ENERGY EFFICIENCY IN THE SOUTH AFRICAN CEMENT FINISHING PLANT:
DRIVERS, BARRIERS AND IMPROVEMENT

BY

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"As the candidate's Supervisors we agree to the submission of this dissertation".

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I, Oluwafemi Ezekiel Ige, declare that:

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ABSTRACT

The cement production is an energy demanding industry that requires a high degree of attention regarding energy use in South Africa. Within the last decade, South Africa has faced a shortage of electricity supply, because the maximum electricity demand has invaded the net maximum capacity and the margin of the reserve storage is reduced. This study investigates a range of barriers, drivers and opportunities to improve the energy performance of a cement plant in South Africa, in order to provide the information necessary to sustain energy efficiency improvement efforts within the cement industry. Energy efficiency can be defined as a cost-effective method of reducing cost of energy and greenhouse gas (GHG) emissions, resulting in extra quality of production and increased environmental benefits. Energy efficiency is widely accepted as an effective tool for improving the global energy situation. Prudent energy use by industry is a solution for a sustainable environment and industrial development. Energy efficiency and energy management cost-effective use measures provide industry with successful ways of achieving economic and social dividends in order to reduce harmful environmental impact of energy usage. Unfortunately, industries from less developed countries are slow in adopting energy efficiency and management measures; therefore, they lack the paybacks of energy efficiency implementation.

This work aims to increase awareness of the need for development of South Africa's industrial energy efficiency and industrial management policies by exploring the current energy efficiency and management practices of one of the oldest cement plants in South Africa. The study also included a survey of barriers and drivers for implementing energy efficiency measures in cement finishing mill plant; and clarified the basis for the adoption and non-adoption of cost-saving energy efficiency in South Africa industries. This research was an exploratory type of the study, conducted by means of semi-structured interviews. The survey was conducted in two parts. In the first part, asked about the plant's energy management policies that in place. In the second part, asked the respondent to complete a prepared questionnaire that cover all aspects of the study.

The results show that poor energy management within the plant and low energy efficiency measures lead to an energy efficiency gap in the plant. Furthermore, it shows that important barriers that hinder the implementation of cost-effective measures within the plant are mainly due to economic related barriers to rational behavior, which are associated with the lack of plant energy efficiency due to the organization structure. The study also found that organizational benefits related to "environmental company profile" and "environmental management systems" followed by economic benefits associated to "cost reductions resulting from lower energy use" are the most high-ranking drivers of energy efficiency measures within the plant.

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ACRONYMS AND ABBREVIATIONS

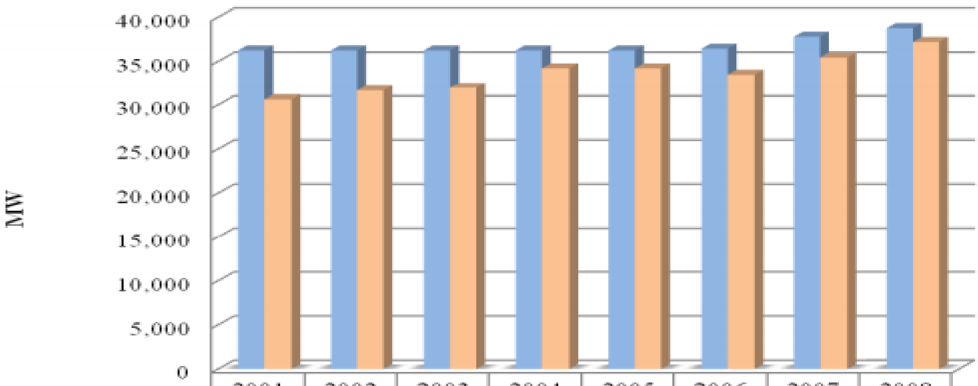
APC	Advanced process control
BEE	Black Economic Empowerment
CO_2	Carbon-dioxide
DSM	Demand Side Management
DME	Department of Minerals and Energy
DOE	Department of Energy
ESKOM	The Electricity Supply Commission
ERI	Energy Research Institute
EJ	Exajoule
EIA	Energy Information Administration
FBE	Free Basic Electricity
GHGs	Greenhouse Gases
Kw/h	Kilowatts per hour
IEO	International Energy Outlook
NPC	Natal Portland Cement
OECD	The Organization for Economic Cooperation and Development
PPC	Pretoria Portland Cement
PID	Proportional-Integral-Derivative
SCI	Sustainable Cement Initiative
UNID	The United Nations Industrial Development Organization
UNEP	United Nations Environment Programme
VSD	Variable speed drive
WEC	World Energy Council

CHAPTER 1: INTRODUCTION

Globally, due to the increase in world population, nations are beginning to encounter the challenge of sustainable energy. This requires behavior regarding energy usage which must support environmental, social, and economic goals. The major challenges that humans encounter are energy sources and climate change (Zhao, He, & Meng, 2015). Economic growth and the rapid growth in population of the world and the constant desire for a better standard of living are the major contributors to increasing industrial energy consumption. Both less developed and developed countries encounter the same environmental and energy related problems, including South Africa. Energy efficiency and energy saving for manufacturing industries such as the cement sector is of vital importance because of the strong impact that the price of energy has on manufacturing costs, which normally exceed 50% of the unit cost, and its impact on the environment by generating greenhouse gases (GHGs), especially CO_2 emission, because of combustion and decomposition of raw materials.

In late 2007 South Africa underwent power outages which led to load shedding, because Eskom lost working capacity to meet the demand for electricity. This awakened interest in energy efficient technologies and the saving of electricity usage by end users (Eskom, 2012). Load shedding simply means temporary relief of electricity shortage and schedule by Eskom. Toward the last quarter of 2014, the problem of load shedding became a regular and more harmful event (Baker, Burton, Godinho, & Trollip, 2015). The importance of this study further connects to the increase in Eskom tariffs, and the directive to mining and all high energy consuming sectors of the industrial sector, including the cement industry, to reduce the energy consume by the sector.

Cement plants are heavy consumers of electricity, which has led to the rapid depletion of excess energy capacity in South Africa. Figure 1-1 shows the correlation between the total supply capacity of Eskom and peak demand over a period of eight years (2001 and 2008). The figure shows the annual reduction of the reserve margin. The instruction by Eskom to lessen energy consumption in the industrial sector forced huge energy consumers such as cement plants to implement short-term load shedding, demand side management in the medium period and more efficient applications for the longer period.



	2001	2002	2003	2004	2005	2006	2007	2008
Total capacity (MW)	36,208	36,208	36,208	36,208	36,208	36,398	37,761	38,747
Peak demand (MW)	30,599	31,621	31,928	34,195	34,195	33,461	35,441	37,158

Figure 1-1: Eskom total supply capacity and peak demand Source: (Eskom, 2011).

The International Energy Outlook of 2016 (IEO, 2016), reported that the total energy consumption globally is projected to increase by 1.2% per year between year 2012 and the year 2040, and this increase will come because of the quantity of energy that the industrial sector utilizes. The consumption of energy by industry is greater than any other sector. Industry consumed about 54% of total energy produced worldwide in 2012 (Figure 1-2). After the political insecurity of the 1990s, the priorities of policy-makers in South Africa changed after the 1994 election in the country. The present government has discovered that the issue of energy as being a crucial key for the country's economic development. The policy of Free Basic Electricity (FBE) points towards the significance of energy related matters and makes sure that a large quantity of electricity is available for free to the people of South Africa. Particularly, with respect to energy efficiency, South Africa's energy policy of 1998 white Paper on Energy Policy (DME, 1998), further encourages the awareness of energy saving and also urges the use of energy-efficiency practices.

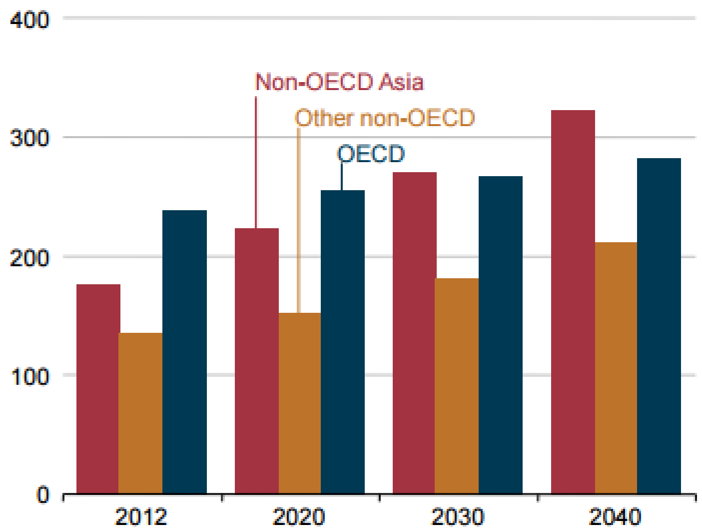


Figure 1-2: World total energy use by country from 2012–2040 (quadrillion Btu)
Source: US Department of Energy (IEO, 2016)

In the report of International Energy Outlook (IEO, 2016), Reference case shown in Figure 1-2 and Figure 1-3, the Energy Information Administration (EIA) expecting that industries will use more than 50% of total energy produce in year 2040 (Abdelaziz, Saidur, & Mekhilef, 2011; IEO, 2016). Industrial activities contribute about 40% of world CO_2 emissions which is likely to rise in year 2040 by 46%, leading to dreadful environmental concerns (Sieminski, 2014).

Region	2012	2020	2025	2030	2035	2040	Average annual percent change, 2012-40
OECD	**238**	**254**	**261**	**267**	**274**	**282**	**0.6**
Americas	118	126	128	131	134	138	0.6
Europe	81	85	87	90	93	96	0.6
Asia	39	43	45	46	47	48	0.8
OECD with U.S. CPP	**238**	**252**	**258**	**265**	**272**	**280**	**0.6**
OECD Americas with U.S. CPP	118	124	125	128	132	136	0.5
Non-OECD	**311**	**375**	**413**	**451**	**491**	**533**	**1.9**
Europe/Eurasia	51	52	55	56	58	58	0.5
Asia	176	223	246	270	295	322	2.2
Middle East	32	41	45	51	57	62	2.4
Africa	22	26	30	34	38	44	2.6
Americas	31	33	37	40	43	47	1.5
Total World	**549**	**629**	**674**	**718**	**766**	**815**	**1.4**
Total World with U.S. CPP	**549**	**627**	**671**	**715**	**763**	**813**	**1.4**

Figure 1-3: World total energy consumption by country from 2012–2040 (quadrillion Btu)
Source: US Department of Energy (IEO, 2016)

Industrial energy consumption in non-OECD countries from 2012 to 2040 will rise by an average of 1.5% every year, compared with the energy consumption in OECD countries which will increase by 0.5% every year (IEO, 2016). Only four main sectors consume almost 65% of all industrial energy consumption, namely, iron and steel (17%), chemical and petrochemical (33%), cement (9%), and lastly pulp and paper (5%). The manufacturing of cement product is an energy demanding process with about 20% to 40% of the energy total costs and 17% to electricity (Cullen & Allwood, 2010).

1.1 Background

Presently, Southern Africa is confronting a wide range of energy crises, linked to the increasing price of electricity, the urgent need for energy security and reduction of carbon emissions. Since coal-fired power generation in South Africa is cheap, the nation had the lowest price of electricity in the whole world until recently. Electricity tariffs increased by 300% from 2007 to 2015 (Moolman, 2015). This fourfold tariff increase has contributed significantly to the South African energy crisis. In the past, the country has been a capital demanding nation and energy growing economy till today. According to international standards, the nation economy is among the energy demanding country, with the focus on the most energy-intensive sectors for example, manufacturing and transportation (Winkler & Van Es, 2007).

The non-metallic industry is the third biggest energy-consuming industry, and consists of brick, cement, ceramics and glass industries. The production of these materials involves a large amount of heat and for this reason, it accounts for 6% of industrial energy use worldwide. Production of cement is the most important non-metallic industry and accounts for around 9.6 EJ of energy use and 85% of all the total energy use in this sector. Even though the cement manufacturing industry has progressed in energy efficiency for many years by changing the production process from the "wet kiln" to "dry kiln" process, which requires less heat, the cost of energy still accounts for about 20 to 40 percent of the aggregate cost of the production (IEA, 2009). A major increase in production of cement in coming years is likely to happen in non-OECD countries. Since the cement production is specifically produces Co_2, the cement industry has acted to address the impact of the production on the environment by finding ways to reduce the use of fossil fuels and improve energy efficiency.

1.2 Significance of the study

In South Africa and around the world, the acceptance of energy efficiency is to some degree within the energy-intensive sectors including cement manufacturing. In addition, there is a lack of knowledge about how effectively to save kilowatt hours of energy, costs and CO_2 emissions. The International Energy Agency in their report Capturing the Multiple Benefits of Energy Efficiency describe the numerous paybacks of energy efficiency, and state that "by 2035 shows that almost two-thirds of the energy efficiency potential will be available unless the policy is changed" (IEA, 2014)

Energy efficiency can be defined as ratio involving an output of the systems performance, service or goods with less input of energy. Energy efficiency is a strong energy saving way to moderate the negative effects of energy use. The purpose is to improve the energy use. Energy efficiency can be describing as an economical way to reduce use of energy, manage and control the growth in energy consumption. It also reduces the cost of production and increases environmental benefits by reducing emissions of GHGs and air pollution (Peña Blume, 2010)

Oikonomou, Becchis, Steg, and Russolillo (2009), reported that improvements in energy usage can only be accomplished through efficiency or social change. Energy savings and the improving of energy efficiency are important challenges that we must face in the coming years. For this reason and to improve effectiveness, we need to put in place the implementation of appropriate strategies and provide the necessary tools for significant improvements in the technical development and guidelines of energy consumption. Increasing in energy efficiency is the best way to lessen GHG emissions (Al-Mansour, 2011). Energy efficiency benefits include improvement of energy savings, environmental improvement, energy security, energy costs reduction, economic competitiveness and job creation (Schnapp, 2012).

The South Africa′s energy policy White Paper Energy Policy of 1998 arose the government's need to introduce policy concerning energy efficiency and to encourage the Department of Energy to support energy efficiency through various means. Energy efficiency has been viewed since 2010 as a means of integrated resource planning and development of new capacity, and is acknowledged as the economical and fastest approach to reducing energy demand in a way to avoid shortages of electricity (Letschert, Leventis, Covary, & Group, 2013). The government of South Africa launched an industrial energy efficiency project in 2010 and the objectives is to contribute to the sustainable transformation of energy usage within the industry, thereby reducing emissions of carbon-dioxide CO_2 whereas demonstrating the effect of energy efficiency practices in terms of environmental and economic benefits. The market competitiveness of energy efficiency, and the concerns of industrial owners regarding the sustainability of their companies in South Africa, has led to significant progress in technology and economic development. This research work seeks to develop an understanding of alternatives aimed at optimizing energy resources in the industrial production process of cement.

1.3 Research objectives and research questions

The research objectives are to investigate the opportunities to energy efficiency improvement in the South African cement plant, and to better understand the acceptance of energy efficiency opportunities in South African cement plants. In view of the lack of energy efficiency literature in the South Africa cement industry, this study will contribute to the current research field by exploring the present industrial energy management practices and energy efficiency in the South Africa cement industry. Furthermore, the study included investigation of barriers and the drivers of energy efficiency in South Africa's cement plants and an explanation of the basic reason for adoption and non-adoption cost-saving energy efficiency measures in the South Africa cement industry. Otherwise stated, the barriers and the driving force of energy efficiency improvement within the cement plant environment were investigated. In order to achieve these objectives, this work answers the following questions:

1. What is the current situation regarding energy efficiency in the South African cement industry?
2. What are the accepted industrial energy management policies among cement plants in South Africa? How effective are these policies/measures?
3. What are the main barriers and drivers that affect the acceptance of energy efficiency opportunities in cement plants?
4. What are the opportunities for existing energy efficiency within the cement plant?

1.4 Methodology

This research work uses methodological methods which include quantitative and qualitative aspects. The research data information was collected through semi-structured interviews. The respondents also filled out a quantitative questionnaire. This method was preferred to view of the complex and correlated factor sets that affect the improvement of energy efficiency within a cement plant.

1.5 The main assumptions

This research work is well-defined by the following vital assumptions:

- Energy efficiency is not the interest of the participants / energy demanding sectors.
- Energy efficiency will reduce energy costs, Kw/h and CO_2 emissions.
- Barriers will include access to financial, inadequate knowledge, human resource capabilities, government grants, energy efficiency and time management knowledge. These assumptions will be measured throughout the study's collection.

1.6 Layout of the dissertation

Chapter 1 outlines the introduction of the study, significance of the study, research objective and questions, methodology.

Chapter 2 reviews literature on energy, cement production, equipment used in cement plants, Portland cement, cement plant layout and components, sources of energy for cement production, demand side management, energy efficiency overview.

Chapter 3 summarizes the barriers and improvement for energy efficiency in cement plants.

Chapter 4 presents the research methods and methodology used in the case study.

Chapter 5 discusses energy efficiency techniques and technologies

Chapter 6 presents the questionnaires results and discussion of barriers and drivers to energy efficiency.

Chapter 7 presents the conclusions and recommendations of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A few papers have reviewed the possibilities of cutting down energy use and emissions of CO_2 in cement plants in India, Europe and the United States (Morrow, Hasanbeigi, Sathaye, & Xu, 2014; Moya, Pardo, & Mercier, 2011; Ernst Worrell, Martin, & Price, 2000). Energy benchmarking can give profitable experiences regarding energy efficiency possibilities of cement industries. At the time of writing, Saygin, Patel, and Gielen (2010) reported that approximately 2 000 cement kiln plants were in operation worldwide.

2.2 Energy

Generally, energy is defined as the ability to do work. Chiras (2011) characterized energy source as either renewable or non-renewable energy. Additional energy is required for sustaining the means of living, although energy supplies are limited (Salonitis, 2015). Renewable energy is energy obtained from regenerative resources. Sources of renewable energy are non-fossil fuel sources for example: hydropower, solar, biomass, wind and waste (Andexer, 2008). Sources of non-renewable energy are limited and reliant on natural means and resources, for example fossil fuels. A few of the non-renewable energy or fossil fuel sources are: oil (petroleum), nuclear (uranium and thorium), natural gas and coal (Ghosh & Prelas, 2009).

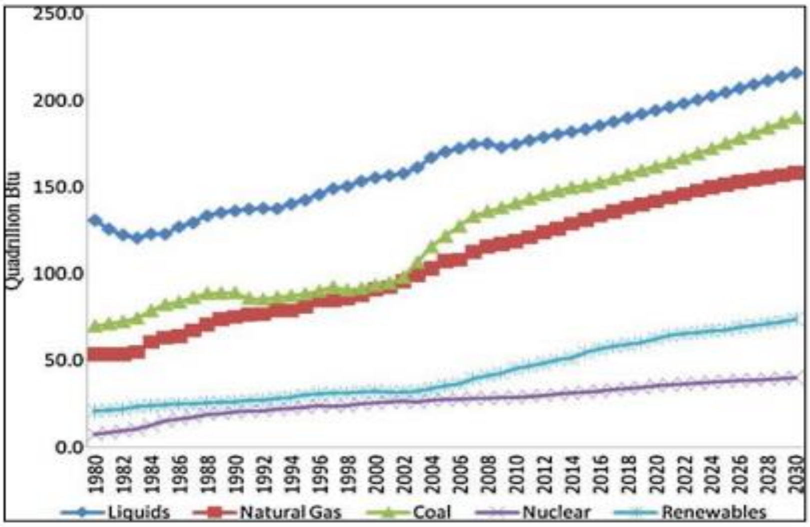


Figure 2-1: Figure 2.2: Historical and projected world energy demand by fuels
Source: (Akorede, Hizam, & Pouresmaeil, 2010).

The challenge is that non-renewable energy sources are rapidly depleting and renewable energy is difficult to produce, utilize and diffuse. In general, the world relies on fossil fuels and natural resources as a source of energy to generate electricity.

Figure 2-1 explains the various sources of energy used and particular amounts that have been used since 1980 and that have been will be used for the 50 years after that. The South Africa energy supply problems are not different from those of other developing countries. In year 2007, South Africa experienced extensive rolling blackouts as supply dropped below demand, also threatening to undermine the national grid. The backup margin was estimated at about 8% or below while the National Energy Regulator needs 16%. Eskom started applying load shedding every time the power generating units were taken off-line for maintenance, repairs or re-fueling (Hartleb, 2008). In early November 2014, load shedding was introduced again due to loss of power generation at the Amajuba power plant, after the breakdown of one of its coal storage silos. The Amajuba power plant generates about 10% of the country's entire capacity (Gibbs, 2014).

2.2.1 Energy demand

Energy demand is the amount of primary energy ultimately consumed in a country or region. Primary energy is composed of the sum of the loads of primary sources (oil, coal, natural gas, nuclear power, and renewable). Final energy is the sum of the energy consumed in the different economic sectors such as transport, industry and services firms. Energy demand management is a fundamental aspect of energy policy of a country. Eskom is in charge of South Africa’s electricity supply. An energy demand chart which contains real time data and future estimates of demand and which also contains the balance of primary energy consumption (monthly or annual) and the final energy consumption, is available on the Eskom website (Eskom, 2016).

Reduction of energy demand is very important because it enables a country to progress towards the objectives of reducing the environmental impact, reducing the cost of supply of energy within the country and growing energy security in the cheapest way possible, by reducing spending. In the case of South Africa, energy demand reduction is considered as the key to reach international agreements on reduction of CO_2 emissions. The energy sector is one of the main sectors responsible for these emissions, so the reduction of energy consumption is essential to achieve the proposed objectives.

Energy demand reduction can be achieved in two ways, By:

(1) Reducing the energy consuming activities.

(2) Increasing efficiency in the use of energy.

Point (2) is usually considered more desirable by governments, as it does not have negative connotations, and does not reduce the well-being of citizens or economic activity. On the other hand, it may have the problem that efficiencies remain simply in relative improvements, without absolute reduction of demand. An example of such an 'improvement' in the industrial sector is when the improvement of energy efficiency is due to the replacement of fossil fuels by electricity. This improves the energy intensity within the industrial sector, but the energy intensity of the electricity sector worsens.

2.2.2 Problems related with energy

The emission of CO_2 due to the production of energy from fossil fuels is the main cause of climate change. Energy security supply is very important for any country; we are totally dependent on fossil fuels and a lack of supply could lead to the collapse of a whole country. Approximately 77% of primary energy needs of South Africa industry is supplied by coal. This makes the nation among the top nations that depend entirely on fossil fuel as its main energy source (DOE, 2010).

Kavalov and Peteves (2007) showed that in South Africa roughly 60% of coal production originates from underground mines and coal mines are reaching the end of their life. This dependence on fossil fuel as the main source of energy is probably going to put the nation under tension when its abundant coal stores are exhausted or turn out to be uneconomical to mine. Promoting the usage of energy saving and implementation of energy efficiency measures are the best way to reduce the damage caused by CO_2 to the planet. Energy efficiency in industry through energy saving not only leads to an improvement of the environment but also increases the profitability of a company, which can be achieved through reductions in energy costs and increases in the efficiency of the process.

2.2.3 Industrial energy efficiency trends

South Africa is respected as the one of most industrialized country across the continent (Inglesi, 2010). The World Energy Council calculates the energy strength of different industrial sectors and countries by calculating the consumption of energy per sector proportional to the production. Figure 2-2 shows how industrial energy strength in South Africa has reduced since 1990 relative to the averages in the rest of continent and the world.

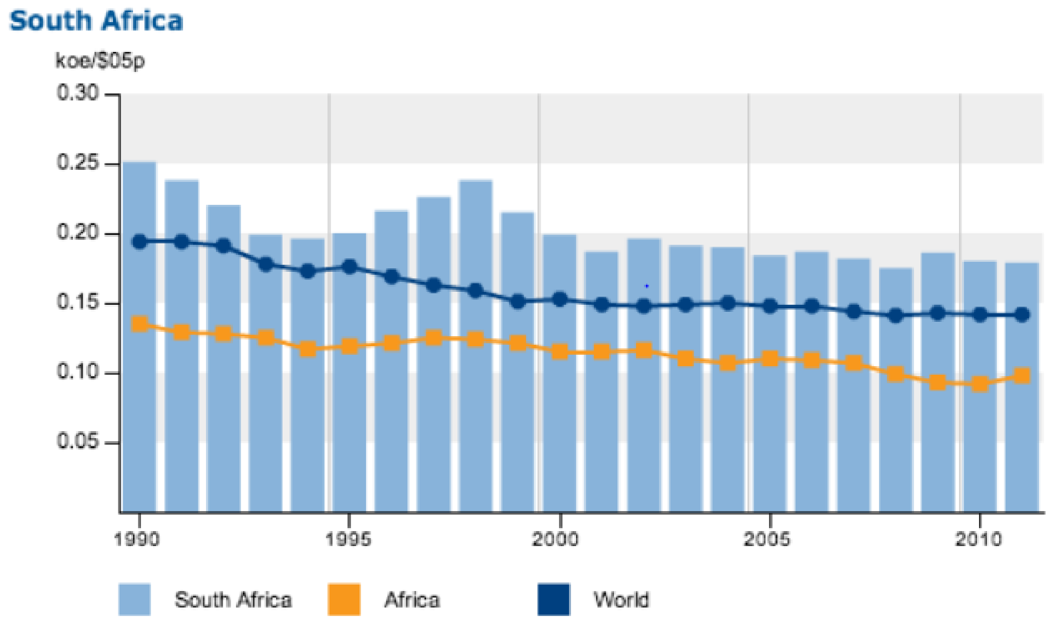


Figure 2-3: Industrial energy strength in South Africa. Source: (IEA, 2013).

There are possible way to reduce industrial energy consumption by ~20% and by making use of best available technologies (IEA, 2013). Expansion in many industries leads to more energy consumption in the sector.

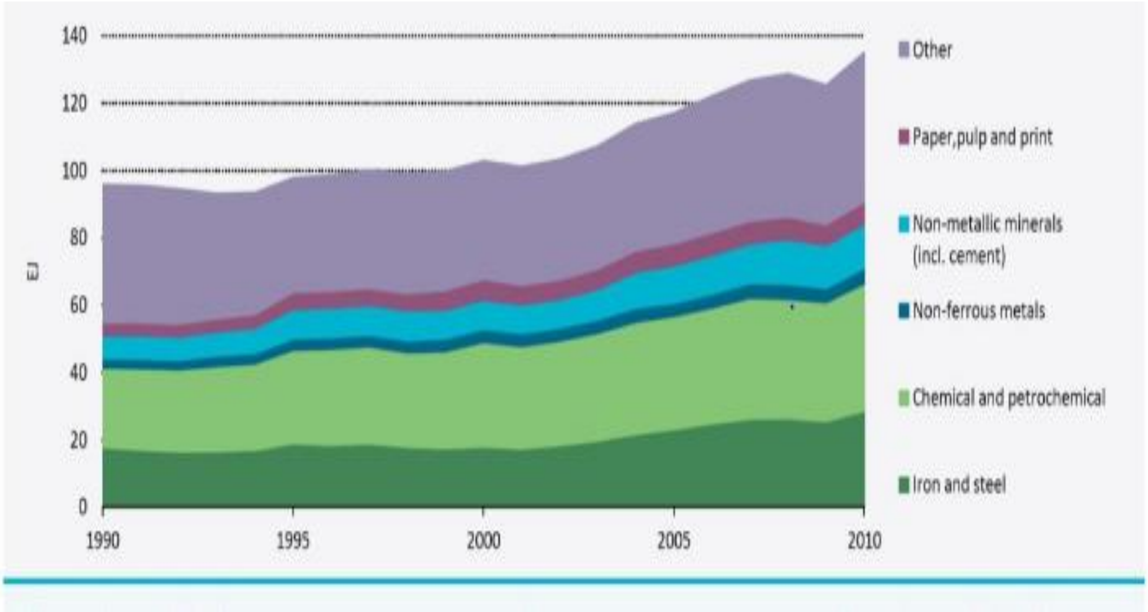


Figure 2-4: Global industrial energy consumption by sector Source: (IEA, 2013)

Figures 2-3 and 2-4 show that since 1990 the consumption of energy in EJ has become more intense in all industrial sectors. Regarding energy intensity, meaningful improvements have been made by China and India, though in recent years the rate of energy improvement has reduced.

