4	-	-	-	39.1
		Others - kWh/MT Cement	28.5	-	-	26.5	-	32.8	-	-	-	-
		Overall - kWh/MT Cement	22.3	23.0	25.9	25.2	30.2	34.1	27.5	24.0	29.8	30.1
7	Packing plant	kWh/MT Cement	1.3	1.4	1.3	0.9	0.7	0.9	1.1	0.8	1.4	0.9
8	Utilities & Others	kWh/MT Cement	1.1	-	-	0.8	0.6	1.1	-	-	1.5	-

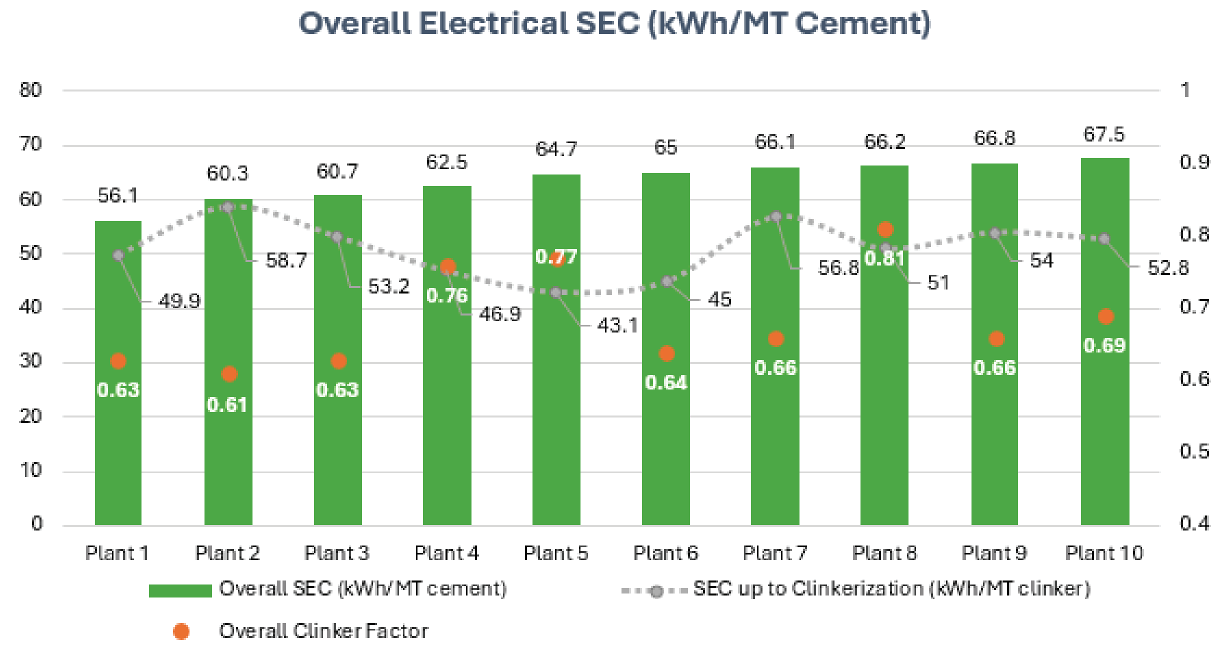

Figure 1: Overall Electrical SEC of top Cement plants in India

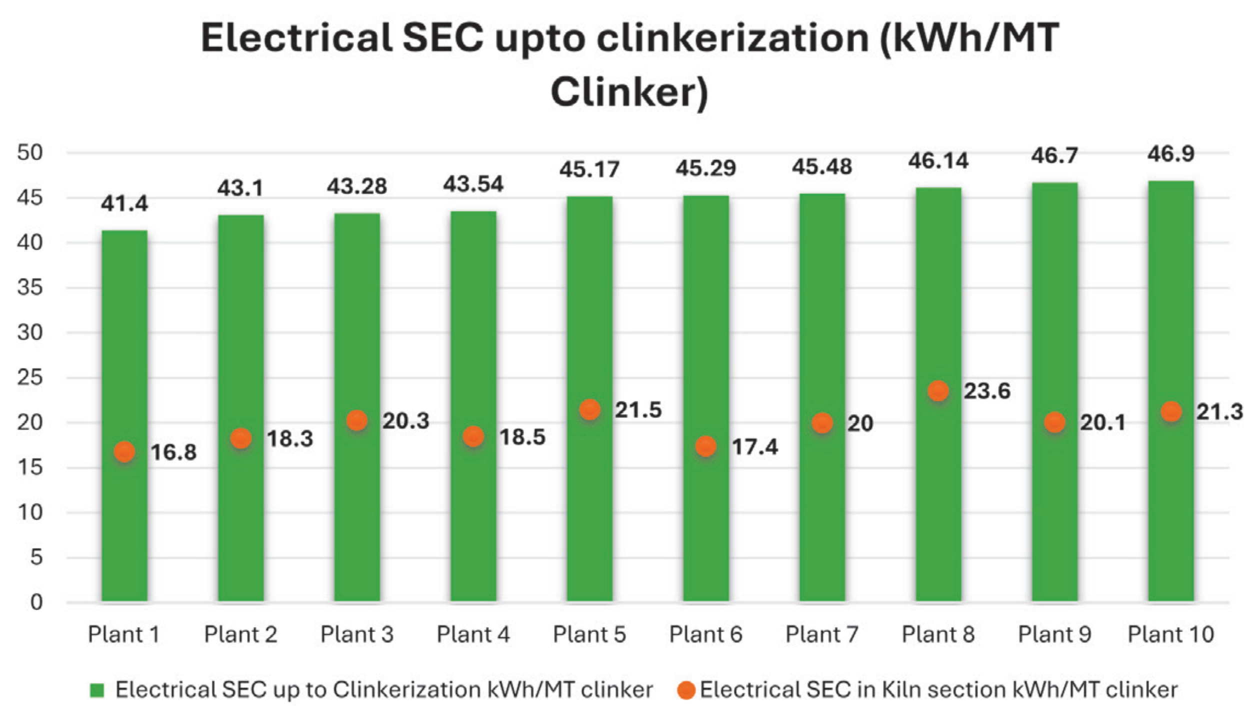

Figure 2 : SEC up to clinkerization of top Cement plants in India

Table 10 : Electrical SEC up to Clinkerization - Top 10 cement plants

S.No.	Section	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
	SEC up to Clinkerization	kWh/MT clinker	41.4	43.1	43.3	43.5	45.2	45.3	45.5	46.1	46.7	46.9
1	Crusher	kWh/MT material	1.1	1.3	1.1	1.2	1.2	1.4	1.7	0.9	0.9	0.9
2	Raw Mill	kWh/MT material	11.6	12.7	10.2	12.6	11.5	12.9	12.7	12.4	14.0	13.9
3	Coal Mill	kWh/MT material	36.3	28.6	50.3	32.7	64.8	42.6	35.8	34.8	42.1	35.6
4	Kiln	kWh/MT clinker	16.8	18.3	20.3	18.5	21.5	17.4	20.0	23.6	20.1	21.3
5	Auxiliaries	kWh/MT clinker	0.9	1.5	-	1.3	-	1.9	1.3	-	-	-

3.2 Specific Thermal Energy Consumption

Table 11 : Specific Heat Consumption

S.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	670	671	682	682	688	688	691	692	693	694
2	No of Stages	No	6	6	6	6	6	6	6	6	6	5
3	TSR	%	0.0	0.8	12.8	1.3	9.1	8.8	6.5	9.0	10.4	0

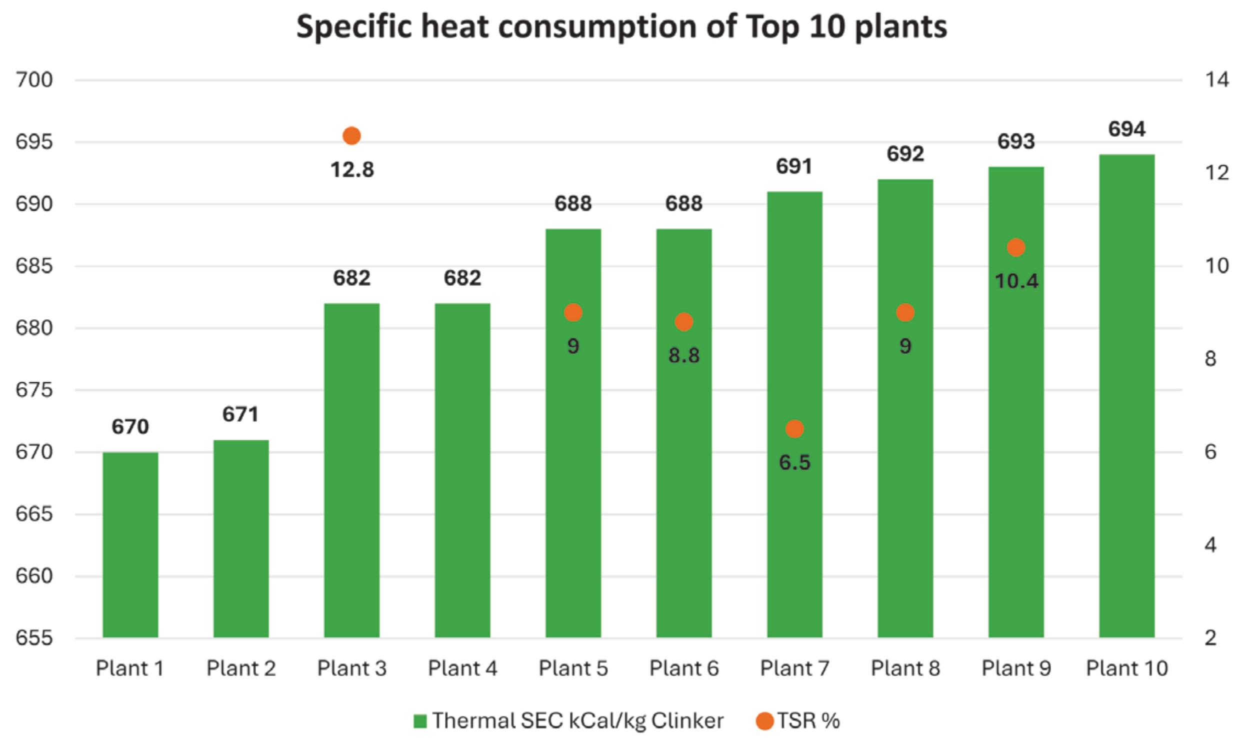

Figure 3 : Thermal SEC of top cement plants in India

3.2.1 Specific Heat Consumption Breakup For Plant 1 (670 kCal/kg Clinker)

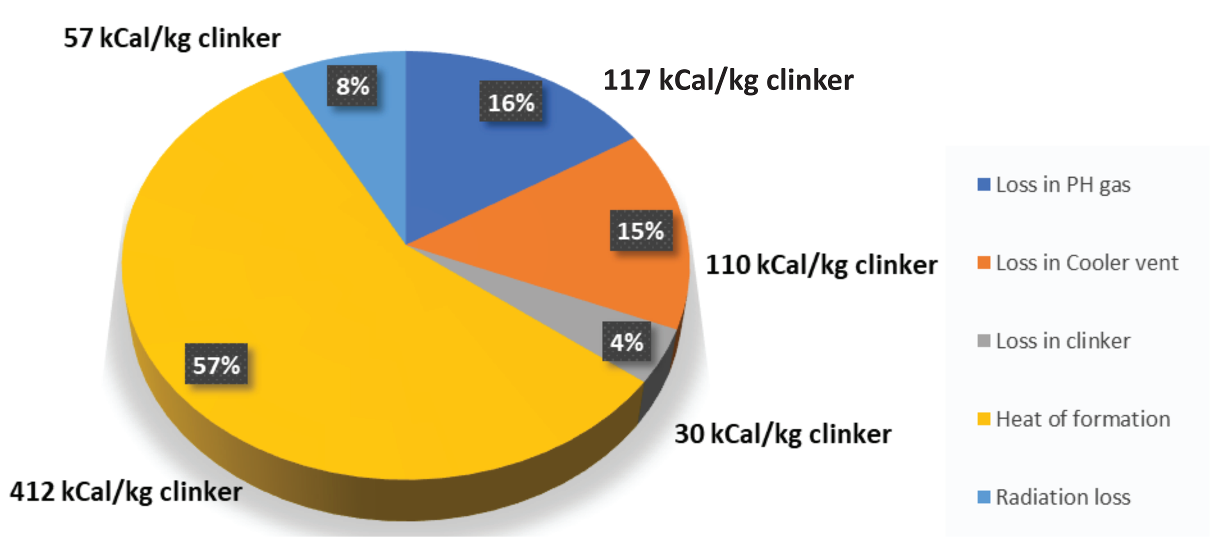

Figure 4:-Thermal SEC Break up of best cement plant

3.3 Alternative Fuel Utilization

Table 12: Alternative Fuel Utilization vs Thermal SEC of Top 10 cement plants

S.No.	Parameter	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Plant 10
1	Overall thermal substitution rate (%)	38	27	25	25	21	18	18	16	15	13
2	Specific Heat Consumption (kcal/kg clinker)	790	770	763	760	762	745	739	744	705	699

