

https://dspace.org/

Analysis of energy consumption, economics and management at New Denmark Colliery

Mogodi, Phillip

2013-08-28
http://hdl.handle.net/10539/13079

Downloaded from a DSpace repository. https://dspace.org/

CHAPTER 1: INTRODUCTION

Energy is an essential driving force behind industrial activities and other sectors of economic development across the globe. The South African energy sector has historically been at the centre of the country's development. The origin of energy industry in the first years of the twentieth century was driven mostly by the needs of a booming mining sector. It was a critical ingredient of major investment in mining. As manufacturing became more important in the economy than mining and agriculture, the energy sector continued to be one of the drivers of the South African economy (Winkler, 2009).

Economic growth has progressively been dependent on sufficient availability and utilisation of energy. The importance of energy is much more than its direct contribution to the national product because it does not only serve as a basic input but also acts as a catalyst for development and growth (DPE, 1997). The South African economy is energy intensive (it uses much energy for every rand of value added). The economy is structured around large-scale, energy-intensive mining and primary minerals beneficiation industries; this pushes its 'energy intensity' to be above average (SA Info, 2010).

Energy is an important input for all forms of mining. It is a major energy source for the transport of personnel, material and ore, production machines and mineral processing. In addition it is the exclusive power source for vital health and safety related applications such as the pumping of water, ventilation and refrigeration. The demand of energy within the mining sector has increased over the years due to changing mining methods, increased level of mechanization, automation and varying mining conditions. Eskom notified mining companies in the 2008 to be prepared for power cuts due to shortfall of electricity in the supply chain (Anglo, 2010 and Mtegha, 2011).

1.1 Problem Statement

South Africa experienced load shedding in recent years which demonstrated that the country did not have sufficient power generation capability to meet the country's needs at all times. Although plans are in place to bring in new capacity, there is a need for an immediate solution to meet the current demand (and energy constraints) and plan future intervention. In the meantime, something must be done to significantly reduce the risk of load shedding, which is very disruptive to industrial activities and the general public (Anglo, 2010 and Lawrence, 2011).

The mining industry was affected by power cuts negatively. The power crisis had impacted negatively not only on production but also on profitability, beneficiation strategy, safety standards and international competitiveness of mining companies in South Africa. The challenge that the companies face is whether Eskom will be able to supply the required amount of energy (or not). Electrical energy security remains a major concern for South Africa and this is not predicted to change in the near future. Mining companies will face demand and energy generating capacity constraints, which may lead to major business disruptions. The mining companies are currently modeling strategies to enhance energy security in the future. They are looking into short term initiatives or mechanism to ensure that energy is used productively and efficiently in mining operations. They are also working plans of action to secure long-term supply of energy (Anglo, 2010 and Mtegha, 2011)

It is imperative for mining companies to do detailed studies at an operational level on the critical aspects of energy economics and management in order to identify potential areas of improvement and secure long term energy supply. Energy management is increasingly recognized as an opportunity to reduce operating costs and increase profitability, yet it is still neglected in many mining operations. High energy consumption and costs are often mistakenly viewed as unavoidable, resulting in their inadequate control when, in fact, effective energy management can have a significant impact on profitability and competiveness of mining companies. From a longer-term perspective, the adoption of energy management measures will result in profitability, which will assure a more sustainable development base for the mining industry (Beggs, 2002 and Villiers, 1996).

1.2 Objectives

The focal point of the research project was on New Denmark Colliery; an Anglo American Thermal Coal operation located in the Mpumalanga Province about 30 km north of Standerton. The main objective of the research project was to analyse energy consumption, economics and management at New Denmark Colliery under which the following were considered:

- To identify electricity consumption per month, annum and specific area at the mine; from which the future energy requirement of the operation would be estimated.
- Financial economics of energy by looking at energy cost break down, yearly and monthly electricity costs, monthly electricity cost distribution and tariff; form which future electricity cost and tariff can be estimated.
- Energy management measures which can be used by the mine in order optimise electricity consumption, minimize electricity cost and enhance security of supply.

The study has been motivated by the following: Recent power cuts which affected production and productivity levels of mining operations; rise in tariff rates of electricity price which increase operational costs of mining operations; the need to find ways of saving energy; the drive by companies to increase returns by lowering production costs through energy optimisation; the need to diversify energy portfolio of mining companies; and securing long-term energy supply to mining operations.

1.3 Methodology and Scope of Study

To address the objectives of this study, the following were undertaken:

- Comparative analysis of electrical energy consumption trends over the years and monthly basis;
- Analysis of factors influencing and affecting supply and consumption of energy at the mine;
- Analysis of financial aspects related to supply and consumption of electricity at the mine; and
- Evaluation of different mechanisms that can be used by the mine to optimise energy usage.

The following methods were used to collect information

- Literature research;
- Site visit (Central Shaft, Engineering Workshop, Okhozini Shaft and Tutuka power station);
- Visiting different departments (mining, engineering and environment);
- Records analysis (Tutuka power station, New Denmark Colliery and other Anglo American Thermal Coal mines;
- Observations and conducting interviews; and
- Making use of computation, qualitative and quantitative methods to present findings.

The area of concentration of the research along the mining value chain was on coal extraction. The study focused mainly on electrical energy (electricity) because it is the main source of energy across different Anglo American Thermal Coal operations.

1.4 Structure of the Report

This report consists of seven main chapters. Chapter 1 introduces the topic and underlines the problem statement, objectives, methodology, scope of study and the structure of the report.

Chapter 2 sets out the literature review which has subsections focusing on overview of energy; South African energy sector; Eskom; environmental economics; and energy and the mining industry

Chapter 3 provides a discussion on the area of study area, which is New Denmark Colliery, an Anglo American Thermal Coal operation.

Chapter 4 provides a discussion on energy consumption at New Denmark Colliery. It takes a look at the following subsections: Use of energy; factors influencing and affecting electricity consumption; electricity consumption per geographical area; yearly and monthly electricity consumption; carbon dioxide per electricity consumed; and estimation of electricity consumption in the mere future (forecast).

Chapter 5 provide a discussion on financial economics of energy at New Denmark Colliery. The following sub-sections were considered: Cost of energy; energy cost break down; tariff; monthly electricity cost distribution; yearly and monthly electricity costs; and electricity cost and tariff forecast.

Chapter 6 provides a summary of different chapters discussed in the report. The second part of this section takes a look at ways in which electricity can be managed at New Denmark Colliery in order to reduce energy consumption, minimise costs, establish energy standards and enhance operational efficiency.

Chapter 7 is a conclusion of the report.

CHAPTER 2: LITERATURE REVIEW

2.1 ENERGY OVERVIEW

Energy is an ability to work, that can be found through energy systems in productive force. The definition of an energy system includes two steps according to energy conversion and utilisation. The first step entails the location of primary energy that includes techniques used to supply energy and its ecological implications. These require the knowledge of its collection or extraction, transportation and storage. Also important is the type of converters used and the forms of final energy obtained. The second step of the definition includes the ways in which energy is conquered through converters and its consumer patterns (Tshisekedi, 2008).

Energy is one of most fundamental resource for future economic prosperity and growth, and its consumption is expected to escalate over the coming decades. The Energy Information Administration (EIA) in the USA predicts that in the twenty-first century there will be substantial increases in energy demand, mainly because of economic growth in developing economies. In developing countries, energy and economic growth tend to move in parallel. Economic development is an energy intensive process which ultimately facilitates broad access to electricity and raises living standards. In contrast to the developing countries, in advanced industrialized nations the link between energy consumption and economic growth is relatively weak, with energy demand growth lagging behind economic growth. As a result, it is predicted that the percentage growth in energy demand will be considerably lower in the developed nations compared with the developing countries (Beggs, 2002).

From an economic point of view, there are two kinds of energy sources, namely: renewable energy sources such as solar radiation, tidal, wind and hydro energy; and non-renewable sources including natural gas, oil and coal. From an industrial development point of view, distinction must be made between traditional sources such as wood, animals and vegetables waste used long time ago and modern energy source namely coal, petroleum, products, natural gas and electricity, that play a crucial role in the world (Tshisekedi, 2008).

From energy flow side, the process allows for a distinction between three energy sources, namely: primary, secondary and final energy (Tshisekedi, 2008). Figure 1 illustrates different forms of energy and energy sources. It also depicts different processes that they undergo before they can be used, namely: supply, transformation, transport and the final state called 'end use'.

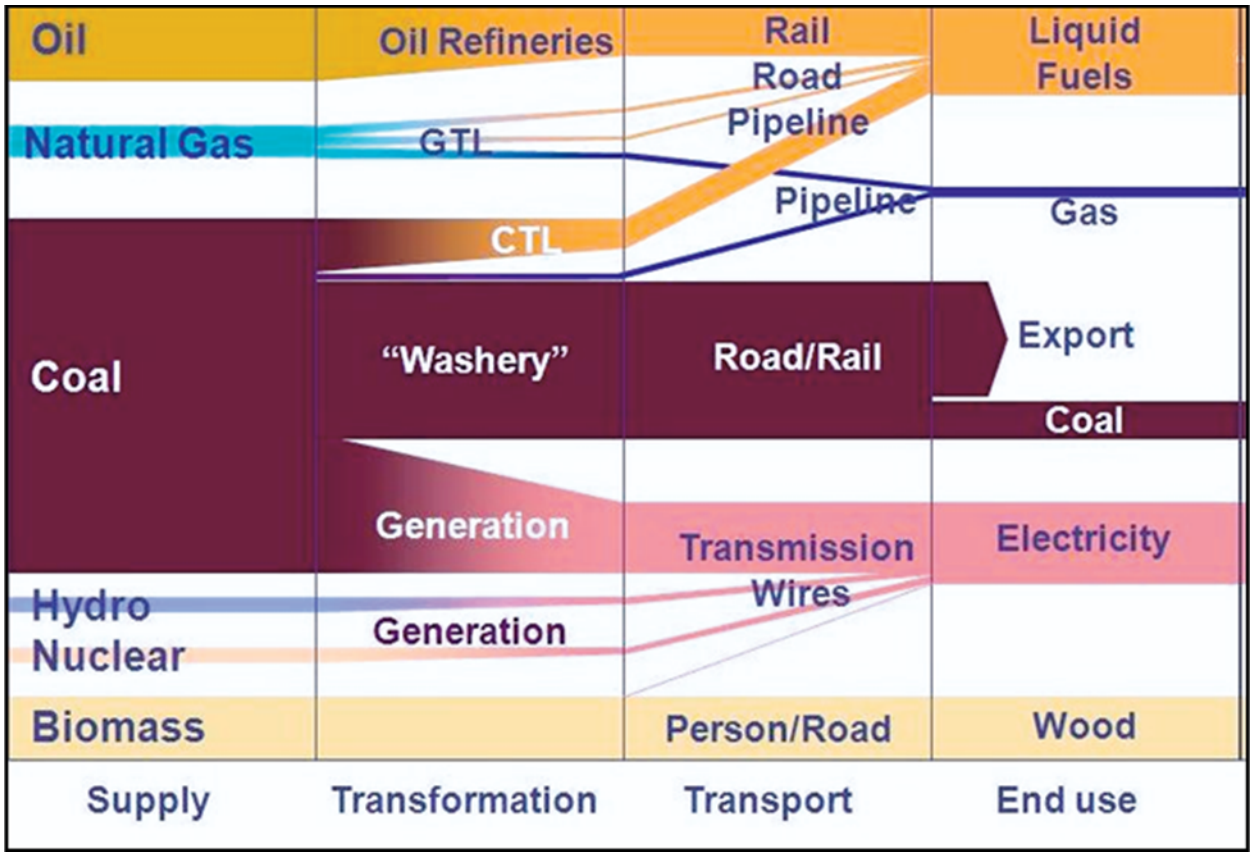


Figure 1: Flow of energy chart (DME, 2008).

Primary energy is the energy available in natural state obtained directly from primary sources such as coal, crude oil, wood, natural gas, uranium, solar and hydro energy. Figure 2 shows different forms of primary energy supply used in South Africa. The energy sector is dominated by coal, which is abundant and cheap according to international standards. Secondary energy is produced by transformation of primary energy, for example: steam, electricity, refined petroleum products and hydrogen (DME, 2008 and Tshisekedi, 2008).

It involves converters, transportation and distribution infrastructure to ensure that energy supplied. In South Africa, the secondary energy is covered mainly by the state owned utility, Eskom for electricity and Sasol for oil and gas. Final energy is the final step of the energy flow system, from which systems are differentiated by forms of appropriation of rent, the quantities of energy mobilized and their overall efficiency (DME, 2008 and Tshisekedi, 2008).

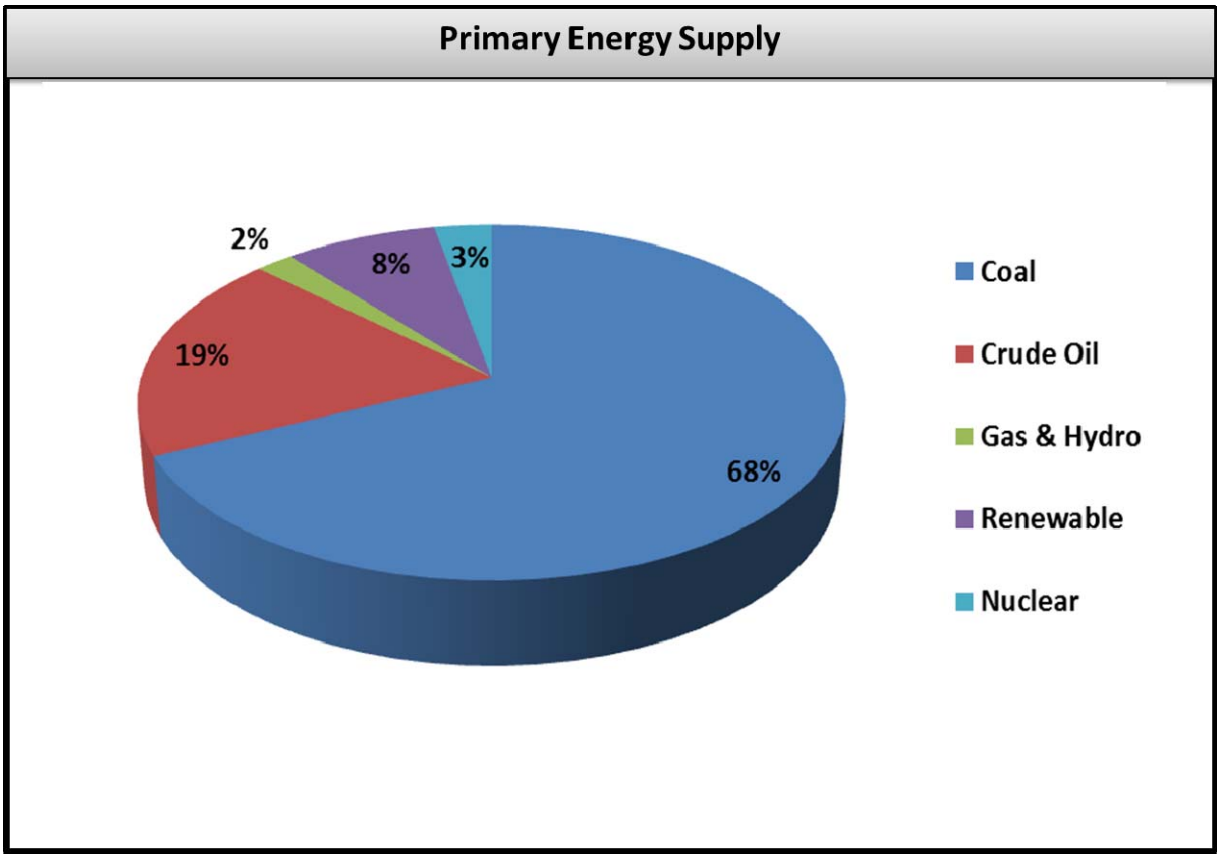


Figure 2: Primary energy supply in South Africa (Tshisekedi, 2008).