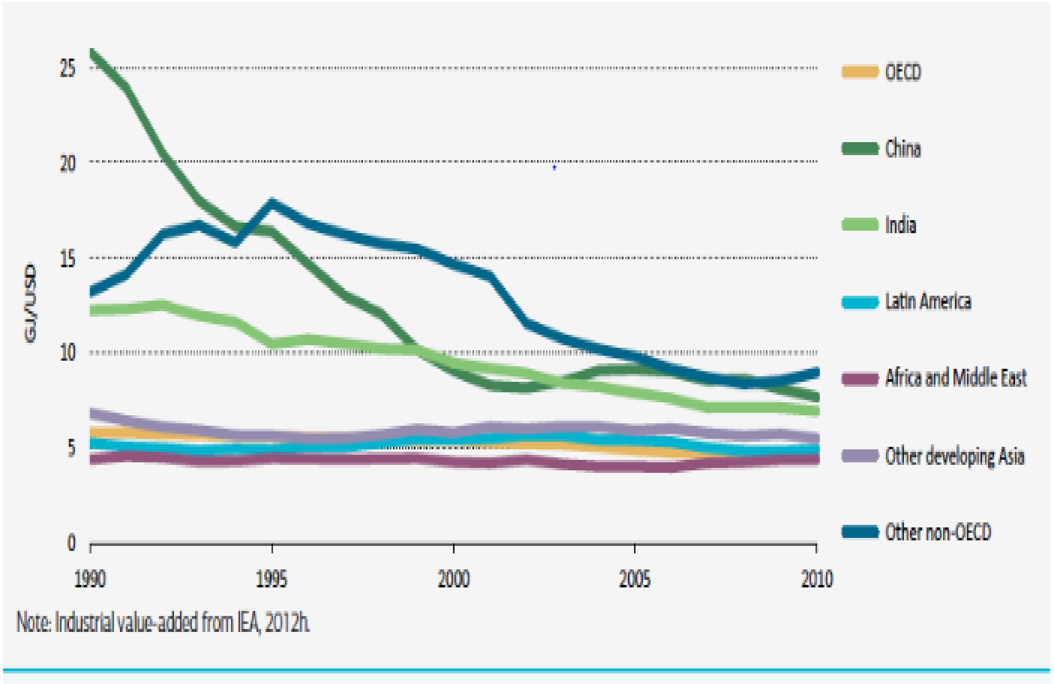


Figure 2-5: Aggregate industrial energy intensity by country/region. Source: (IEA, 2013)

It is essential to understand that the energy intensity of any industry is not an immediate measure of energy efficiency improvements since various components have to be taken into consideration, for example structural changes and variable input prices (IEA, 2013).

The 2013 the International Energy Agency Progress Report on Tracking Clean Energy investigated the potential for improved energy efficiency in the iron and steel industry, cement industry, chemical and petrochemical sectors. In spite of the fact that efficiency measures are specific to the industrial process, there are some cross cutting measures for example: high-efficiency motors and variable-speed drives, sensors and controls, heat recovery technology and co-generation (IEA, 2013).

2.2.4 Energy efficiency gap

Energy efficiency is a cost-effective way to ensure energy security by reducing the input of unit resources per unit of the output. Efficiency can be separated into economic and energy efficiency. From an economic point of view, efficiency is evaluated by improving performance or increasing the utilization of more energy efficient equipment and conservation (Sovacool & Brown, 2010). Sometimes, energy efficiency means the improvement of the operation of energy equipment and changing the attitude of consumers. At present, countries around the world are facing challenges which are causing a reconsideration of global energy consumption. Increased prices of energy, increases in environmental awareness, increased rigor of policy and regulations have all driven energy efficiency improvement. In spite of the considerable need to improve energy efficiency have shown that cost-effective energy saving measures are not generally actualized, which means that there is an efficiency gap (Rohdin, Thollander, & Solding, 2007).

In energy efficiency literature, the term 'efficiency' gap is used widely and means the difference across the stage of energy efficiency that appear to be cost-effective in the light of engineering economic assessment. Technical experts and engineers are optimistic that the way to improve energy efficiency is by technological improvement. This raises the issue of why the presence of cost-effective technology does not fill the efficiency gap; from an economic point of view the reason is because market barriers hinder optimal technology diffusion. Adam B Jaffe and Stavins (1994**),** determine five individual and clear concepts of optimality: the economists' and the technologists', the narrow, the theoretical potential and the real social optimal.

The meaning of efficiency gap appears to be very simple at first look. According to the Allan Consulting Group, however, the definition turns out to be more complicated when a person tries to find or define the optimal investment level, procedures or technologies which would be best for the industry or consumer (Allen, 2008). Bearing this in mind, when determining the scope of the energy efficiency gap requires a reasonable definition of the optimal investment level.

2.2.5 Energy saving

Energy saving is the reduction of energy consumption, without changing the energy efficiency. An example of energy saving in the industrial sector would be the use of inverters (AC drives) to speed up the production processes. A device that is powered by a speed aviator uses less electricity than equipment activated at a constant speed, since it does not use more energy than necessary. The speed can be adjusted depending on the needs. Examples are conveyors belts, pumps and compressors.

The United Nations Industrial Development Organization identified energy efficiency to be the most cost-efficient way of using energy, implementation of manufacturing processes or in the rendering of services, so as to minimize energy waste, and reduce the total consumption of primary energy resources (UNIDO, 2008).

The report of WEC (2010) on energy efficiency in 2010 related energy efficiency to low hanging fruit on the energy tree, emphasizing the importance of energy efficiency, and pointing out that these principles can address several objectives simultaneously, that is, energy security, environmental impact, competitiveness, trade balance, investment needs, social effect and others (WEC, 2010).

Some of the benefits of energy saving according to UNIDO include:

- Reduction in cost of energy service to companies, individuals and economies;
- Reduction of negative impacts on the environment;
- Achievement of best service benefits from the available energy;
- Increase of the life of primary energy reserves; and
- Reducing the risks due to greater predictability of cost and environmental impacts.

As projected by the South African Department of Energy (DOE), an energy saving of between 20% to 30% was achieved in many sections of the nation’s industries during the 2007 energy crisis, which indicates that if the necessary programs are in place, there is a promise for energy saving in the country. The energy saving percentage might increase if the country has high energy strength, mostly if the industrial sector, is taken into consideration (DEA, 2010).

Hepbasli and Ozalp (2003) draw attention to two significant factors that could be advantageous in saving of energy, it can create extra profits and can reduce damage on our environment. These two factors should encourage industries to drive energy efficiency plans. Fawkes (2005) utilized three case studies in different industries to collect and present information on energy efficiency in South Africa, which was finalized by the Energy Research Institute (ERI). The report reveals that leading companies in South Africa have discovered room for efficiency improvement which can generate profitable results if commenced appropriately.

By 2050, world energy demand is projected to have doubled, leading to an increase in the costs of many consumables, particularly if the demand grows bigger than the supply (Nezhad, 2009). In the future, various new sources of energy will be needed in addition to the present ones. Especially in South Africa, energy efficiency might assist with the aim of reducing the pressure on the recent increase in fossil fuel demand. From the trends of the last ten years, it is clear that South Africa will not return to the low-cost and abundant energy of the past due to the increase in costs of energy sources such as coal, oil, water, solar and even wind power. According to the international energy outlook, the world’s energy consumption is set to increase by 49% by 2035, and the increase in energy demand is expected to trigger price increases to the consumer (IEA, 2009)

Energy efficiency has become a social issue. Hepbasli and Ozalp (2003), discuss energy as an important factor for the social and economic development of a nation. Being energy efficient could significantly develop both social and economic circumstances of the society and help to sustain a healthy environment for all. Energy saving could help to correct this situation and save many businesses from drowning in escalating operational costs.

2.3 Cement production

2.3.1 Cement production process globally

Cement is produced in a difficult multistage process, through which the raw materials are changed into clinker which forms an important component of the cement production process. In the production of clinker, limestone (which has been mined from a quarry) is crushed and milled with clay and others similar materials, on occasion also adding small amounts of sand, waste bauxite and iron ore. In state-of-the-art plants, this mixture is pre-heated before entering a kiln for additional heating at high temperatures up to 1450°C to produce clinker. In general, the manufacturer of different types of cement pass through the same process from mining, cement clinker production to cement production.

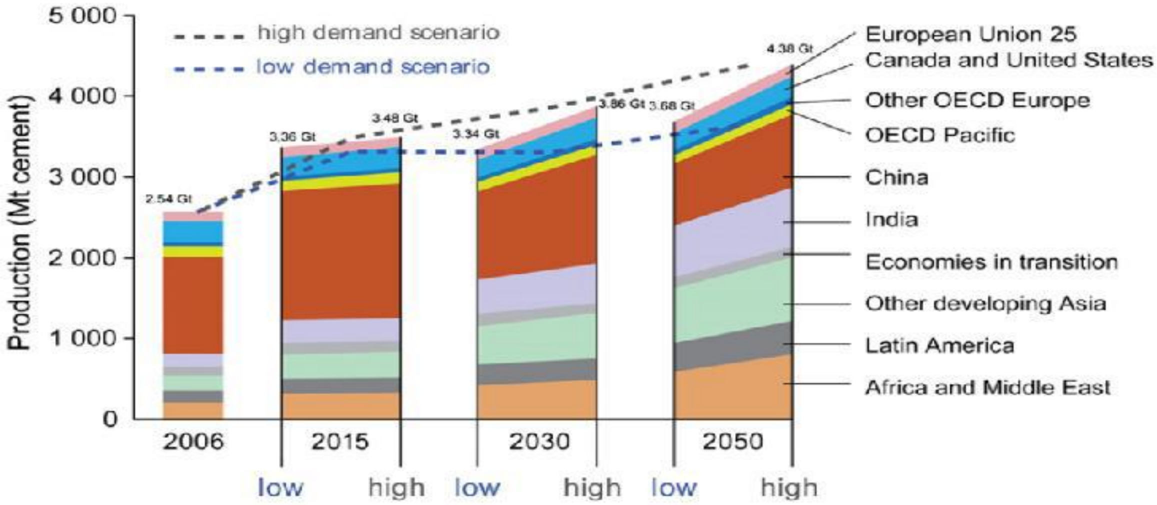


Figure 2-6: Global production of cement Source: (IEA, 2009)

Some cement industries merely involve the production of lime, while others also buy clinker from another company to produce cement. Cement is a significant material used in the construction of houses and foundations. According to the report of the International Energy Agency (IEA, 2009), over 3.6 billion tons of cement product is produced annually in the world and is projected to multiply to four billion tons by 2050. Significant development is predicted in countries like China and India and regions like the sub-Saharan Africa and the Middle East (Tanaka & Stigson, 2009). The real and expected global production of cement is shown in Figure 2-5.

Globally the cement industry is confronting challenges to save material, energy resources and reduce emissions CO_2. According to the Sustainable Cement Initiative (SCI), the most important alternatives for cement manufacturers are to increase energy efficiency, substitution of clinker, and use of alternative fuels (Schneider, Romer, Tschudin, & Bolio, 2011). The production of cement is an energy demanding process requiring an energy input of 850 kWh/ton to 1100 kWh/ton of cement produced (Harder, 2003). The cement industry is the third highest cause of human produced carbon dioxide (Fischedick et al., 2014). Figure 2-6 shows the statistics of cement production in the United States and worldwide from 2010 to 2016. In 2010, the United States produced about 67.2 million metric tons of cement. Cement is an important construction material regularly used to produce concrete (Statista, 2016).

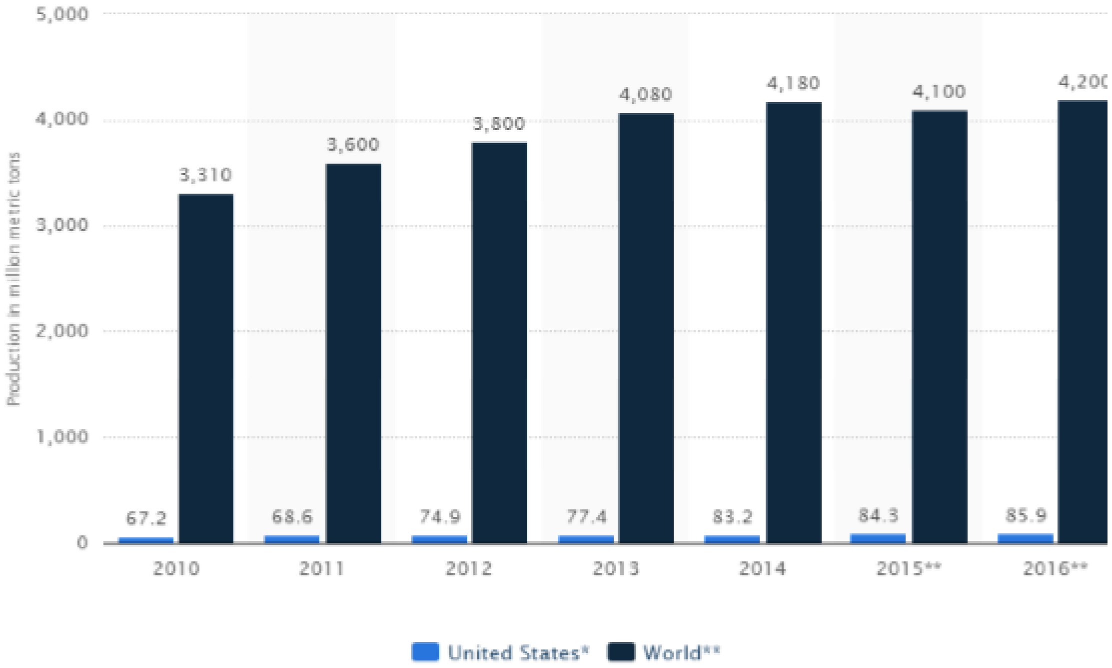


Figure 2-7: Cement production in US and world (2010 to 2016) Source: (Statista, 2016).

Global Cement Production

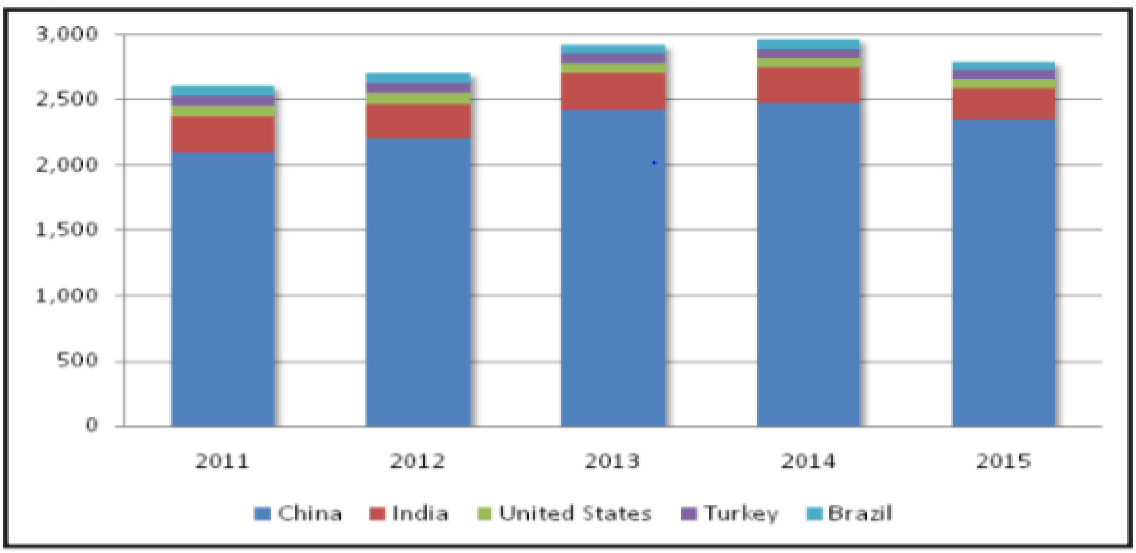


Figure 2-8: Top five cement manufacturing countries (2015). (Jcr-vis, 2016).

In 2015 the production of cement worldwide stood at around 4.1b MT per year as is shown in Figure 2-7. China is the single largest producer of cement globally with 57% of cement production followed by India (6%), USA (1.7%), Brazil and Turkey. Cement consumption globally dropped by more than 2% during 2015 to about 4b MT per year (Jcr-vis, 2016)

2.3.2 World cement outlook

The consumption of cement worldwide grew from 3.6 billion metric tons in the year 2011 to 3.7 billion metric tons in the year 2012. This growth was realized by increased demand from developing countries and due to economies in Asia. Since its peak in the year 2006, consumption of cement among developed economies has dropped by approximately 119 million metric tons (PCA, 2013). The downturn in cement consumption is traceable to lower consumption in republic of China and other countries like Russia including parts of Europe and Latin America as is shown in Figure 2-8. Considering that global economic growth is expected to slow down the geopolitical, commodity and financial risks. Cement consumption is expected to grow at a very low average rate of 2.4% through year 2020 (Jcr-vis, 2016).

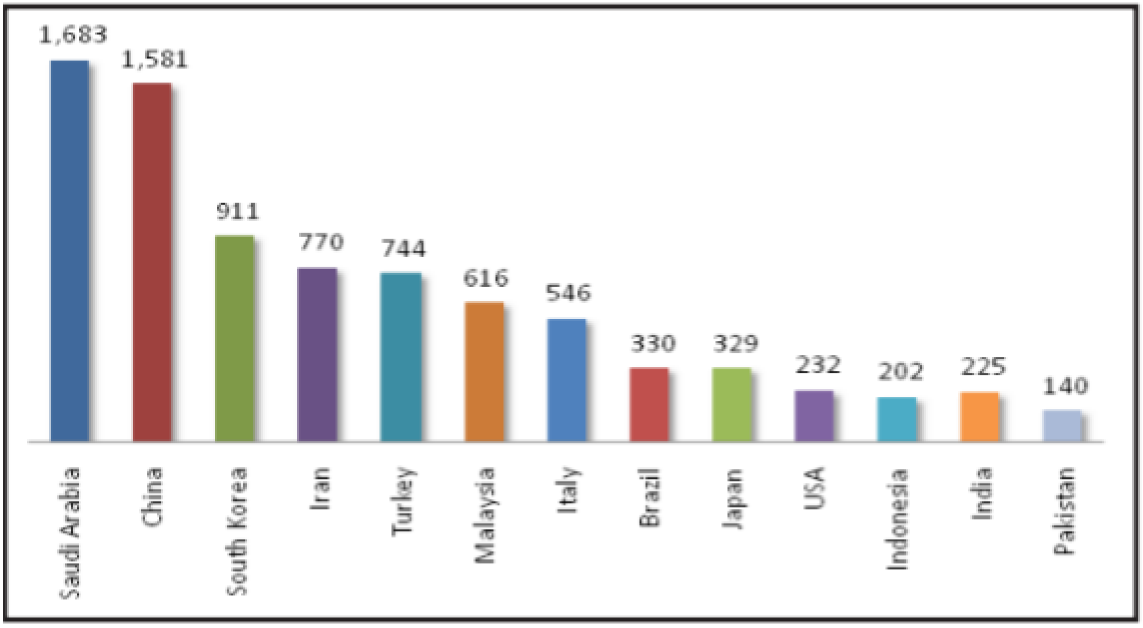


Figure 2-9: Per capita cement consumption (kgs). Source: (Jcr-vis, 2016).

2.3.3 Production of cement in South Africa

(Allwood et al., 2012) reported that cement production is among the leading climate change emissions caused by humans. The cement industry produces roughly 5% of GHGs. This makes the cement industry among the top five GHG sources. The production of cement is energy demanding and represents on average of between 20% to 40% of the aggregate of production. The greatest energy consumption in the production of cement is the production of clinker from limestone. The process of cement production utilises different forms of energy. In the period of calcination, fossil fuel energy is used to heat the kiln to temperatures that are efficient for the burning of raw limestone. The fossil fuels comprise coal, natural gas and fuel oil. In South Africa there is an abundance of coal supply as it is cheaper than other fossil fuels. Consequently, in the South Africa the production of cement utilises coal as the primary fuel for calcination. Electricity is another form of energy consumption in cement plants.

Different types of electric motors utilise electricity to operate the components in grinding equipment like crushers, large fans, mills, silos, roller presses, conveyor transport systems and compressors. Mining equipment and post-production transport utilises fuel oil (diesel or petrol). According to Ali, Saidur, and Hossain (2011), cement production consumes about 12% to 15% of total industrial energy consumption. The cause of the energy crisis can be justifying to the increase in consumption of electricity due to constant growth in the energy sector which is the largest energy consumer, and the depletion of natural resources such as fresh water and global oil reserves. Starting from an energy consumption analysis, the production process of a cement plant can be divided into several individual operational sections performing specific functions throughout the production process.

The demand for cement in South Africa has gone through several cycles for the past 60 years. This is characterized by the recent huge and sustained growth from 2000 and 2007. This period saw local producers having huge turnover and profit for shareholders. Although, there seem to be sharp decline after the market peaked in 2007.

2.4 Portland cement

Portland cement consists of five main components, four of which are in clinker and the fifth which is gypsum, is added in the finish grinding process. Portland cement is mainly composed of limestone and other additives to the temperature of about 1450^0C. Contingent on limestone purity, secondary raw materials for instance chalk, clay, shale, sand, iron ore purity and other materials may be added in order to meet the production specifications (Hassaan, 2001).

2.4.1 Portland cement’s history in South Africa

Hydraulic and non-hydraulic are the two types of cement. Hydraulic cement can be set in wet conditions, while non-hydraulic cement needs to keep dry to harden. Portland cement and its numerous blends is a good example of hydraulic cement. In the South African cement industry, only Portland cement is produced, and is currently responsible for 0.57% of the total cement produced globally. Cement is commonly used worldwide and is used in concrete, mortars, stucco and grout. Over thirty raw materials are used in the production of Portland cement and it can be group into four different categories: ferriferous, calcareous, argillaceous and siliceous.

Cement industries are sometimes demarcated based on geographical location due to the difficulty associated with transporting it. Transportation of the product takes about 33 % of the total cost. This is the reason why the product should not be transported far, at most 250km, from the milling plant. The most efficient route of transporting it is though the sea but this is not the case in South Africa as the product is transported by road. Importation of cement into KwaZulu-Natal cement market accounts for 6 % of the local market. The four key players in South Africa known for manufacturing and marketing of Portland cement are:

- Natal Portland Cement (NPC-Cimpor).
- AfriSam.
- Pretoria Portland Cement (PPC)
- Lafarge.

The location of the various Portland cement plant in South Africa is shown in Figure 2-9. It gives geographic distribution of the cement plants in the country.

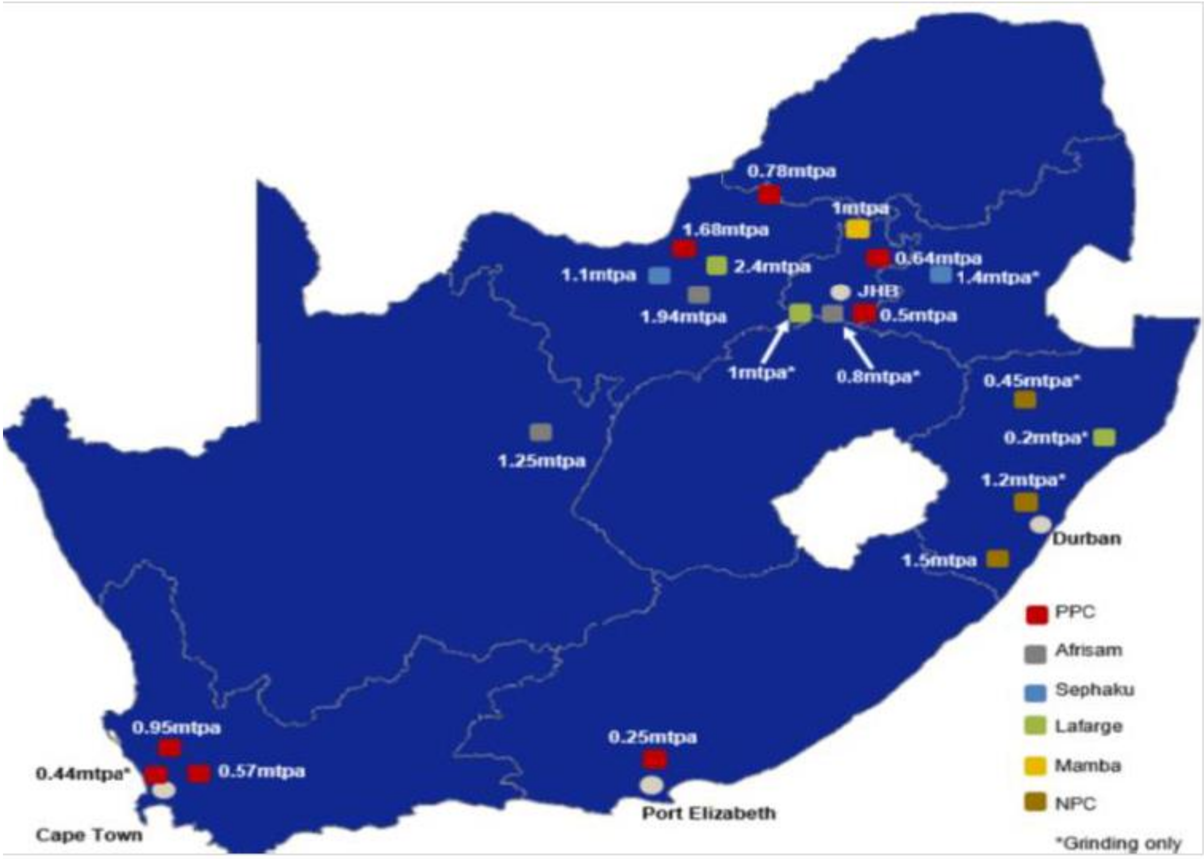


Figure 2-10: Cement Plant Locations in SA Source: (Electus, 2016).

2.4.2 Pretoria Portland Cement (PPC)

Pretoria Portland Cement limited **(**PPC) was established in 1892 and was the first South Africa cement company. The company has eight cement production plants and three milling depots around the Southern African region and its production capacity is 8 million tons of cement every year. PCC is the leading manufacturer and supplier of cement in South Africa with about 35% installed capacity in 2016 operations in five provinces in South Africa as well as in Botswana and Zimbabwe (Electus, 2016). It is advancing into a Pan-African business, with expansion across the continent which includes Rwanda, Congo (DRC) and Ethiopia.

