Improving a plant's operational cost structure

Cost reduction initiatives in cement plants are essential for maintaining competitiveness, profitability and sustainability in a challenging market. Cement producers have a range of options available to lower their production costs: from system design via the use of alternative fuels to improved maintenance practices.

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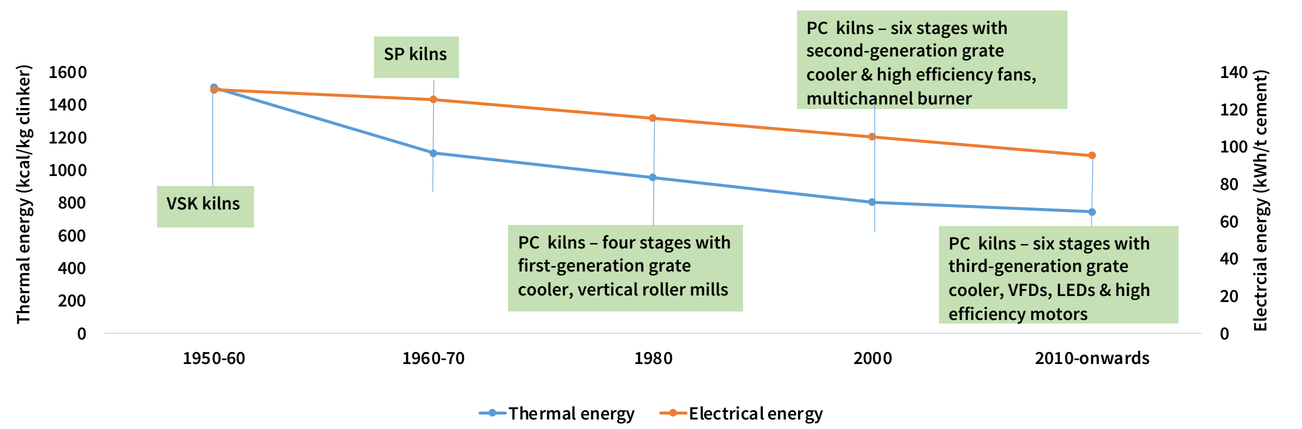
Figure 1: specific energy trend in the development of kiln lines



Source: Holtec Consulting

By optimising operational efficiency and minimising expenses, cement plants can enhance profitability and financial resilience. Cost reduction measures also enable investments in technology and environmental compliance, ensuring long-term viability.

Improvements in operational efficiency result in reduced production costs and help mitigate risks associated with fluctuating market prices, regulatory changes and economic uncertainties. By prioritising cost reduction initiatives, cement plants can improve their ability to adapt to market dynamics and remain resilient in the face of evolving challenges, ultimately securing their position in the industry.

As shown in this article, cement plants have a range of options in terms of implementing cost reduction measures.

Efficient system design

Cost reduction measures usually start at the system design stage. An efficient system design involves some key decisive factors that need to be incorporated while developing the plant's technical concept. Decisions are mainly focussed on investment cost (capex), cost of operation and maintenance (opex), optimised workforce, accessibility of power and fuel resources, and the location of the plant vis-a-vis its prospective market. Key selection criteria for decision makers include:

- system availability and reliability
- ease of operation and maintenance
- availability of skilled staff and subsequent support services
- operating cost
- investment cost.

In addition, the plant layout has a significant impact on the total energy consumption of the plant. Therefore, when finalising the plant concept, it is recommended that the technical approach includes:

- use of natural contours of the plant
- fewer transfer towers for belt conveyors
- using mechanical conveying instead of pneumatic conveying
- minimising ducting length to reduce pressure loss
- proximity of the coal mill to the preheater building
- distributed compressor house instead of centralised compressor room
- positioning of load centres to minimise cable loss and including a decentralised distribution system.

The overall idea for an efficient system design is to select the most suitable option that justifies these points, resulting in optimised operational costs.

Adaptation of advanced technologies

Adapting the most advanced technologies in cement plants is essential for enhancing efficiency, reducing environmental impact, and maintaining competitiveness. Hence, selection of technologies is of prime importance and should be relevant to the particular situation.

Table 1: specific power consumption of clinker grinding technologies

Mill system	Power consumption (kWh/t cement)
Ball mill	38.2
HPGR as pregrinder	29.7
Vertical roller mill	21.8
HPGR in semi-finish mode	20.8

Grinding systems

The selection of grinding technology should take into account factors that impact grinding system performance, including:

- physical characteristics of the material being ground
- moisture content
- grindability of the material
- maintenance cost
- specific investment required.