2.2 SOUTH AFRICAN ENERGY SECTOR

2.2.1 Introduction

This section provides a basic overview of energy from a South African perspective by discussing the following: South African power mix; energy consumption per sector; supply challenge; paradigm shift introduced by the energy crisis; energy efficiency; policies and strategy; and outlook of the energy landscape.

The South African energy sector has historically been at the centre of the country's development. The origin of the energy industry in the first years of the twentieth century was driven mostly by the needs of a booming mining sector. It was a critical ingredient of major investments in mining. As manufacturing became more important than mining and agriculture in the economy, energy sector continued to be one of the drivers of the South African economy (Winkler, 2009).

2.2.2 South African Power Mix

South Africa is a comparatively energy and carbon intensive country with respect to other African countries and developed nations. It is ranked sixteenth in the world in terms of the total amount of primary energy consumption. It is mainly dependent on fossil fuels for its total energy needs. Coal is South Africa's major indigenous energy resource used to generate most of its electricity and a significant proportion of its liquid fuels. As a result of this, South Africa is the 14th highest emitter of greenhouse gases (SA Government, 2000). Table 1 shows energy statistics of Sub-Saharan countries. It can be deduced from the table that South Africa consumes more electricity per capita compared to other African countries and world-wide average.

Table 1: Energy statistics of Sub-Saharan countries (Sterling, 2009).

	Population (Million)	Electricity Consumption (TWh)	Electricity Consumption (kWh/capita)
World	6268	15223	2429
Africa	851	440	518
Angola	13.5	1.7	126
Cameroon	16.9	2.8	174
Congo	3.7	0.5	122
DRC	53.1	4.7	89
Cote d'Ivoire	16.8	3	182
Gabon	1.3	0.4	920
Ghana	20.6	5.2	254
Kenya	31.9	4.1	128
Mozambique	18.8	6.2	343
Namibia	2	2.5	1259
Nigeria	136.5	13.4	99
South Africa	45.8	206.4	4504
Zambia	10.4	6.5	625
Zimbabwe	13.1	10.5	804

Figure 3 illustrates the power mix of South Africa. It can be seen from the diagram that 88 percent of the electrical energy in South Africa is generated from coal. Other sources of electrical energy include nuclear, pumped storage and hydro-energy.

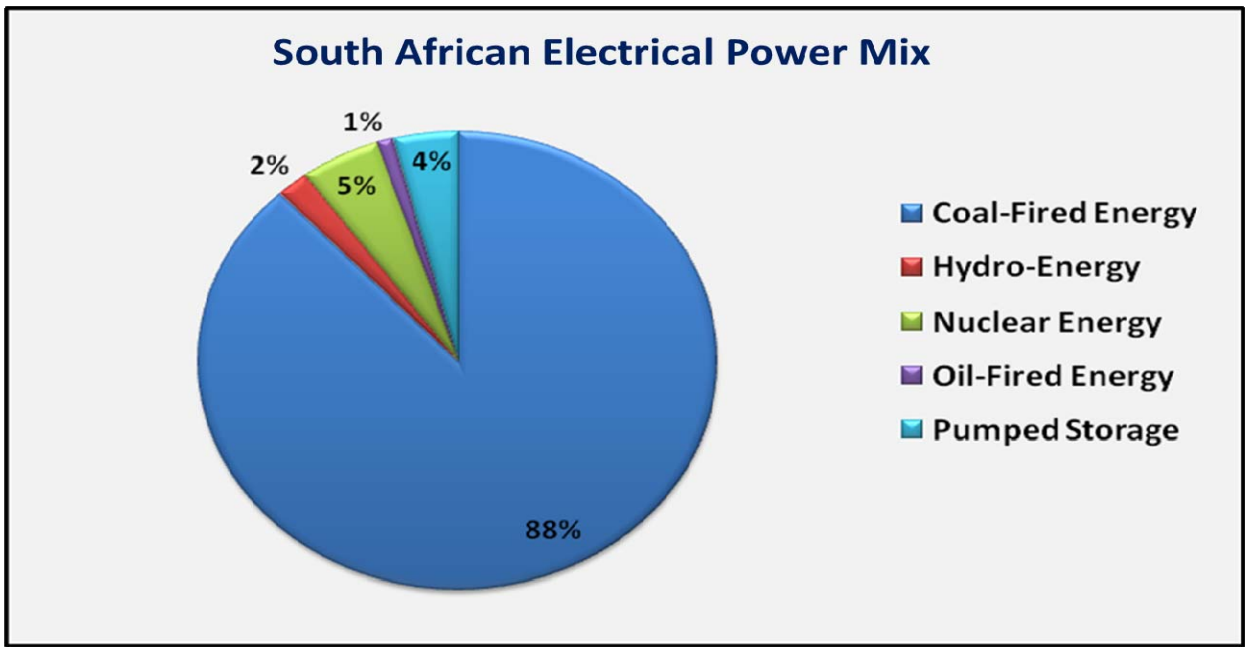


Figure 3: Power mix in South Africa (Exxaro, 2008).

2.2.3 Energy Policies and Strategy

There are a number of institutions which shape the energy sector in South Africa, namely: Department of Energy (DE), National Energy Regulator of South Africa (NERSA), Eskom, Sasol (South African Coal and Oil) and South African Petroleum Industry Association (SAPIA). The government released the Energy White Paper in December 1998, which outlines its objectives and policies for the entire energy sector. The objectives were to increase access to affordable energy service, improve energy governance, manage energy related environmental impacts, stimulate economic development and secure supplies through diversity (Winkler, 2009).

Although the Department of Energy (DE) has had formal responsibility for electricity policy, in practice, electricity sector policy decisions are also taken by a number other agencies and branches of government, such as the DE, NERSA, Eskom and metropolitan local government (Davis, 2010).

Even though electricity sector policy statements are most often officially attributed to the DE, it is often vague which government agency/ department has in fact produced the policies that have been recommended to Cabinet for approval. Nonetheless, policy development has been informally diffused to entities outside and the DE across ministries (Davis, 2010).

2.2.4 Energy Efficiency

Energy efficiency entails taking into account the existing potential energy savings in all economic sectors and environmental improvement to environmental issues; relative to energy generation, transport and final use step (Tshisekedi, 2008). South Africa adopted the energy efficiency strategy which was approved in March 2005. The strategy sets a national target for energy-efficiency improvements of 12 percent by the year 2015. All state-owned enterprises have been asked to make energy efficiency a part of their shareholders' compacts. In addition, large companies have joined forces with the Eskom and Department of Energy by signing an energy-efficiency agreement contract , committing themselves to targets contained in the department's strategy (SANY, 2007).

A secure and reliable energy supply is cardinal to meeting the objectives of social, environmental and economic sustainability of the country. Implementation of energy efficiency measures is one of the contributors to meeting the need for such a supply of energy. These entail making use of less energy to provide the same level of service required by the end user, thus increasing the benefit which can be obtained from often constrained energy supplies. In addition to contributing to energy security, increased investment and level of research and development in energy efficiency (EE) measures could potentially lead to job creation, and would be a critical component of meeting South Africa's emissions reduction targets. A number of EE interventions have been implemented globally, across various industries (Davis, 2010).

In the mining industry, energy efficiency can be defined as a duality because on one hand, there is a need to reduce energy consumption and on the other hand, industry needs to increase production output. A number of constraints and targets are being put into place by the South African government to get the large energy users to use energy more efficiently. Large energy users like the mining industry have been asked by the government to reduce their energy demand of 15 percent by 2015, 11 percent through low-medium cost technical interventions and an additional 5 to15 percent through energy and waste management (Govender, 2008).

2.2.5 South African Sectoral Energy Consumption

The major energy use sectors in the South African economy are: Transport, agriculture, industrial, commerce, residential and mining. The electricity generation sector is the largest consumer of energy; approximately 35 percent of the total energy. The energy is used to generate electricity while certain amount is lost in the transmission and distribution chain. Figure 4 shows energy consumption per sector of the economy. Transport and commercial industries are also major consumers of energy, they use 26 percent and 18 percent respectively. The mining sector consumes about 7 percent of the energy produced in the national grid (Exxaro, 2008).

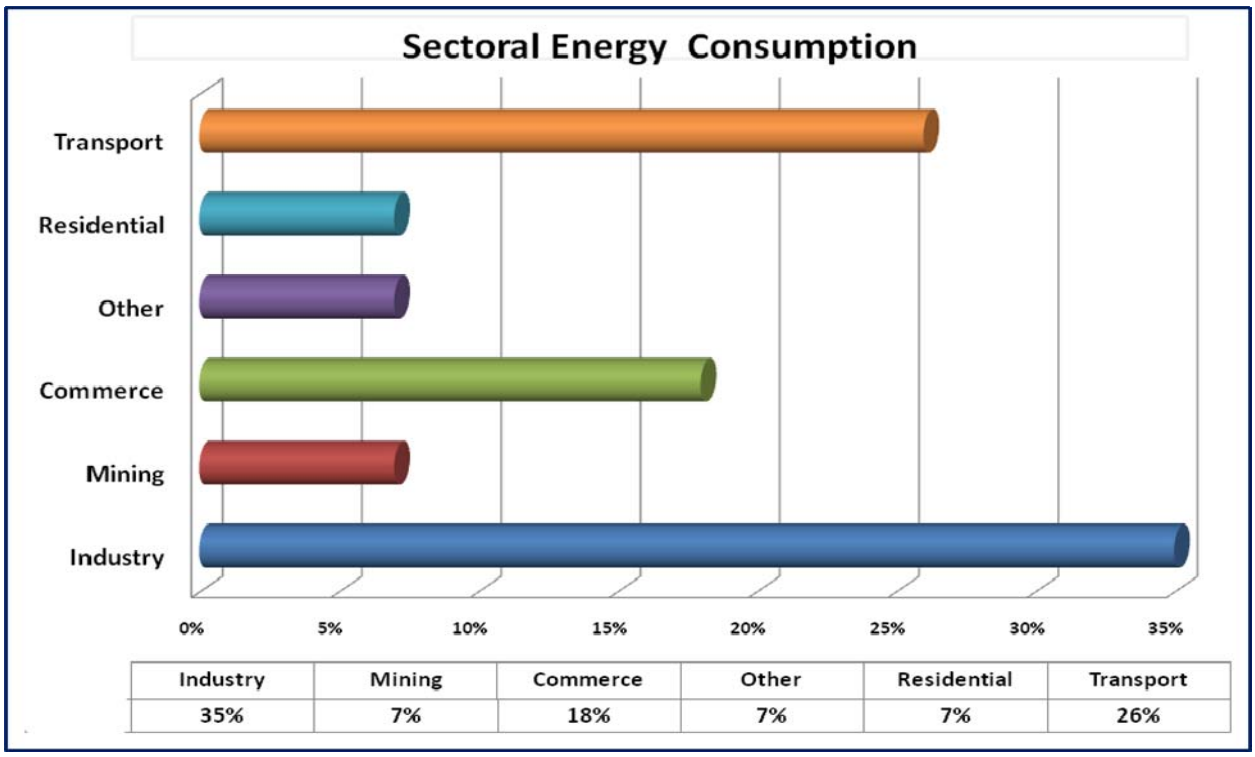


Figure 4: Electricity consumption per sector of the economy (Exxaro, 2008).

2.2.6 South African Energy Supply Challenge

South Africa is a developing country hence the energy demand is expected to increase considerably in the coming years due to rapid industrialization, mass electrification programme and strong economic growth (SA Info, 2010). Electricity demand continues to rise in South Africa and in recent years, it has outstripped the available supply infrastructure to the point where the country suffered rolling blackouts (SA Energy data, 2010). It became clear from events towards the end of 2007 and into 2008 that there is an inadequate supply-demand balance in the country (AMEU, 2010). It can be deduced from figure 5 and appendix A that energy availability rather than capacity is a challenge in South Africa. The amount of energy required outstrips supply; as a result the energy gap in South Africa is expected to occur till the year 2014. On the other hand, capacity is expected to escalate over the upcoming years. The energy situation does not allow space for the ongoing growth taking place in the country (Anglo, 2011).

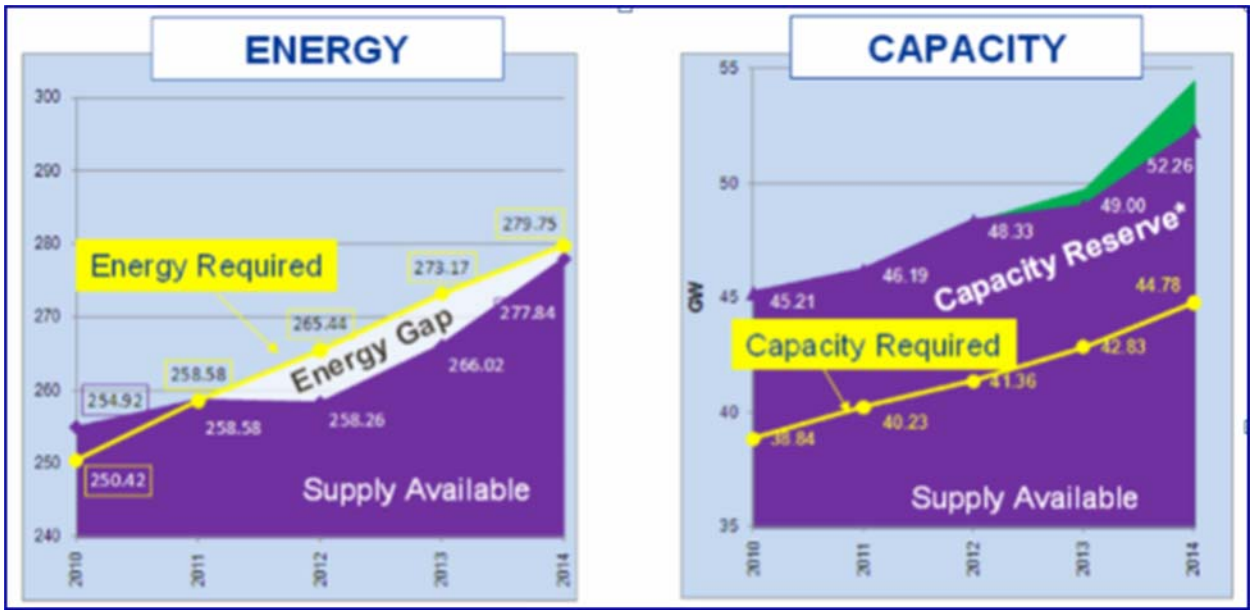


Figure 5: Energy gap and capacity reserve of South Africa (Anglo, 2011).