2.4.3 Lafarge

Lafarge originated from the English company also known as White's South African Cement Company. In 1913 the operation was started in England. Lafarge started production of cement in South Africa at Hennenman in the then Orange Free State (now Free State) province in 1914 (lafarge, 2010b). Lafarge Industries South Africa (Pty) Limited was founded in 1998. Lafarge South Africa, a member of the Lafarge-Holcim group, supplies and manufactures of Lafarge ready mixed concrete, aggregate, cement and fly ash. Lafarge is among the top dealers of building materials in South Africa. In 2009, Lafarge Lichtenburg proved its support to the future of South Africa by commissioning a R1.2 billion project in order to increase Lafarge's cement production by 1 million tons yearly (Lafarge, 2010a).This project was the largest investment in South Africa's cement industry for more than 20 years. The company employs over 2 000 staff and has the capacity to produce 3 million tons of cement every year (Lafarge, 2016).

2.4.4 AfriSam

Anglo Alpha cement Limited was established in South Africa in 1934. The company changed its name to Alpha (Pty) Limited in 1994 then Alpha (Pty) Limited created AfriSam in 2007. AfriSam introduced pre-blended dry mix cement and plaster products delivered to construction sites in a standard volume cement tanker, which is then drawn out into a sealed silo pneumatically. This method successfully got rid of dust on the site and so is more environmentally friendly than the conventional method of delivering a dry mixture to the construction site in open trucks and then supplying by gravity into a silo (Afrisam, 2013). AfriSam has over 2 000 permanent staff and close to 1 000 contractors in Lesotho, Swaziland and Botswana factories. AfriSam has six production facilities and nine cement depots and has the capacity to produce 4.6 million tons of cement every year. Through the production of slagment from its Vanderbijlpark operations, it has the capacity to produce about 800 000 tons of slag cement and close to 200 000 tons of blended cementitious materials every year (Afrisam, 2013).

2.4.5 NPC-Cimpor

The establishment of NPC-Cimpor can be traced back to the year 1964 after the operation of Durban Cement Limited started in Bellair, Durban KwaZulu-Natal province of South Africa. Twenty years later, the company changed its name to Natal Portland Cement (NPC) because it expanded its operations and expansions to Newcastle, Port Shepstone and Durban in the Natal region. Alpha, PPC and Lafarge managed the operation of NPC. In 2002 CIMPOR (*Cimentos de Portugal)* took over Natal Portland

Cement operations completely (NPC, 2013). Natal Portland Cement (Cimpor) operated fully for a period of five years before joining a 26 % Black Economic Empowerment (BEE) shareholding partnership to act in accordance with South Africa's economic empowerment policy drive. NPC-Cimpor's desire for expansion and efficiency was completed in 2008 with the first modern cement kiln in South Africa in over 20 years being installed at its Simuma facility. The leading cement manufacturing company in KwaZulu-Natal province, NPC-Cimpor now has power to produce 1.5 million tons of cement yearly and employs over 1 000 permanent staff. Natal Portland Cement South Africa is a member of the Inter-cement Group of Companies (NPC, 2013).

2.5 Cement: plant layout and components

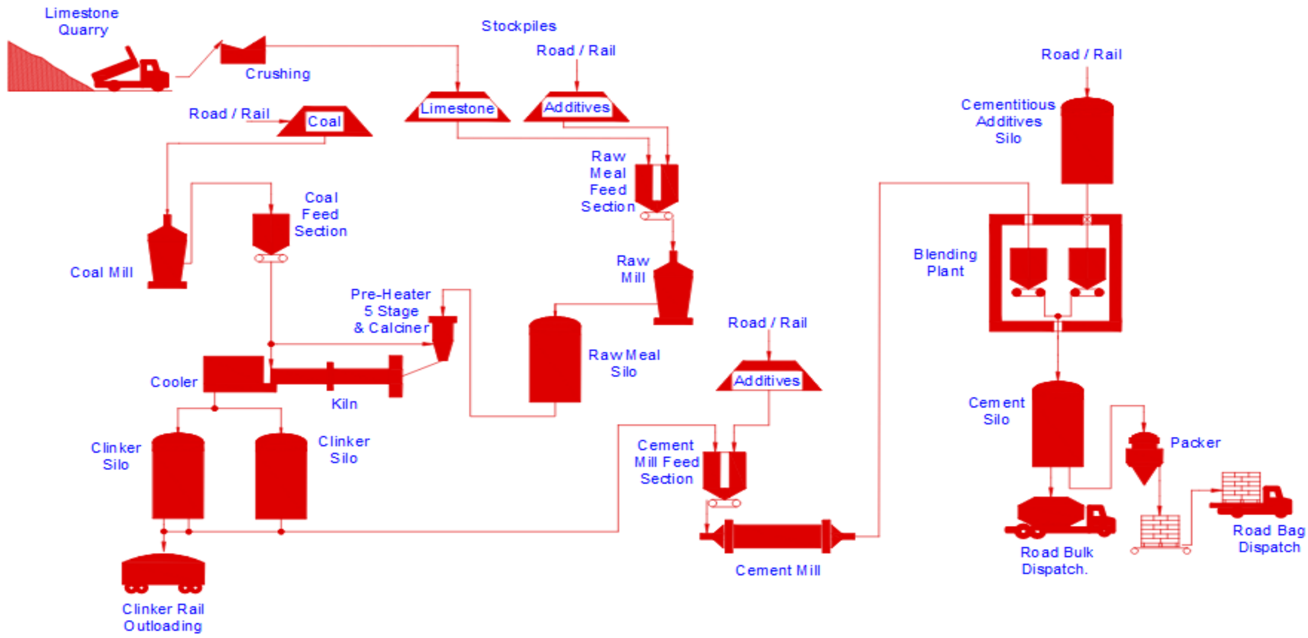


Figure 2-11: Cement Manufacturing Process (NPC, 2013)

2.5.1 Mining of raw material

Limestone is the main raw material that is mined using compressed air drilling and blasting with an explosive device and then transported to the plant via tippers or ropeways. Outside mining is increasingly globally because it prevents environment from damage. A typical mine for a cement plant, natural calcium carbonate minerals such as limestone, marl and white chalk which can provide $CaCO_3$. A small addition of "corrective" materials such as bauxite clay, iron ore, shale, clay or sand can occur by supplying extra iron oxide (Fe_2O_3), alumina (Al_2O_3) and silica ($SiSO_2$); these components can adjust the chemical composition of raw materials in order to meet the process and product requirements.

2.5.2 Crushing

The crushing process involves additional refinement of the fineness of the stone for further processing. The mined raw material (limestone) is supplied to the primary and secondary crusher, whereby the size is cut down into 10 cm large pieces in the size range 3 to 4 inches of gravel. Third crushers are used specifically to reduce the entrance size of the crusher stone to the mill. The limestone that was crushed is stored in the build-up stocks by means of stacker conveyors. The bauxite and ferrite together with the crushed limestone are stored in feed hoppers; from there the raw materials are supplied to the raw mill passing through the weigh feeders in the quantities required. In most cases, crushing circuits are made of primary, secondary and tertiary crushers. This circuit cuts down the size of the limestone through the crushing process, screening, and re-crushing of the limestone (Mejeoumov, 2007a).

2.5.3 Pre-homogenization and grinding of raw material

Pre-homogenization is the mixing of different raw materials to meet the requirements of the chemical composition, then grinding the raw materials together to form raw meal. To ensure the cement quality final product, the raw materials and chemical properties of raw materials should be strictly monitored and controlled.

2.5.4 Preheating

The pre-heater component is made up of series of vertical cyclones. Clinker is produced in the kiln at temperatures of about 1450°C where it is ground with other raw material in the kiln through cyclone hot air which is in contact to produce the powder called cement. In the cyclone, the thermal recycling the exhaust of the hot gases coming out from the kiln is used to heat up the raw materials before entering the kiln to ensure a faster and more efficient drying. Depending on the different moisture content of raw meal, a kiln can have up to a six stages of cyclone pre-heater for each additional level when the heat exchange efficiency is higher. The raw material can be heated up from 70°C to 800°C where de-carbonation begins. This is the place where limestone discharges carbon dioxide during the time of clinker production, the most important compound of cement before it is ground (Swanepoel, 2013).

2.5.5 Pre-calcining

Pre-calcining means the decomposition of limestone into calcium oxide. A fraction of decomposition reaction occurs at the bottom of the “pre-calciner” furnace i.e. above the pre-heater kiln burner, with the rest of the reaction taking place in the kiln. In the process of limestone decomposition, CO_2 emissions account for 60% to 65% of the total discharges, the remaining discharge is from industrial fuel combustion, where 90% occurs in the pre-decomposition stage.

2.5.6 Clinker rotary kiln

The pre-decomposed raw meal enters the kiln. Fuel in the kiln is directly combusted so that the temperature of the kiln can reached 1450^{o}C. When the rotation speed of the kiln is 3r ~ 5r / min, the material within the rotary kiln turns and is gradually moved from the preheating zone to the combustion zone. Inside the kiln, the high temperature, causes chemical and physical reactions in the material which turns the raw meal to form clinker.

2.5.7 Cooling and storage

The hot clinkers from the kiln are cooled down by the mean of the forced air. Clinker is discharged the intake heat and cool down at a lower temperature. The released heat by the clinker enters back into the kiln to minimize the energy lost in the system. A typical cement plant clinker production and grinding with a clinker silo. Clinker can usually sell as a commodity.

2.5.8 Mixing

The clinker is blended with other mineral components; all the types of the cement mixtures contain about 4% to 5% of gypsum which is used to limit the setting time of the cement product. If a certain amount of slag, fly ash, limestone or other materials are used instead of clinker, such products are known as composite cement.

2.5.9 Cement grinding

When clinker and gypsum are ground together into a grey powder this is called ordinary Portland cement (OPC), and grinding of clinker together with other mineral materials is called composite cement. In the past, powder was milled by using ball mills but now many modern plants are using more efficient equipment such as roller presses and roller mills. The finishing process mainly involves the final grinding of the clinker and demands large size electrical motors to operate the cement mill. The surface area of the material and the quality of the finished product is determined by the energy consumption in the mills. It is also largely dependent on the amount of additive required for the hardness of the material (E Worrell, Price, Powell, & Powell, 2005).

Blended cements and granite cements may contain a large proportion of additives (up to 40%) which can include natural pozzolans, fly ash, limestone, silica fume, or metakaolin (Bhatty, Miller, Kosmatka, & Bohan, 2004). In order to improve efficiency, closed-circuit systems are commonly used for grinding of the cement. The material going out of the ball mill is directed to the separator and separated into rough and fine portions. The rough portions are fed back to the mill for re-grinding and the fine portion is cement. The final milling must operate well to ensure the quality and consistency of the final product.

The temperature and fineness of the final product must be carefully controlled to ensure reliable and expected cement quality. In order to ensure the predictability and stability of the cement quality, the finishing process is made up of a milling circuit which also consists of separator and classifiers (Bye, 2011; Madlool, Saidur, Hossain, & Rahim, 2011). The grounded cement is transported by conveyor belt or powder pump into a silo for storage. At this stage, the cement is ready to bag or for bulk transport by trucks, railways, or barge.

2.5.10 Cement silo storage

The final cement product is homogenized and stored in cement silos, and then assigned to production packaging, where the cement is packed into bags or for bulk transport (bulk cement). Various silos are needed for the storage of the cement. New design silos allow for the storage of different type of cement in the same silo. Four types of silo configuration for cement storage are listed below (Association, 1997)

- Single cell silo with discharge hopper.
- Single cell silo with central cone.
- Multi-cell silo.
- Dome silo with central cone.

The compressed air passes through the airing pad at the bottom of the silo, which is used to start and maintain the cement discharge process for the silos. Some obsolete and low energy efficiency technologies such as wet process kilns feed raw materials for slurry instead of as a powder.

2.6 Sources of energy for cement production

The cement industry is widely recognized for its huge consumption of total industrial energy which is estimated to be about 30% to 40% in some countries. Cement production uses different source of energy including thermal energy and electrical energy forms. The production of Portland clinker consumes energy of between 3 MJ/kg to 6 MJ/kg clinker and it determined by the raw materials and the type of the process used.

2.6.1 Technology and thermal energy in production of cement

The thermal energy in production of cement represents about 90% of the total specific energy consumption, with main fuel sources being coal, fuel oil as well as fuels such as biomass and animal wastes. Being an energy demanding industry, energy expenditure accounts for 50% to 60% of the total costs of production (Wang, Dai, & Gao, 2009). If thermal energy is used this is approximately 20% to 25% of the cost of cement production (Singhi & Bhargava, 2010). The thermal energy Cost determines the selection of primary fuel source. Electricity consumption in a modern cement production process plant is on average 110 KWh/ton to 120 kWh/ton of cement (Mejeoumov, 2007b).

The activity of comminution, crushing and grinding of cement raw materials and finished cement product consumes about 70% of the total energy. The grinding phase of cement production for clinker and others extracts consume roughly 40% to 50% of total energy consumption (Harder, 2003). Even with the high individual energy requirement in cement production, for more than 100 years now the two-compartment tube ball mills together with an air classifier in closed circuit have been used for finishing the grinding of cement because of their reliability and the favourable physical and chemical properties of the cement product (Aguero-Starkman & Meech, 2014).

According to M. Taylor, Tam, and Gielen (2006), of the total energy used in the non-metallic minerals manufacturing industry which includes cement plants, the production of cement accounts for almost 66 % of this total. The largest amount of coal is used in relation to the cement kiln. Some processes make use of coal for drying of the raw materials, when there is insufficient energy from the cement kiln to dry the raw materials. In the clinkering stage, fans operate on an electricity supply which consumes up to 6 000 MJ/ton of clinker produced. Coal is the main source of thermal energy (Ottermann, 2011; M. Taylor et al., 2006).

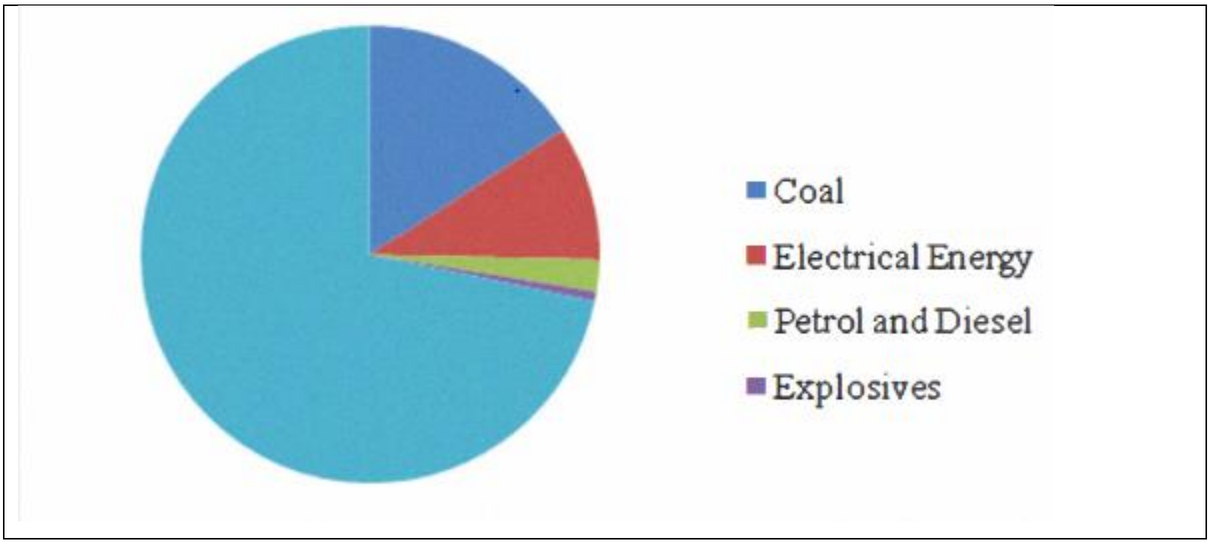


Figure 2-12: A typical 2010 cost split of energy consumption at a cement plant in South Africa (Ottermann, 2011)

Figure 2-11 explains the huge amount of coal consumed compared to other sources of energy in a standard South Africa cement plant. The light blue fraction signifies that coal is about 70% of the whole cost of energy consumed in a typical cement production plant in South Africa. Coal is consumed throughout the raw and finish milling processes. The darker blue fraction which is 15% of the entire cost relates to the use of coal in the clinkering stage. In a cement plant, the electrical energy accounts for 10% of the total energy costs, with remaining 5% made up of petrol, diesel and explosives (Ottermann, 2011).

2.6.2 Energy consumption in a South Africa cement plant

The energy consumption in cement plant differ extensively in their use of electricity, depending on the function and the capacity of the plant. This is the case because some plants are contracted to complete only some parts of the cement production process, while others carry out the whole process of the plant production from the raw materials to the production of cement. South African cement plants consume several megawatt hours every year with limits ranging from 55 megawatt hours to 194 megawatt hours (MWH) yearly (Lidbetter, 2010)**.**

The main energy consuming components in a cement plant can be divided into four categories as shown in Figure 2-12.

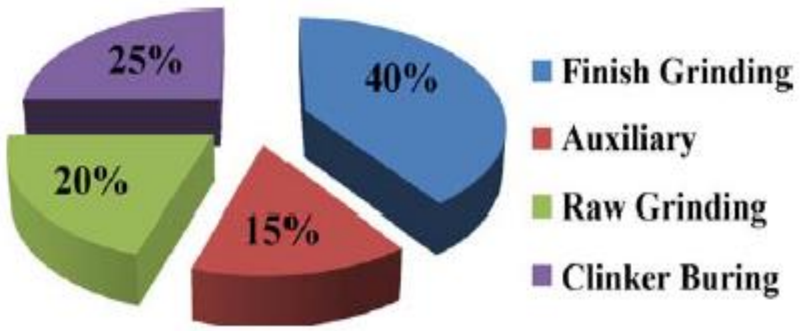


Figure 2-13: Energy distribution of cement manufacturing equipment (Mejeoumov, 2007b).

Figure 2.12 illustrates that the grinding circuits consume roughly 60% of the energy consumed, coming from thermal energy delivered by coal fired kilns and electricity (electrical energy) which is used to run the drive motors, the fans and conveyor transport systems. Cement plants ingest an average of 100 kWh to 120 kWh per ton in the grinding circuit process (Cullen & Allwood, 2010; Mejeoumov, 2007b).The electrical systems in the grinding circuits consist of air compressors, large fans, conveyor transport systems, and water and oil pumps. The total electricity (electrical energy) consumption of the grinding circuits signifies up to 75% of all energy used in the cement plant. The energy consumed in a cement plant comes to a total cost of 50% to 60% of production of which 18% to 43% is apportioned to electricity (Madlool et al., 2011). In a standard cement plant, electricity represent 13% of the total energy inputs, however it accountable for almost 50% of the total energy cost (NRC, 2009).

2.7 Demand side management

The South African electricity service, Eskom, has introduced various ideas to control and manage the limited energy supply efficiently. One of these initiatives, Demand Side Management (DSM) is engaged in the manipulation of demand movements. This approach is designed to provide full implementation and supervision of electricity to customers. It is designed to reduce large "peaks" and "drops" in the country's electricity flow. Another purpose of DSM is to install energy-saving technologies in order to reduce and change the demand profile (Skinner, 2012). DSM is a way to reduce demand, consequently delaying the time that new generation capacity is required. DSM measures encourage customers to use less electricity, and avoid using it at times of peak demand.

Energy efficiency and load shifting schemes present many opportunities. Therefore, in determining the effectiveness of load shifting, the expected trend of electrical consumption should also be taken into account. According to Howells (2006), the non-metallic minerals sector was listed as 8th highest in terms of energy saving potential for DSM in 2003 and is expected to be 5th by the year 2020.

Machine driven processes are the major sources of electricity demand. In typical cement plants, these usually involve driving fans, crushers, mills, conveyors, compressors and turning kilns. Thus, if it is possible to implement changes in this focus area of the load shifting program, it will provide a significant savings in the total electricity consumption of a cement plant. In order to determine the amount of saving possible, there is a need for cement plant energy consumption assessment.

2.7.1 Energy use and management in the South Africa cement industry

Proper planning and budgeting is required for energy in order for cement plants to stay economically viable. As indicated by Ottermann (2011), energy accounts for more than a third of the total cost of production in most cement processing plants. R. P. Taylor (2008) concluded that energy represents between a 5th and almost 40% of the energy cost. Ottermann (2011), states that the difficulties of energy supply in South Africa will remain in the short, medium and long term. Further, the increase in cost of electricity, and rapid exhaustion of coal sources will make it more complex for cement manufacturers to work if the system used remains unchanged.

Energy management in a cement plant is a fundamental element in its success and sustainability, and needs buy in, educated policy and strategy from the corporate are equal. In South Africa, energy management is essential because, as mentioned earlier, the country is one of the highest emitters of CO_2 emission and users of fossil fuel for energy globally. To manage all the production of cement efficiently, it is very important to understand the energy requirements of the various components of the production process.

The effort of energy management is commonly obstructed by numerous factors (McKane, 2010) such as:

(i) Lack of information within the plant.
(ii) Limited awareness of the benefits of energy efficiency measures among the staff.
(iii) Inadequate skills among the management.
(iv) Cultural or financial limitations that lead to investment in production capacity rather than energy efficiency measures.

2.7.2 Emissions of CO_2 in South African cement production plants

South Africa is the 13th largest discharger of CO_2 in the world, and, given the developing nature of its economy, it is likely that these emissions will increase if the improvements in our goals are not followed. In addition to the cost of energy, the reduction of CO_2 emissions and other GHGs is a worldwide concern because of the impact of such emissions on the environmental. Close to 33% of world emissions are associated with uses of energy. Cement plants cause up to 7% of global CO_2emissions (Ali et al., 2011; Anand, Vrat, & Dahiya, 2006)**.**

Müller and Harnisch (2008) reported that global cement plants contribute between 5% to 8% of all anthropogenic CO_2 emissions. Mwakasonda (2007) stated that South Africa contributes about 1.44 % CO_2 equivalent worldwide, and up to 40% to 60% of CO_2 emissions in sub-Saharan Africa. Since 1950, the emissions of CO_2 from burning fossil fuel has increased about seven times in South Africa with coal being responsible for up to 93% of those emissions (Marland, Boden, Andres, Brenkert, & Johnston, 2007)**.** South Africa's primary electricity service, Eskom, supplies 95% of the electricity consumed in South Africa and 93% of the electricity (electric energy) supplied by Eskom is produced by coal-fired power plants and the remaining 7% is produced by hydro, nuclear and gas turbine. Reducing the electricity require from cement plants in South Africa will automatically also cause a reduction of CO_2 emissions and other GHGs.

Constant increases in the cost of fossil-fuel, as well as the worsening of environmental quality globally, have caused energy policy makers to develop strategies to reduce energy consumption and reliance on fossil fuels. However, energy demand and energy consumption worldwide is rising due to the increase in demand of electricity (Enerdata, 2013)**.**

2.8 Energy efficiency overview

2.8.1 Energy efficiency overview in South Africa industry

Energy efficiency is a way of obtaining of the same energy goods and services with less energy input, better quality of life with less pollution at a price that is lower than the current one extending the life of those resources and with less conflict. The manufacturing sector globally provides 33% of the global energy demand and CO_2 emissions. The heavy energy consuming industries are, for example, aluminum, iron and steel, cement, pulp and paper, and chemicals and petrochemicals. It is very important to understanding how energy is being used in the manufacturing sector, and what are the domestic and international trends from that it is possible to plan efficiency improvements (IEA, 2007)**.** South Africa is among the fastest growing developing countries, with large energy consuming industrial sector. About 95% of the energy demand is provided from coal-fired power plants and therefore South Africa has a very high GHG emission factor (Eskom, 2012)**.**

Energy efficiency is important for security of energy supply, economic effectiveness, reduction of global warming and environmental sustainability (R. P. Taylor, 2008). The main opportunity to reduce energy demand growth is to show that it is cost-effective which gives shareholders attractive returns. There are many opportunities for energy efficiency in industrial sectors around the world, with developing countries representing 80% of the whole savings opportunity (Farrell, Remes, Bressand, Laabs, & Sundaram, 2008). The industrial sector remains the main consumer of energy in many countries including in South Africa. In the past decade the South Africa government has introduced several policies and regulations to make sure that energy usage is efficient, mainly because of the economic needs and environmental concerns.

2.8.2 Energy efficiency in the South Africa cement industry

Energy is an important resource used in cement production plants. Primarily this energy is from fossil fuels (thermal energy), electricity (electrical energy) or the both forms of energy. Energy is an essential requirement in a cement plant and therefore it must be in continuous supply to avert breaks in the production process, for example in the manufacturing process which can ruin the total production and productivity. Therefore, it is very important for every company to addresses this issue of energy from a corporate point of view. During the burning process in a cement plant, thermal energy is used while electricity (electrical energy) is used for the cement grinding process (Madlool et al., 2011). Energy efficiency in production of cement has a direct effect on the whole cycle of energy consumption, emission of CO_2 and the cost of energy. In this dissertation, the source of energy that will be considered is energy from coal (thermal energy) and electricity (electric energy) only.

2.8.3 Energy efficiency and energy management in industry

'Energy efficiency' and 'Energy management' are two strategies for reducing the negative effects of energy consumption. Energy efficiency is defined as a ratio involving in an improved performance of systems, service or goods with less input of energy. Energy efficiency is a way of managing and restraining growth in energy consumption. Something is more energy efficient if it provides more services for the same energy input, or the same services for less energy input. Energy efficiency reduces the cost of production and increases environmental benefits by reducing emissions of GHGs and air pollution (Peña Blume, 2010)**.** Energy efficiency management means regulating and improving energy by using systems and techniques in order to lower the energy requirements per unit of the production while maintaining continuous or reducing total costs of the output production from the systems (Chakarvarti, 2011).

The issue of energy efficiency management in the manufacturing industries needs to be the central topic of discussions on cost reduction because it is a fundamental way to reduce the cost of operating and to maximize profits. The idea of the energy efficiency management has appeared as an important tool in realizing efficient energy utilization, it also reduces the demand for energy and helps reduce operational costs associated with energy use. Mohd (2011), defines energy efficiency management as a logical use of management and technologies in order to improve energy performance of an organization, while Bunse, Vodicka, Schönsleben, Brülhart, and Ernst (2011) describe energy as energy efficiency control, monitoring and improvement of performances.

It is extremely important for organizations around the world, many of whom are currently adopting energy management solutions to improve their energy consumption, to act in accordance with legislation and energy standards requirements, and in this way, improve their reputation with their customers. As defined by Kannan and Boie (2003), energy efficiency management is a sensible and efficient use of energy in order to maximize profits and improve an organization's competitive position by organizing measures and optimizing energy efficiency in the process; profit and competitiveness are factors in determining business success. Through the implementation of energy efficiency management plans, organizations can save up to 20% of energy bills, thereby effectively reducing operating costs Mohd (2011).