Grinding systems are energy intensive and consume ~65-70 per cent of the total power demand of cement production. Therefore, selecting the most appropriate technology helps to reduce the plant's operational cost. The main technologies used for grinding in cement plants include:

- **Vertical roller mills (VRMs)** – VRMs are considered to be the most energy efficient system when compared with the traditional ball mill as they have a grinding efficiency that is 30-40 per cent higher than the ball mill. In addition, they have almost no limitations in terms of moisture content of the feed and can grind material with moisture content of ~20 per cent. An external recirculation system will also make the VRM more effective than a ball milll.
- **High pressure grinding rolls (HPGRs)** – HPGRs are also efficient grinding systems and are considered to be a contemporary to the VRMs. HPGRs can be used for pre-grinding, semi-finish and finish grinding. Induction of a HPGR into an existing ball mill system in clinker grinding further reduces energy consumption and enhances the productivity of the cement mill. Product quality is the key factor for HPGR systems as it ensures improved particle size distribution (PSD) and minimum water demand for cement products. The present generation of HPGR systems is more energy efficient when compared to VRMs, particularly in terms of raw grinding applications.
- **High efficiency separators** – High efficiency separators in grinding circuits are very effective in terms of particle size regulation and productivity enhancement. They reduce the power consumption of the grinding process by ~15 per cent. Furthermore, they reduce the likelihood of overgrinding material and help optimise the ball mill charge in case of clinker grinding.
- **Improved ball mill internals** – The introduction of improved ball mill components in an operating cement ball mill will increase grinding efficiency, leading to higher productivity and reduced power consumption. Higher-quality key components include high-chrome grinding media with a lower wear rate, controlled flow diaphragms and boltless liners. These contribute to a significant cost reduction of clinker grinding.

In terms of power consumption in clinker grinding (at equal throughput and product fineness) studies have shown significant differences between the grinding technologies employed (see Table 1).

Pyro-processing system

In the last decade, major technological developments have focussed on thermal energy savings, effective AFR usage to reduce carbon footprint and optimising components of the preheater system while making it more efficient for the WHR boilers at the preheater and cooler ends. Technological developments aimed at reducing the cost of operation include:

- advanced precalcinator systems
- external combustion systems for burning a range of AFRs
- low primary-air multi-channel burners
- improved clinker cooler technology with hot air recirculation
- improved refractory applications in the kiln
- high-efficiency process fans.

Cost reduction through process optimisation

Optimising cement production processes involves maximising efficiency and productivity. In addition, optimisation leads to a lower environmental impact by continuous improvement of raw material preparation, clinker production and clinker grinding. Important optimisation measures include:

- Key tracking parameters such as temperature and pressure need to be held within set limits for efficient system performance.
- It is recommended that system false air filtration is minimised. For example, the pyroprocessing system will operate efficiently if false air across the preheater can be limited to below seven per cent. For every per cent of reduction in false air, the specific heat consumption will fall by ~2-3kcal/kg of clinker.
- Optimisation of the kiln burner operation (ie, maintaining an effective ratio between axial and radial air) and the position of the burner inside the kiln helps achieve the required flame shape and intensity while maintaining the primary air quantity at a minimum.
- Optimisation of the clinker cooler operation will support maximum heat recovery and reduce specific heat consumption. A key factor is the effective balancing between the cooler grate speed and the resulting secondary and tertiary air temperature. In addition, in cases where a waste heat recovery (WHR) system has been installed, striking a balance between effective heat utilisation and WHR generation is also important in defining the system's overall efficiency.
- Maintaining optimum fineness of cement results in lower power consumption and improved production. This can be achieved by analysing the current cement quality and predicting cement strength through implementing AI/ML-based prediction models where the cement fineness targets can be set.
- Idling equipment should be avoided, particularly during plant start-up and shutdowns, through the implementation of sequential interlocking. In addition, creating awareness among team members has a direct impact on reducing operational costs.

