Analysing the effect of DSM projects at South African cement factories

JP Spangenberg
20790902

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Supervisor: Dr JF van Rensburg

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1. Abstract

Title:	Analysing the effect of DSM projects at South African cement factories
Author:	Mr. J.P. Spangenberg
Supervisor:	Dr. J. F. van Rensburg
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In any developing country an increasingly higher demand for electricity supply exists. South Africa experienced load shedding during late 2007 and early 2008 and again in 2014 due to a supply shortfall. New power stations are being built to increase the capacity of the national power grid. However this is a lengthy process.

Demand Side Management (DSM) was adopted by Eskom's Integrated Demand Management (IDM) division. DSM is a short-term solution to stabilise the national grid in South Africa by managing the electricity demand on the consumer's or client's side. DSM aims to reduce the electricity consumption with immediate results in the short-term.

DSM projects were successfully implemented at nine South African cement factories since 2012. Cement factories are ideal for the implementation of DSM projects for the following reasons: cement factories are energy intensive; have adequate reserve production capacity; sufficient storage capacity and interruptible production schedules.

The aim of this study is to analyse the effect of DSM projects at South African cement factories. A detailed understanding of the cement production process is a prerequisite. Therefore a critical review of energy utilisation in the cement industry was conducted. Previous work done in the cement production field is evaluated to identify the possible literature shortfall on DSM projects.

A set of five distinctive parameters was derived from the literature survey to quantify the possible effects of DSM projects at cement factories. The parameters are demand reduction and electricity cost; production targets; infrastructure; product quality and sustainability.

One cement factory, Factory #1, was selected as a primary case study for the analysis model. Factory #1 was used to determine and quantify the effects of DSM projects at cement factories. A simulation was developed to verify the analysis model outcome. DSM projects were implemented at various factories in South Africa and the results from nine sites were used to validate the aim of this study.

The study concluded that most DSM projects at South African cement factories were sustainable. Both the electricity supplier and the factories benefitted from the projects. The funding received from Eskom to implement DSM projects is a short-term initiative. However, sustainability of DSM projects is made possible in the long-term by the substantial electricity cost savings on the client's or factory's side.

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3. Table of contents

4. List of figures

5. List of tables

6. List of abbreviations

c/kWh	Cent per kilowatt-hour
CPI	Consumer Price Index
DSM	Demand Side Management
EMS	Energy Management System
ESCo	Energy Services Company
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ/t	Gigajoule per tonne
GJ/year	Gigajoule per year
IDM	Integrated Demand Management
IEA	International Energy Agency
IRP	Integrated Resource Plan
kT	kilotonnes
kWh	Kilowatt-hour
MT	Megatonnes
MWh	Megawatt-hour
MYPD	Multi-Year Price Determination
NERSA	National Energy Regulator of South Africa
PA	Performance Assessment
PT	Performance Tracking
PTB	Process Toolbox
REMS	Real-time Energy Management System
SEC	Specific Energy Consumption
t/h	Tonne per hour
TOU	Time-Of-Use
VRM	Vertical Roller Mill

1. Introduction

Chapter 1 provides an introduction to the study. This includes an overview of the global electrical consumption and economic growth. It emphasises the importance of sustainable energy conservation. The reader is made aware of the national electricity situation in South Africa and DSM techniques are discussed in brief. Lastly, Chapter 1 states the aim and the scope of this study.
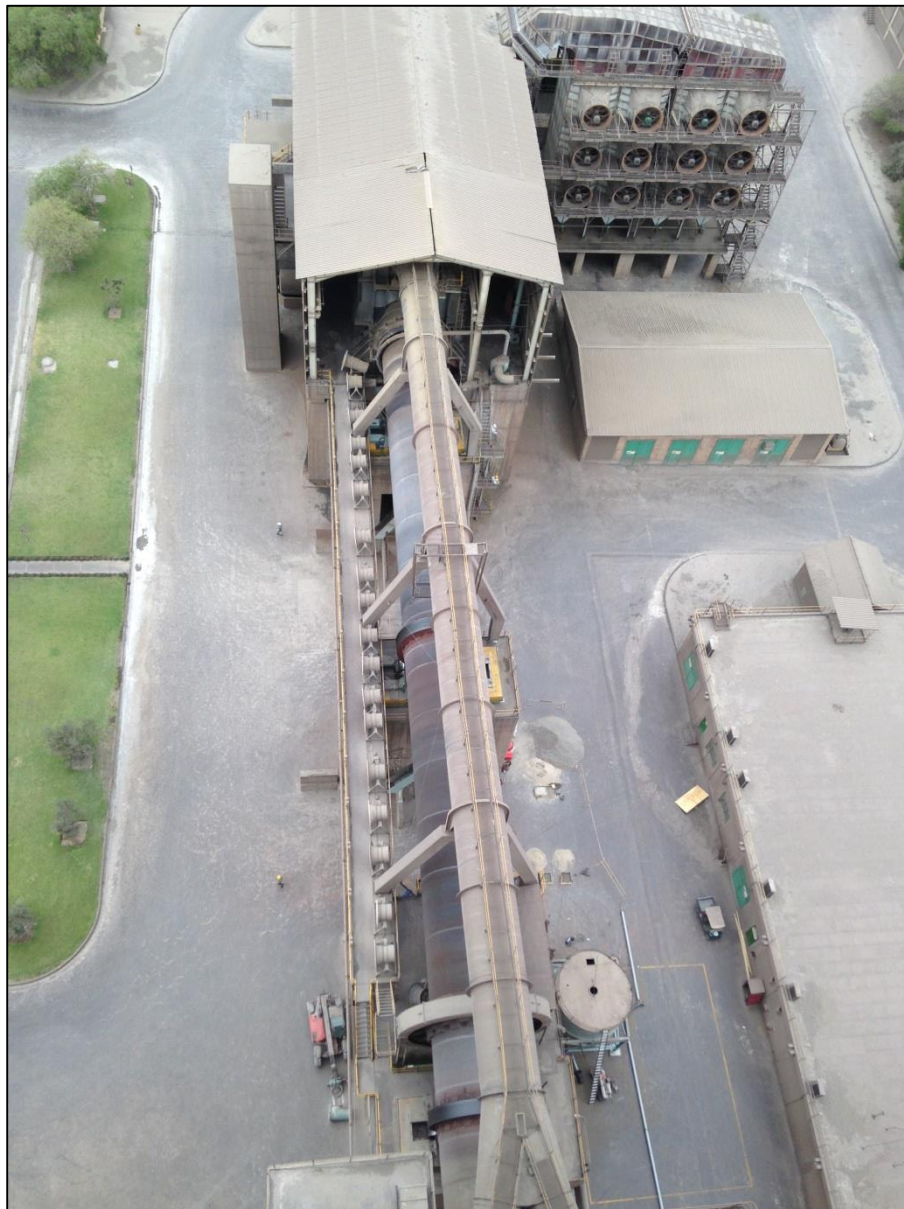
Bird's eye view photo of the kiln (centre) and cooler (top right) taken at Factory #1, courtesy of the author

1.1.   Background on the South African electricity supply and demand

The demand for electricity is growing at an alarming rate. The estimated total global demand increase for the years 2010 to 2030 is 33% [1]. Africa follows the global energy trend, with South Africa consuming 43% of the continent's electrical energy [2], [3]. South Africa is a developing country consuming vast amounts of energy.

Since 1994, South Africa experienced a significant increase in electricity consumption. During this time focus was placed on economic growth, developing previously disadvantaged communities and job creation [4], [5]. Research suggests that South Africa's economy is heavily dependent on the energy sector which accounts for 15% of the Gross Domestic Product (GDP) [6].

In 2007 the electricity demand came dangerously close to the supply capacity. This resulted in load shedding interventions from Eskom to stabilise the national supply grid [7]. The same scenario occurred in 2014 and 2015 [8].

New power stations are being built in an attempt to meet the increasing demand. Unfortunately, there are time constraints involved. New builds, Medupi and Kusile, were expected to supply the grid by 2013 and 2014 respectively. This followed approval for construction in 2007 and 2008 by Eskom's board [8]–[10].

Eskom announced that Medupi is expected to supply stable commercial base load power from mid-2015. This is when the first of six units will be synchronised with the grid. Medupi is expected to reach the final completion stage during 2018 and Kusile during 2019 [9]–[11].

The supply capacity must be adequately managed ensuring sufficient availability when the demand peaks [11]. The reserve margin is the difference between the present supply capacity and the electricity demand. The increasing electricity demand will eventually match the supply capacity of the national power grid [12].

According to the Integrated Resource Plan (IRP) of 2010 new generating capacity of 45 228 MW will need to be developed [13]. This is over and above Eskom's current capacity expansion programme. The present generation capacity of Eskom is 41 194 MW. The capacity expansion programme will increase the national supply capacity by 17 120 MW by 2018 [14]. This increase of 42% will bring much needed stability to the national power grid.

Eskom's tariffs are adjusted on an annual basis. Figure 1 shows the cumulative percentage increase in Eskom's average tariff price and South Africa's Consumer Price Index (CPI) for the past 15 years [15].The Department of Minerals and Energy released a White Paper in 1998 which predicted the supply shortfall that occurred in 2007 [16]. The failure to plan accordingly, urgent need for expansion and accompanying supply shortages needed to be provided for in the tariffs. Therefore the spike in tariff increases above the CPI was justified.
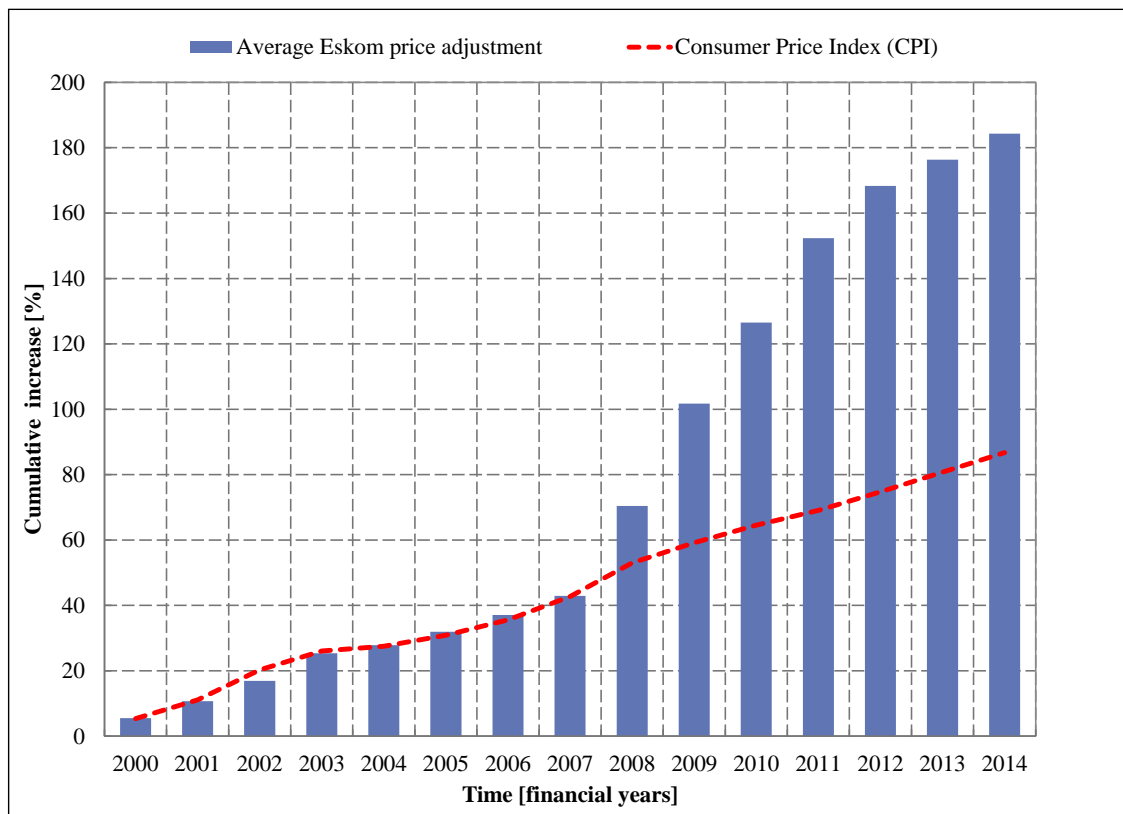
Figure 1: Cumulative Eskom tariff increase vs CPI

In order for a country to sustain economic growth, adequate resources must be readily available. Electricity is a valuable resource without which a country cannot advance competitively in the global market [17]. The supply side capacity will be increased through the new build program. In the meantime, alternative solutions need to be applied urgently to ensure an adequate reserve margin of electricity on the national power grid.

One of these solutions is Demand Side Management (DSM) through Eskom's Integrated Demand Management (IDM) initiative. The International Energy Agency (IEA) found that DSM is more cost effective than conventional short-term supply side initiatives [18]. Findings from the IEA support the existence and importance of the South African DSM program.

Eskom's IDM department is responsible for funding various methods of DSM. Effective management of demand side consumption will ensure a more stable grid for a longer time period and introduce a new cost reducing component for clients in the increasingly competitive cement market.

1.2.   Demand Side Management techniques

The sustainability of energy resources is an increasing global concern [1], [19]. The effective management of electrical energy consumption is crucial within any energy intensive industry. Sustainable energy management is on the forefront of discussion in many countries [20].

The Millennium Development Goals (MDGs) is a United Nations initiative and one of its goals is to ensure environmental sustainability. This is done by integrating the principles of sustainable development into country policies and programmes. DSM is an incentive assisting Eskom in fulfilling its constitutional obligations as set out by the MDGs [21]. The DSM initiative promotes sustainable usage of energy resources in South Africa by reducing the electricity demand.

Figure 2 shows three distinct load profile trends that graphically describe the effect of DSM on the power consumption. These profiles are classified as a) energy efficiency, b) load shift and c) peak clip. These three methods are globally used in DSM initiatives and were adopted by Eskom through the IDM programme.
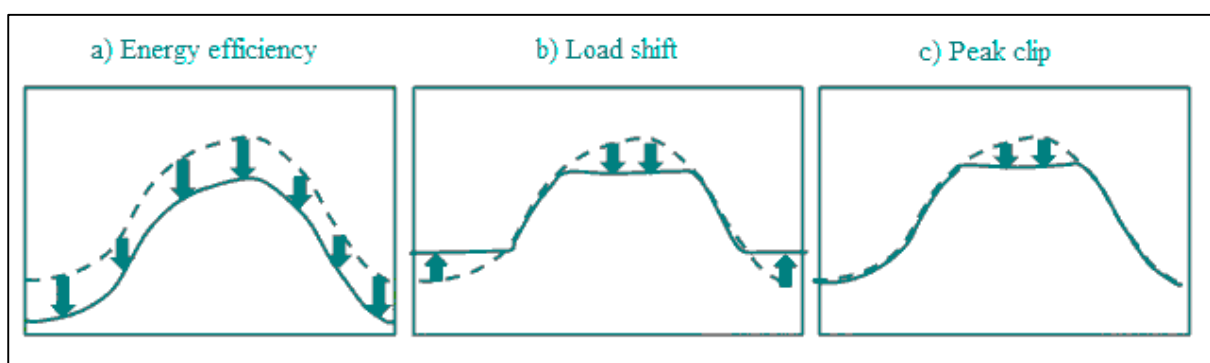
Figure 2: Illustration of various DSM interventions

Energy efficiency is achieved by reducing the electrical input while maintaining the same operational output. Peak clip is best described by an intervention that reduces the electrical input and the operational output for a given peak period in the demand. Load shift aims to

reduce peak load and shift the reduced load into other periods. In the case of energy efficiency and load shift there is no nett effect on the output. Section 2.3 shows that this is very feasible in the cement industry.

1.3.   Possible effects of DSM projects

The energy consumption cost in the cement industry accounts for 50% to 60% of the overall production costs [22]. Thus the opportunity to investigate DSM projects on cement factories was justified. [23], [24].

The cement industry can benefit from implementing electricity cost savings strategies. The typical electricity consumption of a modern cement factory is about 105 – 120 kWh per tonne of cement produced [25]–[27]. The electricity costs associated with cement production, especially after the recent tariff increases, justified the need to investigate the possibility of DMS projects at South African cement factories.

Eskom implements Time Of Use (TOU) tariff structures to promote DSM initiatives. This allows industrial consumers to manage their electricity consumption accordingly to realise maximum cost savings. Cement factories, like most large industrial consumers, can benefit from the various TOU tariff structures and reduce costs. This study will focus on factories that utilise the Eskom Megaflex tariff structure (described in section 2.5).

The advantages of DSM projects are twofold. The demand during the evening peak is reduced which brings much needed relief to the supply side. Additionally the client receives electricity cost savings due to load management practices. Eskom DSM projects are dependent on the client's cooperation to ensure sustainability. The client's best interests are of utmost importance to ensure seamless cooperation.

The energy intensity, adequate reserve production capacity, sufficient storage capacity, interruptible production schedules and a competitive cement market justify the need to develop Energy Management Systems (EMS) specifically for cement factories. Successful implementation of EMS and long-term effects thereof are crucial in determining the feasibility of DSM projects. Sustained peak demand reduction throughout the project lifecycle is required to motivate Eskom funding for similar DSM projects. Therefore a need exists to analyse the possible effects of DSM projects at cement factories.

1.4.   Aim of the study

Various studies on implementing DSM projects in the cement industry have been carried out. To date nine DSM projects were implemented on South African cement factories from 2012. The literature review pointed out that five categories are possibly affected by DSM projects. These categories are demand reduction and electricity cost savings, production, equipment, quality and sustainability. This study aims to analyse these effects of DSM projects at South African cement factories within the five categories described below:

Category 1 – Demand reduction and electricity cost savings:

There exists a need to identify and address the different stakeholder's impacts and benefits. The utility, Eskom, needs to see results in terms of peak demand reduction, whereas the client or factory requires results in terms of electricity cost savings.

> **Aim 1: Analyse the long-term evening peak demand reduction and electricity cost saving**

Category 2 – Effect on production:

Simulations and pilot studies have shown that load shift did not affect the daily sales and production targets. The pilot studies were done on single components with adjoining silos in the production line [23], [28], [29]. A need exists to determine and quantify the effect of load shift on various components of the entire production line over a long time period.

> **Aim 2: Analyse the long-term effect of DSM projects on production**

Category 3 – Impact on cement production equipment:

Infrastructure upgrades that automate and monitor the system can improve the total life cycle of the equipment. Whereas altering the operational philosophy and production schedule might decrease the total lifespan and efficiency of components. This possible effect must be determined and quantified.

Aim 3: Analyse the long-term impact of DSM projects on cement production equipment

Category 4 – Effect on cement quality:

The grinding processes and clinker formation might be very sensitive to changes associated with DSM initiatives. This could have adverse effects on the product quality. This possible effect must be determined and quantified.

Aim 4: Analyse the long-term effect of DSM projects on cement quality

Category 5 – Sustainability:

The implementation and practical follow through of DSM projects could lead to widespread adoption if the benefits are substantial as well as sustainable. The long-term sustainability of these projects are analysed with data obtained after the implementation and handover occurred. The sustainability through awareness must be determined and quantified.

Aim 5: Analyse the sustainability of DSM projects at South African cement factories

1.5.   Scope of the study

The scope of this study entails the following:

Process: This study focusses solely on factories that use the dry process to produce cement. None of the DSM projects were implemented on wet process factories.

Energy source: Electricity is the only energy source analysed in this study. No coal, fuel, oil, natural gas or any other energy source was investigated because DSM is an *electricity* demand management initiative.

Components: Only milling and grinding components were investigated. The electrical motors of these components, together with the kiln drive motor, are the primary electricity consumers. The milling components formed the focus of the analysed DSM projects.

Implementation: Only load shift effects are analysed. The effects considered are due to changes in the electricity demand profile.

1.6. Dissertation overview

Chapter 1 provides an introduction to the study. This includes an overview of the global electrical consumption and economic growth. It emphasises the importance of sustainable energy conservation. The reader is made aware of the national electricity situation in South Africa and DSM techniques are discussed in brief. Lastly, Chapter 1 states the *aim* and the *scope* of this study.

Chapter 2 gives an overview of energy management in the cement industry. It starts with an introduction to the cement production process. A *critical review* of energy utilisation in the cement industry is conducted to determine the various technologies available to the industry. The *fundamental concepts* of cement industry components and infrastructure are discussed. Research carried out on previous DSM projects in the cement and other industries is reported. The gaps in the research field are identified and the *need for this study* is promulgated. Lastly, Chapter 2 investigates the TOU electricity cost structures of South Africa's power utility, Eskom.

Chapter 3 describes the *methodology* to *investigate* the possible effects of DSM projects at South African cement factories. The *research procedures* followed to *design* the analysis model is explained in the introduction to this chapter. The energy management system (EMS) and its functional purpose is described. An overview of the cement factory, Factory #1, and the simulation to *verify* the analysis model is given. The analysis model *designed* to *investigate* the *need for this study* is explained in depth. Finally, Chapter 3 ends with a *comprehensive design* to *validate* the analysis results of DSM effects at South African cement factories.

Chapter 4 discusses the long-term results obtained from the analysis of DSM effects at South African cement factories. The possible effects are analysed and discussed within the determined model categories which are demand reduction and electricity cost; production

targets; infrastructure; product quality; and sustainability. *Verification* of the analysis model is achieved by comparing the simulated and actual factory results. Furthermore, the outcome of the results clearly *validates* the initial *need for this study*. Lastly, Chapter 4 summarises the results obtained from the analysis of DSM effects at South African cement factories.

Chapter 5 provides the final *conclusion* to this study with findings on the effects of DSM projects at South African cement factories. *Validation* of the initial study aim is reiterated. *Recommendations* are discussed and the adoption of this analysis model in other industries is identified for possible future investigation.

2. Overview of energy management in the cement industry

Chapter 2 gives an overview of energy management in the cement industry. It starts with an introduction to the cement production process. A critical review of energy utilisation in the cement industry is conducted to determine the various technologies available to the industry. The fundamental concepts of cement industry components and infrastructure are discussed. Research carried out on previous DSM projects in the cement and other industries is reported. The gaps in the research field are identified and the need for this study is promulgated. Lastly, Chapter 2 investigates the TOU electricity cost structures of South Africa's power utility, Eskom.

Photo of the cement grinding process (front) and cement storage silos (back) taken at Factory # 1, courtesy of the author

2.1.   Introduction to cement production

The typical cement factory is a production line with buffers between the adjoining components. The buffers are huge silos with adequate storage capacity to allow for scheduling of subsequent components. The components have different production rates and can operate independently. The scheduling of the operational intervals of energy intensive components is the key factor in investigating DSM opportunities at cement factories.

The dry process is the market leader and the most energy efficient of all the cement production processes [24]. The dry process with major components is illustrated in Figure 3.
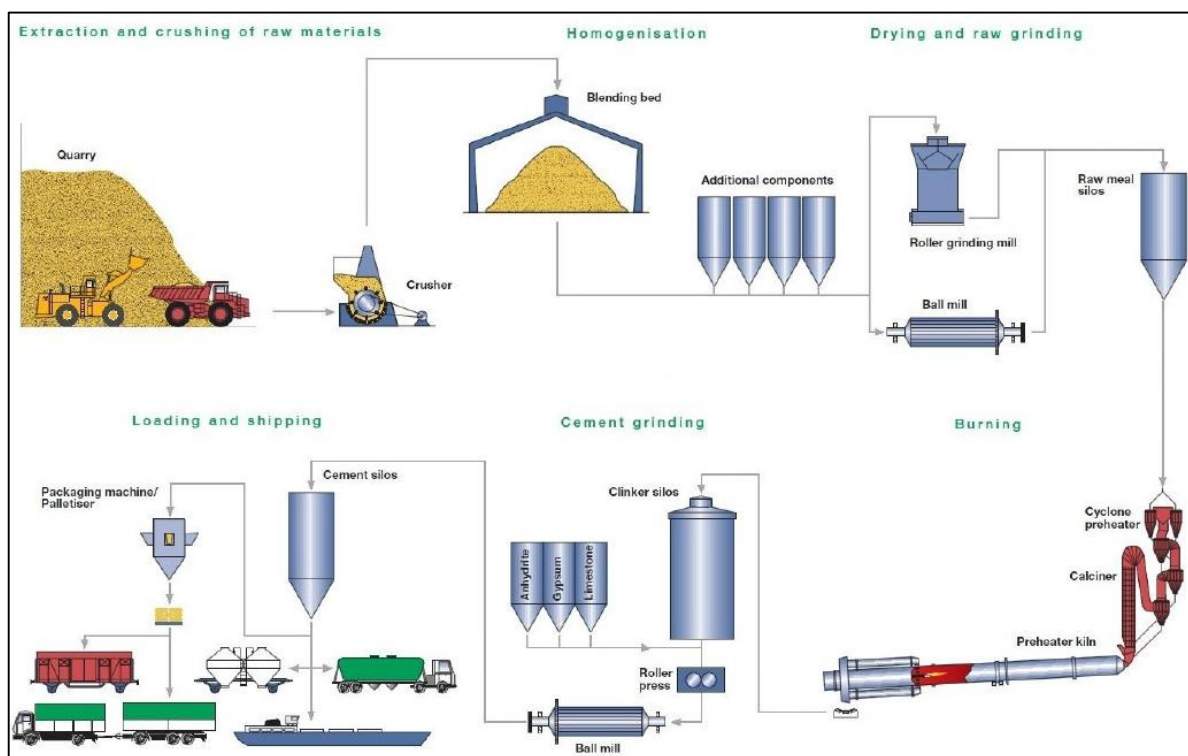
Figure 3: Layout of the dry process[1]

The factories in this study are equipped with a kiln and both raw and finishing mills. This improves the probability of sustainable savings. The reason is because it is not only the general supply and demand that will influence production, but also the conveying of material between the storage silos and the grinding mill.

