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Ministry of Power
Government of India

Improving Energy Efficiency in

Cement Sector

(Achievements and Way Forward)

Perform Achieve & Trade

September 2018

BUREAU OF ENERGY EFFICIENCY

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Cement is an essential part of our daily lives Cement production contributes significantly to annual anthropogenic global CO_2 emissions, mainly because such vast quantities are used. Thus, energy efficiency becomes very important in its production to reduce this carbon footprint. India, being the 2nd largest global cement producer, is amongst the world's most energy efficient cement manufacturer. Needless to say, it has lower carbon footprint per unit of cement produced. The cement production in India is likely to grow at around 6% annually, thereby adding significant amount of CO_2 to the atmosphere. However, the current trend in technological advancement in the industry sustains hope that the carbon footprint per unit of production will continue to decrease as has been in past decades.

Germany has been playing a very active role in promoting energy efficiency in not only its own land, but also supporting the other countries to adopt the same. Germany has been supporting India in various fields since last 60 years, with an aim of promoting cooperation and involving public-private sectors of both sides in the areas of energy, environment and sustainable economic development. The Indo-German Energy Programme (IGEN), works as a partner of Bureau of Energy Efficiency (BEE) in supporting policies and programmes envisaged under the Energy Conservation Act, 2001.

It has been a privilege to work with BEE, the organization spearheading activities on energy efficiency in India. IGEN has been involved with BEE in the Perform Achieve and Trade since its inception, and hence it is blissful to know that the outcome of this scheme led to a huge savings in terms of CO_2 emission reduction and coal.

However, the real outcome of PAT scheme is not only the savings in terms of toe and CO_2, but it is the change in behavior towards energy efficiency. It is astonishing to see the amount of resources and concepts the industries have put together in achieving the target. Some state-of-the-art projects implemented in PAT cycle-I are cross cutting and could have significant potential across the sectors. Some of the positive outcomes of this scheme were the utilization of waste heat in generation of steam and power, adoption of cogeneration, use of alternate fuel and raw material, etc. This report analyses the outcome of PAT scheme in Cement sector in multidimensional ways and forecasts the future savings along with innovative case studies having high replication potential. The estimate suggests the cumulative energy savings from the sector till 2030 to be 34.46 million TOE, which is quite impressive.

We are delighted to be a part of this historic journey where India has been a forerunner in implementing an exceptional scheme, customized to the benefit of the industries as well as the nation. I personally feel that the deepening of this scheme in Cement sectors would prove a game changer in the times to come. This scheme has tremendous opportunities for regional synergies and its adaptation by other countries could lead to address the global climate issues.

Dr. Winfried Damm

अभय बाकरे, आईआरएसईई
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ENERGY IS LIFE
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(भारत सरकार, विद्युत मंत्रालय)
BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

FOREWORD

As we are embarking an ambitious path to provide electricity to all and raise the level of energy availability to the population across the country with limited resources at disposal; efficient use of primary energy resources is absolutely necessary.

Bureau of Energy Efficiency, under the Ministry of Power has been spearheading the promotion of energy efficiency in various aspects of the country's energy landscape, through programs such as Standards & Labelling for appliances, Energy Conservation Building Code (ECBC) for buildings and Demand Side Management (DSM) program for Agriculture and Municipality sectors.

One such flagship program for energy intensive industries namely Perform, Achieve and Trade (PAT) was launched under the National Mission for Enhanced Energy Efficiency (NMEEE). This scheme has demonstrated its value in its first cycle, in which 478 Designated Consumers have achieved 8.67 MTOE of energy savings against the target of 6.68 MTOE, exceeding by about 30 %.

With an objective to have further insight on the actions taken and other notable effects taken by these designated units in achieving the excellent results, a study has been taken up by BEE in partnership with GIZ. The report gives an in-depth analysis of the achievements, projections and success stories across various sectors covered in the first cycle of PAT scheme.

With the continued guidance of Ministry of Power, the Bureau of Energy Efficiency expresses its gratitude towards all the industries, associations and other stakeholders for their significant contribution to achieve the task of saving energy and adoption of energy efficiency measures. BEE intends to convey our congratulations to all who joined us on our collective endeavour of improving energy efficiency in the country.

Abhay Bakre.
(Abhay Bakre)

New Delhi: 19.09.2018

स्वहित एवं राष्ट्रहित में ऊर्जा बचाएँ Save Energy for Benefit of Self and Nation

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1.0 Executive Summary

In a bid to combat increasing energy consumption and related carbon emissions, the Government of India released the National Action Plan on Climate Change (NAPCC) in 2008 to promote and enable sustainable development of the country by promoting a low carbon and high resilience development path. Under the NAPCC, eight national missions were framed to focus on various aspects related to water, solar energy, sustainable habitat, agricultural, energy efficiency, ecosystems, etc. Perform Achieve and Trade scheme (PAT) is a component of the National Mission for Enhanced Energy Efficiency (NMEEE) which is one of the eight missions under the NAPCC.

PAT is a regulatory instrument to reduce specific energy consumption (SEC) in energy intensive industries, with an associated market-based mechanism to enhance cost effectiveness through certification of excess energy savings, which could be traded. Energy Savings Certificate (ESCerts) are issued to the industries which reduce their SEC beyond their target. Those companies which fail to achieve their target are required to purchase ESCerts for compliance, or are liable to be penalised. Trading of ESCerts are conducted on existing power exchanges.

PAT Cycle – I, which was operationalized in April 2012, included 478 units, known as "Designated Consumers" (DCs), from eight energy-intensive sectors viz. Aluminium, Cement, Chlor- Alkali, Fertilizer, Iron &Steel, Pulp & Paper, Thermal Power Plant and Textile were included. The annual energy consumption of these DCs in eight sectors was around 164 million TOE. The overall SEC reduction target in the eight sectors was about 4.05% with an expected energy saving of 6.68 million TOE by the end of 2014-15.

With the completion of the PAT Cycle – I in 2015, the reported overall achievement was 8.67 million TOE, exceeding the target for cycle 1 by almost 30%. The total energy saving of 8.67 million TOE is equivalent to saving of about 20 million tonnes of coal and avoided emissions of about 31 million tonnes of CO_2. In terms of monetary value, saving in energy consumption corresponds to Rs. 95,000 million.

PAT Cycle – I has witnessed an exceptional performance from all the sectors in terms of reducing their energy consumption. The DCs have made commendable efforts to achieve energy efficiency targets by adopting various improvement measures in technology, operational and maintenance practices, and application of management techniques.

India is the second largest producer of cement in the world and is one of the major energy consumers. For the PAT scheme, cement plants having annual energy consumption greater than 30,000 million TOE were included under PAT Cycle – I. Based on the threshold defined, 85 cement plants were included as DCs and their cumulative energy consumption was 15.01 million TOE. Based on their specific energy consumption level, these DCs were given SEC target reduction of an average 5.43% resulting in 0.815 million TOE energy consumption reduction in absolute terms.

Cement sector constituted 12.19% of the overall energy saving target under PAT Cycle – I. Table 1 broadly highlights the achievement of the cement sector.

Parameter	Units	Values
Number of DCs in the sector	nos	85
Total energy consumption of DCs in the sector	million TOE	15.01
Total energy saving target by Cement sector in PAT Cycle I	million TOE	0.815
Total energy savings achieved by Cement sector in PAT Cycle I	million TOE	1.48
Energy savings achieved in excess of the target	million TOE	0.665
Reduction in GHG Emissions in Cycle I	million T CO_2	4.34
Cumulative energy savings with PAT Impact till 2030 over BAU[1]	million TOE	34.46

Table 1: Cement sectoral achievement in PAT Cycle I and projections till 2030

The key focus of Cement sectoral report is on the energy savings resulting from PAT scheme as compared to the business as usual scenario (BAU). The report also includes the impact of PAT on GDP of the country, sector specific data analysis, process trends, sectoral benchmarking of specific energy consumption, success stories implemented in plants, and list of key technologies which can be implemented in the sector. Analysis has been presented until the year 2030.

1. Difference of energy consumption between PAT and Business as Usual scenario(BAU)

2.0 Cement sector in India

India is the second largest producer of cement in the world. India's cement industry is playing a vital part in the overall economy and development of the country. The sector is providing employment to more than a million people, directly or indirectly.

Some of the recent major initiatives taken by governments are Smart cities project, Housing for All, Pradhan Mantri Awaas Yojana – Gramin scheme which are expected to provide a major boost to the sector.

India's total cement production capacity is nearly 425 million tonnes[3], as of September 2017. The growth of cement industry is expected to be 6-7 per cent in 2017 because of the government's focus on infrastructural development. The industry is currently producing 280 million Tonnes for meetings its domestic demand and 5 million Tonnes for exports requirement. The country's per capita consumption stands at around 225 kg[4].

SECTOR HIGHLIGHTS......

- India is the second largest producer of cement in the world.
- The country's per capita consumption stands at around 225 kg
- India's total cement production capacity is nearly 425 million tonnes as of September 2017
- The cement production in India likely to grow at 6% CAGR and the expected cement production in India by year 2030 will be around 598 million tonne.
- Contributes approx. Rs. 32500-35000 crore annually to the national exchequer through various taxes and levies.

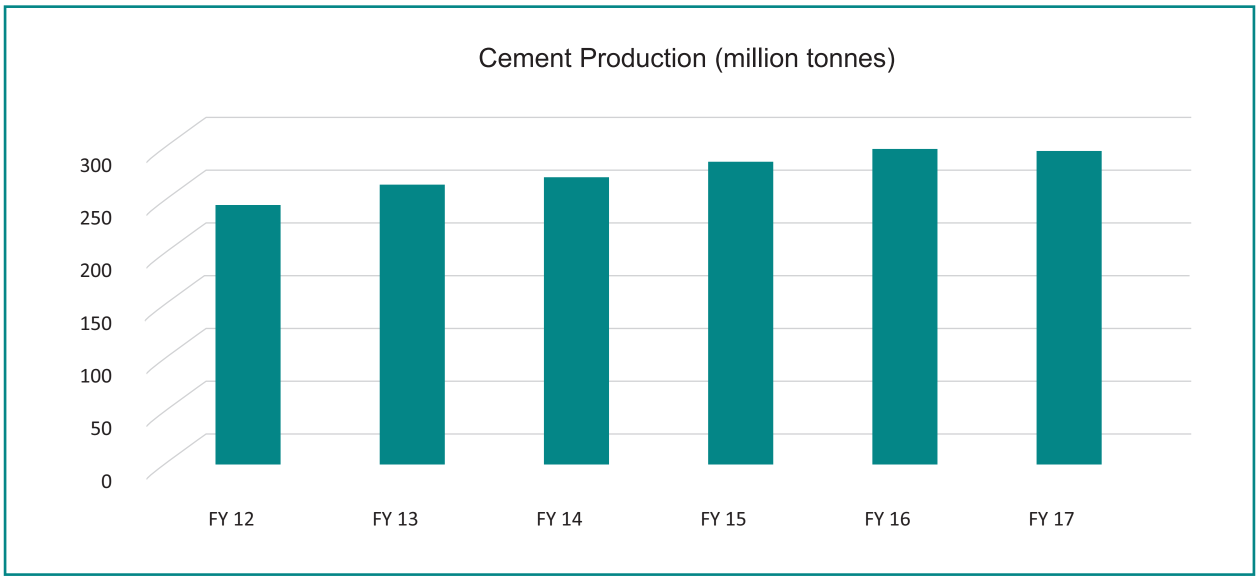


Figure 1: Cement Production in India

3. India Brand Equity Foundation (IBEF) – Report on Cement Industry in India
4. India Brand Equity Foundation (IBEF) – Report on Cement Industry in India

The housing sector is the biggest demand driver of cement, accounting for about 67 per cent of the total consumption in India. The other major consumers of cement include infrastructure at 13 per cent, commercial construction at 11 per cent and industrial construction at 9 per cent.