2.2.7 Energy Crisis Introduced a Paradigm Shift

The energy crisis has provided Eskom, the Department of Energy (DE), the National Energy Regulator of South Africa (NERSA), mining industry and other sectors of the economy with an opportunity to deal positively with energy efficiency in a decisive manner. It has allowed the country to take a closer look at how to use energy effectively and productively. This will accelerate innovation on demand side management and energy technologies. It also provides a platform to focus on climate change mitigation and an opportunity to make appropriate decisions on alternative forms of energy (AMEU, 2010).

The government in conjunction with different stakeholders has been working on different ways in which the energy gap can be mitigated. There are two levers considered for short to medium term energy solutions, namely: increasing the supply and reducing the demand. Figure 6 illustrates the layout of the short to medium term solution. Initiatives that can be taken under increasing supply include: increasing plant efficiency, maintenance, new build (power stations) and electricity co-generation (Eskom, 2008).

The Power Conservation Programme (PCP), Demand Side Management (DSM) and co-generation form the pillars of the national demand management strategy. PCP provides a short to medium term solution to South Africa's electricity shortage. It is designed to result in behavioural change that will ensure sustainable development and reduce environmental impact, whilst meeting the country's energy needs. The Energy Conservation Scheme (ECS) will require all participating consumers to achieve energy savings targets, with associated incentives and penalties which became effective when the mandatory scheme came into effect in the year 2008. The ECS scheme illustrated by figure 6 provides an overview of the anticipated mandatory scheme, which will be implemented once all the regulatory enablers are in place (Eskom, 2008).

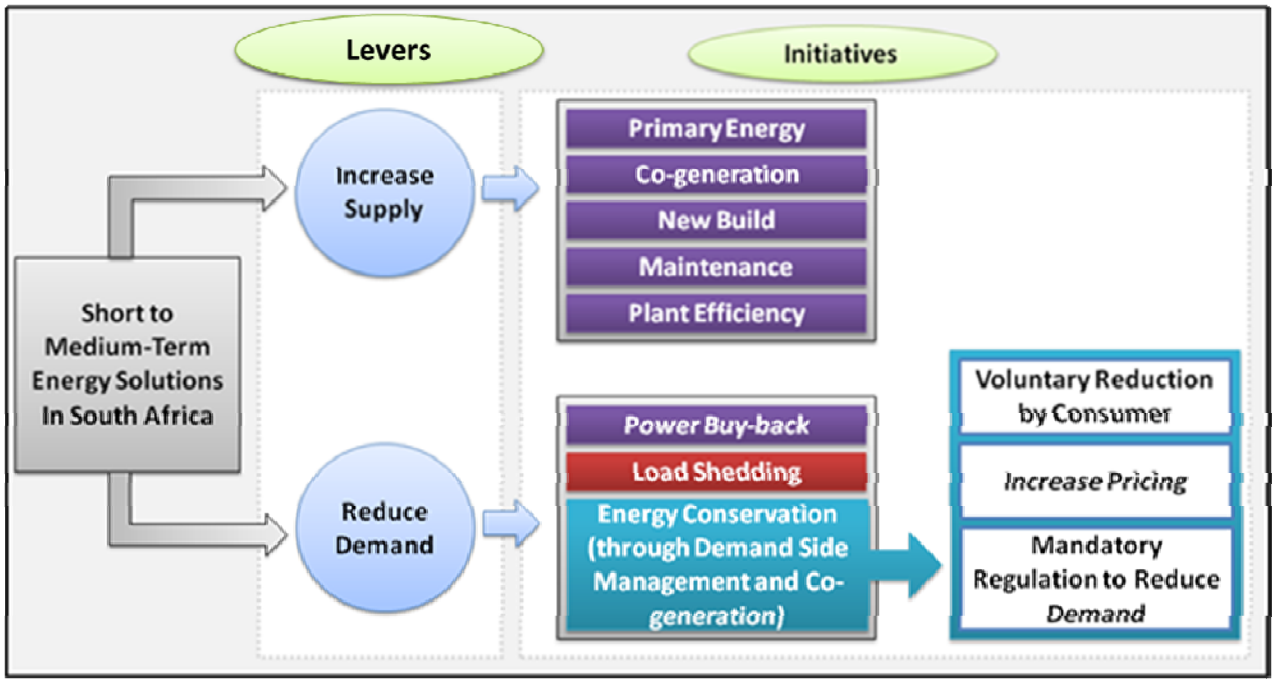


Figure 6: Short to medium term solutions of the energy crisis (Eskom, 2008).

2.2.8 Outlook of the Energy Landscape

The power supply crisis has accelerated the need to diversify Eskom's energy mix and move towards alternative energy sources (Eskom, 2008).

Mining industry is one of the largest consumers of electricity thus it should find or have alternative ways to ensure a more reliable energy supply and less vulnerable disruption. It should look into short term initiatives to ensure that energy is used productively and efficiently. Long term strategic plans of mining companies to enhance energy security could entail reformulation of the current energy policies of mining companies in order to cope with future power demand. Diversifying energy could also entail the following:

- Renewable form of energy;
- Infrastructural development (construction of a power station); and
- Embarking on other projects with Eskom to reshape supply and flexibility to supply through integrated plan and demand side management (Eskom, 2008 and SA Government, 2000).

Investigations of renewable energy sources are conducted so that they can supply more of the total energy demand in the country. Wind, solar, natural gas and hydro electricity seem promising to provide a significant amount of South Africa's future energy needs. Initial capital costs for solar and wind farm installations are still considered high compared to being connected to the existing electricity grid hence economic factors are important when considering the use of renewable energy. Natural gas and hydro electricity are considered on a national level. South Africa may connect to international grid supplies of hydro-electric power and also import natural gas (SA Government, 2000).

2.3 ESKOM

2.3.1 Introduction

This section provides a discussion on the South African electricity utility, Eskom; by focusing on the following: brief background about the company; generation, transmission and distribution of electricity; structure of the electricity supply industry; and challenges encountered by Eskom.

Eskom is a state owned energy enterprise; it generates comparatively large proportion of electricity, approximately 95 percent of the country's and almost two thirds of the African continent. It generates, transmits and distributes electricity to industrial, mining, agricultural, commercial and residential customers and redistributors. Globally, Eskom is the 10th largest energy utility in terms of generation capacity and 9th in terms of sales (Eskom, 2010). Figure 7 shows generation capacity of Eskom in relation to other utility companies in the world.

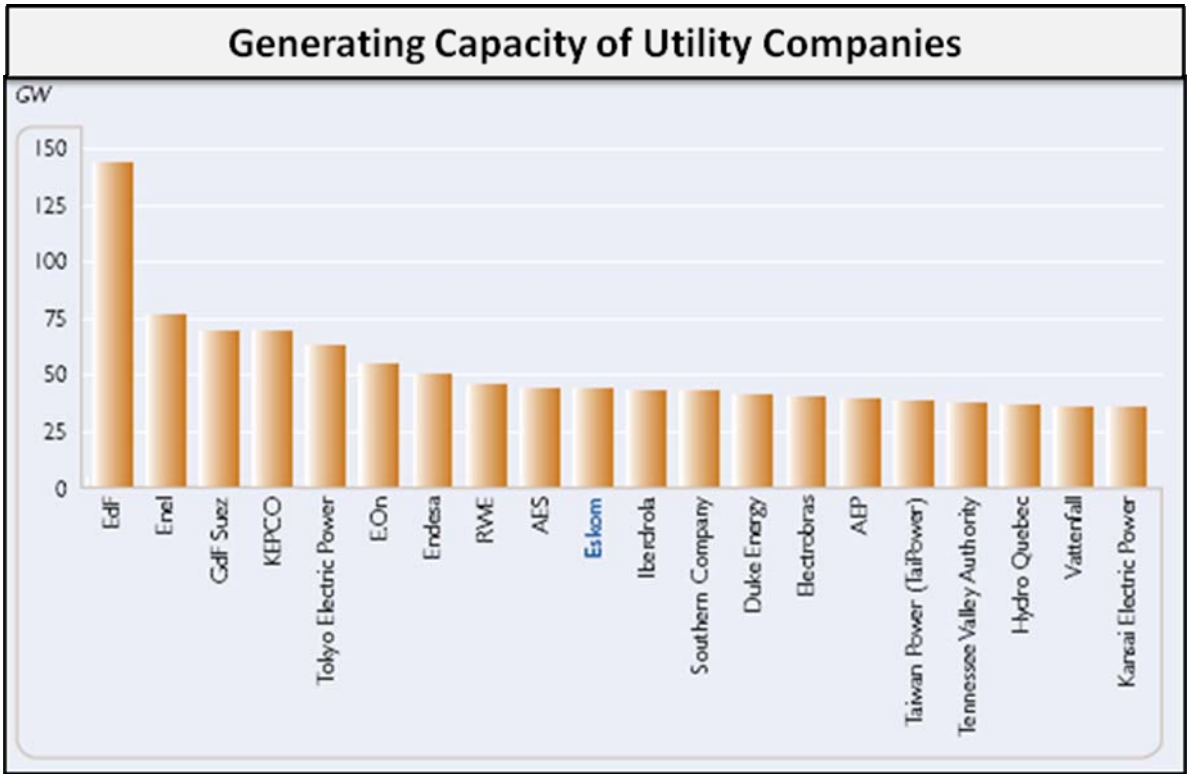


Figure 7: Generating capacity of utility companies across the world (Eskom, 2010).

The electricity generation technology is largely based on coal fired power stations, mostly situated east of Johannesburg, close to the main coal mining areas and major demand centres. All large coal power stations are concentrated around the coalfields in Mpumalanga, Gauteng and the Limpopo province, in order to avoid transport costs. In addition to coal fired power stations, Eskom has gas turbine and hydroelectric power stations. There are 27 power stations in South Africa, 22 of which are owned by Eskom and the rest are municipal and privately owned (Winkler, 2009). Figure 8 depicts the relative position of power stations in South Africa and their ownership.

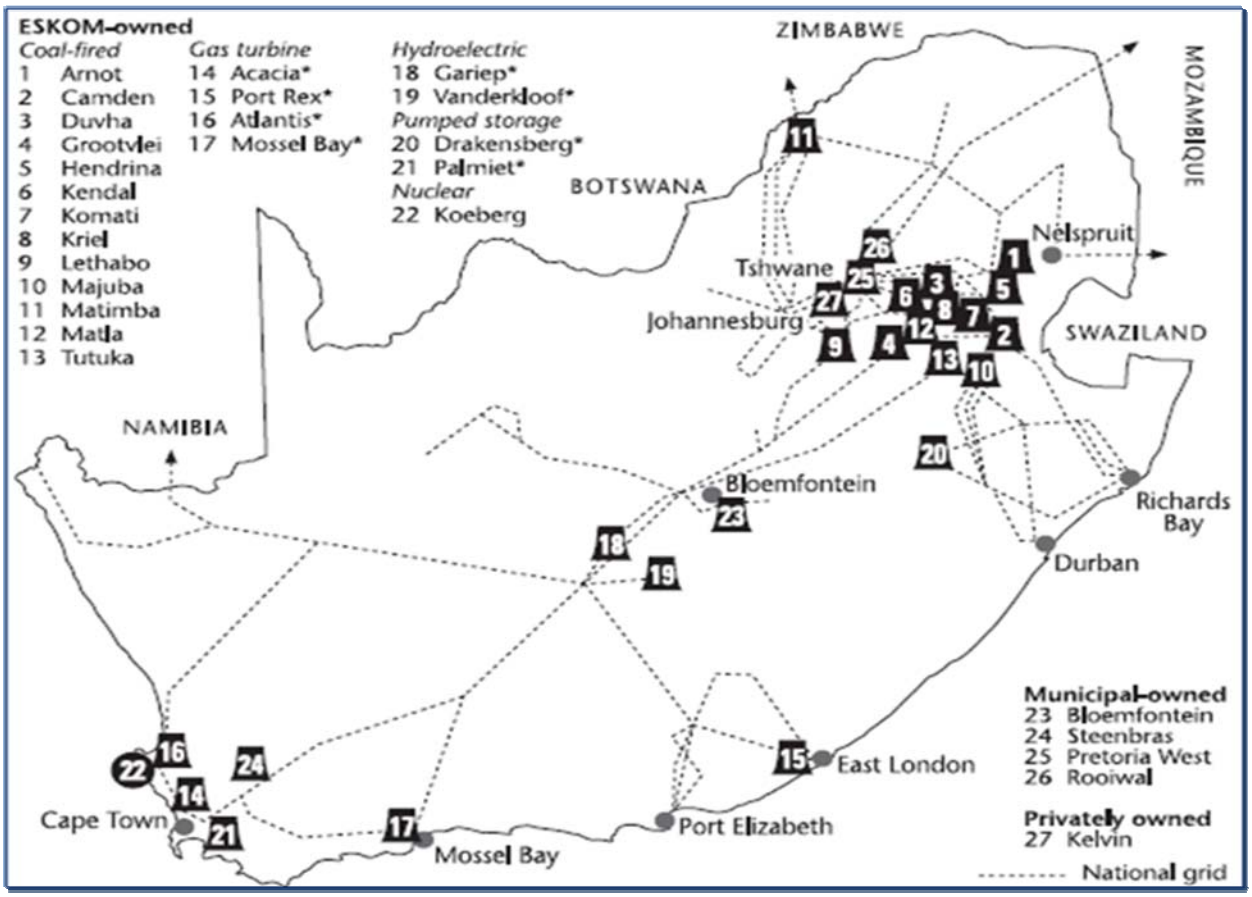


Figure 8: Relative position of power stations and their ownership in South Africa (Winkler, 2009)

The national electricity network is comprised of more than 300 000 kilometres of power lines (transmission grid) with a nominal capacity of 44396 MW (electricity) (Eskom, 2010).