Kok, McGraw, and Quigley (2011) report that there is a worldwide awakening regarding the need to apply energy efficiency measures in the wake of global warming and shortage of resources. Energy efficiency improvement is the best economic and most easily accessible method of increasing energy security and reduction in emissions of GHG. Energy efficiency is now a common policy goal of many nations around the world (Levin, Cashore, Bernstein, & Auld, 2008). Energy efficiency should be considered as an environmental objective in any industrial sector. Energy consumption may vary depending on the type of industry, the type of process, and the volume of production, among other factors. In this present day, the optimization of the energy resources to reduce costs and increase production in an environmentally friendly way is gaining great interest among industries. Industrial energy efficiency management can help countries like South Africa who are planning to increase industrialization in order to develop their economy. Industrial energy efficiency can help create additional energy capacity to further expand the country's economy.

Thus, as Ottermann (2011), proposes, competitiveness in the cement industry will depend on how adequately cement plants can oversee their energy. It is essential for industrial energy users to observe that energy efficiency management can lead to greater cost savings, better use of existing capital equipment, extend the life cycle of equipment and allow further expansion of the plant without new capital expenditure and by utilizing current equipment more effectively (Mahon, Kiss, & Leimer, 1983)**.**

CHAPTER 3: BENEFITS OF ENERGY EFFICIENCY IN INDUSTRY

3.1 Barriers and improvement for energy efficiency in cement plants

Energy efficiency barriers is a multidisciplinary exercise involving theoretical backgrounds such as organizational economics, organizational theory, neo-classical economics and behavioral theory (Backlund, Thollander, Palm, & Ottosson, 2012). This is the reason why is vital to understand the barriers militating against energy efficiency measures within a specific industry, because dealing with these barriers may result in reduction of emissions at a lower cost. Nevertheless, as a company's investment strategy is often the result of a complex decision-making process. These barriers include all the hindering factors that prevent the application of cost-saving energy efficient measures (Fleiter, Worrell, & Eichhammer, 2011).

The fact is that industries faced series of social, financial and technical issues which can act as barriers that limit their capacity to embrace energy efficiency technologies or measures. The relevant question is, what are the barriers and how can we surmount them? Schleich and Gruber (2008), carried out econometric evaluations of 19 German commercial sectors and found that the absence of accurate data on energy consumption patterns and investors were the most important barriers.

3.2 Theoretical barriers

Improving energy efficiency is enormous prospects although it seems ignored because the potential for energy efficiency. These limitations are called “barriers” energy efficiency barriers are the mechanisms that hinder a decision or behavior that looks to be both economic and energy efficient as opined by Sorrell and O’Malley (2004) and Thollander, Palm, and Rohdin (2010).

Energy efficiency barriers are discussed based on taxonomy created by Sorrell and O’Malley (2004) Schleich and Gruber (2008) and Fleiter et al. (2011)**.** The reason for choosing this classification is because it is particularly suited to their method to the different theoretical frameworks, because the barriers can be regarded based on transaction cost, neoclassical and behavioral economics. According to these concepts, energy efficiency barriers are grouped under three main classifications namely; Organizational, Economic, and Behavioral barriers (Backlund et al., 2012; Sorrell & O’Malley, 2004; Thollander et al., 2010). Based on the review of relevant literatures, a taxonomy of energy efficiency barriers was established by Sorrell (2000), ranking 15 theoretical energy efficiency barriers. The objectives for developing this taxonomy was to harmonize the concept of energy efficiency barriers with current theories.

3.2.1 Economic barriers

The idea of energy efficiency barriers comes from conventional economic theory. Although, the use of conventional economic theory is not sufficient to understand energy efficiency barriers, so economists have extended the scope by integrating new economic concepts such as organizational and business (Sorrell, 2000).

Economic barriers can either be economic market failure or economic no-market failure. Neo-classical economists argued that the fundamental theorem of the welfare economy that governs the optimal market state that resource allocation will be best where (Sorrell, 2000);

- a total market with clear property rights, where buyers and sellers are free to exchange their assets;
- consumers and as well as producers show competitive advantage by increasing efficiency while reducing expenses;
- all consumers and companies know the market price; and
- transaction costs are zero.

3.2.2 Market failure related economic barriers

Split Incentives

When the energy performance of the equipment installed by the sub-contractor is difficult to legally implement, this will encourage the sub-contractor to build cheaper energy performance equipment. In a big organization, several set of people and departments may not be responsible for the energy savings. If a person, section, or department cannot gain from investment in energy efficiency measures, the interest in implementation may be reduced (Adam B. Jaffe, Newell, & Stavins, 2004).

Imperfect information

If you do not study the technical feasibility or profitability of an investment, the opportunities of cost-effective investment may continue to be non-implemented. Organizational barriers, for example lack of decision-making may worsen the role of imperfect or deficient information. Lack of correct information could lead to failure to meet cost-effective energy efficiency measures (Howarth & Andersson, 1993)**.**

Adverse selection

Adverse selection connotes a type of information asymmetry, arising from a different level of information held by both parties in a transaction. It occurs when a party is conversant with the technology before signing the contract (Sorrell, 2000). Transaction costs may be affected by the paybacks of efficiency as indicated. An adverse selection occurs when the energy efficiency technology manufacturer has clearer understanding or personal information regarding the equipment's performance than the prospective buyer of the technology. This may result in the prospective buyer not buying the new technology because the information he has is insufficient to make a reasonable decision based on cost implication.

Principal or agent relationship

According to Sorrell (2000), the principal or agent relationship is another type of information asymmetry; this barrier is common at the managerial level of an organization than in the energy services market. The principal or agent relationship exists in the interests of the principal, depending on the action of the agent. The principal or agent relationship is the result of incomplete information about the subject's response to energy efficiency measures from the principal. This tends to cause the principal to enforce harsh investment criteria so that the agent is unwilling to adopt the cost-effective investments (Adam B. Jaffe et al., 2004). Top management may not have a full and complete understanding of energy efficiency investments, so they may ignore it (Brunke et al., 2014).

3.2.3 Non- market failure related economic barriers

Lack of Access to Capital

Lack of access to capital is often considered as an energy efficiency barrier to investments (Sorrell, 2000). To wisely invest in energy efficiency measures, companies need funds from external or internal sources. Although, access to fund from external sources i.e. banks or financial organizations are often restricted by capital market failures (UNIDO, 2008). Due to the failures of the capital market, some banks as well as financial institutions, particularly from less developed countries, are short of technical knowhow to properly estimate energy efficiency projects. Therefore, these investments are high-risk, which hinders the bank from investing in this regard. Limited access to capital may hamper the implementation of measures to enforce energy efficiency projects.

According to Fleiter et al. (2011), if energy prices fall after new technologies are implemented and investing in energy-efficient measures may not be profitable, fewer managers will invest heavily on energy efficiency.

Hidden costs

Certain costs might be very complex to estimate or quantify even if they are known to be real. Many companies may not have interest to allocate fund to energy efficiency because the cost is unseen to the researchers, but unhidden to the companies. According to Venmans (2014), managers may not add these cost effectiveness calculations as they are difficult to quantify. There are some hidden costs, for example, purchasing costs and procurement costs, etc. which can be seen as a barrier because in another organizational structure or policy, they can be avoided. If the hidden costs are removed, this will reduce the company waste in term of material and the cost of maintenance.

The cost incurred in collecting information may be seen as a concealed cost, which is a clear efficiency gap in the neo-classical economic structure of Adam B. Jaffe et al. (2004), Information collection can be subcontracted to a dedicated audit bureau.

Therefore, the assessment of hidden costs is very significant for understanding other prospective barriers. In addition, some hidden costs are obstacles to cost-effective results since they can be avoided in different companies/organizations or regulatory environments (Venmans, 2014). Examples of hidden costs include but not limited to overhead costs, the cost of information collections and analysis, inconvenience and production disruptions.

Risk and Uncertainty

A high percentage reduction in profit calculations is a reasonable way to compensate for technical risks, regulatory uncertainties or energy price uncertainties. However, contract structure, organizational structure, market design and policies influence the risk of energy efficiency investment profile.

According to Greene (2011), if the uncertainty in investment decision is treated in a partial way as emphasized by behavioral economics, the risky nature of the project can be a cost-effective economic barrier. Risk avoidance may be responsible for the limitation in energy efficiency measures.

Heterogeneity

Heterogeneity occurs when a specific technology is cost-effective though not suitable for all the companies. Particularly for those are producing one product or technologies that limited by heat. For instance, a heat exchanger might not be working on an exhaust of a ventilation flow because it contains too many processes that associated with it (Thollander & Palm, 2012). A cost-effective technology or measures may not be suitable in all situations.

3.3 Organizational barriers

If a company's energy management status is very low, it may lead to lower priorities within the establishment. Management may not have an environmental impact study on energy abuse, thereby reducing the priority of energy efficiency improvement. Management can also resist change and pay more attention to certain results, such as production compared to energy efficiency (Trianni & Cagno, 2012). Big organizations with a more diverse staff and greater technical capacity, may have more financial capital and time available for energy efficiency investment. In small companies, energy efficiency programs are often not implemented due to fears of loss of production because production gets a higher percentage of company investment than energy assessment (Chai & Yeo, 2012).

Some managers will hesitate to start energy efficiency projects if they doubt the impact of such projects. Others resist technological change because they lack the knowledge to implement energy conservation projects. The lack of trained personnel leads to a difficulty in implementing energy-efficient strategies. Lack of laboratory equipment and equipment shortages in general is also a barrier to energy efficiency improvement. The government's bureaucratic and financial capital procedures is another barrier. The most important challenge to promote energy efficiency is to conquer energy efficiency barriers to technologies (Sardianou, 2008).

3.3.1 Power

The obligation for energy related matters is commonly delegated to mechanical unit, electrical unit, maintenance unit or energy supervisors who are quite low in an organization, which may cause a barrier to improving energy efficiency within the establishment (Sorrell, 2000). Because of their low significance in an organization, they do not have enough authority to start energy saving projects within their organization and therefore they are subjected to the management bureaucracy. However, top management who are able to start energy efficiency measures often ignore it because energy efficiency improvement is not the main company activity and therefore they do not see any meaning to energy efficiency projects. Energy management practices do not often get enough attention in energy-consuming industries such as cement plants. When top management does not see the importance of energy efficiency within the organization then it is very difficult to implement such measures (Thollander et al., 2010).

3.3.2 Culture

According to (Sorrell, 2000), an organization's culture is not seen as one of the energy efficiency barriers, but a variable to consider for not adopting cost-effective solutions by an organization. Culture can be regarded as an organizational value, standard or practice that may hinder the important efficient investment which leads to the organization not adopting investment. Organizational culture is correlated to the establishment of personal values of industrial organizations (Thollander & Palm, 2012). The culture of a particular organization can influence the action of senior managers and workers regarding energy efficiency.

3.4 Behavioural barriers

The processes of making decision regarding investments in energy efficiency enhancement, as in other similar investments, depend on the behavior of individuals or several players within a company (Sardianou, 2008***)***. Behavioral parameters include the, credibility and trust, inertia values, forms of information can be barriers to improving energy efficiency. These are explained below.

3.4.1 Credibility and trust

The credibility of information encompasses a combination of capability and credibility (Sorrell, 2000). The spread and integration of relevant information depends on the level of the integrity of the source. If the credibility and trust of the information source is questionable, inconsistent and not reliable then the organization might be unwilling to invest in and fund energy efficiency measures based on this information received. In order to effectively provide information on energy efficiency measures, the basis of information should be credible and reliable. If any of these factors is missing, this will lead to inefficient adoptions energy efficiency

3.4.2 Inertia

People who oppose change in an organization may ignore cost effective measures that can ensure energy efficiency. In this case, inertia refers to the group of people or organizations who do not want to change their established habits and practices. Thus, the agent proves their behavior by given the wrong information (Sorrell, 2000). The presence of inertia in an organization can justify rationale behind cost effective energy efficiency investment not been accepted, as they do not fit in with an organization's routine.

3.4.3 Values

Energy efficiency improvements are likely to succeed when led by individuals who are well motivated, and when supported by top management. Values are not a barrier as such, but underlie the reasons why an organization accepts or rejects use of cost-saving energy efficiency measures. When an organization is deeply rooted in the values of energy efficiency and environmental awareness, there is the likelihood they invest in energy efficiency measures than an organization that does not value energy efficiency and environmental awareness. Therefore, the values of an organization can justify why some organizations do not consider energy efficiency measures while others do.

3.4.4 Types of information

The information provided to an organization is an essential parameter for decision-making. It also helps in the execution of energy efficiency cost-effective programs. The type of Information should be detailed, clear and simple. (Sorrell, 2000). summaries five fundamentals of information that affect the effectiveness of energy efficiency related information:

- Information must be accurate.
- Information must be simple and clear.
- Information must be specific and individualized.
- Information must be promptly providing to relevant decision-makers.

3.5 Empirical barriers

A large number of findings have established the presence of barriers or hindrances to industrial energy efficiency improvement. As shown in the literature, the nature of these barriers are different between technology and its adoption. According to Sorrell (2000), barriers vary depending on regional and sectoral conditions. These changes explain the range of empirical methods for studying energy efficiency barriers. The purpose of these empirical barrier surveys is to explain the presence of energy efficiency gaps by scrutinizing how these barriers exist, work, their backgrounds, and the use of different interventions to bridge the efficiency gap.

Industries around the world are facing energy efficiency barriers from various sources including financial, cultural, technical and external sources (UNEP, 2006). In order to seize the significance of social and human aspects of industrial energy efficiency barriers, Palm (2009) explored the life categories to supplement industrial energy efficiency barriers. His study sought to extend the understanding and rationale behind companies not improving their energy efficiency through the observation of the company's energy culture, the perception of energy use, and the ultimate control of energy use habits and practices within the industry. Palm and Thollander (2010) employed a combination of engineering as well as social sciences to justify the barriers to energy efficiency in European industries, taking into consideration the interdisciplinary nature of the study of industrial energy efficiency barriers.

3.6 Lack of energy management policies

Although many companies have strategic ways of minimizing their energy consumption, the influence of government policy can also not be over emphasized. Limited policies, ineffective implementation, inconsistent environmental and economic policies have been associated as barriers. The lack of effective policy is a major issue, although the situation varies from countries to countries.

Hasanbeigi, Menke, and Du Pont (2010)**,** studied six largest cement industries in Thailand. Interviews were also conducted with private experts, policy regulators, policy makers as well as energy services companies. Interviews were based on a questionnaire with six main questions, with a variety of options for response. The outcomes of their finding show the following:

Management regards production as more important than energy efficiency:

In many manufacturing industries, top management pays more attention to production output, the quality of the product and sales, with limited attention to energy efficiency. For instance, in some cement plants, although the cost of energy accounts for a significant share in the cost of cement production (Bounded rationality).

Management is concerned about the cost of investment of energy efficiency measures:

Although the repayment period for energy efficiency measures may be brief, the cement industries find it difficult to obtain the first investment required to purchase energy efficiency measures.

Management are concerned about the time needed for improving energy efficiency:

Interrupting industrial production (and the costs associated with that) can raise anxieties about the timing requirements for energy efficiency measures implementation.

There is no coordination between external organizations:

Energy implementation and environmental regulators do not have proper implementation and enforcement because the various ministries, departments and government agencies in charge of energy and environmental management lack coordination.

The results of Hasanbeigi, Menke, et al. (2010) study show that the perception of barriers were different amongst the three types of respondents. From the standpoint of the cement industry, the energy efficiency barriers may be explained from the perspective of hidden costs, with the importance of maintaining production taking priority over energy efficiency costs. There are many possibilities for improving energy efficiency, but they are often overlooked because the potential for energy efficiency is limited.

3.7 Energy efficiency improvement in cement plants

The goal is to optimize the equipment to operate at optimum capacity, or provide an alternative technology to minimize energy consumption. Energy efficiency optimization provides easier implementation than the actual replacement of equipment. Notable example includes the control of vibration of the mill feed (Gugel & Moon, 2007).

3.7.1 Energy-efficiency opportunities for the cement finishing process

Improving grinding mills and grinding circuits is the best method to save energy in a cement mill. These improvements will allow the cement to be milled with less electricity and also improves the capacity of the cement mill. Cement grinding can be achieved with about 22 kWh/ton of electrical energy by using a two-stage closed circuit having high pressure grinding rollers, two separators, a disagglomerator, as well as a ball mill (Aydoğan, Ergün, & Benzer, 2006). The following section explains measures to improve the energy efficiency of the cement plants finishing mill, as per (Price, Worrell, Galitsky, & Price, 2008),

Process control and management in cement grinding mills for finish grinding

Improvement in process control system can always be implemented for monitoring and maintaining the flow of mills and the separators to achieve fine quality product. Improvement produces a steady and product of high quality while preventing excessive power consumption. Tsamatsoulis and Lungoci (2010), researched the optimization of Proportional-Integral-Derivative (PID) controllers in cement mills. Goebel (2001), valued the energy saving as a result of optimization in cement finishing mills to be between 2.5% to 10%, (Lauer, Becerra, & Deng, 2005), showed a reduction of 2% in energy consumption with improved control systems.

Using high pressure (hydraulic) roller press for finish grinding;

The high-pressure roller press has frequently been proven better than traditional ball mills. Using high pressure roller press can result in 30% energy reduction according to Wustner (1986), or 10% to 50% energy savings according to (Patzelt, 1992). Von Seebach, Neumann, and Lohnherr (1996), recorded 3500 bar energy efficiency improvements with a high-pressure roller press. The operational costs are lower than alternative technologies (Van der Meer & Gruendken, 2010). When the size reduction ratio changed from 308.2 to 4.4 the specific energy consumption of the high pressure roller press also changed from 8.02 kW h/t to 4.05 kW h/t (Aydoğan et al., 2006). Roller press is used for pre-grinding combined with a ball mill. The high pressure roller press is used frequently to expand the production capacity of present grinding mills, particularly in countries where electricity is a very expensive or where the power supply is very poor (Price et al., 2008).

High-efficiency classifiers

The application of high-efficiency classifiers or separators is a modern advancement in efficient grinding technologies and can improve the quality of the product and reduce electricity consumption (Price et al., 2008). According to Ernst Worrell, Kermeli, and Galitsky (2013), separating rough and cement particles by using high efficiency separators is more energy, can reduce the re-grinding of cement particles and this can save energy about 5 kWh/ton to 6 kWh/ton. More energy can be saved by changing from pneumatic to mechanical conveyors, and also by standardizing silos to a gravity-based blending system. If you need more efficiency without buying a new mill, the separators inside the grinding circuit can be improved to a more efficient model, or the current mill can be optimized for maximum efficiency. Upgrading to high efficiency separators can save 8 Kwh/ton of cement (Ernst Worrell et al., 2013).

Improving compressed air systems

Energy saving within the plant can be attained by designing and maintaining proper compressed air systems. Reducing air leakage can save up to 16% of the electrical energy savings in compressed air systems, and 33% of the total energy savings of compressed air can be achieved by using a collection of energy efficiency measures (Radgen and Blaustein, 2001).

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Methodology

4.1.1 Research method and tools

Qualitative and quantitative research methods are hereby introduced and compared. Qualitative and quantitative research methods are carried out in different ways. The best way to do research is to bring together the two research methods so that they can complement each other because it cannot be said that one method is better than the other. This was achieved in this study by utilizing a methodological approach which includes both qualitative and quantitative approaches. The data for the study were collected via qualitative semi-structured interviews and respondents completed a quantitative questionnaire to obtain data regarding energy purchased, energy consumed, energy distribution and energy consumption losses. This approach was chosen so as to attain a holistic view of the complex and interrelated set of factors which affect energy efficiency improvement.

4.1.1.1 Qualitative method

Qualitative research methods are traditionally being used in social science and market research, but now it has been adopted in many different disciplines in the academic arena (Denzin & Lincoln, 2011). The purpose of qualitative researchers is to collect knowledge and to gain an in-depth understanding in-depth human behavior in order to control the causes of such behavior. The method of this research is not only what, where, when, but why and how particular decisions are made. Qualitative research gives comprehensive descriptions of conditions, procedures, problems, observed behavior and general views. Mainly qualitative methods focus on subjective instead of objective data (Graneheim & Lundman, 2004).

There are two types of qualitative research, namely:

Exploratory research

Exploratory research is primarily based on the secondary study and review of existing historical data, literature, as well as case study and pilot study, so as to position the researcher alongside the research topic. Exploratory research aims at solving the knowledge constraints of research topics through a clear and accurate description of the problem.

Attitudinal research

Attitudinal research is in-depth analysis of collected data with the aim of evaluation, understanding, examining the view and belief of a person or group of people on a specific object. Attitudinal research is largely used in the field of marketing research.

According to Hines and Rich (1997), for any successful qualitative research to be undertaken these specific procedures must be followed:

1. Collect the data required using one of the following methods:
   - Interviews, which include:
     - Structured interviews, using a firmly constructed schedule of questions.
     - Semi-structured interviews, using open-ended questions.
     - Unstructured interviews, using unscheduled detail about the research topic.
   - Focus groups, choosing and assembling a group of individuals from a personal point of view to discuss research topics.
   - Direct observation, this method is used when other technologies cannot collect the data required.
   - Case study is used to control all the details and to get an in-depth understanding of a selected sample case rather than the whole population.
2. Profoundly describe the situation, process, people, communications and behavior observed.
3. Study and examine the data collected to determine the problems in the restricted samples.

Researchers are required to select the sample that is best suited for the purposes of the study and they should provide a brief description of the sampling method (Creswell, 2012).

This study uses qualitative methods because the researcher wanted to understand the history of various processes in this particular cement plant.

4.1.1.2 Quantitative method

Quantitative research methods gather systematic and empirical data regarding quantitative properties, phenomena, and their correlations. The purpose is to develop and use mathematical models, theories and hypotheses that influence phenomena. The measurement process is critical to quantitative research methods because it gives a fundamental link between empirical observations and mathematical formulas of the correlations. Quantitative methods use numbers and statistics to explain arguments and include theory to provide clarifications.

According to Axinn and Pearce (2006), quantitative research requires numerical illustration and statistical analysis to examine and determine the authenticity of a theory or a hypothesis in a particular field. Quantitative research examines and analyses the temporary relationships between variables in the process. Quantitative research centers on objective instead of subjective.

The purpose of quantitative research is:

1. To study and to examine the collected data in order to determine the problem based on a particular hypothesis or theory.
2. To use statistical practices to measure and analyze the relationships between the collected data.
3. To display discoveries and result by using tables, graphs and charts.

The data collection process uses standardized methods for instance questionnaires and well-organized interviews. Quantitative methods are applicable in this research work, because the study involved measurements/readings.

Quantitative research methods are more objective, while the qualitative research are more subjective. The research subject id accurately defined and the collected materials are measured numerically.

To realize the study, the following tools were adopted:

1. Questionnaire.
2. Interviews.
3. Observation.

4.1.2 Questionnaire

When information is needed on "characteristics, behavior and attitudes of the population", standardized questionnaires are usually used (McLafferty, 2010). According to Davies and Hughes (2014), questionnaires are commonly used to assist in getting vital information and they are a means for research. A questionnaire provides an opportunity for the respondent to think about the question for a period of time, rather than making an immediate response in which is the case in an interview. A questionnaire also gives respondents an opportunity to express their opinion because it is a more anonymous format, whereas in the interview they may not answer directly as a result of fear. For respondents that are very busy a questionnaire is more convenient, because it can be completed at a time which is suitable to them.

There are various forms of questionnaires items such as matrix questions, rating scales, dichotomous questions, multiple choice questions, contingency questions, open-ended questions and closed ended question (Cohen, Manion, & Morrison, 2013).

Closed-ended questionnaires are faster to code, in addition they are focused and they are straight to the point. Open-ended questionnaires are helpful when the answer is anonymous, or there are many sets of answers or where closed-ended questionnaire would have to provide a long list of options. Open-ended questionnaires allow the respondent to communicate their opinions without fear of being identified. In this particular study, open-ended, closed-ended and multiple choice questions were employed. This questionnaire can be viewed in Appendix 1.

4.1.3 Observation

In terms of observation, the researcher becomes part of the plant or group under study; observation is not just about looking (Cohen et al., 2013). During the period of this study, the researcher noted and documented the behavior of the respondents (VanderStoep & Johnson, 2008). The observation method is a more reliable source of information than the reported survey, although it is very expensive in time because the researcher must be present in the plant. It gives researchers a chance to collect real-time data and direct observation within the plant. Observation allows researchers to collect data on physical environment, human interaction and program settings (Cohen et al., 2013). In this particular work, observations were used to see how the workers utilized energy and how they operated the equipment within the plant.

4.1.4 Interviews

VanderStoep and Johnson (2008), describe interviews as a flexible tool for collecting data, which involves direct conversations with the respondents. Interviews are appropriate for qualitative and quantitative data collection. There are different forms of interviews including: group face-to-face interviews, individual face-to-face interviews and semi-structured interviews. In this study, individual face-to-face semi-structured interviews were used for reasons of convenience and confidentiality, so respondents were free to disclose information without worrying about others' approval. According to Saunders (2011), semi-structured interviews permit the interviewer to ask with respondents specific questions which so they can make specific statements, thereby simplifying the task of assessment.

CHAPTER 5: ENERGY EFFICIENCY TECHNIQUES AND TECHNOLOGIES

This chapter aims to provide guidance to readers by discussing existing methods that can be used in a plant to realize energy efficiency. Although, industry has many existing energy-efficient techniques, the author covered only four common techniques because of his work experience in that area. The purpose of the discussion is to offer guidance to industrial experts, particularly on available energy-saving techniques and their limits, to enable them to gain success in energy efficiency.

5.1 Introduction

There are several means to reduce consumption of energy or change the mode of how energy is consumed. This can be done by using technology, for example a maximum demand controller or by simply changing the time of energy consumption, in other words load shifting. Industrial energy users need to find more information about the method and type of energy efficiency which is right for their production plant to obtain the best outcome for energy saving initiatives. Several factors need to be considered, including existing skills and capital, and the type of processes used in the plant. While all energy-saving techniques or technologies can lead to energy reduction or consumption, it is also important that such techniques drive the operation of the plant and do not reduce the productivity of the plant as this may affect the overall performance or revenue generated by the plant. Energy efficiency techniques should be able to reduce costs while increasing or maintaining the same level of productivity.

5.2 Energy efficiency techniques

5.2.1 Energy efficient equipment

This energy-saving approach includes an initial expenditure to purchase energy-efficient equipment. While this mainly includes high early capital expenditures, it is most appropriate if the company has to purchase new equipment anyway or has to replace old equipment. Energy efficient equipment offers a high proportion of the mechanical power output (Smith, 1979). for instance, in the case of an electric motor, an improved motor air gap design, with winding insulation, can lead to reduction of electrical current, thereby increasing the efficiency of the motor. Energy efficient equipment can help to reduce energy demand and maintenance costs without having to carry out any extra work after installation (Rao & Naqaraian, 2012). Even though this technique has a high initial cost, once it is installed, it has the ability to reduce energy consumption without process adjustments.

According to Mertens (2009), industrial motor-driven equipment constitutes nearly 67% of the total electric consumption; using of energy-efficient induction motors can radically reduce the required input power to perform the same task as inefficient electric motors. Though it may seem doubtful at first glance, Mertens (2009), insists that the choice of more efficient motors can result in significant savings.