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[1] Heidelberg Cement, *How cement is made.* [Online] Available at: http://www.heidelbergcement.com [Accessed 19 July 2013].

It is common that the production rate of the above mentioned components differ from each other. Given adequate storage between components, load shift becomes viable.

Figure 4 shows a flow chart of the cement production process. The section below describes each component of Figure 4. Note that each mill and the kiln have buffers on each side of the component respectively.
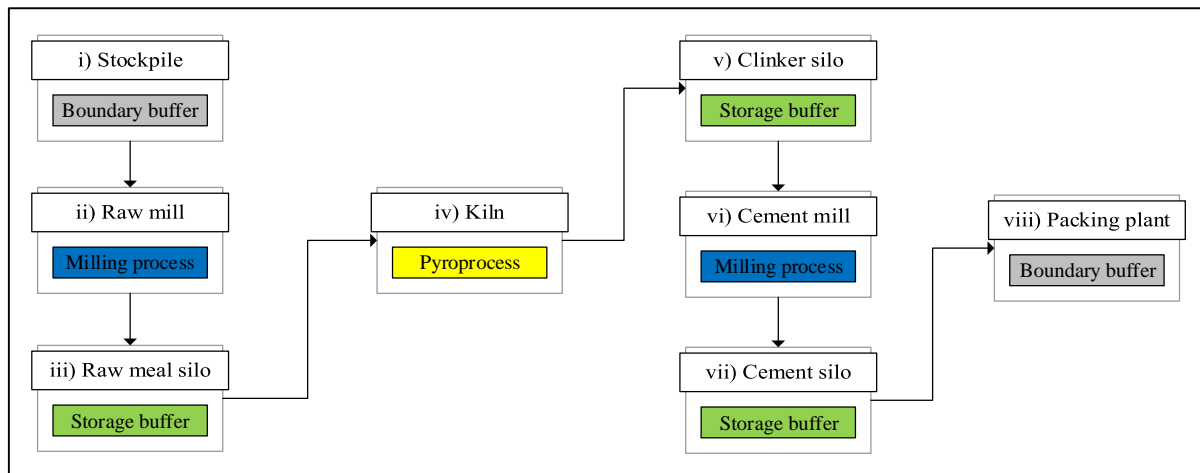
Figure 4: Basic flow chart of the cement production process

i)   Stockpile

The most important raw material for making cement is limestone. This is extracted from quarries by blasting or by ripping using heavy machinery. Wheel loaders and dumper trucks transport the raw material to the crushing installations. The crushers break the rock into pieces until the raw material reaches a specified size which allows easy conveying. The raw material is stored in the stockpile yard. Stackers and reclaimers are heavy machinery used in the stockpile yard. Stackers blend layers of raw material to build a homogenised pile. Reclaimers are used to quarry the raw materials layer by layer from the pile. The raw material is transported to the raw mill by conveyer-belt, cableway, railway or truck.

ii)   Raw mill

The raw material, together with other ingredients, is fed into the raw mill. The desired raw mix of crushed raw material and the additional components is prepared using metering devices. Vertical Roller Mills (VRM) or ball mills grind the mixture to a fine powder. Heat is applied

to the grinding process to dry the material. Once the material reaches the desired particle size, the newly formed raw meal is conveyed to the raw meal silos for further homogenisation.

iii)   Raw meal silo

The raw meal is stored in this silo after being ground. The raw meal silo level is kept above a specified level which allows for homogenisation of the raw meal as it is extracted. It is crucial that raw meal is always available and at a safe level for the kiln.

iv)   Kiln

The burning of the raw meal at approximately 1,450°C is carried out in Lepol or preheater kilns that operate on various methods, the main difference being in the preparation and preheating of the kiln feed. By chemical conversion, a process known as sintering, a new product, called clinker, is formed. This is a very sensitive process and the clinker quality is highly dependent on changes in the feed-rate and raw meal composition. In the final stage of the pyroprocess the clinker is cooled by large cooling grates which allow cold air to blow over the clinker. The cooled clinker is conveyed to the clinker silo.

v)   Clinker silo

The clinker volume inside this silo must be kept within the minimum and maximum thresholds. The next component has an interruptible running schedule and careful planning ensures that the production rate of the kiln is not influenced by this schedule.

vi)   Cement mill

From the clinker silo the material is conveyed to the finishing mills where it is ground down to very fine powder cement. Gypsum, anhydrite and other additives are added during the cement grinding process. The addition of additives allows the cement to have different properties. This is done to increase the strength, setting time or cost of the final cement product and is regulated by the general demand for cement with specific properties.

vii)   Cement mill silo

The finished products are stored in separate silos, classified by cement type and strength class. The majority of cement is usually loaded and transported in bulk via rail, road or ships.

viii)   Packing plant

Only a small proportion of the cement reaches the customer in the form of bags that have been filled by rotary packers and stacked by automatic palletising systems.

The basic composition of cement is given in Table 1 [26]. There are various types of cement depending on the intended use. The most common type of cement is Portland cement.

Table 1: Basic composition of cement

Elements	Composition
	[%]
CaO	65 ± 3
SiO_2	21 ± 2
Al_2O_3	5 ± 2
FeO_3	3 ± 1

Portland cement is made by heating limestone (calcium carbonate) and small quantities of other materials (such as clay) to 1 450°C in a kiln. At this temperature a chemical process known as calcination takes place. During calcination the calcium carbonate splits up into calcium oxide and carbon dioxide. The carbon dioxide is a by-product and naturally dissipates as a gas. The calcium oxide blends with the other materials inside the kiln to form clinker. Clinker is a hard substance which is grinded with the addition of gypsum, fly ash, lime and other raw materials into a powder to make Portland cement [30].

Portland cement is a basic ingredient of concrete, mortar and most non-speciality grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. Concrete can be cast in almost any shape desired and once hardened, can become the basic structural element in most construction applications [30].

There are various facilities in the cement industry. These facilities include production units, milling or blending factories and distribution depots. The production factories manufacture cement and clinker. The milling or blending factories buy clinker and, together with the correct amount of additives, produce different types of cement depending on the present demand [31].

Figure 5 shows the various cement facilities in the South African industry. The production units are labelled as yellow and the milling units are labelled red, each with the corresponding factory's name in the legend. The green labels show the various distribution depots throughout South-Africa. The distribution depots will not form part of this study, because no production of cement takes place there.
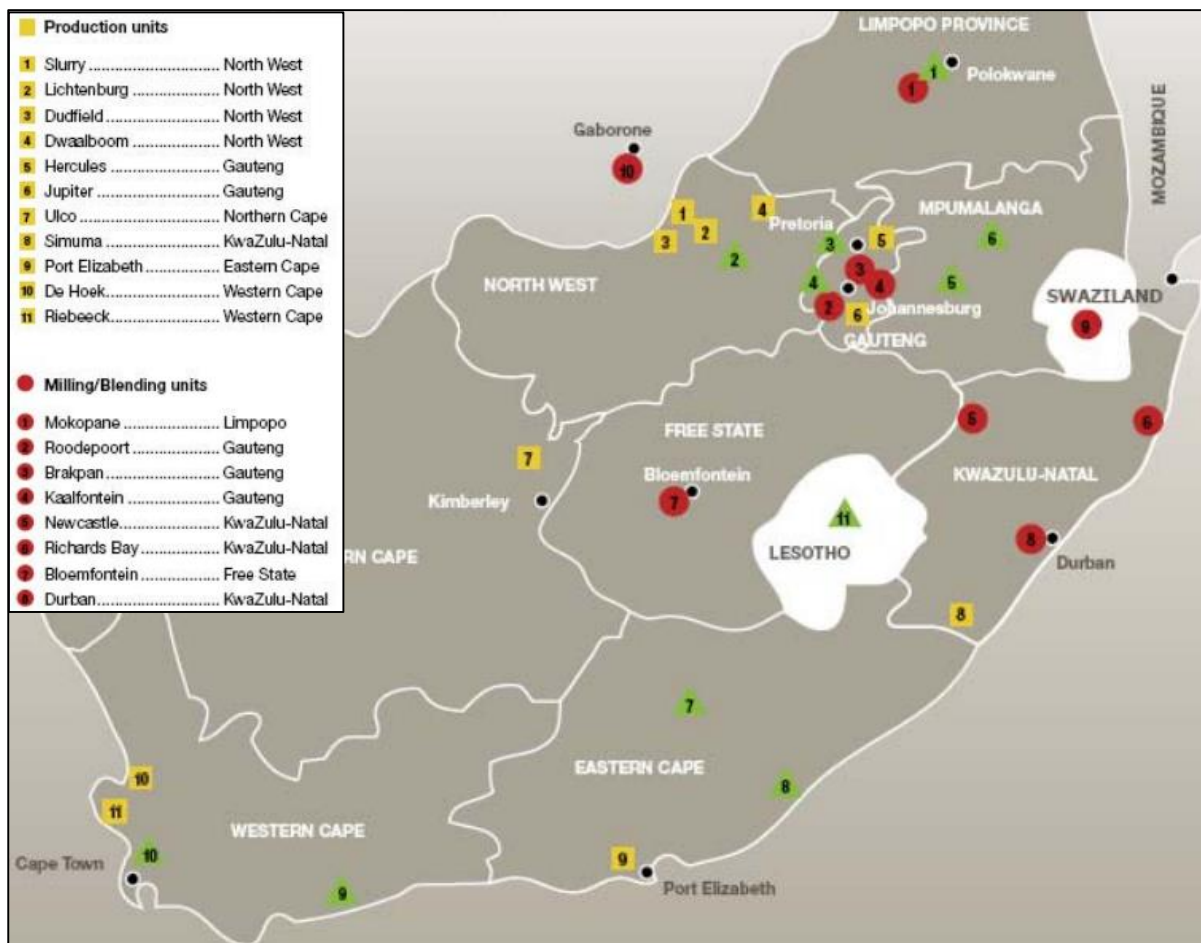
Figure 5: Geographical illustration of South African cement factories[2]

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[2] Adopted from J. Magliolo, "African Research: The Cement Industry," 2007. [Online]. Available: http://www.wealthportfolio.co.za/website/reports/African Research Cement Report 21-01-07.pdf. [Accessed: 12-Apr-2013].

Table 2 shows the global cement production statistics [32]. China is producing almost half of the global cement share. South Africa is producing less than 17% of the global share.

Table 2: Global cement production statistics

Sectors	Production	Share
	[MT/year]	[%]
China	1,064	47%
India	130	6%
United states	99	4%
Japan	66	3%
Korea	50	2%
Spain	48	2%
Russia	45	2%
Thailand	40	2%
Brazil	39	2%
Italy	38	2%
Turkey	38	2%
Indonesia	37	2%
Mexico	36	2%
Germany	32	1%
Iran	32	1%
Egypt	27	1%
Vietnam	27	1%
Saudi Arabia	24	1%
France	20	1%
South Africa	< 20	< 1%
Other (including South Africa)	392	17%
World total	2,284	100%

2.2.   Critical review of energy utilisation in the cement industry

Energy is needed in the industrial sector to produce valuable resources. One of the key resources in any developing country is cement. The world demand for cement was 2 836 million tonnes in 2010, with a growth rate of 4.7% per annum between 2005 and 2010 [26]. Between 12 – 15% of the global industrial sector's energy consumption is allocated to the cement production industry [26], [33].

The aim of this study is to analyse the effect of DSM projects at South African cement factories. This critical review focuses on energy costs associated with various processes and cost reduction methods within the cement industry. Recent spikes in electricity costs further motivate DSM initiatives on cement factories. The Specific Energy Consumption (SEC) is a benchmark indicator of industry intensity and efficiency.

Table 3 [32] shows the electrical and thermal SEC of a few selected countries around the world. The typical cement factory will have an electrical SEC of between 105 – 120 kWh/t [24]–[26]. The thermal SEC of a typical cement factory is between 3.5 – 4.2 GJ/t [34]. Variation energy consumption is mostly due to raw meal composition and different process efficiencies [32].

Table 3: Global comparison of electrical and thermal SEC of cement factories

Country	Electrical SEC	Thermal SEC
	[kWh/t]	[GJ/t]
India	88	3.0
Spain	92	3.5
Germany	100	3.5
Japan	100	3.5
Korea	102	3.7
Brazil	110	3.7
Italy	112	3.8
China	118	4.0
Mexico	118	4.2
South Africa	120	4.3
Canada	140	4.5
US	141	4.6
World best	65	2.7

India, Spain Germany, Japan and Korea have the lowest energy usage per unit of cement produced while Canada and USA are the most energy intensive. The world best cement

factory's SEC is 65 kWh/t electrical and 2.7 GJ/t thermal respectively. The South African cement factories used in this study have an average electrical SEC of 120 kWh/t [27]. The thermal SEC does not form part of the scope of this study as set out in section 1.5.

The energy intensity of the pyroprocess and the electrical energy of the grinding circuits account for a large portion of Greenhouse Gas (GHG) emissions [35]. The GHG emissions at cement factories are excluded from the scope of this study.

The average expenditure for a typical global cement factory is 29% on energy, 27% on raw materials, 32% on labour and 12% on depreciation [26] as seen in Figure 6. Thus, reducing the expenditure on energy will be of substantial benefit to the cement industry.
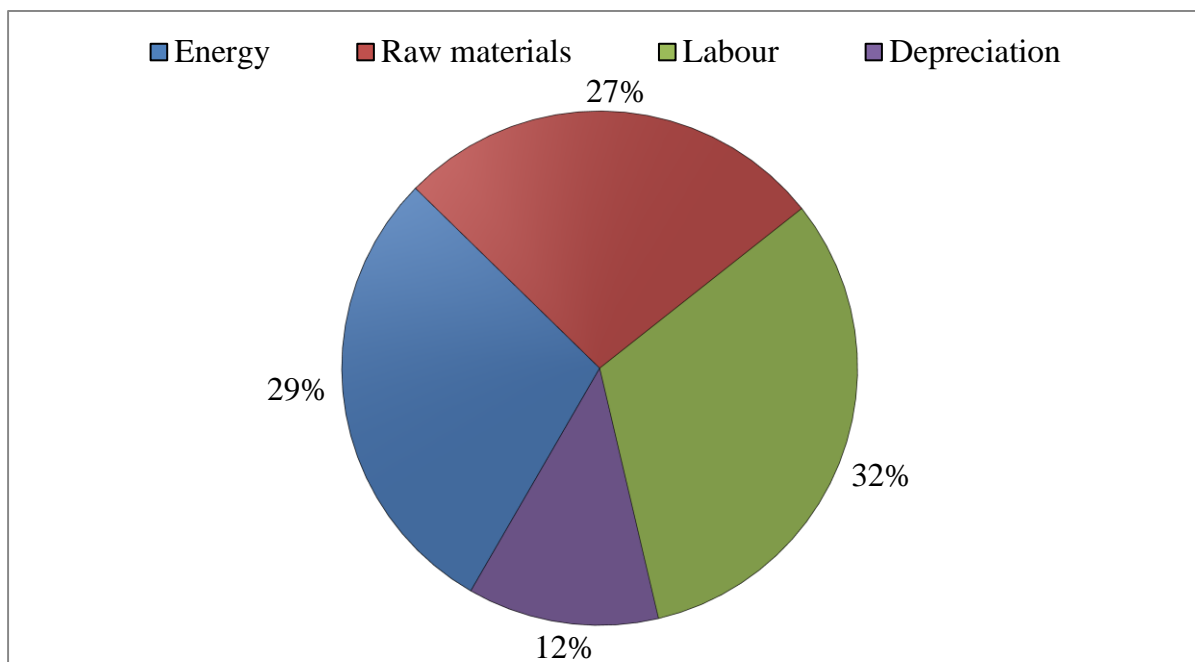
Figure 6: Breakdown of average expenditure of a typical global cement factory

Table 4 provides a critical review of SEC improvements and energy cost reduction interventions in the cement industry. The literature reviewed was divided into the basic production processes seen in the first column. A short description of each intervention is given with the electrical and thermal energy improvement per tonne cement produced.

Factory #1, the main cement factory researched in this study, has an average annual cement output of 1,2 million tonnes as calculated in Appendix D. The annualised electrical and thermal improvements due to possible energy savings interventions for Factory #1 were calculated and noted in Table 4.

Table 4: Critical review of SEC improvements in the cement industry

Process	Energy savings intervention	Electrical improvement	Thermal improvement	Annualised electrical improvement*	Annualised thermal improvement*	Reference
		[kWh/t]	[GJ/t]	[MWh/year]	[GJ/year]	
Raw materials preparation and grinding	Efficient transport systems	1.2 – 3.4	0.02 – 0.04	2 760	36 000	[36]–[40]
	Blending	1.0 – 4.3	0.01 – 0.03	3 180	24 000	[36]–[38], [41]–[44]
	Process control on vertical mills	0.8 – 1.7	0.01 – 0.02	1 500	18 000	[38]–[40]
	Use of roller mills	6.0 – 11.9	0.03 – 0.08	10 740	66 000	[36], [38]–[40]
	High efficiency separators	2.8 – 3.7	0.01 – 0.03	3 900	24 000	[36]–[40], [43], [45]
	Fuel preparation	0.7 – 10.0	-	6 420	-	[38]
Clinker production	Improved refractories	-	0.12 – 0.63	-	450 000	[38], [46]
	Energy and process control systems	2.4 – 2.5	0.10 – 0.20	2 940	180 000	[38]–[40], [43]
	VSD for kiln fan	0.6 – 6.1	0.05 – 0.07	4 020	72 000	[38]–[41], [47]
	Preheater/precalciner	-	0.16 – 0.43	-	366 000	[37]–[40], [48], [49]
	Multi-stage preheater	0.9	0.08 – 4.10	540	2 508 000	[36]–[40]
	Reciprocating grate cooler	-	0.19 – 0.30	-	294 000	[37], [38], [40], [50], [51]
	Kiln combustion system	-	0.10 – 0.24	-	204 000	[37], [38], [40], [46], [52], [53]
	Indirect firing	-	0.02	-	12 000	[38]
	Heat recovery	-	0.05 – 0.10	-	90 000	[36]–[40], [43], [54]
	Seal replacement	-	0.01	-	6 000	[38], [55]
	Low pressure drop cyclones	0.7 – 4.4	0.01 – 0.04	3 060	30 000	[37]–[41], [43], [54]
	Efficient kiln drives	0.6 – 3.9	-	2 700	-	[38]–[40], [56]
Finish grinding	Process control	3.2 – 4.2	0.04 – 0.05	4 440	54 000	[38]–[40], [57]–[59]
	Use of VRM	10.0 – 25.9	0.02 – 0.29	21 540	186 000	[38]–[40], [60], [61]
	High pressure roller press	8.0 – 28.0	0.03 – 0.31	21 600	204 000	[37]–[40], [43], [62], [63]
	Horizontal roller mill	-	0.10 – 0.30	-	240 000	[37], [63]
	High efficiency separators	1.6 – 7.0	0.01 – 0.30	5 160	240 000	[36]–[38], [40], [59], [64]
	Improved grinding media	1.8 – 6.1	0.02 – 0.10	4 740	72 000	[37]–[40], [43], [52]
General applications	High efficiency motors	3.0 – 25.0	0.02 – 0.31	16 800	198 000	[37]–[41], [43], [50]
	Variable speed drives	0.1 – 9.2	0.03 – 0.10	5 580	78 000	[37]–[39], [43]

* Values based on the average annual production of Factory #1

It was deducted from the critical review in Table 4 that various SEC improvement technologies exist within the global cement industry. Implementing some of these technologies and infrastructure has substantial electrical and thermal energy cost saving potential.

The technologies and infrastructure stated in Table 4 require the installation of new equipment and offer an average electrical energy saving of between 1 kWh and 5 kWh per tonne cement produced [38]. These installations are expensive and require prolonged production downtime [65]. The payback periods for these installations are often longer than 10 years [38].

As pointed out in section 1.1, one of the key motivational aspects of DSM projects is the fast implementation time relative to the present delays in Eskom's new build programme. The combination of unbalanced production rates of individual components and adequate storage silos between these components make cement factories excellent candidates for load shift projects [66].

Load shift initiatives were found to be the most cost effective solution as viable DSM projects and it can be implemented within a relatively short time frame [27]. Therefore this study will focus on the effect of load shift projects at South African cement factories.

2.3.   Energy intensity of factory components

The cement production industry is energy intensive and energy utilisation accounts for 50 – 60% of the overall production cost [26]. The primary energy distribution of a cement production factory is 25% electrical energy from the grid and 75% thermal energy from fossil fuels [26]. All grinding and milling processes use electrical energy and the major portion of electrical demand originates from machine driven processes [30]. Large electric motors rotate the grinding mills and kiln.

The SEC is calculated by dividing the energy consumed by the volume of cement produced. Typical values of SEC are given in Table 5 [32], [67]. The largest electrical SEC can be attributed to the mills and kilns.

Table 5: Electrical energy distribution in the cement industry

Section / Equipment	Electrical SEC	Share
	[kWh/t]	[%]
Mines, crusher and stacking	1.5	2.0
Re-claimer, raw meal grinding and transport	18.0	24.0
Kiln feed, kiln and cooler	22.0	29.3
Coal mill	5.0	6.7
Cement grinding and transport	23.0	30.7
Packing	1.5	2.0
Lighting, pumps and services	4.0	5.3
Total	75.0	100.0

Figure 7 shows a photo of a kiln taken at a typical South African cement factory. The pyroprocess accounts for 93 – 99% of the total thermal energy usage [68] and up to 36% of the electrical energy usage. DSM initiatives were not implemented at the pyroprocess due to its inherent sensitivity to change and associated risks. The material feed rate, kiln rotation speed, preheater temperature, chemical sintering and waste gas are among the various factors that make the kiln more sensitive to change than the grinding processes [26].

Figure 7: Cement factory kiln [3]

The grinding mills used in the cement production process have been identified as high electricity consumers. There are several types of mills available for the cement production process including ball mills, hammer mills, high-pressure roller presses, horizontal roller mills and Vertical Roller Mills (VRMs).

The South African cement industry has at least three newer, more efficient VRMs utilised in the raw milling process. Figure 8 shows an illustration of a typical VRM [57]. Studies have shown that these mills have a lower electrical SEC than ball mills [44].

The most widely used finishing mill in the South African cement industry is the ball mill. An illustration of a single compartment ball mill can be seen in Figure 9 [57]. Until recently, VRMs could not be used effectively in the cement grinding process. The particle size distribution band in these VRMs was to narrow. However, recent advances improved the operating band of particle size and at least one VRM is utilised for cement grinding in the South African cement industry for the purpose of cement milling.