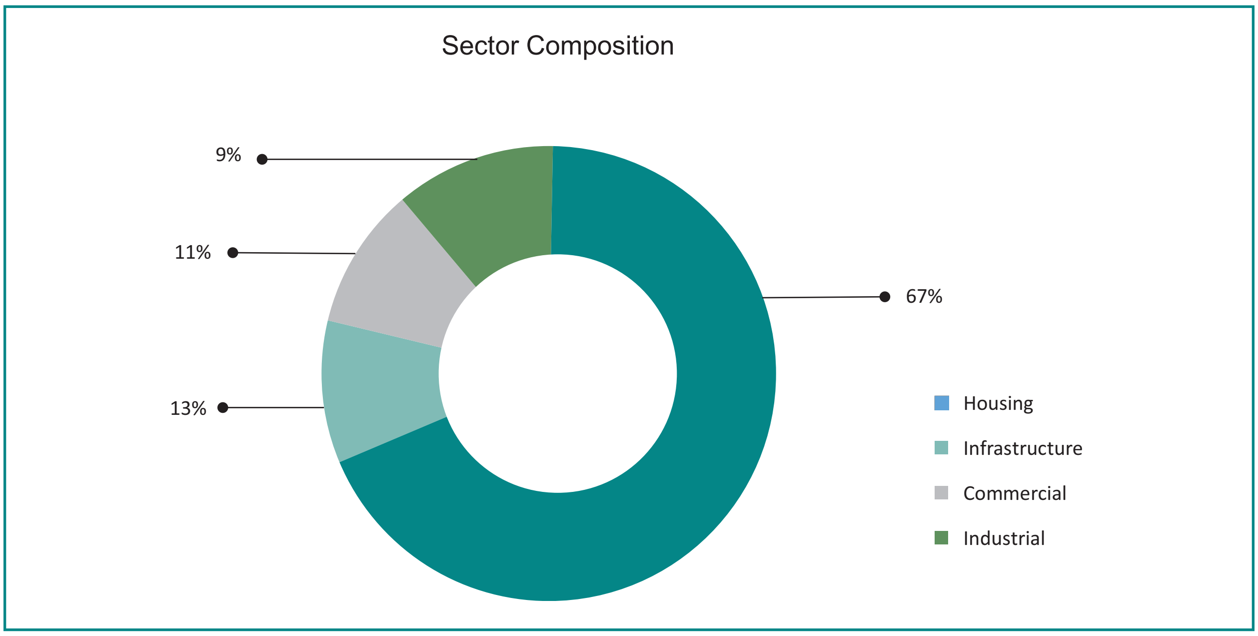


Figure 2: Sector Composition

2.1 Sectoral Contribution to Country's Energy Intensity

Cement is one of the core industries and an important contributor in infrastructural growth of the country. The sector contributes approx. Rs. 32500-35000 crore annually to the national exchequer through various taxes and levies. Cement production in India is likely to grow at 6% CAGR and the expected cement production in India by year 2030 will be around 598 million tonne[5].

Year	Crude Steel Production (million tonne)	Percentage growth (%)
FY12	230	
FY13	248	8%
FY14	256	3%
FY15	270	6%
FY16	283	5%
FY20	333	Expected to grow @ 6% CAGR
FY25	446	
FY30	598	

Table 2: Growth of Cement Industry[6]

The Energy intensity of the country is calculated in Table 3, and is on basis of primary energy consumption and does include energy consumption of non-conventional sources of energy. The sectoral Energy intensity for cement sector DCs in PAT is mentioned in Table 4. The contribution of DC's to overall energy intensity of India is 3.41% for the baseline year. Cement sector has achieved

5. Low Carbon Technology Roadmap for Indian Cement Industry
6. IBEF – Report on Cement Industry in India

1.48 million TOE savings under PAT cycle – I. The contribution of this energy savings to overall total energy consumption of India is 0.22% during the assessment year.

Financial Year	Total Energy Consumption of India[9]	Gross Domestic Product (GDP)	Energy Intensity
	million TOE	Billion USD	TOE/million USD
2008	427	1,187	360
2009	453	1,324	342
2010	512	1,657	309
Average Baseline	464	1,389	334
2015	659	2,102[9]	313
2020	1018[10]	3,018	337
2025	1211[11]	4,233	286
2030	1440[8]	5,937[13]	243

Table 3: India's Energy Intensity

Financial Year	Total Production	Total Energy Consumption	Gross Domestic Product (GDP)	Energy Intensity
	million tonnes	million TOE	Billion USD	TOE/million USD
Average Baseline	177[14]	15.01	1,389	10.81
2015	270	22.45	2,102	10.68
2020	333	26.02	3,018	8.62
2025	446	32.83	4,233	7.75
2030	598	41.61	5,937	7.01

Table 4 Cement Sector Energy Intensity

Cement sector Energy intensity contribution in baseline year and assessment year was 3.23% and 5.16% respectively.

7. Energy consumption values are taken from Energy Statistics 2017 report
8. BP Statistical Review of World Energy 2016
9. GDP from World Bank GDP for India – Upto 2015
10. India Energy Outlook, Year 2015 - IEA
11. Estimated by calculating CAGR for 2020 and 2040 in India Energy Outlook, Year 2015 - IEA
13. GDP values calculated based on CAGR value of 7.5% till 2020 and 7% between 2020 and 2030. Same assumptions have been considered in India Energy Outlook, Year 2015 - IEA
14. Avg. production of cement in India during year 2007-2010

3.0 Process, Technologies and Energy consumption trend of the sector

The cement manufacturing process is complex, involving multiple steps that require specialized equipment.

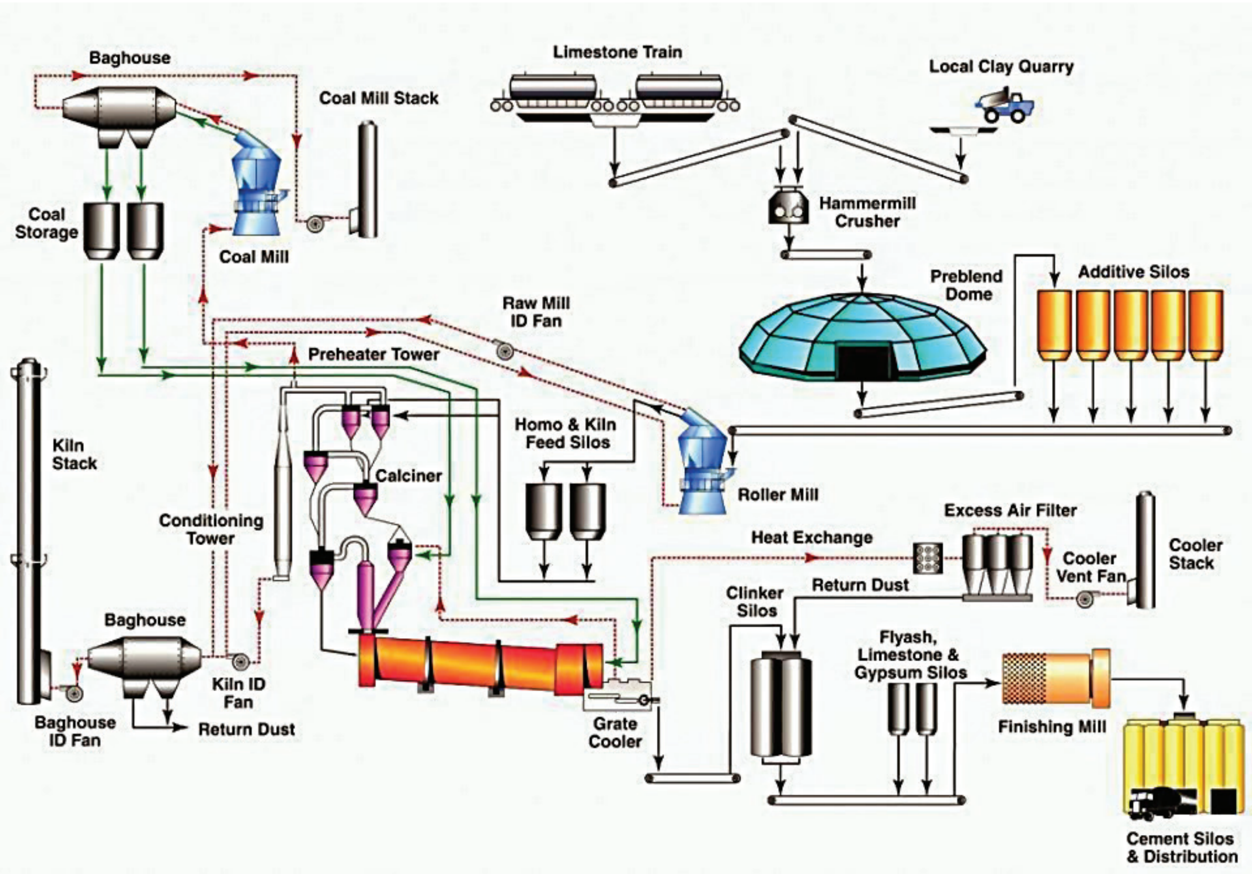


Figure 3: Cement Manufacturing Process flowchart

1. Surface mining/quarrying raw materials

Naturally occurring calcareous deposits, such as limestone, marl or chalk, provide the calcium carbonate ($CaCO_3$) that comprises the raw materials of cement. As these are extracted from surface mines/quarries, a first consideration in energy efficiency is often to locate cement plants close to the source of raw material.

2. Crushing

After the raw material is mined and transported to the cement plant, the first step is to feed it through the primary/secondary crushers, which breaks it down into pieces, approximately 10 centimetres (cm) in size.

3. Pre homogenization and raw meal grinding

Pre homogenization is a process by which different raw materials are mixed to obtain the chemical composition required for the end use of a given "batch" of cement. Very small amounts of "corrective" materials such as iron ore, bauxite, shale, clay or sand may be needed to provide extra iron oxide (Fe_2O_3), alumina (Al_2O_3) and silica

(SiO_2) to adapt the chemical composition of the raw mix to the process and product requirements of cement manufacturing. The crushed pieces are then milled together to produce a "raw meal". To ensure high cement quality, the chemistry of the raw materials and raw meal is very carefully monitored and controlled.

4. Coal grinding/kiln fuel preparation

Coal is grounded into fine powder to enable it to feed into the kiln as a fuel, to generate the required heat for calcination.