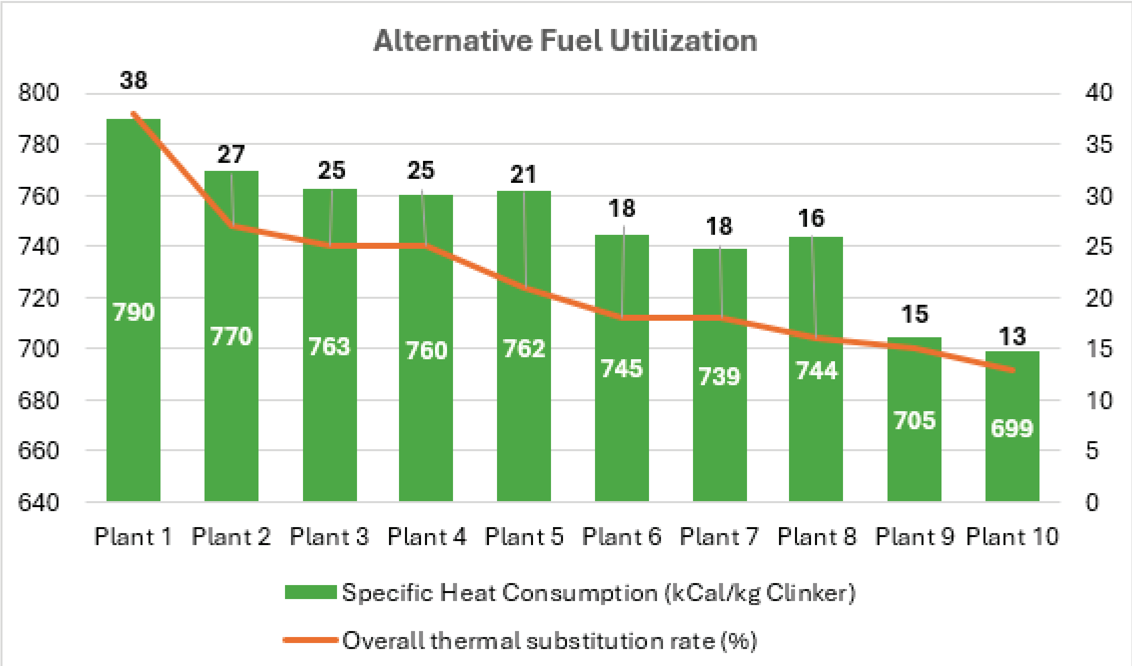

Figure 5: AF Utilization Vs Specific Heat Consumption

3.3.1 Specific Heat Consumption of cement plants with 1-5% TSR

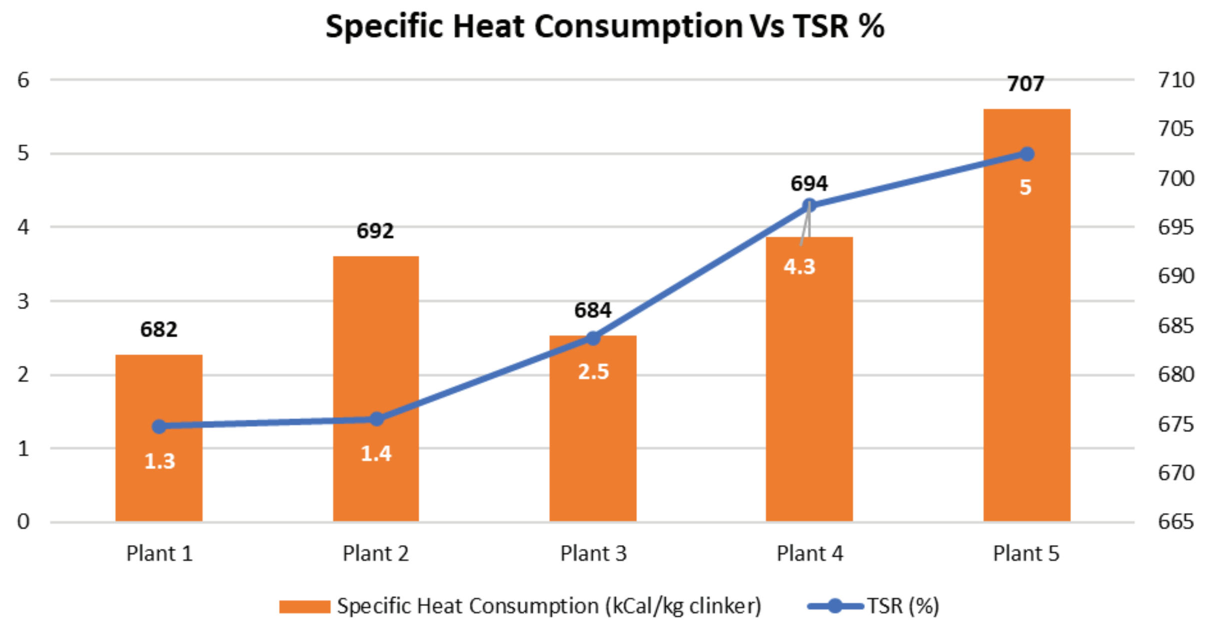

Figure 6: Specific Heat Consumption Vs TSR % - (1-5%)

3.3.2 Specific Heat Consumption of cement plants with 5 – 10% TSR

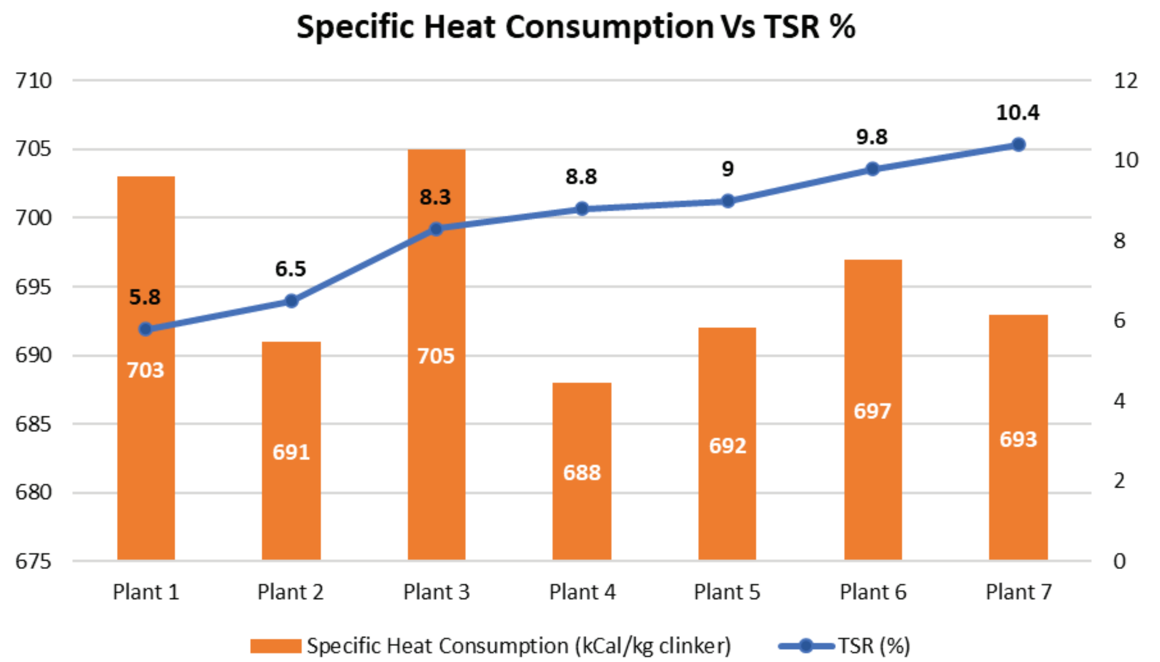

Figure 7: Specific Heat Consumption Vs TSR % - (5-10%)

3.3.3 Specific Heat Consumption of cement plants with 10 – 15% TSR

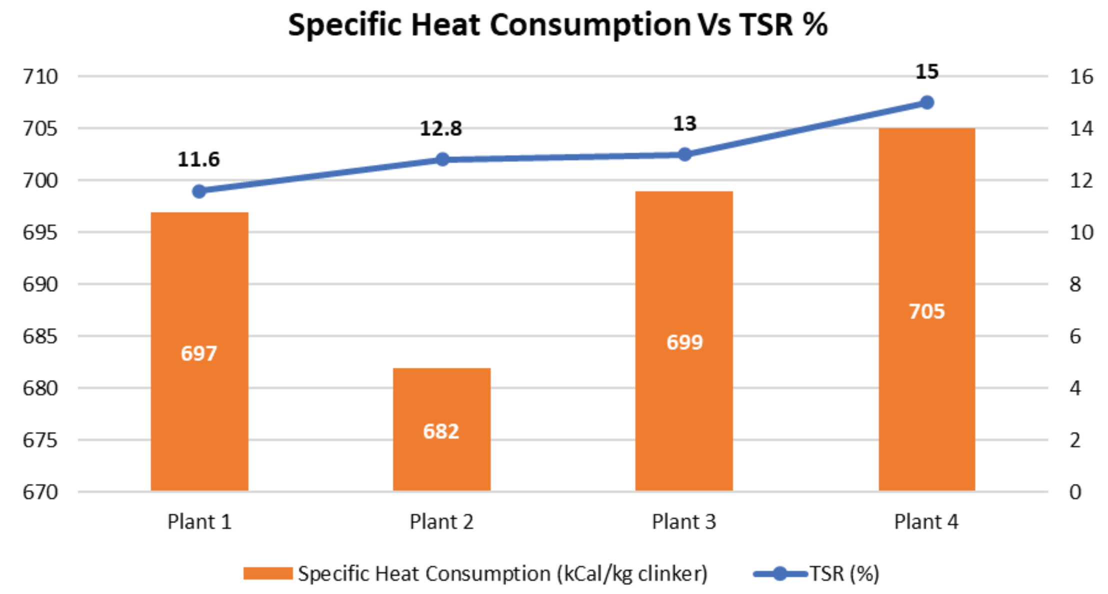

Figure 8: Specific Heat Consumption Vs TSR % - (10-15%)

3.3.4 Specific Heat Consumption of cement plants with 15 – 25% TSR

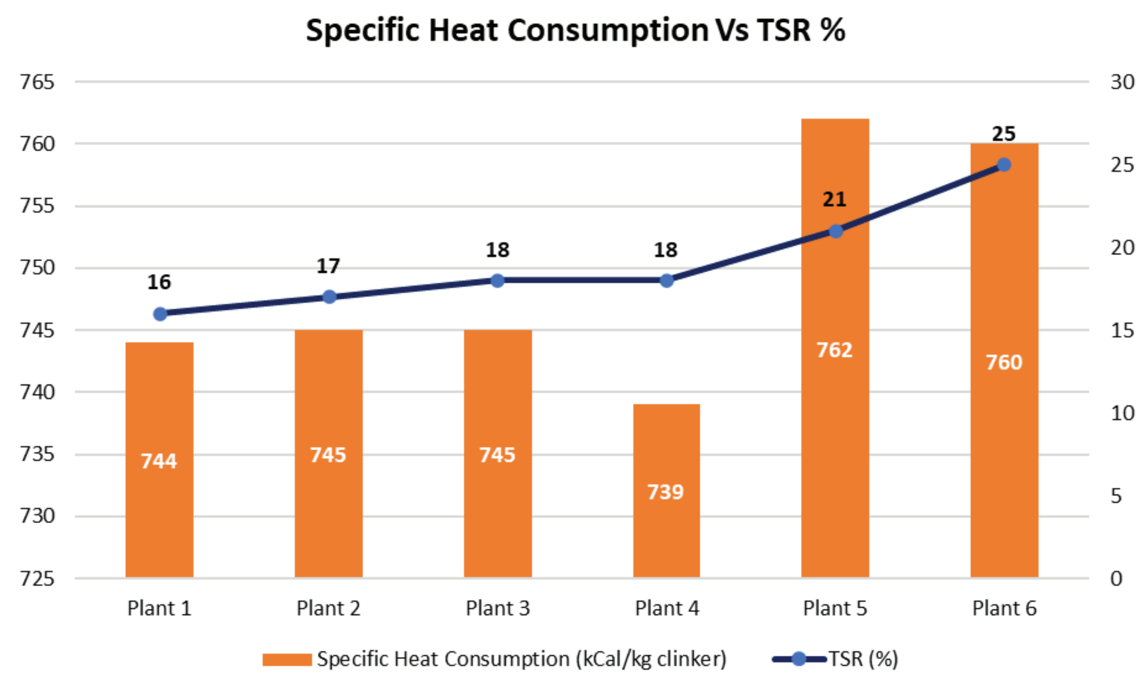

Figure 9: Specific Heat Consumption Vs TSR % - (15-25%)

4 Section Wise Benchmarking Numbers

Section Wise Benchmarking Numbers

4.1 Crusher Section

Table 13 : Benchmarking of Crusher Section

S. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
	Overall SEC	**kWh/MT Limestone**	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**0.8**
a	Crusher Main Drive	kWh/MT Limestone	0.20	0.3	0.4	0.3	0.4	0.3
b	Other auxiliaries	kWh/MT Limestone	0.4	0.3	0.3	0.4	0.3	0.5
1	Crusher Type (Gyratory/Jaw/ Impact/Roller etc)	-	Impact	Impact	Impact	Roll	Impact	Impact
2	No of stages (Eg. Single/ Two)	-	1	1	1	2	1	1
3	Material hardness (soft/medium/ hard)	-	Soft	Medium	Medium	Medium	Soft	Soft
4	Product Size (% oversize on 75 mm)	%	5.6	8	6.4	5	5	12
5	Design output	TPH	500	900	1,000	1,000	1,200	800
6	Operating output	TPH	463	905	943	750	1, 150	732
7	Material moisture	%	6.5	1	2.9	13.5	-	12.5

4.2 RAW MILL SECTION

4.2.1 RAW MILL SECTION – VRM CIRCUIT

Table 14: Benchmarking of Raw Mill Section-VRM Circuit

S.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
	Overall SEC	**kWh/MT Material**	**10.6**	**10.8**	**11.1**	**11.2**	**12.1**
a	Mill drive	kWh/MT Material	5.1	4.6	5.5	4.4	5.7
b	Mill fan	kWh/MT Material	3.9	5.0	3.9	5.0	5.1
c	Auxiliary	kWh/MT Material	1.6	1.2	1.7	1.8	1.3
1	Make	-	Pfeiffer	FLS	Pfeiffer	Loesche	Loesche
2	Type / Model	-	MPS5000B	ATOX 32.5	MPS3750B	LM 46.4	LM 36.41
3	Material Bond Index	kWh/ short ton	8	10	-	9	-
4	Material Hardness		Soft	Medium	Soft	Soft	Medium
5	Design output	TPH	500	180	220	320	250
6	Operating output	TPH	506	245	280	312	260
7	Product (% residue on 90 micron)	%	18.3	17	21	19.3	14.1
8	Feed Material moisture	%	2	5	2	1	6.2
9	Mill DP	mmwc	494	464	530	-	510
10	Pressure drop across separator	mmwc	-	-	-	-	180
11	Cyclone pressure drop	mmwc	95	100	87	110	110
12	Mill Fan Inlet pressure	mmwc	-715	-960	-722	-920	-930
13	Mill fan operating flow	m3/hr	7,45,226	2,94,000	3,95,550	5,81,000	4,50,000
14	Mill fan speed control type		VFD	GRR	VFD	VFD	SPRS
15	Mill fan operating efficiency	%	76.5	90	80.1	83	81
16	False air in the circuit	%	17.2	17	15	15	15.4
17	Separator loading	gm/m^3	679	683	705	604	649
18	Nozzle ring velocity	m/s	44	51	38.8	49	54
19	Dam ring height	mm	-	120	85	90	95
20	Table Diameter	mm	-	3,250	-	4,600	3,600

4.2.2 RAW MILL SECTION-ROLLER PRESS CIRCUIT

Table 15: Benchmarking of Raw Mill Section-Roller Press Circuit

S. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
	Overall SEC	**kWh/MT Material**	**10.4**	**11.5**	**11.6**	**12.8**	**13.6**
a	Main drive	kWh/MT Raw meal	5.1	4.9	5.7	6.5	5.7
b	Mill separator fan	kWh/MT Raw meal	2.9	3.0	3.2	2.4	4.9
c	Auxiliary	kWh/MT Raw meal	2.4	3.6	2.7	4.0	3.0
1	Roller Press Make	-	FLS HRP 3.07	KHD RP VP-15-140/160		FLS HRP 3.0	KHD RP ZM 13-170/140
2	Bond index	kWh/ ton	-	8			7
3	Design output	TPH	2*300	200	400	300	230
4	Operating output	TPH	611	200	425	323	220
5	Product size (% on 90 micron)	%	16	13.5		16.7	14.6
6	Feed Material moisture	%	2.2	1.8	2.02	1	2
7	Separator type/ model	-	RAR M 52.5	-		RARL 40	DYNAMIC / SKS LC 3500
8	Separator loading	g/m^3	710	698	725	670	641
9	Cyclone pressure drop	mmwc	74	65	82	55	88
10	Separator Fan inlet pressure	mmwc	-556	-635	-670	-505	-690
11	Separator fan flow	m^3/hr	7,84,800	2,95,352	5,85,512	4,81,772	3,81,500
12	Separator fan speed control type		VFD	VFD	VFD	VFD	VFD
13	Separator fan operating efficiency	%	76.0	82.8	76.6	75.3	72.0

4.3 COAL MILL SECTION

4.3.1 COAL MILL SECTION–MIX COAL (VRM)

Table 16 : Benchmarking of Coal Mill Section–Mix Coal (VRM)