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[3] Image courtesy of M van Heerden.
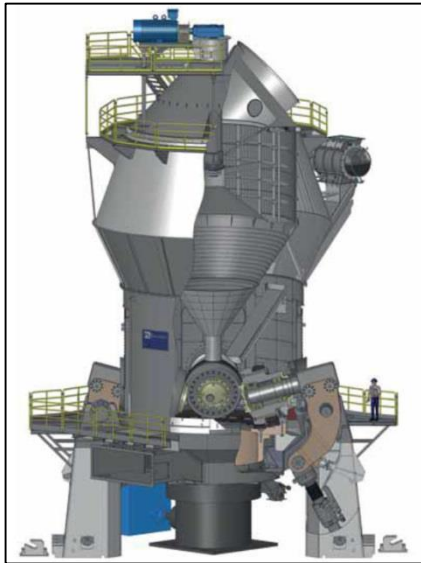
Figure 8: Vertical Roller Mill
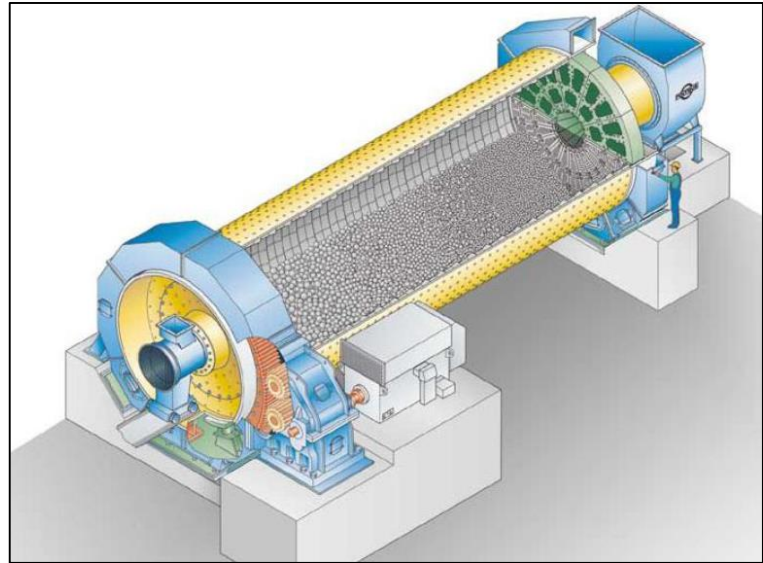
Figure 9: Ball mill

Auxiliary equipment for the pyroprocess use 36% of the total electrical energy. The combined electrical energy consumption of the grinding circuits account for 55% of the total electricity consumption [23], [24]. This fact points to substantial demand reduction potential through load shift initiatives. The distribution is clearly depicted in Figure 10.
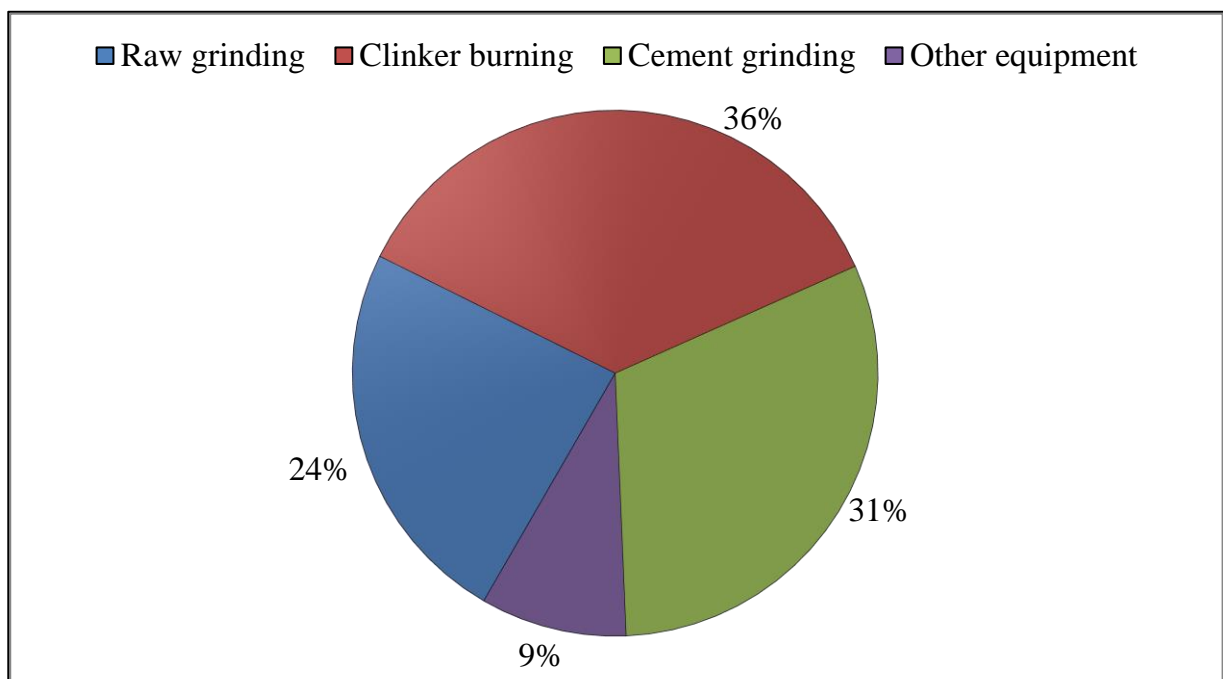
Figure 10: The breakdown of electricity consumption by factory process

Figure 11 shows the energy flow diagram for a typical cement factory [69]. Investigating the energy intensive components yielded that load shift initiatives, through the EMS, are justified on the raw milling and cement grinding processes [37], [38], [69].
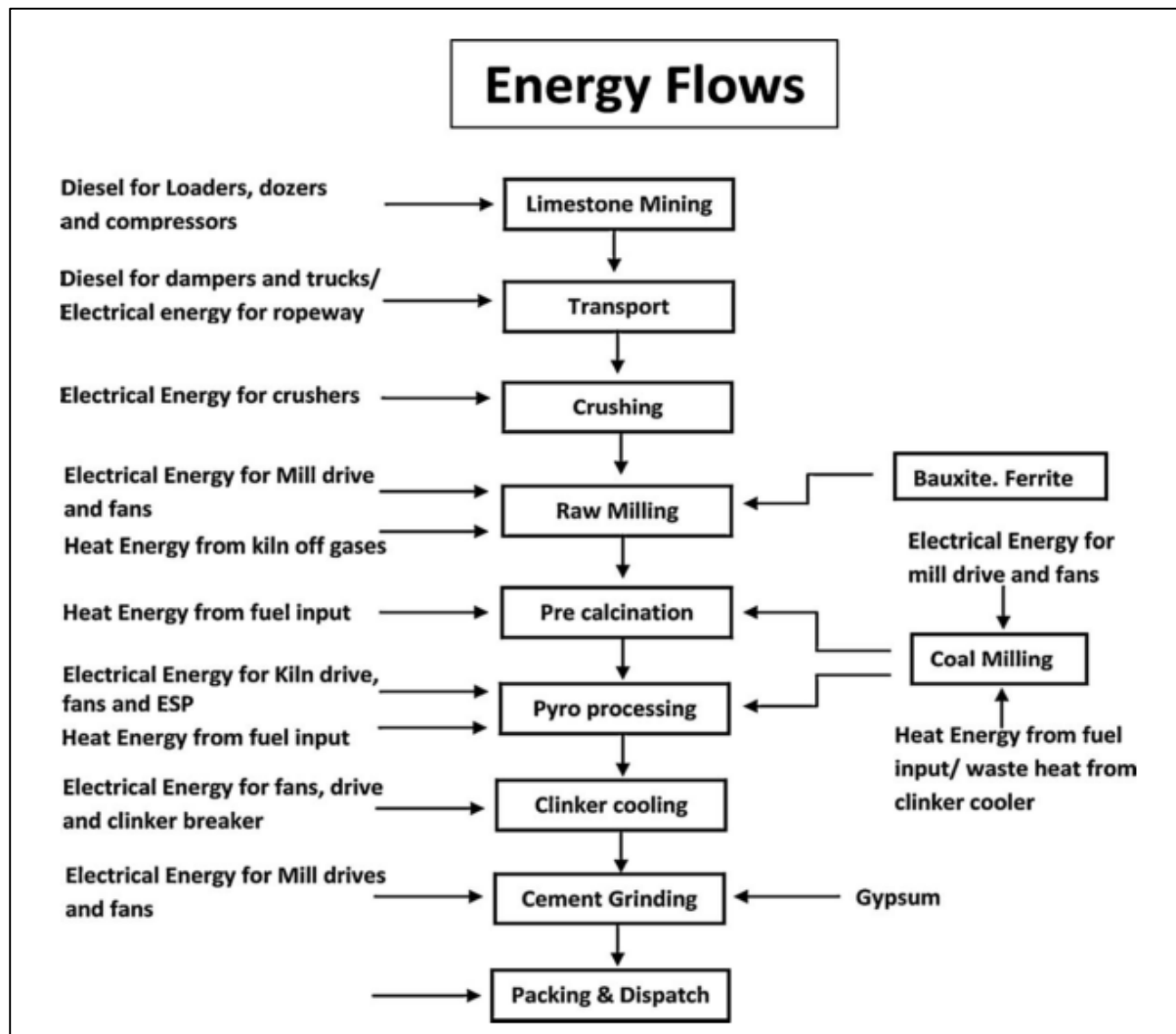
Figure 11: Electrical and thermal energy flow in a typical cement production process[4]

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[4] N. Madlool, R. Saidur, M. S. Hossain, and N. Rahim, "A critical review on energy use and savings in the cement industries," *Renew. Sustain. Energy Rev.*, vol. 15, no. 4, pp. 2042–2060, May 2011.

2.4.   Previous DSM projects

A system was required to manage the demand side usage of electricity to promote effective use of electrical energy. DSM was introduced and led to various cost saving strategies with incentives, thereby decreasing cost for the consumer and stabilising the national power grid of the supplier.

The need for an Energy Services Company (ESCo) and the development of an Energy Management System (EMS) arose. The main objective of an EMS is to assist the consumer to actively manage the energy consumption and reduce costs. The detailed analysis within an EMS enables monitoring, reporting and intelligent planning of energy consumption. The development and optimisation of an EMS relies strongly on the technical research of the applied industry.

Jordaan [29], [70] investigated DSM opportunities in the cement industry. He identified criteria that affect the load shift process (silo capacity, equipment fatigue, product quality, production targets). Jordaan developed procedures to identify viability and researched a case study by successfully simulating a 9 MW load shift on two raw mills.

Future research recommended by the study suggested research on the entire production line and not only the raw mill. The study suggested practical testing to determine the impact on the entire factory [29].

De Kock [12], [71] investigated the impact and knock-on effects of DSM projects in the industrial sector. The impacts were divided into three categories, namely cost benefits; other benefits and possible hidden costs. Cost benefits included calculating the electricity cost saving; reducing the labour cost; increasing the operating life of the equipment and enhancing preventative maintenance.

Other benefits included control infrastructure funding and ensuring sustainable savings through an EMS. Possible hidden costs included controlling the maximum demand; risk reduction and possible costs to the client when taking on a DSM project [71].

Venter [28] used a simulation model to simulate load shift on various cement factories. The data from several factories were used. The model simulated one section at a time (either raw meal grinding or cement grinding) with the next in line silo level taken into consideration. Future research recommended by this study suggests practical implementation and simulating the effect on the full production line [28].

Lidbetter [72] did a thorough investigation of the feasibility of energy efficiency interventions at a typical South African cement factory. The research also addressed most of the previously identified needs by performing a load shift pilot study on one cement factory. Lidbetter found that the availability of the load shift components was severely influenced by unscheduled breakdowns. Pressure to meet the production targets further influenced the load shift possibility. It was found that electrical energy cost savings was a low priority for the production team.

Lidbetter's study suggested that load shift on the raw mill will influence the raw meal quality. Further research was recommended to determine the full impact on the raw meal quality due to the load shift stop start occurrences [73].

Swanepoel [24] modelled an EMS for cement factories. The simulation was based on a discrete-time interval model. The model's parameters included crushers, raw mills, kilns, coal mills, finishing mills and storage components. He identified the constraints of the model which are maintenance (scheduled and unscheduled), raw material requirements, production rates (constant and variable) and energy requirements [24].

Maneschijn [74] developed and implemented a computerised system to optimise production cost reduction. The system was used as a visual planning aid to schedule production according to Eskom TOU electricity tariff structures [74].

DSM projects on cement factories with their accompanying load shift targets are listed in Table 6. These projects have been previously identified as viable. This was done through simulation models and practical tests. Further research suggested from the studies above emphasises the need to analyse the post DSM impact. A model is needed to determine, analyse and quantify the effects of DSM projects at cement factories for an extended period. Section 1.3 addresses how this study aims to fill the gaps in the South African cement industry literature.

Table 6: Previous DSM projects at South African cement factories

DSM project	Load shift target
	[MW]
Factory #1	2.70
Factory #2	2.60
Factory #3	3.00
Factory #4	2.90
Factory #5	1.06
Factory #6	2.55
Factory #7	2.50
Factory #8	2.55
Factory #9	2.50
Total	22.36

2.5.   Energy cost structure

The National Energy Regulator of South Africa (NERSA) effectively monitors and regulates the electricity price increase set out by Eskom each year. On 28 February 2013, during Eskom's third Multi-Year Price Determination (MYPD3), the yearly tariff increase for 2013 to 2018 was determined. During MYPD3, NERSA allowed Eskom to raise the tariffs by 8% each year for the specified five year period [15].

Large electrical energy consumers, in excess of 1 MVA demand, either opt for the Nightsave Urban Large or the Megaflex tariff structure. Consumers that are able to shift their electrical load would benefit from using the Megaflex tariff structure. This structure comprises of fixed TOU periods divided according to Eskom's transmission and distribution demand.

The Megaflex tariff structure has three TOU periods (peak, standard and off-peak) for each of the two demand-seasons (winter and summer) respectively. Figure 12 graphically represents the weekly cycle of the Megaflex TOU periods [15]. Appendix C supplies the full Megaflex tariff structure pricing.
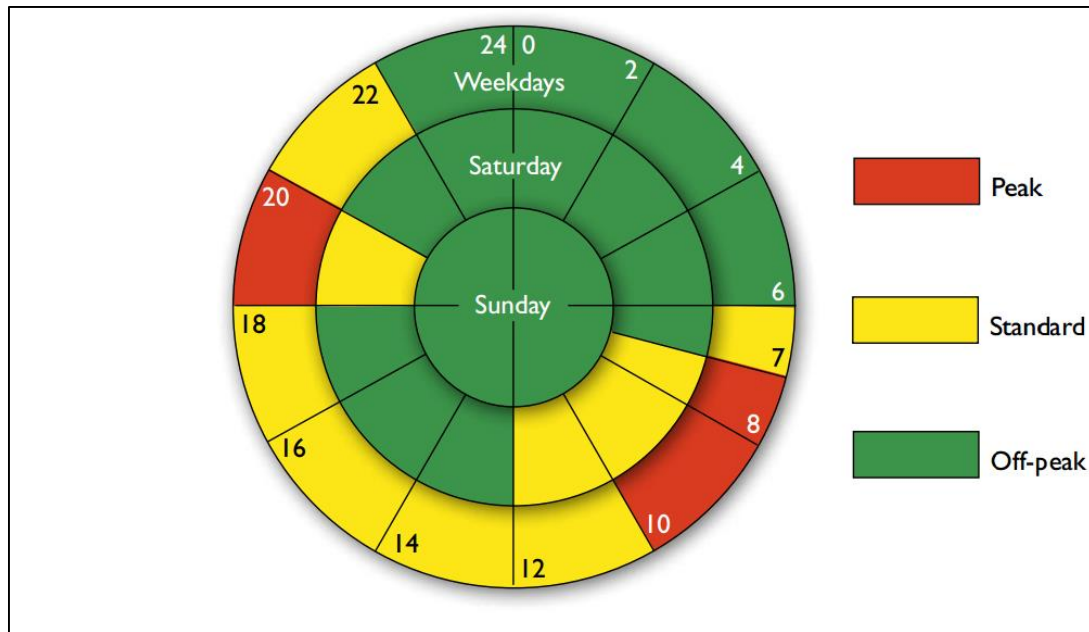
Figure 12: Eskom defined TOU periods

There is also a price difference in electricity cost for these periods during the high and low demand-seasons (winter and summer), as seen in Table 7. It is clear that improper load management could result in significant cost implications for consumers using the Megaflex tariff structure.

Table 7: Eskom Megaflex 2013/2014 TOU tariffs

Electricity costs [c/kWh]	
Summer peak	74.1
Summer standard	51.13
Summer off-peak	32.59
Winter peak	226.3
Winter standard	68.86
Winter off-peak	37.58

From Table 7 it is clear that the cost implications of consuming electricity in the winter peak periods are significant. From the literature review on previous DSM projects it becomes clear why integrated real-time planning of electricity consumption could result in substantial cost savings for the customer. However, shifting the electrical load to different TOU periods directly impacts the cement production process. This resulted in the need for a system that can accurately measure and verify the effect of DSM projects at South African cement factories.

2.6.   Conclusion

This chapter started with a critical energy review of the cement industry. The review shows that the SEC, in terms of electrical and thermal energy, serves as a relevant benchmark for energy savings initiatives. The review found that the implementation of most energy efficiency initiatives were expensive and had long implementation times. Previous research determined that load shift projects were viable within the South African electricity costing structure.

Load shift projects present relatively short implementation times and the infrastructure cost is far less than most energy efficiency projects. The implementation of load shift projects does not require production shutdowns to install additional infrastructure. On the other hand, the installation of energy efficiency infrastructure usually requires prolonged shutdowns. It was found that, if DSM projects that focus on load shift were sustainable, it would be beneficial to the cement factory and Eskom.

No literature could be found that focusses on the long-term effects of DSM projects at cement factories. That need was met in this study.

3. Methodology to investigate the possible effects of DSM

Chapter 3 describes the methodology to investigate the possible effects of DSM projects at South African cement factories. The research procedures followed to design the analysis model is explained in the introduction to this chapter. The Energy Management System (EMS) and its functional purpose is described. An overview of the cement factory, Factory #1, and the simulation to verify the analysis model is given. The analysis model designed to investigate the need for this study is explained in depth. Finally, Chapter 3 ends with a comprehensive design to validate the analysis results of DSM effects at South African cement factories.

Photo of the cement storage silos taken at Factory #1, courtesy of the author

3.1.   Introduction to methodology

An analysis model was used to determine and quantify the possible effects of DSM projects at South African cement factories. Figure 13 shows an overview of this model. The green blocks and arrows represent the simulation as part of the analysis model. The simulation used pre-implementation data from Factory #1 to predict the possible effects of DSM.
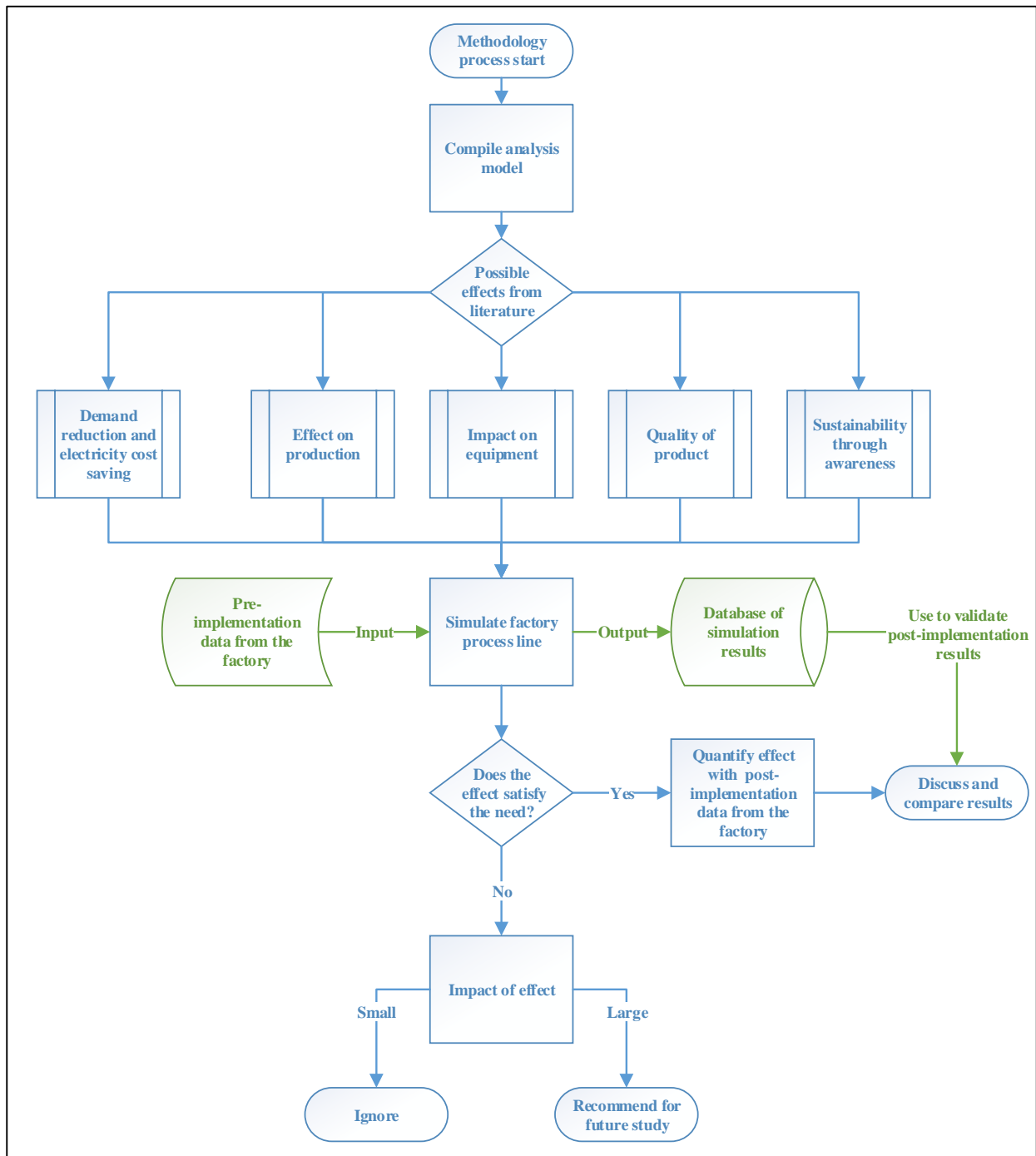
Figure 13: Methodology overview

3.2.   Energy Management System

To ensure that sales targets are met, a weekly sales order is handed to the production superintendent. This order gives an estimate of the cement demand and is used to plan the production schedule on a weekly basis. An intelligent production management tool, Process Toolbox (PTB), was developed by the ESCo [74] to assist with monitoring and optimising the production schedule. PTB forms part of the EMS

The EMS provides a user friendly interface for factory personnel to perform production planning. Features include optimised production schedules, material requirements to meet production needs, real-time feedback on factory operating costs and electricity consumption, silo level monitoring and prediction to limit material shortages and maintain an adequate blending level.

The EMS display, mounted in the control room, supplies the factory personnel with an increased level of real-time decision making abilities with regards to maintenance scheduling, unplanned breakdowns and production feedback. Various alarms were built into the system, e.g. alerts of upcoming changes or deviation in the production plans and alerts of upcoming peak TOU electricity periods.

The aim of the EMS is to manage the operational load within required constraints while minimising electricity costs. The system includes components that collect, process, interpret and integrate operational data and information from various sources. The factory operations were modelled and simulated while calibration parameters were continuously updated.

The EMS provides optimised production schedules. Furthermore, the real-time production is monitored to update the production schedules. Data on component reliability is included to provide realistic schedules and compensates for unexpected breakdowns within an acceptable timeframe.

Figure 14 displays the PTB viewer screen. This screenshot was taken from Factory #1 on 26 June 2012 at 15:34. This screen is located in the main control room and was installed as part of the DSM project. The purpose of this screen is to assist the factory control room operators in monitoring valuable operational parameters as well as conforming to the proposed production schedules.
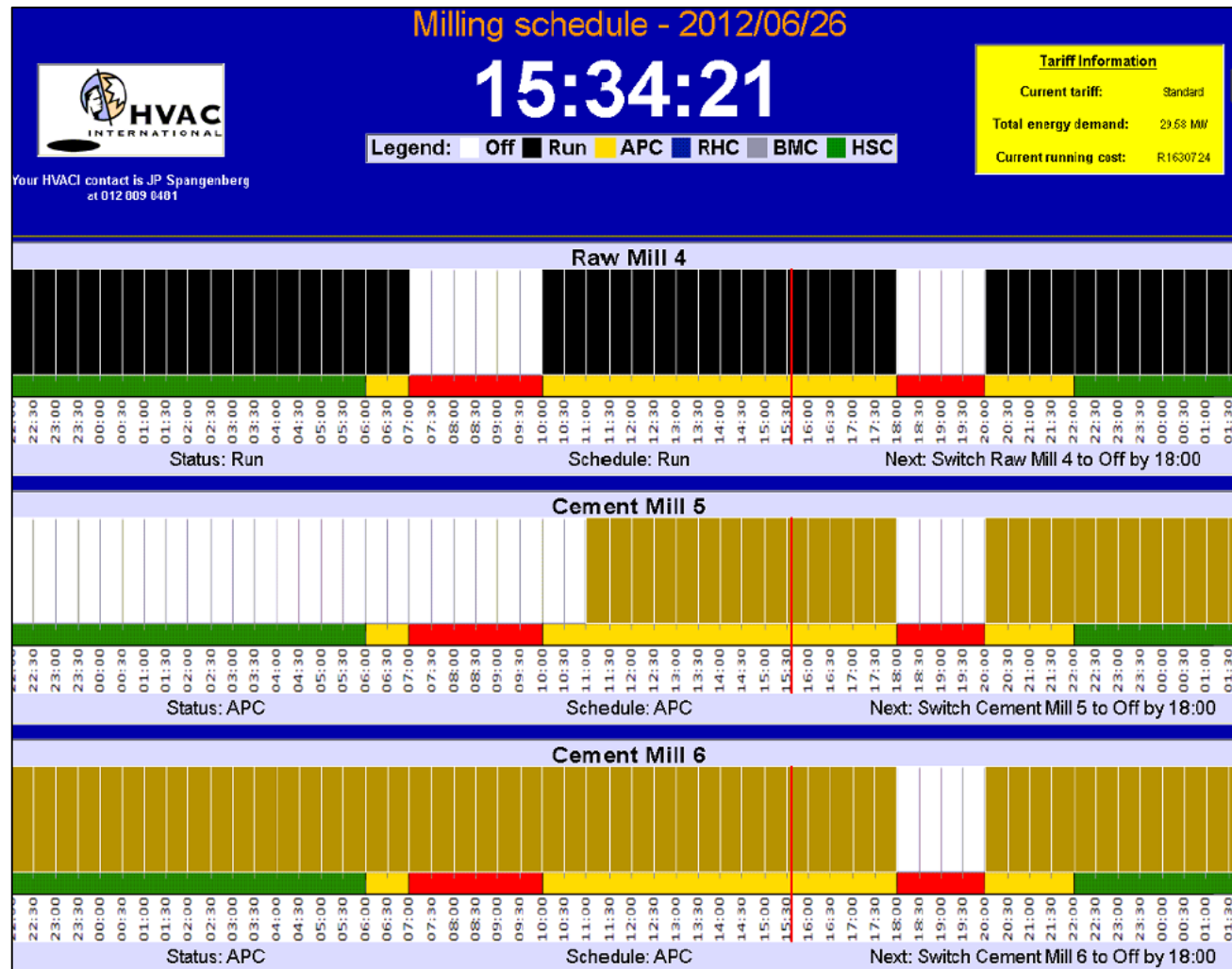
Figure 14: PTB viewer screen

3.3. Overview of factory

The initial focus of this research project relies on the feasibility and the sustainability of the DSM model at cement factories. Factory #1 was simulated as a simplified production line. This production line consists of various components with unique attributes. The important elements of each component were imbedded in the simulation model. A simulation model was used to predict the post-implementation impact of the DSM project with the pre-implementation data from Factory #1.

