Concrete steps towards profitability
Solid ways to ensure energy efficient cement production
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1. Concrete steps towards more energy efficient cement production

The unique properties of cement make it indispensable in the construction of almost every type of building, facility or infrastructure. It is well known that the manufacturing of cement is an energy-intensive process, requiring substantial heating and the movement of bulk materials. With any energy intensive process, opportunities are likely to exist for improvements in energy efficiency which can in turn, provide for considerable cost saving as well as a reduction of greenhouse gases being emitted into the atmosphere.

2. Sustainable use of electricity is a necessity

The cement production industry can reap much reward from implementing energy efficiency policies. By optimising processes and plant efficiency, companies reduce input costs; increase their return on investment and stand a chance to gain from tax incentive schemes that are promoted by the government from time to time. As an added benefit, reduced energy consumption means reduced environmental impact, an important part of the “triple bottom line”.

Through its work, Eskom’s Integrated Demand Management (IDM) department is assisting a range of industries to examine and gauge their energy consumption and thus seek opportunities for consumption reduction. South Africa is leaving behind its history of low-cost, freely available electrical power as economic growth, social development and an increasing population puts pressure on existing reserves. As a consequence, industries across the board, which formerly had little motivation to even consider energy efficiency, are obliged to reduce their consumption where possible in order to maintain sustainability and profitability. While a number of companies have already taken this challenge to heart by, for example, committing themselves to the Energy Efficiency Accord, a combined concentrated effort is needed.

3. A perspective on power consumption in cement production

Cement manufacturing is one of the world’s three major energy intensive industries along with steel and aluminium manufacture. Cement production accounts for about 70-80% of the energy use in the non-metallic minerals sub-sector, consuming 8.2 exajoules of energy a year, or some 7% of the total industrial fuel use worldwide. A breakdown of the costs of cement production (from Philippe Lasserre, Globalisation Cement Industry – 2007) reveals that nearly a third of the cost comes from energy expenses. While much of the energy for cement production comes from the consumption of fossil fuels (predominantly coal, which is necessary to fire clinker kilns), the industry remains a substantial consumer of electricity throughout the industrial processes for operating factories and in bulk materials handling. The primary focus of energy reduction in cement plants is usually on the thermal energy required to fire the kiln. This can be expected since approximately 90% of the energy used in a cement plant is thermal energy (In Energy, 2011). The remaining 10% is electrical energy used to drive the process machinery. In South Africa electrical energy is roughly four times more expensive than thermal energy from coal when compared on an “as delivered kWh” basis using 2011 price levels. Thus the electrical cost portion of a cement plant’s energy bill is closer to 30%. Minimisation of electrical energy should therefore also be a key focus point.

4. Electricity use in cement production

Cement is generally produced from a feedstock of limestone, shale and iron ore. These materials provide the four key ingredients required: calcium, silica, alumina and iron. Grinding these ingredients together and exposing them to intense heat converts the partially molten raw materials into clinker. After adding gypsum and extenders, the mixture is ground to a fine grey powder, called cement. The steps in the cement manufacturing process are listed below.

Figure 1. Electricity use in cement production
1. Raw Material Quarrying
2. Raw Material Milling
3. Clinker Manufacture
4. Cement Milling
5. Packing & Dispatch

Of the five steps, the majority of energy use takes place in the three highlighted departments. The greatest focus for electricity savings in a cement plant should thus be on these departments.

Some technologies and hence Energy Conservation Measures are specific to these departments. The Raw Material Milling department is predominantly focused on material grinding and so is the Cement Milling department. The Clinker department includes a large number of fans and drives.

Some technologies are common throughout the process. These include material transport systems and the so called auxiliaries such as lighting and compressed air systems.

5. Levels of electricity consumption in cement production

Looking at the most recent trends in the graph, most countries for which data is shown fall within the range of 90-120kWh/t of cement. It can also be seen that the general trend for the consumption of electricity for every ton of cement produced is coming down. It is the goal of Eskom’s IDM department to encourage all South African cement producers to join the drive towards improved energy efficiency and reduced cost of production.

In some countries, part of the decrease in specific electricity consumption is a result of reductions in the clinker to cement ratio as well as improved energy efficiency of the process. In countries where electricity consumption per tonne of cement declined, the rate of decline was between 2.1-0.2% between 1990 and 2003/2004.

In some cases such as Japan, China and Italy, electricity consumption has actually increased in recent years. In Japan, this has been due to the increased electricity used in handling alternative fuels and materials. Such handling can be ascribed to commonly-used industrial processes and electricity consumers – that is, electric motors, pumps, compressed air and heating, ventilation and air conditioning (HVAC).
Furthermore, it can be argued that the wide range in electricity consumption may reflect different electricity prices and different manufacturing technologies employed. Savings focuses depend on the balance between thermal and electrical consumption and their relative costs. In cases where electricity is relatively expensive, organisations are compelled to seek out and apply strict electricity savings measures to control production cost.

6. Priority technologies showing largest potential for savings

6.1. Grinding Technologies

Raw material, fuel and cement mills

At a cement plant material grinding is required in a number of steps in the process

• Raw materials like limestone need to be milled fine before being fed into the kiln system so that more effective mixing, heating, decarbonisation and clinkerisation can take place
• Fuels like coal also need to be milled fine so that they create the required burning conditions
• Clinker nodules from the kiln need to be milled fine together with various additional components to create the cement powder as we know it

To get an idea of the relative consumption of milling departments at cement plants, the applicable rule of thumb would be to assume roughly two thirds of the electricity consumption at a cement plant is related to milling, i.e., the majority.