S.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
	Overall SEC	**kWh/MT Coal**	**21.2**	**22.2**	**23.6**	**26.1**	**28.6**
a	Mill drive	kWh/MT Coal	10.9	11.1	9.5	12.4	12.1
b	Mill vent fan / Bag	kWh/MT Coal	7.0	7.2	7.7	7.1	12.2
c	Booster fan	kWh/MT Coal	-	1.1	1.8	1.3	1.6
d	Auxiliary	kWh/MT Coal	3.3	2.8	4.5	5.3	2.7
1	Make	-	FLS	Loesche	Loesche	Pfeiffer	Loesche
2	Type / Model	-	ATOX 22.5	-	LM20.2	GYLM1700	LM26.3
3	Design output	TPH	40	47	30	25	30
4	Operating output	TPH	42	52	25	26.4	28
5	Product residue on 90 micron	%	12	8	12	12.5	12
6	Feed Material	%	12	10	7.5	12	7.5
7	Mill DP	mmwc	344	410	530	350	490
8	Pressure drop across bag filter	mmwc	110	100	125	120	105
9	Mill Fan inlet pressure	mmwc	-614	-655	-705	-650	-665
10	Mill fan operating flow	m^3/hr	1,54,000	1,55,000	85,845	73,700	1,20,305
11	Fan speed control type		VFD	VFD	VFD	VFD	VFD
12	Mill fan operating efficiency	%	76.4	76.0	84.6	76.3	80.2
13	False air in the circuit	%	19	16	16.3	23	19.7
14	Nozzle ring velocity	m/s	47	52	55	48	56

4.3.2 COAL MILL-PETCOKE GRINDING (VRM)

Table 17 : Benchmarking of Coal Mill-Petcoke Grinding (VRM)

S.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
	Overall SEC	**kWh/ MT Pet Coke**	**33.9**	**36.2**	**37.1**	**39.1**	**39.8**
a	Mill drive	kWh/ MT Pet Coke	15.9	18.9	17.2	16.9	20.4
b	Mill vent fan / Bag	kWh/ MT Pet Coke	12.3	12.3	11.6	16.2	15.1
c	Auxiliary	kWh/ MT Pet Coke	5.7	5.0	8.3	6.0	4.3
1	Make	-	FLS	Polysius	FLS	Loesche	Pfeiffer
2	Type / Model	-	Atox-27.5	-	Atox-25	LM-26.3D	MPS-3550 BK
3	Design output	TPH	65	38	50	45	90
4	Operating output	TPH	30	18	26	16	58
5	Product residue on 90 micron	%	2.5	3	3.5	4	1.5
6	Feed Material	%	7	6	5	6	5
7	Mill DP	mmwc	350	420	-	355	550
8	Separator type	-	RAKM-30	Dynamic	RAKM-LVT-27.5	LSKS	Dynamic
9	Pressure drop across bag filter	mmwc	80	110	130	115	110
10	Mill Fan inlet pressure	mmwc	-550	-580	-495	-750	-790
11	Mill fan operating flow	m^3/hr	2, 16, 160	1, 11,371	1, 13,000	1,45,000	3,09, 124
12	Fan speed control type		VFD	VFD	SPRS	VFD	VFD
13	Mill fan operating efficiency	%	79	75	77	81	76
14	False air in the circuit	%	19	16	18.6	22.2	19.5
15	Nozzle ring velocity	m/s	45.6	52	55	48	46.7

4.4 PYROSECTION

Table 18 : Benchmarking for Pyrosection (With WHRS)

S.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**	**16.8**	**17.4**	**17.4**	**18.3**	**18.5**	**20**	**20.3**	**20.5**
a	PH Fan	kWh/MT	4.7	4.9	5.7	5.2	4.1	5.3	4.9	7.0
b	RABH/RMBH fan	kWh/MT	1.7	1.4	1.5	1.5	1.1	1.1	2.2	0.9
c	Cooler fans	kWh/MT	3.6	3.9	5.0	4.9	4.9	4.9	4.6	4.1
d	Cooler vent fan	kWh/MT	0.9	0.8	0.7	0.4	0.9	1.5	0.5	1.7
2	Thermal SHC	kCal/kg	670	682	701	691	682	692	733	708
3	TSR	%	0	12.8	0.7	6.6	1.2	9	16.2	14.5
4	Kiln output rated	TPD	9,000	6,000	10,000	-	8,000	8,000	8,000	9,500
5	Kiln output operating	TPD	9,550	7,174	9,744	7,400	8,440	8,741	8,628	10,400
PREHEATER SECTION										
1	PH type (ILC/SLC)	-	ILC	ILC	ILC	ILC	ILC	ILC	ILC	ILC
2	No of PH strings	Nos.	2	2	4	2	2	2	2	2
3	No of stages	Nos.	6	6	6	6	6	6	6	6
4	PH exit O_2	%	2.5	2.6	2.8	2.5	2.8	3.3	2.8	2.7
5	PH exit temperature	°C	255	267	257	263	260	272	295	255
6	PH exit pressure	mmWC	-450	-345	-410	-460	-355	-490	-396	-630
7	PH top cyclone efficiency	%	96	96	95	95	95	95	93	93
8	PH fan inlet flow	Nm^3/kg	1.36	1.35	1.39	1.43	1.33	1.45	1.50	1.37
9	PH Fan inlet pressure	mmWC	-570	-474	-470	-525	-440	-624	-592	-780
10	PH fan operating efficiency	%	83	82	79.1	75	82.1	79.6	81	83
11	False air across PH	%	10.7	5.8	6.5	7.6	6.7	8.3	8.2	6.9
12	Kiln Bag house flow	Nm^3/kg clinker	1.93	1.62	1.67	1.80	1.69	1.86	1.71	1.80

13	Kiln Bag house pressure drop	mmWC	105	85	110	95	88	100	145	75
14	Kiln Bag house Fan Inlet pressure	mmWC	-148	-135	-155	-154	-152	-175	-248	-165
15	Kiln Bag house fan operating efficiency	%	72.3	79	77.8	75	68.9	78.25	80	75
16	Kiln size	Dia(m) × length(m)	-	5 x 78	5.8×85	-	5 x 75	5 x 75	5 x 81	5.6x85
17	Kiln Volumetric loading	tpd/ m^3	-	5.6	4.5	-	-	-	6.7	6.1
18	Kiln Thermal loading	MkCal /hr /m^2	-	4.7	-	-	-	-	4.8	6.5
19	Kiln percentage filling	%	-	13.6	14	-	-	-	-	-
COOLER SECTION										
20	Total cooler flow (Cold air + hot air)	Nm^3/kg clinker	1.8	1.6	1.8	1.9	2.1	2.0	1.9	2.0
21	Cooler vent flow	Nm^3/kg clinker	1.1	1.0	1.2	1.1	1.3	1.1	1	1.2
22	Pressure Drop across cooler ESP/ Baghouse	mmWC	33	35	35	45	28	26	34	44
23	Cooler Vent Fan Efficiency	%	68.6	62	67	58.3	55	61.3	64	65
24	Clinker temp at cooler exit	˚C	150	138	165	161	146	135	148	152
25	Cooler Grate Loading	TPD/m^2	43	-	45	46.5	40.6	44.1	46	-
KILN THERMAL HEAT CONSUMPTION										
26	Kiln Thermal SEC	kCal/kg clinker	670	682	706	705	682	692	733	708
a	Loss in PH gas	kCal/kg clinker	117.1	112	119	121	110	118	165.1	114.3
b	Loss in Cooler vent	kCal/kg clinker	110	92	123	94	131	139	130	130

c	Loss in clinker	kCal/kg clinker	30	26	33	32	29	27	29	26
d	Heat of formation	kCal/kg clinker	412	410	411	410	409	410	418	421
e	Radiation loss	kCal/kg clinker	57	42	54	54	55	60	56	68
27	TSR	%	0	12.8	0.7	6.6	1.2	9	16.2	14.5
28	TAD temperature	^{0}C	980	1,015	965	945	971	959	885	995
29	Primary air including kiln coal conveying	%	8	7.8	9.7	-	8.9	9.2	10.1	9.5
30	Coal Phase density – PC Firing	kg Coal / kg air	3.5	3.8	3.3	3	3	2.9	2.7	-
31	Coal Phase density – Kiln Firing	kg Coal / kg air	2.9	2.7	2.8	1.6	2.3	2.3	1.8	-

4.5 CEMENT MILL SECTION

4.5.1 CEMENT MILL – BALL MILL

4.5.1.1 Cement Mill Section – Ball Mill – PPC

Table 19: Benchmarking of Cement Mill Section – Ball Mill – PPC

S.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
1	Overall SEC	kWh/MT cement	25.3	25.6	27.1	27.2	27.6
a	Mill Drive	kWh/MT cement	20.8	21.1	21.9	21.6	22.6
b	Separator Fan	kWh/MT cement	2.3	2.1	1.3	2.2	2.2
2	Design output	TPH	120	150	150	133	200
3	Operating output	TPH	158	183	203	186	225
4	Final Product Blaine	m^2/kg	340	300	320	380	320
5	Final product residue (% residue on 45 micron)	%	16	16	15	22	19
6	Fly ash addition	%	34.7	35	34	30	30
7	Clinker factor		0.62	0.61	0.60	-	-
8	Mill specification (Dia × Length)	m × m	4.4 x 15	-	4.6 × 17.1	4.4×13.5	5 × 15
9	Gas Velocity across mill	m/s	1.1	1.2	-	1	1.1
10	Circulating load		1.8	-	2.0	1.8	1.6
11	Separator reject residue (on 45 microns)	%	80	78	63	87	77
12	Mill discharge residue (on 45 microns)	%	44	48	39	45	47
13	Mill discharge Blaine	m^2/kg	195	-	200	305	200
14	Separator fan flow	m^3/hr	-	-	4,18,000	1,60,000	2,75,000
15	Separator fan operating efficiency	%	78	80.6	-	-	-
16	Grinding media-specific surface area in the second chamber	m^2/MT	44.6	43.5	-	-	-

4.5.1.2 Cement Mill Section Ball Mill-OPC

Table 20: Benchmarking of Cement Mill Section Ball Mill-OPC

S.No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	Overall SEC	kWh/MT cement	29.8	29.9	30.0	30.5	31.1	31.4
a	Mill Drive	kWh/MT cement	25	24.5	23.8	25.1	26.3	24.9
b	Separator Fan	kWh/MT cement	1.5	1.5	2.3	2.4	2.4	
2	Design output	TPH	110	105	120	200	110	58
3	Operating output	TPH	120	115	130	200	120	55
4	Final Product Blaine	m^2/kg	300	300		270	300	300
5	Clinker factor		-	-	0.96	-	0.9	0.91
6	Mill specification (Dia × Length)	m × m	4.2 × 13.5	4 × 11.5	4.4 x15	4.81 × 15	4.2 × 14.5	3.2×12
7	Gas Velocity across mill	m/s	1.2	1.2	1.1	1	0.8	0.8
8	Circulating load	-	1.2	1.2	1.7	1.6	1.8	0.9
9	Separator reject residue (on 45 microns)	%	-	-	82.6	-	85	75.5
10	Product residue (on 45 microns)	%	-	-	11.2	-	16	25
11	Mill discharge residue (on 45 microns)	%	35	37	44.7	40	45	46.4
12	Mill discharge Blaine	m^2/kg	180 to 220	180 to 220	200	204	180	225
13	Separator fan flow	m^3/hr	1,45,000	-	-	2,48,000	1,54,449	82,150
14	Separator fan operating pressure	mmWC			-		-380	-490
15	Separator fan operating efficiency	%	-	-	78.3	-	76	77.1
16	Grinding media-specific surface area in the second chamber	m^2/MT	-	-	44.6	-	40.3	42.4

4.5.2 CEMENT MILL-VRM

4.5.2.1 Cement Mill Section VRM-PPC

Table 21: Benchmarking of Cement Mill Section VRM-PPC

S.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	Overall SEC	kWh/MT cement	18.8	19.7	21.2	21.8	22.3	22.3
a	Mill drive	kWh/MT cement	11.9	13	12.8	13.8	12.3	13.7
b	Mill fan	kWh/MT cement	4.2	4.6	5.2	5.0	6.5	6.5
2	Make	-	Loesche	FLS	Loesche	FLS	Peiffer	Loesche
3	Type / Model	-	LM 53.3+3S	OK 39.4	LM 56.3+3	OK 40.4	MPS 5600 BC	LM 53.3 + 3 CS
4	Design output	TPH	280	265	305	100	280	200
5	Operating output	TPH	320	300	342	130	330	220
6	Product Blaine	m^2/kg	330	350	350	340	360	340
7	Product residue (on 45 micron)	%	14	14	18-20	13.8	-	13.5
8	Fly ash addition	%	32	34.5	31.8	35	32	35
9	Clinker factor		0.66	0.63	-	0.61	0.62	0.60
10	Pressure drop across separator	mmwc	100	150	-	-	-	-
11	Mill Dp	mmwc	350	360	540	-	400	-
12	Baghouse pressure drop	mmwc	140	25	175	-	-	-
13	Mill fan operating flow	m3/hr	5,55,000	5,85,000	7,40,000	-	9,20,000	5,85,000
14	Mill Fan inlet pressure	mmwc	-595	-595	-785	-	-680	-600
15	Mill fan operating efficiency	%	73	78	78	81.1	80	72.4
16	Nozzle ring velocity	m/s	31	44	49	-	32	42

4.5.2.2 Cement Mill Section VRM OPC

Table 22: Benchmarking of Cement Mill Section VRM OPC

S.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 5
1	Overall SEC	kWh/MT cement	22.3	24.0	25.0	27.6	28.1	28.6
a	Mill drive	kWh/MT	15.4	15.2	16.5	16.6	15.1	17.5
b	Mill fan	kWh/MT	5.4	5.8	5.4	7.1	7.4	6.2
2	Make	-	Pfeiffer	FLS	Loesche	Pfeiffer	Loesche	Pfeiffer
3	Type / Model	-	-	OK39.4	LM 53.3+3S	MVR 5000C4	VRM LM 56.3 +3 C	MVR 5000C4
4	Design output	TPH	226	250	210	190	275	160
5	Operating output	TPH	241	235	230	190	250	170
6	Product Blaine	m^2/kg	310	320	300	310	300	300
7	Product residue (on 45 micron)	%	12.5	14	15	18	25	16.1
8	Clinker factor		0.96	0.91	0.93	-	-	0.95
9	Pressure drop Across separator	mmwc	-	168	100	-	-	-
10	Mill Dp	mmwc	405	-	350	395	530	-
11	Baghouse pressure drop	mmwc	110	100	150	110	95	110
12	Mill fan operating flow	m^3/hr	-	6,10,000	5,65,240	7,56,109	7,10,000	-
13	Mill Fan inlet pressure	mmwc	-580	-610	-580	-557	-730	-
14	Mill fan operating efficiency	%	79	78	74	73	75	76.4
15	Nozzle ring velocity	m/s	46	44	-	50	53	-