Figure 15 gives the layout of Factory #1. The basic processes of a typical cement factory are raw meal grinding, clinker formation and the finish grinding. The components used in the simulation model are given in Table 8.
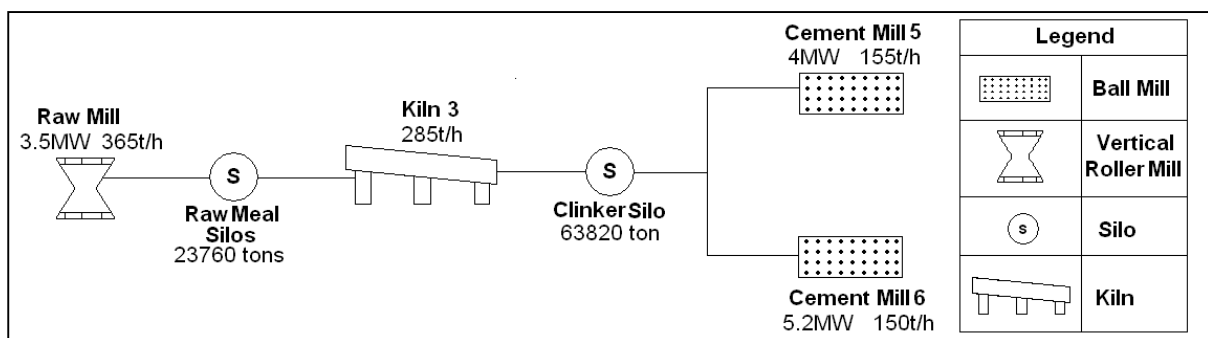
Figure 15: Factory #1 layout

Table 8: Functional components of Factory #1

Process	Component	Total production rate
		[t/h]
Raw meal formation	Raw mill	365
Clinker formation	Kiln	285
Cement formation	Cement or finishing mill	305

Between adjacent components of the cement production line there are storage facilities in the form of silos. The sizes of the silos are vital to the feasibility of the DSM project. Each silo serves as a buffer for the adjacent components. The maximum capacities of the silos used in the simulation are given in Table 9.

Table 9: Storage facility capacity of Factory #1

Process	Component	Capacity
		[t]
Lime storage	Stock yard	300,000
Raw meal storage	Raw meal silo	23,760
Clinker storage	Clinker silo	63,820
Cement storage	Cement silo	80,000

The simulation model must ensure that production meets the demand for cement. If there is a shortfall in supply, the electricity cost saving will not justify the financial losses associated with reduced sales. Additionally, in a competitive market, if one supplier cannot meet the demand, a gap will open for a second supplier to win market share. The basis of this simulation rests on the ability to perform load shift and still meet the factory's production targets.

The utilisation of each component depends on its availability. Planned and unplanned maintenance form an intricate part of a good simulation. Accurately accounting for these factors will decrease the risk of underutilisation. Production must sustain a rate that accounts for downtime and silos must be filled with adequate material to ensure high overall factory availability.

3.4. Analysis model

The analysis model will use the parameters of Factory #1 specified in the factory overview (Section 3.3) to determine the possible effects as described in Table 10. The simulation predicts the possible effects of DSM projects after the implementation thereof. This is accomplished by using pre-implementation data from Factory #1 as input. Load shift scheduling is simulated and the outcome will be used in Chapter 4 to verify the actual long-term effects of the analysis model.

Table 10: Analysis model description

Need	Section	Simulation outcome	Analysis outcome
Demand reduction and electricity cost saving	3.5.1	Predict possible effect on demand reduction and electricity cost saving	Measure long-term demand reduction and electricity cost saving
Production	3.5.2	Predict possible effect on production	Measure long-term production volumes
Impact on equipment	3.5.3	Predict increase in post-implementation stoppages	Measure long-term stoppage occurrence
Product quality	3.5.4	Predict raw mill silo level control improvement after implementation	Measure improvement in control level
Sustainability	3.5.5	Predict long-term sustainability through awareness	Measure long-term sustainability through awareness

Over a period of three months, an electrical demand baseline was developed to accurately depict the three grinding mills' power consumption under normal operating conditions. This was done by measuring the electrical demand and the production rate of each mill while it is operational. It was found that the mills operate at only two modes, which are on and off. When the mills are on, they operate at constant electricity consumption and production rate. When the mills are off, the electricity consumption and production rates are zero.

The actual baseline shows the electrical demand while the factory is producing cement. The three month period was simplified to a one week power profile which shows the average production schedule with hourly resolution as seen in Figure 16.
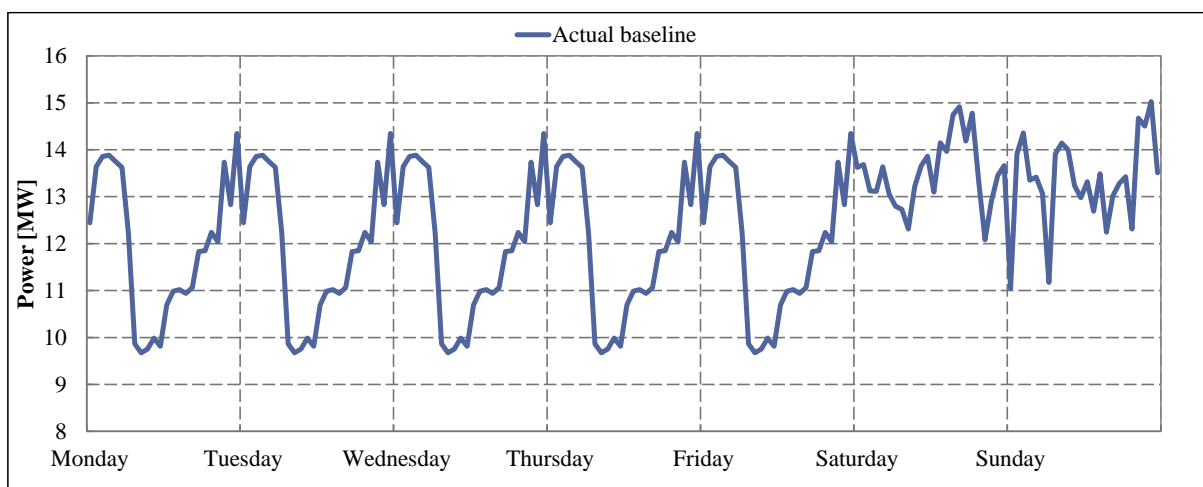
Figure 16: Power profile of the baseline model

The energy consumption (MWh) is calculated by multiplying the average power demand (MW) by the consumption period (h). From Figure 16 it is clear that more energy per day is consumed over the weekend than the average working weekday (Monday to Friday). This is due to the fact that the electricity cost over the weekend is cheaper than during the working weekdays. It also shows a decrease in energy consumption in the mornings of the working weekdays. This is due to maintenance carried out on the factory equipment.

The following assumptions were made:

Due to the complexity of the production process the minimum simulation time span was set at one week. This was found to be the shortest possible time span in which to observe the full effect of load management, production, sales and maintenance trends on the factory.

The assumption was made that cement sales took place during weekday mornings from 08:00 to 13:00 (excluding weekends). Therefore the simulation showed an outflow from the cement silo equal to the total amount of cement sold over the same period. The outflow took place in five hour intervals per day from Monday to Friday. The simulation model must ensure sufficient cement quantity to sustain this outflow without declining below the minimum silo level constraint.

The clinker factor, ratio between the kiln inflow and outflow, was constant at 0.65. The start-up delay on all components was zero. Component availability and utilisation factors were constant and calculated using historic data.

The demand reduction and electricity cost savings were calculated with the weekly scaling method. This scaling method used a scaling factor to ensure energy neutrality between the actual and baseline profiles on a weekly basis.

The production targets used in the simulation were calculated from monthly production figures over a two year interval. Monthly production was equally distributed per 24 hour day interval. Factory #1 data shows a monthly variance in cement demand and there is a clear reduction in December due to decreased sales. The seasonal production difference was modelled and baseline scaling was used to accurately measure the effects of DSM within this model.

The weekly simulation model will use the actual data obtained from Factory #1 to simulate the effects of DSM at the factory. The outcome will be used to verify the simulation model. The

simulation will then run for each week of the year over a two year period. The information obtained from this action will be used to determine the long-term effects and in doing so, validate this study's outcome.

3.5.   Possible effects on cement factories

The project feasibility is largely dependent on the demand reduction and electricity cost savings from two perspectives. The utility receives evening peak demand reduction, who in turn supplies funding directly related to the magnitude of this load shift target. The client or cement factory receives infrastructure and an electricity cost saving for participating in the DSM initiative.

The literature survey showed that there are three different types of DSM projects. Energy efficiency and peak clip initiatives were not simulated for the following reasons: energy efficiency technologies were found to be too expensive; peak clip projects were found to be non-beneficial to the cement factories because the production losses cannot be justified by the electricity cost saving. The focus point of this research is load shift initiatives.

3.5.1.   Demand reduction and electricity cost savings

The demand reduction is determined by shifting the evening peak load, between 18:00 and 20:00, to other periods of the day. The simulation model used actual data from Factory #1 to establish a benchmark model. The proposed load shift schedule was implemented on the benchmark model and the possible demand reduction and electricity cost savings were quantified. Figure 17 shows the results of the simulation model.

Figure 17 displays the actual and proposed power profiles of the simulation model within an average week. The x-axis represents a week from Monday to Sunday. The y-axis shows the power consumption of the cement mills and auxiliary equipment. The blue line follows the actual profile of Factory #1 which will also be called the actual baseline. The brown dashed line represents the proposed load shifting profile. The exact form of the proposed profile results from the EMS and aim to minimise electricity cost without a shortfall in production targets.
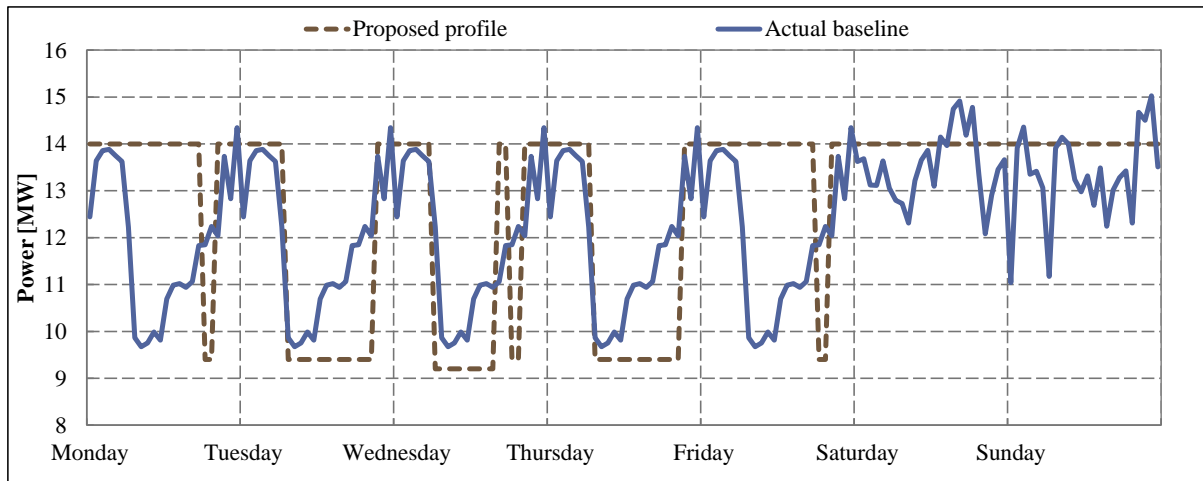
Figure 17: Simulation model power profiles

The actual profile will differs from the baseline as each weekly demand varies from the previous week. This is due to demand fluctuations in the market which lead to different weekly production targets. Therefor the baseline is scaled to be energy neutral with the actual profile. The difference between the baseline and the proposed profile will be used to determine the proposed evening peak demand reduction and electricity cost savings.

To account for the difference due to the reason stated above, the baseline is scaled to be energy neutral with the proposed profile as seen in Figure 18. In other words the areas underneath the blue and brown line differ. The baseline is adjusted with a scaling factor to account for this difference. This is to ensure energy neutrality between this newly developed scaled baseline profile (red) and the proposed profile (brown dotted line) over the weekly period.
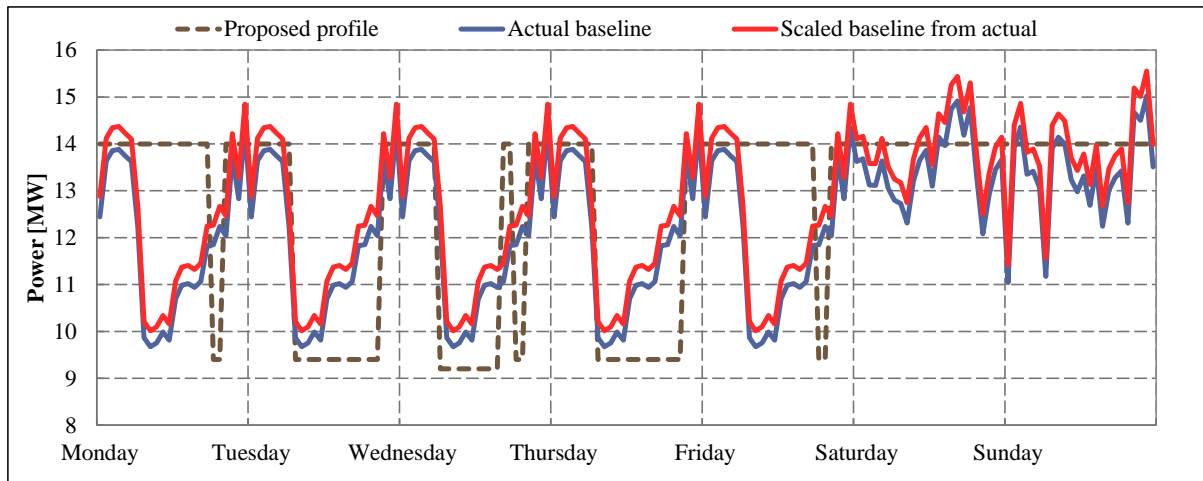
Figure 18: Simulation model power profiles (energy neutral)

The proposed (simulated) and scaled baseline profiles are used to calculate the theoretical savings. The scaled baseline profile is calculated from the baseline profile as described in the previous paragraph. The demand reduction and electricity cost saving is calculated between the proposed profile and scaled baseline profile. The evening peak demand reduction is calculated as seen in Figure 19. The simulated weekday evening peak demand reduction is calculated as 3.07 MW.

Actual power consumption [MW]					Proposed power consumption [MW]			
Hour	**Weekday**	**Saturday**	**Sunday**		**Hour**	**Weekday**	**Saturday**	**Sunday**
0:00	12.88	14.10	11.43		0:00	14.00	14.00	14.00
1:00	14.12	14.16	14.40		1:00	14.00	14.00	14.00
2:00	14.35	13.58	14.87		2:00	14.00	14.00	14.00
3:00	14.37	13.58	13.82		3:00	14.00	14.00	14.00
4:00	14.23	14.12	13.89		4:00	14.00	14.00	14.00
5:00	14.11	13.52	13.52		5:00	14.00	14.00	14.00
6:00	12.66	13.25	11.56		6:00	13.04	14.00	14.00
7:00	10.21	13.17	14.40		7:00	11.20	14.00	14.00
8:00	10.01	12.75	14.64		8:00	11.20	14.00	14.00
9:00	10.10	13.68	14.49		9:00	11.20	14.00	14.00
10:00	10.34	14.13	13.70		10:00	11.20	14.00	14.00
11:00	10.16	14.35	13.44		11:00	11.20	14.00	14.00
12:00	11.07	13.56	13.79		12:00	11.20	14.00	14.00
13:00	11.37	14.64	13.14		13:00	11.20	14.00	14.00
14:00	11.41	14.46	13.96		14:00	11.20	14.00	14.00
15:00	11.32	15.27	12.67		15:00	11.20	14.00	14.00
16:00	11.45	15.44	13.47		16:00	12.16	14.00	14.00
17:00	12.25	14.68	13.75		17:00	12.16	14.00	14.00
18:00	12.26	15.30	13.90		18:00	9.40	14.00	14.00
19:00	12.67	13.81	12.75		19:00	9.40	14.00	14.00
20:00	12.46	12.51	15.19		20:00	12.16	14.00	14.00
21:00	14.22	13.36	15.01		21:00	14.00	14.00	14.00
22:00	13.28	13.93	15.55		22:00	14.00	14.00	14.00
23:00	14.85	14.14	13.98		23:00	14.00	14.00	14.00

3.07

Figure 19: Simulated hourly energy consumption

The Eskom TOU tariff structure, seen in Figure 12 in section 2.5, was used in the simulation to calculate the actual and simulated electricity cost saving. Notice the difference between the summer and winter tariffs.

The electricity cost saving for a typical winter week is calculated in Figure 20. The actual electricity cost is calculated per hour while the simulated profile's electricity cost is also calculated. The entire seven-day profile must be included in the calculation to account for energy neutrality and equal production output between the practical and simulated cement factories.

	Actual profile energy cost [R]				Proposed profile energy cost [R]		
Hour	Weekday	Saturday	Sunday	Hour	Weekday	Saturday	Sunday
0:00	4840.67	5299.90	4294.48	0:00	5261.20	5261.20	5261.20
1:00	5306.13	5323.08	5413.20	1:00	5261.20	5261.20	5261.20
2:00	5391.83	5104.52	5586.31	2:00	5261.20	5261.20	5261.20
3:00	5400.91	5101.88	5193.78	3:00	5261.20	5261.20	5261.20
4:00	5348.56	5304.60	5219.93	4:00	5261.20	5261.20	5261.20
5:00	5300.86	5079.13	5081.84	5:00	5261.20	5261.20	5261.20
6:00	8714.62	4978.02	4345.83	6:00	8979.34	5261.20	5261.20
7:00	23103.71	9072.04	5410.70	7:00	25345.60	9640.40	5261.20
8:00	22661.71	8777.31	5502.05	8:00	25345.60	9640.40	5261.20
9:00	22853.87	9422.32	5446.40	9:00	25345.60	9640.40	5261.20
10:00	7120.73	9732.69	5150.33	10:00	7712.32	9640.40	5261.20
11:00	6995.49	9881.24	5048.88	11:00	7712.32	9640.40	5261.20
12:00	7623.00	5095.61	5181.25	12:00	7712.32	5261.20	5261.20
13:00	7830.82	5503.21	4936.65	13:00	7712.32	5261.20	5261.20
14:00	7854.28	5432.92	5247.17	14:00	7712.32	5261.20	5261.20
15:00	7797.22	5737.06	4762.56	15:00	7712.32	5261.20	5261.20
16:00	7885.73	5802.22	5063.15	16:00	8373.38	5261.20	5261.20
17:00	8433.80	5518.40	5165.82	17:00	8373.38	5261.20	5261.20
18:00	27752.62	10536.40	5222.23	18:00	21272.20	9640.40	5261.20
19:00	28670.64	9512.61	4789.93	19:00	21272.20	9640.40	5261.20
20:00	8582.92	4700.86	5708.92	20:00	8373.38	5261.20	5261.20
21:00	9790.13	5020.99	5641.47	21:00	9640.40	5261.20	5261.20
22:00	4991.70	5234.25	5844.94	22:00	5261.20	5261.20	5261.20
23:00	5580.60	5314.97	5255.16	23:00	5261.20	5261.20	5261.20
	255832.53	156486.20	124513.00		250684.59	156923.20	126268.80

	R	5,147.94 X 5
+	R	(437.00)
+	R	(1,755.80)
=	R	23,546.89

Figure 20: Simulated average weekly electricity cost saving for the winter demand-season

The electricity cost savings of an average week in the winter demand-season was calculated to be R 23,546.89 which is a 2% improvement. The electricity cost saving for a typical summer week is calculated in the same way as a winter week. The simulation calculated the electricity cost saving for a summer week to be R 3,913.90 which is only 0.4% of the weekly electricity

cost. Therefore it is more rewarding to participate in load shift initiatives during the winter months.

Figure 21 shows a breakdown of the yearly electricity cost saving calculations. To successfully analyse and quantify the long-term energy cost saving the simulation model included weekly scaling, seasonal tariffs and public holidays. The annual electricity cost savings was calculated at R 450,535.54.

	Summer electricity cost saving		
	Weekday	Saturday	Sunday
Total	R 1,149.42	-R 310.62	-R 1,522.66

Avg Daily Savings	R 559.11	
Summer Savings	R 152,638.25	

Classified as	Saturday	Sunday
Public Holliday	5	6

Total Summer Savings	R 141,938.19

	Winter electricity cost saving		
	Weekday	Saturday	Sunday
Total	R 5,147.94	-R 437.00	-R 1,755.80

Avg Daily Savings	R 3,363.84	
Winter Savings	R 309,473.35	

Classified as	Saturday	Sunday
Public Holliday	2	0

Total Winter Savings	R 308,597.35

Total annual savings	R 450,535.54

Figure 21: Calculated annual electricity cost saving

3.5.2. Effect on production

The simulation model predicted the volume of cement produced. The main objective is to reduce the evening peak load without reducing the production. This entails that the simulated and actual production must be equal on a weekly basis. Additionally the volume of cement

within each silo must remain within the minimum and maximum constraints. Figure 22, Figure 23, Figure 24 and Figure 25 show the results of a seven day simulation.

The cement production was simulated over the period of a week, as shown in Figure 22. The actual cement produced during an average week was used as benchmark. The simulation goal was to shift maximum load while reaching the same weekly cement production volume as the given benchmark value.

In Figure 22 there is a visible difference in the actual and proposed (simulated) volumes between Monday and Friday. The proposed volume was lagging until Friday, however this difference is corrected over the weekend when the simulation proposed full production. It is clear that the production target was reached by the end of Sunday.
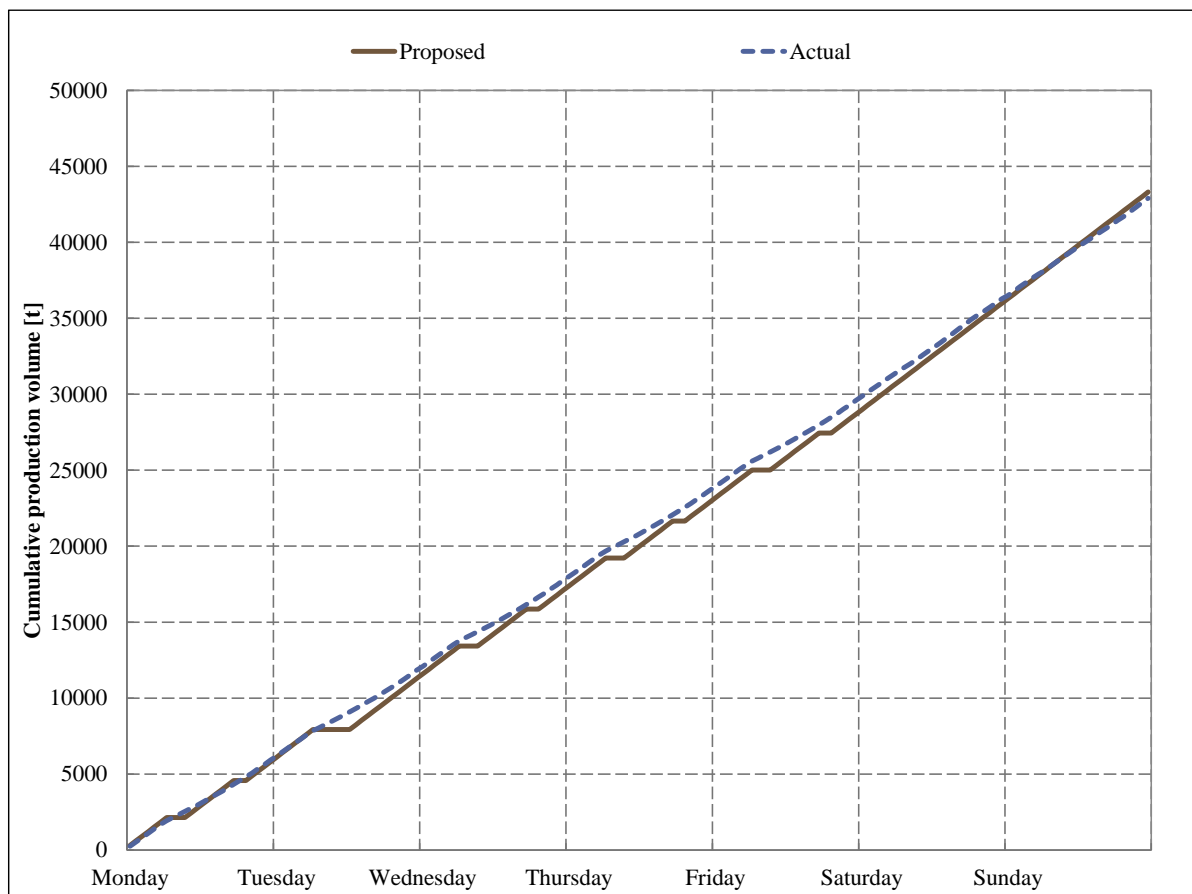
Figure 22: Simulated cement production

The data obtained from the raw meal silo in the week simulation is shown in Figure 23. Notice that the actual raw meal volume nears the minimum level constraint by the end of Friday.