The coal share of total power capacity is 42466 MW, while wind and hydro distribution (capacity) account for less than 10 percent of total power capacity. Due to the capacity constraint, certain power stations were de-mothballed (returned to service). Table 2 shows power stations and their capacity for the year 2008. A new coal power station called Medupi will be contributing additional power on the national grid in the quantity of 4788 MW. There is only one nuclear power generator in South Africa (Koeberg) and it is based in the Western Cape (Eskom, 2010).

Table 2: Eskom power stations (Eskom, 2010).

Eskom Power Stations in 2008			
Base Load	**Capacity (MW)**	**Other**	**Capacity (MW)**
Coal-fired		**Hydro**	
Arnot	2100	Gariep	360
Duvha	3600	Vanderkoof	240
Hendrina	2000	**Hydro Distribution**	
Kendal	4116	First Falls	6.4
Kriel	3000	Second Falls	11
Lethabo	3708	Colley Wobbles	42
Majuba	4110	Ncora	24
Matimba	3990	**Pumped Storage**	
Matla	3600	Drankensberg	1000
Tutuka	3654	Palmet	400
New Build (Coal)		Ingula (New build)	1332
Medupi	4788	**Open Cycle Gas Turbine**	
Return to Service		Acacia	171
Camden	1600	Port Rex	171
Grootvlei	1200	Ankerlig	592
Komati	1000	Gourikwa	444
Nuclear		Gas I (new build)	1036
Koeberg	1930	**Wind**	
		Klipheuwel	3.2
Total Base Load	**44396**	**Total Other**	**5833**
Coal Share of Total Capacity	**42466**	**Total Overall Capacity**	**50229**

2.3.2 Generation, Transmission and Distribution of Electricity

South Africa has three groups of electricity generators namely Eskom (national public electricity utility), municipal generators and auto-generators. Modern power stations in South Africa burn coal in order to heat water and convert it into steam (SANEA, 2010). Ingredients used to generate electricity include coal, water and diesel (Eskom, 2010). The coal is carried by conveyor belts into the plant, crushed into fine powder and burned in modern boilers to produce high-pressure steam. The steam is then directed onto the blades of a turbine in order to make it spin. The magnetic rotor will then spin inside the coil to generate electricity. Transformers at the power stations are used to increase the voltage of the electricity for transmission along the power lines. When it has reached its destination, transformers in substations near towns and cities decrease the voltage to a level where it can be used by the consumer (SANEA, 2010).

Electricity is transported along power lines from the power stations to the areas where it is needed. Not all consumers are located next to the power station hence electricity is transported to consumers at high voltages which minimises losses that occur over long distances and limit the number of power lines needed. Transmission lines are usually comprised of overhead conductors suspended from transmission towers. Transformers are installed at power stations to increase the voltage of the electricity to a level that will be suitable for transmission over long distances. Voltage will then be stepped down using transformers before entering reticulation system of the customers/consumers (Eskom, 2009). Figure 9 depicts schematic representation of electricity generation, transmission and distribution.

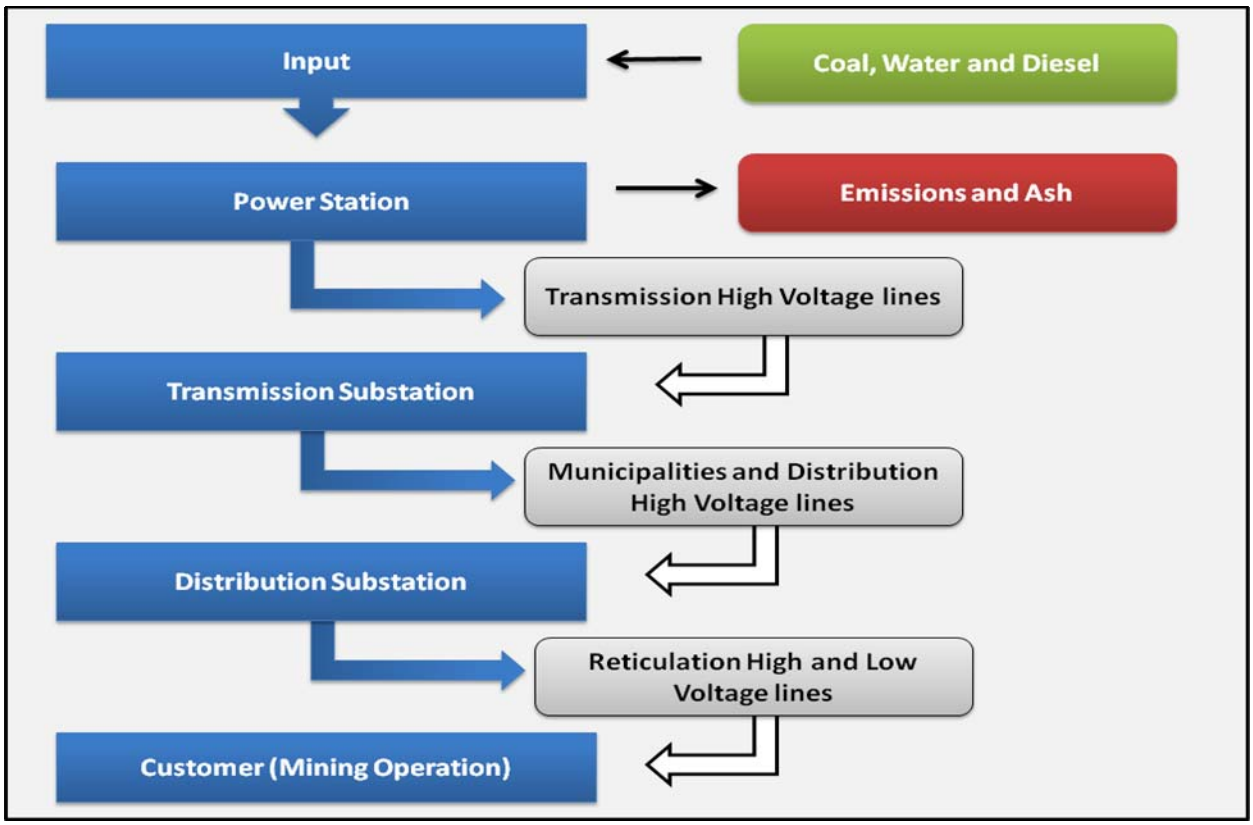


Figure 9: Electricity generation, transmission and distribution (Eskom, 2009).

2.3.3 Structure of the Electricity Supply Industry

The electricity supply industry (ESI) has undergone significant reforms over the past two decades. Eskom is an energy utility that owns and operates the national high voltage transmission grid and distribution system. In 2005, total electricity production in South Africa was 230 TWh, of which 3.1 percent was generated by private generators, 0.5 percent by local authorities and 96.4 percent by Eskom (Tshisekedi, 2008).

Figure 10 illustrates the South African energy flow through the electricity supply industry. Eskom and municipality distribute most of the electrical energy to different sectors of the economy, namely: domestic, mining, agriculture, manufacturing, transport, general and the commercial industry.

Less than 10 percent of electricity generated is exported (transmitted and distributed) to Southern African Power Pool (SAPP). The Southern African Power Pool (SAPP) is a cooperation of the national electricity companies in Southern Africa under which members have created common power grid between their countries and a common market for electricity in their region (Winkler, 2009).

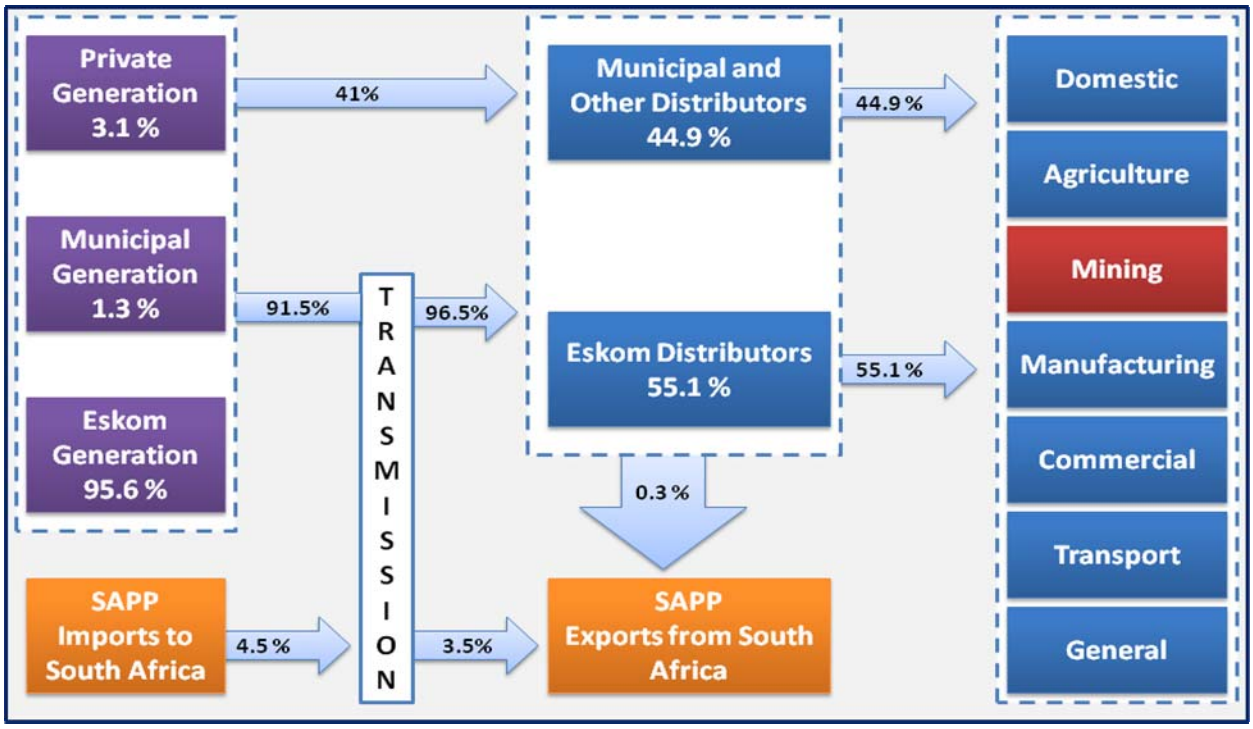


Figure 10: Energy flow through the electricity supply industry (Winkler, 2009).

2.3.4 Challenges Encountered by Eskom

The growth in electricity demand over the past several years has resulted in an increasing erosion of Eskom's generation reserve margin; as a result the existing power stations had to be operated at much higher load factors. The direct consequence of this has been a deficit in coal supplied from the tied collieries (since the mines were never designed to meet the present station burn levels) and a need for new coal supplies to meet the requirements of the return to service (RTS) and newly built power stations. Importantly, the bulk of this coal has to be transported from more distant mines, requiring road transportation in the short and medium term, and investment in a longer-term logistics infrastructure (Eskom, 2010).

Other challenges encountered by Eskom include the following:

- Increased level of particulate emissions;
- Number of trips at the power stations;
- Undersupply of coal by collieries and the poor quality of coal supplied to power stations; and
- Funding constraints (insufficient) for new projects (Eskom, 2010).

2.4 SECURITY OF COAL SUPPLY

This section provides a discussion on the economics of coal in relation to the energy landscape in South Africa by taking a look at coal resources, production and consumption; dependence on coal; and strategic analysis of the coal mining industry.

The economy of South Africa is heavily dependent on coal. According to the World Energy Council (WEC) coal resources in South Africa were estimated to be approximately 34 billion short tons at the end of 2007, accounting for roughly 95 percent of African coal reserves and 4 percent of world reserves (SA Energy Data, 2010). Coal is also used as a fuel by certain industries and indirectly as feedstock for petrochemical products. In addition, roughly a third of the nation's annual coal output is exported, generating an important source of foreign exchange earnings (Doug, 20008). Figure 11 illustrates South African coal production and consumption between the year 1998 and 2008.

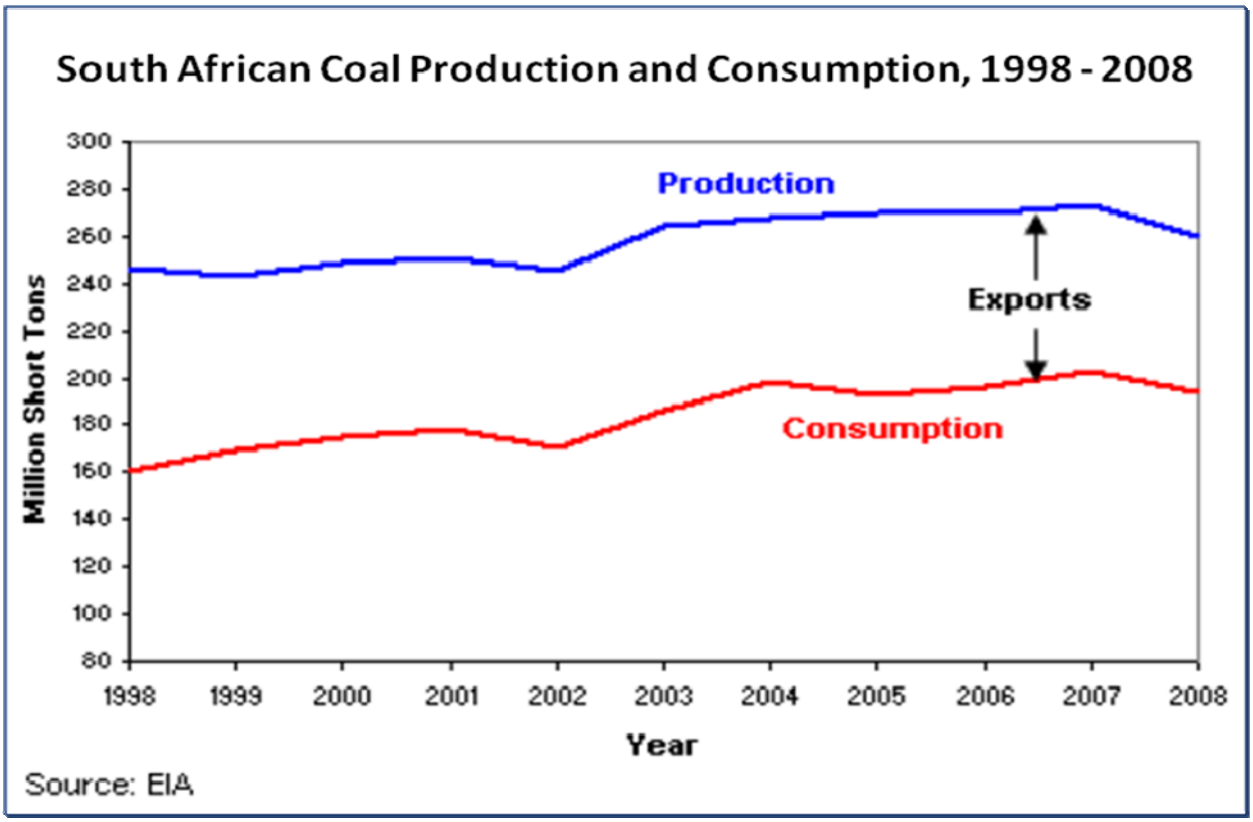


Figure 11: Coal production and consumption trends (SA Energy Data, 2010).