5. Preheating

One of the means to improve the efficiency of the process is to pre-heat the raw meal before it enters the kiln, which stimulates faster chemical reactions. A pre-heater is a series of vertical cyclones through which the raw meal is passed, coming into contact with swirling hot gases moving in the opposite direction. As these gases exhaust from the kilns, efficiency is gained by using heat generated by one production process to provide energy needed for another. Depending on the moisture content of the raw material, a kiln may have up to six stages of cyclones with higher temperatures – obtained through increased heat recovery – at each extra stage.

6. Precalcination

Calcination is the decomposition of limestone to lime. The required reactions, which also need heat energy inputs, are stimulated at two points in the manufacturing process: within the "precalciner", a combustion chamber at the bottom of the pre-heater above the kiln, and within the kiln itself. This is the first point of the manufacturing process at which emissions are produced: the chemical decomposition of limestone typically accounts for 60% to 65% of total emissions. The fuel combustion needed to generate heat in the precalciner also produces emissions, accounting for about 65% of the remainder of total emissions.

7. Clinker production in the rotary kiln

The precalcined meal then enters the kiln, where intense heat – up to 1 450°C – causes chemical and physical reactions that partially melt the meal into "clinker", an intermediate product in cement manufacturing that becomes the main substance in cement and is commonly traded. Fuel is fired directly into the kiln: as the kiln rotates, about three to five times per minute, the material slides and tumbles down towards the flame, through progressively hotter zones.

8. Cooling and storing

From the kiln, the hot clinker falls onto a grate cooler where it is cooled by incoming combustion air, thereby minimising energy loss from the system. A typical cement plant will have clinker storage facilities between clinker production and the plant components that handle blending and/or grinding.

9. Blending

Increasingly, cement producers are using materials such as slag, fly ash, limestone or other mineral components to reduce the amount of clinker required for a given batch of cement. In such cases, the end product is called "blended cement"; it can be customised to provide characteristics needed for the end-use. For example, all cement types contain around 4% to 5% gypsum to control the setting time of the product.

10. Cement grinding

The cooled clinker and/or blended mixture is grounded into a grey powder, known as Ordinary Portland Cement (OPC), or ground with other mineral components to make blended cement. Traditionally, cement plants used "ball mills" for grinding. Today, more efficient technologies – including roller presses and vertical mills – are used in many modern plants. Wider deployment could further improve efficiency of the industry as a whole.

11. Storing in the cement silo

Once homogenized, the final product is stored in cement silos, ready to be dispatched either to a packing station (for bagged cement) or to a silo truck.

Refer Chapter 6 Benchmarking (National & Global) for Energy consumption trends in Indian Cement plants.

4.0 Methodology adopted for the project

The activities were initiated with the collection of sector specific data from Bureau of Energy Efficiency (BEE). In addition, data was also collected through secondary research. Data analysis was conducted to assess the impact of PAT Cycle – I on energy intensity in the BAU v/s PAT scenario, GDP of the country, trend analysis for energy efficiency, quantification of energy saving in terms of TOE and coal saving. Feedback was also collected from DCs on benefits and the challenges experienced through the PAT scheme.

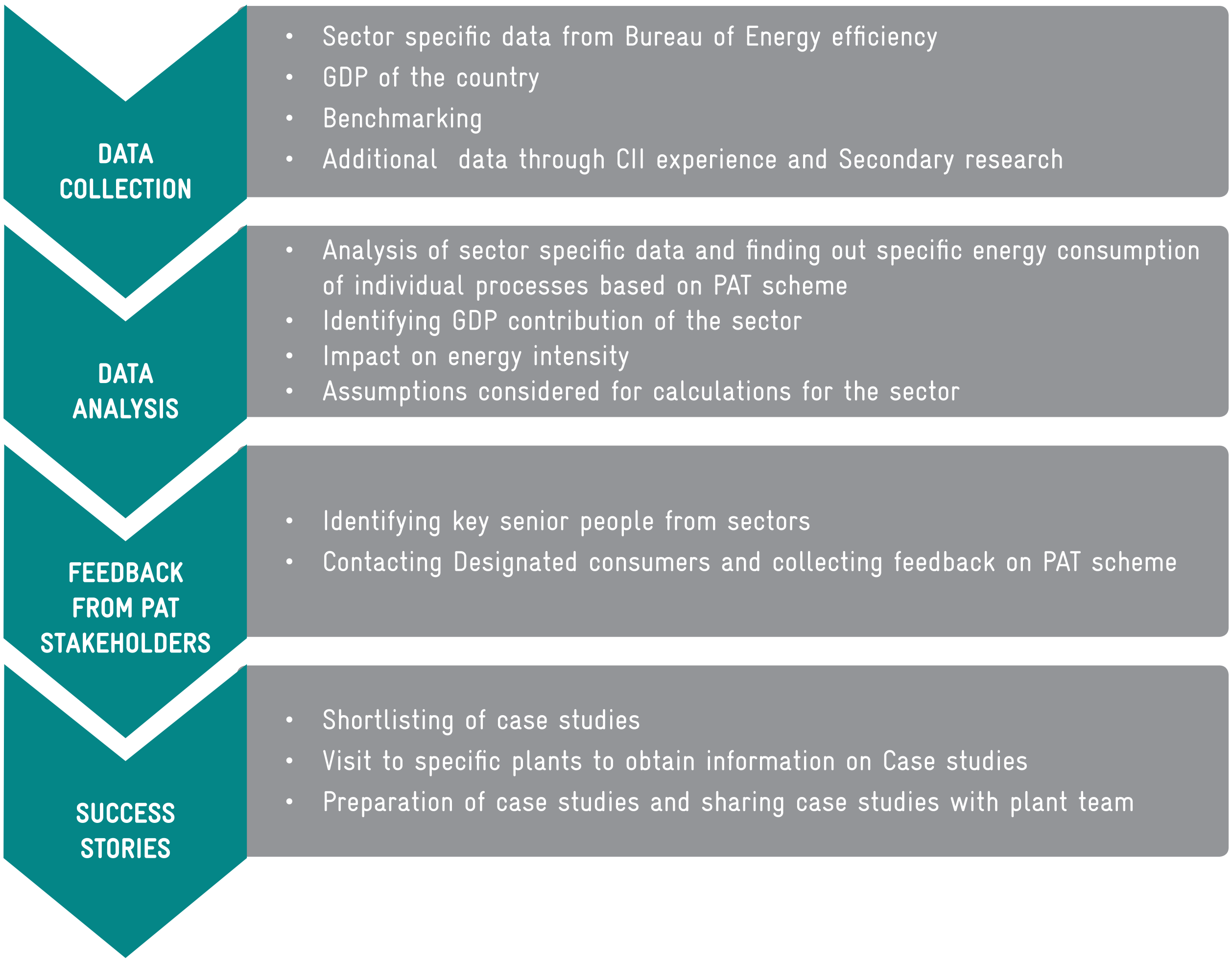


Figure 4: Methodology adopted for Impact assessment of PAT Cycle – 1

The case studies were shortlisted based on higher savings, low cost implementation, innovative projects and high replication potential across the sector. With the assistance of BEE and GIZ, various plant visits were scheduled and conducted across various sectors to study the technical benefits and challenges faced by designated consumers in implementing their projects. Based on the feedback from the respective plants, success stories were developed on the same.

5.0 PAT Cycle – I and its Impact on Cement sector

PAT is a regulatory instrument to reduce specific energy consumption (SEC) in energy intensive industries, with an associated market-based mechanism to enhance cost effectiveness through certification of excess energy savings, which could be traded. Energy Savings Certificate (ESCerts) are issued to the industries which reduces their SEC beyond the target. Plants which do not achieve the specified target will be obliged to purchase the certificate for compliance or will be liable for penalisation. The existing power exchangers are platforms for trading of ECerts.

PAT Cycle – I started from 2012, with its baseline from Financial years 2007 – 08 to 2009-10. The average value of specific energy consumed by the plant was taken for three years. The minimum threshold considered were based on the sectors. The minimum energy consumption of Cement sector is 30, 000 MTOE above which the plant is declared as a Designated Consumer (DC).

The total reported energy consumption of these designated consumers was about 15.01 million TOE. These DCs were given a target of 0.815 million TOE energy consumption reduction, which was around 12% of the total energy saved under PAT Cycle – I.

5.1 PAT Cycle-1 Impact

Cement sector has achieved 1.48 million TOE in comparison to the target of 0.815 million TOE. This achievement has estimated GHG emission reduction of 4.34 million tonnes of CO_2 equivalent. The results of PAT Cycle–I are summarised in Figure 5.

Energy Savings 1.48 million tonnes of oil equivalent

3.42 million tonnes of coal

4.34 million tonnes of CO_2 equivalent

Savings 16 billion INR

Reported Investment 25.68 billion INR

Figure 5 PAT-1 Savings achieved by Cement Sector under PAT Cycle-1

The savings are attributed to a number of measures adopted by the DCs. Some of the DCs have implemented short term measures with minimal investment, others have opted for medium and long-term measures requiring considerable investment. Investment of 25.68 billion INR was reported by 76% of DCs in the sector against implementation of energy conservation.

The emissions reduction for the sector due to energy savings achieved under PAT Cycle – I and contribution of these emissions to overall GHG reduction achieved are mentioned in Table 5. The emission reduction due to reduction in fossil fuel consumption only is considered for reduction in GHG emissions.

Parameter	Value
Reduction of CO_2 emission due to implementation of PAT Cycle – I (All sectors)	31 million Tonnes of CO_2 equivalent
Reduction of CO_2 emission due to implementation of PAT Cycle – I Cement sector	4.34 million Tonnes of CO_2 equivalent
Contribution to CO_2 emission reduction in overall PAT Cycle – I	14%

Table 5: Reduction in CO_2 emissions from PAT cycle - I

5.2 Energy Scenario at Business as usual (BAU) vis-à-vis With PAT impact

This section describes the impact of PAT and comparison with BAU scenario. Summary of the performance of the sector and its projection for 2030 is highlighted in Table 6. The calculation of GHG emissions for PAT cycle – I has been done based on the fuel mix of the cement sector under PAT. The impact of PAT has been assessed for PAT Cycle – I and with the current trend for energy reduction has been estimated for the year 2030.

Particulars	Unit	Value
Number of plants in the sector	Nos.	85
Baseline Energy Consumption in PAT Cycle I	million TOE	15.01
Energy reduction target for the sector	million TOE	0.815
Energy Savings achieved in PAT Cycle I	million TOE	1.48
Energy Saving achieved in excess of target	million TOE	0.665
Reduction in GHG Emissions in Cycle I	million T CO_2	4.34
Cumulative energy savings with PAT Impact till 2030 over BAU[15]	million TOE	34.46

Table 6: Achievements of Cement sector in PAT Cycle I and Projections till 2030

The energy saving of 8.67 million TOE declared for PAT Cycle - I has been calculated based on notified production for the baseline period. It may be noted that the actual energy saving achieved will be higher since actual production would have been higher in the assessment year.