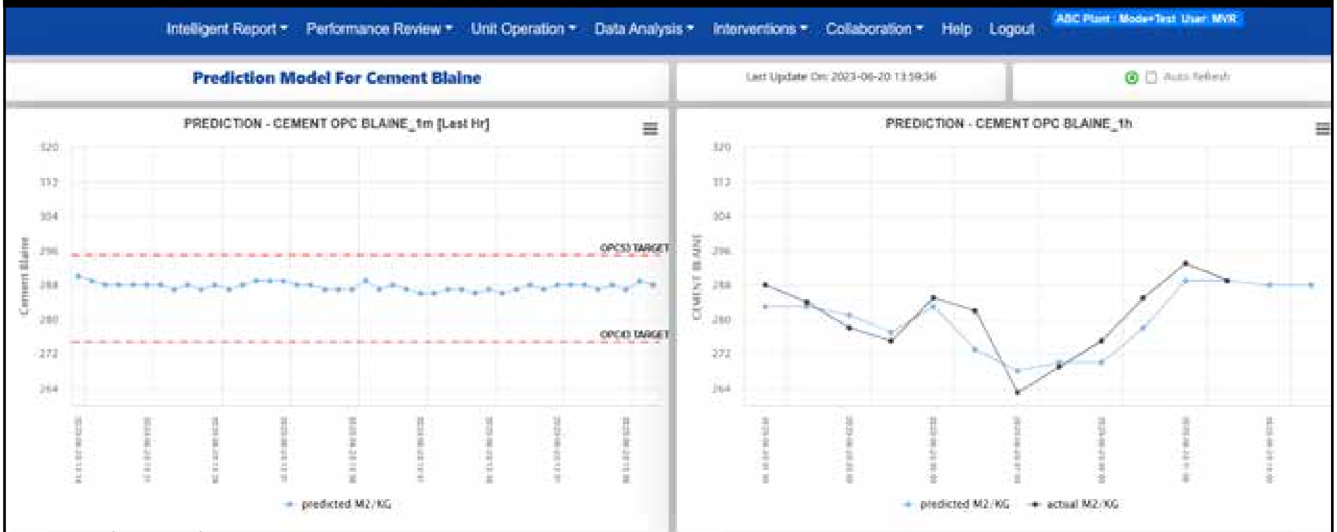
Furthermore, it is recommended that periodic audits are conducted to assess the system's performance and its inefficiencies.

The exercise should focus on optimising system throughput, specific energy consumption and the quality of the final product as well as promptly addressing mechanical, electric, process and environmental issues.

Figure 2: real-time heat and mass balance with effective heat utilisation vs WHR power generation

Source: Holtec Consulting

Figure 3: cement fineness and cement compressive strength AI/ML-based prediction models



Source: Holtec Consulting

The role of data analytics

There is an increasing trend of optimising plant operations through the implementation of advanced data analytics. Various AI/ML models are being used to forecast the key variables that have a significant impact on the plant's operational performance. These machine-guided solutions help the plant operation team to take proactive measures, which ensures sustainability of the ongoing processes.

To optimise the operation using data analytics, AI/ML-based analytics models, developed by Holtec, provide additional advantages towards the fulfilment of cost reduction initiatives.

Holtec's proprietary cement fineness prediction model and 28-day compressive strength prediction model help to eliminate under- or over-quality product, before being distributed to the market. Cement producers can save an estimated 2-3 per cent of production cost.

Optimisation of raw material costs

Effective use of raw materials in cement plants requires optimising their sourcing, handling and processing to ensure uninterrupted production while minimising the operation costs and environmental impact.

When setting a target for raw materials reduction, it is useful to consider:

- Usage of cost-effective correctives and additives, while keeping a close watch on their quality aspects and formulating a competitive, low-cost raw mix design.
- Using high MgO limestone in the clinkering process can impact the clinker quality, leading to expansion of cement. Hence, the same can be used in the clinker grinding process, as performance improver, limiting to the maximum allowable as per standards.
- Exploring the use of limestone with higher alkali content, by balancing with high-sulphur, low-cost fuels, which results in a decrease in raw materials cost. Adding a small amount of gypsum during the grinding stage also helps.
- Alternative raw materials such as iron sludge, red mud, red ochre, LD slag and zinc slag, etc are being used successfully in several plants. Use of ARMs can reduce the raw materials cost to the tune of US$0.05-0.07/t of clinker.

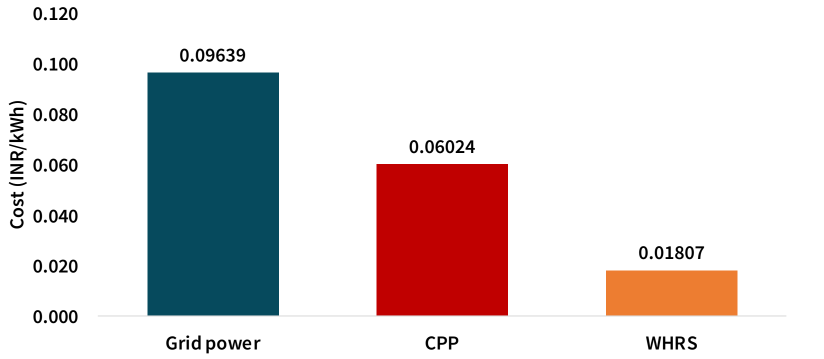
Figure 4: fuel mix optimisation model for optimising specific fuel cost and maximising thermal substitution rate