Production and consumption of coal has remained relatively stable over the past decade. In 2008, the country produced an estimated 260 million short-tons and consumed 194 short tons. The remaining 66 million were exported, mainly to East Asia and Europe. South African coal production and consumption have grown reasonably steadily over the past two and a half decades, at average annual rates of 2.9 percent and 2.5 percent respectively (Doug, 2008).

2.4.1 Coal Producers in South Africa

Figure 12 depicts largest coal producers in South Africa, namely: Anglo American, BHP Billiton, Sasol, Exxaro and Xstata. Coal produced by these companies accounts for more than 80 percent of coal produced in the country. While there have been some decreases in reserves, production, and consumption in recent years, environmental organisations continue to target the industry for land, air and water pollution through all of the industry's stages from extraction to end use (Doug, 2008 and Exxaro, 2008).

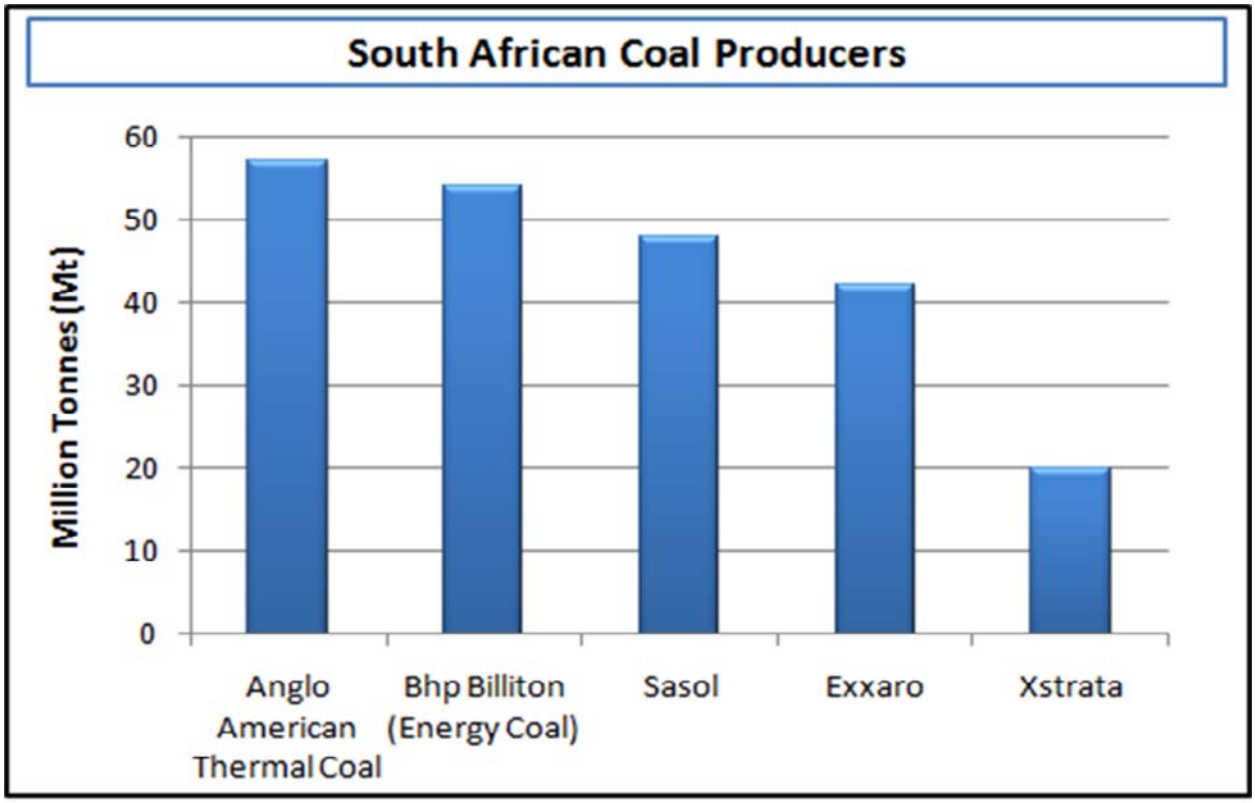


Figure 12: Largest coal producers in South Africa (Exxaro, 2008).

2.4.2 Dependence on Coal

The amount of coal burnt by Eskom for power generation accounts for 64 percent of coal produced in South Africa. Three main suppliers of coal to Eskom are Exxaro, BHP Billiton and Anglo American Thermal Coal. Each of the three companies supplies Eskom with more than 30 million tonnes of coal per annum (Exxaro, 2008). Figure 13 shows mining companies that supply comparatively large share of coal to Eskom. The growth of coal use is expected to continue or even accelerate over the next few years. This raises an important question: for how long will South Africa's coal reserves be able to sustain current and projected rates of consumption (Doug, 2008)?

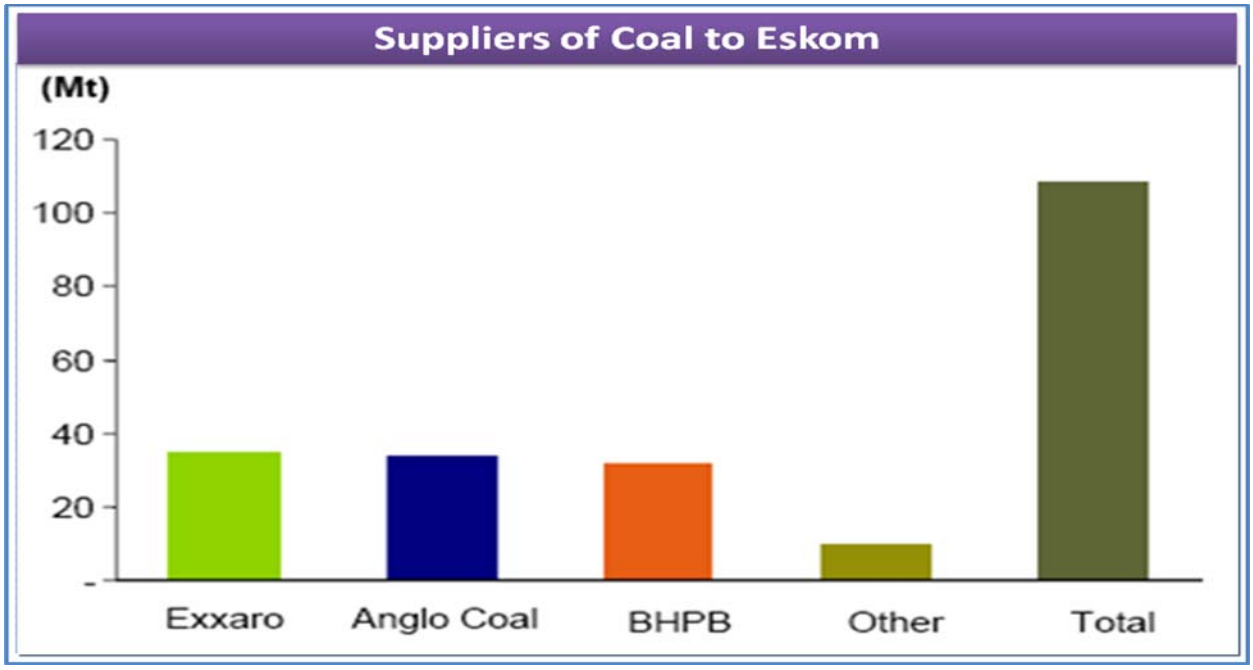


Figure 13: Mining companies supply coal to Eskom (Exxaro, 2008).

The future of coal in South Africa is not as certain as it was commonly believed. The risks of continuing heavy dependence on coal are finite nature of its supply, contribution to global warming and financial risks related to carbon pricing. From a long-term perspective it makes sense for the country to diversify its energy sources by investing in renewable energy technologies and industries as ultimately these will be needed (Doug, 2008).

The electricity crisis has already thrown a spotlight on the status of the South Africa's coal reserves. Eskom ascribed a part of its electricity supply problems at the start of the year 2008 to difficulties it experienced in sourcing sufficient quantities of suitable grade coal. According to international statistical energy reviews, South Africa's proved reserves of coal stood at 48.750 billion tonnes at the end of the year 2006, represents 5.4 percent of the world total. It was estimated that reserve to production (R/P) ratio (i.e. the number of years production could be sustained at current rates) of South Africa is approximately 190 years. However, the official government figure for reserves has been revised downward sharply to only 28.6 billion tonnes (South Africa Yearbook 2006/7), giving an R/P ratio of approximately 115 years (Doug, 2008).

2.4.3 Strategic Analysis of South Africa's Coal Mining Industry

The global consumption of coal is expected to increase by 4 percent per annum between the year 2010 and 2030 in line with the rising global energy demand. The South African coal mining industry needs to open up new mines in the Waterberg coal basin to replace the depleting mines in the Highveld, Ermello and Witbank coalfields in Mpumalanga in order to boost production. Coal mining industry in South Africa remains unbalanced with rising coal demand on one hand and constrained supply sources on the other. With the global demand for coal escalating by an annual average of 4 per cent, the country's available supply capacity may not be able to cope with the rush in demand. Despite the logistical and environmental constraints that the South African coal mining industry is facing, coal production is likely to be on the upward trend by 2012 when new mines are opened in the Waterberg coalfield (Businesswire, 2009).

The coal demand/supply imbalance has been accompanied by several other critical adverse dynamics in the South African coal industry:

- Ongoing deregulation of the coal mining industry, with a corresponding shift in the power balance to shareholders of the mining companies, away from the national interest. This has directly impacted the quality, cost and quantity of coal supplied to Eskom;
- Exports of lower quality coal to India, has created direct competition for new coal sources that were previously only suitable for domestic use, and a marked deterioration in the coal offered to Eskom from existing collieries;
- Extensions of Eskom's coal-fired stations' lives of operation from 40 to 60 years, beyond the contracted duration of the tied collieries, which were originally set up to supply only for 40 years. These contracts commence to expire as early as 2013, and in many cases coal reserves have not yet been dedicated to meet the full life extensions;
- Depletion of the higher grade coal reserves in Mpumalanga, resulting in increased level of competition for the remaining reserves suitable for supplying Eskom's older power stations; and
- Dramatic escalation in costs, partly driven by various factors resource depletion, commodities boom, more stringent environmental, safety standards and also by a diversion of scarce resources (management focus, capital and skills) away from the Eskom mines to the higher margin export businesses (Eskom, 2010).

2.5 ENVIRONMENTAL ECONOMICS

2.5.1 Introduction

This section provides a discussion on the environmental economics in relation to the energy landscape in South Africa by focusing on the following: energy used and environmental effects; how energy generation causes environmental change; and climate change strategy.

Electricity is the most widely utilised and rapidly growing form of secondary energy supply, globally. The most critical fuel for generating electricity is coal, which provides approximately 39 percent of all electricity generated. Coal-fired power stations worldwide consume more than 3200 million tonnes of coal each year to produce electrical energy. There are environmental concerns associated with the use of any fuel. As with other fuels, combustion of coal produces carbon dioxide which contributes to global climate change. Emissions of carbon dioxide from burning fossil fuels are over 25 billion tonnes a year worldwide, of which around 38 percent comes from coal, 41 percent from oil and 21 percent from gas. In addition to carbon dioxide, coal-fired power stations produce sulphur dioxide, ash and other waste products that affect the environment badly (Winkler, 2009 and Wits, 2009).

2.5.2 How Energy Generation Causes Environmental Change in SA

South Africa is a comparatively energy and carbon intensive country with respect to other African countries and many developed nations. In terms of total amount of energy consumption South Africa is ranked 16^{th} in the world. The coal reserves are mainly bituminous with a relatively low sulphur content (about 1 percent) and high ash content (about 45 percent) (SA Gov, 2000). Figure 14 depicts levels of particulate emissions produced during electricity generation process at Eskom, between the year 2007 and the 2010. It can be seen from the diagram that the level of emission has been increasing over the years.

The poor particulate emissions performance from the coal-fired power stations in the year 2009/10 is the result of:

- Deterioration of coal quality at some power stations;
- Continued reduced opportunity for maintenance due to lower reserve margin;
- Power stations running continuously at higher load factors; and
- Refurbishment work on pollution abatement equipment (sulphur trioxide injection plants) at certain power stations cross the country (Eskom, 2010).

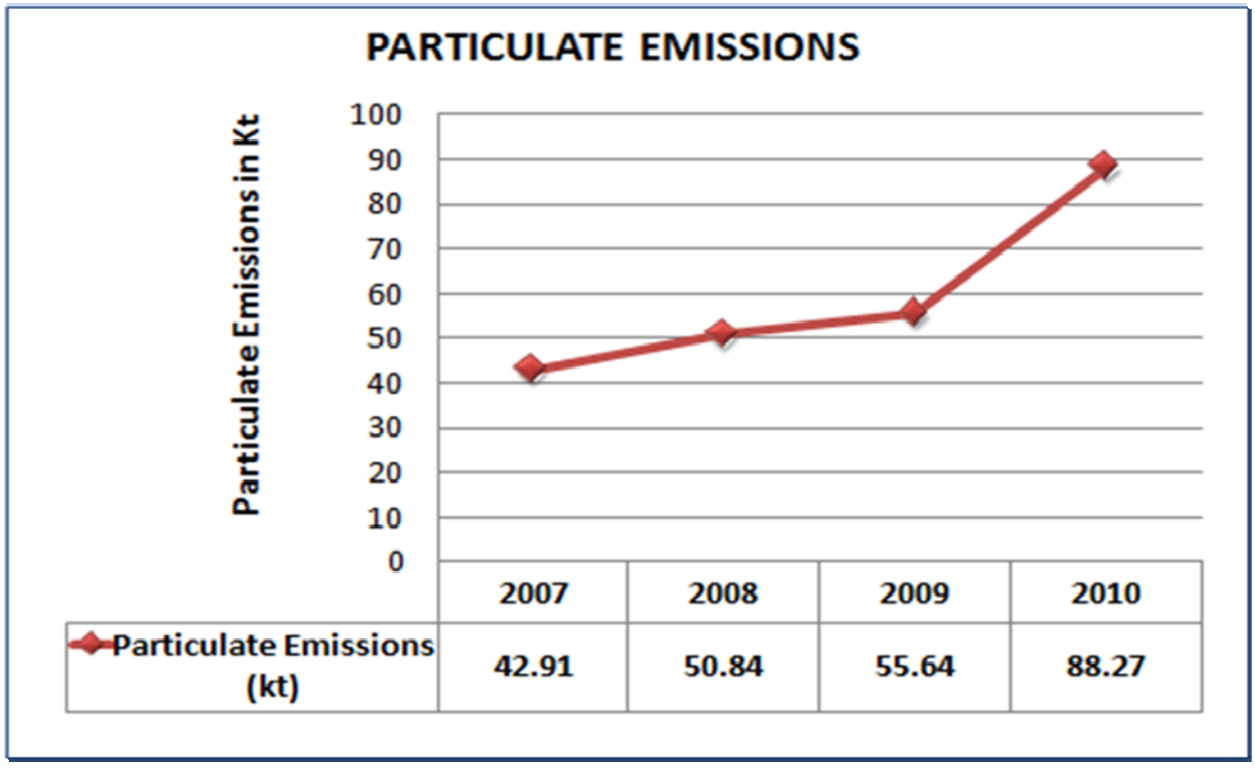


Figure 14: Particulate emissions due to power generation at Eskom (Eskom, 2010).