The reduction in specific energy consumption in the baseline year from 2007 – 08, 2008 – 09 and 2009 – 10, has been calculated and considered as Business as Usual scenario (BAU). This reduction in specific energy consumption is used to project the reduction by the sector till 2030.

The graphs in this section show specific energy consumption and energy consumption for Business as Usual and impact of PAT, projected till 2030. The reduction from baseline to assessment year with PAT scenario is the reduction in specific energy consumption based on PAT Cycle I allotted target.

15. Difference of energy consumption between PAT and Business as Usual scenario(BAU)
16. Difference of GHG reductions between PAT and Business as Usual scenario(BAU)

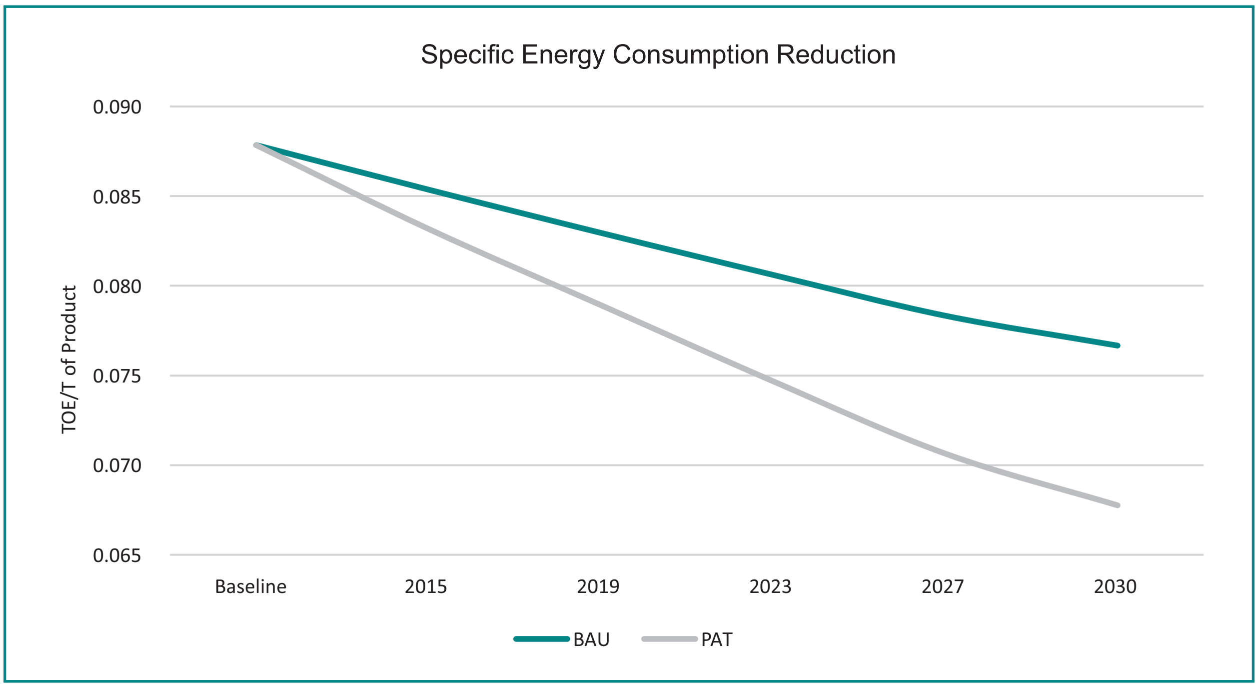


Figure 6: Specific Energy consumption of Cement Sector BAU vs PAT

Figure 6 shows the specific energy consumption trend for the sector till 2030. Blue colour line indicates reduction in specific energy consumption in business as usual scenario and Red colour line indicates reduction in specific energy consumption in PAT scenario.

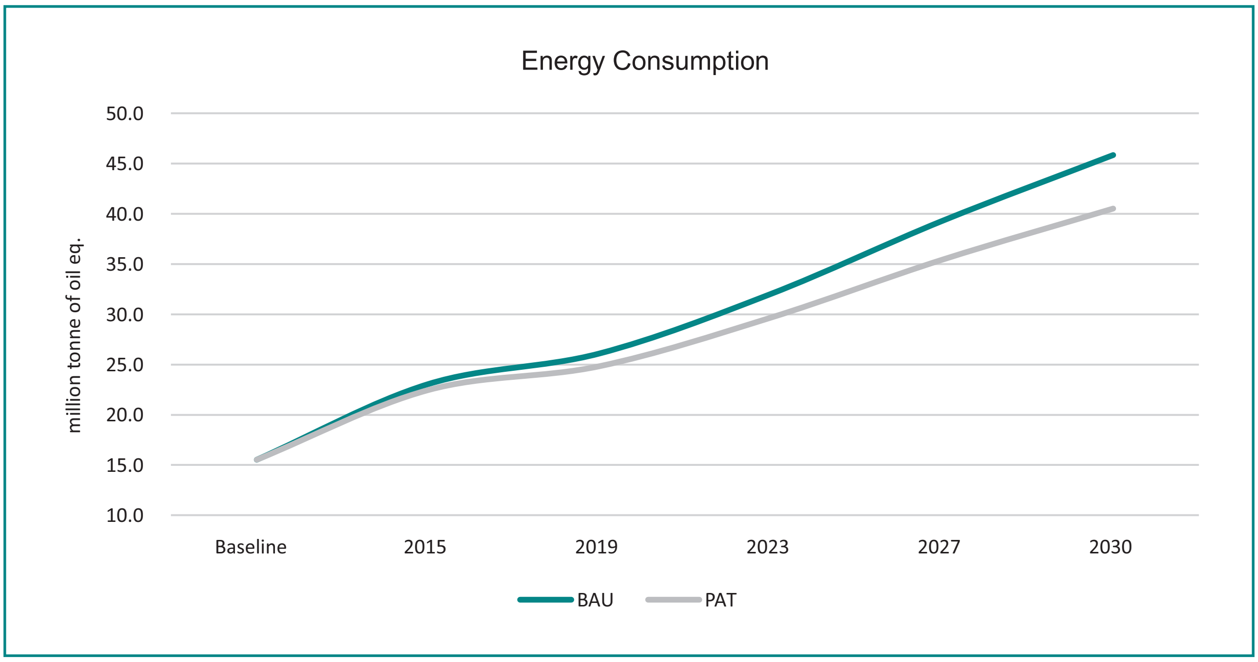


Figure 7: Energy Consumption of Cement Sector BAU vs PAT

The total energy consumption for Cement sector in the year 2030 without the impact of PAT is estimated to be 45.8 million TOE, which may reduce to 41.6 million TOE considering the impact of PAT.

Figure 7 shows the energy consumption trend for the sector till 2030. Blue colour line indicates energy consumption of the sector (million tonne of oil eq.) in business as usual scenario and Red colour line indicates energy consumption of the sector (million tonne of oil eq.) in PAT scenario.

Figure 8: A view of Cement plant

Year	GDP	Business as usual	With PAT
	Billion USD	Energy Intensity	Energy Intensity
		Toe/million USD	Toe/million USD
Baseline	1389	10.81	10.81
2015	2102	10.96	10.68
2020	3018	9.10	8.62
2025	4233	8.38	7.75
2030	5937	7.72	7.01

Table 7: Energy Intensity with PAT and BAU for Cement Sector

Assumptions considered for BAU Vs PAT calculation till 2030

Specific Energy Consumption

- The SEC of the sector has been calculated by considering the total production of the sector and the total energy consumption in the sector, and hence may not represent the actual SEC of any particular sub-sector/ product/ process.

Business as usual scenario:

- The plant would have undertaken activities on energy efficiency on its own, even without the intervention of PAT scheme.
- The reduction in specific energy consumption in the baseline year from 2007 – 08, 2008 – 09 and 2009 – 10, has been calculated and the same reduction is projected till the year 2030 to get the BAU scenario.

With PAT scenario:

- The actual energy saving achieved in the PAT Cycle I is taken for the assessment year 2014 – 15.
- It has been assumed that the plants meet the target allotted to them till the years 2030.
- The target for the subsequent PAT cycles is calculated based on the current trend of reduction in percentage of target between PAT Cycle I and II.
- It has been considered that the target will go on decreasing in the subsequent cycles owing to the diminishing potential in the plant as they go on implementing projects on energy efficiency.
- It has also been considered that some breakthrough technological advancement might provide further reduction potential in the sector.
- It has been considered that 90% of the energy intensive plants will come under PAT.

5.3 Cement Sector Proforma Data Analysis of PAT Cycle - 1

Table 8 indicates the number of cement plants involved in PAT-I based on their major equivalent product. Total 85 number of cement plants involved in PAT-I with maximum share from plants making Pozzolana Portland Cement followed by Ordinary Portland Cement & Portland Slag Cement.

Major Equivalent Product	Ordinary Portland Cement (OPC)	Pozzolana Portland Cement (PPC)	Portland Slag Cement (PSC)	White Cement	Only Grinding Unit	Only Clinkerisation Unit	Wet Processing Unit
No of Plant	16	55	07	02	02	01	02

Table 8: No of Cement Plant in PAT-I based on Major Equivalent Product

Some of the key findings of Proforma is listed below:

- Increase of Renewable Energy Share 13%
- Power Generation through WHRS increase from 62.7MW to 167.95 MW
- Capacity utilization of plant during baseline ~90% (except PSC plants) whereas during assessment year it is decreased to ~70%
- OPC clinker factor increased by ~1%
- PPC clinker factor decreased by ~3%
- PSC clinker facto decreased by ~13%
- Specific Power Consumption Reduction for PPC ~9%, for PSC ~19% & for OPC 1%
- Specific Thermal Energy Consumption Reduction for PPC~4%, for OPC~2%

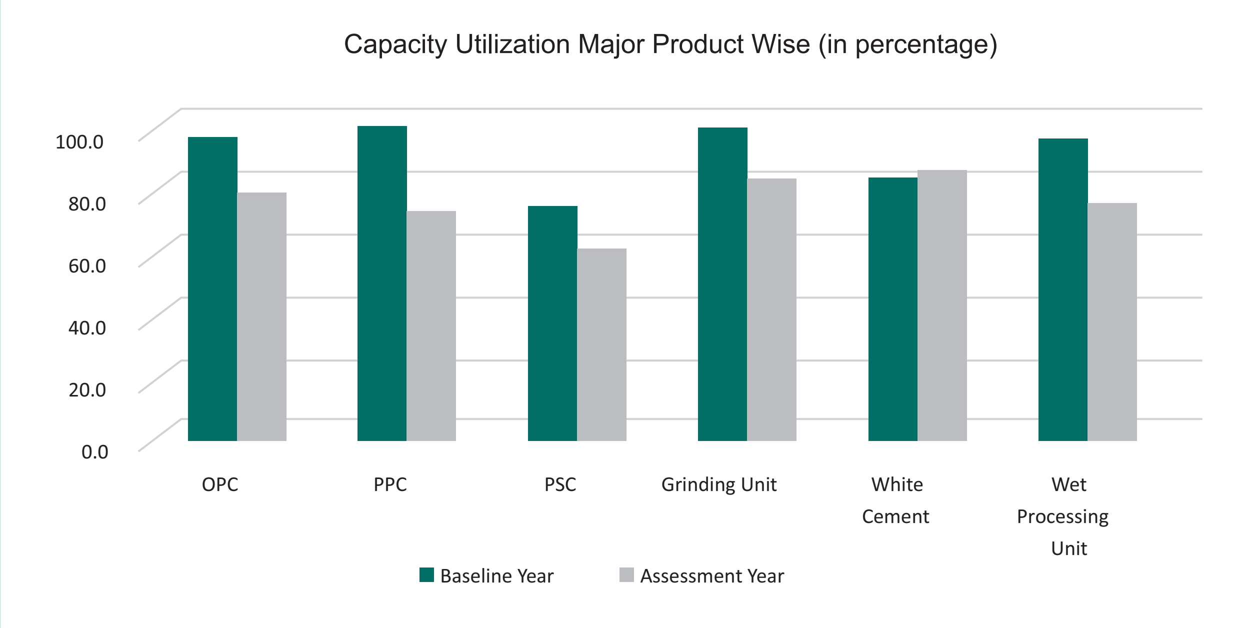


Figure 9 Capacity Utilization (Major Product Wise)

