



THE REVIEWS ARE IN

**Marco Lindemann Lino
and Volker Hoenig, VDZ,**
explain how energy reviews
at cement plants can be
a step towards higher
efficiency and lower CO₂
emissions.

Introduction

The use of cement as a key material for present and future global economic development is unquestionable. However, the cement industry also accounts for 6 – 7% of global anthropogenic CO₂ emissions. Long before the Paris Agreement was signed with the aim to mitigate the effects of greenhouse gas emissions, there was already a joint effort in the cement industry to reduce its carbon footprint and increase cement production sustainability: the Cement Sustainability Initiative (CSI). In 2009, the International Energy Agency (IEA) elaborated a Cement

Technology Roadmap and identified four main levers to comply with ambitious CO₂ reduction targets: clinker substitution, alternative fuels (AFs), energy efficiency, and carbon capture and storage.¹ Carbon capture technologies have been investigated in the past two decades but they are still not mature and require demonstration. Clinker substitution is making good progress, taking into account the respective cement markets, national

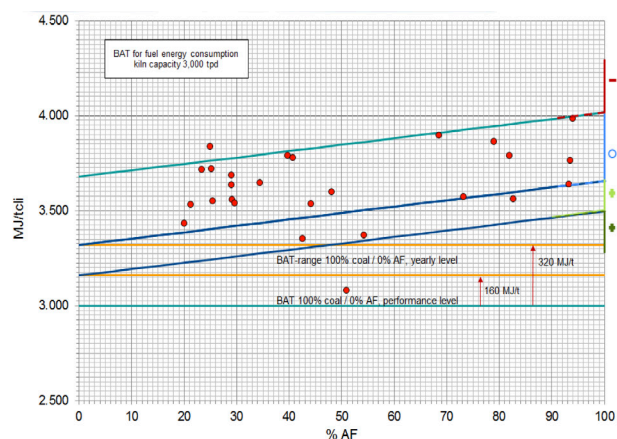


Figure 1. Assessment of fuel energy performance according to VDZ's methodology.

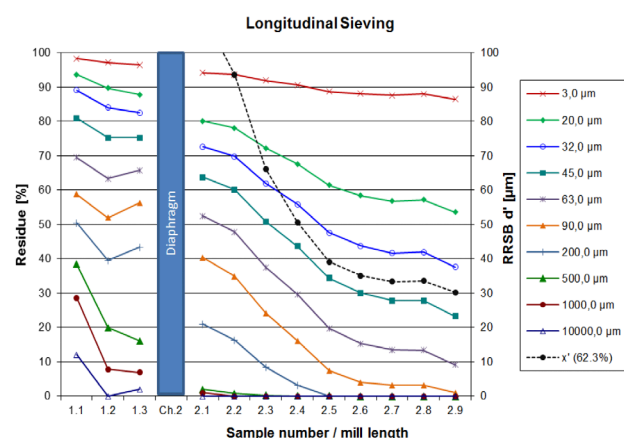


Figure 2. Results from a meter sampling of a two chamber ball mill for cement grinding.

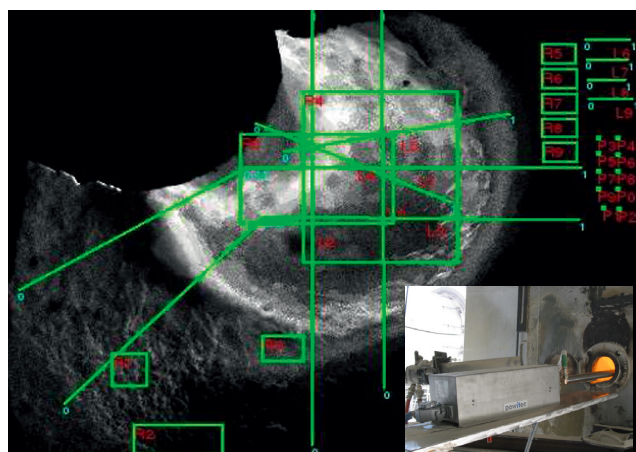


Figure 3. Use of thermography for flame shape monitoring and optimisation of AF firing.

cement standards, customers' awareness and acceptance, and the availability of non-clinker cement constituents.² The use of AFs is rising worldwide but it is a stepwise process and needs careful control with regard to process, product quality, and environmental aspects. The increase of the thermal substitution rate usually requires a long learning curve to re-optimize the process and deal with many techno-economic challenges that compete against each other. Field experience and technical knowhow are fundamental to reach higher substitution rates and shorten the learning curve.