Table 3 shows the energy sector carbon dioxide emissions, various measures and timeframes of South Africa in relation to Africa and, World and other nations. South Africa's per capita emissions are higher than those of many Organizations for Economic Cooperation and Development (OECD) and more than three-and-half times the average for developing countries (Winkler, 2009).

Table 3: Energy sector carbon dioxide (CO2) emissions, various measures and time frames (Winkler, 2009)

	CO2/Capita	CO2/GDP	Cumulative energy CO2 emissions from the year 1950 to 2000	
	tons/capita	*kg/1995 US$*	*Mt CO2*	*% of World Total*
South Africa	6.65	1.65	10165	1.29
Africa	0.89	1.16	13867	1.75
Non-OECD	1.65	1.33	318117	40.23
OECD	10.96	0.44	472635	59.77
World	3.89	0.68	790753	100
Note: Percentages in the last column do not add up to 100 as rows are not mutually exclusive				

2.5.3 Climate Change Strategy

South Africa is committed to reducing emissions to the extent that it is a signatory to both the Kyoto Protocol and the UNFCCC (United Nations Framework Convention on Climate Change) (Oliver, 2009). Eskom has proactively developed comprehensive range of voluntary climate change initiatives to minimise greenhouse gases emission. Its climate change strategy proposes immediate and longer term (post-2012) action to reduce these emissions and adapt to the negative impacts of climate change. The strategy is multifaceted and encompasses different ways to reduce emissions as well as adapt to the impacts of a changing climate, including:

- Short- to medium-term initiatives focused on promotion of energy efficiency;
- Adaptation measures including the consideration of dry cooling on new power stations; and
- Diversification of the energy mix (medium- to long-term initiative), which will result in significant cuts in emissions (Eskom, 2010).

2.6 ENERGY AND THE MINING INDUSTRY

2.6.1 Introduction

This section provides a discussion on the relationship between the mining industry and energy sector by focusing on: energy consumption in the mining sector and also mining industry as part of the energy crisis solution.

The key factor that influences the amount of energy consumption per unit of production for a particular commodity is the quantity of material that must be extracted, transported, processed, and disposed. Therefore, energy consumption in the mining sector is dictated by the quantity of material that must be handled for every tonne of saleable mineral product. The amount of energy used in the mining industry accounted for 7 percent of total sectoral energy consumed in South Africa in the year 2007. Major energy sources used in mining include electricity as well as fuel oil, natural gas and coal. The amount of electrical energy consumed by the mining industry accounts for 17.4 percent of the total electricity consumption in South Africa (Exxaro, 2008 and Tshisekedi, 2008). Figure 15 depicts the amount electricity consumption per sector.

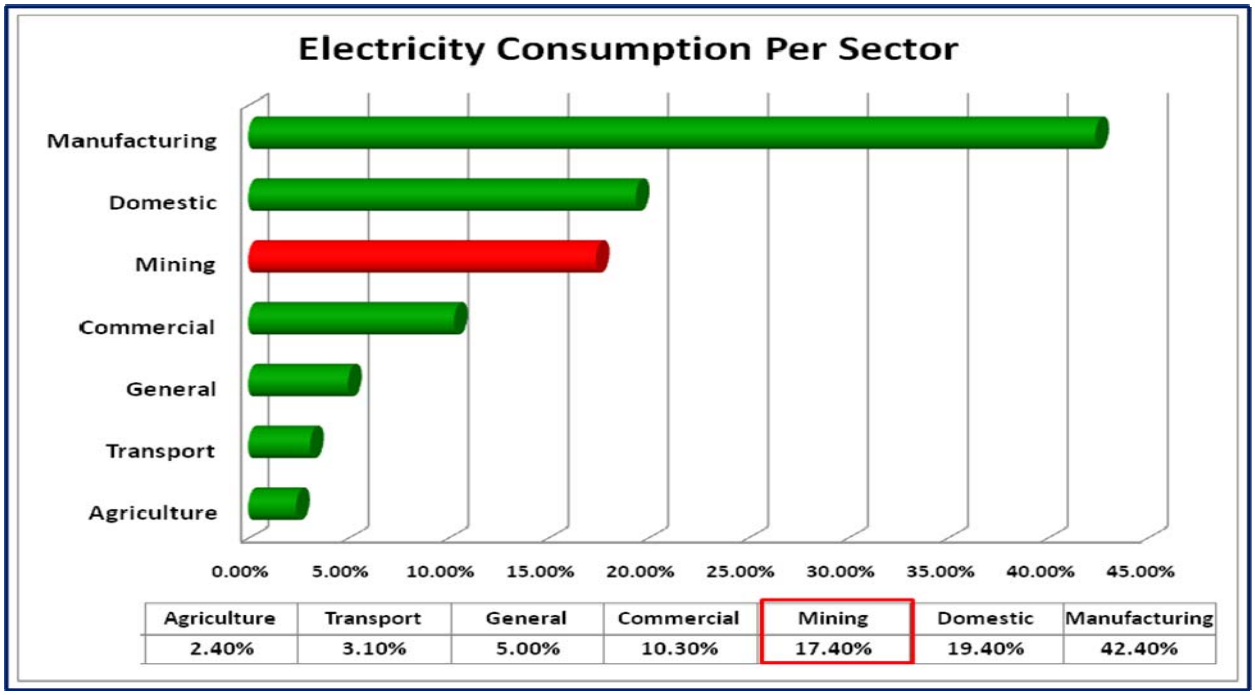


Figure 15: Electrical energy consumption per sector (Winkler, 2009).

Figure 16 shows electricity consumption in the mining industry per commodity. Gold, platinum and coal mining operations account for approximately 89 percent of electricity consumption in the mining sector. The amount of energy requirement varies considerably for each commodity and depends upon the type being mined, whether it is surface or underground, whether it must be beneficiated or processed, and the extent to which it must be beneficiated or processed. For example, energy requirement for underground coal mining is significantly lower on a per-ton basis compared to underground gold mining where the resource can be obtained in smaller quantities. Underground mining operations require greater amounts of energy than surface operations. While the majority of energy used in surface mining is diesel fuel for haulage, electricity is a major source of energy for underground mining where the ore must be hoisted to the surface and the mine ventilated (Tshisekedi, 2008).

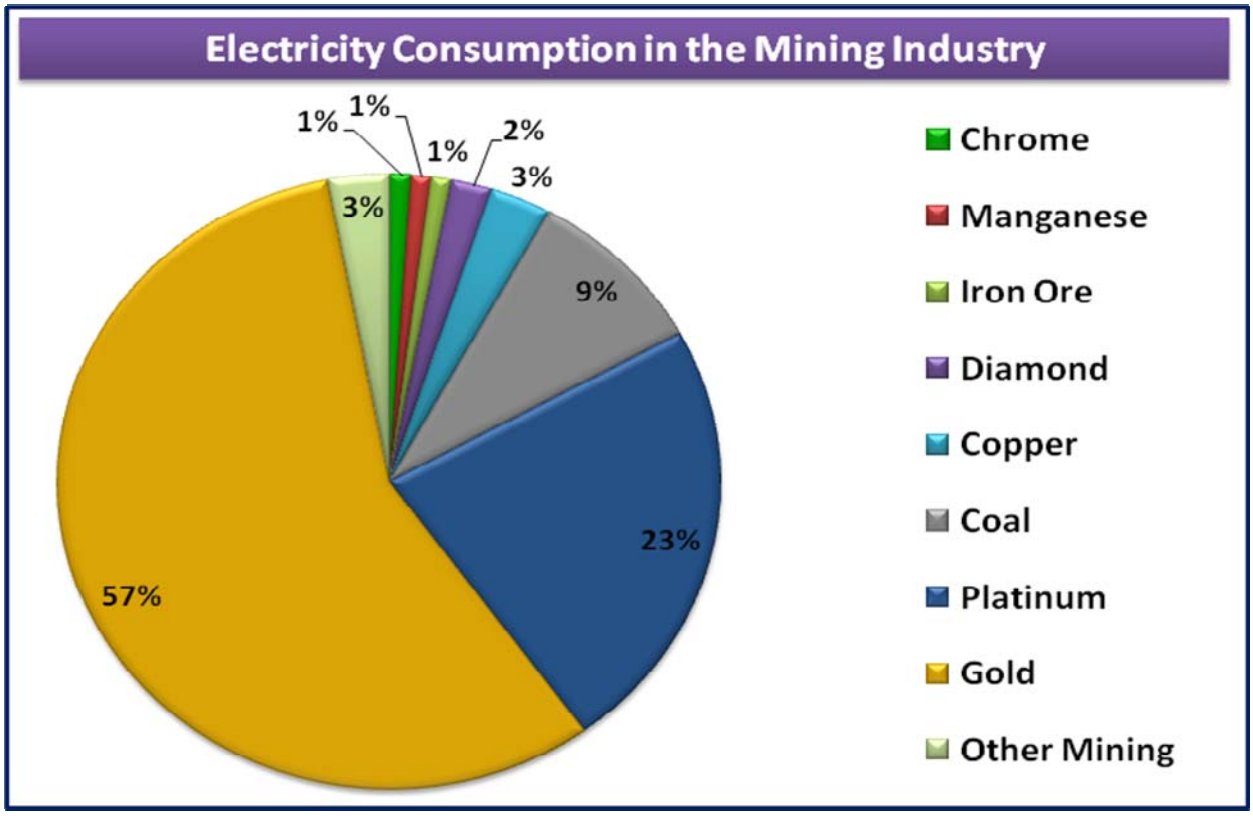


Figure 16: Electricity consumption in the South African mining industry for the year 2007 (Tshisekedi, 2008)

A review of global energy scenarios indicates that global supply is likely to become more volatile and fragile. The clear message is that as the mining companies expands, consumption will grow proportionately but the costs associated with energy will grow faster, resulting in a potentially negative impact on profit margins. Risks associated with reliability and securities of supply; as well as the emerging international and national environmental legislations, are also likely to increase (Anglo, 2011).

2.6.2 Mining Industry as part of the Energy Solution

The mining industry is one of the major consumers of electrical energy and it was severely affected by power cuts. The impact of electricity crisis reduced national production of commodities in South Africa by 10.7 percent. The industry can become part of the energy solution by becoming more energy efficient and thereby reducing the carbon footprint. Other options include utilizing and exploiting electricity co-generation possibilities to enhance energy efficiencies and reduce emissions. These entail the mining industry working together with Eskom on electricity generation capacity to secure long term supply and also ensuring a stable and reliable supply of coal to the power stations (Anglo, 2010 and Tshisekedi, 2008).

2.7 Summary

This section has provided an overview of literature focusing on the following: Energy overview; South African energy sector; Eskom; coal economics; environmental economics; and energy and the mining industry.

South Africa is a developing country hence the energy demand is expected to increase considerably in the coming years due to rapid industrialization, mass electrification programme and strong economic growth. Electricity demand continues to rise in South Africa and in recent years, it has outstripped the available supply infrastructure to the point where the country suffered rolling blackouts. It became clear from events towards the end of 2007 and into 2008 that there is an inadequate supply-demand balance in the country.

The major energy use sectors in the South African economy are: transport, agriculture, Industrial, commerce, residential and mining. The mining sector consumes about 17.4 per cent of the electricity produced in the national grid.

The energy crisis has provided Eskom, mining industry and DE opportunity to deal positively with energy efficiency in a decisive manner. It has allowed the country to take a closer look at how to use energy effectively and productively. The mining industry is one of the major consumers of energy and it was severely affected by power cuts. The mining industry can become part of the energy solution by becoming more energy efficient and thereby reducing the consumption energy. This entails the mining industry working together with Eskom on energy generation capacity to secure long term supply and also ensuring a stable and reliable supply of coal to the power stations.

The mining industry should find or have alternative ways to ensure a more reliable energy supply and less vulnerable disruption. It should look into short term initiatives or mechanisms to ensure that energy is used productively and efficiently. Based on the findings of the literature review, it becomes critical for studies to be conducted in mining operations to determine the amount of energy consumed, costs and management techniques in order to establish energy standards, identify improvement opportunities, set-up energy management systems, enhance operational efficiency and secure long-term energy supply.

The next chapters of the report will focus will provide a discussion and analysis of energy consumption, financial economics of energy and energy management techniques at New Denmark Colliery (area of study); from which recommendations will be drawn. The study provides a framework for understanding significant energy uses in a mining operation; electricity costs and some of the mechanisms, tools and initiatives that can be used to manage energy effectively.

CHAPTER 3: AREA OF STUDY

The main objective of this chapter is to provide a discussion on the area of study area, which is New Denmark Colliery (NDC), an Anglo American Thermal Coal (AATC) operation. This chapter outlines the following aspects of AATC: general company background, energy consumption and strategy. The second part of the chapter takes a look at the mining operation which is the area of study, NDC. It defines the mine background and general information; structure of the mine; supply of the electricity to the mine; shafts, mining methods and equipment; relationship between the mine and power station; type of electricity account used; supply, transmission and distribution of electricity; and electricity demand profile of the mine.