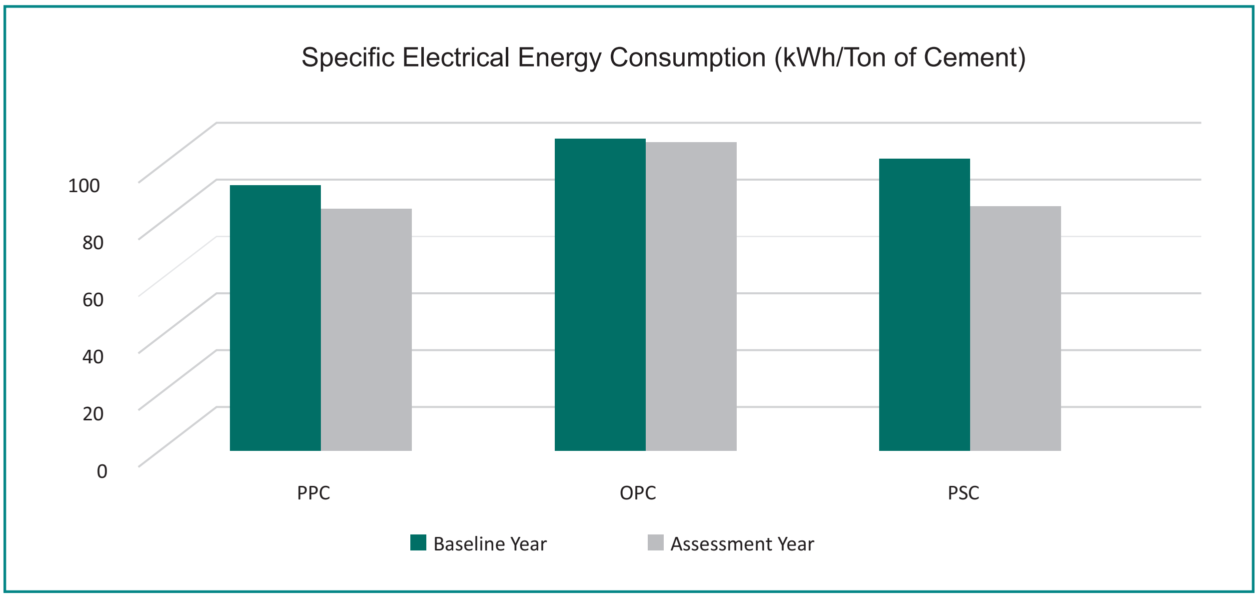


Figure 10: Specific Electrical Energy Consumption

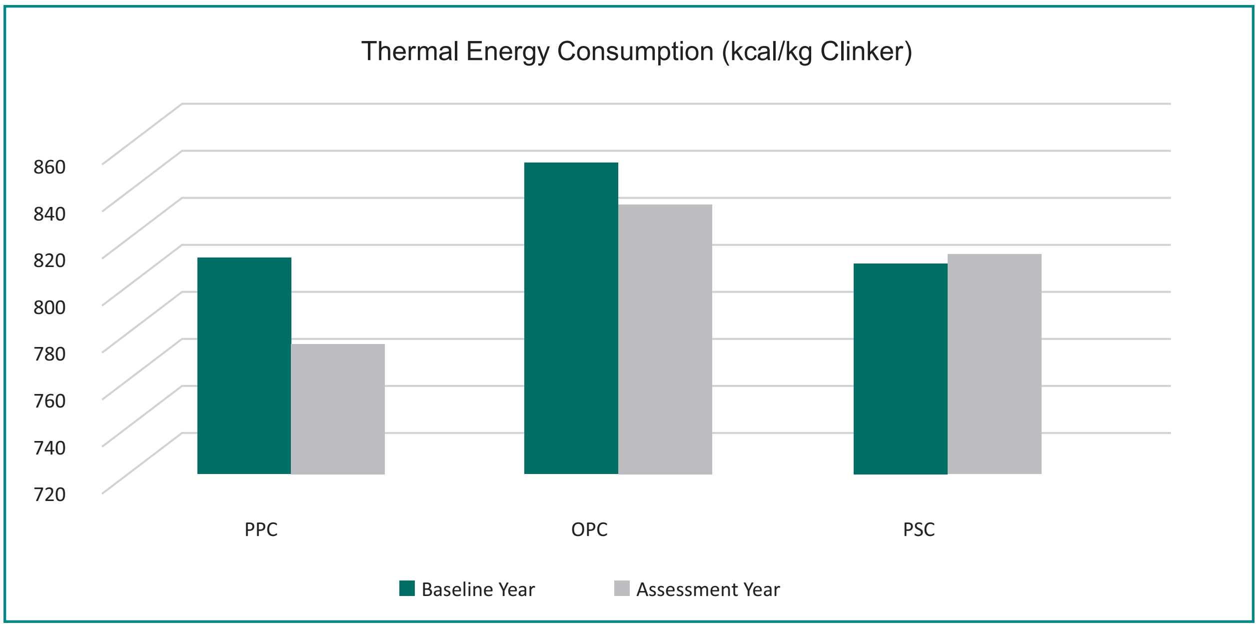


Figure 11: Thermal Energy Consumption

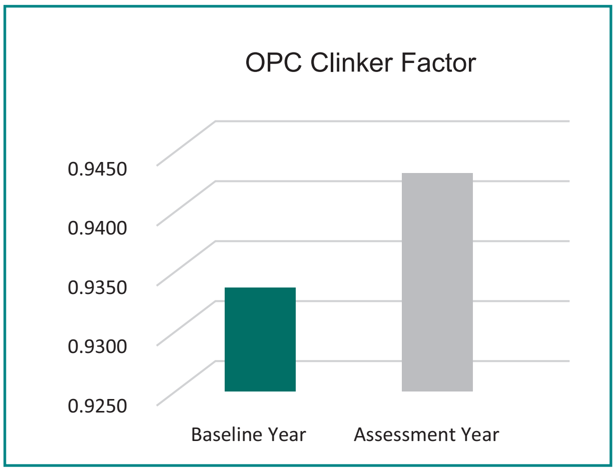


Figure 12: OPC Clinker Factor

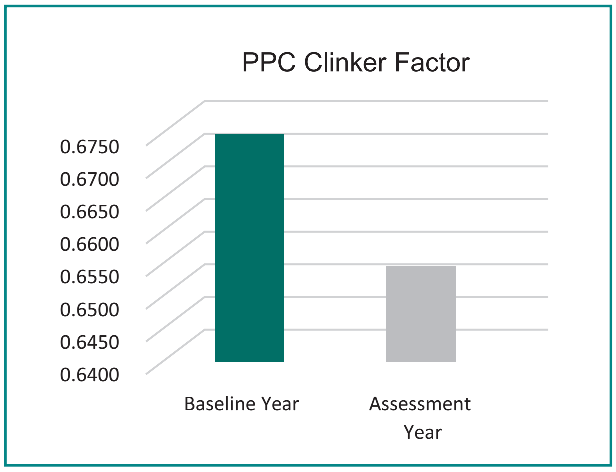


Figure 13: PPC Clinker Factor

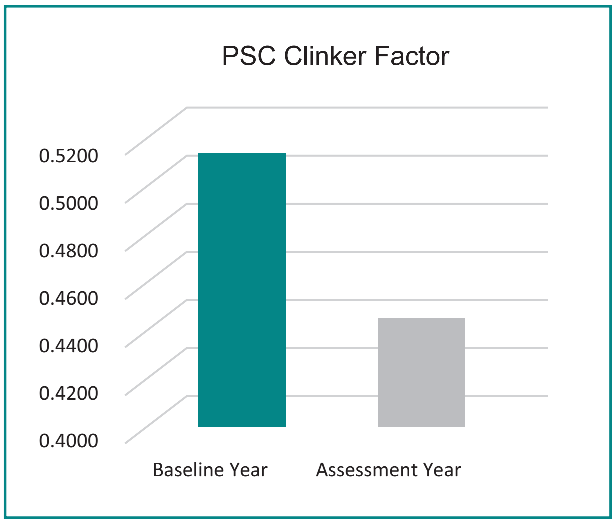


Figure 14: OPC Clinker Factor

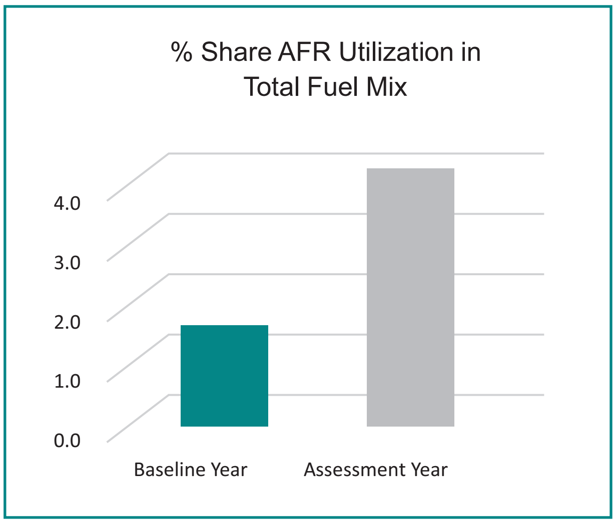


Figure 15: PPC Clinker Factor

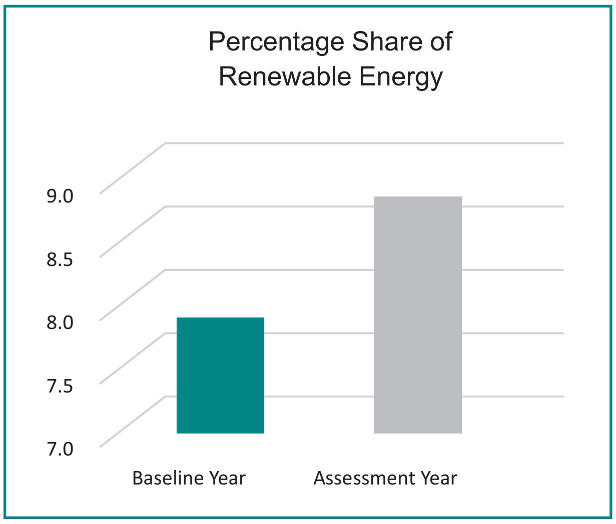


Figure 16: OPC Clinker Factor

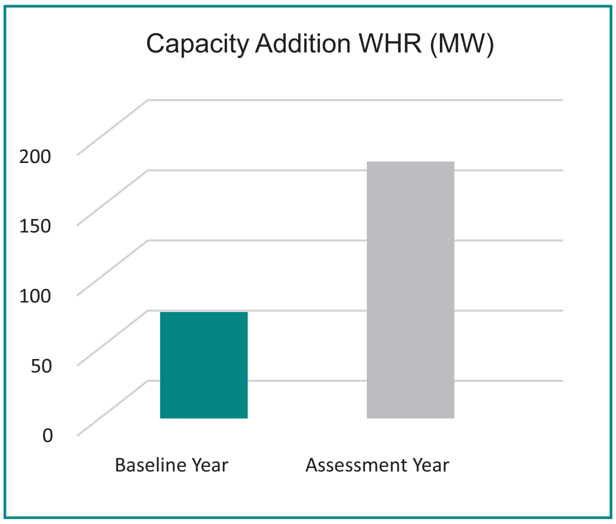


Figure 17: PPC Clinker Factor

6.0 Benchmarking (National & Global)

Benchmarking is an important tool to establish how one is performing and suggests what other avenues can be adopted to achieve the highest level in energy efficiency. The following section provides a comparison of India's Aluminium sector performance with the best efficiency levels in the world.