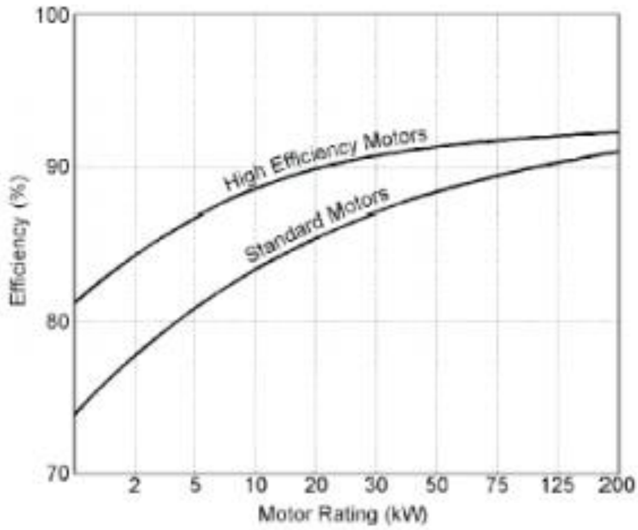


Figure 5-1: 3-Phase Standard electric motor vs High Efficiency Motors. (BEE, 2005)

Van Rhyn and Pretorius (2015), studied the use of high and best three-phase electric motors with variable frequency drives (VFDs) in a public water supply system. The authors reported that by switching the original electric motors with high and premium efficiency three-phase induction motors with VFDs, an energy saving of 46% was achieved, along with a power demand reduction of about 53% in the outcome of public utilities in the critical evening peak.

5.2.2 The load shifting

The load shifting technique also classified as the time of use (TOU) method is similar to the maximum demand controller technique. The approach of energy demand control includes using energy when the price is low, during standard or off-peak periods. This method will assist in in reducing the electricity costs incurred during the peak demand periods.

According to Mohamed and Khan (2009), the load shifting method is the best means to reduce customer demand throughout peak periods. The electricity service companies regularly advertise their electricity rate formation, as can be seen in Figures 5-2 and 5-3.

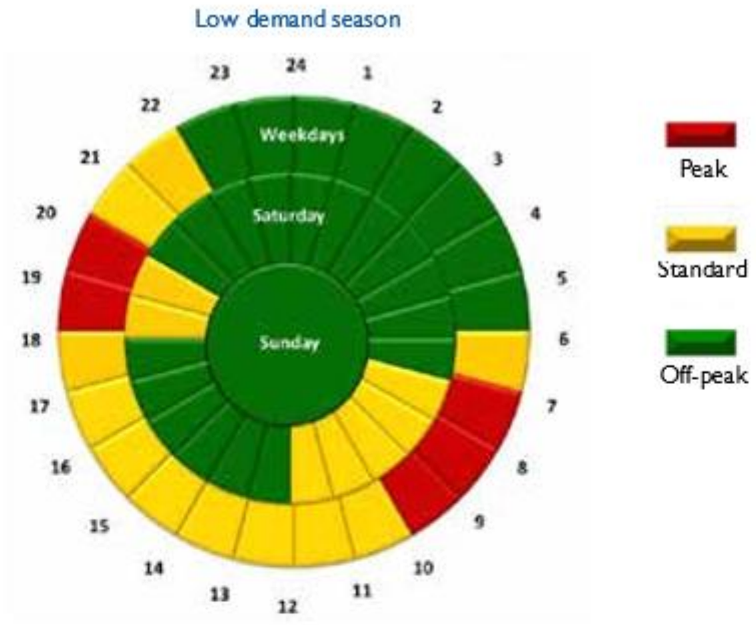


Figure 5-2: Peak, standard and off-peak period tariff in low demand season (Eskom, 2016)

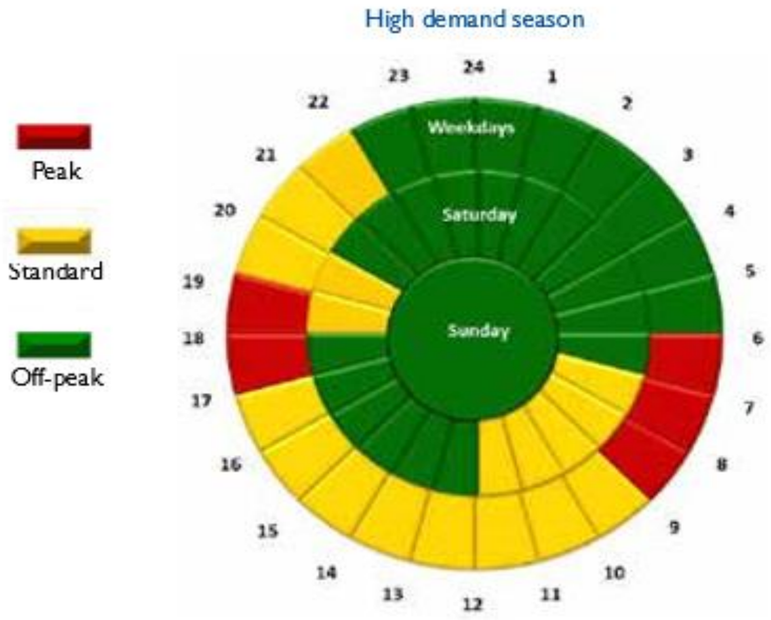


Figure 5-3: Peak, standard and off-peak period tariff in high demand season (Eskom, 2016)

The figures above indicate Eskom's electricity tariff periods. The rate structure is divided into three groups and each group has special rates:

- The peak rate is when customers are charged above average rate for electricity consumption.
- The standard rate is when customers are charged an average rate.
- The off-peak rate is the lowest rate is a below average rate.

According to Numbi, Zhang, and Xia (2014), load shifting can help to reduce utilities bills, but this approach does not address the need for reduction in energy demand because an equal amount of energy can still be used even though at different times. Although cost may be the driving force behind the decision to employ load shifting in a manufacturing industry, this technology needs a high level of supervision, control and planning because the off-peak periods usually happen after working hours. When appropriate measures or plans are not followed, this method can have an adverse effect on production output.

5.2.3 Power factor control method

Ware (2006), defined power factor as the ratio between active power in watts (W) or kilowatts (kW), to the total apparent power, measured in volts ampere or kilovolts ampere (kVA) consumed by an item of alternating current electrical equipment or the fully installed project. The power factor is also described as a measure of how effectively electricity is being converted to work outputs. Ideally, power factor is equivalent to unity required i.e. (one) because anything smaller than one means that extra power is needed to accomplish the real task at hand Ware (2006). A low power factor signifies that the consumer does not make full use of the electricity they have paid for (Eaton, 2014).

Mohamed and Khan (2009) reported that the inductive load, mostly from induction motors, instigates a low power factor in industries. The authors state that an inductive load needs reactive power to create a magnetizing current that promotes the magnetic field in the desired circuit. Control of the power factor can be accomplished by using various control methods, for example when connecting the capacitors in parallel to the load, or by using a synchronous condenser. The capacitor approach is commonly used as a solution because it is actually free of charge or requires very little maintenance compared to other methods of power factor control (Eaton, 2014).

The power factor method is method is often neglected as an energy saving method (Su, Lin, & Liao, 2013).The authors point out that decreasing the reactive power generated by the generator by the power factor correction improves operating efficiency of the system and the economic indicators and reduces GHG emissions.

According to (Mohamed & Khan, 2009), the benefits of improving the power factor include the following:

- Lesser utility bills;
- Increases the internal voltage drop at the point of use
- Improves voltage regulation; and

- Improves system efficiency.

5.2.4 Process optimization

The optimum control of a process can effectively utilize the demand or the minimum required energy to process the material. For instance, the visualization of the real-time process on a SCADA system offers assistance to the process operator so that they can adjust the plant variables so that only the required energy is utilized. Although this technique requires a lot of technical knowledge, especially the skills involved to install or design a control system, the process optimization technique has great potential to reduce energy demand if applied properly. Siemens (2011), stated that the advanced process control (APC) method is an important tool to improve plant efficiency while maintaining the quality of a product and ensure operability.

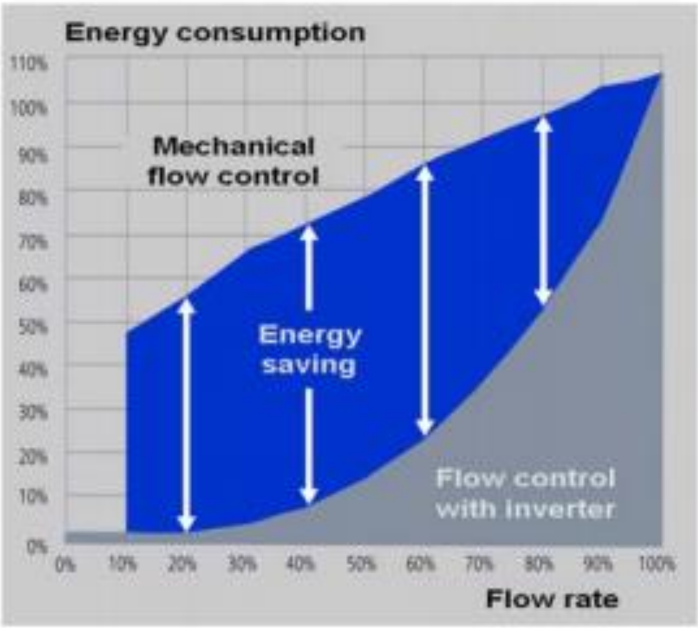


Figure 5-4: Energy saving through optimized speed-controlled pumps Vs of throttle valves (Siemens, 2011)

Through the intelligent process automation, the industrial plants can achieve about 15% energy savings (Siemens, 2011) (Figure 5-4). Process automation as a segment of optimization has the capacity to control all the variables and to make sure optimum energy resource utilization. This can be achieved by turning off unused energy consumption loads or controlling power consumption automatically, so that nothing other than the optimum energy is used in the energy consumption process.

5.3 Energy savings technologies for cement plants

There are many new technologies that can make the cement plant more efficient in operation (Madlool et al., 2011). These new technologies can be used for different components in the cement plant, which include both raw mills and cement mills, crushers, kilns and transport systems.

5.3.1 Replacement of the components

Another way of reducing the electricity demand in cement plants is to replace obsolete equipment with modern-day, more efficient replacements.
Possible replacement equipment consists of:

- Replacement vertical roller mills (Cullen & Allwood, 2010).
- Installation of new Pre-calciner (Cullen & Allwood, 2010).
- Bucket elevators to replace airlift systems (Cullen & Allwood, 2010).
- Replacement of variable speed drive (VSD) (Al-Bahadly, 2007; Saidur, Mekhilef, Ali, Safari, & Mohammed, 2012).

The above-mentioned technologies and equipment need to be installed as new equipment and can provide an average energy savings of 1 kWh and 5 kWh per ton (Hasanbeigi, Price, Lu, & Lan, 2010). Variable speed drives (VSD) is an example of cost effective technologies in which energy consumption can be reduced in an average cement production plant.

Saidur et al. (2012) discovered that a ducted fan's electrical demand can be reduced by between 30% and 60%. Installing a variable speed drive on the electric motors of a fan provides a way to decrease electrical energy demand when the required flow rate is less than the installed capacity of the fan (Saidur et al., 2012). However, these installations are costly and require high production down time (Mejeoumov, 2007a).. The payback period is mostly longer than 10 years after installation

5.4 Conclusion

Industrial energy users need to understand the effect of energy efficiency technologies on production processes and output, in order to plan and schedule accordingly. For instance, applying load shifting techniques may have an impact on the productivity of the plant, especially when the production plan is unreasonable. This technique demands shifting of the energy load to periods when the cost of energy is cheap, which is usually after office working hours without supervision. This also applies to energy efficiency techniques such as the maximum demand controller. While this approach can help to suppress unwanted electrical energy peak demand to avoid the cost of maximum demand (KVA), it may have a negative impact on the production plan, especially when the key process equipment is shut down to avoid high energy peaks, this can lead to very low load factors. For that reason, it is necessary to assess the best matched energy-saving technologies for a particular process plant, thereby maximizing benefits from implementation

CHAPTER 6: QUESTIONNIARES RESULT AND DISCUSSION BARRIERS AND DRIVERS TO ENERGY EFFICIENCY

6.1 Result from the questionnaire

6.1.1 Socio-economic composition of respondents

The study was conducted in South Africa's oldest cement plant that produces Portland cement. The plant has about 150 employees, both contract and permanent staff. Owing to the work demand and working terrain of the study area, there was a low response by staff of the plant to the request for interviews. The purpose of this research was to properly determine the present practice of industrial energy management in a cement grinding plant by means of investigating the level of implementation of energy efficiency measures in the plant, and the barriers and the drivers of acceptance of energy efficient measures. The plant does not have an active energy manager; therefore, the questionnaires were distributed to plant managers and all engineering staff who are directly involve with energy related issues. In total, 55 questionnaires were distributed by the engineering and production department which included the electrical and mechanical departments; 15 via email and 40 were physically distributed to the staff with a request to participate in the study.

A total of 17 respondents or 31% of the staff responded to the questionnaire, 16 of whom were males and one female. The job description of the respondents was electrical inspector, process engineer, trainee engineer, production planner, mechanical inspector, methods technician, trainee technician, clerk, plant planner, engineering manager, process controller, production staff, coordinator, senior buyer and supervisor.

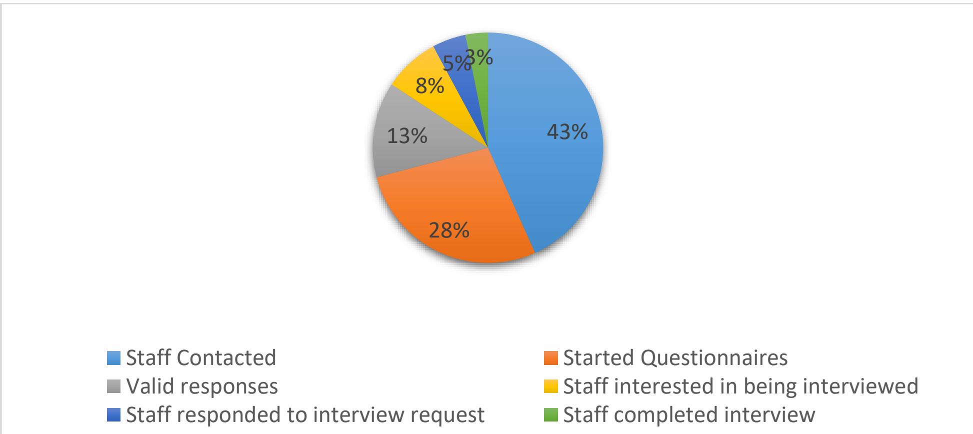


Figure 6-1: Sampling structure composition

Six questionnaire respondents agreed to be interviewed. In total, only four were interviewed because of their position in the plant which included Engineering Manager, Process Engineer, Electrical Inspector and Production Planner, which represented a broad range of knowledge and responsibilities (Figure 6-1).

6.1.2 Plant energy management

Understanding the energy characteristics i.e. consumption, policies and practices, is an integral aspect of sustainable energy routine practices and policy. As the findings presented in Figure 6-2. show, 7 of the total of 17 respondents answered in the negative that the plant does not have an energy manager, 5 respondents were not sure if they do have an energy manager while the remaining 5 responded in the affirmative that they do have an energy manager.

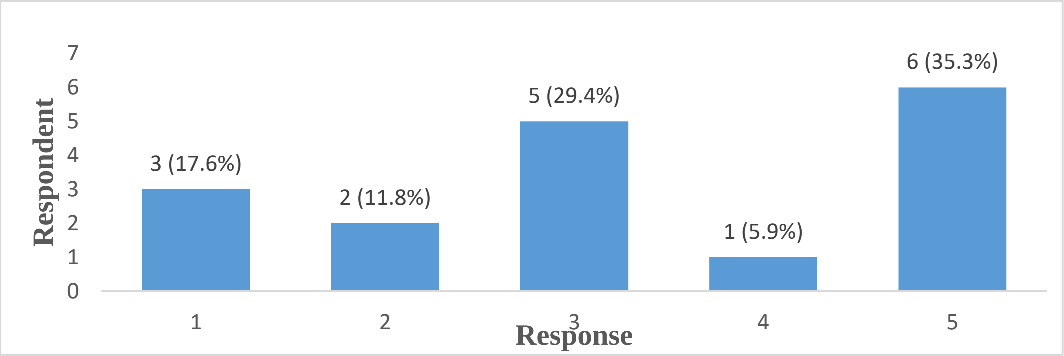


Figure 6-2: Plant Energy Manager Information

Figure 6-3. shows that 3 of the total 17 respondents strongly agreed that the plant does have an energy efficiency policy, 4 respondents agreed that it does have an energy efficiency policy, 4 respondents were not sure if the plant has an energy efficiency, and the remaining 6 respondents gave a negative response (strongly disagree or disagree) to the question on the presence of an energy efficiency policy.

Brunke, Johansson, and Thollander (2014) and Christoffersen, Larsen, and Togeby (2006) stated that there is a relationship between an energy manager and the possibility of a plant or industry adopting an energy efficiency policy.

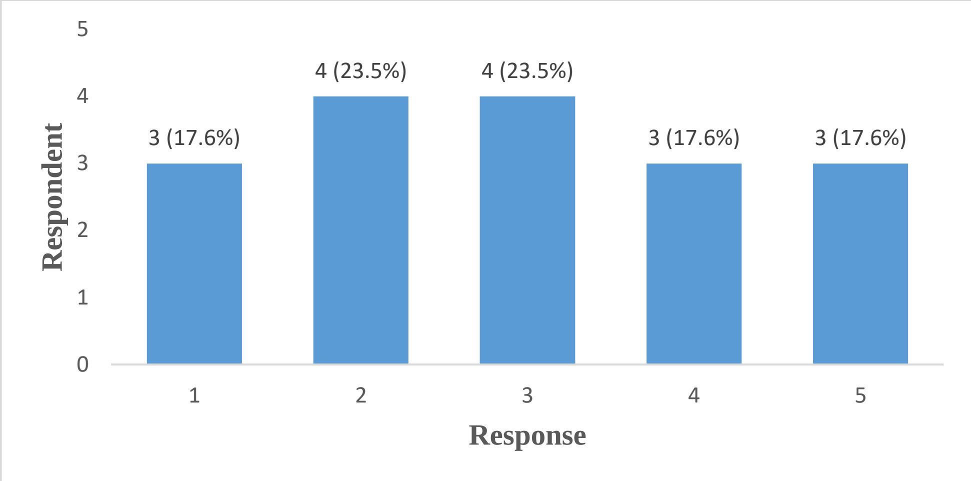


Figure 6-3: Plant Staff Perception on Availability of Energy Efficiency Policy

Mohd (2011) argued that the application of an energy efficiency policy is a function of a factory understanding the need to maximize energy use. Figure 6-4. shows that 8 respondents agreed or strongly agreed that the policies are often reviewed in accordance with the production targets, 4 respondents were not sure that the policies are reviewed while the remaining 5 respondents disagreed that the policies are reviewed.

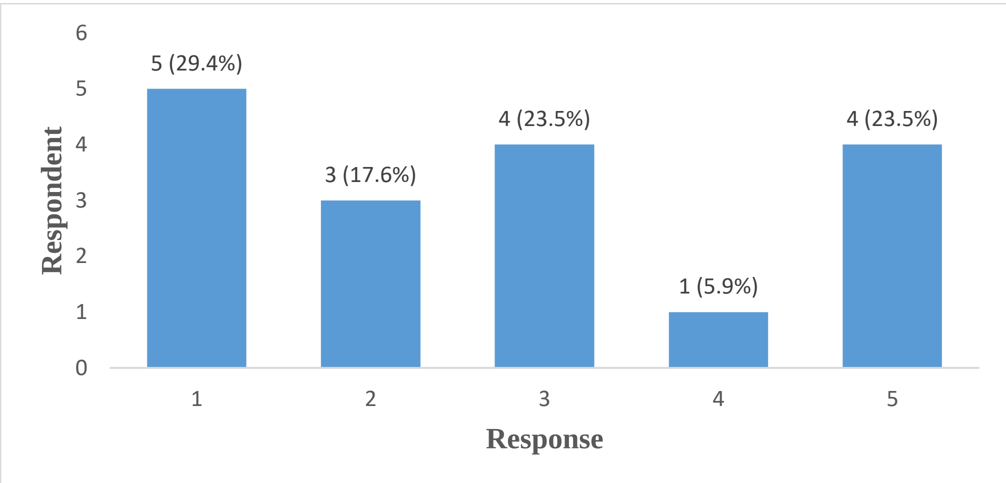


Figure 6-4: Plant Staff Perception on Energy Efficiency Policy Review

Figure 6-5. shows that 8 of the total 17 respondents stated that there is a strong top management commitment to energy policy, 3 respondents were not certain of their commitment while the remaining 6 respondents were of the view that the energy efficiency policy commitment by top management is poor or weak.

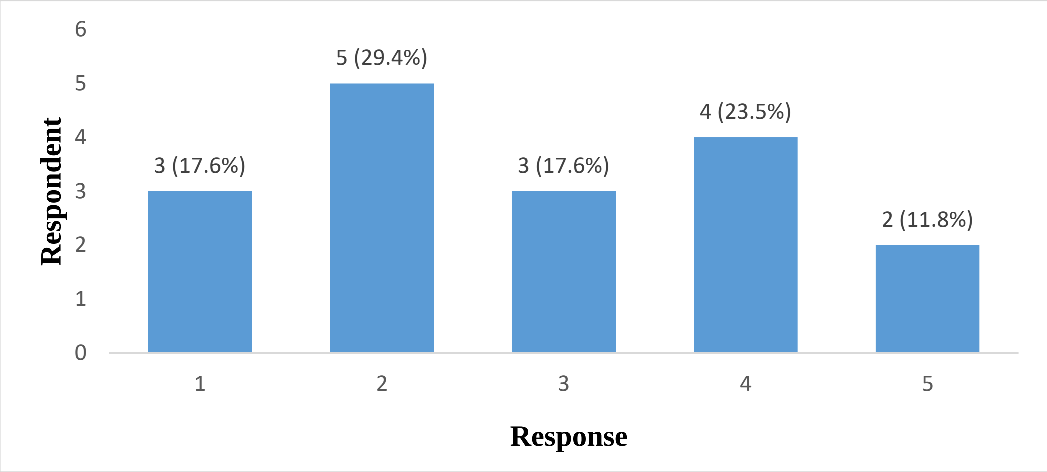


Figure 6-5: Plant Management Involvement in Energy Efficiency Policy

The weak policy commitment can be traced to the (15 respondents) very poor level of awareness of energy policy among the participants (Table 6-1). This shows that awareness plays a vital role regarding commitment to an energy policy.

Table 6-1: Energy Policy Awareness Among the Staff

Level of Awareness	**Number of respondent**	**%**
Low Level	15	88.2
High Level	2	11.8
Total	17	100

Table 6-2 shows that 10 of the total 17 respondents reported that the energy policy is not integrated into the plant's operation, 4 respondents did not know if is integrated or not, while the remaining 3 respondents stated that the energy policy is fully integrated into the plant's operation.

Table 6-2: Energy Policy Integration within the Plant

Energy Policy integration into Plant	**Number of respondent**	**%**
Yes	10	58.8
Not sure	4	23.5
No	3	17.7
Total	17	100

Worth noting is the view by 6 of the total 17 respondents that the plant has a working energy management system, 5 respondents did not observe this while the remaining 6 respondents stated that there is no working energy management system (Figure 6-6).

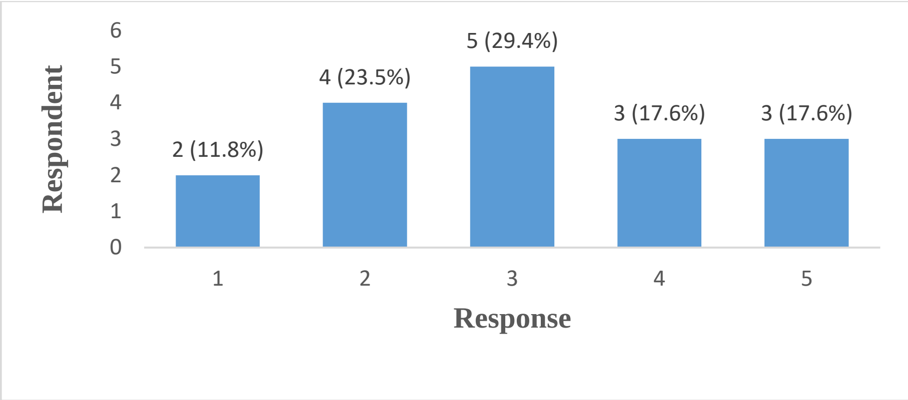


Figure 6-6: Plant Energy Management System

This is a pointer to the disagreement between respondents' understanding of energy management and policy. These findings were as a result of the respondents unaware of whether energy efficiency efforts had already started or were in the planning phase. The findings presented in Table 6-3 shows that 6 and 10 respondents were unaware of the stage the plant was at regarding energy efficiency efforts.

Table 6-3: Plant Energy Efficiency Effort

Level of Energy Efficiency effort in plant	Start-up stage (%)	Planning Stage (%)
Yes	29.4	17.7
Not Sure	35.3	58.8
No	35.3	23.5
Total	100	100

Figure 6-5 shows that 8 of the total 17 respondents stated that the top management is committed to an energy policy, 3 respondents were unaware of the top management's efforts to implement the energy policy while the remaining 6 respondents asserted that top management is not committed to an energy policy. These findings help establish the reason for the weak implementation of energy policy as presented in Figure. 6-7 which shows that 7 respondents disagreed that the policy is not fully integrated, 3 respondents strongly disagreed with this question, 4 respondents were unaware while the remaining 3 respondents assert that the energy policy is well integrated into the plant operation.

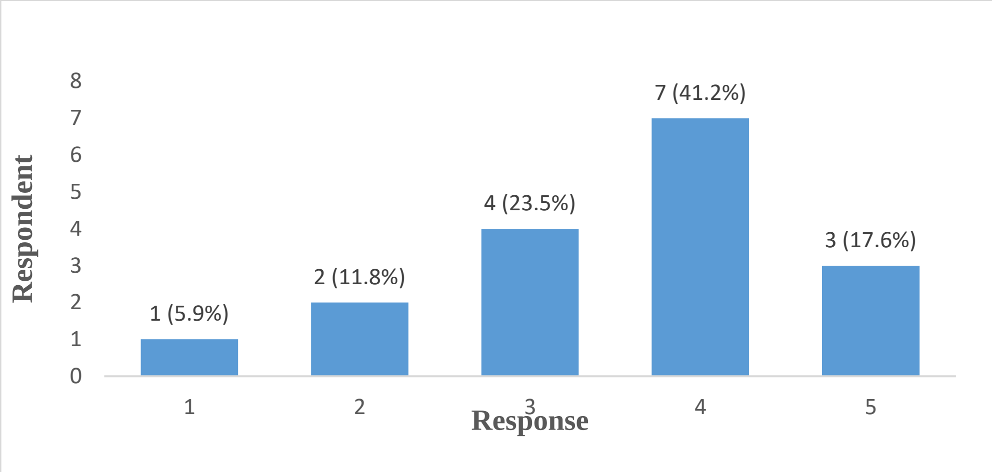


Figure 6-7: Energy Policy Implementation with the Plant

The level of awareness of energy efficiency among respondents was minimal, and 7 respondents disagreed and 4 respondents strongly disagreed that it is high (Figure 6-8).