Energy typically accounts for about 40% of operational costs in the cement industry.³ For this reason, cement companies have always recognised energy efficiency as a subject of major interest that is crucial to a successful business. The factors affecting energy demand in cement production are well known, but the assessment of the influence of their interactions is complex. A simultaneous examination of the interactions between the energy performance of individual process steps and the entire process chain, including the product portfolio, is necessary. The replacement of single, outdated major equipment units by others with higher energy efficiency can provide considerable gains and has already been extensively described in the CSI/European Cement Research Academy (ECRA) technology papers.⁴ However, such a strategy also requires significant investments, which have to be carefully assessed on a case-by-case basis. In addition, energy efficiency is often improved through process optimisation without major technology changes. While in well-operated and maintained cement plants measures with high improvement potentials have been implemented, it is always worth identifying potential small improvements in the process. Experience has shown that, in total, they can provide relevant energy savings without disregarding product quality or breaching emissions limits.

Energy reviews

VDZ has developed and refined its assessment methodology for conducting energy reviews. Depending on the objectives of the plant management, reviews at three different levels can be provided:

- Basic: assessment based on information available in the plant.
- Advanced: basic review plus onsite visit and inspection.
- Detailed: advanced review plus performance of onsite measurements, such as mass and airflows, heat and energy balances, emissions, and material sampling, etc.

Energy reviews address all relevant energy aspects and energy performance indicators of the cement manufacturing process as a whole, from the quarry to cement dispatch. This includes fuel and power consumption, the plant's design, operation, and energy management. The comparison of assessment results is done against the reviewer's database and internationally

accepted standards, such as the European best available technique (BAT). Inefficiencies are identified and improvement measures are recommended according to the level of detail and quality of the information gathered. Some relevant outcomes from VDZ's energy reviews are presented below.

Thermal energy consumption

In order to assess the performance level of a cement plant with respect to its thermal energy consumption, a comparison with BAT and reviewer performance indicators is made. The BAT performance level without using AFs, mentioned in the European BAT reference document (BREF) for the cement industry, is 2900 – 3300 MJ/t clinker for a 3000 tpd kiln.³ This level should be seen as a performance level that can be achieved under optimum conditions in a short term performance test. The European BREF also states that on a yearly level the energy demand can be 160 – 320 MJ/t clinker higher because of heating up and shutting down the kiln, unplanned kiln stops, etc. This results in a BAT range on a yearly level of 3160 – 3320 MJ/t clinker (using 3000 MJ/t clinker as a basis). Experience shows that the use of AFs, depending on their physical and chemical properties, often leads to an increase in the fuel energy demand of cement kilns. Based on process modelling, the relation between fuel energy demand and AF ratio was determined.² The AF mix that was taken as a basis comprises several typical AFs being used in the cement industry. The modelling – as well as the European BREF document – considers a precalciner kiln with a five-stage preheater. Furthermore, data from the CSI's Getting the Numbers Right (GNR) database have been considered. It has to be highlighted that a careful and methodical assessment is required when comparing real plant data with BAT, as plant specific conditions must be taken into account. Figure 1 shows data from kiln lines that VDZ was asked to review. As production capacity also influences the specific energy demand, the figure only depicts kilns of the same size, in this case with production capacities of about 3000 tpd. Similar schemes are also available for other kiln capacities (e.g. 1500 and 5000 tpd). The diagram shows that most of the kiln lines reviewed had a fuel energy demand higher than the BAT range, which uncovers potential for optimisation. The following factors can be related to these potentials:

- Technological factors (type of equipment and equipment design).
- Operational factors (thermal substitution rate, kiln instability, coating formation, blockages, refractories, and frequent kiln starts and shutdowns for process reasons, etc.).
- Maintenance factors (kiln seal condition, preheater and calciner condition, kiln stops due to malfunction of equipment, and lack of calibration of instrumentation, etc.).
- Quality factors (fuels, raw materials and raw mix chemical and physical properties, and LSF fluctuation).

- Environmental factors (control of emission levels).

All the factors listed above shall not be assessed separately, as most of them are interrelated. Moreover, Figure 1 also shows that only a few plants have performed within the limits defined for the BAT range. One single cement plant stands out from all the others as operating at an outstanding performance level. VDZ's energy reviews brought to light some similarities among cement plants operating in or close to the BAT range. All of them have the following in common:

- Tight control of the whole process.
- Use of state-of-the-art equipment.
- Equipment operation and maintenance performed properly.
- Kiln operation close to nominal production capacity.
- Technical staff with deep knowledge of cement manufacturing.

For outstanding performance levels in plants with high thermal substitution rates, the use of tailor-made AFs and respective fuel quality control is also required.