3.1 ANGLO AMERICAN THERMAL COAL

Anglo American Thermal Coal is a division of Anglo American that owns and operates nine collieries and a washing plant. Five of the mines together supply 22 Mtpa of thermal coal to both export and local markets. The company has domestic operations (New Denmark, New Vaal, and Kriel collieries) which supply 32 million tonnes of thermal coal to Eskom per annum. The strategy of the company is focused on serving the power generation and industrial sectors from large, low cost coal basins. The business unit has a diverse, high quality asset portfolio in South Africa and South America; and it aims to be a long term reliable supplier of coal. It also strives to be an industry leader in the pursuit of cleaner coal solutions to the world's energy needs (Anglo, 2010). Figure 17 illustrates the production profile of Anglo American Thermal Coal from the year 2007 to 2013 and beyond. The level of production is expected to ramp from the year 2013.

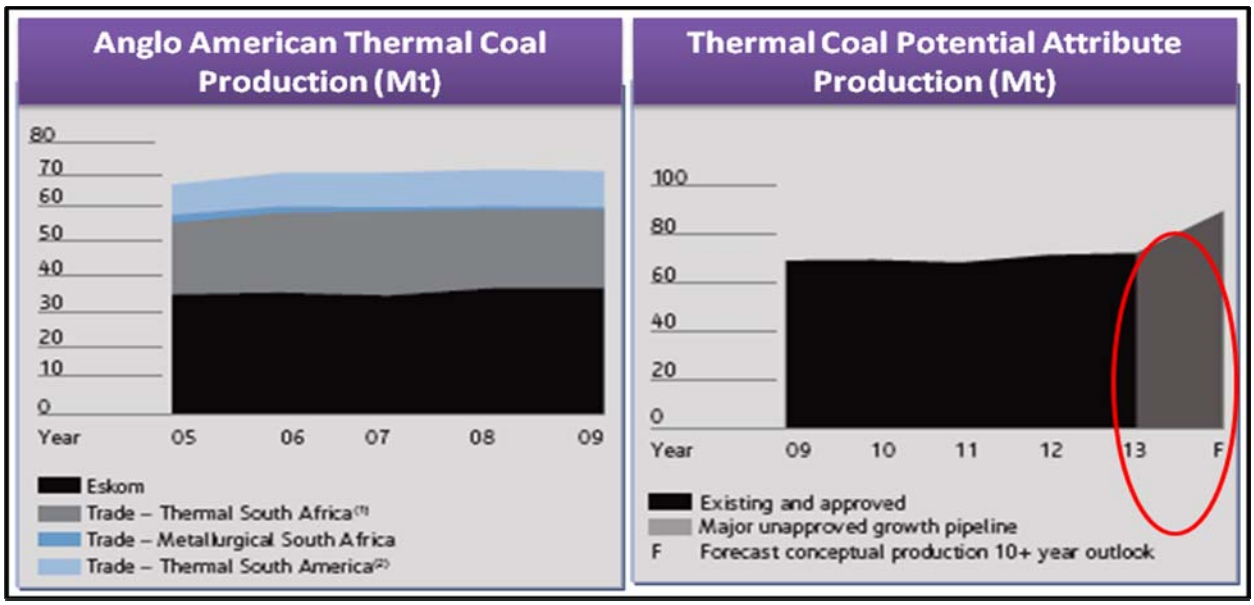


Figure 17: Production of Anglo American Thermal Coal (Anglo, 2010).

Coal produced by Anglo American Thermal Coal in South Africa has three market streams, namely: thermal sector, metallurgical industry and Eskom. Metallurgical and thermal coal produced by the company is consumed by both local and export market. The majority of the coal produced is consumed by the local market. Table 4 shows the amount of coal production data of Anglo American Thermal Coal.

Table 4: Coal production data of Anglo American Thermal Coal (Anglo, 2010).

Anglo American Thermal - Coal Production (t)						
	2005	**2006**	**2007**	**2008**	**2009**	**Average**
South Africa						
Eskom	**34327900**	**34821200**	**34064000**	**36158100**	**36225100**	**35119260**
Trade Thermal	20281100	22754000	23952400	22286800	22185900	22292040
Trade Metallurgical	2268800	1768200	1143700	971900	747100	1379940
South Africa Total	**56877800**	**59343400**	**59160100**	**59416800**	**59158100**	**58791240**
South America						
Thermal	8656300	9477200	9875400	10410300	10189600	9721760
Total Thermal Coal Segment	**65534100**	**68820600**	**69035500**	**69827100**	**69347700**	**68513000**

3.1.1 Energy Consumption of Anglo American Thermal Coal

Anglo American Thermal Coal operations in South Africa use energy in the form of electricity, liquid fuels and explosive in order to extract coal from underground and opencast cast operations. It is also used to beneficiate coal, load coal onto trucks, trains or overland conveyors in order to distribute it to local or export market. Energy is also used for daily activities, operations, surface facilities including mine villages. Contractors to Anglo American Thermal Coal also use energy in various forms to perform their tasks (Anglo, 2009). Figure 18 illustrates energy usage by type of Anglo American Thermal Coal for the year 2010.

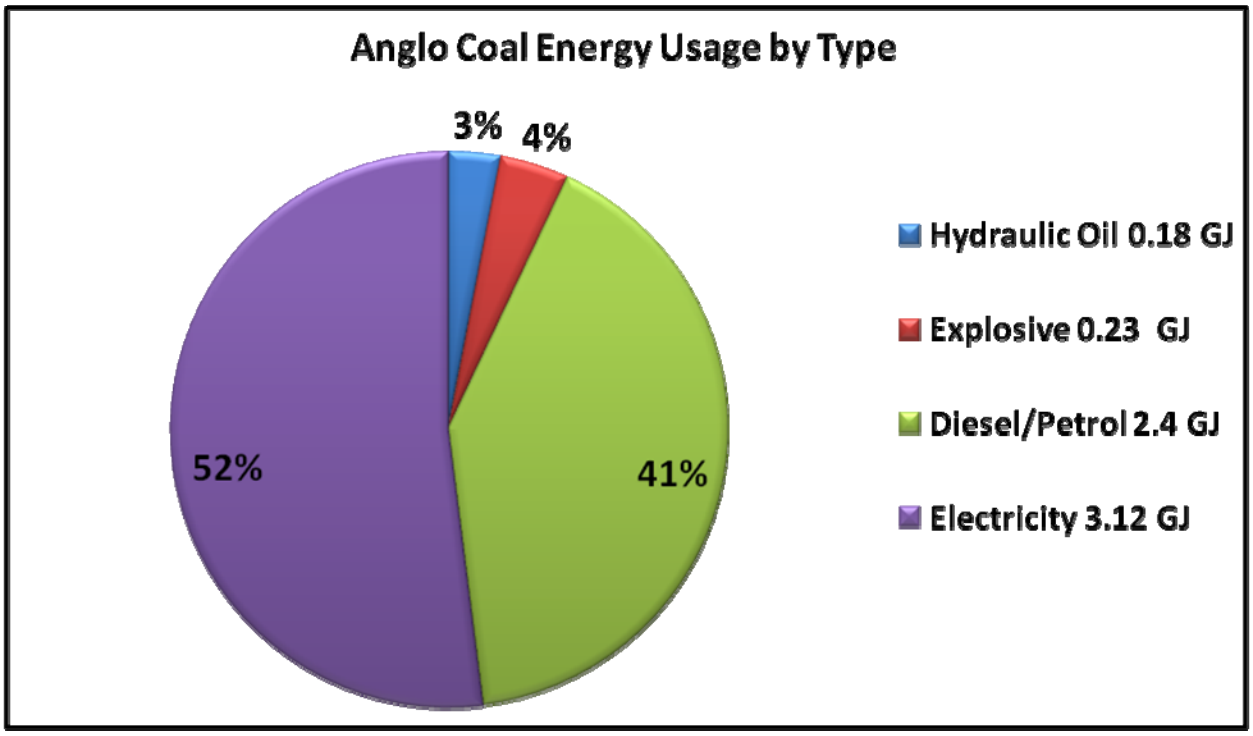


Figure 18: Energy usage by type at Anglo American Thermal Coal (Anglo, 2010).

The energy intensities and usage of individual collieries vary significantly and are largely dependent on the level of difficulty involved in the particular coal extraction process. Some mines remove vast quantities of overburden and then still process the coal, whereas other mines remove the coal and sell it directly to the power stations, with a net reduction in energy intensity as the coal is not processed for export (Anglo, 2010 and Hunter, 2011).

Differences could also be indicative of wastage in certain operations and activities. The primary elements of the collieries' value chain are considered to be mining, transport, processing and stockyards/load outs. Inadequate metering however prevents accurate recording of energy consumption into these value chain elements (Anglo, 2010). Figure 19 shows energy consumption of Anglo American Thermal Coal from the year 2002 to 2006. The level of energy consumption has been escalating over the years at a rate of approximately 194457 gigajoules per annum.

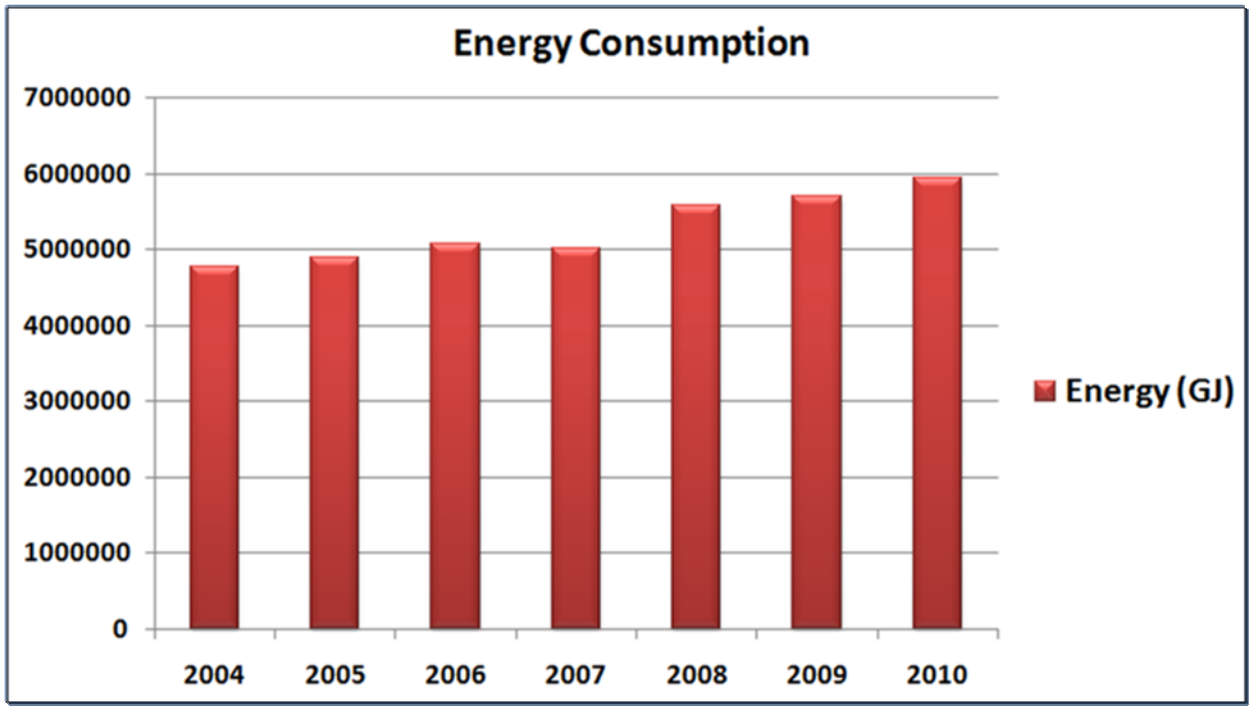


Figure 19: Annual energy consumption of Anglo American Thermal Coal (Anglo, 2010).

Figure 20 depicts average energy consumption at an AATC colliery. Major energy consuming activities are mining, ventilation, coal transportation and processing.

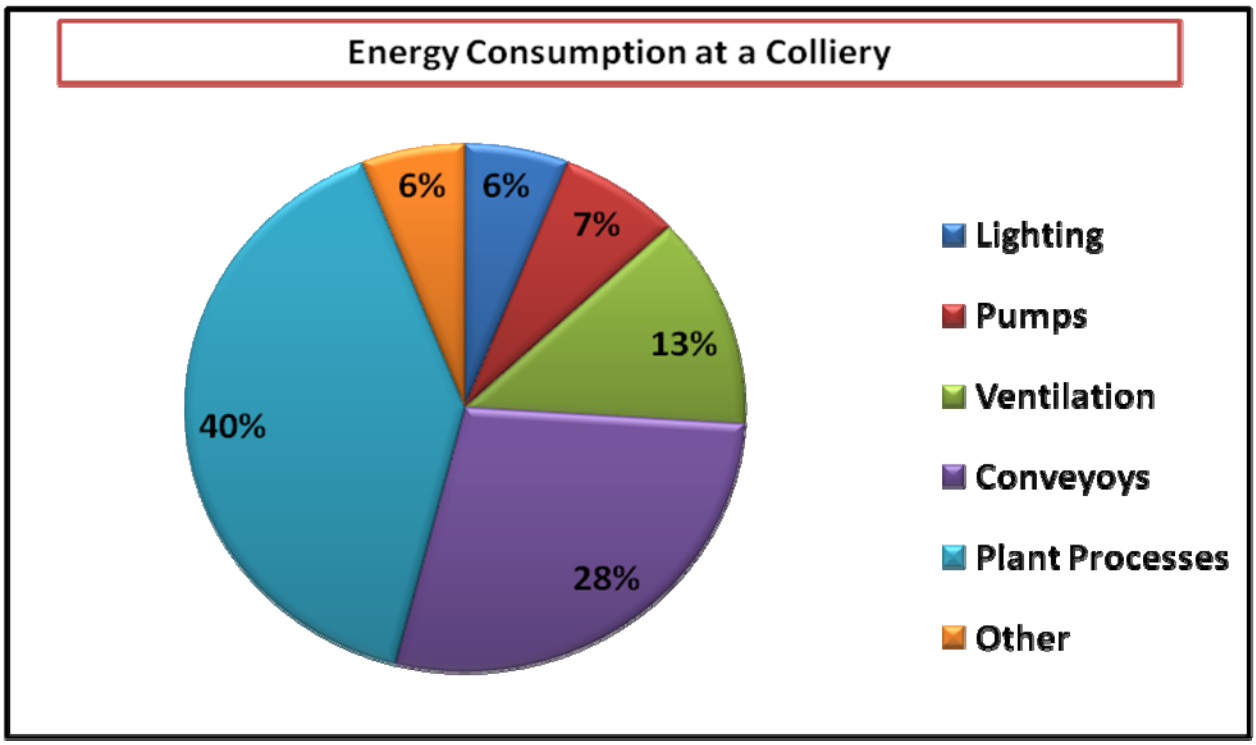


Figure 20: Average energy consumption at Anglo American Themal Coal (Anglo, 2009).