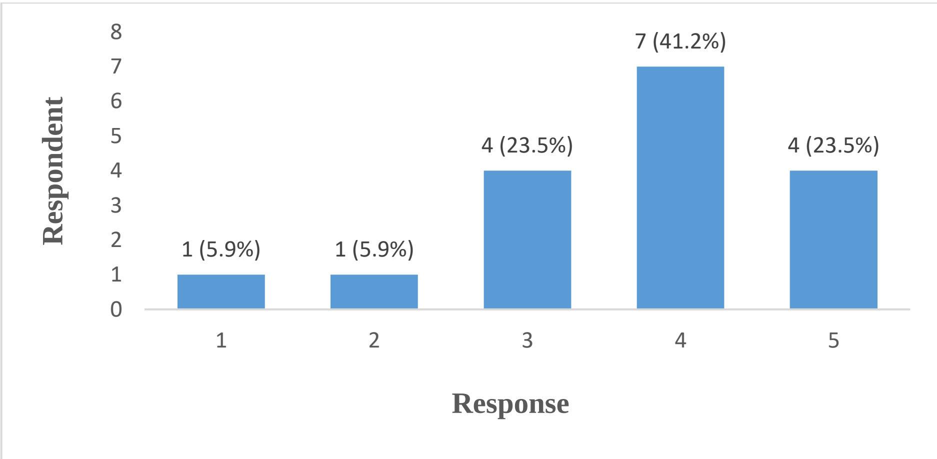


Figure 6-8: Plant Energy Efficiency Awareness among Staffs

The perception by 6 of the total 17 respondents was that there is a working energy management system, 5 respondents were unaware, and 6 respondents perceived that there was no working energy management system (Table 6-4). Figure 6-9 shows that the awareness of the plant energy management system is very low that 12 respondents were not aware of it.

Table 6-4: Working Energy Management

Working Energy management	Number of respondent	%
Yes	6	35.3
Unaware of its use	5	29.4
No	6	35.3
Total	17	100

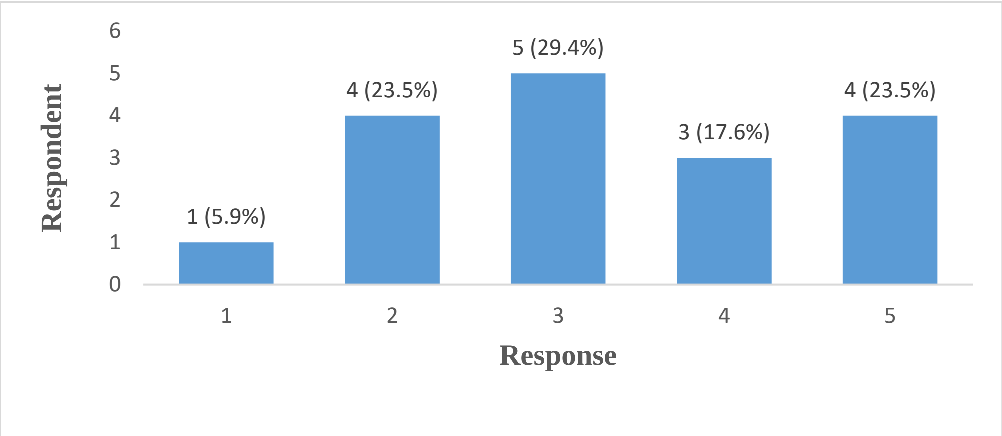


Figure 6-9: Energy Management Awareness

The availability of energy consumption information was perceived as low among the staff in the plant (8 respondents) as seen in Table 6-5, and that there was energy sub-metering installed within the plant was perceived as high (12 respondents) as seen in Figure 6-10.

Table 6-5: Energy Consumption Information

Energy Consumption Information	Number of respondent	%
Low Level	8	47
High Level	9	53
Total	17	100

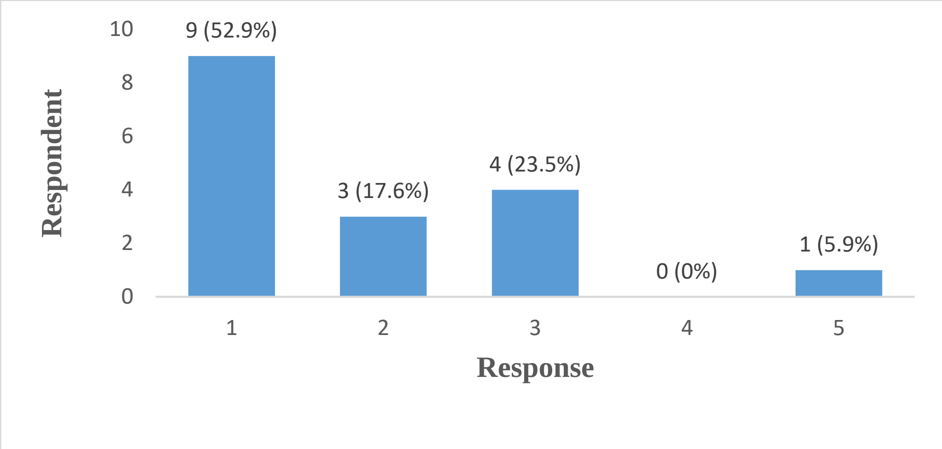


Figure 6-10: Energy Sub-Meter Information

Figure 6-11 shows that respondents perceived that data on energy consumption trends was available. Likewise, the history of energy saving remains unrecorded. This points to the fact that environmental performance is not considered important (8 respondents) when compared to cost saving in plant energy efficiency decision-making. Although, self-motivation and encouragement with respect to improving environmental performance among fellow workers was reported by respondents.

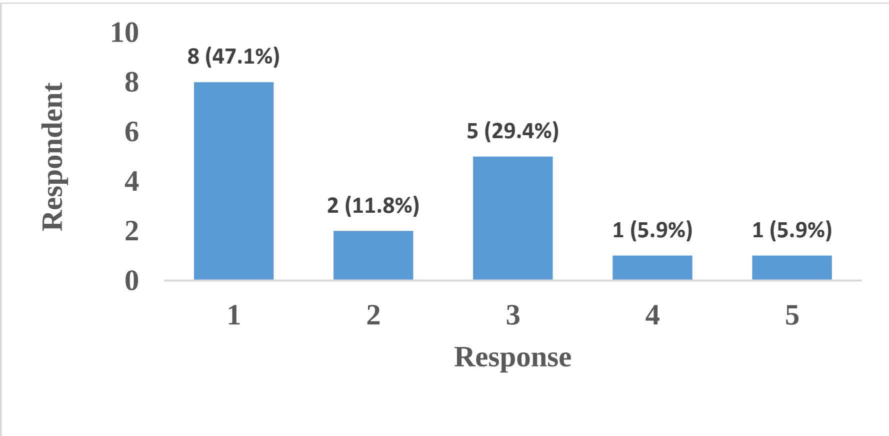


Figure 6-11: Availability of energy consumption data trends

Figure 6-12 shows that 10 of the total 17 respondents perceived internal pressure, while in the interview question responses are presented in Table 6-6.

Table 6-6: External Pressures to Improve Environmental Performance

Pressure from External factor	**Number of respondent**	**%**
Yes, external effect experienced	12	70.6
Unfelt/unaware of effect	4	23.5
No external effect experienced	1	5.9
Total	17	100

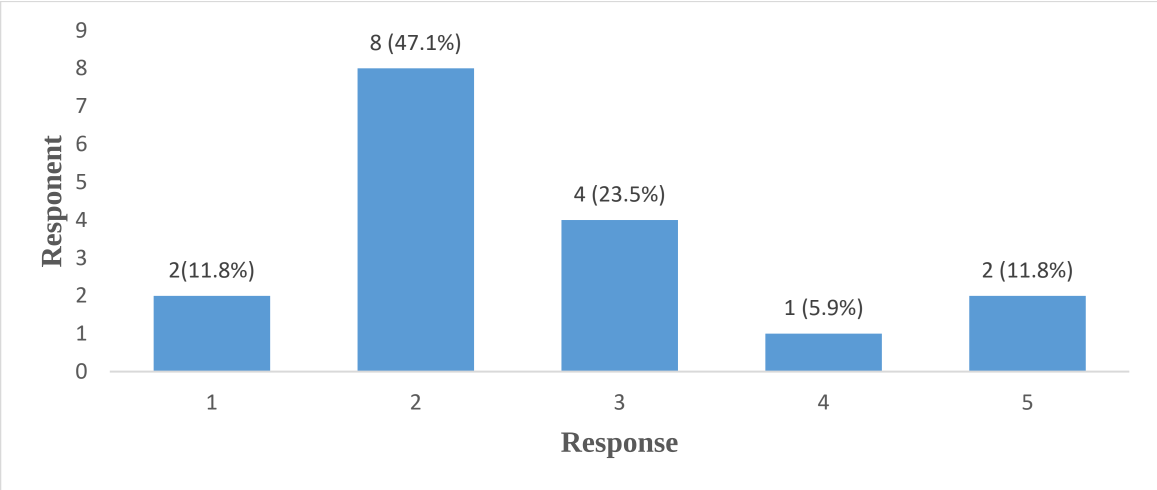


Figure 6-12: Internal Pressures to Improve Environmental Performance

Figure 6-13 shows that 12 of the total 17 respondents perceived external pressures from sources such as government, media, municipality, industry sector, etc. to improve environmental performance.

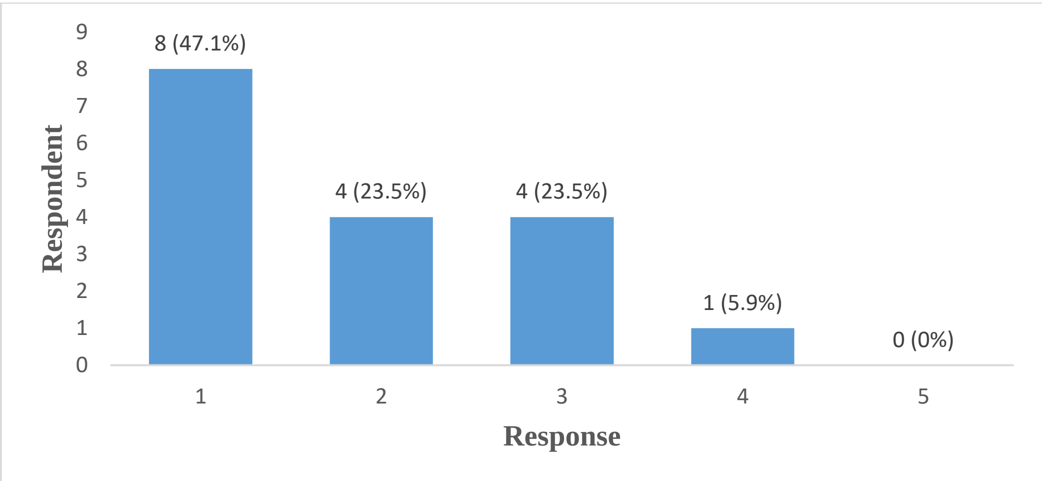


Figure 6-13: External Pressures to Improve Environmental Performance

Eight 8 of the 17 sampled respondents reported that senior management was seriously committed to improving the environmental performance of the plant, 4 respondents were neutral and the remaining 5 respondents were of the view that the management is not committed to the environmental performance of the plant (Figure 6-14).

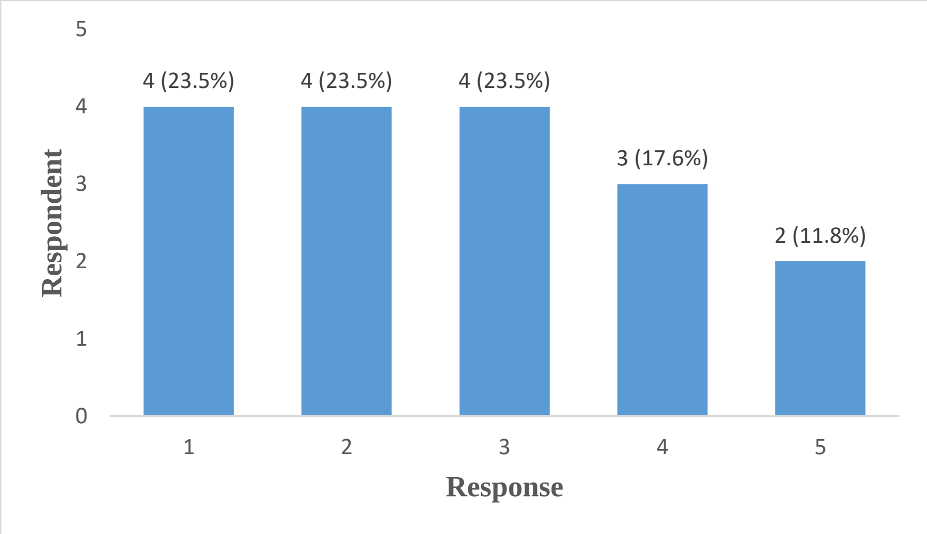


Figure 6-14: Plant Environmental Performance

The respondents were asked to make suggestions regarding the energy management and how to improve energy efficiency within the plant. The suggestions raised by the workers in the plant included alignment of plant policies and procedures towards energy saving; running the operation during off peak hours in such a way that the production output will be high; stop milling between the hours of 6:00a.m-10:00a.m, 6:00p.m-10:00p.m; improved and well defined work duties for a certain individual who will be focus on energy management; improved awareness on the part of the workers on energy utilization and incorporation of environmental practice.

Workers suggested the optimization of the plant to run efficiently on less kilowatts per ton, improved work ethics of office administrators, switching off the electricity during closing hours, and the need for proper information flow and continued interaction between the management and factory workers.

6.1.3 Plant energy saving practice

Defining energy saving practices, energy wastage and proper use of energy is very important. All respondents acknowledged the presence of energy saving opportunities in the plant. Findings from this study as presented in Figure 6-15. shows that 3 respondents strongly agreed that energy is being wasted, 6 respondents agree that there is energy wastage, 5 respondents cannot define if there is waste or not, while a total 3 respondents strongly disagreed or disagreed that there is energy wastage in the plant.

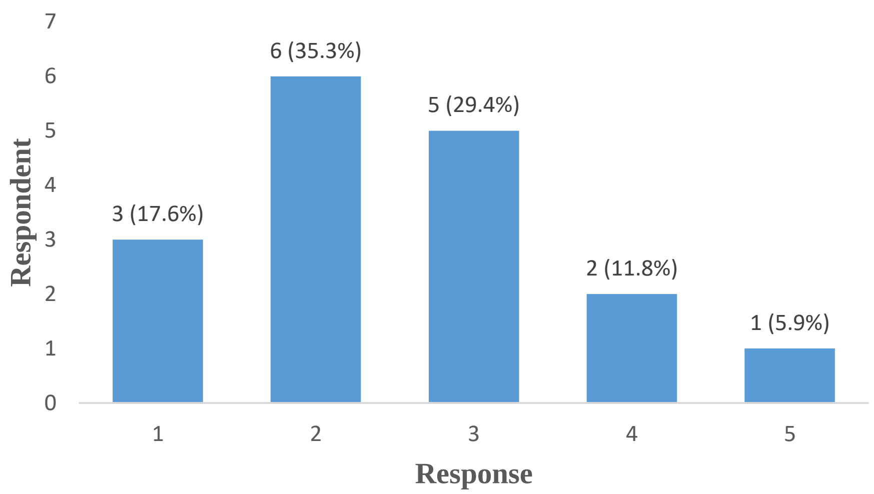


Figure 6-15: Result from Plant Energy saving

Likewise, Figure 6-16. shows that 3 respondents strongly agreed that there are energy saving techniques in the plant, 6 respondents agreed, 5 respondents were neutral, and a total 3 respondents strongly disagreed or disagreed that there are energy saving techniques in the plant.

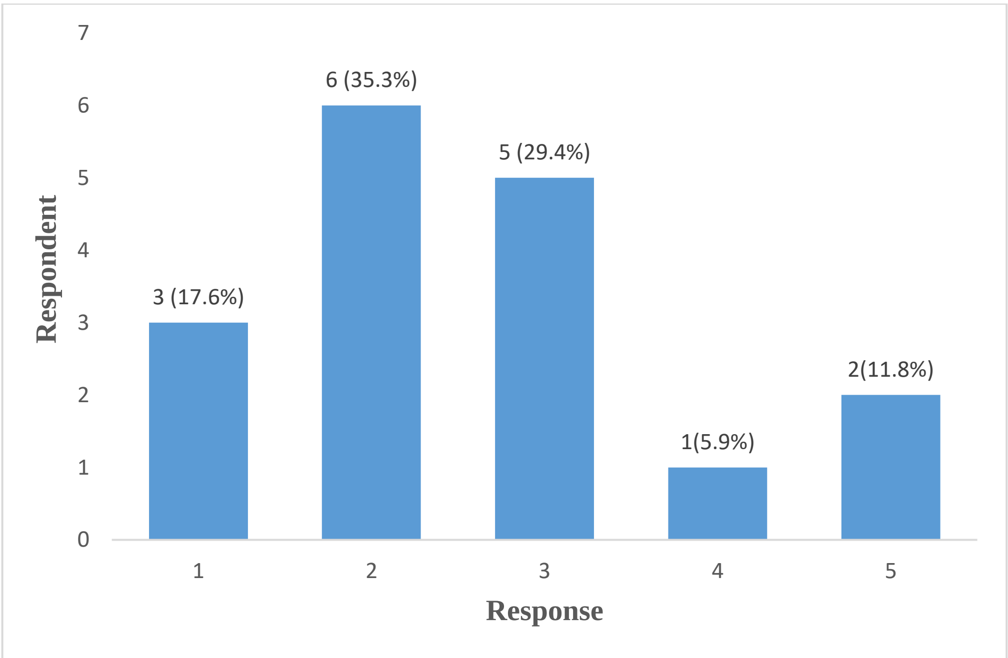


Figure 6-16: Plant energy saving techniques

Energy saving awareness among the workers is low. As presented in Figure 6-17. 3 of the 17 respondents strongly agreed or agreed that management are fully committed to energy efficiency and energy saving awareness at the plant, 6 respondents were neutral and 8 respondents strongly disagreed or disagreed that there is commitment by management in this regard.

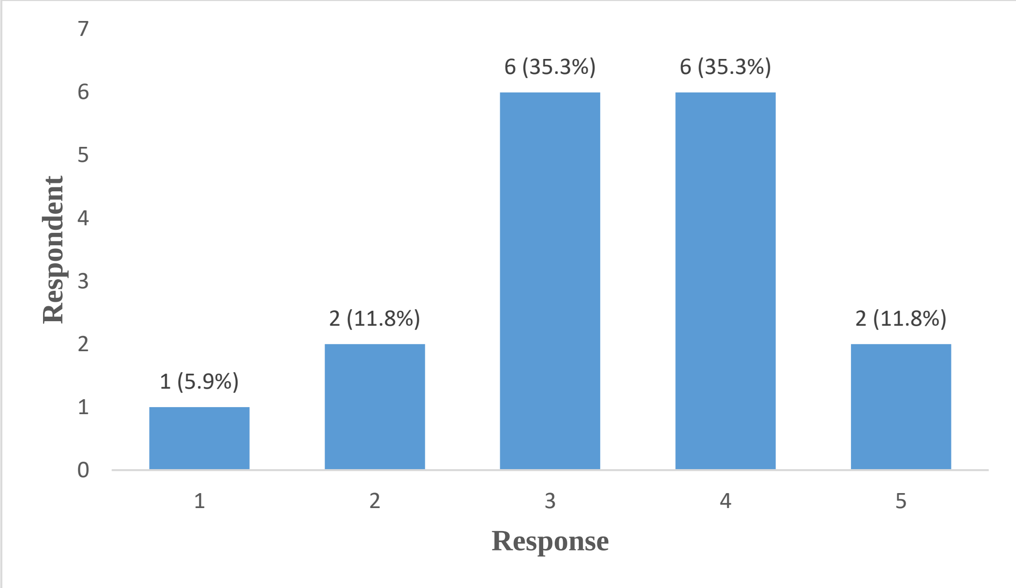


Figure 6-17: Plant energy saving awareness among the management

The data analysis presented in Table 6-7 shows that 6 of the total 17 respondents were neutral regarding the general staff's commitment to energy efficiency and energy saving awareness in the plant, while 11 respondents strongly disagreed or disagreed with this. This finding shows a negative attitude of workers in the factory to energy efficiency as most workers remain uncommitted and unaware of the need for energy efficiency.

Table 6-7: Staff commitment to energy efficiency

Staff commitment to energy efficiency	**Number of respondent**	**%**
Yes	0	0
Unfelt/unaware of effect	6	35.3
No	11	64.7
Total	17	100

Figure 6-18 shows that 11 respondents of respondents reported that they switch off their machines / equipment / lights / computer when not in use while 3 respondents were neutral and another 3 respondents do not do so.

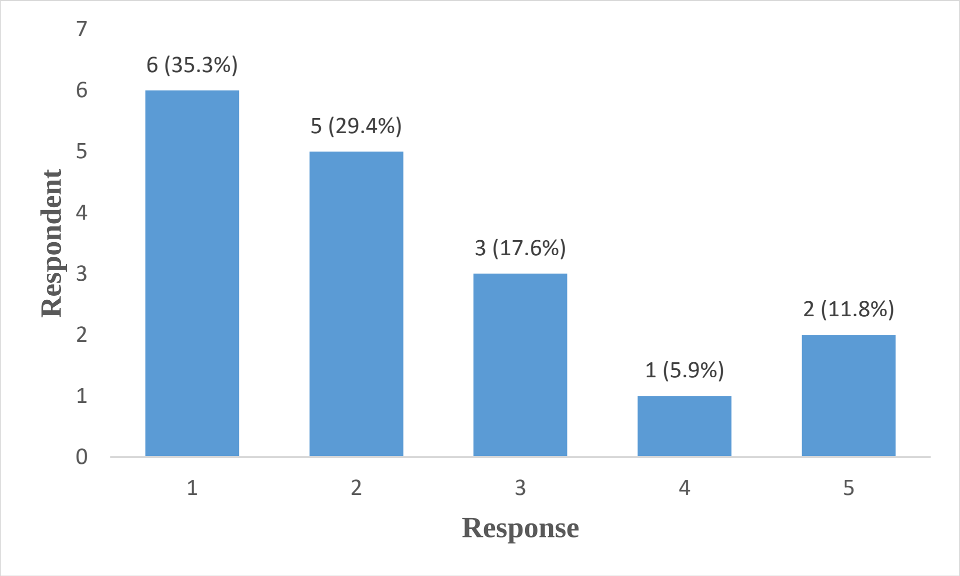


Figure 6-18: Information on Electrical Appliances

About 88.2% of respondents identified the need for energy training programs while the remaining 11.8% do not value energy training programs.

6.1.4 Plant energy consumption

Participants were asked which sections/equipment in the plant they thought consumed a lot of power. Eleven (11) respondents reported that the cement mill consumes most energy, followed by the roller press (5 respondents), followed by packaging (1 respondent) (Figure 6-19).

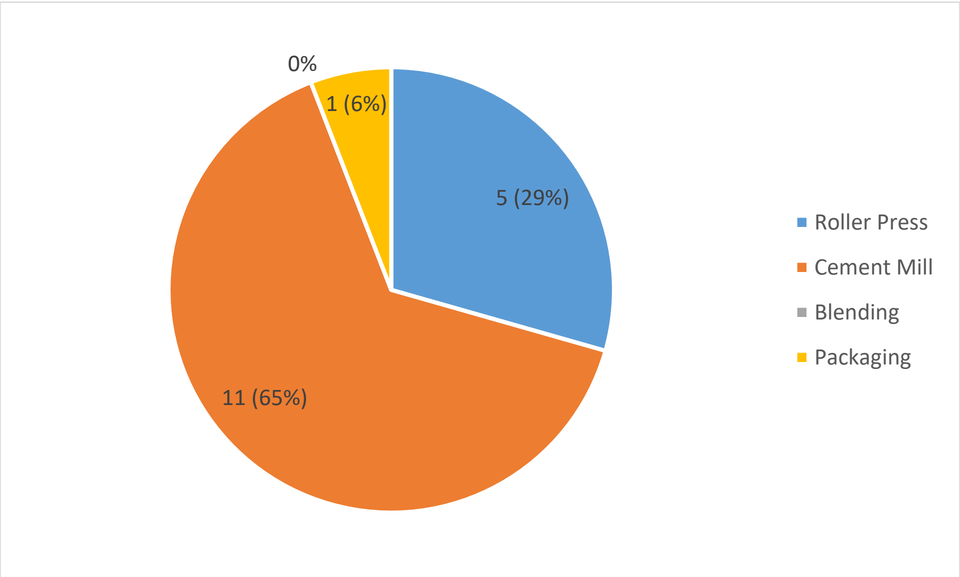


Figure 6-19: Opinion about the Energy Consumption Section within the Plant

The interviews identified the causes of energy loss in the plant as being the running of production/main machine during peak hours, heavy power consuming machines, plant failure to use efficient induction motors, use of old equipment, conveyor belt running when it is not being used, poor maintenance and the lack of knowledge about the need for saving energy.

Participants identified steps that can be taken towards energy saving. They identified the need for storage facilities which will help reduce the energy use in crushing of material, change of the drive motor to a shell ring geared drive, reduction of circulating load, upgrading of the separator on the mill system, use of energy efficiency equipment, optimization of the use of natural light, upgrade/incorporation of spinning mill to generate electricity, efficient hourly usage of power, power saving exercises (stop production at peak time), conduct an audit of process power, staff awareness of energy saving practices, high power solar panels, and switching off of equipment when not in use.

The study also established the role of managers, supervisors and staffs in efficient energy management of the plant. Figure 6-20 shows that 9 respondents of the respondents perceived that staff are the main group responsible for energy management in the plant, 6 respondents perceived it be the duty and responsibility of the manager, and the remaining 2 respondents identified it to be the work of the supervisor to bring about efficient energy management of the plant.

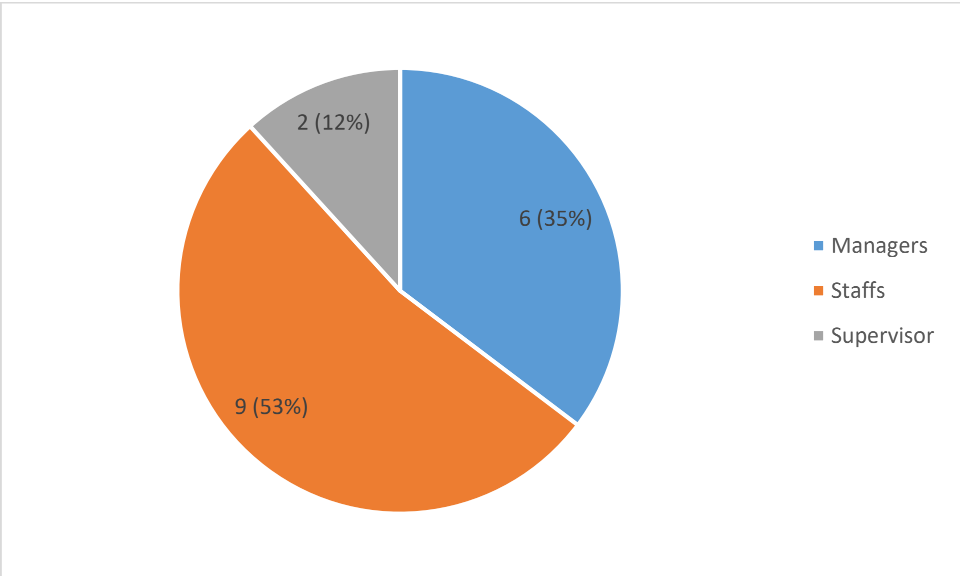


Figure 6-20: Energy Management within the Plant

6.1.5 Barriers to energy efficiency improvement

Energy efficiency improvement remains the basis on which efficiency within the energy sector can be achieved. In this section the study investigates the barriers to energy efficiency, factors of importance to cost-effective energy efficiency, and non-compliance to energy efficiency measures. These are summarized in Table 6-8.