4.5.2.3 Cement Mill Section VRM - PSC

Table 23: Benchmarking of Cement Mill Section VRM - PSC

S.No	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	Overall SEC	kWh/MT cement	31.1	31.9	32.6	33.2	33.9	34.8
a	Mill drive	kWh/MT cement	20.7	21	21.8	21	21.2	23.0
b	Mill fan	kWh/MT cement	7.2	6.1	6.0	8.1	7.6	11
2	Make	-	Pfeiffer	Loesche	Loesche	OK Mill	Loesche	Pfeiffer
3	Type / Model	-	MVR 6000 C6	56.3+3	53.3+3S	42.4	LM 46.2 + 2CS	MBR 6000 C6
4	Design output	TPH	250	220	150	215	-	250
5	Operating output	TPH	280	260	170	230	130	260
6	Product Blaine	m^2/kg	364	368	330	355	380	390
7	Product residue (on 45 micron)	%	-	-	15	-	-	8
8	Clinker factor		0.35	-	0.4	-	0.4	0.3
9	Pressure drop Across separator	mmwc	-	168	100	-	-	123
10	Mill Dp	mmwc	-	373	320	475	340	500
11	Baghouse pressure drop	mmwc	100	150	110	110	110	120
12	Mill fan operating flow	m^3/hr	-	5,74,000	4,90,000	7,15,000	3,15,000	10,45,000
13	Mill Fan inlet pressure	mmwc	-	-720	-570	-680	-555	-710
14	Mill fan operating efficiency	%	78.7	-	74	-	79	76
15	Nozzle ring velocity	m/s	-	-	-	-	46	43

4.5.3 CEMENT MILL - BALL MILL+HPRG

4.5.3.1 Cement Mill Section - Ball Mill + HPRG - PPC

Table 24: Benchmarking of Cement Mill Section - Ball Mill + HPRG - PPC

S. No.	Parameter	Unit	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
1	Overall SEC	kWh/MT	18.6	22.6	24.0	24.9	25.7	25.7
a	Mill drive ball mill	kWh/MT	6.4	8.9	6.3	8.3	11.8	12.6
b	Separator fan	kWh/MT	2.5	2.6	-	2.9	-	3.0
c	Booster fan	kWh/MT	-	-	2.7	-	-	-
d	HPRG drive	kWh/MT	6.9	7.1	10.5	6.6	6.7	6.7
e	Dry Fly ash unloading	kWh/MT	2.5		2.5	-	0.1	-
2	Design Output	TPH	260	210	155	175	210	225
3	Operating Output	TPH	272	230	180	194	224	238
4	Final Product Blaine	m^2/kg	380	330	310	320	324	320
5	Final Product residue (on 45 micron)	%	-	12	10	8	13.1	8
6	Fly ash qty	%	-	33	34	35	31.6	35
7	Clinker factor	-	-	0.64	-	0.63	0.65	0.63
8	Ball Mill Make	-	Thyssen Krupp	KHD	FLS	TCDRI	KHD	-
9	Mill specification	Dia(m) × Length(m)	4.4 × 11.0	-	3.0 × 11	3.8 × 12	4.2 × 13	4.2×13.5
10	Type of liners	both compart-ments	Thin & classify-ing	-	Semi & classify-ing	UVL & classify-ing	Classify-ing	
11	Velocity inside mill	m/s	1.2	-	1	0.7	1.2-1.3	0.8
12	Mill outlet draft	mmwc	-70	-	-155	-80	-95	-90
13	Separator type/ model	-	-	-	SKS	VSK/ Sepol	-	SKS
14	Pressure drop across separator	mmwc	300	-	550	180	-	240
15	Circulating Load	-	2.3	-	2.9	1.8	2.3	1.9

16	Separator reject residue (on 45 micron)	%	80	-	72	85	62	70
17	Separator reject blaine	m^2/kg	120	-	-	65	92	70
18	Product residue (on 45 micron)	%	12	-	12	17	-	-
19	Product blaine	m^2/kg	350	-	315	400	-	380
20	Mill discharge residue (on 45 micron)	%	50	-	60	27	55	65
21	Mill discharge blaine	m^2/kg	192	-	130	280	138	180
22	cyclone pressure drop	mmwc	50	80	-	100	-	80
23	No. of cyclones	Nos.	-	-	2	4	-	4
24	Mill vent fan operating flow	m^3/hr	60,000	-	23,000	17,653	40,000	24,109
25	Mill fan operating efficiency	%	81	71.1	80	53	72-76	63
26	Mill vent fan inlet pressure	mmwc	-100	-	-170	-159	-180	-168
27	Separator fan operating flow	m^3/hr	5,00,000	0	20,000	49,997	3,00,000	51,899
28	Separator fan operating efficiency	%	72	79	82	80	76	67
29	Separator fan inlet pressure	mmwc	-	-	-619	-	-650	-
30	Grinding media specific surface area	m^2/MT	-	44	-	42	-	41
31	HPRG Make	-	KHD	KHD	KHD	TCDRI	-	KHD
32	HPRG separator Fan Volume	m^3/hr	5,00,000	-		-	-	

5 Best Practices, Facts And Important Thumb Rules

Best Practices, Facts And Important Thumb Rules

5.1 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% 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 suction box velocity & duct Velocity should not be greater than 8 m/s
6) Increase the stack height & temperature of gas for maximizing the natural draft effect
7) Efficiency Losses due to Faults in

   a. Cone condition or cone gap: 3-4%

   b. Absence of inlet flow guide: 2-5%.

   c. Build up on impeller: 4-6 %
8) Allowable pressure loss across multi louver type damper in 100% open condition 10-15 mmWC.
9) In a closed-circuit loop fan , Outlet pressure should be within -10 to -20 mmWC , irrespective of the flow to the mill.
10) Suction at cooler fan inlet should not be more than -30 mmWC

5.2 RAW MILL & COAL MILL

1) The circumferential velocity of the rotor inside the pet coke grinding should be in the range of 27-30 m/s for achieving the product residue.
2) Recommended gas velocity in ducts at cement plant 12-16 m/s
3) Pressure drops in latest generation LP cyclones 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: 1.2 m^3/ m^2/min for air slide design
12) Separator venting air quantity (m^3/h) should be more than 10-15 % of the separator fan inlet air quantity.

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

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

15) The gas temperature of the mill stack/chimney should be greater than dew point by 20 ^{0}C

16) Dew point range in coal mill from flue gases (50-52 ^{0}C)

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

18) 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.

19) Ball mill can accommodate input moisture level up to 5% (Max); whereas Vertical Roller Mill can accommodate moisture level even up to 20%.

20) Roller Press with V separator combination can accommodate up to 15% input moisture level

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

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

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

Table 25: 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 26: Important Norms & Guidelines for grinding mills

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

5.3 PYROSECTION

1) 20 % increase in height of chimney (stack) can save power consumption of the connected ID fan
2) Latest generation low NOx burners can operate with a Primary air % as low as 4-6%
3) PID loop optimization will result in savings of 3-5 kcal/kg of clinker
4) The temperature drop across TAD should not be greater than 20 ^{0}C
5) Recommended phase density for pet coke should be in the range of 5-6 kg coal/kg air
6) Phase density for normal coal: 4-6 kg coal/kg air
7) The specific consumption of coal firing blowers should be in the range of 0.4-0.7 kW/m^3/min
8) 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 anti-coating with insulation backup.
d. Cooler	:	40% to 90% alumina with insulation backup.
e. TAD	:	40% to 60% alumina with insulation backup

9) 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

10) The top cyclone efficiency should be greater than 95 %
11) Null point for pet coke firing lies between 0.75 -0.80 Nm^3 air/kg clinker.
12) Overall cooler efficiency should be greater than 70% efficiency
13) Cooler losses should not be greater than 120 kcal/kg clinker
14) Overall radiation losses contribute around 6-8% of total heat losses
15) False air across preheater circuit should be less than 8%
16) An increase in specific exit gas amount (example change of fuel, etc.) by 0.1 Nm^3/kg increases the preheater exit gas temperature of the preheater by 17°C.
17) The kiln should be operated in the oxidizing atmosphere during pet coke firing
18) Pressure drop across ESP should not be greater than 30 mmWC
19) Down comer duct velocity should be in the range of 15-16 m/s

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

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

22) Ceramic coating can save up to 8% – 15% radiation loss in furnaces and hot surfaces

5.4 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 trunnion: 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 1,400-1,500 gm/MT without pre-grinder & Roller press

13) Recommended piece weight in the first chamber with HPRG lies in the range from 900-1,100 gm/MT.

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 ½ 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

5.5 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 be not more than 2 m if it is more than 2 m then baffle plates are provided.
7) The ideal height of discharge hood is 1,200 mm from belt top
8) The skirtboard should be min of 5m length for each transfer points
9) Velocity Vent Norms:
   a. 10m/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 and above there is loss of energy.
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.

5.6 COMPRESSED AIR

1) 1 bar reduction in compressed air pressure will save 6- 8 % power
2) Recommended compressed air velocity in the pipeline is 6 - 8 m/sec
3) Reduction in Cooling tower fan speed by 50 % by VFD can save power by 75%
4) 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
5) Maintaining intercooler performance can save 7 % power on the compressor
6) Every 4˚C rise in inlet air temperature of the compressor results in higher energy consumption by 1 % to achieve equivalent output".
7) Recommended compressed air outlet temperature after intercooler is ambient temperature + 20 ^{0}C
8) The minimum quantity of Cooling Water required (in litres per minute) is 2.85 m^3/min for a single-stage compressor operating at 7 bar pressure
9) Transvector nozzles can reduce power and save compressed air up to 50%
10) 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)
11) Compressed air leakage quantity to be as low as 10%
12) In 800 m length compressed air pipeline, pressure drop should not be more than 0.3 kg/cm^2
13) Centrifugal and Screw blowers can save up to 40 % power when compared with PD blowers for the same application (pressure and volume)
14) Flat belt pulley can save 3 – 5 % compared with V pulley
15) The typical power consumption of a conventional vapor compression refrigeration system is 1.2 kW / TR
16) Typical power consumption of Screw chiller system is 0.35 kW / TR for 10 deg 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
17) Evaporative cooling can reduce the compressor or chiller load by 20 -40%

5.7 COOLING TOWER

1) Reduction of 10˚C in the combustion air of DG will save 1.5 gm of Fuel / kWh of power generated
2) 150 sq ft of room area needs 1 TR Air Conditioning load in a conventional building.
3) The optimum approach (Difference between Coldwell temperature and wet bulb temperature) in a cooling tower is 2- 4 ˚C
4) Recommended increase in temperature of water (Delta T – Cooling water outlet – inlet temperature) for condenser and compressor is 10 ˚C and for process heat exchanger 5 ˚C
5) FRP Blades in an axial cooling fan can save up to 15-40 % power compared with metal blades

5.8 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

5.9 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 27 : Important Norms for Captive power Plant

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.
Compressed air pressure for fly ash conveying from ESP	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	-
Gross Heat rate (<30 MW)	kCal/kWh	2,950-3,100	-
BFP & CEP efficiency	%	70-80	Should be above 75%

6 Decarbonization levers for the Indian Cement Industry

Decarbonization levers for the Indian Cement Industry

The cement industry is one of the largest industrial sources of carbon dioxide (CO_2) emissions globally, accounting for approximately 7-8% of global emissions. As the demand for infrastructure and construction continues to rise, decarbonising cement production is critical for achieving climate targets. The industry is pursuing several key levers to reduce its carbon footprint. The Indian cement industry can explore following levers to decarbonize the sector:

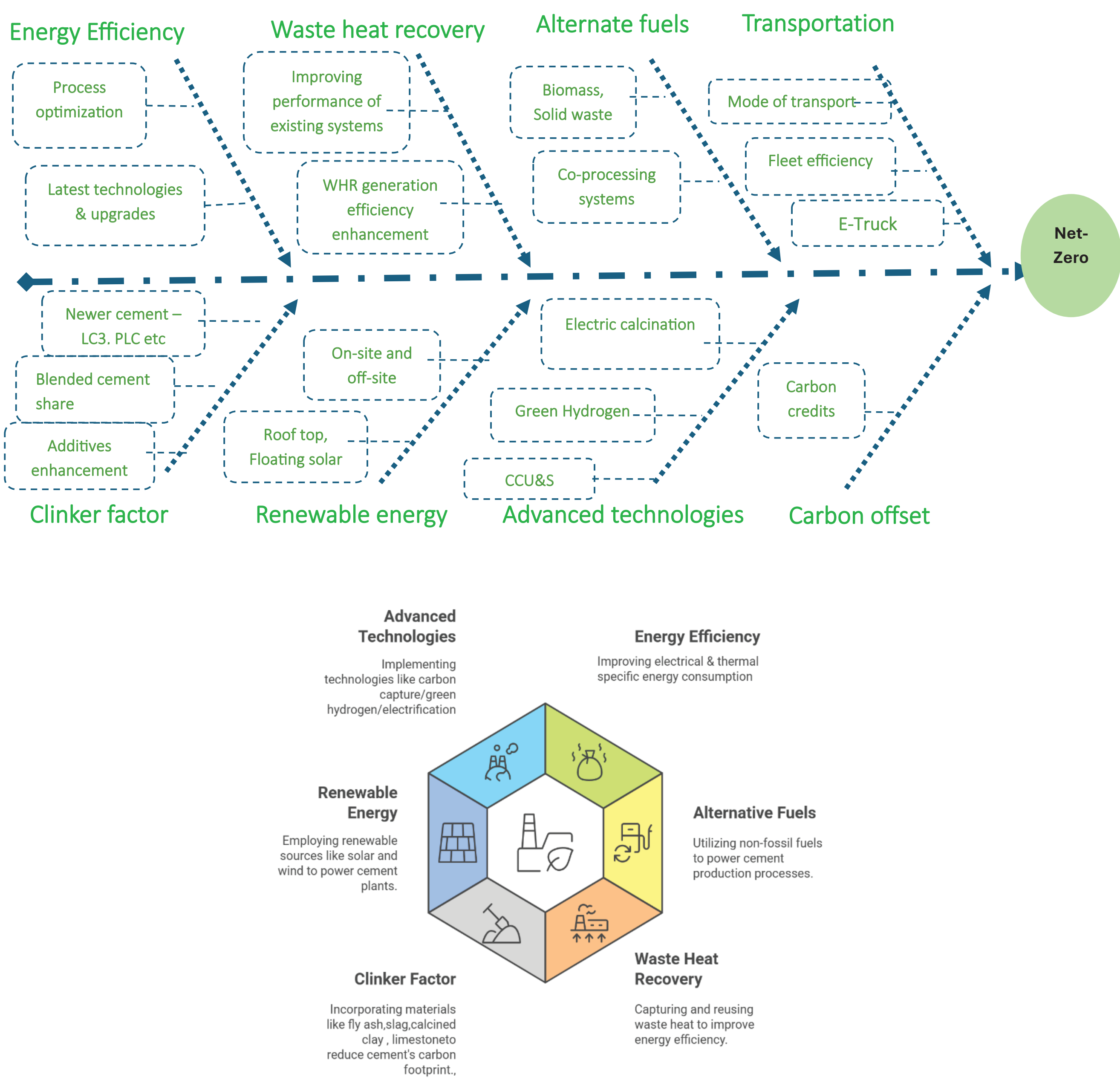

Figure 10 : Decarbonisation Levers

6.1 Clinker Factor

Reducing the clinker factor, the proportion of clinker in cement, is one of the most impactful strategies for lowering CO_2 emissions in cement production.

Clinker substitutes can potentially reduce 10 - 20% of overall emissions. India has made notable progress in reducing its clinker factor. The national average has dropped to around 0.68–0.70, compared to the global average of about 0.75–0.77. Leading Indian producers are pushing further, targeting levels as low as 0.65 or below through increased use of blended cements like PPC (Portland Pozzolana Cement) and PSC (Portland Slag Cement).