When investigating energy savings potentials in cement plant milling departments it is very important to note the following:

• In cases where additional capacity is desired, it is clear that it would be prudent to either consider newer more efficient milling technologies outright, or consider “retrofit” options of making use of newer milling technology in conjunction with existing older technology
• In cases where the older technology is already in use and still in a good condition, the large capital expense of replacing the older technology with newer units may make such projects financially unattractive. In these situations companies need to consider ways of operating existing equipment more efficiently, i.e., optimising processes with minimal capex expenditure

6.1.1 Mill Types

Ball Mills

The majority (60%) of finish grinding in the world is still performed using the ubiquitous ball mill. Ball mills are cylindrical steel shells with steel liners. These rotating drums contain grinding media that crash and tumble onto the raw material to grind down the particle size. Almost all ball mills use a form of closed circuit grinding that returns material that is too coarse back to the ball mill inlet while material fine enough to meet product requirements is sent to the product silo. A separator determines which particles will be returned and which particles are sufficiently fine. Ball mills may not be the most efficient means of size reduction but their reputation for product consistency and their simplicity of operation have made them a historic favourite for raw materials, fuels as well as cement milling.

Vertical Roller Mills

In terms of grinding of raw materials, fuels and cement grinding ball mills are now considered to be outdated technology, especially when considering their electricity consumption. While the specific energy consumption of standard ball mills has been improved with the development of high efficiency separators, a major technological step was achieved with the development of the Vertical Roller Mill (VRM). The VRM is now considered by many companies as standard and tested technology for milling in cement plants. VRMs present a compact and efficient grinding method. Roller mills employ a mix of compression and shearing, using 2-4 grinding rollers carried on hinged arms riding on a horizontal grinding table. The feed material is ground on the rotating table by rollers that are pressed down using spring or hydraulic pressure. The material is forced off the table by centrifugal force, where it is then swept up into an airstream to an internal classifier immediately above. Material that is too coarse is returned to the table for additional grinding while material that is fine enough is collected as product. Hot gas is used for drying during the grinding process when required. The compact design of a VRM allows it to dry, grind, and classify, all within one piece of equipment and all in a relatively compact space. VRM technology allows power consumption savings, consistent product quality and process simplification.
Horizontal Roller Mill

Grinding technology has not stood still however and there are now more efficient mill designs on the market. In the late 1990s the Horizontal Roller Mills (HRM) and Roller Press systems were seen as untested and unreliable. Today these technologies are at the forefront of milling electrical efficiency and are more and more being considered for new cement plant installations around the world.

The HRM consists of a tube shell, supported by slide shoes, that rotates at a hypercritical speed. Inside the shell, a hydraulic roller exerts a pressure on the grinding bed, often causing material to become attached to the inner face of the shell by hypercritical shell speed. Scrapers are employed to remove this material, which then falls onto a diverting system, which pushes the material against the shell face for regrinding and adjusts the motion of this material inside the mill. The material is ground several times before leaving the mill and being classified by a dynamic separator. HRMs have first made an appearance for cement milling.

Roller Press

Like the VRM and the HRM, roller press systems are also based on the particle bed compression principle of energy saving. High pressure roller press systems for finish grinding employ a static V-separator to first separate the fine fraction from the feed. The coarse fraction is fed in to the roller press itself and the fine fraction is fed into a dynamic separator to separate out the final product. The coarse fraction is fed back to the roller press. The two rollers of the roller press pressurise the coarse material to break up the particles. One advantage of this milling system is that the return of the coarse material from the static separator is performed by a bucket elevator instead of less energy efficient pneumatic conveying (as is done internally in a VRM).

Roller presses also were first introduced for cement milling, but now offer a solution for raw material milling too.

The following graph shows how the new grinding technologies have reduced the relative specific electricity consumption needed to mill raw materials and cement.

![Figure 3. Cement Finish Grinding Technologies](image)

6.1.2 Optimising existing grinding systems

Seeing that the installed base of operational ball mills is still very wide, it makes sense to focus on improving the efficiency of these units as opposed to trying to completely replace them with new more modern mill types. The grinding efficiency of ball mills is low and much of the energy that is input via the mill motor escapes as heat, with only a fraction of the input energy actually performing the required work of breaking down the particles to the required fineness. A number of techniques are available to improve the grinding efficiencies of ball mills, allowing a better conversion of energy input to grinding work.

Process control and management in grinding mills

- Control systems for grinding operations have been developed using the same approach as for kilns. Model-based Predictive Control and Fuzzy Logic are the two competing decision technologies most commonly used for grinding control systems. These “autopilot” systems control the material flow in the mill circuit and separators, attaining a stable and high quality product. Several systems are marketed by a number of manufacturers who have shown their products allow for a reduction in power consumption of up to 12%.
Level control systems

- The sonic method of assessing the filling degree of ball mills is now archaic technology that has been superseded by vibration monitoring techniques. These techniques allow the extent of the vibration of a mill compartment to be correlated to its filling degree. This information can then be fed into process control software to even better maintain the material filling levels of ball mills, thus ensuring a more optimal milling environment. Case studies employing this technology have shown reductions in power consumption of up to 6%.