Table 6-8: Barriers to improvement of energy efficiency

S/N	**Barriers to energy efficiency**	**Agree**		**Neutral**		**Disagree**	
		Response	**%**	**Response**	**%**	**Response**	**%**
1	Lack of access to capital	7	41.2	9	53.1	2	11.8
2	Government does not give financial incentives to become energy efficient	6	35.4	7	41.2	4	23.6
3	Management find production more important?	13	76.7	3	17.7	1	5.9
4	Cheap cost of electricity	0	0	4	23.6	13	76.7
5	Management concerns about the investment costs of energy efficiency measures	8	47.2	3	17.7	6	35.4
6	Lack of technical knowledge on energy efficiency	5	29.5	5	29.5	7	41.2
7	Cost of production disruption is high	5	29.5	5	29.5	7	41.2
8	Lack of budget funding	4	23.6	7	41.2	6	35.4
9	Lack an adequate awareness on energy efficiency	4	23.7	4	23.6	9	53.1
10	Conflicts of interest within the company	5	29.5	4	23.6	8	47.2
11	Energy objectives and policies are not specified.	7	41	0	0	10	59
12	Technical risk	6	35.4	6	35.4	5	29.5
13	Costs of hiring specialists / employees with adequate technical skills	4	23.6	1	5.9	12	70.8
14	Management concerns about time required to improve energy efficiency	4	23.6	8	47.2	5	29.5
15	Lack of time / other priorities	8	47.2	3	17.7	6	35.4
16	Other priorities for capital investment?	8	47.2	7	41.2	2	11.8
	Mean of Agree response = 5.875.						

Based on the identified barriers, the study revealed that the barriers to energy efficiency included:

- Lack of access to capital (7 agree, 9 neutrals, 2 disagree),
- Government does not give financial incentives to become energy efficient (6 agree, 7 neutrals, 4 disagree).

- Management focus on production and not energy efficiency (6 agree, 7 neutral, 4 disagree).
- Cheap cost of electricity (4 neutral, 13 disagree).
- Management concerns about the investment costs of energy efficiency measures (8 agree,3 neutrals, 6disagree).
- Lack of technical knowledge on energy efficiency (5 agree, 5 neutrals, 7 disagree).
- Cost of production disruption is high (5 agree, 5neutral, 7disagree).
- Lack of budget funding (4 agree,7neutral, 6 disagree).
- Lack an inadequate awareness on energy efficiency (4 agree, 4 neutrals, 9 disagree).
- Conflicts of interest within the company (5 agree, 4neutral, 8 disagree).
- Energy objectives and policies are not specified (7 agree, 10 disagree).
- Technical risk (6 agree, 6 neutrals, 5 disagree).
- Costs of hiring specialists/ employees with adequate technical skills (4 agree, 1 neutral, 12 disagree).
- Management concerns about time required to improve energy efficiency (4 agree, 8 neutrals, 5 disagree).
- Lack of time / other priorities (8 agree, 3 neutrals, 6 disagree).
- Company capital investment priorities (8 agree, 7 unsure, the remaining 2 disagree).

6.1.6 Drivers for improving energy efficiency in the cement plant

Findings on the various factors and levels of importance to cost-effective energy efficiency are presented in Table 6-9.

Table 6-9: Drivers for energy efficiency improvement

S/N	Factor(s) and level of importance for cost-effective energy efficiency	Important		Not Important	
		Response	%	Response	%
1	People with real ambition	16	94.1	1	5.9
2	Environmental company profile	16	94.1	1	5.9
3	Environmental management systems (EMS)	17	100	0	0
4	Long-term energy strategy	17	100	0	0
5	Improved working conditions	16	94.1	1	5.9
6	Cost reduction resulting from lowered energy use	17	100	0	0
7	Network with the company/group	15	88.2	2	11.8
8	Threat of rising energy prices	15	88.2	2	11.8
9	International competition	17	100	0	0
10	Energy tax	16	94.1	1	5.9
11	Emission tax (CO_2, NO_x and Sulphur)	16	94.1	1	5.9
12	General energy advice through seminars	16	94.1	1	5.9

13	General energy advice through journal articles or booklets	16	94.1	1	5.9
14	Voluntary agreement with tax exemption	16	94.1	1	5.9
15	Energy efficiency requirement by South Africa government	16	94.1	1	5.9
16	Publicly financed energy audit by energy consultant	16	94.1	1	5.9
17	Publicly financed energy audit by sector organization expert	16	94.1	1	5.9

Table 6-9 shows that 16 of the total 17 respondents agreed that the people with real ambition, environmental company profile, the improved working conditions, the energy tax, the emission tax (CO_2, NO_x and Sulphur), general energy advice through seminars, energy advice through relevant journal articles, voluntary agreement with tax exemption, energy efficiency requirement by South Africa government, energy consultant and publicly finance are important factors for cost-effective energy efficiency, while the remaining 1 respondent perceives these factors as not being important. All the respondents perceived that long-term energy strategy, cost reduction resulting from lowered energy use, and international competition are the important factors for a cost-effective energy efficiency. 15 of the 17 respondents agree that network with the company/group and threat of rising energy prices are important factors for cost-effective energy efficiency while 2 respondents consider it not important.

Table 6-10: Rating of approaches for maintaining energy efficiency

S/N	**Approaches to maintaining energy efficiency.**	**YES**		**NO**		**Total Response**
		Response	**%**	**Response**	**%**	
1	Are there penalties for non-compliance with energy efficiency measures?	10	59	7	41	17
2	Are there incentives for compliance to energy efficiency measures?	6	35.1	11	64.9	17
3	Do you feel that an incentive towards energy efficiency measures will improve worker/staff behavior to becoming more energy efficient?	16	94.1	1	5.9	17
4	Are there regulations which target worker/staff of the plant or their behavior towards energy efficiency?	9	53.1	8	47.2	17

As can be seen from Table 6-10, 10 of the 17 respondents perceived that penalties exist for non-compliance with energy efficiency measures, while the remaining 7 respondents disagree. Despite the reported penalties, 11 respondents were of the view that there are no incentives for compliance to energy efficiency measure while the remaining 6 respondents affirm that there are incentives towards energy efficiency. Although the majority (16 out of 17 respondents) feel that an incentive towards energy efficiency measures will improve worker/staff behavior to become more energy efficient, the remaining 1 respondent disagreed. It was further reported by 9 of the 17 respondents that there are regulations that target worker/staff behavior with respect to energy efficiency, while the remaining 8 respondents stated that there are no regulations.

Table 6-11: Rating of significant factors in energy efficiency projects

S/N	**Significant factor(s) in energy efficiency projects**	**Important**		**Not Important**	
		Response	**%**	**Response**	**%**
1	Corporate support	16	94.1	1	5.9
2	Organizational energy policy/strategic energy objectives	16	94.1	1	5.9
3	Awareness and knowledge from training	16	94.1	1	5.9
4	Awareness and knowledge from information sources such as conferences, visiting other plants.	16	94.1	1	5.9
5	Individual motivating a project	16	94.1	1	5.9
6	Team/group motivating a project	16	94.1	1	5.9
7	Vendors offering/providing solutions	16	94.1	1	5.9

As can be seen from Table 6-11, of the majority of respondents (16 out of 17 respondents) respondents agreed with the importance of corporate support, organizational energy policy/strategic energy objectives, awareness and knowledge from training, awareness and knowledge from information sources such as conferences, visiting other plants, individual motivating a project, team/group motivating a project, and vendors offering/providing solutions as being factors that significantly influence energy efficiency projects, while 1 respondent did not consider these factors to be important.

Respondents further suggested the following: introduction of extra charges or fines, improved awareness and training, introduction of government incentives (criminalizing energy wastage, energy saver equipment, strict energy policy implementation, management of energy consumption, communication with energy users), implementation of housekeeping practices for staff, identification and implementation of cost-saving opportunities for reducing energy consumption, support for the formulation of the investment program for reducing energy consumption, participation in annual audits and management energy reviews, conducting of audit inspection by relevant inspectors and improved integration of modern energy saving modern technology.

The respondents, when asked in an open-ended question whether stakeholders and local authorities are putting enough efforts to ensure better energy efficiency targets, responded that that there is low awareness and that local stakeholders aren’t responsive enough.

The study further attempted to understand workers' perception by rating the potential for energy efficiency improvement using maintenance best practices (maintenance, individual, organization, optimization, utilities, and processes) (Figure 6-21).

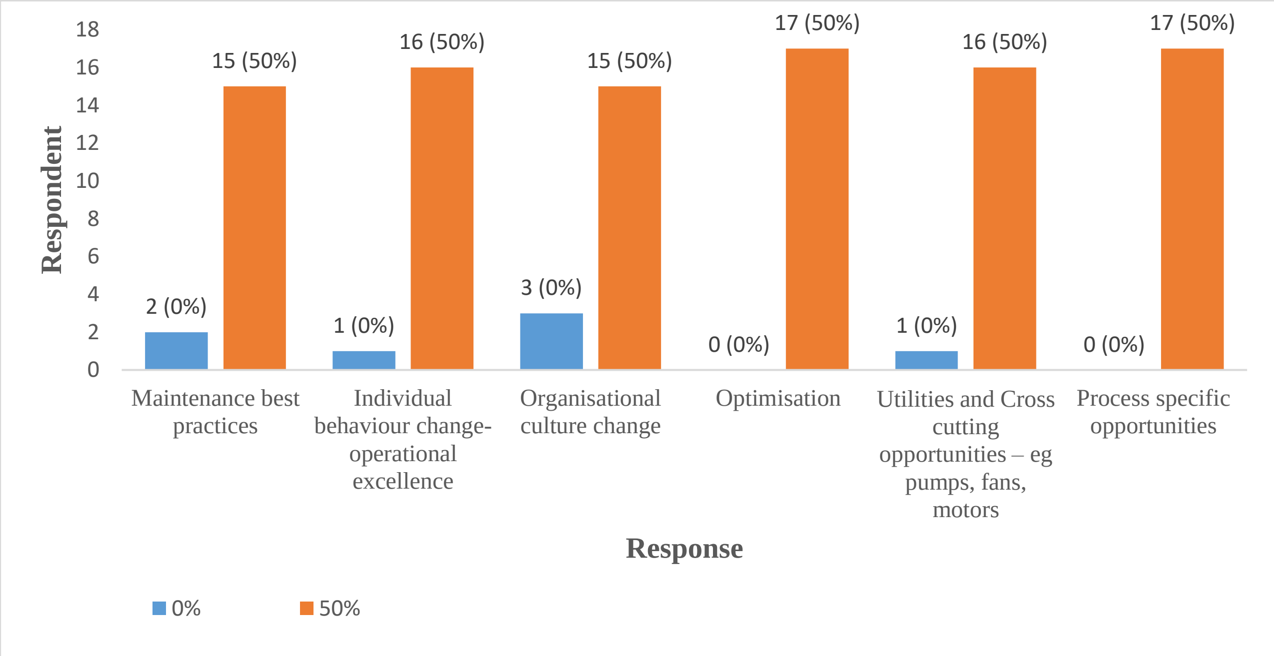


Figure 6-21: Result from the potential for energy efficiency improvement

The finding presented in Figure 6-21 show that all the 17 respondents perceive that optimization and process specific opportunities improve energy efficiency, 16 respondents perceive that individual behavior change and utilities improve energy efficiency, and 15 respondents perceived that maintenance best practices and organizational culture change play a vital role in energy efficiency.

Table 6-12: Measures for reducing energy consumption

Use of centrifuge pumps and throttle controls	**Number of respondent**	**%**
Yes	10	58.8
Unfelt/unaware of effect	6	35.3
No	1	5.9
Total	**17**	**100**

Respondents indicated that adhering to energy consumption reduction requires certain measures including: energy efficient lighting system which entails the use of energy saving fluorescent (i.e. replacement of 38 mm fluorescents with 26 mm and replacement of tungsten filament lamps with compact lamps and optimal use of natural light to which 10 respondents strongly agree, 2 respondents agree, 4 respondents are neutral, and 1 respondent strongly disagree (Figure 6-22). Findings presented in Table 6-12 show that 4 respondents agreed that the plant should make use of centrifuge pumps and throttle controls, 6 respondents were neutral while the remaining 1 respondent disagreed.

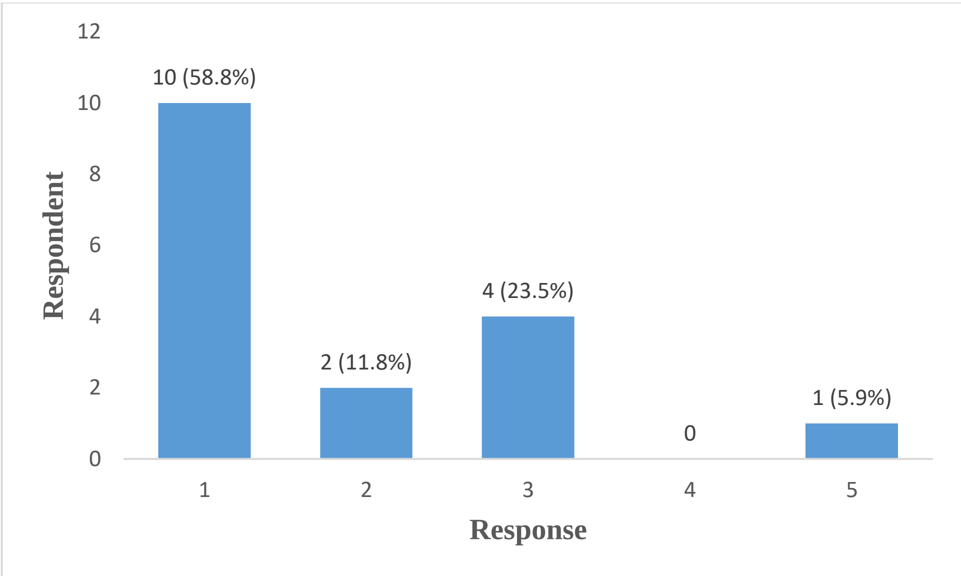


Figure 6-22: Optimize the use of natural light

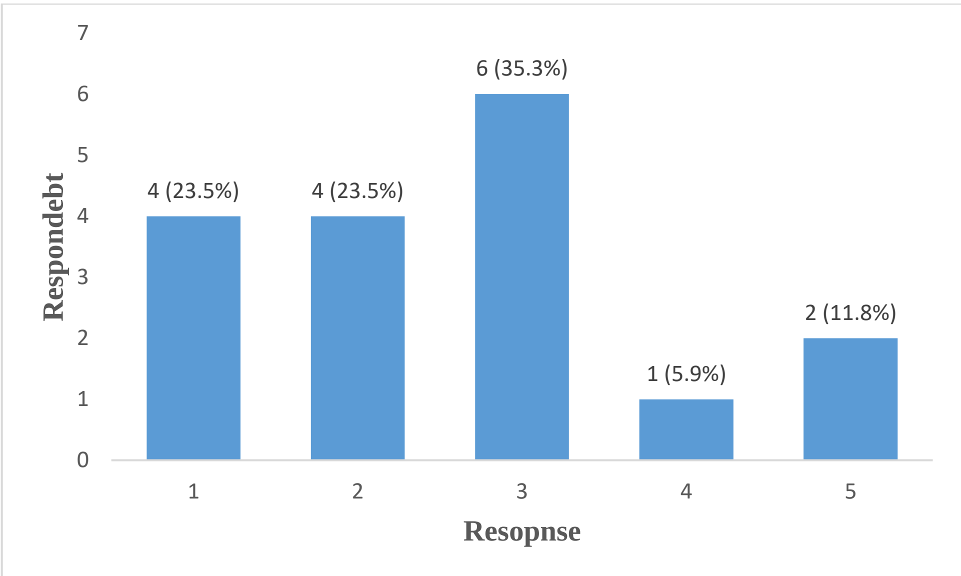


Figure 6-23: Average of Measures for Reducing Energy Consumption through Lighting

Table 6-13: Rating of Measures for Reducing Energy Consumption

Use of efficient motors			**Use of Power Factor Correction**			**Use of automatic power switch**		
Respons e	**Number of respondent**	**%**	**Response**	**Number of respondent**	**%**	**Response**	**Number of respondent**	**%**
Yes	13	76.5	Yes	13	76.5	Yes	13	76.5
No	4	23.5	No	4	23.5	No	4	23.5
Total	**17**	**100**	**Total**	**17**	**100**	**Total**	**17**	**100**

It was further reported by 13 of the 17respondents that the plant had implemented energy saving measures such as efficient motors, power factor and automatic power switches (for pumps, fans, conveyor and other equipment when not in use) while the remaining 4 respondents were of the perception that the factory did not such measures (Table 6-13).

6.2 Discussion

6.2.1 Barriers to energy efficiency improvement in a cement finishing mill

To quantify the existence of improvement in energy efficiency, the respondents were asked to rate the importance of 16 energy efficiency barriers using a scale of 0 (Don't know), 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree) and 5 (Strongly Agree). The average score of all responses ranged from 1.47 to 4.06 (See Figure 6-24). The empirical results of a barrier survey can be explained by the theoretical framework in Table 6.14 which shows the rank and theoretical origin of significant barriers whose average result is greater than or equal to 2.5.

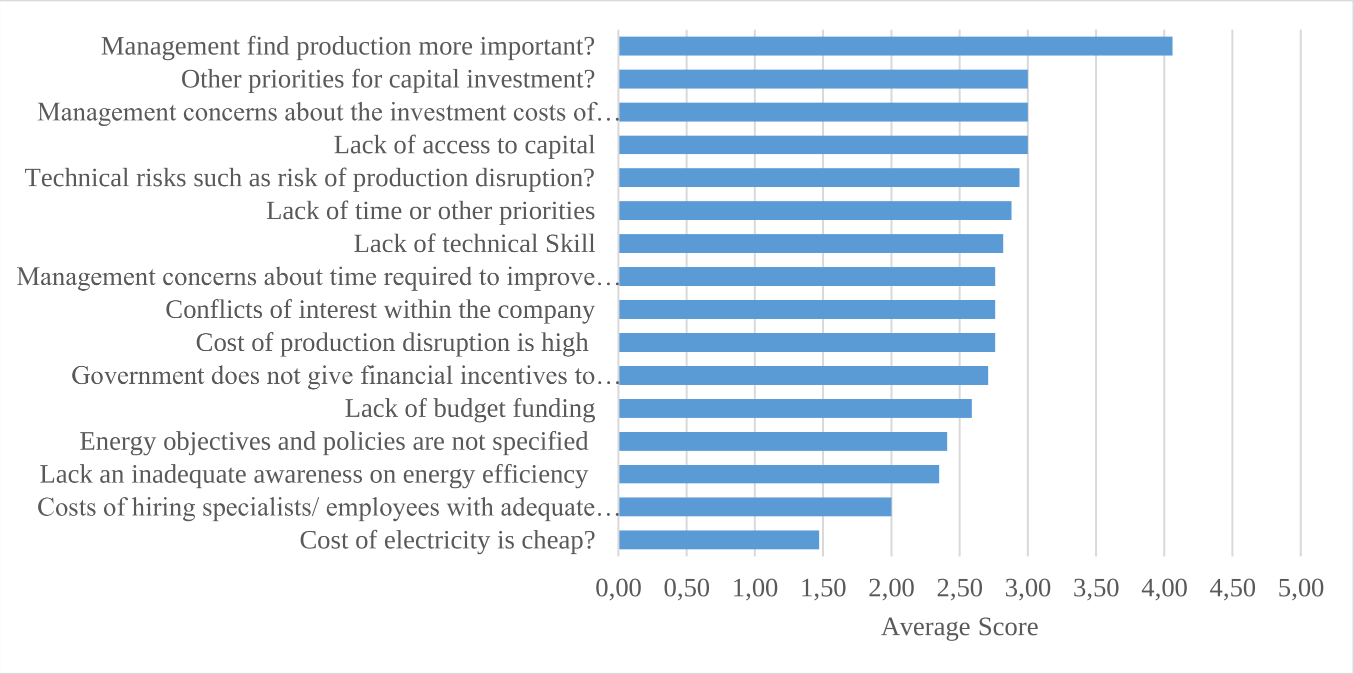


Figure 6-24: Ranking results from barriers energy efficiency improvement

Table 6-14: Classification of barriers to energy efficiency

Rank	Empirical barrier	Theoretical Barrier
1	Management finds production more important?	Bounded rationality
2	Other priorities for capital investment.	Hidden costs
2	Management concerns about the investment costs of energy efficiency measures.	Hidden costs
2	Lack of access to capital	Access to capital
5	Technical risks	Risk or Uncertainty
6	Lack of time or other priorities	Hidden costs
7	Lack of technical knowledge/skills	Imperfect information
8	Management concerns about time required to improve energy efficiency	Risk or Uncertainty
8	Conflicts of interest within the company	Split incentives
8	Cost of production disruption is high	Hidden costs
11	Government does not give financial incentives to become energy efficient	Not relevant
12	Lack of budget funding	Access to capital
13	Energy objectives and policies are not specified	Risk or uncertainty
13	Lack an inadequate awareness on energy efficiency	Split incentives
14	Costs of hiring specialists/ employees with adequate technical skills	Hidden costs
15	Cost of electricity is cheap	Hidden costs

The most outstanding result from the survey was that management finds production more important than energy efficiency (which is associated with bounded rationality) with an average score of 4.06, which was found to be much more important than the other related barriers listed in the questionnaire. This is similar to the investigation by Hasanbeigi, Menke, et al. (2010), in six Thai cement plants which found that management is more concerned about production issues rather than energy efficiency. The study made it clear that a possible way to reduce the cost of production is through the reduction in cost of energy which is the driving force for investing. The production manager has more power and influence than the energy manager and maintenance manager because of the higher priority for production by top management. The second, third and the fourth position with an average score of 3.0 are: other priorities for capital investment (this barrier can theoretically be related to hidden cost according to Rohdin and Thollander (2006), management concerns about the investment costs of energy efficiency measures, (theoretically associated with hidden costs) and lack of access to capital (related to access to capital).

All the respondents that rated other priorities for capital investment barrier as very important believed that energy costs are relatively insignificant parameters according to senior management; therefore, their senior managers tend to ignore energy efficiency investment as a substitute for capital compared to other production related investment. Most respondents within the plant pointed out that energy efficiency improvements in cement plants involve significant capital investments; the lack of internal or external access to capital or limited capital availability is a very important or often important factor in the implementation of energy efficiency improvement.

In fifth position is the barrier of “technical risks” (related to risk or uncertainty) which is associated with production risk by changing of technology as a result of improving energy efficiency. The average score of 2.94 indicates that respondents perceived that this is an important reason why the plant does not improve energy efficiency. The sixth position is lack of time/other priorities (associated with Hidden costs) which leads to personal customary decision-making in order to save time. Lack of technical knowledge/skills (related to Imperfect information) is the seventh position of ranking barriers. Assessing and implementing the performance of energy efficiency measure requires specialized skills, so a lack of these technical skills limit a company's technical capabilities. Barriers related to lack of knowledge and technical skills, according to economic theory, may represent a market / organizational failure, which may validate imperfect information activities. These results are very important because some of the barriers may be categorized as market / organizational failures, thereby justifying market and policy intervention within the organization.

In eighth, ninth and tenth position are “Management concerns about time required to improve energy efficiency” (related to (risk or uncertainty), “Conflicts of interest in the company” (associated with split incentives) and “Cost of production disruption is high” (hidden costs). Government does not give financial incentives to become energy efficient and lack of budget funding are the eleventh and twelfth position of ranking barriers. Lack of budget funding is a barrier associated with access to capital. Several factors related to capital market failures make it difficult for the plant to obtain funding for energy efficiency.

According to the respondents, the least important barriers are those ranked in decreasing order of the mean score, that is below 2.5. These are “energy objectives and policies are not specified” (related to risk or uncertainty) implying that energy efficiency measures can lead to risks of security and have legal consequences; “lack an inadequate awareness on energy efficiency” which can lead to the plant being unaware of energy saving potential; cost of electricity is cheap; and, costs of hiring specialists / employees with adequate technical skills which can lead to additional salary costs. Most respondents perceived that the cost of the hiring experts to identify and analyze energy efficiency opportunities is very high, and that management usually overlooks these projects.

Lack of access to capital

As highlighted in the results, access to capital was among the second highest ranking barriers, and is connected to financial constraints. This discovery illustrates the importance of access to capital to improve energy efficiency in cement plants within South Africa. Lack of access to external funds is another barrier to improving energy efficiency in the perception of the majority of respondents. This fact is positive when the respondents said that top management within their plant cannot borrow money to finance energy efficiency projects due to high interest rates and the doubts related with such projects.

Bounded rationality

The transaction cost economics explain how people can save efforts to deal with information that leads to satisfaction rather than maximizing decision-making heuristics. Behavioral economics emphasizes on the systemic preference in human decision-making.

Lack of awareness among the management staff

The key barrier to energy saving is that the industry lacks awareness of the potential benefits of improving efficiency, that is why they do not assign funds for energy because they consider energy as a minor component of production. Industry and government have not yet taken into consideration necessary factors like tax credits, depreciation benefits, rising electricity prices, investment lifecycle savings and timely release of funds. Energy efficiency can only be successful if senior management knows the value of it

Notwithstanding the high level of awareness of energy efficiency improvement and energy management among the respondents i.e. the engineering manager and production staff, most respondents confirmed that the plant's top management generally had a very low level of awareness of energy efficiency. This low level of awareness among top management within the plant is reflected in the energy use and poor energy management in the plant, which is the source of some high-level barriers.

The barrier "other priorities of capital investment" is ranked second in the classification of important barriers to energy efficiency; this ranking is to a degree due to the low level of the energy efficiency awareness within the top management of the plant. The low awareness level at top management is likely to make energy efficiency improvement a less important consideration than other investments. A respondent said that the plant top managers would rather assign money for energy equipment such as electricity generation to ensure consistent power supply than to invest in energy efficiency equipment.

Lack of equipment standardization and out-of-date equipment

According to Backlund et al. (2012), decision-making made on energy investment are often not established on the real information due to the time constrains and lack of appropriate equipment. Many industries use only one utility meter to quantify the energy consumption for the whole plant. The slow rate of progress in improving energy efficiency standards for equipment and appliances' energy consumption also has a negative impact on the adoption of energy efficiency measures. The selection of the inappropriate equipment or appliances for the wrong job is another barrier (de Almeida et al., 2003). The breakdown of the equipment can lead to increased utilization of energy consumption in the plant. The poor maintenance of machines and equipment delays work and makes the operator feel exhausted. Expensive energy-saving equipment, cannot guarantee the desired results, which can make an organization lack trust in their supplier due to previous poor experiences on energy-saving equipment (Beyene, 2005). The plant in this study is very old and the equipment is outdated There are many break downs in the production process within the plant.