However, the raw meal volumes increase over the weekend and stabilises at the desired value by the end of Sunday.
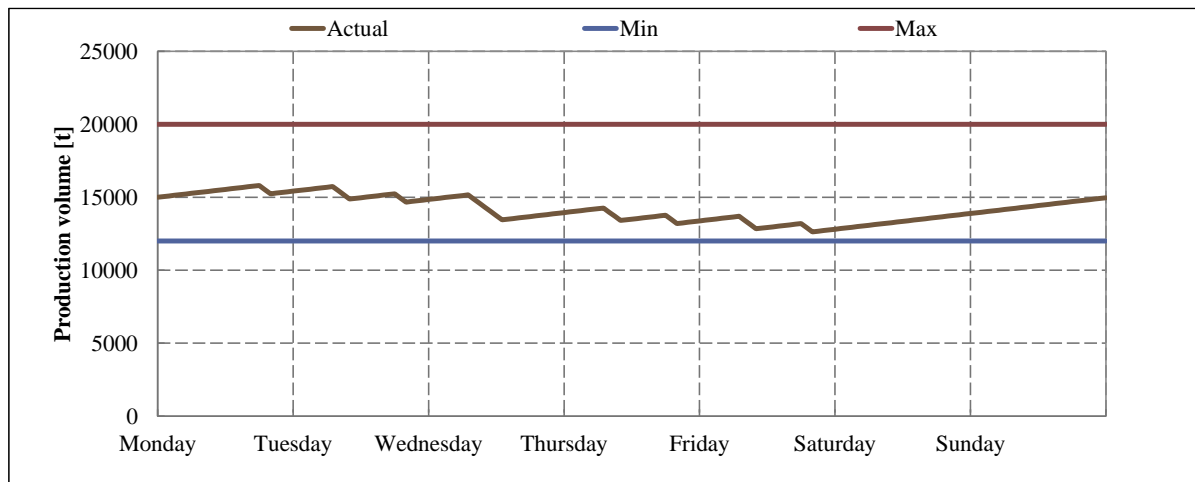
Figure 23: Simulated raw meal silo level

The clinker silo was simulated as shown in Figure 24. It was assumed that the kiln production rate remains constant throughout the week, which will be the actual case as well. The clinker silo nears the maximum level on Friday and then stabilises over the weekend. This is because of the cement mills' clinker consumption through the weekend.
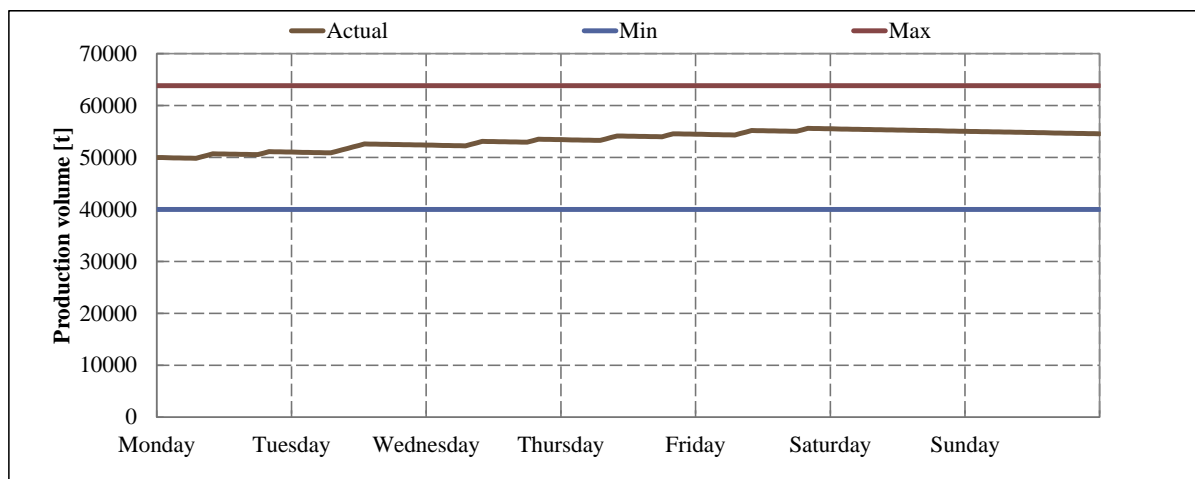
Figure 24: Simulated clinker silo level

The cement silo, as the final storage unit, was simulated and the results are shown in Figure 25. Each day shows a drastic decrease in cement volume. This is due to load shift on the cement mills and the cement sales throughout the week. Figure 25 clearly shows that the cement volume stayed within the system boundaries. Secondly, it shows that the cement volume

increases throughout the weekend where it converges to the initial starting value. From the simulation it is clear that no production losses occurred due to the load shift initiative.
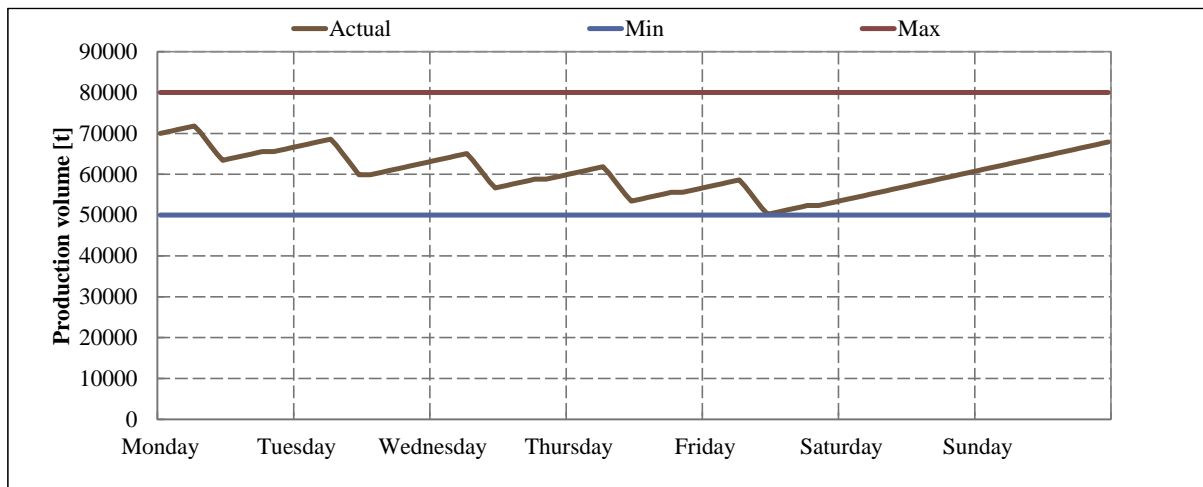
Figure 25: Simulated cement silo level

The simulation showed that the effect on the cement production and all the affected silos reaches equilibrium at the end of the week. This results in a zero nett effect within the seven day time span of the model.

3.5.3. Impact on cement production equipment

Increased stopping and starting of the grinding mill will have a negative impact on some of the individual component lifecycles. Motors experience inrush current during start-up. Shafts and gearboxes driving the mills experience fatigue. This is due to the large amount of torque required to overcome the initial start-up inertia. This can be overcome by using soft starters and VSDs [75]–[80].

A simplified method was used to perform the analysis within the framework of this study. Quantifying the amount of stoppages before and after the implementation of the DSM project at Factory #1 can be used to analyse the impact. One of the benefits of the EMS was that it aimed to minimise the electricity cost by optimising the stoppages. Therefore, the EMS aims to reschedule the stoppages rather than increasing the number thereof.

Table 11 shows the simulated impact on equipment. The average weekly stoppages were calculated from the Factory #1's actual data. The simulation model proposed an increase from five to six stoppages per week which relates to a 20% increase. This increase, although undesired, will result in an average cost saving of R 8,664.15 per week.

Table 11: Simulated impact on equipment

	Average weekly stoppages	Average weekly electricity cost saving
Actual	5	R 0.00
Simulated	6	R 8,664.15

This amount will be used as a baseline to measure the increase or decrease in stoppages after implementation of the EMS. Note that increased stoppages are not encouraged by this model, is merely serves as an analysis tool to quantify the effect.

3.5.4. Effect on the cement quality

Cement production is a competitive market and the product quality is of upmost importance. Each product is required to have certain qualities in terms of strength, hardening rate and environmental impact. Achieving the required attributes represents a great cost incentive on the production side. Disrupting the production flow of cement has a negative effect on the quality of the product [81].

During normal operation the quality of the product is checked at various stages including the raw meal, clinker and final cement product. Additives are added during the raw meal and clinker grinding processes. These additives are added through hopper bins. The feed rates of these hoppers are adjusted on regular intervals according to the reported quality of the downstream sample result.

The samples are taken to an onsite lab and analysed to check if the product adheres to the requirements. The lead time on the results is usually between one and three hours. If the results suggest an increase or decrease in an additive component the hopper is adjusted to allow the correct amount to be added.

Substandard quality in the production is a notable concern which will lead to poor product quality [82]. The start-up of a grinding process after a load shift shutdown needs to be monitored for deviation in product quality. Increased cycling in the production process has a negative effect on the product quality. This can be overcome if the level of substandard quality is quantified and corrected. For example, producing one tonne of raw meal with 5% less than required iron ore added will result in a correction of 5% more than required iron ore during the next tonne of raw meal produced.

The two variants of raw meal will form layers in the silo. During extraction from the silo a natural blending process, called homogenisation, takes place that results in a uniform composition of raw meal. The extracted raw meal remains within the required quality specifications. There are extreme cases where the volume of substandard product exceeds the threshold for correction through homogenisation. In such cases the substandard product is dumped from the silo and usually recycled for use upstream in the production line.

Silo levels that surpass this threshold are noted and used in the simulation. The levels are referred to as minimum level constraints. The aim of the DSM project's EMS is to ensure that the minimum silo levels were not reached. The reason is that production losses can occur due to insufficient blending storage capacity.

Optimal load shift will not be possible if homogeneity is not achieved through silo blending. Therefore production losses will not only result in inefficient operation, but also have a negative effect on the demand reduction and electricity cost saving of the DSM project.

Figure 26 shows the simulated raw meal silo levels. The blue bars refers to the frequency of occurrences within a given control level and the red line follows the normal distribution of the occurrences. The x-axis shows the deviation from the control level. This distribution shows that it is possible to keep the silo level above the control level.
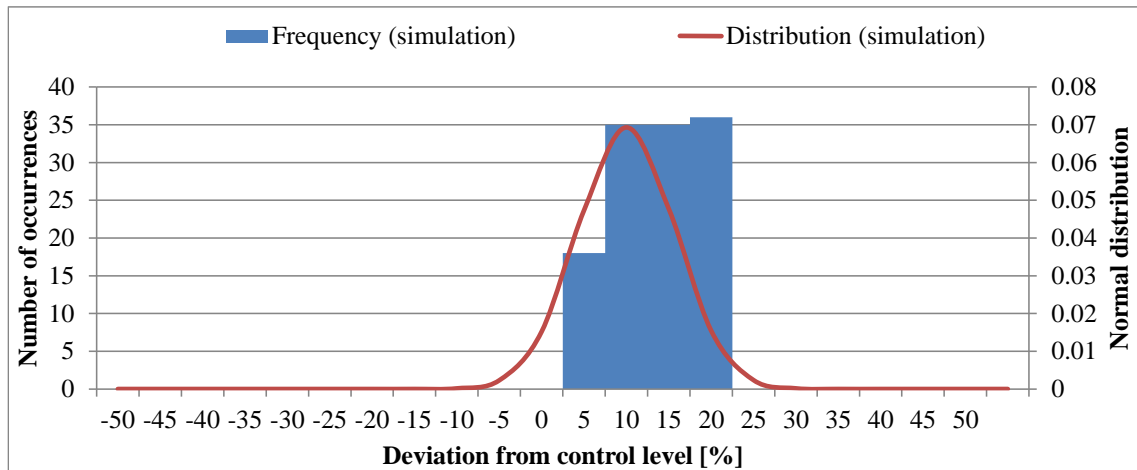
Figure 26: Simulated raw meal silo control level distribution

Figure 27 shows the difference between the actual and the proposed silo level distribution. The dotted red line shows the variance in silo level obtained from Factory #1's actual data. The silo level varies largely with a high number of occurrences outside the control level. The blue line shows the simulated distribution of occurrences when the proposed schedule is followed. The simulation model shows that an improvement in the raw meal silo level control will be achieved by implementing the EMS at Factory #1.
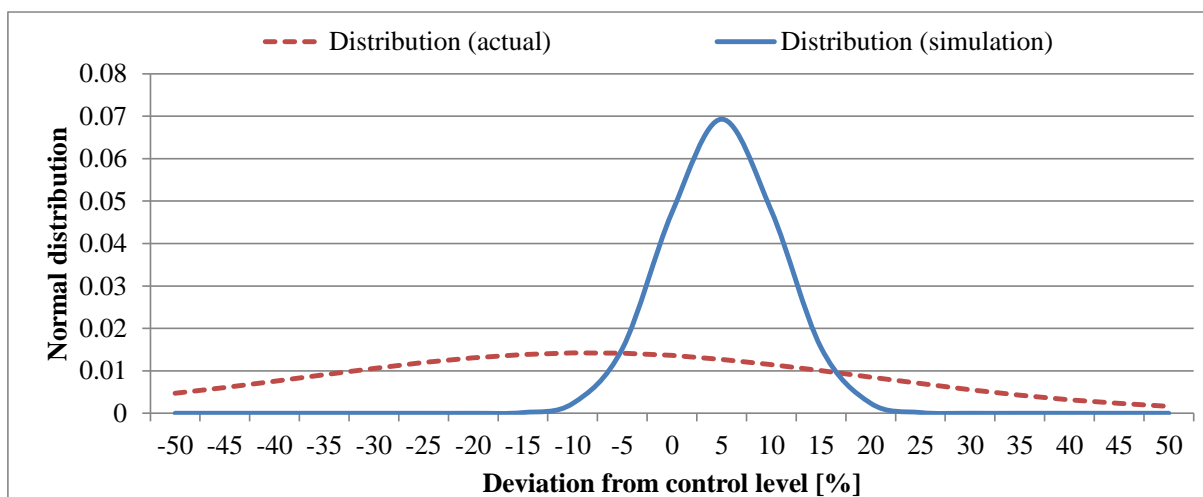
Figure 27: Simulated improvement in raw meal silo control range

This method will be used to determine if the control level will improve after implementation of DSM projects at cement factories. Only Factory #1 will be used to verify this effect.

3.5.5. Sustainability

DSM projects influence the electricity cost savings, production and quality associated with the cement production processes. Therefore DSM projects form an intricate part of each cement factory and is relevant for discussion in production, electrical, maintenance and general meetings. Discussions include production schedules, maintenance planning, electricity cost savings and future applications.

Lidbetter [72] found that the electricity cost savings was low on the priority list during the production planning meetings. The magnitude of the electricity cost savings were clearly depicted in daily savings reports as seen in Appendix E. These reports were sent out to key personnel within the factory's organisation.

The sustainability of DSM projects is largely dependent on the cement factory's input. This model will be used to analyse the variance in demand reduction and electricity cost savings over long periods. Initially, the factory personnel were sceptical about following the proposed schedules set out by the EMS. However, as increased electricity cost savings and no production losses were reported, the factories became more pro-active in following the proposed production schedule.

3.6.   Conclusion

PTB, as part of the EMS, was found to be a valuable resource in the verification process of the actual DSM projects. The knowledge obtained from previous research done in the South African cement industry led to the development of an analysis model. This model was built around the parameters required to address the need for this study.

The minimum time span of the model was set at one week. It was found that various effects of DSM projects could be accurately observed within this weekly analysis period.

The possible effects of DSM projects on cement factories were simulated as seen in Table 12. This simulation used the EMS to propose the optimum schedule based on pre-implementation results from Factory #1.

Table 12: Summary of simulation results

Effect of DSM	Simulation	Predicted analysis outcome
Demand reduction and electricity cost saving	Long-term savings were simulated	Load shift target reached and electricity cost saving predicted
Effect on production	Long-term production figures were simulated	No long-term effect on production
Impact on equipment	Amount of stoppages recorded	20% increase in stoppages predicted
Product quality	Raw meal silo levels simulated within boundaries	Improved control predicted on the raw meal silo volume
Sustainability	Sustainability was predicted	Factory will adopt DSM strategy

The simulation yielded demand reduction and electricity cost savings without influencing the production negatively. The impact on equipment was found to be not so severe, although it does decrease the lifecycle. The amount of stoppages was scheduled to remain the same. The cement quality is influenced, but this can be overcome by sufficient blending in the silos. The DSM project will increase awareness of electricity consumption in various interdisciplinary departments of the cement industry.

The long-term impact of the effects with actual factory data after implementation of the EMS will be analysed in the next chapter.

4. Sustainability results

Chapter 4 discusses the long-term results obtained from the analysis of DSM effects at South African cement factories. The possible effects are analysed and discussed within the determined model categories which are demand reduction and electricity cost; production targets; infrastructure; product quality; and sustainability. Verification of the analysis model is achieved by comparing the simulated and actual factory results. Furthermore, the outcome of the results clearly validates the initial need for this study. Lastly, Chapter 4 summarises the results obtained from the analysis of DSM effects at South African cement factories.

Photo of the clinker silo (far left), cement grinding process (centre) and cement silos (far right) taken at Factory #1, courtesy of the author

4.1.   Introduction

The impact on the specific cement factory was analysed after successfully completing the project. The Performance Assessment (PA) phase lasted three months and the results were quantified. After the PA the client took over the project. This is called the Performance Tracking (PT) phase. The PT results for two years were included in this study.

4.2.   Demand reduction and electricity cost savings

Factory #1 was used to analyse the possible effects of DSM projects at South African cement factories. The baseline for Factory #1 was calculated over a three month period with data extracted directly from the factory's historical data server. The expected performance assessment results were achieved and the factory adopted the load management intervention.

Figure 28 shows the average power profiles of Factory #1 during the baseline establishment period. The baseline was broken down into three distinct categories namely; weekday, Saturday and Sunday. The weekday parameter includes all workdays of the week (Monday, Tuesday, Wednesday, Thursday and Friday).
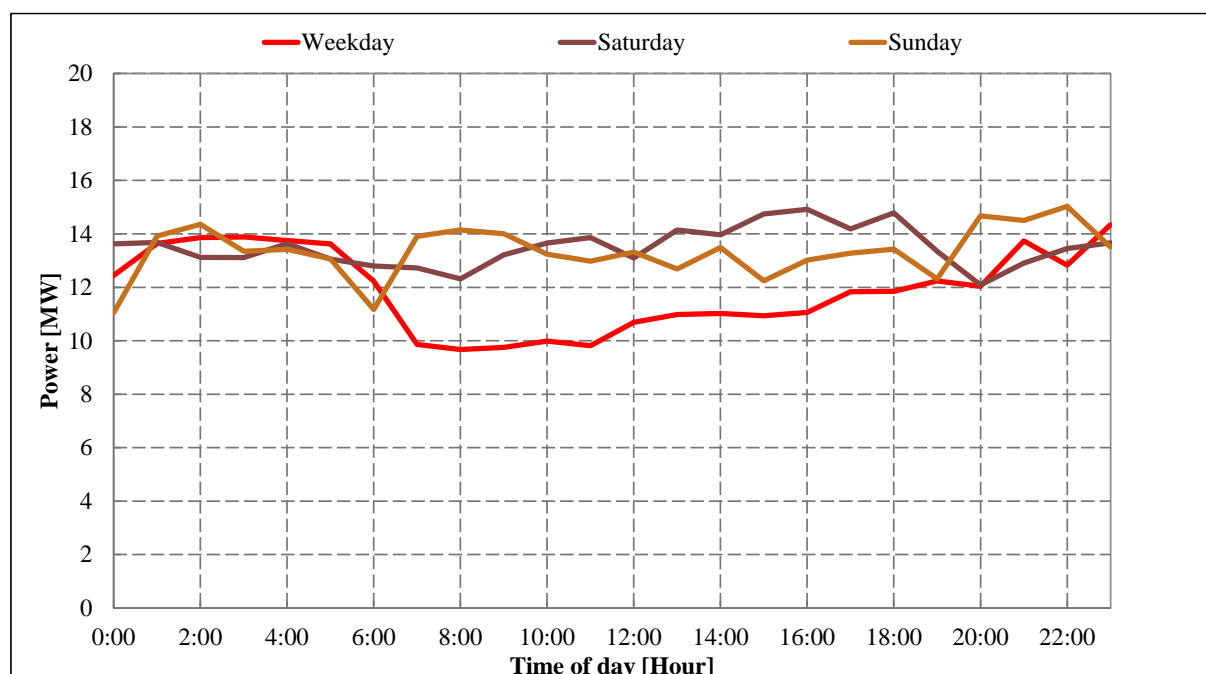
Figure 28: The baseline power profiles for Factory #1

The power profile shows a variation in the average power consumption over the 24 hour daily interval. The variation is between 9 and 15 MW with a clear reduction during the weekday morning hours from 06:00 to 12:00. The reason for this decrease is associated with scheduled maintenance on the grinding mills. The maintenance is carried out during the week and the average weekday power profile shows an incline after 12:00. Evidently, this suggests the component start-up after completion of each maintenance task.

The TOU power consumption for Factory #1 during the baseline period is given in Table 13. The average weekday evening peak load was 11.641 MW. During the load shift intervention the primary aim is to shift the weekday evening peak load to the other TOU intervals.

Table 13: The average electricity demand for the baseline period

Weekday [MW]						
Morning Off-peak	Morning Standard	Morning Peak	Midday Standard	Evening Peak	Evening Standard	Evening Off-peak
13.179	9.179	8.79	10.337	11.641	12.935	14.144

Saturday [MW]					Sunday [MW]	
Morning Off-peak	Morning Standard	Midday Off-peak	Evening Standard	Evening Off-peak	Off-peak	
13.22	13.229	14.457	12.714	13.341	13.336	

During the three month performance assessment period, the DSM project performance was closely monitored and the EMS system was fine-tuned. Reports were sent out on a daily basis to keep all the relevant parties informed of the demand reduction and electricity cost saving. An example of such a report can be seen in Appendix G.