Table 9 indicates national and international trends on Electrical & Thermal energy consumption of the cement sector

Particulars	Units	Global Avg.[17]	India Best[18]	India Avg.
Specific Electrical Energy Consumption	kWh/tonne of cement	91	64	80
Specific Thermal Energy Consumption	GJ/tonne of clinker	3.5	2.83	3.1

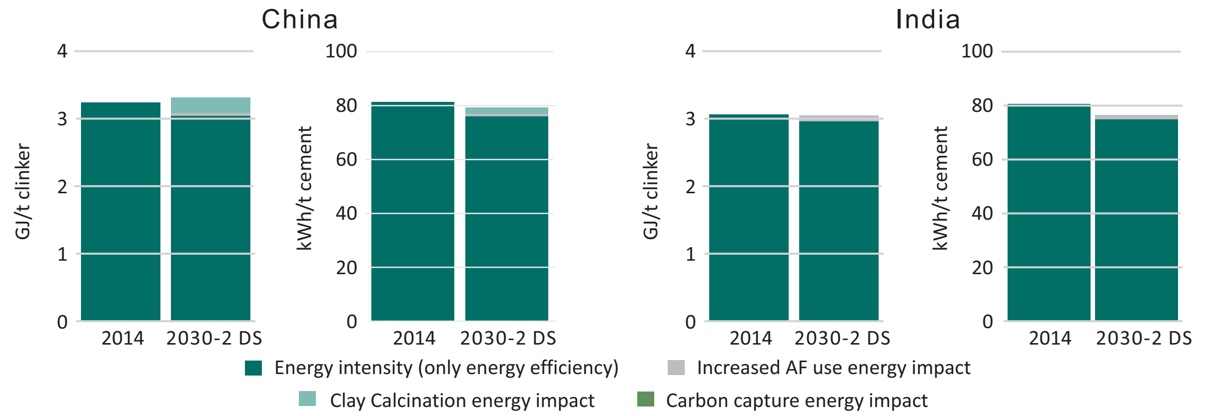
Table 9: Specific Energy Consumption (Global & National)

Table 10 highlights the electrical specific energy consumption trends section wise of cement plants in India.

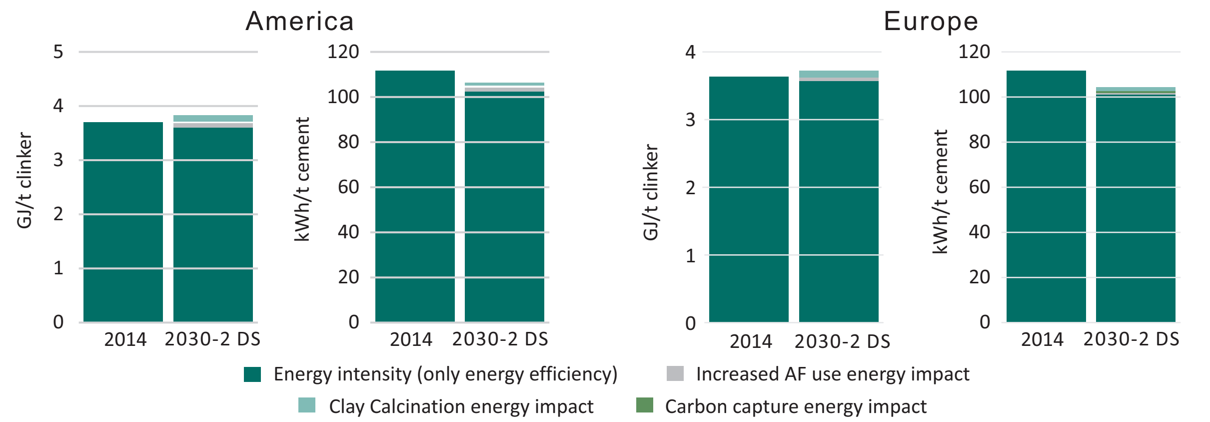
Particulars	Units	Specific Power Consumption
Single Stage Crusher	kWh/Tonne of Material	0.7 – 1.8
Two Stage Crusher	kWh/Tonne of Material	0.65 – 2.3
Raw Mill – VRM	kWh/Tonne of Material	13 – 16
Raw Mill – Ball Mill	kWh/Tonne of Material	16 – 25
Pyro Section (5 stage Preheater)	kWh/Tonne of Clinker	16 - 32
Pyro Section (6 stage Preheater)	kWh/Tonne of Clinker	17 - 28
Cement Mill – Ball Mill	kWh/Tonne of Cement	27 – 40
Cement Mill – VRM	kWh/Tonne of Cement	21 - 36
Packing Plant	kWh/Tonne of Cement	0.65 – 1.9

Table 10: Section Wise Specific Energy Consumption Trend[19]

17. Technology Roadmap Low Carbon Transition in the Cement Industry by IEA & WBCSD
18. CII Database
19. CII Benchmarking Manual for Cement Industry in India Volume:2



Source: Base year data from CII, WBCSD and IEA (forthcoming, Status Update Project from 2013 Low-Carbon Technology for the Indian Cement Industry, data submitted via personal communication by Sinema Research Institute and China Cement Association (2016-17).



Source: Base year data from CSI (2017), Global Cement Database on CO2 and Energy Information, www.wbcsdcement.org/GNR; SNIC (forthcoming), Low-Carbon Technology for the Brazilian Cement Industry.

Figure 18: Global Energy Intensity Comparison

From Table 9 it is evident that Indian cement sector is one of the most energy efficient in the world and continuously adopts latest technologies for energy conservation. Energy efficiency in the Indian cement industry are already of high standards. However there is still scope for improvement in this area, providing continued use of energy efficient technologies in new plants and old plants.

The factors supporting Energy Efficiency in the Indian cement Industries are

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

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

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

Government Policies: Another factor which is enabling energy efficiency movement in India is Ministry of Power's- Bureau of Energy Efficiency (BEE) - Perform Achieve and Trade scheme. The key goal of the scheme is to mandate reduction in specific energy consumption for the most energy-intensive industries, and incentivize them to achieve more than their specified specific energy consumption improvement targets. The star rating program for the equipment is also bringing revolutionary changes in the energy consumption levels.

Technology Suppliers: Due to concerted efforts in bringing innovations and advancement in the technology, some of the most efficient global technologies have been adopted in major Indian cement plants. There is growing interest evinced by international suppliers to enter the Indian market to supply energy efficient technologies.

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

7.0 List of major energy saving opportunities in the sector

A list of major energy saving opportunities in the sector have been identified and listed below. The projects are listed based on readiness level, co – benefits obtained by installing the system and based on expected payback range by implementing the project.

Technology Readiness Level (TRL):	Co-Benefits: PQCDSME	Payback Horizon (PB)
TRL 1 – Research (Basic or Advanced)	Productivity (P)	PB 1 - less than 1 year
TRL 2- Proof of concept	Quality (Q)	PB 3 – 1 year to 3 years
TRL 3- Demonstration(Pilot)	Cost(C)	PB 5 – 3 to under 5 years
TRL 4- First of a Kind	Delivery (D)	PB 8 – 5 to under 8 years
TRL 5- Fully Commercial	Safety (S)	PB 12 – 8 to under 12 years
	Moral (M)	PB >12 – over 12 years
	Ethics, Environment (E)	

SL No.	Energy Saving Opportunities	Co-Benefits	Technology Readiness Level	Payback Band
1	High efficiency clinker coolers	P,Q,C,S,M,E	TRL – 5	PB 5
2	Waste Heat recovery	C,M,E	TRL – 5	PB 8
3	Co-processing & preprocessing platform for increased alternative fuel utilization	M,E	TRL – 5	PB 12
4	Installation of High tension(HT) VFD for Speed Control of process fans	C,M,E	TRL - 5	PB 3
5	Utilization of Advanced Automation systems in Cement Manufacturing	P,Q,C,D,S,M,E	TRL – 5	PB 3
6	Carbon capture through algal growth	E	TRL-4	-
7	Oxy-fuel combustion technology	P,Q,C,M,E	TRL – 3	-
8	High Efficiency Separator/classifier	P,Q,C,M,E	TRL – 5	PB 5
9	Installation of Pre-grinder along with Ball Mill for Material Grinding	P, Q, C, E	TRL-5	PB 8
10	Installation of Fly Ash Dryer	P, Q	TRL-4	PB 5
11	Kiln surface heat recovery system		TRL-3	PB 1

Table 11: List of key technologies in the sector

8.0 Success stories – Case Studies in Cement Sector

8.1 Cooler Hot Air Recirculation (HAR) to Increase Waste Heat Power – An Innovative Approach to Optimise Power Generation

Introduction

The JK Lakshmi Cement Jaykaypuram plant is located in the southwest part of Rajasthan, India. It has three kilns, which share an annual clinker production capacity of 4.8 million tonnes. Kiln 1 was originally designed as a 1500 tonnes/day line in 1982 but currently has a rated capacity of 4500 tonnes/day. Kiln 2 was originally designed for 2500 tonnes/day in 1995 but has doubled in size to 5000 tonnes/day at present. Kiln 3 was similarly designed for 2500 tonnes/day in 1996, but has since also doubled to an operating capacity of 5000 tonnes/day.

The heart of cement manufacturing process are Kiln, Preheater and Cooler systems. The kilns include multi-stage preheaters and pre-calciners to pre-process raw materials before they enter the kiln, and as the hot clinker is produced from kiln in a cooler through an air-quench system to cool the clinker product. The exhaust streams from Preheater and cooler contain useful thermal energy that can be converted to power through waste heat recovery systems and the generated power can offset a portion of power purchased from the grid, or captive power generated by fuel consumption at the site. Many of the cement plants in India have utlilised these potential and have implemented waste heat recovery system.