Internal mechanics

- Modern liner designs like classifying liners for example allow a better ball distribution throughout the milling chamber, ensuring large balls tend to stay at the inlet side where they are needed to crush the feed materials, and ensuring small balls tend to move towards the chamber outlet side where finer grinding is required more than crushing.
- Ball charge management is important to ensure that the grinding process occurs optimally along the length of the mill.
- Modern intermediary diaphragms allow for better flow control of the ground material through the mill, thus ensuring optimal material levels in the mill allowing for a more optimal grinding environment.

High-efficiency separators

- Since the installation of the original simple ball mill circuits, technology has progressed further with the development of high-efficiency separators. These units can be retrofitted to existing mill installations for improved grinding efficiency. The output of a ball mill is passed through the separator, which separates the finely ground particles from the coarse particles. The large particles are then recycled back to the mill. Standard separators may have a low separation efficiency, which leads to the recycling of fine particles, resulting in extra power use in the grinding mill. In high-efficiency separators, the material is more cleanly separated, thus reducing over-grinding. High-efficiency separators have had the greatest impact on improved product quality and reducing electricity consumption. Newer designs of high-efficiency separators aim to improve the separation efficiency further and reduce the required volume of air (hence reducing power use), while optimising the design.

Grinding aids

- Grinding aids are used in the cement grinding process to improve the grinding efficiency of ball mills by allowing a better flow of material through the mill, reducing coating on the balls and liners, and improving separation in classifiers. Grinding aids are expensive organic compounds and generally impact on the production cost of cement.

6.2. Gas handling systems

The nature of the production process of cement requires the transport of large volumes of air, combustion and drying gases. The kiln itself requires a large volume of oxygen for combustion purposes. The resulting waste gases are then used further in the preheater to allow counter-current heat exchange to heat up the incoming raw materials and to start the decarbonisation process (which in itself generates more waste gases). Fans are also used to transport air used for drying and for separation of product in the high-efficiency separators of milling systems.

For many years now fan specialist companies have been pushing the limits of fans to obtain the best aerodynamic efficiencies. Due to the nature of the process, fans in cement plants underperform mostly due to dust build up, abrasion and/or poor inlet design. Improvement of filter technology now enables high efficiency fan rotors to be installed in more locations in the cement plant. The replacement of a worn rotor in an existing casing can not only reduce the fan motor’s consumption but can better suit it to production conditions. In fact, a repaired or rebuilt fan impellor can often outperform a new impellor seeing as a repair will allow the engineers to improve on the original design to reduce undesirable wear characteristics or corrosion.

Fans are subject to more misuse and faulty applications than virtually any other type of equipment. The energy consumed by fans must be controlled as this contributes to the overall energy efficiency of a system. A cement kiln system generally has two or three large fans inducing gas flow through the kiln and raw milling system. These fans need to be focussed on first. Then a plethora of smaller fans abound a cement plant and their efficiency improvement potentials need to be considered on a case by case basis.
Save energy in the following ways:

**Specification of fans**

- Fan efficiency and failures have a significant impact on plant operation. It is thus critical to choose the correct fan design. It is especially important to consider the operating environment of the fan, i.e., prevailing temperature, corrosion and abrasion conditions.

- Designers tend to compensate for uncertainties by oversizing the fan systems. This may initially be an oversized fan and, thereafter, an oversized motor to drive the fan. Oversizing fans is often an attempt at providing adequate impact, however, this creates operating problems such as expensive operating costs, noise and airflow problems. When checking fan designs, accurate modelling of process conditions is a prerequisite. Fans need to be best matched to the required load.

- Specify an appropriate and efficient drive system. When using a direct drive where the impeller is attached to the motor shaft, losses of up to 10% can be experienced. In the case of belt driven fans, an additional power loss of 2-7% between the pulleys and fan belts can be expected.

**Variable speed drives for fans**

- Control the airflow to accommodate demand changes by using inlet vanes, outlet dampers or fan speed control. This single point can bring along with it significantly improved energy efficiency. While it is the ultimate goal of a cement kiln operator to run the kiln as stably as possible, this is sometimes not entirely possible when factors such as the variabilities in fuel quality, changes in fuel type, raw material burnability, moisture variability, mechanical failures and electrical failures, for example, impact on the process. Such process impacts inevitably change the gas volume loading on the process fans in the system. Historically the common process control method for adjusting gas flowrates has been by means of inlet dampers. However, in situations where the volume flowrate needs to be adjusted frequently, i.e., when the fan load profile is variable and operating time is high, other flowrate management techniques can be much more energy efficient. One such technique is the installation of a variable speed drive.

![Figure 4. Fan Curves](image)

A fan inlet damper alters the volume of gases drawn through the fan by changing the system characteristic curve of the fan. The resistance of the system to drawing gas through the fan is increased or decreased to vary the volume. While the total volume flowrate drops, the pressure differential across the fan increases and so the power drawn by the fan motor remains high. If the volume of gas drawn through the fan has to be varied frequently or constantly then a variable speed fan is a much better solution than damper control.
With a Variable Speed Drive (VSD), when the speed of the fan is varied the fan characteristic curve is also varied and the system resistance curve remains constant. The total volume of gas drawn through the fan varies in direct proportion with the speed of the fan. The pressure differential across the fan varies with the square of the speed of the fan and the power drawn by the fan motor varies with cube of the speed of the fan. So, if the fan speed is reduced to 80% then the power drawn by the motor reduces to 51%. If the fan speed is reduced to 60% then the power drawn by the motor reduces to 22%. It is thus obvious, that replacement of a fixed speed fan with inlet damper gas volume control by a variable speed fan is one of the most effective ways to reduce electrical energy consumption at a cement plant.