Reduce the clinker factor by enhancing the use of supplementary cementitious materials, Increasing the use of blended materials, and the market deployment of blended cements. Some of the low carbon-based cements are

- Portland Pozzolana Cement (PPC)
- Portland Slag Cement (PSC)
- Limestone Calcined Clay Cement - LC_3,
- Portland Limestone Cements (PLC)
- Multi-blend Cements

Key Benefits:

Direct emission reduction: Less clinker means fewer emissions from calcination and combustion.

Resource efficiency: Promotes the use of industrial by-products, reducing landfill and raw material extraction.

Cost-effectiveness: SCMs are often less expensive than clinker, offering both environmental and economic benefits.

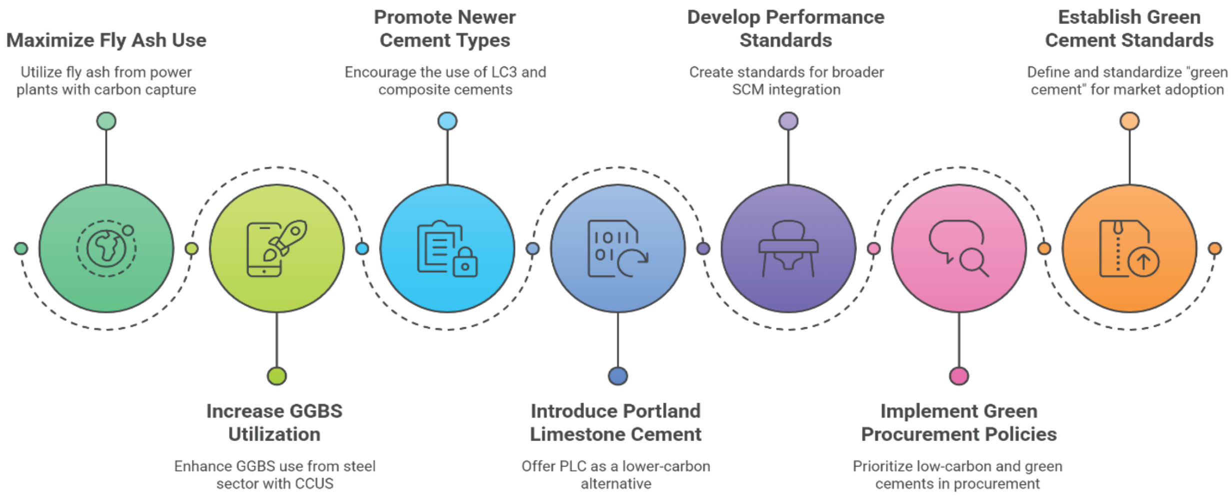

Figure 11: Various levers for reducing clinker factor

6.2 Alternative Fuels

India's cement sector has achieved an average Thermal Substitution Rate (TSR%) of 7%, marking steady progress in reducing dependence on conventional fossil fuels. By leveraging biomass and industrial waste as alternative fuels in cement kilns, the industry is embracing a cleaner, more sustainable path forward. This transition not only cuts carbon emissions but also contributes to circular economy principles by converting waste into energy.

Key highlights:

- Average TSR 7% , with a leading cement plant achieving up to 38% TSR.
- 30% TSR on continuous basis at 4 cement plants
- 20% TSR on continuous basis at 9 cement plants
- 15% TSR on continuous basis at 14 cement plants

4% TSR in India = 100 % TSR in Australia

4% TSR in India = 50 % TSR in France

4 % TSR in India = 16 % TSR in South Korea

Types of major alternative fuels used in the Indian cement industry:

- **Hazardous Waste :**

  ETP Sludge, Paint sludge, Opium Marc, Process Sludge, Ink sludge, Organic solvent, spent solvent, benzofuran, etc.

- **Non-Hazardous Waste :**

  Agro waste, tyre chips, RDF, plastic waste, biomass, FMCG expired products, wood chips, etc.

Target set on TSR % by major Indian cement groups :

TSR %	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
2023 – 24	7.8%	9.2%	22%	16.3%	2.4%	5.1%
Target - 2030	25%	28%	100% by 2035	35%	25%	30%

Key to this transition is the development of a reliable supply chain, including consistent waste availability, proper segregation, transportation, and preprocessing. Local governments play a critical role in enabling waste segregation at the source.

By 2070, the industry aims to fully replace fossil fuels with a mix of 50% green hydrogen/electricity and 50% alternative fuels, including 15% biomass and 35% fossil waste-derived fuels. This shift is expected to contribute an additional 4.6% CO_2 reduction

Table 28 : Low carbon Technologies to enhance Alternative fuel usage

ALTERNATE FUELS AND RAW MATERIALS		
S. 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	• 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). • Average 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

6.3 Waste Heat Recovery

Waste Heat Recovery (WHR) is a proven and efficient decarbonisation strategy for the cement industry, enabling the capture and reuse of heat from high-temperature exhaust gases produced during clinker production. This otherwise wasted thermal energy is used to generate electricity or for process heating, thereby reducing reliance on grid power and fossil fuels. The technologies available for Waste Heat Recovery include Rankine Cycle, Organic Rankine Cycle, and Kalina Cycle.

The Indian cement industry has made strong strides in adopting WHR systems. As of recent estimates, the installed WHR capacity in Indian cement plant is 1289 MW (as of March 2025)

Table 29 : Best Performance figures - WHR

S.No	Performance Indicator	Best Value
Best achieved generation (kW/MT of clinker)		
1	Power generation (AQC + PH)	43
2	Power generation (AQC + PH + TAD)	50
3	Power generation (AQC + PH + TAD + Auxiliary firing)	75
Best auxiliary power consumption (APC)(%)		4.1
Best cycle efficiency (%)		23

Key Benefits:

- Lowers indirect emissions (Scope 2) by reducing electricity demand from fossil-fuel-based grids.
- Improves overall energy efficiency of the cement plant.
- Reduces operational costs over the long term despite moderate initial capital investment.

6.4 Renewable Energy

The integration of renewable energy into cement manufacturing is an increasingly important strategy to reduce indirect (Scope 2) emissions arising from electricity consumption.

Electricity consumption contributes to approximately 12% overall carbon emissions from the cement industry in India.

While thermal processes in cement production are still largely dependent on fossil fuels, a growing share of electrical energy used in grinding, material handling, and auxiliary operations can be powered through solar, wind, hydro, or hybrid renewable sources.

Indian cement companies are increasingly investing in solar PV installations, wind farms, and renewable power purchase agreements (PPAs) to meet sustainability targets. Many leading producers have already met 10–20% of their power needs from renewable sources, with ambitions to reach 40% or more by 2030.

Present installed RE Capacity - 1833 MW

- Major groups are targeting > 50% RE share by 2030.
- More than 10 grinding units have > 30% RE share.
- More than 10 integrated units have > 10% RE share.

6.5 Energy Efficiency

Decarbonizing the cement industry is challenging due to the need for high temperatures, process-related CO_2 emissions, and growing global demand. A combination of solutions is required to reduce emissions and environmental impact across the value chain.

- Improving Energy Efficiency
    1. Electrical
    2. Thermal

3% of overall emissions can be reduced by implementation of existing energy efficient technologies

6.5.1 Electrical Efficiency

Presently, the average Specific Energy Consumption (SEC) Electrical in Indian cement plants is around **73 kWh per tonne of cement** . Electricity usage contributes approximately 10% to the overall carbon footprint of the Indian cement industry. Currently, power is sourced through a combination of captive power plants, waste heat recovery (WHR) systems, and grid electricity, with only a small portion coming from renewable sources. As the industry moves toward net-zero goals, decarbonizing electricity supply is a key lever. There are various low-carbon technologies available to enhance electrical energy efficiency :

Table 30 : Low carbon Technologies to enhance Electrical Energy Efficiency

ELECTRICAL ENERGY EFFICIENCY		
S. 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 preheater system is small, minimizing 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	4^{th} Generation Separators- High Efficiency separators	• 4^{th} 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 3^{rd} 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 crushers 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.
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 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 is high, and they 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 an 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 and throughput of the mill increases. • Due to higher clinker substitution, it reduces energy consumption for clinkerization and operating costs.

6.5.2 Thermal Efficiency

Reducing Thermal Specific Energy Consumption (SEC) is key to decarbonizing the cement industry, as a major share of emissions comes from heat used in clinker production. The top 10 plants operate under 695 kcal/kg (thermal). The Indian cement industry has already improved thermal efficiency but aims for further reduction to meet long-term climate goals. The low-carbon technologies available to enhance thermal energy efficiency are listed below :

Table 31 : Low carbon Technologies to enhance Thermal Energy Efficiency

THERMAL ENERGY EFFICIENCY		
S. 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 the latest generation clinker coolers is less than 110 kCal/kg of clinker and has a recuperation efficiency of >70%.
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 clinker temperature by around 30 °C. • Electrical savings: Reduction in power consumption up to 1 kWh/ MT.
3	PID Loop optimization	• A smart tool with Artificial Intelligence and Machine Learning features that optimizes the PID loop by reducing 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 • 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	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.
6	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.

8	Advanced multi-channel burner	• Lower primary air percentage (7-8%) in burner including kiln coal conveying air • 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 analyzer	• Cross-belt analyzers will analyze 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 resources. • 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

6.6 Electrification of Trucks

Freight vehicles, particularly medium and heavy-duty vehicles, are significant contributors to global greenhouse gas emissions. In India, although they represent merely 2% of all road vehicles, they are responsible for over 45% of road transport emissions1. This substantial impact positions them as a primary target for emission reduction initiatives. With India aiming for net-zero status by 2070, the decarbonization of transport is pivotal.

Figure 12 : E-Truck

The transition to E-trucks presents an opportunity to slash logistics costs by 25-40%. Vehicles that operate over 8,000 km per month can achieve profitability considering current energy and infrastructure costs. Additionally, E-trucks powered by renewable energy could cut CO_2 emissions by up to 100% when compared to ICE trucks, which emit approximately 6 kg of CO_2 per ton of cement transported over a 100 km range.

- Emission reduction potential by switching to EV trucks 2.3 million Tons / annum
- 50 E-Trucks already deployed

Enablers :

- RTA policy – Gross / Net weight
- Green Finance & extended loan
- Green channel at cement plants & raw material source
- Charging infra & subsidy
- Incentives for retrofit

6.7 Advanced Technologies

6.7.1 Carbon Capture, Utilization and Storage

CCUS is considered a crucial strategy for addressing process-related CO_2 emissions in the cement industry and achieving net-zero targets. However, its deployment in India is still in the early stages, with no cement plants currently implementing CCS technologies. Only a few companies have initiated preliminary exploration of CCUS options.

Globally, various carbon capture technologies are under operation and development, but their high capital costs and early commercial maturity present challenges for adoption in India.

- Currently more than 40 units are in operation globally, with a capacity of 45 $MtCO_2$
- 65% are natural gas-based processing plant

Industry name	Ref. Plant capacity	CCU capacity (mtpa)	Capital Costs, Rs. crores	Capital Charges (A), Rs./T_{CO_2}	Cash Cost (B), Rs./T_{CO_2}	Total Capture Cost (A+B), Rs./T_{CO_2}
Gasification based production	70 ktpa H_2	1 mtpa	Rs. 80-100 Crore	90-120	250-300	340-420
NG based SMR for H_2 production	130 ktpa H_2	0.7 mtpa	Rs. 700-800 Crore	900-1,200	1,150-1,400	2,050-2,600
Cement	2.5 mtpa clinker	2 mtpa	Rs. 1,600 to 1800 Crore	800-1,000	1,050-1,600	1,800-2,600
Iron and Steel	2.0 mtpa BF-BOF based ISP	2 mtpa	Rs. 1,600-2,000 Crore	1,000-1,300	1,900-2,300	2,900-3,600
Refinery (CDU & FCC)	5 mtpa crude processing	1 mtpa	Rs. 1,100-1,300 Crore	1,200-1,400	2,700-3,100	3,900-4,500
Coal-based power	800 MW	5 mtpa	Rs. 3,500-4,000 Crore	700-1,000	2,100-2,500	2,800-3,500
Total		**11.7 mtpa**	**Rs. 8,600 - 10,000 Crore**			

Figure 13 : Total carbon capture cost for various industries1

- The global market for CO_2 utilization will reach USD 70 billion by 2030 and USD 550 billion by 2040
- Building materials will become the largest sector for CO_2 utilization, capturing 86% of the total market value by 2040.

1 NITI Ayog : Carbon Capture, Utilization and Storage (CCUS) Policy Framework and its Deployment Mechanism in India

Table 32 : Carbon uptake Potential for various pathways

Pathway	Market Size (Million Tonnes/yr)	Carbon Uptake Potential (Mt/yr)	TRL
Aggregates	53,200	3,600	9
Carbonated Concrete	16,500	1,650	9
Methane	1,100	3,025	9
Ethanol	86.8	166	5
Methanol	80	110	9
$CaCO_3$ (GCC)	75	33	7
Biodiesel	20	30	5
Di-methyl Ether	8	7.65	9
$CaCO_3$ (PCC)	14	6.16	7
PPC	6	3	9
Polyols	10	2	9
Food-grade CO_2	17	17	9

Developing dedicated CO_2 transport and storage infrastructure is equally important. Institutions like NITI Aayog have recommended creating CCUS clusters—shared transport and storage hubs for industrial CO_2, including cement. These can also support utilization pathways that convert CO_2 into low-carbon products.

Reports from global agencies (GCCA, Global CCS Institute, etc.) highlight the potential for CCUS hubs in India, analyse storage and transport costs, and propose regulatory and financing frameworks needed to support CCUS development.

Over time, with technological progress and international collaboration, CCUS is expected to become more affordable and viable for large-scale use in India's cement industry.

6.7.2 Green hydrogen

Green Hydrogen produced via electrolysis powered by renewable energy, is emerging as a promising long-term solution for deep decarbonisation in hard-to-abate sectors like cement. Unlike conventional fuels, hydrogen combustion emits only water vapour, offering a clean alternative to fossil fuels used in high-temperature cement kilns.

Potential in Cement Production:

- Substitutes fossil fuels in the calciner or kiln, reducing Scope 1 CO_2 emissions.
- Enables high-temperature combustion required for clinker production.

- Can be integrated into hybrid fuel strategies alongside biomass or alternative fuels.

Globally and in India, the use of green hydrogen in cement is still at a pilot or experimental stage. Challenges include:

- High production cost of green hydrogen compared to coal or pet coke.
- Limited infrastructure for storage, transport, and on-site usage.
- Need for kiln modifications and safety adaptations.

Under the National Green Hydrogen Mission, India aims to scale up domestic hydrogen production, making it more accessible to industrial users. The cement industry is actively monitoring this space, with some companies exploring R&D partnerships, feasibility studies, and pilot trials.