Electric energy efficiency

Cement and raw materials grinding represent together about two thirds of the total power consumption of a cement plant. Consequently, they also present the most significant power saving potentials. Through process optimisation, energy efficiency gains from 1 – 5% can commonly be achieved in grinding plants and without major investments. In well operated and maintained grinding plants, uncovering energy efficiency gains usually requires a detailed review (i.e. assessment of process data, equipment inspection, crash stop of the mill for material and ball sampling, and assessment of mill internals condition, etc.). Figure 2 shows the results from a meter sampling of a two-chamber ball mill for cement grinding performed during a detailed review. Displayed are the residue values for different particle sizes measured by laser granulometry and sieve analysis (< 500 µm), as well as the Rosin-Rammler-Sperling-Bennet (RRSB) location parameter x. The first impression is that the overall reduction of residue values in the example shows good comminution behaviour. However, after a more detailed assessment, it becomes clear that, in the last third of the mill, almost no size reduction is visible. This is clear evidence of an ineffective comminution process and thus a reason for an increased electric energy demand. Further investigations showed that about 20% of the grinding media in that area was highly deformed. The behaviour of the grinding media movement was being affected and was consequently leading to overgrinding, agglomeration, and heat problems. After inspection, the grinding media were cleaned and the deformed balls replaced by new ones. The first tests revealed a cement production increase of 10%, followed by a respective reduction in specific electric energy consumption.

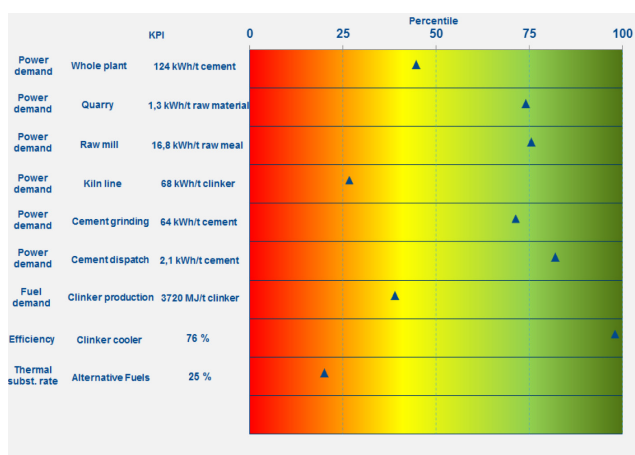


Figure 4. Example of a benchmarking and performance assessment scheme.

Energy management

Energy management includes power, as well as fuel management. VDZ has concluded that fuel management is generally performed in an appropriate way. Nevertheless, there is still some room for improvement in areas including fuel handling, storage, dosing, and firing, as well as the type of fuel purchased. Common to all reviewed plants is the objective of reducing energy costs by strategically increasing the thermal substitution rate. Figure 3 shows an example of using thermography for flame shape monitoring and optimisation, with the objective of keeping the temperature profile in the sintering zone constant when using high levels of AF in the kiln firing. The use of AFs is limited by price, amount, and the quality available on the market. On the other hand, alternative fuel suitability and the impact on the clinker manufacturing process depends on the technology installed in the plant and emission limits imposed by local regulations.

In order to obtain higher power savings, a deeper look into the cement grinding process is necessary. Equilibrium between production flexibility, power efficiency, and power management must be attained in order to achieve the best results. The trend should be the optimisation of the ball charge for the types of cement that are most often produced. The specific power consumption of certain types of cement can probably increase, but a correct optimisation will decrease the global specific power consumption of cement production.

Benchmarking

Benchmarking is used by many companies worldwide as the first step towards highlighting potential inefficiencies and improvement potentials. The benchmarking of energy key performance indicators (KPIs) is state-of-the-art in many cement plants around the world. The comparison of energy performance indicators from reviewed plants against VDZ's database (Figure 4) has shown that it is common for some trade-offs to be negotiated by different production stages, in accordance with the objectives of the plant. A simple comparison of KPIs can be misleading, as the energy inefficiency of a certain production stage might be related to the optimisation of the plant as a whole or

linked to a certain type of technology or product. Thus, a proper technical assessment is fundamental, otherwise benchmarking runs the risk of becoming a purely statistical exercise, of which the added value for energy efficiency optimisation purposes might be questionable.

Conclusion

By increasing the use of AFs and improving energy efficiency, the cement industry has proven in the past decades that sustainability and the simultaneous reduction of operational costs can go hand in hand. Energy reviews are one of the most time- and cost-effective ways to uncover potential energy savings in cement plants and thus reduce CO₂ emissions even further. Potential energy savings are plant specific and some trade-offs must be negotiated. Therefore, recommendations must be technically supported and customer oriented. Numerous energy reviews have shown that practically all plants reviewed showed potentials for improvement with regard to energy demand and, consequently, reducing energy costs. In order to reach the highest technical level, the correct operation and maintenance of state-of-the-art equipment, tight control of the whole process, and careful selection of fuels and raw materials is fundamental. A detailed review can always help to uncover improvement potentials, which was also the case in plants that were well-operated and maintained, and where major energy efficiency measures had already been identified and implemented. 🌐

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About the authors

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