Design of gas handling systems

- Design the system so that the inlet and outlet ducts to and from the fan are straight
- Use devices such as turning vanes, airflow straighteners or splitters to accommodate the air profile
- Optimize the duct sizing as larger ducts create lower friction losses and thus lower operation costs
- Make use of lower pressure drop designs, especially in the preheater tower cyclones

Maintenance of fans, ducting and other gas handling equipment

- Repair leaks. Holes in gas ducting can result in an unnecessary and considerable additional workload for fans and drives when the apertures allow air to be sucked in from the outside. These leaks, often called “false air”, can be identified by personal inspection or by performing oxygen profiles for example
- Maintain kiln seals. These seals are used at the kiln inlet and outlet to reduce false air penetration, as well as heat losses. Seals may start leaking over time, increasing the heat requirement of the kiln. Most often pneumatic and lamella-type seals are used, although other designs are available (e.g., spring-type). Although seals can last up to 10,000 to 20,000 hours, regular inspection may be needed to reduce leaks
- Check and adjust belt drives and fans regularly
- Lubricate fan components
- Clean fan components regularly
- Correct excess noise and vibration to ensure smooth and efficient operation
- Replace loaded air filters
- Implement a fan maintenance programme

6.3. Material conveying systems

One of the material transport systems used in many cement plants is called an air lift. An air lift is a system that transports fine powdered material in a piped stream of fast blowing air from one floor level to another higher floor. The disadvantage of an air lift is that it requires a very large amount of air to overcome the gravity forces of the material to be conveyed. To provide such large volumes of air requires much electricity to be consumed.

Figure 5. Comparative Electricity Consumption

Another possibility for large scale material transfer when powdered material needs to be vertically transferred is a bucket elevator. The installation of bucket elevators eliminates the need for large power hungry blowers. Bucket elevator technology has progressed considerably over the last couple of years and so the mechanical reliability of such units has dramatically improved and the energy consumption has drastically reduced.
In a study in 2004 it has been shown that bucket elevators drew on average 0.41 kWh/t of material, while air lifts drew 1.10 kWh/t of raw material (World Cement, 2004). This translates into a saving of 63%. Today, the latest technology bucket elevators have been shown to draw 0.17 kWh/t of material per 100m of height lifted.

6.4. Motors and motor systems

Of the total electricity consumed by the industrial sector, about 60% is used to drive motor systems such as pumps, ventilation fans, compressed air systems, conveyor belts, etc. Over its life a motor can cost 100 times more to run than it did to buy. This provides significant scope for cost reduction.

Motors and drives are used throughout a cement plant to move fans (e.g., preheater, cooler), to rotate the kiln, to transport materials and, most importantly, for grinding. In a typical single kiln cement plant, 500-700 electric motors may be used, varying from a few kW to MW size.

Cement producers can achieve significant energy savings by using high-efficiency motors.

Specific application example: Efficient kiln drives for clinker production

A substantial amount of power is used to rotate the kiln. Recently, the use of AC motors is advocated to replace the traditionally used DC drives. Technological advances now allow the use of AC drives to supply the enormous starting torque required for cement kilns. Modern AC drives use less energy, are more reliable and are easier to maintain. The AC motor system may result in reduction in electricity use of the kiln drive by between 0.5-1%, and this at a lower investment cost than a DC drive.

General application example: High efficiency drives for smaller motor applications (<=90 kW)

Electric motors are the heart of most industrial process plants, converting electrical to mechanical power. The three major applications of motors in large industrial settings are for driving pump systems, fan systems and compressed air systems.

Due to the high number of smaller motors in use at a cement plant it is imperative to ensure that motors are selected and maintained appropriately to minimise electrical consumption. When considering smaller sizes, high-efficiency motors use around 1-4% per cent less electricity than standard motors and they are typically more reliable, last longer and result in lower transformer loading. High-efficiency motors are more expensive to purchase given the higher copper content required in their manufacture, but the Eskom Energy Efficient Motors (EEM) initiative has introduced a subsidy to make high-efficiency motors more affordable when replacing old motors.

Further, it is not uncommon to find that motors used in industry are oversized. This results in poor efficiency, which leads to more energy consumption and energy cost (even by more than 25% in certain scenarios). Therefore, onsite motor loading surveys and corrective action must be a part of any comprehensive energy conservation effort.

Specifications of motors and motor systems

- Standard efficiency electric motors tend to perform at their best around the 75% of full load point
- High efficiency electric motors possess a relatively flat efficiency as opposed to a load curve, which operates from around 70% and extends up to the rated load
- Energy efficient electric motors should be specified wherever appropriate. They run cooler, are compatible with Variable Speed Drives (VSDs) and reduce energy costs

The most commonly accepted definition used for the classification of motors according to their efficiencies is IEC60034-30: 2008.