Description of the Project

J K Lakshmi Cement has been continuously innovating and pioneering the implementation of energy efficient technologies and various environment improvement initiatives. To further improve the waste heat recovery from cooler vent and increase the power generation, the plant implemented an innovative measure to circulate the hot air in cooler. Recirculating hot air from the cooler vent stack to the cooler improves the available heat at boiler inlet due to additional mass flow and constant temperature or at constant mass flow and increased temperature. The project was conceptualised internally (Engineering and process team at the plant). This unique adaptation was installed on Kiln 1 in and the project was commissioned in 2014. As this was the first of its kind project in India, the project team anticipated many challenges for implementation and were able to overcome those challenges with appropriate technology upgradation and optimisation. Before the project implementation, the following challenges were foreseen and addressed:

Dealing with the high clinker temperature;

1. Volume of air for recirculation and working out how many cooler fans should be used to recirculate the hot air;
2. Selecting fan motors considering both hot and cold air condition and also high level of dust concentration.

3. Reliability of sensitive parts for cooler grate due to exposure of cooling air at high temperature

The proactive approach from the initial phase of the project helped the plant to address these challenges smoothly. The biggest challenge was related to concerns over excessively high clinker temperature after installation of the HAR system. In order to solve this, an idea was conceived to connect the HAR duct only to those fans from which the output is transferred to the waste heat recovery (WHR) boiler (Fan No 6, 7 and 8 below). The remaining fans (9 and 10) were left with ambient air to cool the clinker.

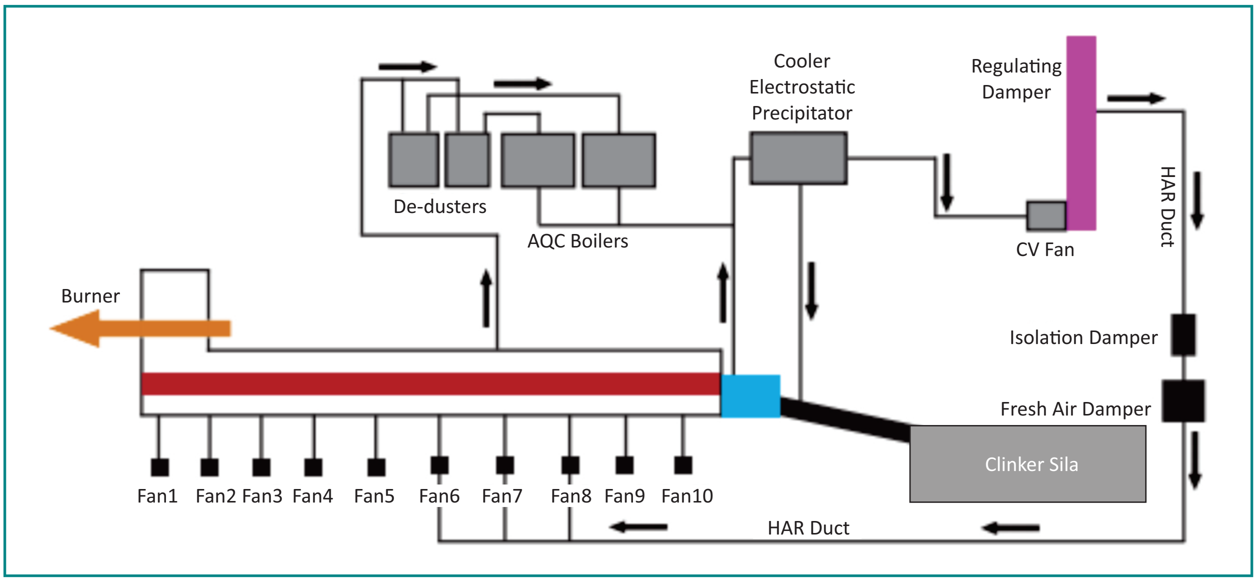


Figure 19: Schematic representation of HAR system

As the fans initially were designed to handle only cold air and large variation in air flow as well as wear and tear due to dust was anticipated. Thus, the appropriate fan selection was critical to the success of the project. The fans were selected with hard facing over the impeller considering challenges such as temperature and operation variation and dust concentration. These fans were designed considering the operating temperature of 140°C. Since the fans need to operate in both cold and hot air conditions, motor rating was determined based on the maximum demand possible in a cold air supply.

Figure 20: Hot air recirculation from stack to cooler

The risk of damage to sensitive parts of the cooler was also another concern. Hence the plant team consulted the cooler supplier and it was agreed that the implementation would not pose any major risk to the cooler pendulum or grate as they were designed to handle and operate in such conditions. Following table highlights the cooler heat balance with and without HAR:

Parameter	With HAR			Without HAR		
Input	**Nm3/kg dry**	**Temperature (oC)**	**kCal/kg**	**Nm3/kg dry**	**Temperature (oC)**	**kCal/kg**
Clinker in	1	1450	382.68	1	1450	382.68
Cooling Air	1.287	30	19.64	1.955	30	18.22
Air from HAR	0.54	130	14.3	NA		
Total Input	**416.62**			**400.9**		
Output	**Nm3/kg dry**	**Temperature (oC)**	**kCal/kg**	**Nm3/kg dry**	**Temperature (oC)**	**kCal/kg**
Clinker Out	1	144	27.36	1	124	23.42
Secondary Air	0.36	1072	128.86	0.35	1075	126.41
Tertiary Air	0.41	999	136.85	0.42	882	138.47
Mid Air to Boiler	0.85	410	110.6	0.8	390	99.38
Vent Air	0.22	145	9.99	0.39	82	10.03
Radiation Loss	NA		3	NA		3
Total Output	416.60			400.7		
Cooler Efficiency (%)	69.4			69.2		

Table 12: Comparison with HAR & without HAR

The successful execution of the HAR project has resulted in better heat recovery and has enabled plant to generate 2.5 tonne/hr more steam from the WHR boiler. As a result, the plant is now able to generate net excess power – 10,040 kWh/day. Following is the comparison of key parameters considering the production at 4,500 tonne/day:

Parameter	Unit	With HAR	Without HAR	Difference
Mid Air to Boiler	oC	410	390	20
HAR Temp	oC	130	30	100
Clinker Temperature	oC	144	124	20
Total Steam Generated	tonne/hr	27.23	24.72	2.51
Total Power Generated	MW	4.54	4.12	0.42
Total Power Generated	kWh/day	108,920	98,880	10,040

Table 13: Improvement in Parameters with HAR

Benefit Achieved

As a result of the interventions, annual cost saving of INR 16.7 million was achieved due to excess power generation at waste heat recovery plant. Thus, the project would payback in less than one year. An overall saving of 1,127 metric ton of oil equivalent (MTOE) was obtained in this implementation. This has resulted in annual CO_2 reduction of 3,850 T CO_2 eq.

Parameter	
Improved Power Generation	10,040 kWh/day
MTOE equivalent savings	1,127 MTOE
Total benefit	Rs 16.7 million
Investment	Rs. 15.0 million
Payback	1 year
GHG reduction	3,850 tCO_2
Replicability	The installation of HAR system is possible in all waste heat recovery system and installation of HAR is feasible which would result in increased power generation from waste heat recovery.
	At present, the current installation of waste heat recovery in Indian Cement sector is more 307 MW. This could result in overall reduction of energy consumption in sector by 67000 TOE equivalent to cost savings of Rs. 960 million. These saving could be achieved by investing Rs. 950 million.

Table 14: Benefit achieved by implementation of Project

Unit Name	J K Lakshmi Cement Limited
Contact Person Name	Mr. Rajpal Singh Shekhawat
Designation	General Manager (Production)
Phone	02971-24440409-10
Email	rajpal@lc.jkmail.com

Table 15: Plant Contact Details

8.2 Reheating Furnace with Re-Generative Burner at Tata Steel, Jamshedpur

Introduction

The Ramco Cements Ltd., Alathiyur is situated in Ariyalur district of Tamil Nadu. It has two kilns of 3500 TPD clinker capacity. Line 1 was installed with a capacity of 2350 TPD & Line II has a capacity of 3000 TPD. The plant has installed Loesche mills for raw material and coal grinding. The products manufactured are OPC as per BIS & SLS, PPC and SRPC. Two coal based captive power plants each of 18 MW ensure uninterrupted power supply.

The plant details are as below,

	Line 1	Line 2
Commissioned year	1997	2001
Kiln	FLS-3500 TPD	FLS-3500 TPD
Raw Mill	Loesche LM 38.3	Loesche LM 38.3
Coal Mill	Loesche LM 20.2D	Loesche LM 20.2D
Cement mill	OK 33.4	Loesche LM 56.2+2C

Table 16: Plant Details

The plant has upgraded the raw mill classifier with energy efficient classifier & vortex rectifier and has achieved significant savings in power consumption.

Description of the project

The raw mill was designed for feed moisture of 5% normal % 10% maximum. Over a period of time the normal feed moisture increased to more than 10% causing a reduced raw mill output to 205-210 TPH from 215-220 TPH.

During monsoon, mill output was further reduced to 190 TPH. Hot gas generator (HGG) had to be operated to get the output of 210 TPH to meet clinker production. HGG was consuming about 2 TPH of fine coal. Since more heat was required for drying, the gas volume was to be increased in mill thereby causing higher product residue. To overcome this problem raw mill classifiers of both units were changed from LSKS 52 to LSKS 57.Details of the project before and after modifications is as below,

Description	Raw Mill 1		Raw Mill 2	
	Before Modification	After Modification	Before Modification	After Modification
Classifier size	LSKS 52	LSKS 57	LSKS 52	LSKS 57
Feed Moisture (%)	>=10	>=10	>=10	>=10
Mill output (TPH) dry	207	231	210	233
Residue (212 mic) %	2.3-3.0	1.5-2.0	2.3-3.0	1.5-2.0
Product residue (90 mic) %	19-20	16-17	19-20	15-16
Mill Sp. Power (kWh/ MT)	5.56	4.55	5.57	4.42
Fan Sp. Power (kWh/ MT)	6.33	6.28	7.29	6.52
Total specific power	11.89	10.83	12.86	10.94

Table 17: Comparison before and after modification

This has resulted in saving of about 1.2 kWh/ MT in specific power drawn by mill & fan

Details of modification done

1. Modified louvre and armor ring to maintain uniform gas flow/velocity profile inside the mill.

2. Increase the capacity of the raw mill fan by replacement/ retrofitting

3. Increase the size of the following ducts due to higher gas flow

4. Mill inlet duct, Mill Outlet duct & Duct from Cyclone to mill fan inlet

Raw mill Classifier up-gradation:

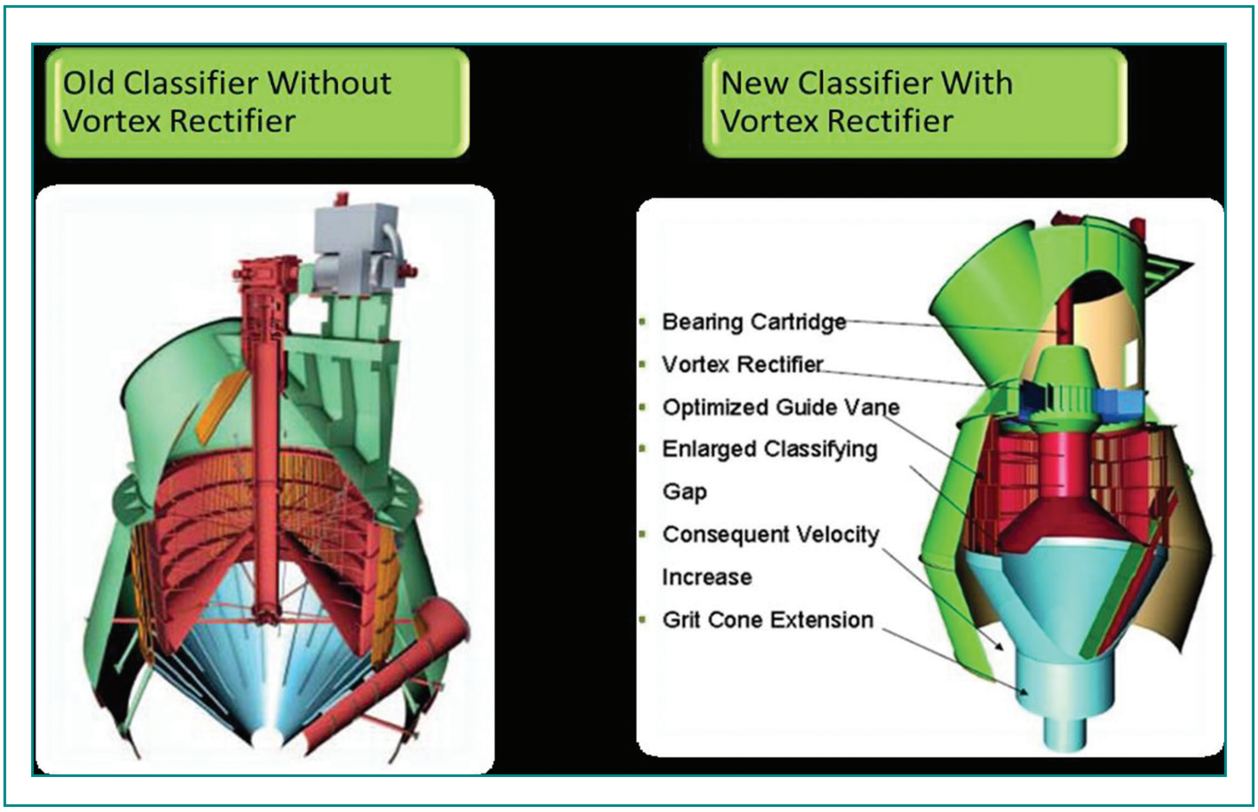


Figure 21: Schematic representation of Vortex rectifier

The installation of vortex rectifier for the classifier has resulted in restoring a linear flow in the ductwork & maintaining homogeneous velocity distribution thus resulting in a lower pressure drop and reduced specific energy consumption.

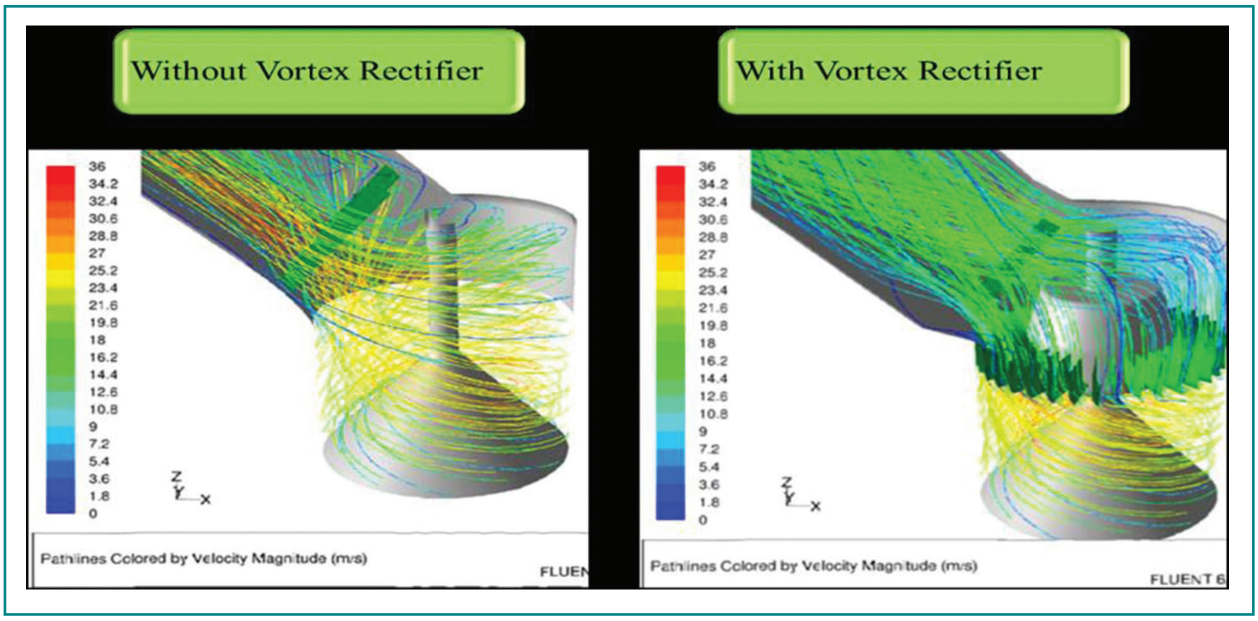


Figure 22: Result of CFD Study with & without Vortex rectifier

Benefits with vortex rectifier:

1. Vortex kinetic energy recuperation
2. Homogenous velocity distribution at mill outlet
3. Uniform flow pattern at mill outlet

Figure 23: Actual Photograph during installation at site

Benefits Achieved

Parameter	
Energy savings	Rs. 4.3 million
MTOE equivalent savings	86 MTOE
Total benefit	Rs 73.4 million (including additional realization of cement)
Investment	Rs. 20.00 million
Payback (months)	3 months
Replication Potential	Idea and installation of vortex rectifier is the first of its kind in the country
	Vortex rectifier gives us rich benefits in the areas of Production, Quality, maintenance & Energy
	There are more than 200 vertical roller mills in Indian cement industry

Table 18: Benefit Achieved by implementation of Project

Intangible Benefits

- Improvement in quality of clinker
- Free Lime < 2% and C3S > 55%
- Stability in kiln operation

Contact details for the project

Plant Name	Ramco Cements, Alathiyur
Person to be contacted	Mr. S Shanmugam
Designation	Vice President- Manufacturing
Email – ID	Email: ss@ramcocements.co.in
Address for communication	The Ramco Cements Ltd., Alathiyur Cement Works

Table 19: Plant Contact Details

9.0 List of Technology suppliers

S No	Company Name	Technology	Website link
1	Clair Engineers Pvt. Ltd.	Electrostatic Precipitator, Pulse Jet Bagfilter	www.clair.in
2	Claudius Peters (India) Pvt. Ltd.	Pneumatic Conveying System, Clinker Cooler, Packing Plants, Silo System, Pulverised Coal Injection System	www.claudiuspeters.com
3	Fives India Engineering & Projects Pvt. Ltd.	Ball Mill, Classifier, Crusher	www.fivesgroup.com
4	FLSmidth Private Limited	Rotary Packers, Silo Feeding & Extraction System, Bulk Loading System, Clinker Cooler, Preheater & Kiln Design & Equipment Supply	www.flsmidth.com
5	Humboldt Wedag India Private Limited (KHD)	Full Line Engineering & Equipment Supply, Process Automation & Instrumentation, Erection Supervision & Commissioning	www.khd.com
6	IKN GmbH	Clinker Cooler	
7	Loesche India Pvt. Ltd	Dry Grinding Plant for Cement Raw Material, Coal and Clinker/Slag Grinding, High Efficiency Classifier	www.loescheindia.com
8	Thermax Ltd.	Waste Heat Recovery System, Air Pollution Control Equipment, Absorption Chiller, Power & Captive Cogeneration Plants	www.thermaxindia.com
9	Flakt India Private Limited	Axial Fan, Centrifugal Fan, Air Handling Unit	www.flaktwoods.com
10	REITZ INDIA LTD	Design, Engineering & Manufacturing of Industrial Fans	www.reitzindia.com
11	Atlas Copco	Industrial Compressor, Air & Gas Treatment Equipment	www.atlascopco.com
12	Elgi Equipments Limtied	Centrifugal, Reciprocating & Screw Compressors	www.elgi.com
13	Godrej & Boyce Mfg. Co. Ltd.	Compressed Air System, Air Treatment Equipment, Automation	www.godrej.com
14	Transparent Technologies Pvt. Ltd.	Waste Heat Recovery System	www.ttpl.co.in
15	Grundfos Pumps India Pvt. Ltd.	Industrial Pumps Design, Engineering & Manufacturing	www.grundfos.com
16	KSB PUMPS LTD	Centrifugal Pump, Multistage Pressure Pump, Submersible Pump	www.ksb.com

Table 20: List of key technology suppliers in Cement Sector

Abbreviations

AFR
Alternate Fuel and Raw Material, 3, 20
BAU
Business As Usual, 2, 3, 5, 14, 17
BEE
Bureau of Energy Efficiency, 12, 22
CAGR
Compounded Annual Growth Rate, 7, 8
CII
Confederation of Indian Industry, 21, 22
CMA
Cement Manufacturers' Association, 8, 22
CO2
Carbon dioxide, 7, 8, 13, 14, 17
DCs
Designated Consumers, 4, 7, 13
ESCerts
Energy Saving Certificates, 13
GDP
Gross Domestic Product, 5, 8, 12, 17
GHG
Greenhouse Gas, 8, 13
HAR
Hot Air Recirculation, 2, 25, 26, 27, 28
INR
Indian Ruppee, 7, 8, 13, 17
mic
micron, 29
million TOE
million Metric Tonnes of Oil Equivalent, 4, 8
MW
Mega Watt, 18, 27, 28, 29
NAPCC
National action plan on climate change, 4
NCBM
National Council for Cement & Building Materials, 22
NMEEE
National mission for Enhanced energy efficiency, 4
OPC
Ordinary Portland Cement, 3, 11, 18, 19, 29
PAT
Perform Achieve and Trade, 2, 3, 4, 5, 7, 12, 13, 14, 15, 16, 17, 18
PPC
Pozzolana Portland Cement, 3, 18, 19, 29
PSC
Portland Slag Cement, 3, 18, 20
SEC
Specific Energy Consumption, 4, 13
toe
Tonne of oil equivalent, 7
TPH
Tonne per Hour, 29
UOM
Unit of Measurement, 21
WHR
Waste Heat Recovery, 3, 20, 26, 27
WHRS
Waste Heat Recovery System, 18

Bureau of Energy Efficiency

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