Green Hydrogen as an Alternate Fuel in Cement Industry

For a 1 MnTPA Cement plant with 5% to 35% (i.e, 100% Kiln firing) Substitution with Green Hydrogen

- Hydrogen Requirement – 900 to 6,400 MT/annum
- Water Requirement – 50 to 345 m^3/day
- Power Requirement – 150 to 1050 MW/day
- Emission Reduction – 10,000 to 75,000 Tons of CO_2
- Extended Mines Life – ~0.5 to 1 year (with 1% H_2 substitution)
- CAPEX Cost – 45 to 55 Cr/ MW , OPEX Cost – INR 350 to 400 /kg of H_2

Current Scenario of Hydrogen :-

- Global Capacity : 97 million T/annum
- India Target by 2030 : 5 million MT/ annum

Potential Solutions :-

- Present Hydrogen production Cost : ~ Rs 400/ kg
- For economic viability cost has to reduce to Rs 65 – 80/ kg
- SIGHT (Smart Interventions of Green Hydrogen Transition)
  - ➢ Budget for hydrogen manufactures – 89%
  - ➢ Budget for pilot projects – 7.4%

With decreasing costs of renewable energy and electrolysis technologies, green hydrogen has the potential to play a transformational role in the sector's path to net zero—especially after 2040

7

Islands of Excellence

Islands of Excellence

Table 33 : Islands of Excellence

S. No.	Parameter	Unit	Indicator
	CRUSHER		
1	Crusher specific power consumption	kWh/MT Limestone	0.6
	RAW MILL		
2	Raw mill specific power consumption- VRM	kWh/MT Limestone	10.6
3	Raw mill fan specific power consumption- VRM	kWh/MT Limestone	3.9
4	Raw mill specific power consumption- Roller Press	kWh/MT Limestone	10.4
5	Pressure drop across Nozzle ring-VRM (400 TPH)	mmWC	200
6	Pressure drop across VRM	mmWC	464
7	Pressure drop across Separator-VRM	mmWC	100
8	False air infiltration across VRM Circuit (Mill IL to Fan OL)	%	10.4
9	Raw Mill fan efficiency-VRM	%	90
10	Separator loading-VRM	gm/m^3	715
	COAL MILL		
11	Coal mill specific power consumption- VRM (Coal)	kWh/MT Coal	22.2
12	Coal mill specific power consumption- VRM (Pet Coke)	kWh/MT Pet Coke	33.8
13	Output rate from normal to Pet Coke	%	65
14	Dust loading in Pet Coke grinding	gm/m^3	220
15	False air infiltration across the circuit - Mill IL to fan OL	%	9
	PYRO SECTION		
16	Electrical SEC-KILN (6-Stage)	kWh/MT Clinker	16.8
17	Electrical SEC up to Clinkerization (6 stage)	kWh/MT Clinker	41.4
18	Thermal SEC-5 Stage	kCal/kg Clinker	694
19	Thermal SEC-6 Stage	kCal/kg Clinker	670
20	Thermal substitution rate-5900 TPD (6 stage)	%	38
21	Preheater fan SEC (With WHRS)	kWh/MT Clinker	4.7
22	Preheater fan SEC (Without WHRS)	kWh/MT Clinker	3.4

Table 33: Islands of Excellence

S. No.	Parameter	Unit	Indicator
23	Cooler fans SEC (without WHRS)	kWh/MT Clinker	3.1
24	Cooler vent fan SEC (without WHRS)	kWh/MT Clinker	0.2
25	Radiation loss from kiln & preheater	%	5
26	Preheater loss excluding dust	kCal/kg Clinker	110
27	Preheater outlet temperature (6 stage)	^{0}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	^{0}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	7.8
36	Clinker temp at cooler exit	^{0}C	95
37	Preheater fan flow	Nm^3/kg Clinker	1.25
38	Air infiltration across preheater	%	5.3
39	Preheater top cyclone efficiency	%	97
40	Pressure drop across RABH	mmWC	80
41	Pressure drop across PH (6 stage)	mmWC	350
42	Pressure drop across PH (5 stage)	mmWC	460
	WHR		
43	Power generation per clinker production (AQC+PH)	kWh/MT Clinker	43 @ 715 kCal/ kg Clinker- 6 stage
44	WHR pressure drop (AQC)	mmWC	32
45	WHR false air	%	2.8
	CEMENT MILL		
46	Cement mill specific power consumption- Ball Mill+HPRG-PPC	kWh/MT Cement	18.58
47	Cement mill specific power consumption- Ball Mill+HPRG-OPC	kWh/MT Cement	25.2
48	Cement mill specific power consumption- VRM-PPC	kWh/MT Cement	18.8
49	Cement mill specific power consumption- VRM-OPC	kWh/MT Cement	22.3

Table 33 : Islands of Excellence

S. No.	Parameter	Unit	Indicator
50	Cement mill specific power consumption- VRM-PSC	kWh/MT Cement	31.1
51	Cement mill fan efficiency (VRM)	%	82
52	Fly ash addition	%	35
53	Slag addition	%	70
	ELECTRICAL		
54	Electrical distribution losses	%	3.2
55	Capacitor power loss	W/kVAR	3
56	Optimum voltage for lighting	V	210
57	Efficiency of motors in LT & HT	%	97.1
58	VFD loss and SPRS loss	%	3.4
59	Harmonic distortion in cooler fans (V,I)	%	2.8
60	Capacity of renewable energy in onsite installation	MW	29
	COMPRESSOR		
61	Compressor air generation pressure	Bar	4.5
62	Pressure drop in compressed air distribution system	Bar	0.2
63	Pressure drop across dryer	Bar	0.1
64	SEC for blower @1 bar	kWh/MT Coal	1.1
65	Compressor air load of Cement mill, CPP and Pyro for 4200 TPD plant	CFM	2,450
	CPP		
66	Gross Heat rate in CPP < 30 MW	kCal/Mwh	3,006
67	CPP auxiliary power consumption-AFBC	%	5.36
68	CPP auxiliary power consumption-CFBC	%	6.53
69	Conveying pressure from ESP hopper to bunker in CPP	Bar	3
70	Excess air in CPP-Indian Coal	O_2%	2.5
71	Excess air in CPP-Pet Coke	O_2%	2.8
72	Pressure drop between BFP and drum	Bar	10
73	Pressure drop in flue gas path(Boiler O/L – FD fan I/L)	mmWC	64
74	Circulation rate for water cooled condenser	m^3/MW	239
75	Auxiliary cooling water circulation	m^3/MW	10.5

8

Innovative Projects

Innovative Projects

Project 1: Increase in Calciner residence time to increase AF feed rate

Problem Statement:

"Incomplete combustion of alternative fuels (AF), primarily due to lower residence time, leading to carbon monoxide (CO) formation at the pre-calciner (PC) outlet and preheater outlet."

Before & After Specifications of the project

Specifications	Before	After
Clinker Production (tpd)	4,000	4,950
PH Fan Volume (m^3/hr)	6,87,000	7,40,000
Calciner Residence Time (sec)	6	11
TSR (%)	20	35

Solution Implemented:

Calciner height increased to 120 m from pre calciner bottom cyclone inlet, that increased the residence time from 6 seconds to 10-11 seconds.

Technical Details:

The existing AFR system has a feeding capacity of 25 TPH and is operating at 15 TPH. By increasing the calciner height, AF feeding quantity increased up to 25 TPH and the TSR % increased up to 30%, with lesser temperature fluctuations.

Key Outcomes and Cost Savings:

Improved TSR and clinker production rate was observed by increasing the calciner height, with reduced CO spikes at the calciner outlet and preheater outlet.

Impact and Scalability:

This improvement enhances clinker production and enables more efficient handling of alternative fuel (AF) materials with high moisture content. It can be replicated in plants with the flexibility to increase calciner height, thereby improving residence time and combustion efficiency of AF, ultimately supporting higher thermal substitution rates (TSR).

Project 2: AF Discharge Chute Modification

Problem Statement:

Frequent jamming in the AF double flap chute due to higher size material, causing material accumulation and CO formation.

Solution Implemented:

Modified the chute with stainless steel plates and added an air blaster, all done in-house.

Technical Details:

The SS plate reduced wear, and the air blaster ensured consistent material flow, preventing jams.

Key Outcomes and Cost Savings:

"The initiative led to an increase in the alternative fuel thermal substitution rate (TSR) to 25%, reduced carbon monoxide (CO) formation, and ensured consistent material flow.

Impact and Scalability:

This solution enhances alternative fuel (AF) utilization and improves kiln stability. It is replicable across all AF feeding circuits, offering significant potential to increase AF usage and reduce fossil fuel dependency across the industry

Project 3: Intelligent Flow Controller for Compressed Air System

Problem Statement:

High energy consumption in the cement mill's compressed air system, leading to inefficiencies and increased operational costs.

Solution Implemented:

A Control AIR Intelligent Flow Controller (IFC) was installed to optimize airflow within the cement mill's compressed air network, improving system efficiency and reducing energy consumption.

Technical Details:

The IFC regulates air supply and distribution by reducing artificial demand, pressure fluctuation and unloading power. It was integrated into the existing air treatment and distribution system, connecting air compressors to plant operations.

Key Outcomes and Cost Savings:

Reduced energy consumption from 6,370 kWh to 5,623 kWh, achieving 12% energy savings (exceeding the 5% proposed and 3% guaranteed targets). Specific cost savings were not quantified, but the reduction implies significant operational cost benefits.

Impact and Scalability:

Demonstrates substantial energy efficiency improvements in compressed air systems, a critical component in cement plants. The IFC solution is scalable to other plants with similar air systems, offering potential for widespread energy savings and cost reductions across the industry.

Project 4: AI-Based Pre calciner Temperature Optimization

Problem Statement:

Unstable pre calciner temperature when using Alternative Fuels (AF), leading to energy inefficiency and process variability.

Solution Implemented:

A feed-forward control logic was developed using the OPTIMakx AI tool to stabilize pre-calciner temperature during alternative fuels (AF) feeding.

Technical Details:

Adjusted PID values for pre calciner temperature control, integrating AI-driven parameters to optimize fuel and air flow.

Key Outcomes and Cost Savings:

The initiative resulted in energy savings of 240 kWh/day in preheater (PH) fan power consumption and a reduction of 1 KCal/kg clinker in thermal energy. The total cost savings amounted to approximately Rs. 40.5 lakhs, with a project cost of Rs.37 lakhs, achieving a payback period of 1 year.

Impact and Scalability:

This solution enhances alternative fuels (AF) utilization and improves process stability. It is scalable to other plants using AF, with AI tools offering significant potential to drive broader digitalization in cement production—ultimately reducing energy costs and emissions.

Project 5: WHR Generation Increase through AQC Boiler Damper Upgradation

Problem Statement:

Inefficient AQC boiler operation due to a faulty bypass damper (SS 304 metallurgy) that failed to close fully, causing flue gas bypass and a loss in turbo generator (TG) power generation.

Solution Implemented:

The damper metallurgy was upgraded to SS 316, and a 70 mm thick refractory lining was added at the flap—supplied by M/s Dyrocon—to enhance abrasion resistance and improve sealing efficiency

Figure 14 : Before & after damper upgradation

Technical Details:

The upgraded damper improved heat recovery in the AQC boiler, leading to an increase in turbine-generator (TG) generation by 0.7 MW/day, equivalent to 16,680 units/day. The new metallurgy and refractory lining effectively prevented erosion and ensured reliable, long-term operation.

Key Outcomes and Cost Savings:

This upgrade resulted in savings of 1,00,800/day (16,680 units/day), amounting to 3.02 lakh/month and 3.6 crore annually. The enhanced damper reliability has been demonstrated by the absence of erosion after one year of operation

Impact and Scalability:

This solution enhances the efficiency of the Waste Heat Recovery (WHR) system, leading to reductions in both energy costs and emissions. It is scalable to other plants with AQC boilers, offering substantial potential for energy recovery improvements across the industry

Project 6: Pressure Drop Reduction in Cement Mill Classifier with Baffle Plate

Problem Statement:

High pressure drops (400 mmWC) across the classifier in Cement Mill-03 caused the circulating air fan to run on the high side, increasing energy consumption and reducing classifier efficiency.

Solution Implemented:

A baffle plate was installed at the inlet of the classifier duct, positioned at the center of the circular duct and inclined at a 30-degree angle to the incoming gas flow.

PARAMTERS BEFORE AND AFTER BAFFLE PLATE CEMENT MILL 03 (43 GRADE)				
S.NO	PARAMETRS	UNITS	BEFORE BAFFLE	AFTER BAFFLE
1	TOTAL FEED	TPH	74	75.5
2	RETURN	TPH	72	76
3	SEPERATOR RPM	RPM	744	730
4	CA FAN	KW	266	256
5	CA FAN FLOW	M3/HR	156500	158500
6	CA FAN EFF	%	87	89
CLASSIFIER EFFICIENCY (45 U)				
1	PRODUCT	%	13	11
2	SEPERATOR FEED	%	51	52
3	REJECT	%	79	83
4	CIRCULATION FACTOR		2.36	2.32
5	SEPARATOR EFF.	%	79	85

Figure 15 : Parameters before & after the baffle insertion

Technical Details:

The installation of the baffle plate reduced the pressure drop from 400 mmWC to 370 mmWC, optimizing gas flow dynamics. Following the installation, separator fan power consumption decreased from 266 kW to 256 kW, while classifier efficiency (at 45 μm) improved from 87% to 89%.

Key Outcomes and Cost Savings:

The total feed increased from 74 TPH to 75.5 TPH, leading to a reduction in specific power consumption by 0.1 kWh/ton. This resulted in annual savings of 76,650 units, amounting to Rs. 5.36 lakh per year

Impact and Scalability:

This solution enhances grinding efficiency and reduces energy cost. It is replicable across all types of cement mills, offering significant potential for broader energy savings in similar mills.

Project 7: Dust Settling Hopper Installation in Raw Mill Bag House Inlet

Problem Statement:

High differential pressure (DP) in the raw mill pulse jet bag house (180-200 mmWC) due to excessive dust load and high air-to-cloth ratio, leading to increased fan power consumption.

Solution Implemented:

A dust settling hopper was installed at the baghouse inlet, equipped with a GD screen and rotary air lock (RAL) to reduce the dust load.

Technical Details:

The settling hopper effectively captures coarse dust before it enters the baghouse, reducing the differential pressure (DP) by 60 mmWC. The GD screen and rotary air lock (RAL) ensure efficient dust separation and continuous removal, thereby lowering the dust loading in the bags and reducing the differential pressure.

Key Outcomes and Cost Savings:

The installation decreased baghouse fan power consumption by 38 kWh, resulting in annual savings of 2,50,008 kWh (Rs. 15 lakh/year). The investment of Rs. 19 lakh was recouped in a payback period of 1.26 years.

Impact and Scalability:

This solution improves baghouse performance and energy efficiency. It is replicable in other raw mills with high dust loads, offering significant potential for energy and cost savings across the industry.

Project 8: Clinker Cooler Upgrade with High-Pressure Pyro Step Grate

Problem Statement:

Inefficient clinker cooling leading to high specific heat consumption and power usage, impacting operational costs and heat recovery.

Solution Implemented:

The cooler was upgraded with a static grate and a 1st/2nd grate pyro-step cooler, utilizing CemProTec's high-pressure, low-volume technology.

Technical Details:

The pyro-step grate improves air distribution and heat recuperation, leading to a reduction in specific heat consumption from 706 KCal/kg clinker (2022-23) to 694 KCal/kg clinker (2023-24), and a decrease in specific power consumption from 18.1 kWh/MT (2022-23) to 17.6 kWh/MT (2023-24).

Key Outcomes and Cost Savings:

Achieved a 12 KCal/kg clinker reduction in heat consumption and improved reliability. Investment for this upgradation project was Rs. 991 lakhs.

Impact and Scalability:

Enhances heat recovery and operational efficiency. Scalable to other plants with similar cooler systems, offering potential for energy savings and improved reliability across the industry.

Project 9: Ballistic separator installed to remove the foreign material in receipt RDF

Problem Statement:

Challenges in increasing RDF co-processing due to quality issues, including stones mixed with RDF waste, ineffective manual sorting, and high wear and tear in the shredder, leading to operational inefficiencies and equipment damage, hindering sustainable fuel usage.