<table>
<thead>
<tr>
<th>Standard efficiency</th>
<th>IE1</th>
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<tbody>
<tr>
<td>High efficiency</td>
<td>IE2</td>
</tr>
<tr>
<td>Premium efficiency</td>
<td>IE3</td>
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<tr>
<td>Super premium efficiency *</td>
<td>IE4</td>
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*The standard also introduces IE4 (Super premium efficiency), a future level above IE3
Figure 6. Efficiency ranges for various motor classification

**Maintenance**

- Electric motor maintenance when neglected, can negatively impact the energy efficiency of motors
- Studies have shown that the first rewind of a new electric motor can result in as much as a 3% reduction in efficiency so the rewinding of motors has a greater negative impact on energy efficiency
- Ensure that your rewind vendor has an SABS mark and rewinds your low voltage motors in accordance with SANS 10242-1
- Avoid continually using repeatedly rewound electric motors
- Develop an electric motor management strategy that is focussed on life cycle costing (including maximum number of rewinds per size, minimum rewind size, etc.), in order to guide staff from procurement to operations, maintenance and disposal.

It does need to be noted that high-efficiency motors are not suitable for every application. In general motors with higher efficiency may run at slightly higher speeds. In centrifugal pump and fan applications, for example, the energy consumed is proportional to the speed cubed. Therefore, small increases in speed can increase energy consumption significantly. In these cases it may be necessary to adjust the drive pulleys or the drive system to ensure the load is operated at the same speed.

To encourage users to switch from conventional motors to high-efficiency motors, Eskom offers a rebate programme where it subsidises the cost of replacement. Details can be obtained on www.eskom.co.za/idm

### 6.5. Compressed air systems

Compressed air is widely used to drive a variety of tools and applications. Although some have realised the benefits of using electrically powered tools, none have been able to dispense completely with their compressor rooms and compressed air pipes.

Unfortunately, compressed air systems are vulnerable to damage and leaks, which result in wasted energy. Compressed air is found in a cement plant operating control valves, packing plant equipment, silo aeration, air cannons, conditioning towers, bag filters, pneumatic transport systems, air cooling systems and a variety of other applications. The following should be adhered to when considering energy efficient air compressors:

**Specification of energy efficient air compressor systems**

- A modular arrangement, when coupled with an energy management system, can allow for better control of compressed air to match the air requirements without driving each unit out of their best efficiency zone
- Use compressors with high efficiency motors instead of standard motors
- Ensure compressors are appropriately sized
- Reduce the number of inline filters required by purchasing a unit that delivers the required air quality straight from the discharge flange. This reduces the overall pressure drop of the system
• New compressor designs are generally more efficient than their old counter parts and payback periods based on energy savings are fairly short
• Look for value-added options, such as recovering heat generated during air compression from the cooling medium used
• Keep inlet air temperatures at the lowest possible levels by correct inlet design
• Maintain the system operating pressure at the lowest level practical

Maintenance of air compressors

• A monitoring system will ensure that early warnings are identified on time and acted upon, thus avoiding costly downtime losses
• Continuously identify, classify and fix leakages
• Maintain the compressor inlet pressure at levels as high as possible for example by ensuring that inlet filters are cleaned regularly
• Case studies that demonstrate significant savings of energy and running costs are readily available from IDM

Compressed air usage

• Consider alternatives to compressed air for example by switching silo aeration from compressed air to blowers
• Consider systems that require a lower usage of compressed air or example by switching time controlled bag filter pulsing to differential pressure pulsing
• Manage air leakages; a good system should not leak more than 5% of the compressor capacity. Bad systems lose over 20% to leaks
• Discourage misuse of compressed air in the plant, e.g., for cooling or cleaning purposes
• Only run compressors during the time of the day when the compressed air is needed

For more detail, please refer to the Eskom IDM brochure on improving the energy efficiency of industrial compressed air systems.

6.6. Lighting

Lighting is one of the technologies perceived as minute when it comes to energy savings, especially in the industrial sector. However, it does constitute significant electrical load. The power consumed by industrial lighting generally varies between 2-10% of the total power; while at a cement plant this would be at lower end of the scale.

Energy savings are not only achieved from merely retrofitting from one lighting system to another, but also from the intuitive understanding of all lighting requirements and the analysis of inefficiencies of the old lighting system.

Every aspect of an operation must be lit with quality illumination, much of it for many hours of the day.

Lighting audits show that much light is wasted, and that large amounts of energy can be saved by applying scientific rules and energy efficient behaviours.

Specifications for lighting

• Lighting is divided into two main categories, namely interior and exterior lighting. Within both categories there are level specifications (SABS standards and OHS Act specifications on lighting), these specifications vary depending on the activities undertaken and the work environment
• A luminaire for a hazardous location (such as explosive locations) needs to be correctly selected and installed when doing a retrofit. It needs to be flameproof or of non-sparking specification standard design depending on the area classification
• Industrial lighting in production plants also include floodlighting which must also conform to legal and the area classification requirements
• Industrial sectors are required by law to install emergency lighting along the exits and escape routes

Energy efficient lighting operation

• Ensure that lights in unoccupied and naturally lit areas are switched off. Operating switches can be done by automatic controls including photo cells, occupation sensors and time switches
• Replace non-functioning lights in areas that are modified and reorganised
• Electronic Control Gear (ECG) versus Magnetic Control Gear (MCG): ECG consumes less energy when compared to MCG; by retrofitting MCGs with ECGs, significant energy savings can be achieved on the ballast operation alone

Maintenance for lighting

• The type of lamp reflector used determines the light beam characteristics and therefore affects light output. If not properly maintained, the reflector can affect the required lux levels
• Lighting systems need to be maintained regularly, especially in environments where there is dust, chemically aggressive gases or vapour
• Light diffusers need to be cleaned properly to improve light output levels and hence efficacy. This point is especially relevant in a cement plant with the existing levels of ambient dust

This frequently overlooked technology provides ample savings for comparatively little investment.