	1 day Strength	28 Days Strength
Predicted Value	21.1	58.3
Target Value	21.0	56.0
Target Blaine	302	

PRODUCT	1D TARGET STRENGTH	28D TARGET STRENGTH	IR	CaO	Na2O	SO3	BLAINE	+45 MICRON	1D PREDICTED STRENGTH	28D PREDICTED STRENGTH	TARGET BLAINE	RUN BY
opc53	20.00	58.00	1.66	63.29	0.16	2.16	298.00	12.80	20.90	58.80	0.00	

Source: Holtec Consulting

Figure 5: cost of power generation from various sources



Source: Holtec Consulting

Regular testing and analysis of raw materials is key and ensures compliance with quality standards. Subsequent optimisation of the process parameters will lead to improved performance and competitiveness in the cement industry.

Fuel cost optimisation

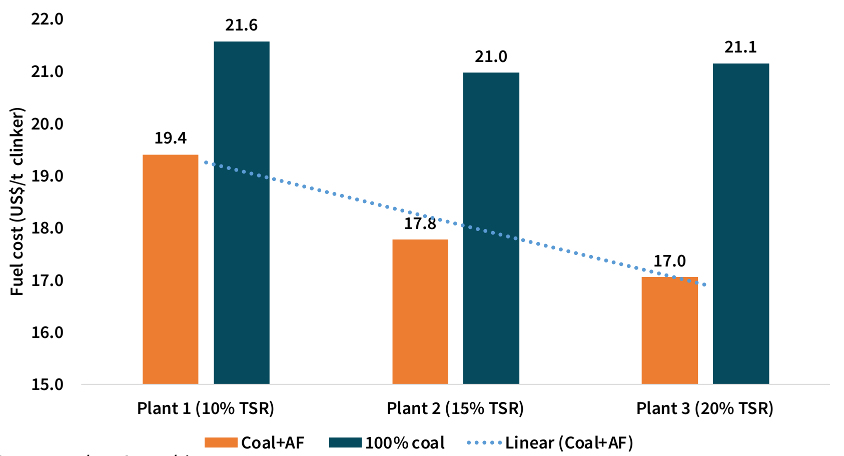
The cost of fuel is a significant part of a cement plant's operational cost structure. Therefore, fuel optimisation is essential to reduce cost and environmental impact while maintaining operational efficiency.

Conventional fuels (coal, natural gas, petcoke) as well as alternative fuels (biomass, carbon black, rice husk, tyre- and refuse-derived fuels) need to be proportioned effectively to result in lower fuel costs and enable a viable cement plant operation. Holtec has developed a fuel mix optimisation model to help achieve optimised fuel costs as well as secure the maximum possible thermal substitution rate (TSR).

There are several factors that need to be taken into account while optimising the plant's fuel use and cost:

• Too high ash content in solid fuels may lead to a higher LSF target, thereby increasing heat consumption and cost of production. Therefore, the fuel mix optimisation is essential to maintaining the ash content within acceptable limits.
• To maintain an optimised operational limit, it is recommended that fuels with a high sulphur content are avoided or blended with low-sulphur fuels. In case of high-sulphur inputs, alkalis need to be introduced to prevent build-ups in the preheater system. The installation of a gas by-pass system will further increase the specific heat consumption, leading to higher operational costs.
• As volatile matter impacts the energy consumption of the coal mill due to the higher fineness of fine coal, it is recommended that volatile matter in the fuel is checked before the coal is used.
• Fuel burning should always be in an oxidising environment. Heat liberation from the fuel will be doubled as when compared to incomplete combustion in a reducing environment. Furthermore, few mineralisers such as CaF_2, AlF_3 and ZnO can be used to reduce the overall thermal energy demand, thus saving on the overall production cost. Studies suggest that by using mineralisers, specific heat consumption can be reduced by ~30kcal/kg clinker.

Figure 6: cost reduction achieved by alternative fuel use



Source: Holtec Consulting

Alternative fuel use

Co-processing alternative fuels in cement kilns not only reduces reliance on finite resources but also mitigates greenhouse gas emissions by diverting waste from landfills.

However, careful selection, processing and monitoring of alternative fuels are crucial to ensure compliance with environmental regulations, maintain product quality and optimise energy efficiency, contributing to a sustainable and circular approach to cement production while reducing overall environmental impact.

Particularly, high moisture content in alternative fuels should be avoided, even if their unit cost is at the lower end. Higher moisture leads to lower net calorific value, resulting in higher fuel consumption and therefore, higher production costs.