Solution Implemented:

An action plan was implemented to address RDF co-processing challenges by installing a ballistic separator to sort mixed wastes into flat (2D) and rolling (3D) materials, based on their gradability and ballistic movement

Technical Details:

The installed ballistic separator efficiently separates fine fractions using various screen hole sizes, improving waste sorting accuracy and reducing equipment wear.

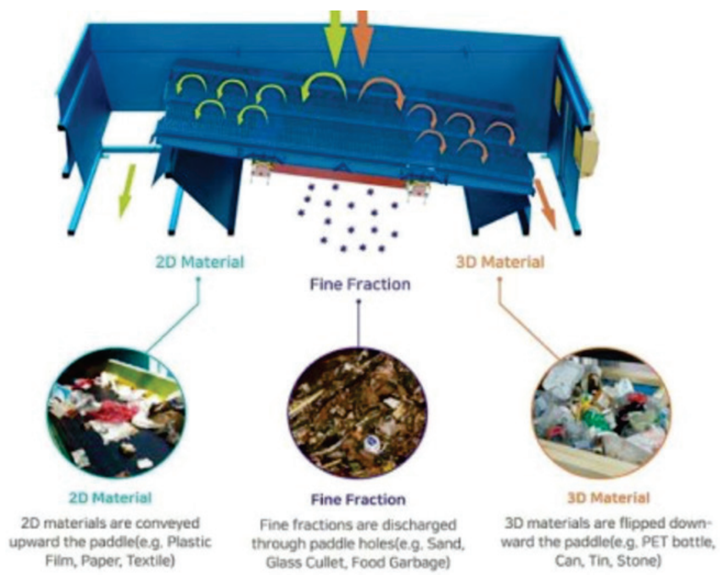

Figure 16 : Ballistic separator installation

Key Outcomes and Cost Savings:

The RDF utilization has increased from 1097 MT in April 2022 to 7899 MT in March 2023, with an RDF % increase from 6% to 28.3%, in the same timeframe.

Impact and Scalability:

This solution enhances mill efficiency and reduces energy costs. It is replicable in other raw mills facing similar duct issues, offering significant potential for energy savings across the industry.

Sample	Moisture	Ash	NCV(ARB)
	%	%	Kcal/kg
Input	22.55	41.4	2014
Middle(Reject)	24.09	56.1	1514
Output	16.48	38.8	2361

Figure 17 : Moisture & ash content of the sample

Project 10: Chlorine Bypass System

Problem Statement:

The plant currently operates at a Thermal Substitution Rate (TSR) of 25%, nearing its upper operational limit without compromising kiln stability. However, the chlorine content in the clinker exceeds 0.07%, which is above the generally accepted threshold (0.03–0.05%) for safe kiln operation without the risk of buildup or ring formation

Solution Implemented:

A chlorine bypass system, designed for maximum of 20% gas extraction from the kiln inlet riser duct, effectively removes volatile components to prevent buildup and operational issues. The dust disposal circuit is fully internal, eliminating the need for external handling.

Technical Details:

A chlorine bypass system is installed in cement plants to control the build-up of volatile components—primarily chlorine, alkalis (Na, K), and sulphates—that can circulate within the kiln system, causing blockages, coating, and reduced efficiency. The bypass typically extracts 10–20% of the kiln exhaust gas (15% in this case), rapidly cooling it to condense and remove these volatiles along with dust.

Key Outcomes and Cost Savings:

The chlorine bypass system facilitates higher alternative fuel (chlorine content) usage and enhances process stability, though it results in a slight increase in power consumption. It serves as a strategic investment for plants focused on improving sustainability and reducing dependence on fossil fuels.

Impact and Scalability:

It's scalable across the cement plants, having thermal substitution rate more than 25% and offering significant potential to enhance energy efficiency and reduce operational costs.

Project 11: Floating Solar

Problem Statement:

The lower utilisation of renewable energy in cement plant operations results in a higher reliance on conventional power sources.

Solution Implemented:

A floating solar system was installed in the mine pit, allowing for the generation of electricity from solar energy. This approach effectively utilizes used/operating mines pit, water reservoirs in mine pit. Also reduces the water loss in the rain water harvesting ponds, reducing water withdrawl from the borewells/ rivers by integrating renewable energy generation.

Technical Details:

The solar panel system converts solar energy into electrical power, which is integrated into the plant's energy system. This project marks the first DGMS-approved floating solar installation in a mine pit, with a capacity of 1 MW.

Key Outcomes and Cost Savings:

- 1.4 million units of renewable electricity generated annually,
- 1,000 Tons of CO_2 offset per year through green energy use,
- 4% higher efficiency compared to conventional land-based solar installations (e.g., via elevated or waterbody-mounted systems)
- 8,000 m^3/year water evaporation saved, contributing to water conservation in arid mining regions.

These outcomes reflect both the environmental and operational benefits of integrating renewable energy systems at mine sites.

Impact and Scalability:

This project promotes renewable energy adoption in cement plants, reducing carbon footprints. It's replicable in facilities with vast mines, though scalability depends on the area available and solar potential.

- Land Area Savings: Approx. 7,200 m^2 (e.g., through elevated or dual-use installations)
- Equivalent Tree Savings: Approx. 1.5 lakh trees/year (based on CO_2 offset equivalence)

Financial Savings: Approx.Rs. 25 Crores over 25 years (from reduced electricity bills and avoided diesel/ grid dependency)

9 Key Formulas Used in Cement

Key Formulas Used in Cement

9.1 Quality Control Formulae for Raw Mix Design

1. Loss on ignition (LOI) (CO_2 from calcination)

LOI refers to the release of volatile matter such as CO_2, water vapor and other combustibles.

Ignition loss = $0.44 \times CaCO_3 + 0.524 \times MgCO_3$ + Combined H_2O + Organic matter

2. Silica modulus (SM)

$$SM = \frac{SiO_2}{Al_2O_3 + Fe_2O_3}$$

Typical range: 1.8-2.7

Higher silica modulus: Harder to burn and exhibits poor coating properties

Lower silica modulus: There may be more melt phase, and coating can become thick leads to ring formation and low early strength (3-7 days) in the cement.

3. Alumina modulus (AM)

$$AM = \frac{Al_2O_3}{Fe_2O_3}$$

Typical range: 1.0-1.5

A clinker with a higher alumina modulus contributes to the production of cement with enhanced early strength.

4. Lime saturation factor (LSF)

It is the ratio of effective lime content to the maximum possible lime content in the clinker.

a. If alumina modulus (AM) > 0.64

$$LSF = \frac{CaO}{2.8\ SiO_2 + 1.65\ Al_2O_3 + 0.35\ Fe_2O_3}$$

b. If alumina modulus (AM) < 0.64

$$LSF = \frac{CaO}{2.8\ SiO_2 + 1.18\ Al_2O_3 + 0.7\ Fe_2O_3}$$

Typical range: 92-98%

If the LSF approaches unity the clinker is hard to burn and often results in excessive free lime.

5. Bogue's formula for cement constituents

a. If alumina modulus (AM) > 0.64

C_3S = $4.071\ CaO-(7.602\ SiO_2+6.718\ Al_2O_3+1.43\ Fe_2O_3+2.852\ SO_3)$

C_2S = $2.867\ SiO_2-0.7544\ C_3S$

C_3A = $2.65\ Al_2O_3-1.692\ Fe_2O_3$

C_4AF = $3.043\ Fe_2O_3$

b. If alumina modulus (AM) < 0.64

C_3S = $4.071\ CaO-(7.602\ SiO_2+4.479\ Al_2O_3+2.859\ Fe_2O_3+2.852\ SO_3)$

C_2S = $2.867\ SiO_2-0.7544\ C_3S$

C_3A = 0

$C_4AF + C_2F$ = $2.1\ Al_2O_3 + 1.702\ Fe_2O_3$

Typical value: C_3S- 45-55%, C_2S- 20-30%

6. Degree of Calcination

$$C\ (\%) = \frac{(1-LOI_{sample}) \times (100-LOI_{feed})}{(100-LOI_{sample}) \times (LOI_{feed})}$$

C - Apparent percent calcination of the sample

7. Raw meal to clinker factor

$$\text{Raw meal to clinker factor} = \frac{100 - \text{ash absorption}}{100\text{-LOI}}$$

Ash absorption = % of ash in fuel × specific fuel consumption

$$\text{Specific fuel consumption} = \frac{100 - \text{ash absorption}}{100\text{-LOI}}$$

8. Kiln feed to clinker factor

$$\text{Kiln feed to clinker factor} = \frac{\text{Kiln feed (kg)}}{\text{Clinker output (kg)}}$$

Note: Considering errors in the kiln feeding system as negligible

OR

$$\text{Kiln feed to clinker factor} = \frac{\text{Raw mill to clinker factor} \times 100}{\text{Top stage cyclone efficiency}}$$

9. Clinker to cement factor

$$\text{Clinker to cement factor} = \frac{\text{Clinker consumed (kg)}}{\text{Clinker+Gypsum+Flyash/Slag+Additives (kg)}}$$

10. Separator efficiency

$$\text{Separator efficiency} = \frac{(100\text{-\%residue of separator fines on 45micron sieve})}{c\times(100\text{-\%residue of separator feed on 45micron sieve})}$$

c = (%residue of separator reject on 45micron sieve - %residue of separator fines on 45micron sieve) / (%residue of separator reject on 45micron sieve - %residue of separator feed on 45micron sieve)

9.2. Formula used in combustion calculations

1. Conversion of gross calorific value (GCV) to net calorific value (NCV)

NCV = GCV - 51.5×H (kcal/kg)

H = % Hydrogen (sum of total H in the fuel and moisture)

2. Ultimate analysis

Ultimate analysis is useful to calculate theoretical combustion air and volume of combustion gases.

C +H +N +S +O +Ash = 100% (By weight)

C = % Carbon

H = % Hydrogen

N = % Nitrogen

S = % Sulphur

O = % Oxygen

3. Proximate analysis

Proximate analysis involves quantitative determination of moisture, carbon, volatile matter and ash. This analysis is used for quick preliminary appraisal of coal.

% Volatile+ % Fixed carbon +% Ash+% Moisture = 100%

4. Theoretical air required to burn fuel

Air (kg air/kg fuel) = $(8/3)\ C + 8(H_2-(O_2/8))+S\times(100/23)$

C = Mass of carbon per kg fuel

H = Mass of hydrogen per kg fuel

S = Mass of sulphur per kg fuel

5. Primary air % & Flame momentum

Sample calculations

Basic Data:

Table 34 : Basic Data for calculation of Primary air % & Flame momentum

S.No	Description	Unit	Value
1	Jet air velocity	m/sec	1.95
2	Inlet area for jet air	m^2	0.15
3	Swirl air velocity	m/sec	0.74
4	Inlet area for swirl air	m^2	0.05
5	Kiln coal conveying velocity	m/sec	1.71
6	Inlet area for kiln coal conveying air	m^2	0.25
7	Temperature of jet air	°C	83
8	Temperature of swirl air	°C	45
9	Temperature of kiln coal conveying air	°C	83
10	Ambient air temperature	°C	40
11	Barometric pressure	mmWC	10,170
12	Jet air pressure at the burner tip	mmWC	9,000
13	Swirl air pressure at the burner tip	mmWC	360
14	Kiln coal firing pressure at the burner tip	mmWC	200
15	Normal density	kg/Nm^3	1.29
16	Clinker production	tph	117
17	O_2 at kiln inlet	%	1.5
18	Kiln firing quantity	tph	3.2
19	NCV of pet coke	kcal/kg	7,403
20	Theoretical air required for 1,000 kcal heat	kg air/1,000 kcal	1.41
21	Jet air nozzle area	m^2	0.0008
22	Swirl air nozzle area	m^2	0.0013
23	Coal injection area	m^2	0.012

Calculations for primary air %:

1.	Jet air flow	=	1.95 m/sec× 0.15 m^2
		=	1,053 m^3/hr
	Corrected density for jet air at blower inlet		
		=	1.293×(273/273+40)×(10,170/10,336)
		=	1.11 kg/m^3
	Jet air flow	=	(1053 m^3/hr×1.11 kg/m^3)/1.293 kg/Nm^3
		=	904 Nm^3/hr
		=	(904 Nm^3/hr)/ (117×1,000 kg clinker /hr)
		=	0.01 Nm^3/kg clinker
		=	904 Nm^3/hr×1.293 kg/Nm^3
		=	1,168 kg/hr
		=	0.325 kg/sec
	2.Swirl air flow	=	0.74 m/sec× 0.05 m^2
		=	133 m^3/hr
	Corrected density for swirl air at blower inlet		
		=	1.293×(273/273+40)×(10,170/10,336)
		=	1.11 kg/m^3
	Swirl air flow	=	(133 m^3/hr×1.11 kg/m3)/1.293 kg/Nm^3
		=	114 Nm^3/hr
		=	(114 Nm^3/hr)/ (117×1,000 kg clinker /hr)
		=	0.001 Nm^3/kg clinker
		=	114 Nm^3/hr×1.293 kg/Nm^3
		=	147 kg/hr
		=	0.041 kg/sec
3.	Kiln coal conveying air flow	=	1.71 m/sec× 0.25 m^2
		=	1,539 m^3/hr
	Corrected density for kiln air at tip		
		=	1.293×(273/273+83)×((10,170+200)/10,336)
		=	1.0 kg/m^3
	Kiln coal air flow	=	(1,539 m^3/hr×1.0 kg/m^3)/1.293 kg/Nm^3
		=	1,190 Nm^3/hr

= (1,190 Nm^3/hr)/ (117×1,000 kg clinker /hr)

= 0.01 Nm^3/kg clinker

= 1,190 Nm^3/hr×1.293 kg/Nm^3

= 1,538 kg/hr

= 0.42 kg/sec

4. Theoretical combustion air required

O_2 at kiln inlet = 1.5%

Excess air = 1.5×100/(20.9-1.5)

= 7.73 %

Theoretical combustion air required

= (3.2×1,000) kg coal/hr×(1.41kg air/1,000kcal) ×7,403kcal/kg coal×(1+7.73%)

= 35,969 kg air/hr

5. Primary air %

Jet air quantity = (1,168 kg/hr/35,969 kg/hr) ×100

= 3.25 %

Swirl air quantity = (147 kg/hr/35,969 kg/hr) ×100

= 0.41 %

Kiln coal air quantity = (1538 kg/hr/35,969 kg/hr) ×100

= 4.27 %

Primary air % = 3.25%+0.41%+4.27%

= 7.93 %

Calculations for flame momentum

1. Jet air burner tip velocity = (1053 m^3/hr/0.0008 m^2) /3600

= 384 m/s

Jet air force = 0.325 kg/sec×384 m/s

= 124.8 N

2. Swirl air burner tip velocity = (133 m^3/hr/0.0013 m^2)/3,600

= 28 m/s

Swirl air force = 0.041 kg/sec×28 m/s

= 1.14 N

3. Kiln coal air burner tip velocity = $(1{,}538\ m^3/hr/0.012\ m^2)/3{,}600$

= 36 m/s

Kiln coal conveying air force = 0.42 kg/sec×36 m/s

= 15.12 N

4. Total force = 124.8+1.14+15.12

= 141 N

5. Petcoke consumption = 3,200 kg/hr

Energy = 3,200 kg/hr×7,403 kcal/kg

= 2,36,89,600 kcal/hr

= 2,36,89,600 kcal/hr/860/1,000

= 28 MW

Flame momentum = 141 N/28 MW

= 5.03 N/MW

9.3 Kiln performance

1. Volumetric loading of kiln

$$\text{Volumetric loading } (TPD/m^3) = \frac{\text{Clinker production (TPD)}}{\Pi(D^2/4) \times L}$$

D = Effective diameter of kiln (ID of kiln) (m)

L = Length of the kiln (m)

2. Thermal loading of kiln

$$\text{Thermal loading } (kcal/hr/m^2) = \frac{\text{Clinker (TPD)} \times \text{Heat consumption} \times \text{\%Firing in kiln} \times 1{,}000}{\Pi(D^2/4) \times 24}$$

Heat consumption = kcal/kg

D = Effective diameter of kiln (ID of kiln) (m)

3. Kiln thermal efficiency

$$\text{Kiln thermal efficiency (\%)} = \frac{\text{Heat of formation of clinker (kcal/kg clinker)}}{\text{Specific heat consumption (kcal/kg clinker)}}$$

4. Cooler loading

$$\text{Volumetric loading (TPD/m}^3\text{)} = \frac{\text{Clinker production (TPD)}}{\text{Effective grate area (m}^2\text{) of cooler}}$$

5. Cooler recuperation efficiency

$$\text{Cooler recuperation efficiency (\%)} = \frac{\text{Recuperated heat (Heat through secondary and tertiary air) (kcal/kg clinker)}}{\text{Total heat input to cooler (kcal/kg clinker)}}$$

6. False air estimation O_2 method

$$\text{\% False air (In terms of outlet)} = \frac{O_2\text{ (Outlet)}-O_2\text{(Inlet)}}{21-O_2\text{(Inlet)}}$$

$$\text{\% False air (In terms of inlet)} = \frac{O_2\text{ (Outlet)}-O_2\text{(Inlet)}}{21-O_2\text{(Outlet)}}$$

False air estimation is mostly done by outlet method.