7. Additional technologies showing potential for savings

The following list of technologies can also be considered for the reduction of electricity used at a cement plant, and while they each do not necessarily offer large savings potentials it is useful to know these potentials exist:

7.1 Improved quarry blasting techniques

• The use of electronic detonators instead of pyrotechnic detonators has been proven to save 5% energy in excavation, 1% in rock transportation due to reduced idle times at the excavation stage, and 10% electricity in the primary crushing section in one trial (Biodeau et al, 2008). This is because the higher accuracy of electronic detonators contributes to a reduction of run-of-mine rock size distribution of about 15%. These detonators are more expensive but increases in productivity commonly outweigh these costs (Botes, 2001; Ricco, 2005; McFerren & Moodley, 2008, Pritchard, 2008)
• Blast management software can be implemented for the characterisation and modelling of blast fragmentation to improve energy efficiency. Savings of up to 10% in energy have been reported, but the costs of this technology may prove inhibitive for some operations (Meredith, 2005)
• Improvement in shot-rock yields and hence downstream energy efficiency have also been achieved by increasing blast hole diameter, using stemming plugs in the blast holes, increasing sub-drilling depth, using 3-D imaging to develop blast patterns (Moray et al, 2006)

7.2 Improved power quality and power factor

The efficiency and performance of distributed generation equipment is significantly impacted by power quality issues such as power factor, voltage drop and harmonics. When power systems have purely resistive loads, the power is called real power which is measured in watts. Systems with inductive loads that require magnetic fields to operate (i.e., motors) have reactive power present which is measured in Volt-Amperes-reactive or VArS.

The ratio of true power to apparent power delivered to an AC circuit is called the Power Factor (PF), which is equal to kW/kVA. If the power factor is low (less than one) the current draw from the utility (or generator) will be higher than necessary resulting in excessive line losses and inefficiencies.

Capacitors are commonly used to correct or raise the power factor by providing VArS, counteracting inductance. Dynamic Reactive Power Compensation Systems correct both power factor and improve power quality at distributed generation installations. Dynamic compensation systems help stabilise voltage and current fluctuations caused by power system/load interactions. These disturbances arise due to loads such as variable speed drives, welding machines or large motor starting. (Impact Energy, 2011).
Improved Electrical System Capacity

- Capacitors in a facility produce reactive energy that motors require to produce magnetising current for induction motors and transformers. This reduces the overall current needed from the power supply. This translates into reduced loads on both transformers and feeder circuits. Reduced loads on transformers can have a variety of positive impacts that include but are not limited to: less maintenance, reduced breaker trips, and higher full-load capacity.

Improved Voltage Levels

- Low voltage may be caused by a lack of reactive power. Additionally, voltage drops are often caused by dynamic load changes. In both cases, the effects can be harmful. In facilities with motors, low voltage situations reduce motor efficiency and can cause overheating. Interference may be introduced by low voltage in lighting and other electrical instruments (e.g., computers). Real-time capacitor systems have the capability of providing fast compensation to a dynamic load that cannot typically be seen by other conventional capacitor banks. It can help to raise and stabilise voltage across a facility by providing reactive power, thus improving overall production.

Reduced Line Losses & Waste Heat Recovery

- Differences exist between DC resistances of various conducting elements and actual “apparent” AC resistances of those same elements. There are many different phenomena present in electrical systems, which, when combined, can create substantial energy losses. Reducing the current used in a facility as well as properly minimizing harmonics can have a significant effect on reducing line losses. Capacitors can help a system by supplying kVAR as needed, therefore reducing line currents. However, extreme care should be taken when installing capacitors as it is quite possible to increase harmonics by installing capacitors. Installed capacitor systems ought to have tuned filters to reduce the effects of harmonics and resonance.

7.3 Co-generation

- The waste gasses discharged from the kiln preheater and the clinker cooler system (in grate cooler systems only) contain useful energy that can be converted into electricity.
- Investment and maintenance costs of such systems need to be carefully considered since the applicable co-generation technology is not viable in all kiln setups.
- Self generation of 20% or more of a cement plant’s electricity requirements via co-generation can be expected.

7.4 Solar Water Heating

- A number of cement plants have company villages for its staff right next to the plants, drawing power on the plants’ accounts. There is often great potential for Solar Water Heating systems to be retrofitted to the houses, thereby reducing the plant’s electricity bill.

8. Net electricity savings resulting from changing product and feedstock

Historically cement had been produced by milling a blend of clinker and gypsum into fine cement powder. This cement was called OPC (Ordinary Portland Cement). The problem with using high proportions of clinker in cement is that clinker is very energy intensive to produce. Hence the final cement produced required excessive electricity and coal to produce. The cement industry identified by-products from other industries that have cementitious properties and decided to introduce these alternative materials into its cements in a highly controlled and monitored fashion. These alternative materials are called cement extenders; they are beneficial to the production of cement due to their mineral characteristics. Extenders are accepted worldwide and include: ground granulated blast furnace slag, power station pulverised fly ash, silica fume (from ferrosilicon production) and limestone (from limestone quarrying) (Volek, 2009).