The following results were obtained during the performance assessment period. Figure 29 shows the average power profiles of Factory #1 after implementation of the EMS.
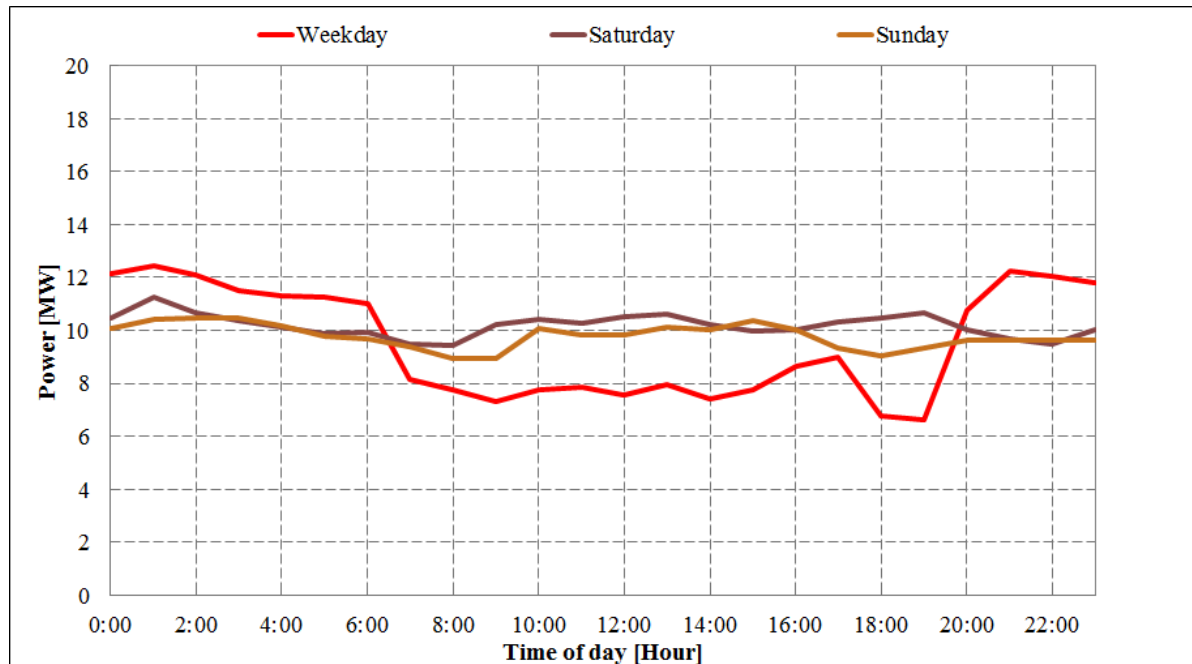
Figure 29: Average power profile of Factory #1

The overall energy consumption is less than the baseline. This shows that the factory was not operating at the same output level as during the baseline period. The baseline is scaled to be energy neutral with the actual electricity consumption over the performance assessment period to validate the savings and can be seen in Figure 30.
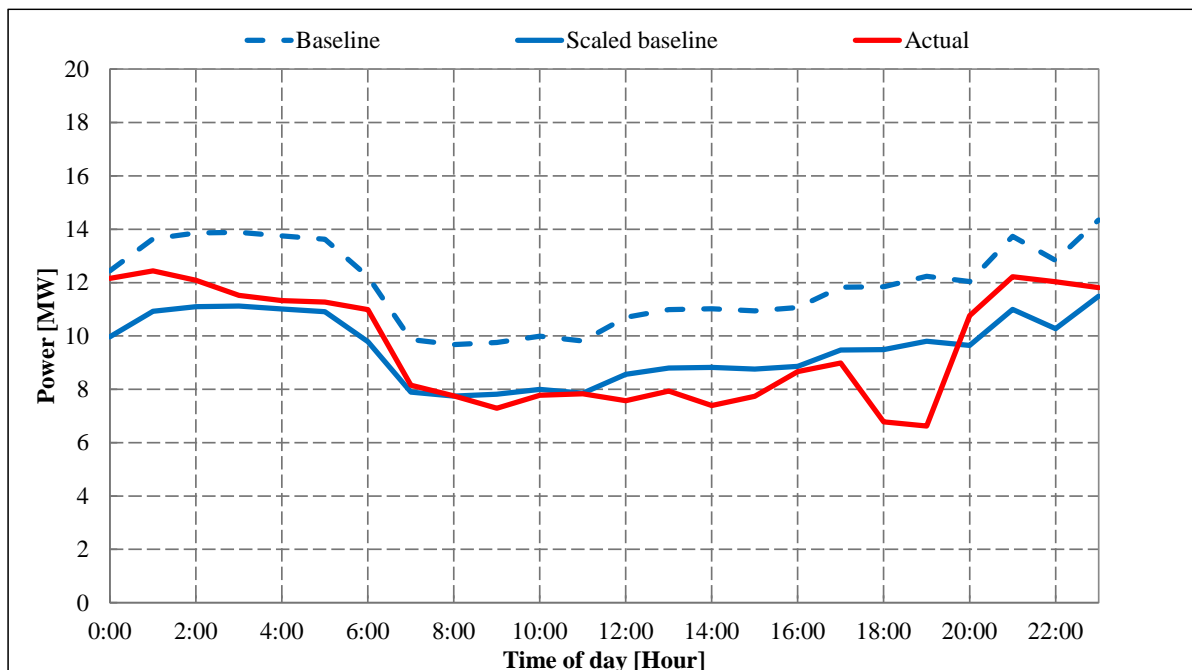
Figure 30: Average daily power profile of Factory #1 during PA

The load management intervention can be clearly seen from Figure 30. A reduced demand is evident between the actual and scaled profiles from 18:00 and 20:00. There is a reduction in power consumption. There is also an increase in electricity demand during the off-peak hours (20:00 to 06:00). This is evidence of effective load management.

After performance assessment (PA) the DSM project was handed over to the client/cement factory. The load management effect was analysed over a two year period. Figure 31 gives a clear indication of the operation/production philosophy adopted. The simulation model primarily focused on evening peak load reduction whereas the client used the EMS as a tool to also focus on the morning peak period to maximise electricity cost savings.
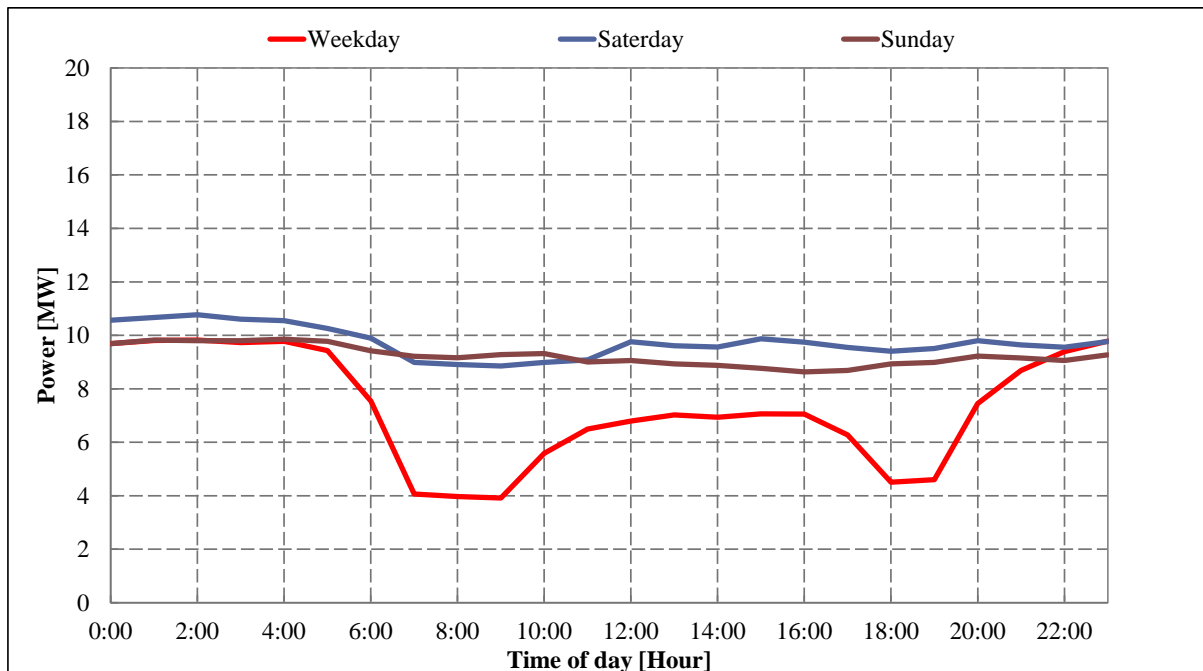
Figure 31: Average daily power profile of Factory #1 during PT

The impact is quantified by comparing the baseline with the actual power profile over the project lifetime. See Figure 32 for a graphical comparison.
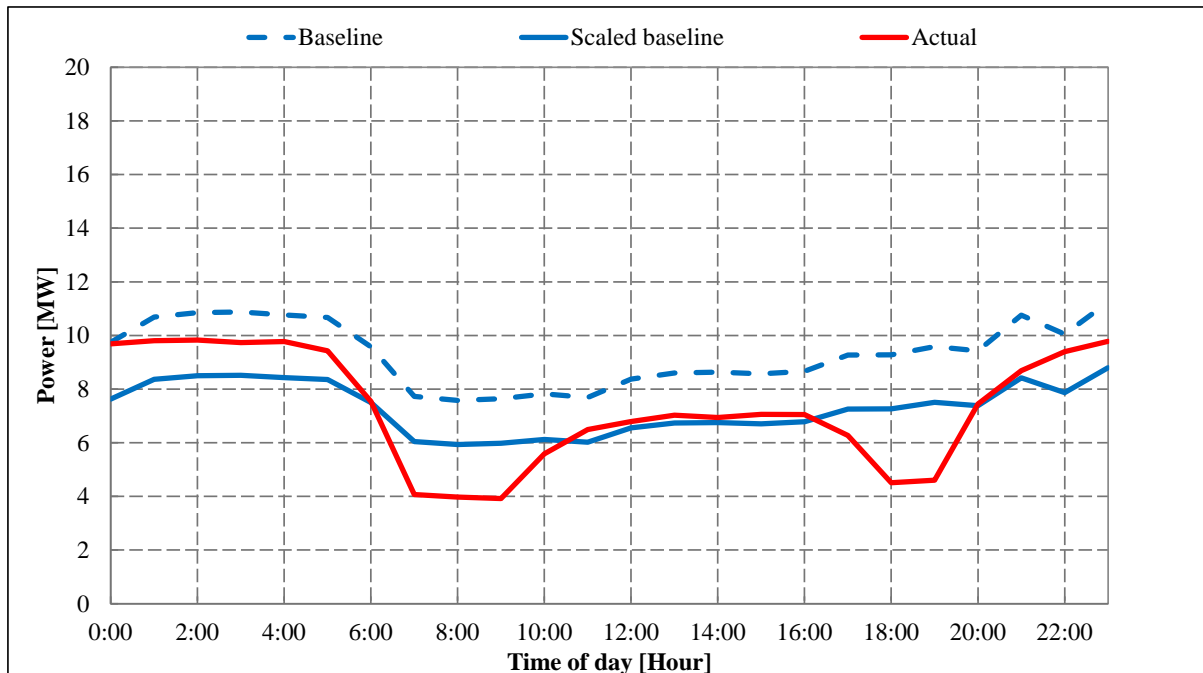
Figure 32: Comparison between baseline and PT power profiles of Factory #1

The average weekday power profile shows a reduction in load between 18:00 and 20:00. There is another negative deflection in the weekday power profile from 07:00 to 10:00 during the morning peak hours. There is also an increase in power consumption during the off-peak hours. It is clear that load management was adopted as part of the production schedule to reduce electricity costs.

The two year PT period was divided into two seasonal groups in accordance with Eskom's winter and summer billing structures. Figure 33 and Figure 34 show the winter and summer power profiles of Factory #1. There was a 2.5% variance in the cumulative weekly electricity demand between the summer and winter during PT.

This proves that seasonal demand constraints cannot be the sole reason for the deviation in the power profiles between winter and summer. It is evident that electricity cost savings, as an incentive for DSM, will result in effective load management by the client.

The demand reduction and electricity cost saving of the two demand-seasons were calculated. Figure 33 shows the evening peak demand reduction of 5.89 MW for the winter demand-season. The summer evening peak demand reduction was 2.55 MW as seen in Figure 34.
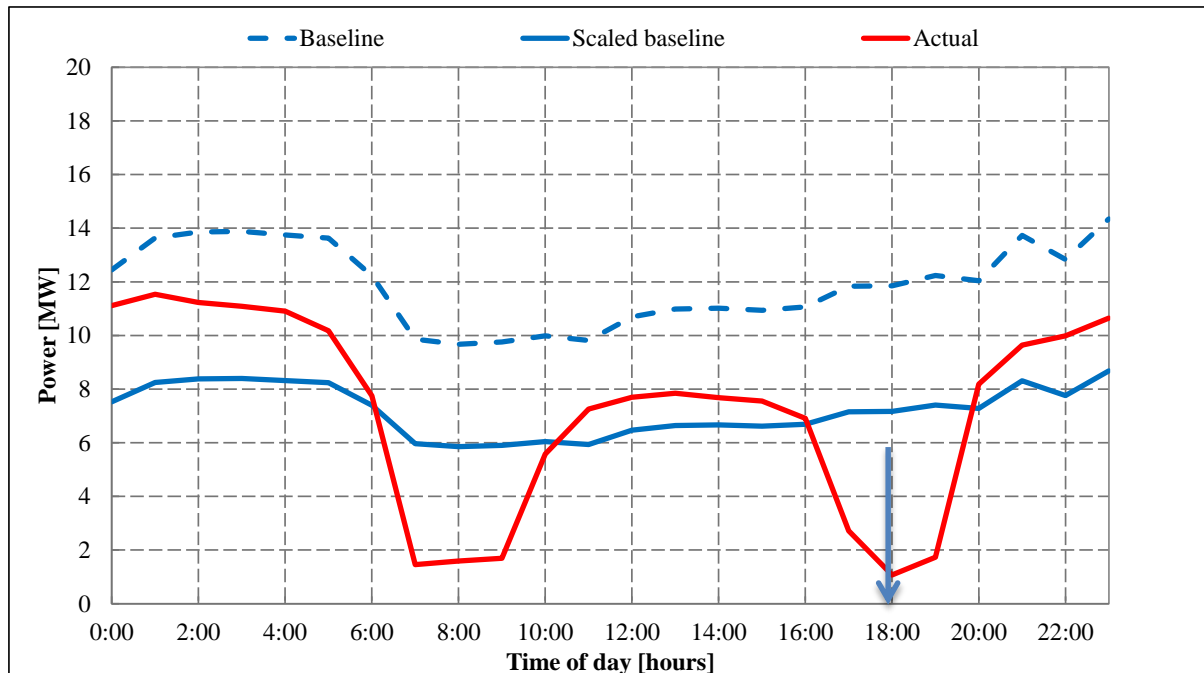
Figure 33: Winter power profile of Factory#1 during PT
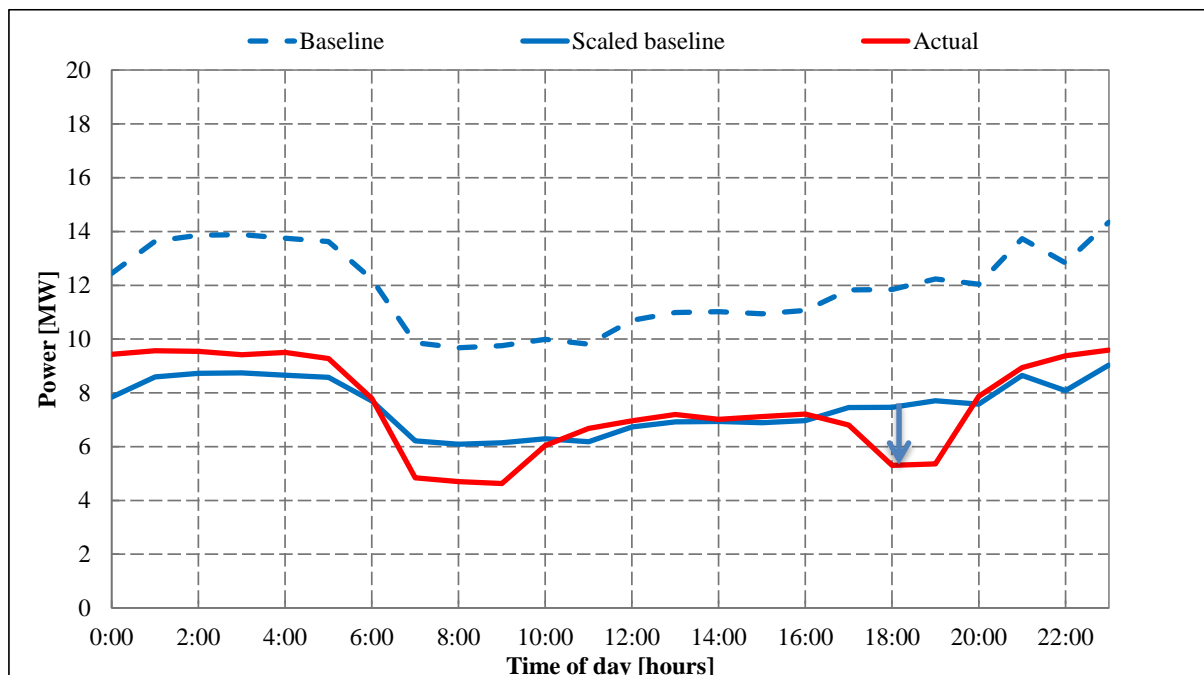
Figure 34: Summer power profile of Factory #1 during PT

The average winter week electricity cost saving is calculated as R 43,584.48 and the average summer week electricity cost saving is calculated as R 6,791.59. The annual electricity cost saving is calculated in Figure 35 as R 3,938,951.72.

Summer electricity cost saving		
	Weekday	Saturday	Sunday
Total	R 6,791.59	-R 8,488.58	-R 3,847.17

Avg Daily Savings	R 3,088.89
Summer Savings	R 843,266.27

Classified as	Saturday	Sunday
Public Holliday	5	6

Total Summer Savings	R 777,729.32

Winter electricity cost saving		
	Weekday	Saturday	Sunday
Total	R 52,258.76	-R 10,273.65	-R 8,928.84

Avg Daily Savings	R 34,584.48
Winter Savings	R 3,181,771.71

Classified as	Saturday	Sunday
Public Holliday	2	0

Total Winter Savings	R 3,161,222.41

Total annual savings	**R 3,938,951.72**

Figure 35: Annual electricity cost saving for Factory #1

Figure 36 shows the cumulative evening peak hour demand reduction of Factory #1. The straight line follows the performance target which was set during PA. The yellow bars represent the monthly average energy saving. There is a non-linear increase during the winter months as indicated by the red arrows.
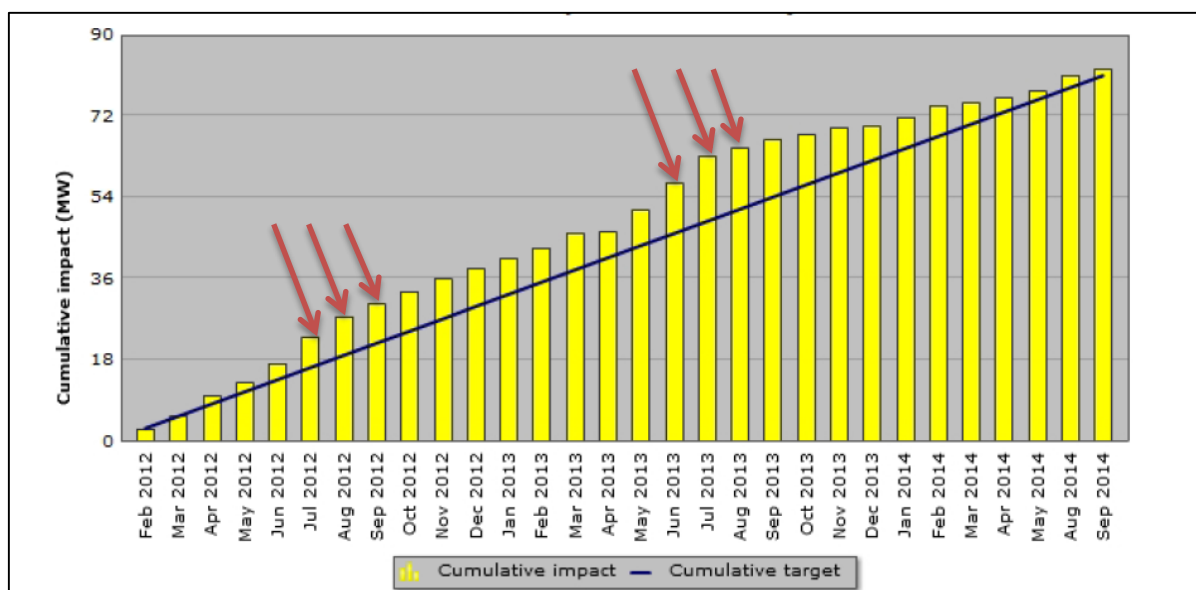
Figure 36: Cumulative evening peak demand reduction of Factory #1

4.3.   Effect on production

There was a concern regarding decreased production due to load shift initiatives. To address this concern the weekly sales targets were used in conjunction with maintenance schedules to accurately forecast the production of cement. An EMS tool, PTB, was developed by the ESCo [74] to assist with the planning of the production schedule as seen in Figure 37. See Appendix A for the weekly production planning sheet and Appendix B for the maintenance schedule, both obtained from Factory #1.
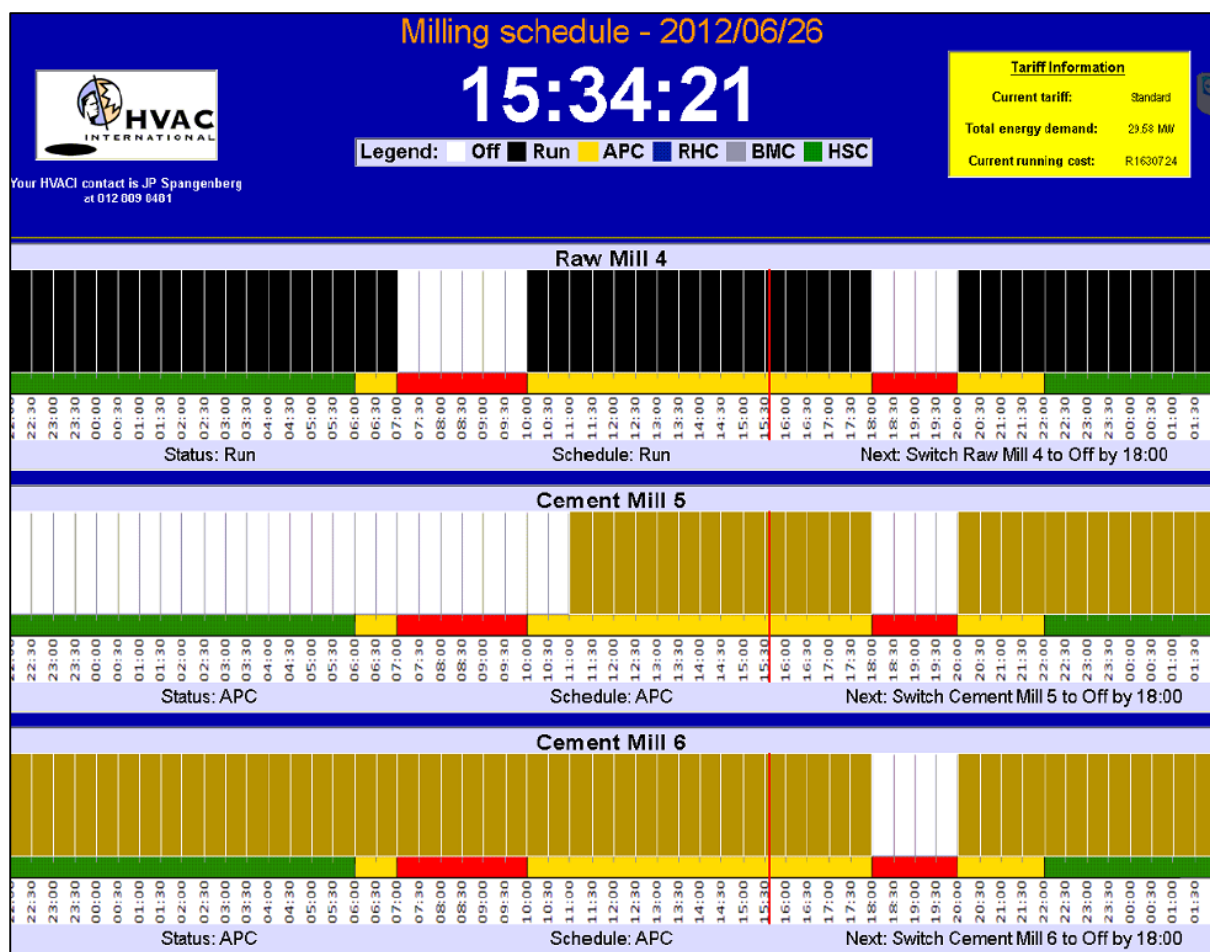
Figure 37: PTB viewer used at Factory #1

The primary objective of PTB was to optimise the production schedule to maximise evening peak demand reduction and electricity cost saving while still meeting the production targets. PTB had to adhere to system constraints at all times. These constraints included production tempos, maintenance schedules and silo levels (minimum and maximum). There was no loss in production due to load shift initiatives.