6.2.2 Driving forces for energy efficiency improvement

Investigation of the driving forces behind the implementation of energy efficiency provides policy makers with good insight into how energy efficiency measures and technologies are being implemented in a cement plant. In order to determine the reasons for industrial energy efficiency, respondents were asked to rate the 17 most important driving forces, using 0 (not important), 1 (Slightly Important), 2 (Moderately Important), 3 (Important) and 4 (very important). Table in appendix shows the top ten important driving forces that the respondents considered as the driver for improving energy efficiency in the surveyed plant.

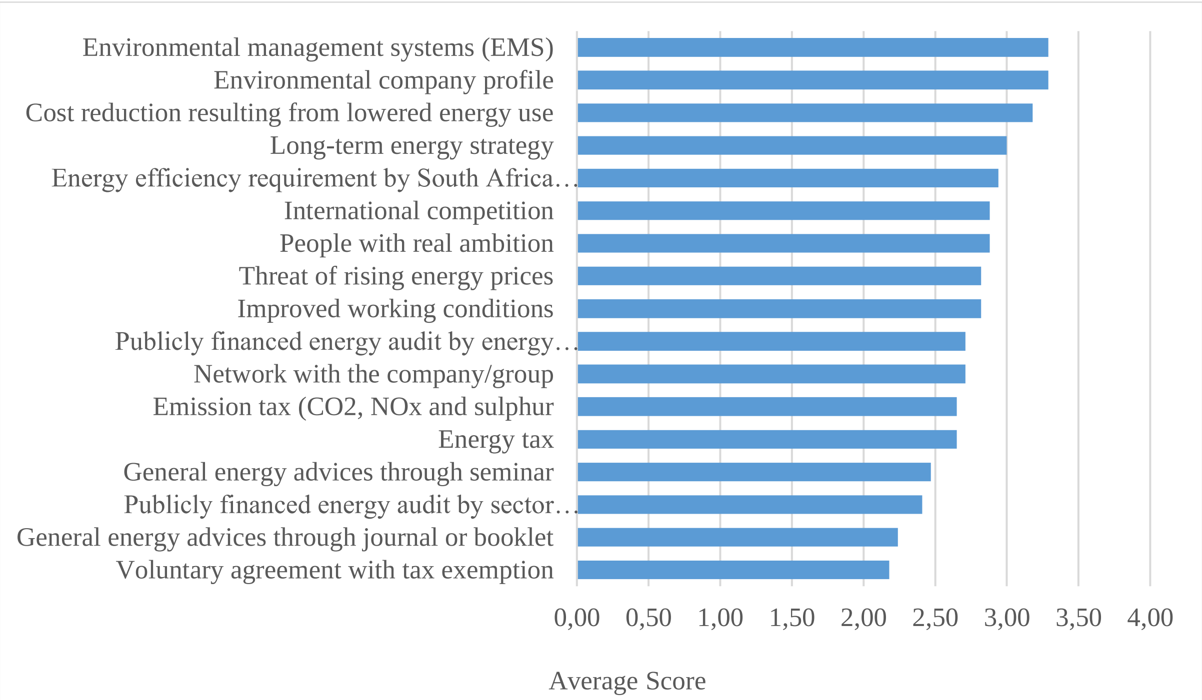


Figure 6-25: Ranking of driving forces for improving energy efficiency

Table 6-15: Classification of barriers to energy efficiency

Ranking	Empirical barrier	Classification
1	Environmental management systems (EMS)	Organizational
2	Environmental company profile.	Organizational
3	Cost reductions resulting from lowered energy use	market-related
4	Long term energy strategy	Organizational and behavioral factors
5	Energy efficiency requirement by South Africa government	Energy policies related

The average score of all the responses ranged from 2,18 to 3,29 (Figure 6-25). The two most important ranking drivers within the plant are environmental management systems (EMS), and environmental company profile. These barriers are external driving force for improving energy efficiency in cement plant, particularly for a plant that contends with international markets which have high environmental interests and environmental protection regulations. These are followed by "cost reduction resulting from lowered energy use". This driver is market-related to increase the company's dividend or ensuring its future dividend. Respondents listed the energy efficiency requirements of South Africa government as another important driver, although the South Africa government has tight laws or standards on the use of industrial equipment for energy. The threat of rising energy prices ranked eighth and is also a market-related driver.

Energy tax is also an effective driver used by governments globally to support improvement of the energy efficiency in an industry, but in the survey it was ranked thirteenth. This low priority/ranking result within the plant can be ascribed to the fact that the energy prices in South Africa are subsidized for industries and therefore lack of competitive pricing or taxation negatively affects improvement of energy efficiency. Some other low-level ranked drivers include voluntary agreement with tax exemption, general energy advice through relevant journal articles or booklets, publicly financed energy audits by sector organisation expert, and general energy advice through seminars. However, despite the presence of these barriers within the cement plant, there were attractive driving forces which when implemented by the plant and policymakers could promote energy efficiency improvement in South Africa's cement industry. The reasons for adopting energy efficiency in an organization can be either internal forces or external forces or both.

6.3 Correlational analysis

6.3.1 Cross-tabulation analysis: awareness if the organization has an energy manager

Table 6-16: Respondent position/job designation and awareness of energy manager

Awareness of organization energy manager	**Position/Designation in organization**		
	Administrative/Managerial Position	**Technical Position**	**Total**
Yes	4	1	5
No	3	9	12
Total	7	10	17

To establish the awareness among respondents of whether the organization has an energy manager in the plant or not, and the relationship between plant respondents job designation and awareness of energy manager in the plant, data recoding was done based on the job title. Respondents' job descriptions were re-coded as administrative or technical job descriptions. Respondents that fell within the chain of command of various departments and also in an administrative position were coded as administrative/managerial position while workers that work within the plant engineering workers were classified as technical office holders. Data on the awareness of the respondents of the organization has an energy manager was re-coded into a yes or no response.

Analysis presented in Table 6-16 shows that 5 of the 17 respondents responded in the affirmative that the plant has an energy efficiency manager while the remaining 12 respondents were of the view that there is no energy manager in the plant. From the 5 affirmative responders, 4 are in the chain of command that is within the administrative and managerial role in the plant. It can then be deduced that people within the management are more familiar with the availability of energy manager due to their frequent contacts with that manager at the management position. This is evident in that more than half of the 7 responders that work within the administrative and managerial role in the plant and also 4 of the total 17 responders. Also from Table 6-16 one can see that the 9 respondents that were not aware of their organization having an energy manager work within the technical unit job description. This shows that 1 out of every 10 respondents within the technical departmental job description in the plant was not aware of the availability of an energy manager in the plant.

6.3.2 Cross-tabulation analysis: awareness of energy efficiency policy

Table 6-17: Respondent position/job designation and awareness of energy efficiency policy

Awareness of organization energy efficiency policy	**Position/Designation in organization**		
	Administrative/Managerial Position	**Technical Position**	**Total**
Yes	4	3	7
No	3	7	10
Total	7	10	17

To establish the awareness of energy efficiency policy availability among respondents, and the relationship between plant respondents job designation and awareness of energy efficiency policy in the study data, recoding was done based on the job title description. Respondents' job descriptions were re-coded as administrative or technical job description. Respondents that fell within the chain of command of various departments and also in an administrative position were coded as administrative/managerial position while workers that work within the plant engineering workers were classified as technical office holders. Awareness of the respondents on the availability of energy manager of data received from respondents was re-coded into a yes or no response.

Analysis presented in Table 6-17 shows that 7 of the 17 respondents responded in the affirmative that the plant has an energy efficiency policy while the remaining 10 respondents were of the view that there is no awareness of energy efficiency policy in the plant. From the 7 affirmative responders, 4 were in the chain of command that is within the administrative and managerial role in the plant. It can then be deduced that people within management are more familiar with the availability of energy efficiency policy due to their frequent contacts with that manager at the management position. This is so because these 4 of the total of 7 respondents that work within the administrative and managerial role in the plant out of the total 17 sampled respondents.

Also from Table 6-17, one can see that the 7 respondents in the technical unit are not aware of the availability of energy efficiency policy work. This shows that 1 out of every 3 respondents within the technical departmental job description in the plant is not aware of the availability of an energy efficiency policy in the plant. A total of 10 out of the 17 sample respondents gave negative responses towards the availability of energy efficiency policy in the plant.

To establish job designation of respondents and awareness of energy efficiency policy, inferential statistical analysis was carried out using a chi-square test. For the purpose of chi-square analysis, the study hypothesized that there is a significance difference in respondents' awareness of energy manager in the plant. Findings as presented in table 6-17 shows a significant value 0f 0.263.

Based on a significant value being less than 0.05, the result in this case is not significant, and the study accepts the null hypothesis which agrees that there does not exist a significant difference in respondents' job designation and awareness of an energy efficiency policy in the plant. This assertion can also be supported by the fact that not all the respondents have the same awareness of the place of energy efficiency policy. This can be established by the descriptive distribution of responses which shows a ratio of 7:10 of the affirmative and negative response to energy policy in a sample population of 17 respondents.

6.3.3 Cross-tabulation analysis: energy policy perception

Table 6-18: Respondent awareness of energy manager and energy policy perception

Awareness of organization energy manager	**Does your organization have an energy efficiency policy?**					
	Strongly Agree	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**	**Total**
Yes	1	1	1	1	1	5
No	2	3	3	2	2	12
Total	3	4	4	3	3	17
Awareness of organization energy manager	**Does your organization have an energy efficiency policy?**					
	Strongly Agree	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**	**Total**
Strongly Agree	0	0	1	1	1	3
Agree	1	1	0	0	0	2
Undecided	1	2	2	0	0	5
Disagree	0	1	0	0	0	1
Strongly Disagree	1	0	1	2	2	6
Total	3	4	4	3	3	17

As presented in Table 6-18, only 7 of the 17 respondents strongly agreed that the plant has an efficient energy efficiency policy. 7 respondents were undecided while the remaining 6 respondents believed the plant lacks a workable energy efficiency policy. The implication of these is that majority of the respondents has not seen any energy efficiency policy implemented despite the claim to the contrary. The level of awareness of the energy efficiency policy in the plant is low.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The overall impact of a cement plant's energy efficiency barriers was studied. Based on this study, a survey was used to identify the barriers that affect a cement finishing mill's energy efficiency. The plant engineering staff and the management staff were questioned and the results analyzed. One of the limitations of this survey is that the number of respondents in the categories within the plant is low. The technical aspect of this thesis involved the study of potential areas of energy savings within a cement plant.

Therefore, the energy saving potential of the cement finishing mill was established, then the estimated energy savings, energy investment and payback periods were calculated. Substantial energy savings were estimated (Table 7-1). Therefore, if the remaining area is taken into account, then the plant can save a lot of energy.

Table 7-1: Energy-saving estimation of different methods

Recommendations	Cost saving per annum (Rand)	Investment (Rand)	Simple payback
Improving system power factor using capacitors	2,467.00	15,814.00	6 years
Installation of variable frequency drive for motors	1,012,099.00	131,784.00	1 month
Use of energy efficient lighting Replacement of 38mm fluorescents with 26mm	44,219.00	53,613.00	14 months
Optimize the uses of natural light system	29,092.00	20,404.00	8 months
Use of efficient motors/ Use of automatic power switch	14,979.00	41,117.00	3 years

Concerning the barriers to the improvement of energy efficiency within the plant, management concerns about production rather than energy efficiency was rated as being the highest barrier, indicating the respondents' perception that there was a lack of interest in improving energy efficiency by top management within the plant, considering that energy efficiency investment is not the main concern by top management. One of the respondents (a Production Coordinator) made it clear that a payback period of energy efficiency investment that is more than 3 years would discourage top management within the plant. He said that the top management are more interested in investing in productivity that will generate real-time dividends in less than a year.

In the energy management section of the survey, the results show a lack of energy management within the plant regarding effective low-cost energy-saving technologies. The main reason for this low implementation is the collection of market related barriers due to the lack an inadequate awareness on energy efficiency related to South Africa's industrial energy efficiency improvement efforts. More importantly, the results show that the plant case study does not have a complete or a standardized energy policy nor an energy management system. The analytical summary of these results shows that this particular cement plant in South Africa has a huge industrial energy efficiency gap, given the low implementation of energy efficiency measures in the case study.

7.2 Recommendations

The workers must understand the plant's energy and utility costs and the level of these expenditures. A lot has been done by the government, but government should not relent on the awareness campaigns, training events, and polices about energy efficiency in the industrial sector, and they must give more incentives to energy savers and criminalize the wasting of energy. Regulations that limit the waste of energy should be put in place to reduce usage.

The plant studied is the one of the oldest cement plants in South Africa which means that the plant needs to upgrade its equipment to meet the standards and use energy efficient equipment. The plant needs enough storage facilities for crushed material prior to the cement mill operation in order to save energy. It would be cost effective to change the drive motor to a shell ring geared drive. instead of using a big chain with attached buckets as a conveying system they can use a belt with bolted buckets to save energy and costs.

The management of the cement mill in this case study needs to do more on energy efficiency in the plant such as: implementation of energy policy; management of information on energy consumption; effective communication with energy users i.e. the workers; implementation of housekeeping practices for staff; implementation of training on energy related matters where necessary; identification and implementation of cost-effective opportunities for reducing energy consumption within the plant; support for the formulation of an investment program for reducing energy consumption and participation in annual audits and management energy reviews. Lastly the plant needs audit processes in order to maximize production output.

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APPENDICES

Appendix 1: Questionnaire on energy efficiency and management in the cement industry

Energy information systems and **Energy management profile**

Barriers	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Does your organization have energy manager?					
Does the organization have energy efficiency policy?					
Does the organization review those policies on an annual basis and establish reduction targets?					
What energy efficiency efforts have been completed in your plant? Started					
What energy efficiency efforts have been completed in your plant? Planning					
Does the top management of your organization full committed to the energy policy?					
Would you describe the level of the energy policy awareness among staff in the plant as high?					
Is the energy policy fully integrated into your plant's operation					
Does your plant have a working energy management system					
Would you describe the status of energy management within your plant as high?					
Is there information available to you on the energy consumption of the plant?					
Is energy sub-metering used in the plant					
Is any data information available on the trends in energy consumption?					
Is information available on the performance of previous energy efficiency investments and the savings achieved?					
Do you consider that you have adequate information, or constraints on using existing information on energy efficiency					
Is environmental performance more important when compared to cost saving in decision-making on energy efficiency of the plant?					
Do you perceive any internal pressures (e.g. colleagues, etc.) to improve environmental performance?					
Do you perceive any external pressures (e.g. government, media, municipality, industry sector, etc.) to improve environmental performance?					
Is senior management seriously committed to improving the environmental performance of the plant?					

Energy savings and Information sources

Barriers	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Are you aware of energy efficiency/ energy saving?					
Do you think you waste energy in your Plant?					
Do you practice any energy saving techniques at your plant?					
Have you ever attended any energy trainings programs before?					
Would you like to attend energy training programs					
At the moment, do you think management are fully committed to energy efficiency and energy saving awareness in your plant?					
At the moment do you think the general staff are fully committed to energy efficiency and energy saving awareness in your plant?					
Do you switch off your machines/ equipment's/lights computer when not in use?					

Energy Consumption

Which sections/equipment do you think consumes a lot of power in your plant?

a) Roller Press

b) Cement Mill

c) Blending

d) Packaging

What do you think can be done to that sections/equipment to save energy? Please specify.

In your opinion, what do you think can be done to save energy in your plant? Please Specify

What do you think are the sources of energy loss in your plant?

Whom do you think is responsible for energy management in your plant?

a) Managers

b) Supervisor

c) Staffs

Barrier to energy efficiency improvement:

Please, I would like to understand what makes it difficult for plant to become more energy efficient.

Barriers	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
Lack of access to capital						
Government does not give financial incentives to become energy efficient						
Management find production more important?						
Cost of electricity is cheap?						
Management concerns about the investment costs of energy efficiency measures?						
Lack of technical Skill						
Cost of production disruption is high						
Lack of budget funding						
Lack an inadequate awareness on energy efficiency						
Conflicts of interest within the company						
Energy objectives and policies are not specified						
Technical risks						
Costs of hiring specialists/ employees with adequate technical skills						
Management concerns about time required to improve energy efficiency						
Lack of time or other priorities						
Other priorities for capital investment?						

Please rate the potential for energy efficiency improvement in the following: (%)

0% means being operations excellence and no room for improvement. 50% meaning we can improve by 50% on current situation)

	0%	50%
Maintenance best practices		
Individual behavior changes operational excellence		
Organizational culture change		
Optimization		
Utilities and Cross cutting		
opportunities – e.g. pumps, fans, motors		

Drivers for energy efficiency improvement

Successful industrial energy management is characterized by a number of factors, external as well as internal.

According to the aggregated experience in your company, how do you value the following factors impact on the implementation of cost-effective energy efficiency measures at your company?

	Very Important	Important	Moderately Important	Slightly Important	Not important
People with real ambition					
Long-term energy strategy					
Environmental management systems (EMS)					
Environmental company profile					
Improved working conditions					
Cost reduction resulting from lowered energy use					
Network with the company/group					
Threat of rising energy prices					
International competition					
Energy tax					
Emission tax (CO_2, NO_x and sulphur					
General energy advices through seminar					
General energy advices through journal or booklet					
Voluntary agreement with tax exemption					
Energy efficiency requirement by South Africa government					
Publicly financed energy audit by energy consultant					

Barriers	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Are there penalties for non-compliance with energy efficiency measures					
Do you feel that an incentive towards energy efficiency measures will improve worker/staff behaviour to becoming more energy efficient?					
Are there regulations which target the worker/staff of the plant, or their behaviour toward energy efficiency?					
Are there incentive's for compliance of energy efficiency measures?					

Please rate the significance of the following on the uptake of energy efficiency projects.

(1 complete insignificance - 5 very significant)

Barriers	Very important	Important	Fairly important	Slightly important	Not important
Corporate Support					
Organizational energy policy/strategic energy objectives					
Awareness and Knowledge from training					
Awareness and Knowledge from information sources such as conferences, visiting other plants.					
Individual motivating a project					
Team/group motivating a project					
Vendors offering/providing solutions					

The following list are some common measures for reducing energy consumption.

Please indicate the extent to which your company has implemented each measure by assigning it a number. Use a scale of 1 to 5, with 1 being "completely significant" and 5 being "completely insignificant".

	1	**2**	**3**	**4**	**5**
LIGHTING:					
Replacement of 38mm fluorescents with 26mm?					
Replacement of tungsten filament lamps with compact					
Use of high frequency fluorescents in new & replacement fittings?					
Optimize the use of natural light					
COMPRESSOR and PUMP MEASURE:					
Use of centrifuge pumps and throttle controls?					
Use of appropriate and efficient motors (or variable speed Regular inspection & elimination of leaks?					
ELECTRICAL EQUIPMENT:					
Power factor correction?					
Automatic switch off of pumps, fans, conveyors & other equipment when not required?					
Purchase of energy efficient computers, photocopiers & other office equipment?					

Appendix 2: Results from questionnaires

The Significance of Technological Barriers

TECHNOLOGICAL	Average	Standard Error
Technical risks such as risk of production disruption?	2.94	0.36
Lack of time/ other priorities	2.88	0.37
Costs of hiring specialists/ employees with adequate technical skills	2.00	0.23
Lack an inadequate awareness on energy efficiency	2,35	0.39

The Significance of Organizational and Behavioral Barriers on the Uptake of Energy Efficient Technologies

ORGANISATIONAL AND BEHAVIOURAL	Average	Standard Error
Management find production more important	4.06	0.31
Government does not give financial incentives to become energy efficient	2.71	0.39
Lack of technical Skill on energy efficiency	2.82	0.35
Conflicts of interest within the company	2.76	0.24

The Significance of Financial, Economic and Market Barriers

FINANCIAL, ECONOMIC AND MARKET	Average	Standard Error
Lack of access to capital	3.00	0.37
Other priorities for capital investment	3.00	0.44
Management concerns about the investment costs of energy efficiency measures	3.00	0.31
Cost of production disruption is high	2.76	0.33
Lack of budget funding	2.59	0.35
Cheap cost of electricity	1.47	0.21

The Significance of Uncertainty to the Uptake of Energy Efficient Technologies

UNCERTAINTY	Average	Standard Error
Management concerns about time required to improve energy efficiency	2.76	0.36
Energy objectives and policies are not specified.	2.41	0.27

The Significance of Drivers for Energy Efficiency Projects

Drivers for Energy Efficiency Projects	Average	Standard Error
Awareness and knowledge from training	3.35	0.26
Corporate support	3.24	0.25
Individual motivating a project	3.24	0.30
Organisational energy policy/strategic energy objectives	3.24	0.26
Awareness and knowledge (from information sources such as conferences, visiting other Plants etc.)	3.18	0.29
Team/group motivating a project	3.18	0.29
Vendors offering/providing solutions	2.88	3.24

LIGHTING:	Average	Standard Error
Replacement of 38mm fluorescents with 26mm?	2.59	0.63
Use of high frequency fluorescents in new & replacement fittings?	2.53	0.61
Replacement of tungsten filament lamps with compact	2.24	0.54
Optimize the use of natural light	1.82	0.44
COMPRESSOR and PUMP MEASURE:		
Use of centrifuge pumps and throttle controls?	2.29	0.56
Use of appropriate and efficient motors (or variable speed Regular inspection & elimination of leaks?	1,94	0,47
ELECTRICAL EQUIPMENT:		
Power factor correction?	1,82	0,44
Automatic switch off of pumps, fans, conveyors & other equipment when not required?	1,88	0,46
Purchase of energy efficient computers, photocopiers & other office equipment?	2,06	0,50

Result from the potential for energy efficiency improvement

Opportunities	Respondent Rate																
Maintenance best practices	50	50	50	0	50	50	50	0	50	50	50	50	50	50	50	50	50
Individual behavior change-operational excellence	50	50	50	50	50	50	50	0	50	50	50	50	50	50	50	50	50
Organizational culture change	50	50	50	0	50	50	50	0	50	50	50	50	50	50	50	50	50
Optimization	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Utilities and Cross cutting opportunities – e.g. pumps, fans, motors	50	50	50	50	50	50	50	0	50	50	50	50	50	50	50	50	50
Process specific opportunities	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Barriers	Respondent Rate																
Management find production more important?	5	5	5	4	4	0	5	4	4	3	5	3	4	5	5	5	3
Lack of access to capital	5	5	0	3	3	0	1	3	3	3	5	3	4	2	4	4	3
Other priorities for capital investment?	4	2	5	4	4	1	1	2	4	2	1	3	3	4	4	4	3
Technical risks such as risk of production disruption?	5	1	5	0	3	3	4	0	0	2	5	3	4	5	4	4	3
Lack of time or other priorities	5	1	5	3	3	1	4	3	0	2	2	3	4	5	3	2	4
Lack of technical Skill	4	1	5	3	4	1	4	0	1	2	4	3	4	5	2	2	4
Cost of production disruption is high	5	2	5	2	3	1	1	3	1	2	1	3	3	3	4	4	5
Conflicts of interest within the company	3	5	5	3	1	1	1	2	2	2	4	3	3	4	1	4	3
Management concerns about time required to improve energy efficiency	4	4	2	3	2	1	2	3	2	2	4	3	2	2	3	4	4
Government does not give financial incentives to become energy efficient	3	2	5	3	1	2	3	3	0	3	1	3	5	1	3	4	5
Lack of budget funding	3	4	0	1	3	1	1	4	3	3	5	3	0	4	4	5	2
There is lack of information on equipment	3	3	5	4	1	1	1	3	2	2	1	3	0	5	3	4	3

Energy objectives and policies are not specified	3	1	2	2	4	2	1	4	2	1	4	3	3	4	2	2	1
Lack an inadequate awareness on energy efficiency	3	1	5	0	1	1	1	4	2	2	1	3	3	5	1	5	2
Costs of hiring specialists/ employees with adequate technical skills	3	2	1	2	3	1	1	3	1	1	1	3	2	2	2	2	4
Cost of electricity is cheap?	0	1	1	1	2	0	1	2	1	2	1	3	2	1	2	2	3

Energy Efficiency Driving Force	**Respondent Rate**																
Voluntary agreement with tax exemption	2	1	0	3	4	3	2	2	2	2	1	2	2	2	4	2	3
General energy advices through journal or booklet	4	1	0	1	4	4	2	2	2	2	1	2	2	2	4	2	3
Publicly financed energy audit by sector organisation expert	3	2	0	3	4	2	3	3	2	3	1	2	2	2	4	2	3
General energy advices through seminar	4	1	0	3	4	3	3	2	3	2	1	2	2	2	4	3	3
Energy tax	4	3	0	3	4	2	4	3	3	2	3	2	2	2	2	3	3
Emission tax (CO_2, NO_x and sulphur	2	3	0	4	4	2	4	3	3	2	2	2	2	3	4	2	3
Network with the company/group	3	0	0	3	4	3	3	2	4	4	2	2	4	3	3	3	3
Publicly financed energy audit by energy consultant	3	4	0	4	4	3	4	3	2	3	1	2	2	2	3	3	3
Improved working conditions	4	0	1	2	4	4	3	1	4	4	2	2	4	3	4	3	3
Threat of rising energy prices	4	3	0	3	4	2	4	2	3	3	4	2	0	3	4	4	3
People with real ambition	4	3	0	4	4	3	3	2	3	3	3	2	2	4	4	3	2
International competition	4	4	1	2	4	3	4	3	3	3	2	2	2	4	2	3	3
Energy efficiency requirement by South Africa government	4	4	0	3	4	4	3	3	3	3	1	2	3	2	4	4	3
Long-term energy strategy	3	4	3	3	4	3	2	2	3	3	2	2	3	3	4	4	3
Cost reduction resulting from lowered energy use	4	4	1	1	4	3	4	2	4	4	4	2	4	3	4	3	3
Environmental company profile	4	3	0	3	4	4	4	3	4	3	4	2	3	4	4	4	3
Environmental management systems (EMS)	4	4	3	3	4	3	4	2	4	3	3	2	3	3	4	4	3

LIGHTING:																	
Replacement of 38mm fluorescents with 26mm?	2	2	5	4	2	1	2	3	3	3	5	1	3	3	1	3	1
Replacement of tungsten filament lamps with compact	3	3	1	2	2	1	2	3	1	3	4	3	3	3	1	2	1
Use of high frequency fluorescents in new & replacement fittings?	1	2	1	4	2	1	3	1	3	3	4	3	2	3	5	3	2
Optimize the use of natural light	1	1	5	1	2	1	3	3	1	1	3	1	1	3	1	2	1
COMPRESSOR and PUMP MEASURE:																	
Use of centrifuge pumps and throttle controls?	3	2	5	1	2	1	2	3	2	3	2	3	3	3	1	2	1
Use of appropriate and efficient motors (or variable speed Regular inspection & elimination of leaks?	1	1	5	1	2	1	2	2	2	3	2	1	3	3	1	2	1
ELECTRICAL EQUIPMENT:																	
Power factor correction?	1	1	5	3	1	1	2	2	1	2	1	1	3	3	1	2	1
Automatic switch off of pumps, fans, conveyors & other equipment when not required?	1	1	5	1	1	1	2	2	1	2	2	3	3	3	1	2	1
Purchase of energy efficient computers, photocopiers & other office equipment?	1	2	5	2	1	1	2	3	1	2	4	1	3	3	1	2	1