Cement produced from these components often actually has other benefits, improving the quality of cement over OPC. The SABS has included the use of extenders in the cement specifications and blend limits are prescribed to best ensure a good quality product is manufactured.

Ground Granulated Blastfurnace Slag (GGBS)

GGBS is produced from a by-product from the steel smelting industry. Slag is taken from the waste stream of large steel works like the Arcelor-Mittal plants in Vanderbijlpark, Newcastle and Saldanha Bay. This slag is then dried, milled fine and blended in with OPC, for example. Without any further thermal processing GGBS itself already is a latent hydraulic binder. The preparation of GGBS for use in cement requires on average approximately half as much electricity as Ordinary Portland Cement (depending on required fineness). This means that blending GGBS with OPC to form a new cement type is definitely beneficial to the net electrical consumption per ton of final product.
Pulverised Fly Ash (PFA)

Fly ash is generated from the combustion of coal, for example, at Eskom’s coal fired power stations. This fine ash dust is captured by electrostatic precipitators before it can be released out the chimney along with the exhaust gases. From the electrostatic precipitators, the ash of varying size fractions is then normally conveyed to a land fill site. Now, instead of land filling the fly ash, a portion of the ash can actually be processed into a more acceptable range of sizing for cement production. The first method of “processing” is classification and is necessary because as the fly ash comes out of the precipitator, the fly ash has a very wide and variable particle size distribution. Due to the strict quality specifications of cement all the raw materials going into cement also need to be strictly controlled. Classification is normally done by an independent company and after classification the fly ash is ready to be blended in with cement. Another option of “processing” is in a closed circuit milling system where coarse fly ash particles are ground finer in the cement mill together with the other cement components.

![Figure 7. Electricity Consumption Comparison](image1)

Fly ash is a pozzolan that closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. A pozzolan is a siliceous or siliceous/aluminous material that, when mixed with lime and water, forms a cementitious compound. Fly ash is the best known, and one of the most commonly used, pozzolans in the world. Fly ash is a fine, glass powder and these micron-sized earth elements consist primarily of silica, alumina and iron.

![Figure 8. Electricity Consumption Comparison](image2)
Fly ash particles are much finer to start off with than slag for example and much less electricity is required for the processing of fly ash. In fact fly ash processing requires less than 5% of the electricity required for Ordinary Portland Cement as a rule of thumb. This means that adding fly ash to OPC to form a new cement type is extremely beneficial to the net electrical consumption per ton of final product.

Silica Fume

Silica fume is a by-product of silicon and ferro-silicon alloy production. Silica fume (also called microsilica) is produced in a submerged arc furnace. The charge comprises of quartz, mlscale, wood chips and coal. In the burning zone, the charge is reduced to a ferro-silicon alloy at a temperature of about 2000 Celsius. At the same time the fume, or smoke, that is produced converts from mainly silicon oxide to silicon dioxide. The particles are extremely fine, reactive and amorphous and these are the qualities that are good in cement. Like fly ash, silica fume can be termed a synthetic pozzolan. Pozzolans are materials that have reactive amorphous silica as a component of their make-up. Silica fume is a specialty extender that is actually only used in unique concrete applications due to its properties. It is not a large scale extender like GGBS or fly ash, but needs mentioning nevertheless, seeing that its addition reduces the specific electricity consumption almost as much as fly ash does.

Limestone

Another extender that is gaining popularity is limestone itself. While it does not exhibit the same strength properties as OPC, limestone does indeed operate as more than just a filler in cement. Limestone has been found to improve the workability of cement thereby reducing the water requirement of a concrete mix. Also generally speaking the less water you need to add to a concrete mix, the better the strength.

Limestone is normally blended in with OPC during the milling of clinker. Crushed limestone is drawn from the quarry and interground with clinker & gypsum to form a limestone cement. While limestone is much softer than clinker itself, it nevertheless requires some milling energy to reduce the particle sizing to that required for cement.

Milling trials seem to show that the reduction in electrical energy consumption relative to OPC corresponds directly to the level of limestone addition, i.e., a 10% addition of limestone to OPC results in a 10% reduction in kWh/t in the final milling section. Naturally it greatly depends on the cement type that is being aimed for, i.e., 32.5 or 42.5 MPa, but this rule of thumb gives one a rough idea of the relationship of power consumption. The great benefit however is that limestone needs much less electricity to prepare for the final milling stage when compared to clinker. Limestone only needs to be crushed in preparation, while clinker needs to go through the whole manufacturing process from quarry through raw milling to kiln burning. The preparation of limestone draws about 5% of the electricity that is required for clinker.

To summarise, the use of extenders allows cement producers to effectively produce a cement that needs less electricity to get it to its final state. What needs to be remembered is that the introduction of an extender in effect increases the production capacity of a cement plant. In a situation of stagnant sales demand, it would mean that with higher extension less clinker would be required and that the cement plant as a whole would consume less electricity in relative as well as in absolute terms, i.e., the electricity required to produce each bag of cement would be lower, and the power demand on the grid would be lower too since the clinker manufacturing equipment would stand idle for longer.
On the other hand in a growing cement market, the introduction of an extender would allow the cement plant to sell more cement and inevitably a situation would arise when the absolute consumption of the cement plant would be higher than before, increasing the demand on the grid. This would be counter the drive of Eskom’s IDM department of reducing the absolute demand on the grid. It should thus be noted that extender efficiency projects needing the assistance of IDM, will be studied on a case by case basis taking growth effects into consideration.