The monthly production and dispatch figures are shown in Figure 38. The blue line follows the volume of cement produced while the red dotted line represents the volume dispatched. There is a notable variation in the supply and demand quantities per month. The cement silo levels were inspected to further analyse the possible effect on production.
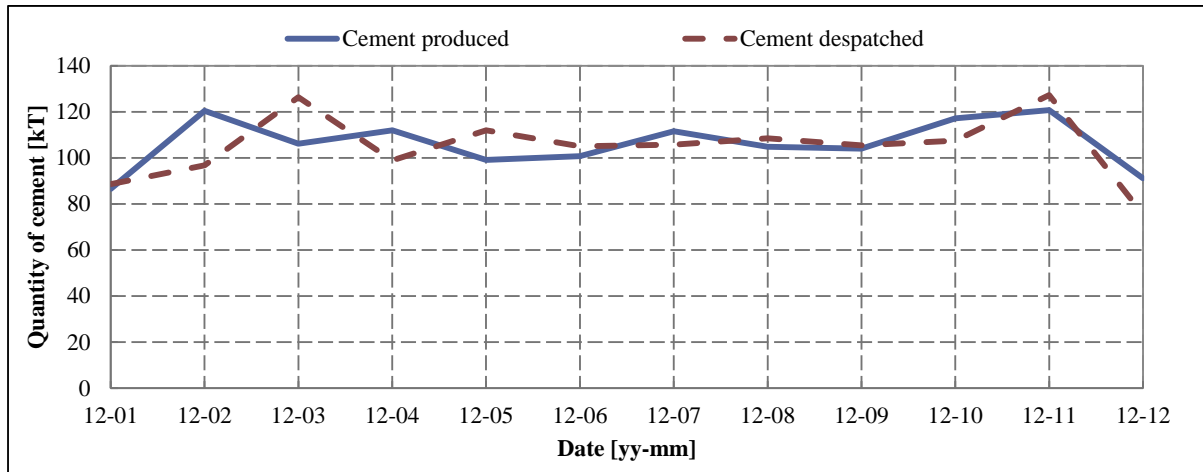
Figure 38: Monthly production and sales figures of Factory #1

Figure 39 trends the cement silo level for a year after the DSM project implementation at Factory #1. The trend shows that the cement level never went below the minimum level.
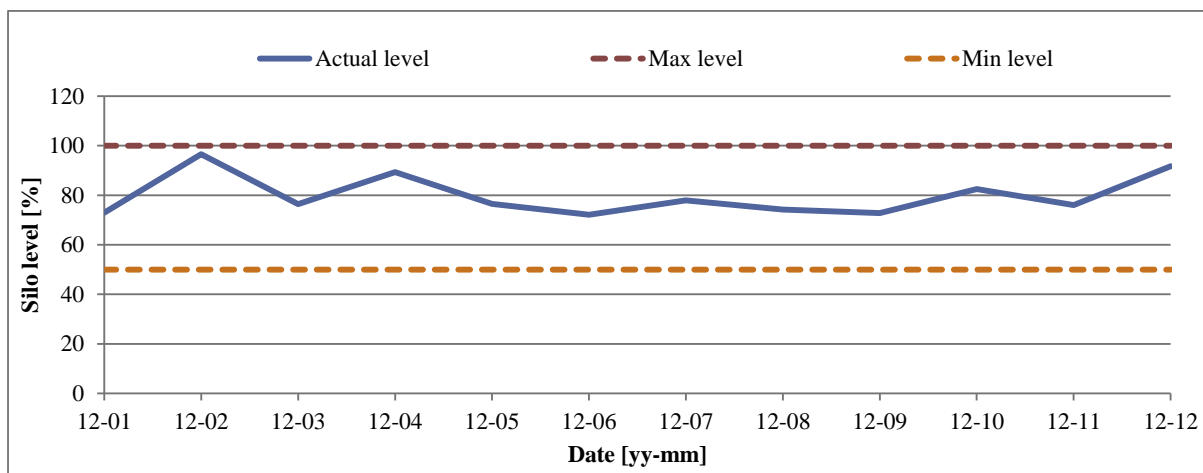
Figure 39: Cement silo level of Factory #1

The monthly variation in Figure 38 together with the cement silo level trend in Figure 39 suggests that the production was not negatively influenced by the DSM project. Therefore it can be concluded that no long-term production loss was experienced due to the load shift intervention.

4.4.   Impact on cement production equipment

Factory #1 is equipped with a liquid resistance starter on the raw mill. During start-up of the raw mill the temperature within the liquid resistance starter increases. The starter is equipped with a cooling system to assist with heat dissipation after start-up. Thus addressing starter temperature increases during bi-daily start-ups associated with load shift initiatives.

The starter will also address the concern with inrush current during start-ups associated with electric motors. Ball mills require high torque during each start-up. Therefore each start-up will decrease the lifecycle of some of the components. It can be argued that this is normal wear and tear and that the aim of this analysis should be to determine the increase in stoppages, therefore increasing the amount of wear and tear.

An example of a component affected by the start-up and shut-down forces is the gearbox. Factory #1 had problems with the gearbox on one of the cement mills. To resolve this problem load shift on this mill was kept to the minimum. Careful planning allowed coordination of the mill shut-down and start-ups with a combined maintenance and load shift schedule.

The mill was shut down before the morning peak and only started after the evening peak during times when the cement demand allowed this prolonged stop. During this time, routine inspection was performed on the mill components and conveyer system and proactive maintenance was carried out. This resulted in lower unplanned stoppages. The average weekly stoppages are less than the 20% increase anticipated from the simulation.

Table 14 shows the results of a study that was done on Factory #1. The aim of the study was to determine the amount of stoppages before and after implementing the DSM project. The study found that over the given time period the average weekly stoppages increased by only 0.75 (15%) after the DSM project implementation. The load shift initiative resulted in a weekly electricity cost saving of R 82,061.49 during the same time.

Table 14: Impact on equipment

	Average weekly stoppages	Average weekly electricity cost saving
Before implementation	5	R 0.00
After implementation	5.75	R 82,061.49

One of the goals of the EMS is to optimise the stoppages that would have happened anyway. This is done by scheduling the planned stoppages to reduce the evening peak electricity consumption without impacting production targets. This slight increase in stoppages resulted in a substantial electricity cost saving. It was previously noted from the long-term results in Figure 21 that the average annual saving after implementation was R 3,938,951.27. An possible increase in maintenance costs is recommended for further study.

4.5.   Quality of the cement product

Rough approximation of the effect on the grinded material quality could be determined without chemical analysis. Through homogenisation in the blending silos the effect of DSM on product quality is neutralised. The method states that if the silo level stays above the minimum constraint; then the effect of DSM on product quality is disregarded.

To determine the effect on the quality, the study focused on the raw meal silo. The raw meal silo feeds raw meal into the kiln and a homogeneous mixture is crucial to ensure optimal clinker production. The raw meal silo level was recorded on a daily basis before and after the DSM project implementation. An optimum control level was selected as a minimum silo level constraint at which homogeneous blending would still result.

Figure 40 shows a pre-implementation frequency graph for the study. The x-axis represents the deviation from the control level in percentages where 0% would be the optimum silo level.

Every occurrence below the 0% level will not allow planned stoppages for load shifting on the raw mill. This is due to the risk of insufficient homogenisation. The flat shaped normal distribution curve suggests poor control.
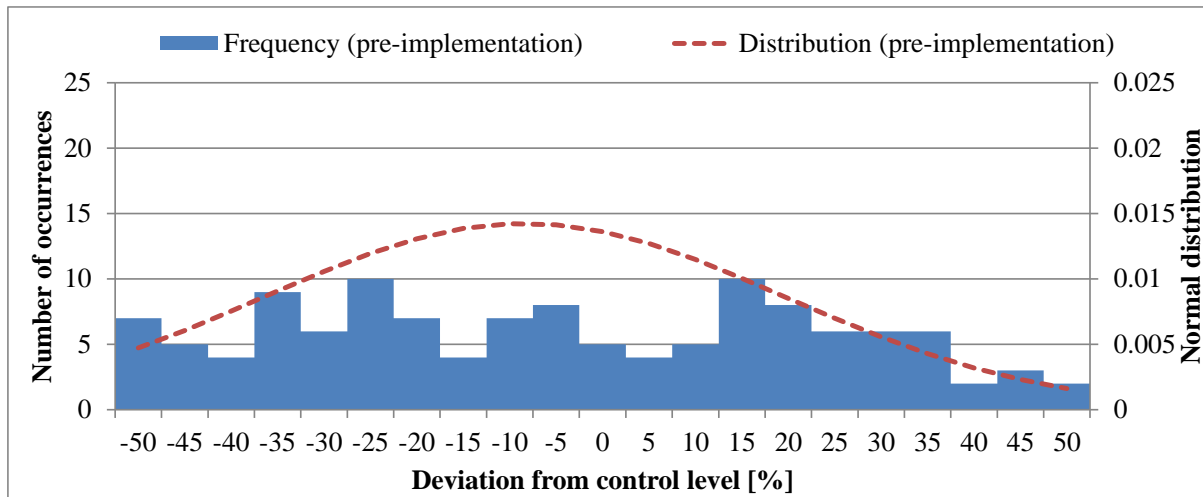
Figure 40: Pre-implementation raw meal silo level distribution

The post-implementation frequency graph can be seen in Figure 41. Notice the typical bell shape of normal distribution curve which suggests improved intelligent production scheduling through the EMS. The median is at 6.9% which indicates that the control philosophy focused on sustaining high raw meal silo levels. High silo levels will result in increased load shifting opportunities.
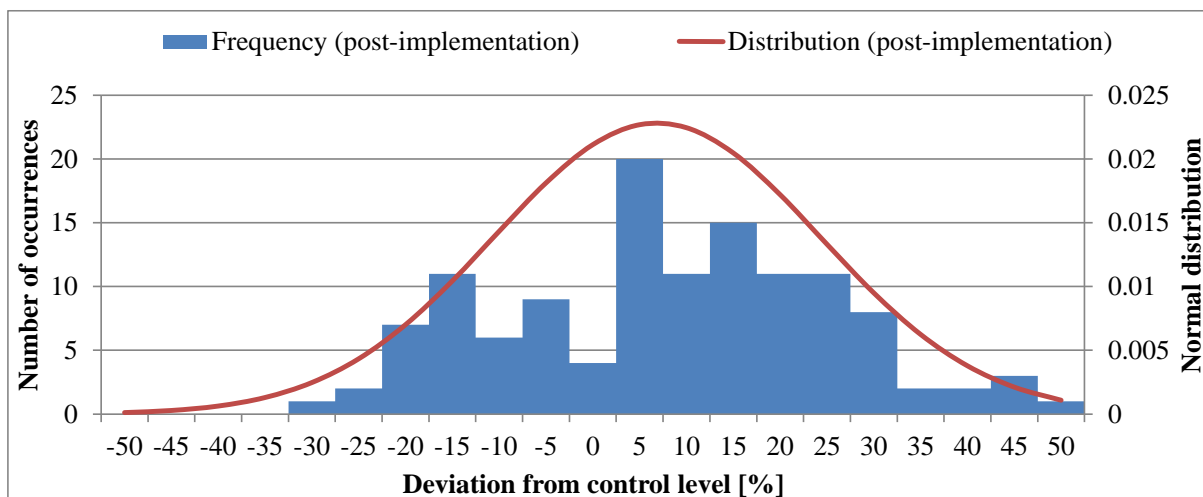
Figure 41: Post-implementation raw meal silo level distribution

Figure 42 shows the difference between the pre- and post-implementation normal distribution curves. Notice the mean shift from -8.4% to 6.9% and the increased distribution around the optimum level which indicates improved control.
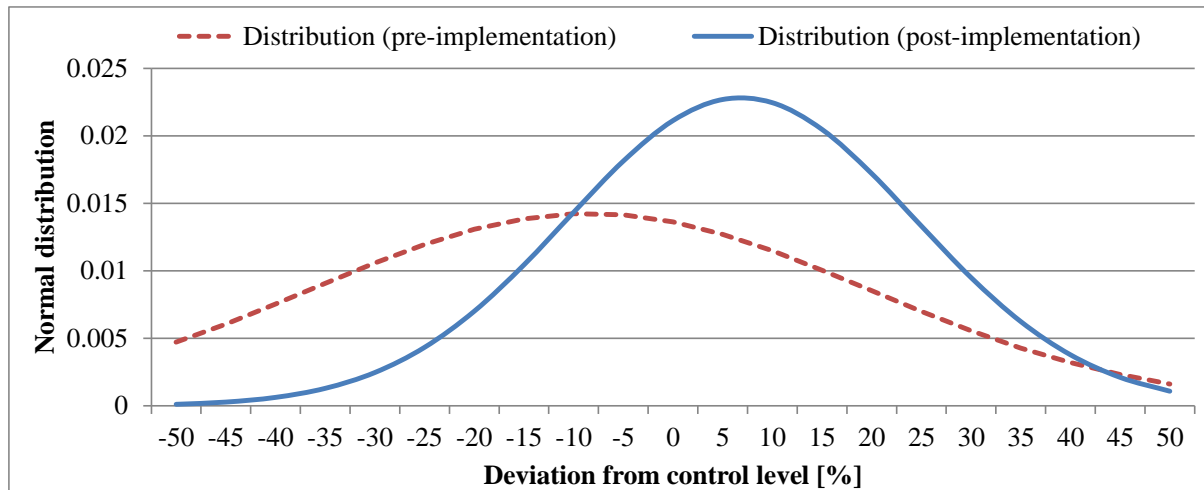
Figure 42: Pre- and post-implementation raw meal silo level control improvement

Production output was one of the primary constraints in the EMS. Sufficient silo levels were prioritised above load shift stoppages. Load shift was not suggested by the EMS if the raw meal silo level was below the optimum level. This resulted in an improvement in silo level control and therefore, through this analysis, the nett effect on product quality was positive.

Figure 43 shows room for further improvements in silo level control. This simulation model suggested that a much more effective control band is possible. The reason why the actual post-implementation control level distribution differs from the simulation is a direct result of the factory's need for electrical cost savings.

The simulation model was executed to realise maximum peak demand reduction without affecting production. This is done by optimising the production schedule to plan around silo levels while realising maximum evening peak demand reduction.

After implementation of the project the factory prioritised morning peak load reduction. This led to a larger deviation in control level to include capacity for prolonged stoppages and thus maximising electrical cost savings.
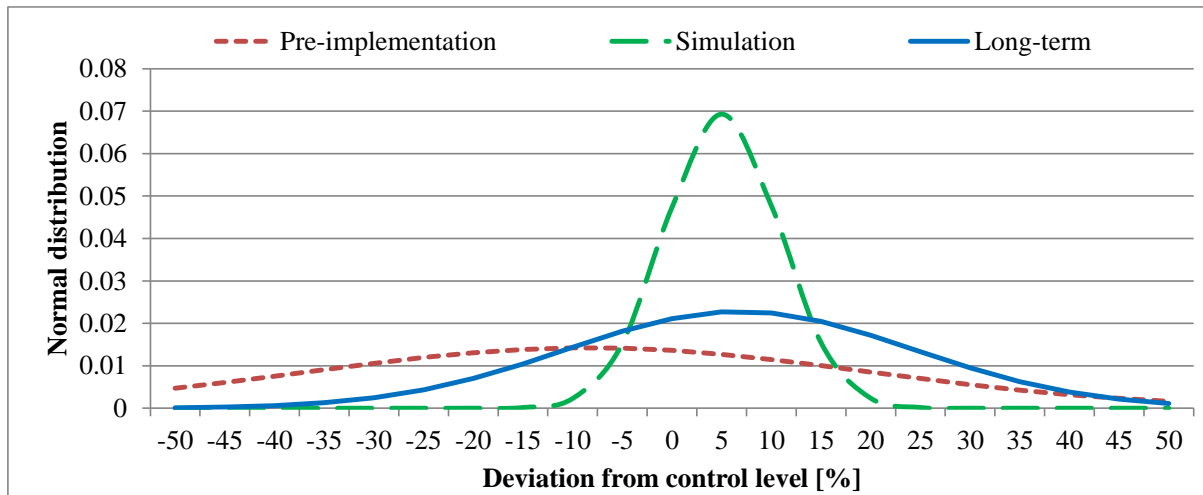
Figure 43: Difference between simulated and actual raw meal silo level control

4.6.   Sustainability

The sustainability of DSM projects in any industry depends largely on stakeholder awareness. Previous success within the field of DSM at cement factories will improve the sustainability of these projects. This study includes references to media announcements and reports. After a successful three month winter performance in 2012, Factory #1 released a statement in their monthly newsletter. The holding company pursued more DSM projects on three of their other factories.

This newsletter together with the savings reports were seen by key personnel in the planning, maintenance and electrical departments of the factory. Appendix G is an example of the daily report issued by the ESCo.

This led to adoption of DSM initiatives at other parts of Factory #1. The initial project only focused on the cement mills. Successful electricity cost savings were reported and in doing so improved the sustainability of the project. The factory quickly adopted the strategy to the raw milling part of the production line which led to further electricity cost savings.

A second company released a statement on their website stating the successful implementation on two of their sites. The company also reported that they are expanding DSM projects on three of their other sites. The statement can be seen in Appendix F.

The implementation of DSM projects on South African cement factories raised awareness within the entire local cement industry. Group reports were sent out to the stakeholders of each company that participated in the DSM initiative.

Successful DSM project implementation with sustained electricity cost savings on the researched factory led to wider adoption within the South African cement industry. The initial mind shift was difficult to achieve, but once the results validated the concept, the factories used the DSM projects to their advantage.

4.7.   Conclusion

The load shift project was monitored over a period of two years. The quantified long-term demand reduction and electricity cost implications were compared with the expected simulation results. Table 15 gives a summary of the expected simulation results and the actual long-term results for Factory #1.

Table 15: Summary of demand reduction and electricity cost saving results

	Simulation	Actual	Percentage
Load shift target	3.07 MW	3.39 MW	110%
Summer	3.07 MW	2.55 MW	83%
Winter	3.07 MW	5.89 MW	192%
Annual cost saving	R 450,535	R 3,938,951	774%
Summer	R 141,938	R 777,729	548%
Winter	R 308,597	R 3,161,222	1,024%

The peak demand reduction for Factory #1 was 10% more than the simulated target anticipated. A seasonal effect was visible from the long-term results. The summer evening peak demand reduction is 17 % less than the simulation suggested and the winter saving is 92% more. This increase is guided by awareness of the electricity cost saving.

The electricity cost saving was more than anticipated throughout the year. Figure 30 and Figure 31 in section 4.2 show the difference between the PA and PT power profiles. This correlates with the over performance in demand reduction and electricity cost savings. The PA phase was

handled by the ESCo and focus was placed on achieving the evening peak load reduction target. It is clear that the cement factory adopted the EMS as an optimisation tool after the PA phase.

During the PA phase adoption of the EMS gradually incentivised the production team during the weekly feedback meeting with the ESCo. There was no effect on production, quality of the cement product and minimum impact on the equipment. After handover the PT phase commenced and the factory was contractually obligated to sustain the evening peak demand reduction target for the duration of five years.

A mind shift was made by the production team to realise maximum electricity cost saving by implementing morning load shift as first priority. This was clearly deducted from the increase in load management performance during the winter months. As seen in Table 15, the winter energy saving was 92% more than the simulated yearly average and the electrical energy cost saving was 774% more that the simulated yearly total. Lastly, the over performance shows the positive effect that increased awareness has on DSM projects at South African cement factories. Increased awareness leads to sustainable DSM projects.

Table 16 gives a summary of the long-term results assessed by this research project. The summary clearly shows that the research project addressed the need described in section 1.3.

Table 16: Summary of long-term results

Effect of DSM	Simulation	Actual implementation
Demand reduction and electricity cost saving	Long-term savings were simulated	Actual savings were quantified
Production	Long-term production figures were simulated – no effect on production anticipated	Actual production figures were quantified with – no effect on production found
Impact on equipment	20% additional stoppages anticipated	15 % increase in stoppages were recorded – less than anticipated
Product quality	Silo levels simulated within boundaries	Silo levels controlled within boundaries – improved control visible
Sustainability	Sustainability was predicted	The substantial electricity cost savings increased the awareness and improved the sustainability

5. Conclusion and recommendations

Chapter 5 provides the final conclusion to this study with findings on the effects of DSM projects at South African cement factories. Validation of the initial study aim is reiterated. Recommendations are discussed and the adoption of this analysis model in other industries is identified for possible future investigation.

Image courtesy of C Kriel

5.1.   Introduction

The research objective was to analyse the effect of DSM projects at South African cement factories. South-Africa is on the industrial forefront in Africa, producing 43% of the continent's energy. The national power grid is under pressure in an attempt to supply the growing electricity demand with a safe reserve margin intact. It was noted that, in 2007, previous attempts to keep the power grid stable resulted in load shedding throughout South Africa. In 2014/2015 load shedding was once again implemented by Eskom.

DSM was initially proven as a successful short-term intervention to increase the stability of the national power grid. This led to the implementation of DSM projects in the industrial sector. Various research studies and simulations were conducted on the possibility of DSM projects at cement factories. The projects were found to be feasible and implementation started in 2012.

The fundamental structure of the analysis was constructed throughout the literature review and by studying the South African cement factories during and after the implementation of DSM projects.

5.2.   Addressing the effect of DSM projects

A need existed to analyse the effect of DSM projects at South African cement factories. This section gives a brief overview of the need that existed and how each of these gaps was addressed.

Demand reduction and electricity cost savings:

There existed a need to identify and address the different stakeholder's impacts and benefits. Eskom needs to see results in terms of energy savings, whereas the factory requires results in terms of energy cost savings. The long-term sustainability of demand reduction and electricity cost savings was quantified and reported in this study.

The energy saving was within 10% of the predicted simulation savings. However the cost savings was significantly larger than estimated. The analysis showed adoption of the evening peak load shift strategy into the morning peak was also important.

Effect on production:

Simulations and pilot studies showed that load shift did not affect the daily sales and production targets. The pilot studies were on single components with adjoining silos of the production line. There existed a need to determine the effect of simultaneously load shifting on various components of the production line over a long period of time. The long-term effect on production and sales targets was recorded.

There was no negative effect on the production targets. The simulation model scheduled the milling components to minimise electricity cost within the production constraints. The long-term results showed the importance of silos as a buffer component in the DSM model. Without adequate storage capacity the DSM project will not be sustainable.

Impact on cement production equipment:

DSM project funding allows for infrastructure upgrades that automate and monitor the system. The projects also allow for optimisation of the operational philosophy and production schedule. The long-term effect on cement production equipment was determined.

The simulation model rescheduled the planned stop/start intervals to optimise energy and cost savings without increasing the amount of stoppages. The long-term effects showed an increase in stoppages of 15%. The increase was due to the additional morning stoppages to maximise electricity cost savings. A longer time period is required to quantify the financial implication of the additional stoppages.

Effect on cement quality:

The sensitivity of DSM initiatives on the grinding processes and clinker formation was researched. The effect on the product quality was discussed and found negligible. Homogenisation occurs naturally in the silos. The simulation model and actual results showed that the silo levels were kept within the acceptable boundaries and allowed sufficient blending. The long-term results showed *improved* silo level management.

Sustainability:

The successful implementation and practical follow-through of DSM projects at South African cement factories led to widespread adoption in the cement production market. The substantial electricity cost savings increased the awareness. The initial mind shift to focus on the energy management through the DSM project was difficult to achieve. However the results supported the concept and widespread adoption followed throughout the South African cement industry.

Table 17 summarises the effects of DSM projects at South African cement factories.

Table 17: Summary of the effect of DSM projects at South African cement factories

Effect of DSM	Simulation	Actual implementation	Outcome	Additional remarks
Demand reduction and electricity cost savings	Long-term savings were simulated	Actual savings were quantified	Savings were found to be sustainable and load management practices was adopted by the factory	Morning peak TOU period was also utilised, especially in the winter
Effect on production	Long-term production figures were simulated	Actual production figures were quantified	No effect on production targets were found	PTB decreased the risk of short-fall with better monitoring
Impact on equipment	20% additional stoppages anticipated	Only 15% increase in stoppages	The increase in stoppages were found to be minimal and resulted in increased electricity cost savings	Additional stoppages were enforced by factory personnel to minimise electricity cost during winter months
Product quality	Silo levels simulated within boundaries	Silo levels controlled within boundaries	Homogenisation in silos eliminated the effect of stoppages and the silo level control improved	The effect of stoppages on product quality does exist, but the effect is neutralised with sufficient homogenisation
Sustainability	Sustainability was predicted	The substantial electricity cost savings increased the awareness and improved the sustainability	Results validated the concept and wide spread adoption followed throughout the South African cement industry	The initial mind shift to was difficult as with each new technology or method

5.3.   Recommendations for future research

The study addressed the stakeholder's primary questions. Future work might include, but is not limited to the following:

Production line industries: Analysis of the effects of DSM projects on other production line industries might yield positive results, i.e. palletiser plants, base metal refineries, bulk water transfer schemes, gold plants and ore distribution logistics.

New built factories: The optimisation of new built cement factory designs to account for TOU production philosophies. The cost saving effect might justify design alterations to minimise electricity cost through intelligent load management scheduling.

Increased maintenance cost: The full effect of load shift on electrical and mechanical equipment was not analysed. Load shifting on cement factory equipment has only been done for a short while and might have a substantial increase in maintenance costs and decreased equipment lifetime. This possible effect needs to be quantified over a prolonged time period.

5.4.   Conclusion of study

Analysing the effects of DSM projects at South African cement factories contributes to the industrial sector by addressing various shortcomings in literature. The broad spectrum of effects highlights the sustainability of DSM projects on production line factories. The load shift initiative contributes to the stability of the national power grid through peak demand reduction. Electricity cost savings that are realised through the load shift initiative were found to be substantially beneficial to the factory.

This research reassures South African cement factories that the case study showed no negative effects on the sustainability of DSM projects after implementation. The long-term impacts on equipment, cement production and quality showed no reason for concern. The DSM projects contributed to the cement industry by supplying an edge in a highly competitive market. The financial benefits resulted in widespread awareness within the industry and emphasised the importance of DSM for both the client and the supplier. Sustainability of DSM projects within the cement production industry improves the electricity situation in South Africa.