7. % Excess air

a. For complete combustion (Nil CO)

$$\text{\% Excess air} = \frac{O_2}{21-O_2}$$

b. For incomplete combustion (With CO)

$$\text{\% Excess air} = \frac{189(2O_2-CO)}{N_2-1.89(2O_2-CO)}$$

9.4 Fluid flow

1. Flow calculations

Barometric pressure(B) = $10336\times e^{-(0.0001255\times H)}$ (mmWC)

H = Height above sea level

Corrected density(ρ_C) = $\rho_N\times(273/273+T)\times(B+Ps)/B$

ρ_N	=	Normal density (kg/Nm^3)
T	=	Temperature of gas flow (˚C)
B	=	Barometric pressure (mmWC)
Ps	=	Static pressure (mmWC)

Velocity(m/s)	=	$C_p \times (2 \times g \times P_d / \rho_c)^{1/2}$
C_p	=	Pitot tube constant
g	=	Acceleration due to gravity(m/s^2)
P_d	=	Dynamic pressure (mmWC)
ρ_c	=	Corrected density (kg/m^3)

Standard gas flow -Q_N	=	$Q \times \rho_c / \rho_N$
Q_N	=	Standard gas flow (Nm^3/Hr)
Q	=	Actual gas flow (m^3/hr)
ρ_N	=	Normal gas density (kg/Nm^3)
ρ_c	=	Corrected gas density (kg/m^3)

9.5 Heat Transfer

1. Natural convection loss

Convection loss	=	$80.33 \times ((T+Ta)/2)^{-0.724} \times (T-Ta)^{1.333}$
Convection loss	=	kcal/hr m^2
T	=	Surface temperature (K)
Ta	=	Ambient temperature (K)

2. Forced convection loss

Forced convection loss	=	$28.03 \times (T+Ta)^{-0.351} \times V^{0.805} \times D^{-0.195} \times (T-Ta)$
Forced convection loss	=	kcal/hr m^2
T	=	Surface temperature (K)
Ta	=	Ambient temperature (K)
V	=	Wind speed (m/s)
D	=	Outer diameter of kiln (m)

3. Radiation loss

Radiation loss = $4\times10^{-8}(T^4-Ta^4)$

Radiation loss = kcal/hr m^2

T = Surface temperature (K)

Ta = Ambient temperature (K)

9.6 Fan Engineering

1. Fan Efficiency

$$\text{Fan efficiency (n)\%} = \frac{\text{Volume } (m^3/s) \times \Delta P(\text{mmWC}) \times 100}{102 \times \text{Power input to fan shaft(kW)}}$$

ΔP = Head developed by the fan(mmWC)

Power input to fan shaft(kW) = Input power to motor(kW)× n_{motor}

n_{motor} = Motor efficiency

2. Volume, Head, Power variation with fan speed (Affinity Law)

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$\frac{H_1}{H_2} = \frac{(n_1)^2}{(n_2)^2}$$

$$\frac{P_1}{P_2} = \frac{(n_1)^3}{(n_2)^3}$$

Q = Volumetric flow (m^3/s)

H = Head developed by the fan (mmWC)

P = Fan power (kW)

n = Fan speed (RPM)

3. **Volume, Head, Power variation with impeller diameter of fan (Affinity Law)**

$$\frac{Q_1}{Q_2} = \frac{(D_1)^3}{(D_2)^3}$$

$$\frac{H_1}{H_2} = \frac{(D_1)^2}{(D_2)^2}$$

$$\frac{P_1}{P_2} = \frac{(D_1)^5}{(D_2)^5}$$

Q = Volumetric flow (m^3/s)

H = Head developed by the fan (mmWC)

P = Fan power (kW)

D = Fan Impeller diameter (m)

9.7 Waste heat recovery potential

Sample calculation for waste heat recovery potential:

Basic data:

Table 35 : Basic Data for calculation of waste heat recovery potential

Sr No	Description	Unit	Value
1	Kiln capacity	TPD	5,000
2	No of stages in preheater		6
3	Preheater exit gas flow details		
3.1	Flow	kg/kg clinker	1.9
3.2	Specific heat capacity	kcal/kg ˚C	0.24
3.3	Temperature	˚C	322
4	Cooler exit gas details		
4.1	Flow	kg/kg clinker	1.4
4.2	Specific heat capacity	kcal/kg ˚C	0.24
4.3	Temperature	˚C	335
5	Limestone moisture content	%	2
6	Raw mill running hours	hrs/day	20
7	Kiln running days per annum	days/annum	330
8	Heat transfer efficiency of WHR boiler	%	85

9	Heat transfer efficiency of AQC boiler	%	85
10	TG system efficiency	%	33
11	Specific heat consumption	kcal/kg clinker	732
12	Raw coal moisture	%	0.4
13	Raw mill to clinker factor		1.55
14	Heat requirement for moisture in raw mill and coal mill	kcal/kg water	539
15	Calorific value of fine coal used	kcal/kg coal	7,403
16	Coal mill running hours per day	Hrs/day	20
17	PH gas temperature at WHRB outlet	˚C	240
18	Cooler exit temperature at AQC boiler outlet	˚C	120

Calculations:

1. Heat available in preheater gas = m×Cp×T
 = 1.92×0.244×322
 = 150.8 kcal/kg clinker

2. Heat available in cooler exit gas = m×Cp×T
 = 1.4×0.245×335
 = 114.9 kcal/kg clinker

3. Heat requirement for raw mill

a) Raw mill capacity = 5,000 TPD×1.55×24/20
 = 9,300 TPD
 = 387.5 TPH
 = 1.86 kg/kg clinker

b) Moisture in raw mill = 387.5 TPH×2%
 = 7.75 TPH
 = 0.037 kg /kg clinker

c) Heat requirement in raw mill = m×heat of vaporization
 = 0.037 kg /kg clinker ×539 kcal/kg
 = 20.0 kcal/kg clinker

4. Heat requirement for coal mill

a) Coal requirement = Specific heat consumption/CV of coal
 = 732 kcal/kg clinker/7,403 kcal/kg coal
 = 0.098 kg/kg clinker

b)	Coal mill capacity	=	0.098× (5,000/24) ×1,000kg clinker/hr×24/20
		=	24.5 TPH
c)	Moisture in coal mill	=	24.5 TPH×0.4%
		=	0.098 TPH
		=	0.469 kg /T clinker
d)	Heat requirement in coal mill	=	m×heat of vaporization
		=	0.469 kg /T clinker ×539 kcal/kg/1,000
		=	0.25 kcal/kg clinker
5.	Excess heat available in preheater		
		=	Heat available in preheater gas- (Heat required for raw mill and coal mill)
		=	150.85-(20.0+0.25)
		=	130.6 kcal/kg clinker
6.	Total excess/waste heat available		
		=	Excess heat available in preheater+ Heat available in cooler exit gas
		=	130.6+114.9
		=	245.5 kcal/kg clinker
7.	Heat recoverable in preheater side boiler	=	1.92×0.244× (322-240)
		=	38.4 kcal/kg clinker
8.	Heat recoverable in cooler side boiler	=	1.4×0.245× (335-120)
		=	73.7 kcal/kg clinker
9.	Heat available for steam power generation	=	(38.41×0.85) +(73.7×0.85)
		=	95.3 kcal/kg clinker
10.	Power generation possible		
		=	Heat available for steam power generation× TG efficiency
		=	95.3×0.33

= 31.5 kcal/kg clinker

= 0.0365 kWh/kg clinker

= 36.5 kWh/T clinker

= 7.6 MW

9.8. GHG Emission Intensity Estimation

Basic Data:

Table 36 : Basic Data for calculation of emission intensity

S.No	Levers	Unit	Value
1	Thermal SEC	Kcal/kg clk	730
2	AFR	%	20.0
3	Overall Clinker factor	-	0.70
4	Electrical SEC		
4.1	Up to clinkerization	kWh/ton Clk	50
4.2	Cement grinding	kWh/ton cement	35
4.3	Overall SEC	kWh/ton cement	70
5	WHRS (% Electricity Generation)	kWh/ton Clk	30
		%	30
6	Renewable Energy (% Electricity Generation)	%	20
7	Grid (% import from grid)	%	20
8	Own Generation (CPP) (% electricity generation	%	30
9	Default Grid emission factor	kg CO_2/kWh	0.72
10	Default CPP emission factor	kg CO_2/kWh	1.19
11	Default Emission factor for coal	g CO_2/kcal	0.396
12	Default CO_2 emission from Process	kg CO_2/MT clinker	529

Sample Calculations:

1. CO_2 emissions from process

= CO_2 emissions from process × Overall clinker factor

= 529 kg CO_2/MT clinker× 0.7

= 370 kg CO_2/MT Cement

2. CO_2 emissions from kiln heat consumption

= Thermal SEC×(100-AFR%) % × Emission factor for coal × Overall clinker factor

= 730kcal/kg clinker × (100-20) %× 0.396 g CO_2/kcal×0.7

= 162 kg CO_2/MT Cement

3. CO_2 Emission from CPP

= Overall SEC× Own Generation (CPP) (% electricity generation) × CPP emission factor

= 70 kWh/MT cement×30%×1.19 kg CO_2/kWh

= 25 kg CO_2/MT Cement

4. Total scope 1 emissions

= 370+162+25

= 557 kg CO_2/MT Cement

5.Scope 2 emissions (with grid power)

= Overall SEC× Grid (% import from grid) × Grid emission factor

= 70 kWh/MT cement× 20%×0.72 kg CO_2/kWh

= 10 kg CO_2/MT Cement

6. Total Scope 1 & Scope 2 emissions with respect to overall clinker factor

= 557 kg CO_2/MT Cement + 10 kg CO_2/MT Cement

= 567 kg CO_2/MT Cement

GHG Emission Intensity			
1	CO_2 emission from Process	kg CO_2/MT cement	370
2	CO_2 emission from kiln heat consumption	kg CO_2/MT clinker	162
3	CO_2 Emission from CPP	kg CO_2/MT cement	25
4	Total Scope 1 emissions	kg CO_2/MT cement	557
4	Scope 2 emission (with Grid power)	kg CO_2/MT cement	10
5	Total Scope 1 & Scope 2 emissions with respect to overall clinker factor	kg CO_2/MT cement	567

Abbreviations

AC - Alternating Current
ACC - Air Cooled Condenser
ACWP - Auxiliary Cooling Water Pump
AF - Alternative Fuel
AFBC - Atomospheric Fluidised Bed Combustion
BDP - Best Demonstrated Practice
BEE - Bureau of Energy Efficiency
BFP - Boiler Feedwater Pump
BH - Bag House
BLDC - Brushless Direct Current
CA - Circulating Air
CAGR - Compound Annual Growth Rate
CCR - Central Control Room
CCUS - Carbon Capture Utilisation & Storage
CEP - Condensate Extraction Pump
CF - Continuous Flow
CFBC - Circulating Fluidised Bed Com-bustion
CFC - Chlorofluorocarbons
CFD - Computational Fluid Dynamics
CMA - Cement Manufacturers Association
CO - Carbon monoxide
COC - Cycle of Concentration
CPP - Captive Power Plant
CWP - Cooling Water Pump
DG - Diesel Generator
DP - Differential Pressure
EC - Electronically Commutated
EOT - Electric Overhead Travelling
ESP - Electrostatic Precipitator
FA - False Air
FD - Forced Draft
FRP - Fibre Reinforced Plastic
GCT - Gas Conditioning Tower
GCCA - Global Cement and Concrete Association
GGBS - Ground Granulated Blast Furnace Slag
GI - Galvanized Iron
GRR - Grid Rotor Resistance
HAR - Hot Air Recirculation
HPRG - High-Pressure Roller Grinding
HT - High Voltage Transmission
IL- Load Current
ILC - In-Line Calciner
ISC - Short circuit Current
ICE - Internal Combustion Engine
LC3 - Limestone Calcined Clay Cement
LDR - Light Dependent Resistor
LED - Light Emitting Diode
LOI - Loss on Ignition
LRR - Liquid Rotor Resistance
LSF - Lime Saturation Factor
LT - Low Voltage Transmission
MT - Metric Ton
MTPA - Million Tons Per Annum
NCCBM - National Council for Cement and Building Materials
NCV - Net Calorific Value
OPC - Ordinary Portland Cement
PAT - Perform, Achieve and Trade
PD - Positive Displacement
PH - Pre Heater
PLC - Portland Limestone Cement
PLC - Programmable Logic Controller
PLF - Plant Load Factor
PPC - Portland Pozzolana Cement
PPM - Parts Per Million
PSC - Portland Slag Cement
PV - Photo Voltaic
RABH - Reverse Air Bag House
RE - Renewable Energy
RPM - Revolutions Per Minute
RTA - Road Transport Authority
SCM - Supplementary Cement itious Materials
SEC - Specific Energy Consumption
SHC - Specific Heat Consumption
SLC - Separate Line Calciner
SPRS - Slip Power Recovery System
STP - Sewage Treatment Plant
TAD - Tertiary Air Duct
TG - Turbo Generator
TPH - Tonnes Per Hour
TR - Tons of Refrigeration
TSR - Thermal Substitution Rate
VAM - Vapour Absorption Machine
VFD - Variable Frequency Drive
VRM - Vertical Roller Mill
WHR - Waste Heat Recovery

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 CCTS (Carbon Credit and Trading Scheme of BEE) targets in a cost- effective manner.
3. Development of 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.

Notes

Notes

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 2026.

Conclusion

We feel that this Energy Benchmarking Version 7.0 for Cement Industry would have given you useful tips/ information and is helpful for you in your day-to-day energy conservation activities. We invite your valuable feedback for any corrections /suggestions to be added for updating the details in the future version of this handbook.

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