9. Load management at a cement plant

In addition to there being a number of energy savings initiatives that can be implemented at a cement plant, the design and standard layout of a cement plant lends itself to various load management possibilities. As can be seen from Figure 1, there are five main steps in the process of cement manufacturing. What is important to note is that between these process steps there are normally intermediate stocks of material. These process buffers are either stockpiles, or silos storing intermediate products.

Step 1: Quarrying

The limestone quarry, with the primary crusher being the major electrical unit, is most commonly run during the day to build up raw material component stockpiles. This means that relative to the kiln, the primary crusher has a higher relative production capacity. For purposes of maximum demand it is important for the plant to know when the primary crusher is starting up. Depending on the raw material requirements and the level of the crushed limestone stockpiles, the run time of the crusher can be adjusted/shifted to cater for load management situations.

Step 2: Raw Material Preparation

The raw mill is the primary unit in this department. The raw components including limestone are brought in from the stockpiles to be milled finer in the raw mill. The milled raw meal is then transported to a silo for intermediary storage. The raw mill is also normally designed with a spare capacity relative to the kiln output of at least 15%. This extra capacity determines the run time per day of the raw mill to ensure that the kiln does not stop because of the lack of raw meal. Similar to the primary crusher as mentioned before, for purposes of Maximum Demand it is important for the plant to know when the raw mill is starting up. Depending on the raw meal requirements and the level of the raw meal silo, the run time of the raw mill can also be adjusted/shifted to cater for load management situations.

Step 3: Clinker Manufacture

Of the process steps the clinkerisation step (i.e., kiln burning) is the only process that is continuous, i.e., 24/7. The kiln needs system to run stably for extended run periods. Periods of intermittent kiln stops place unnecessary stresses on the kiln refractories, and kiln cool downs and warm ups and can result in extremely costly premature refractory failures. Ideally the kiln is shut down once a year for five or so weeks to repair the old refractories and then it is expected to run continuously for the rest of the time with few unplanned stops. Thus no load management is possible in the kiln section. The intermediary product from the kiln is called clinker and this material is normally stockpiled in silos or sheds. Often the fuel preparation department is bundled into the definition of the Clinker Department. Fuel preparation commonly includes a small coal mill which normally does have some spare capacity with very limited load management potential.

Step 4: Cement Milling

The cement mills extract clinker from the storage and, along with additional cement components, mill this material finer into the final product, i.e., cement powder. The cement powder is stored in various silos depending on product type. The cement mill is normally designed with spare capacity relative to the kiln, allowing for a similar load management potential as the raw mill.

Step 5: Packing and Dispatch

In this department the cement is withdrawn from the silos and either transported directly to bulk tankers for delivery to clients, or to packing machines that bag the cement. There is no single large electrical unit in this section, and while the packing plant capacity is normally also sized with excess capacity, little load management potential exists here.
Cement production equipment generally has a poor turn down ratio, meaning that major equipment is either run at its standard output or it is switched off. In summary, the design spare capacities of the primary crusher, raw mill and cement mill normally allow for load management to a various degrees. A key point to remember is that equipment positioned before the clinker section needs to run in such a fashion as to ensure the kiln has a supply of raw materials as it needs it, i.e., the raw mill and/or crusher cannot be stopped for load management if the kiln has a limited supply of feed material. Also if the raw mill and cement mills are already standing, for example for scheduled stops, limited further load management is possible.

<table>
<thead>
<tr>
<th>Department</th>
<th>Run Time</th>
<th>Load Management Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarry</td>
<td>Day shift</td>
<td>✓</td>
</tr>
<tr>
<td>Raw Milling</td>
<td>Non-continuous, standing time depending on extra capacity</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Clinker</td>
<td>Continuous</td>
<td>X</td>
</tr>
<tr>
<td>Cement Milling</td>
<td>Non-continuous, standing time depending on extra capacity</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Packing &amp; Dispatch</td>
<td>Day shift</td>
<td>✓ X</td>
</tr>
</tbody>
</table>

Figure 9. Typical plant department load management potentials

Cement production equipment generally has a poor turn down ratio, meaning that major equipment is either run at its standard output or it is switched off. In summary, the design spare capacities of the primary crusher, raw mill and cement mill normally allow for load management to a various degrees. A key point to remember is that equipment positioned before the clinker section needs to run in such a fashion as to ensure the kiln has a supply of raw materials as it needs it, i.e., the raw mill and/or crusher cannot be stopped for load management if the kiln has a limited supply of feed material. Also if the raw mill and cement mills are already standing, for example for scheduled stops, limited further load management is possible.

10. Eskom’s energy advice

Advice on the many techniques and technologies that are available for the purpose of saving energy can be obtained from consultants or Eskom energy advisors. Interested persons can call the Eskom Contact Centre on 08600 ESKOM (08600 37566) and log a query for an energy adviser in their area to contact them, or visit www.eskom.co.za/idm for more information.

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