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Appendix A – Factory #1 production schedule

Product	HSC	APC	BPC	Roadstab		TOTAL/WEEK orders	
Rate	140	155	145	145		Product	Ton
Req	4136	22550	880	220		HSC	4136
Additional	0	0	0			APC	22550
Total	4136	22550	1100			BPC	880
Hrs req	30	145	8			Roadstab	220
Milled	5785	23700	0			Total	27786
Surplus	1649	1150	-1100				
Total	29485						

		Raw Mill	Run Hours			
Day	**Date**	**Off Peak**	**Hrs**	**Rate**	**Tons**	
Mon	2013-06-03	06:45 - 10:15	0	350	0	Power Planning
Mon	2013-06-03	10:15 - 17:45	7.5	350	2625	
Mon	2013-06-03	17:45 - 20:15	0	350	0	Power Planning
Mon	2013-06-03	20:15 - 06:45	10.5	350	3675	
Tue	2013-06-04	06:45 - 10:15	0	350	0	Power Planning
Tue	2013-06-04	10:15 - 17:45	7.5	350	2625	
Tue	2013-06-04	17:45 - 20:15	0	350	0	Power Planning
Tue	2013-06-04	20:15 - 05:30	9.75	350	3412.5	
Wed	2013-06-05	05:30 - 10:15	0	350	0	Schedules
Wed	2013-06-05	10:15 - 17:45	0	350	0	Schedules
Wed	2013-06-05	17:45 - 20:15	0	350	0	Power Planning
Wed	2013-06-05	20:15 - 06:45	10.5	350	3675	
Thu	2013-06-06	06:45 - 10:15	0	350	0	Power Planning
Thu	2013-06-06	10:15 - 17:45	7.5	350	2625	
Thu	2013-06-06	17:45 - 20:15	0	350	0	Power Planning
Thu	2013-06-06	20:15 - 06:45	10.5	350	3675	
Fri	2013-06-07	06:45 - 10:15	0	350	0	Power Planning
Fri	2013-06-07	10:15 - 17:45	7.5	350	2625	
Fri	2013-06-07	17:45 - 20:15	0	350	0	Power Planning
Fri	2013-06-07	20:15 - 06:00	9.75	350	3412.5	
Sat	2013-06-08	06:00 - 06:00	24	350	8400	
Sun	2013-06-09	06:00 - 06:45	24.75	350	8662.5	
		Sub Totals	129.75	350	45412.5	

		CM 5	Run Hours			Rate			Tons			
Day	**Date**	**Off Peak**	**HSC**	**APC**	**BPC**	HSC	APC	BPC	**HSC**	**APC**	**BPC**	**Clinker extraction**
Mon	2013-06-03	06:45 - 10:15	0	0	0	135	150	145	0	0	0	Power Planning
Mon	2013-06-03	10:15 - 17:45	0	7.5	0	130	150	145	0	1125	0	25% old 75% fresh
Mon	2013-06-03	17:45 - 20:15	0	0	0	130	150	145	0	0	0	Power Planning
Mon	2013-06-03	20:15 - 06:45	10.5	0	0	130	150	145	1365	0	0	Silo
Tue	2013-06-04	06:45 - 10:15	0	0	0	130	150	145	0	0	0	Power Planning
Tue	2013-06-04	10:15 - 17:45	0	7.5	0	130	150	145	0	1125	0	25% old 75% fresh
Tue	2013-06-04	17:45 - 20:15	0	0	0	130	150	145	0	0	0	Power Planning
Tue	2013-06-04	20:15 - 06:45	0	10.5	0	130	150	145	0	1575	0	25% old 75% fresh
Wed	2013-06-05	06:45 - 10:15	0	0	0	130	150	145	0	0	0	Power Planning
Wed	2013-06-05	10:15 - 17:45	7.5	0	0	130	150	145	975	0	0	Silo
Wed	2013-06-05	17:45 - 20:15	0	0	0	130	150	145	0	0	0	Power Planning
Wed	2013-06-05	20:15 - 06:45	0	10.5	0	130	150	145	0	1575	0	25% old 75% fresh
Thu	2013-06-06	06:45 - 10:15	0	0	0	130	150	145	0	0	0	Power Planning
Thu	2013-06-06	10:15 - 17:45	0	7.5	0	130	150	145	0	1125	0	25% old 75% fresh
Thu	2013-06-06	17:45 - 20:15	0	0	0	130	150	145	0	0	0	Power Planning
Thu	2013-06-06	20:15 - 06:45	10.5	0	0	130	150	145	1365	0	0	Silo
Fri	2013-06-07	06:45 - 10:15	0	0	0	130	150	145	0	0	0	Power Planning
Fri	2013-06-07	10:15 - 17:45	0	7.5	0	130	150	145	0	1125	0	25% old 75% fresh
Fri	2013-06-07	17:45 - 20:15	0	0	0	130	150	145	0	0	0	Power Planning
Fri	2013-06-07	20:15 - 06:00	0	9.75	0	130	150	145	0	1463	0	Silo
Sat	2013-06-08	06:00 - 06:00	0	24.0	0	130	150	145	0	3600	0	Silo
Sun	2013-06-09	06:00 - 06:45	16.0	8.0	0	130	150	145	2080	1200	0	Silo
		Sub Totals	44.5	92.8	0	130.2	150	145	5785	13913	0	
		CM 6	Run Hours			Rate			Tons			
Day	**Date**	**Off Peak**	**HSC**	**APC**	**BPC**	HSC	APC	BPC	**HSC**	**APC**	**BPC**	**Clinker extraction**
Mon	2013-06-03	06:45 - 10:15	0	0	0	135	150	145	0	0	0	ND
Mon	2013-06-03	10:15 - 17:45	0	0	0	130	150	145	0	0	0	ND
Mon	2013-06-03	17:45 - 20:15	0	0	0	130	150	145	0	0	0	ND
Mon	2013-06-03	20:15 - 06:00	0	0	0	130	150	145	0	0	0	ND
Tue	2013-06-04	06:00 - 10:15	0	0	0	130	150	145	0	0	0	Schedules
Tue	2013-06-04	10:15 - 17:45	0	0	0	130	150	145	0	0	0	Schedules
Tue	2013-06-04	17:45 - 20:15	0	0	0	130	150	145	0	0	0	ND
Tue	2013-06-04	20:15 - 06:45	0	0	0	130	150	145	0	0	0	ND
Wed	2013-06-05	06:45 - 10:15	0	0	0	130	150	145	0	0	0	ND
Wed	2013-06-05	10:15 - 17:45	0	0	0	130	150	145	0	0	0	ND
Wed	2013-06-05	17:45 - 20:15	0	0	0	130	150	145	0	0	0	ND
Wed	2013-06-05	20:15 - 06:45	0	0	0	130	150	145	0	0	0	ND
Thu	2013-06-06	06:45 - 10:15	0	0	0	130	150	145	0	0	0	ND
Thu	2013-06-06	10:15 - 17:45	0	0	0	130	150	145	0	0	0	ND
Thu	2013-06-06	17:45 - 20:15	0	0	0	130	150	145	0	0	0	ND
Thu	2013-06-06	20:15 - 06:45	0	0	0	130	150	145	0	0	0	ND
Fri	2013-06-07	06:45 - 10:15	0	0	0	130	150	145	0	0	0	ND
Fri	2013-06-07	10:15 - 17:45	0	7.5	0	130	150	145	0	1125	0	25% old 75% fresh
Fri	2013-06-07	17:45 - 20:15	0	0	0	130	150	145	0	0	0	Power Planning
Fri	2013-06-07	20:15 - 06:00	0	9.75	0	130	150	145	0	1463	0	Silo
Sat	2013-06-08	06:00 - 06:00	0	24	0	130	150	145	0	3600	0	Silo
Sun	2013-06-09	06:00 - 06:45	0	24	0	130	150	145	0	3600	0	Silo
			0	65.3	0	130.2	150	145	0	9788	0	
		Total	44.5	158	0	130.2	150	145	5785	23700	0	

Appendix B – Example of Factory #1 stop matrix

Date	Day	Week Number	Crusher	Raw Mill	Kiln	Coal Mill	Cement Mill 5	Cement Mill 6	Pack 3 & Pall 1	Pack 1,2 & Pall 2	Bulk Loading	Tippler
03-Jun	Monday	23							X			
04-Jun	Tuesday	23						X				
05-Jun	Wednesday	23		X								
06-Jun	Thursday	23	x			X						
07-Jun	Friday	23										
08-Jun	Saturday	23										
09-Jun	Sunday	23										

Appendix C – Eskom Megaflex tariff pricing

Megaflex tariff — Non-local authority

Transmission zone	Voltage	Active energy charge [c/kWh]												Transmission network charges [R/kVA/m]	
		High demand season [Jun - Aug]						Low demand season [Sep - May]							
		Peak		Standard		Off Peak		Peak		Standard		Off Peak			
			VAT incl		VAT incl		VAT incl		VAT incl		VAT incl		VAT incl		VAT incl
≤ 300km	< 500V	204.55	233.19	62.23	70.94	33.97	38.73	66.98	76.36	46.22	52.69	29.46	33.58	R 5.85	R 6.67
	≥ 500V & < 66kV	201.33	229.52	60.99	69.53	33.12	37.76	65.68	74.88	45.20	51.53	28.68	32.70	R 5.35	R 6.10
	≥ 66kV & ≤ 132kV	194.96	222.25	59.06	67.33	32.07	36.56	63.60	72.50	43.77	49.90	27.77	31.66	R 5.21	R 5.94
	> 132kV	183.75	209.48	55.66	63.45	30.23	34.46	59.94	68.33	41.25	47.03	26.18	29.85	R 6.58	R 7.50
> 300km and ≤ 600km	< 500V	206.21	235.08	62.48	71.23	33.93	38.68	67.27	76.69	46.31	52.79	29.38	33.49	R 5.90	R 6.73
	≥ 500V & < 66kV	203.34	231.81	61.60	70.22	33.45	38.13	66.34	75.63	45.65	52.04	28.96	33.01	R 5.40	R 6.16
	≥ 66kV & ≤ 132kV	196.88	224.44	59.64	67.99	32.38	36.91	64.22	73.21	44.19	50.38	28.04	31.97	R 5.25	R 5.99
	> 132kV	185.58	211.56	56.22	64.09	30.52	34.79	60.53	69.00	41.66	47.49	26.43	30.13	R 6.65	R 7.58
> 600km and ≤ 900km	< 500V	208.27	237.43	63.08	71.91	34.25	39.05	67.94	77.45	46.76	53.31	29.66	33.81	R 5.97	R 6.81
	≥ 500V & < 66kV	205.38	234.13	62.22	70.93	33.79	38.52	67.00	76.38	46.11	52.57	29.25	33.35	R 5.44	R 6.20
	≥ 66kV & ≤ 132kV	198.88	226.72	60.25	68.69	32.71	37.29	64.87	73.95	44.65	50.90	28.32	32.28	R 5.29	R 6.03
	> 132kV	187.45	213.69	56.78	64.73	30.84	35.16	61.15	69.71	42.08	47.97	26.70	30.44	R 6.74	R 7.68
> 900km	< 500V	210.36	239.81	63.74	72.66	34.61	39.46	68.63	78.24	47.23	53.84	29.97	34.17	R 5.99	R 6.83
	≥ 500V & < 66kV	207.43	236.47	62.83	71.63	34.11	38.89	67.66	77.13	46.56	53.08	29.54	33.68	R 5.51	R 6.28
	≥ 66kV & ≤ 132kV	200.88	229.00	60.85	69.37	33.04	37.67	65.52	74.69	45.10	51.41	28.61	32.62	R 5.32	R 6.06
	> 132kV	189.29	215.79	57.37	65.40	31.17	35.53	61.78	70.43	42.53	48.48	27.00	30.78	R 6.79	R 7.74

Distribution network charges

Voltage	Network access charge [R/kVA/m]		Network demand charge [R/kVA/m]		Urban low voltage subsidy charge [R/kVA/m]	
		VAT incl		VAT incl		VAT incl
< 500V	R 11.63	R 13.26	R 22.05	R 25.14	R 0.00	R 0.00
≥ 500V & < 66kV	R 10.67	R 12.16	R 20.23	R 23.06	R 0.00	R 0.00
≥ 66kV & ≤ 132kV	R 3.81	R 4.34	R 7.05	R 8.04	R 9.39	R 10.70
> 132kV	R 0.00	R 0.00	R 0.00	R 0.00	R 9.39	R 10.70

Reliability service charge [c/kWh]

Voltage		VAT incl
< 500V	0.27	0.31
≥ 500V & < 66kV	0.26	0.30
≥ 66kV & ≤ 132kV	0.25	0.29
> 132kV	0.23	0.26

Customer categories	Service charge [R/account/day]		Administration charge [R/POD/day]	
		VAT incl		VAT incl
> 1 MVA	R 133.50	R 152.19	R 60.17	R 68.59
Key customers	R 2,616.06	R 2,982.31	R 83.55	R 95.25

Reactive energy charge [c/kVArh]

High season		Low season	
	VAT incl		VAT incl
9.40	10.72	0.00	0.00

Electrification and rural network subsidy charge [c/kWh]		Affordability subsidy charge [c/kWh] payable by non-local authority tariffs	
All seasons		All seasons	
	VAT incl		VAT incl
5.20	5.93	2.07	2.36

Appendix D – Factory #1 production data

	Clinker produced [ton]	Cement produced [ton]	Despatches [ton]	Coal usage [ton]	Coal CV [MJ/kg]
		██████ production and sales figures			
Jan-12	80,825.00	86,576.00	88,640.35	11,333.09	25.87
Feb-12	100,097.00	120,493.00	96,864.54	14,675.05	25.97
Mar-12	47,598.00	106,174.00	126,382.40	6,922.00	26.64
Apr-12	101,794.00	111,982.00	98,961.25	15,639.75	27.00
May-12	89,631.00	99,118.00	112,047.00	14,077.00	26.75
Jun-12	94,502.00	100,793.00	105,120.60	13,849.00	26.73
Jul-12	97,124.00	111,597.00	105,784.15	15,070.00	26.80
Aug-12	45,543.00	104,860.00	108,597.05	6,321.61	26.76
Sep-12	89,812.00	104,030.00	105,460.20	14,239.00	27.09
Oct-12	112,106.00	117,212.00	107,484.43	15,757.00	26.94
Nov-12	56,177.00	120,804.01	127,314.75	7,618.00	26.41
Dec-12	101,795.00	91,228.00	75,530.65	13,996.00	25.88
Jan-13	110,387.00	74,867.00	84,861.15	15,329.00	26.14
Feb-13	19,274.00	63,949.00	92,699.20	2,438.00	26.49
Mar-13	24,781.00	95,108.00	92,767.00	3,399.00	26.59
Apr-13	80,425.00	102,634.00	97,939.05	10,256.00	27.31
May-13	120,501.00	113,999.00	114,934.50	15,771.00	26.35
Jun-13	87,446.00	109,015.00	105,134.02	11,630.00	26.38
Jul-13	102,993.00	103,546.00	99,742.49	14,779.00	26.20
Aug-13	64,795.00	89,376.00	106,926.47	8,549.00	26.77
Sep-13	25,503.00	110,725.00	112,843.60	3,548.00	26.92
Oct-13	97,408.00	119,953.00	144,826.09	12,789.00	26.73
Nov-13	104,145.00	106,069.00	136,568.99	14,662.00	26.43
Dec-13	116,760.00	105,802.00	77,265.99	16,031.00	25.12
Jan-14	117,313.00	62,966.00	91,783.27	17,494.00	24.77
Feb-14	99,336.00	104,218.00	100,201.24	14,276.00	24.63
Mar-14	104,849.00	105,223.00	109,828.90	14,255.00	25.11
Apr-14	97,826.00	101,496.00	98,490.15	14,312.81	25.69
May-14	32,803.00	95,241.00	106,484.88	4,513.00	25.43
Jun-14	108,352.00	128,607.00	112,715.56	15,043.00	25.75
Jul-14	87,422.00	70,148.00	151,576.37	11,625.00	25.20
Aug-14	15,130.00	96,968.00	124,070.20	1,828.00	26.35
Sep-14	68,237.00	92,422.00	106,564.35	9,174.00	25.82

Appendix E –Awareness statement

███ does its share for the national energy grid

In partnership with energy service company HVAC, South Africa's leading cement manufacturer, █████, has been doing its part to take the stresses off the national energy grid through predictive production software.

HVAC, in line with Eskom, has been providing technology to sites, such as ██████████plant in Pretoria that helps monitor electricity consumption and production levels, in order to plan production around peak times.

███ Group Energy Manager, Egmont Ottermann says, "We have been working with HVAC since 2006, constantly trying to optimise the performance of our equipment so we can minimise electrical costs. Essentially, this software helps us monitor factory production and silo levels to ensure stock levels are high enough for us to switch off a unit during peak times."

This energy saving initiative has already been rolled out to five███ plants, including ███████ and plugs directly into ███ control systems. According to Ottermann, the███████ plant alone, can consume up to 10 megawatts depending on which equipment is being used. Ottermann believes this project has been resoundingly successful and has saved███ a lot of money.

"Load shifting is an important part of reducing the likelihood of load shedding and, although each single contribution seems as if it is just a drop in the ocean, everyone needs to do their part. I encourage everyone to participate and shift as much load as possible," implores Ottermann.

"By doing so, it is only going to make us all more resilient once we come out of this crisis. If this power crisis is going to last five years, then we all need to do as much as we possibly can to become as efficient as we can. This will help reduce the occurrences of load shedding tremendously because Eskom's systems are under immense strain in peak times. By cutting our peak time use, we can allow that electricity to be distributed elsewhere."

Being well versed in matters of energy consumption around the world, Egmont firmly believes that industry in South Africa is actually on the leading edge of the energy fight - more out of necessity than anything else.

"Since 2008, in my experience, South African industry has been carrying the torch in terms of handling electricity consumption on a national level. It's just that now, it is not simply a nice to have, it is an absolute business imperative," he says.

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Issued by: Ogilvy Public Relations Worldwide
Cheryl Reddy
Group Account Director
Direct: +27 (0) 11 709 9616
Mobile: +27 (0) 79 881 2417
cheryl.reddy@ogilvypr.co.za

Appendix F – Example of the daily reports issued

Daily report for

████████████ **process line**

4 June 2013

Generated on 5 June 2013
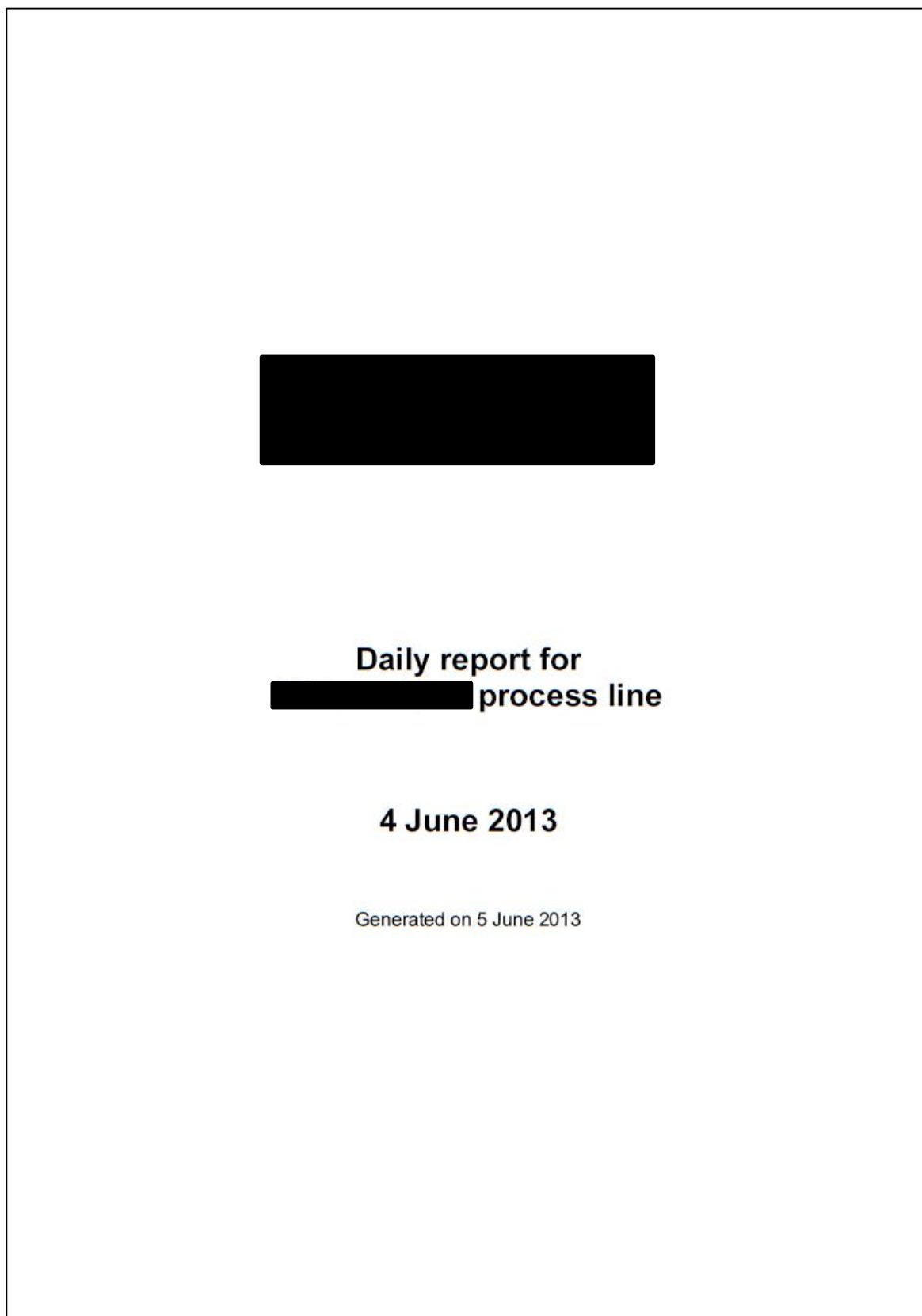
1 Project information

Project name: █████████ process line
Project number: 2010175
Tariff structure: MEGAFLEX
Target impact: 2.70 MW

2 Performance (Tuesday 2013-06-04)

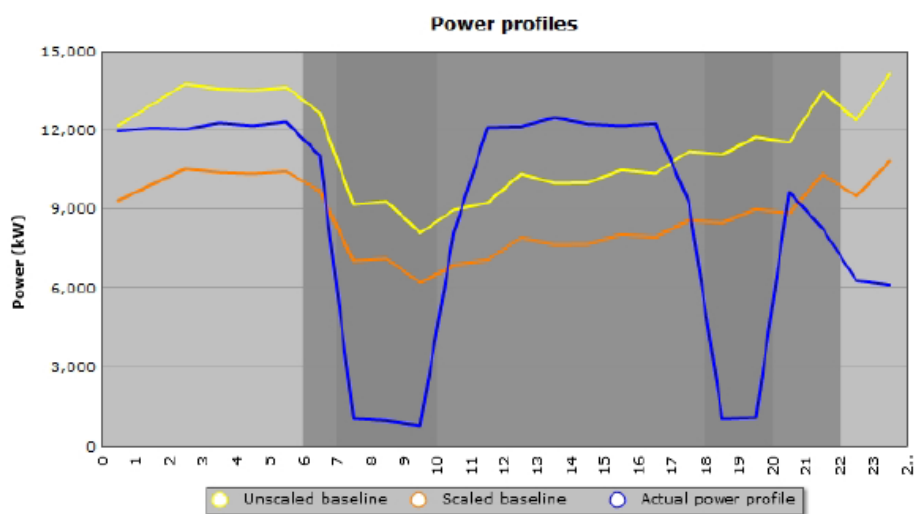| Performance of day:		Month-to-date performance:	
Impact:	7.68 MW	Average impact:	8.67 MW
Cost saving:	R 56,340	Cumulative cost savings:	R 130,588
Missed opportunities:	-	Cumulative missed opportunities:	-

Figure 2-1: *Power profile and baseline for 4 June 2013*

Maintenance Toolbox™
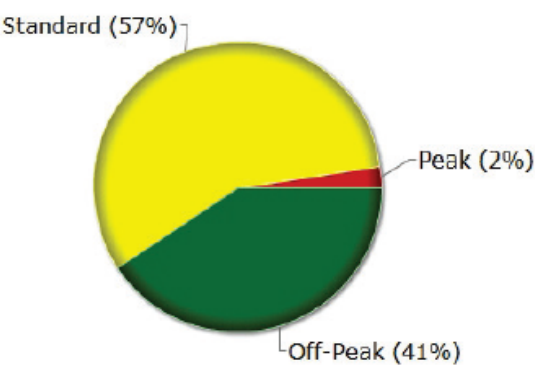maintenance.mtbpower.com - Confidential document generated on 5 Jun 2013 - ©

Figure 2-2: Weekday usage distribution - 4 June 2013

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