Installation of WHR system

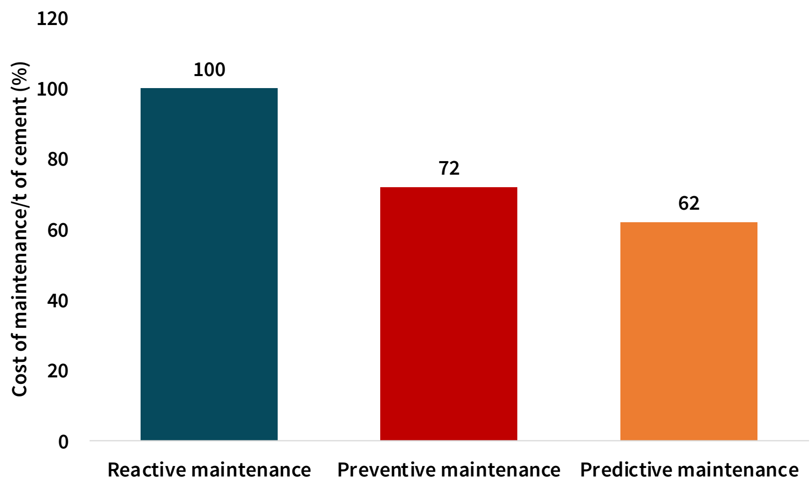
Waste heat recovery (WHR) systems in cement plants are instrumental in energy cost reduction by harnessing the excess heat liberated from the pyro-process system and using this for power generation. This reduces the need for purchasing power from the country's power grid or reduces fossil fuel usage in the plant's captive power plant.

Depending on preheater stages and WHR technology used, the WHR system can generate ~25-30 per cent of the plant's total power demand. It is possible that WHR power generation can drive the pyroprocessing operation, reducing the specific power consumption of the operation.

For example, in India, the cost of generating power by utilising a WHR system is ~US$0.01807/kWh, when compared to a cost of US$0.06025/kWh in a captive power plant. India's total WHR installed capacity is ~400MW (up to PAT cycle II), against a potential capacity of ~1200MW, according to recent studies.[1] Therefore, enormous savings potential exists and with each WHR plant installation, some of this potential is realised as the commissioning will directly reduce fossil fuel consumption as well as the plant's carbon footprint.

In addition, the implementation of a WHR system will improve overall energy efficiency, maximise resource utilisation and enhance the competitiveness of cement plants while contributing to a more sustainable and economically viable operation – a key factor in reducing costs.

Figure 7: cost savings of different maintenance practices



Source: Holtec Consulting

Improved maintenance practices

Maintenance practices in cement plants are vital for ensuring equipment reliability, minimising downtime and maximising production efficiency. This includes preventive maintenance scheduling, regular inspections and predictive maintenance techniques to anticipate and address potential failures.

Predictive maintenance practices are slowly picking up momentum for managing assets, which will significantly reduce the cost of piling up of inventory and reduce breakdowns by detecting any unusual operation of the equipment in an early stage.

Moreover, equipment performance is improved by implementing condition monitoring systems, lubrication management and spare parts inventory optimisation.

Additionally, establishing a comprehensive maintenance management system facilitates tracking maintenance activities, prioritising tasks and optimising resource allocation.

By maintaining equipment in optimal condition, cement plants can achieve higher productivity, extend equipment lifespan and minimise operational costs while ensuring safety and environmental compliance.

Advanced electrical and automation systems

Implementation of advanced electrical and automation techniques also reduces operational costs. Key measures include the use of:

- higher efficiency motors
- capacitor banks to maintain a higher power factor (above 0.99)
- automatic control systems for plant illumination
- variable frequency drives (VFDs) for all major process fans
- an advanced kiln scanner with refractory condition monitoring
- energy management system
- a centralised DCS control system
- laboratory and dispatch control system.

Conclusion

Implementing effective cost reduction measures is vital for sustainable cement plant operations. By optimising energy usage, enhancing raw material efficiency, and streamlining production processes, significant savings can be achieved. Investing in modern technology such as AI-driven process controls and predictive maintenance systems can also minimise downtime and maintenance costs.

Furthermore, fostering a culture of waste reduction and continuous improvement among employees can lead to innovative solutions and additional cost savings. Ultimately, these measures not only enhance profitability but also contribute to the overall competitiveness and the long-term viability of the cement plant in a dynamic market environment. ■

REFERENCES

[1] ALSOPP, PA, CHEN, H AND TSENG H (2007) *Cement Plant Operations Handbook for Dry-Process Plants. Fifth Edition.* Dorking, UK: Tradeship Publications Ltd, 276p.