3.1.2 Anglo American Thermal Coal Energy Strategy

Anglo American Thermal Coal was affected by power cuts negatively even though some of the operations were exempted from power cuts (and encouraged to save electrical power). The power crisis had impacted not only on production but also on profitability, safety standards and international competitiveness of the company. The company is currently modeling strategies to enhance energy security in the future. It is looking into short term initiatives or mechanisms to ensure that energy is used productively and efficiently at mining operations. Long term strategic plans of the company entail reformulation of the current energy policies in order to cope with future power demand (Anglo, 2009).

The energy vision of the company entails the following: reducing the amount of energy used during production; saving on the total energy bill; causing less damage to the health and environment; and ensuring that there are sustainable resources for future generation (Anglo, 2010).

The company is presently working with the South African government, Eskom, the Chamber of Mines of South Africa, and National Union of Mineworkers to urgently identify and implement solutions for the short and long term to guarantee the integrity of electricity supply. Anglo American and the mining industry have already made proposals to reduce electricity usage in the short term and it will be of critical importance for all major industries to act in the country's best interests and play their part in resolving this national emergency. Anglo American has formed an energy task team to address the vital issues and meetings with the ministerial committee charged with resolving the power emergency have taken place (Anglo, 2010).

There are good financial and strategic reasons why Anglo American Thermal Coal and its mining operations need to address the energy issue. Many opportunities exist to improve energy efficiency and mitigate supply-side risk through management interventions. The key learning which flowed from this exercise is that future energy markets will be less stable and environmental pressure will be enormous, exposing the company to greater supply-side risk and greater regulatory and reputational pressure. Thus, energy management and supply-side risk management will become increasingly important, particularly in the face of upward pressure on energy costs. Figures 21 and 22 illustrate the energy cost (in R million) and average energy cost (in R/kWh) of Anglo American Thermal Coal from the year 2006 to 2011. It can be seen from both diagrams that electricity costs have been escalating over the years. It becomes necessary for the company to conduct studies in its mining operations in order to reduce energy consumption and costs (Anglo, 2011). The next sections of the report will focus on New Denmark Colliery, one of Anglo American Thermal Coal mining operations.

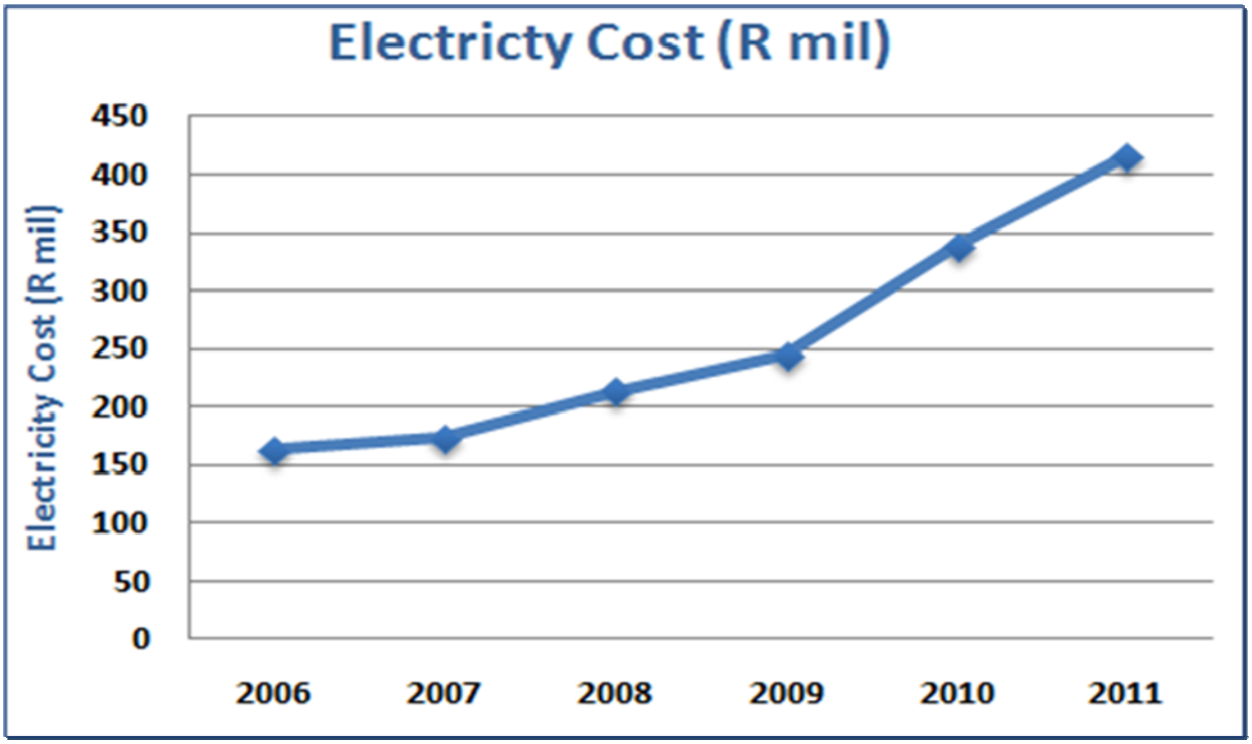


Figure 21: Electricity cost of Anglo American Thermal Coal (Anglo, 2011).

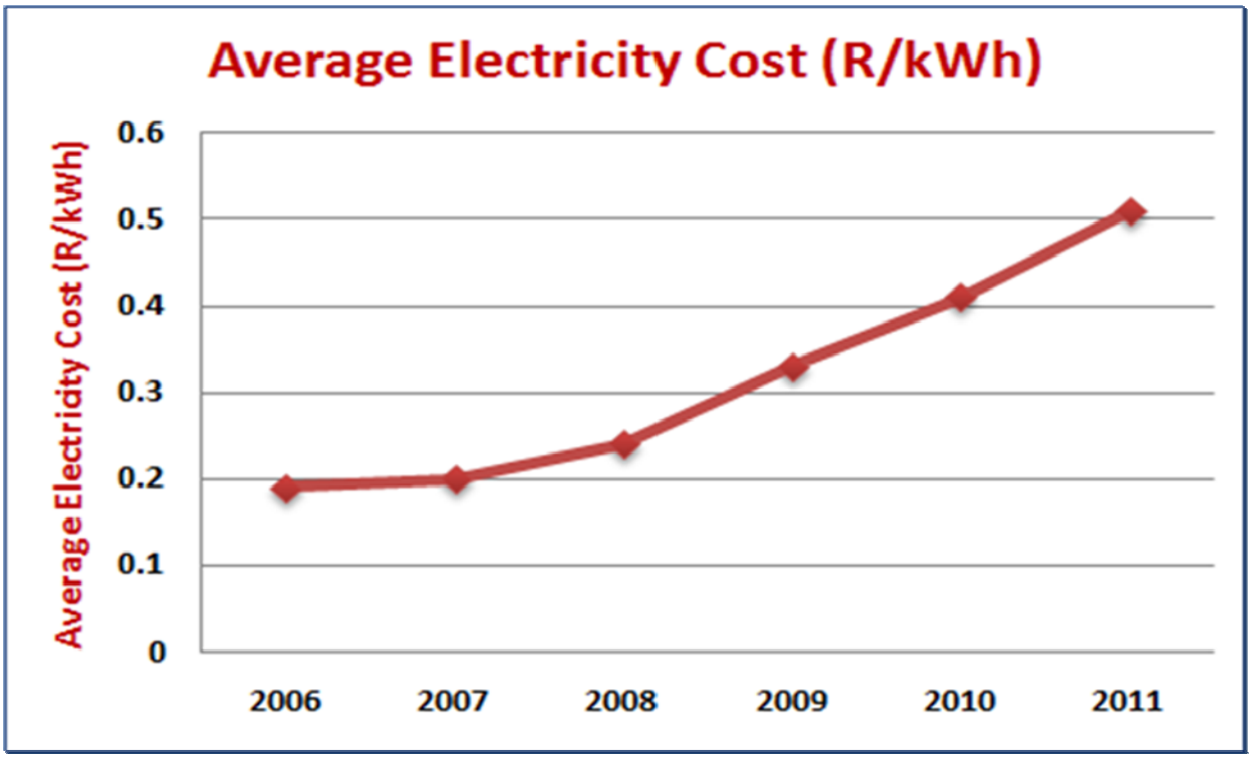


Figure 22: Average electricity cost of Anglo American Thermal Coal (Anglo, 2011).

3.2 New Denmark Colliery

This sub-section provides a discussion on the area of study, which is New Denmark Colliery. It defines the mine background and general information; structure of the mine; supply of the electricity to the mine; shaft, mining methods and equipment; relationship between the mine and power station; type of electricity account used; supply, transmission and distribution of electricity; electricity demand profile; and electricity management at the mine.

3.2.1 Mine Background and General Information

New Denmark Colliery (NDC) is an Anglo American Thermal Coal operation, which opened in 1982 and started production in 1984. The mine is located in the Mpumalanga Province about 30 kilometre (km) north of Standerton and 200 km from Pretoria on the Highveld Coalfield. Figure 23 illustrates the position of New Denmark Colliery in relation to the other Anglo American Thermal Coal operations and South African coalfields (NDC, 2009). NDC has a resource base of 147 million tonnes (Mt) with an estimated life of mine of 29 years. It has an annual production of 5.4 Mt. It is the deepest coal mining operation in South Africa at a depth of more than 200m. Number 4 seam (with a thickness of 1.92 m) is mined using two mining methods, namely; bord and pillar mining and longwall mining (NDC, 2010).

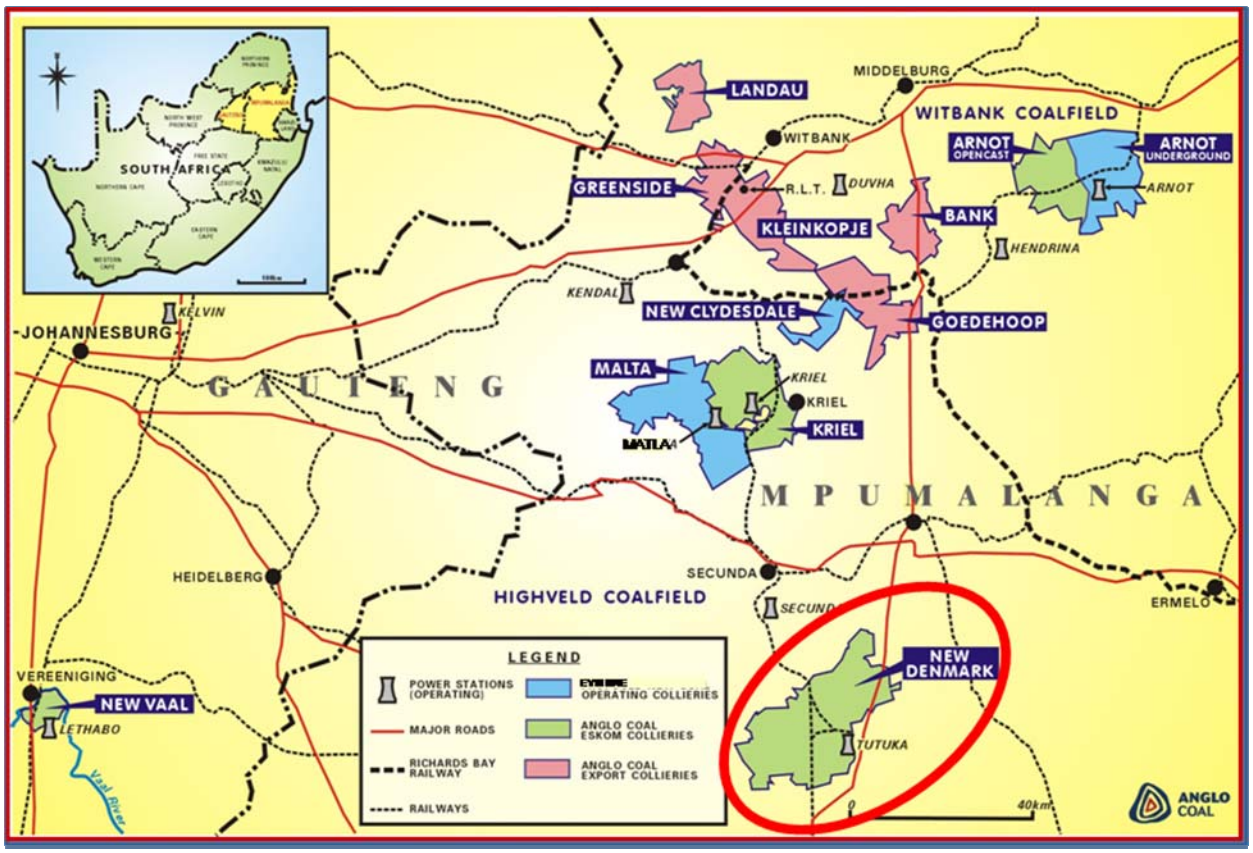


Figure 23: Location of New Denmark Colliery in relation to other Anglo American Thermal Coal Operations (NDC, 2008).

The operation has three shafts, namely: Central shaft, Okhozini shaft and North shaft. The North Shaft is mothballed; and Central and Okhozini Shaft are in operation and they have a total of 6 continuous miner sections and 1 long wall section between themselves. New Denmark Colliery's Central Shaft and the main offices are situated about 28 km north of Standerton, and Okhozini Shaft is another 10 km north (NDC, 2010).

3.2.2 Structure of the Mine

The underground coal seam is accessed by means of three shaft systems namely: Central Shaft, North Shaft and Okhozini Shaft. The Central Shaft complex consists of 2 vertical upcast shafts; 1 vertical downcast man and material shaft; and 1 inclined downcast shaft with twin conveyor belts to remove coal from the mine (NDC, 2009).

The Okhozini Shaft complex consists of 1 vertical upcast shaft and 1 vertical downcast man-conveying shaft. The North Shaft complex is currently mothballed and consists of 1 vertical upcast shaft; 1 vertical downcast man and material shaft; and 1 inclined downcast shaft with a conveyor belt to remove coal from the mine (NDC, 2009).

The Central Shaft has 3 sections which uses bord and pillar mining method. Machinery used include: continuous miner, shuttle cars, LHD and roof bolter. Okhozini shaft has four sections; three of them use bord and pillar mining method and the other one uses Longwall mining method. Hence the mine has 6 continuous miner sections and one Longwall section (NDC, 2009). Figure 24 illustrates the structure of New Denmark Colliery with individual shafts, sections and mining methods.

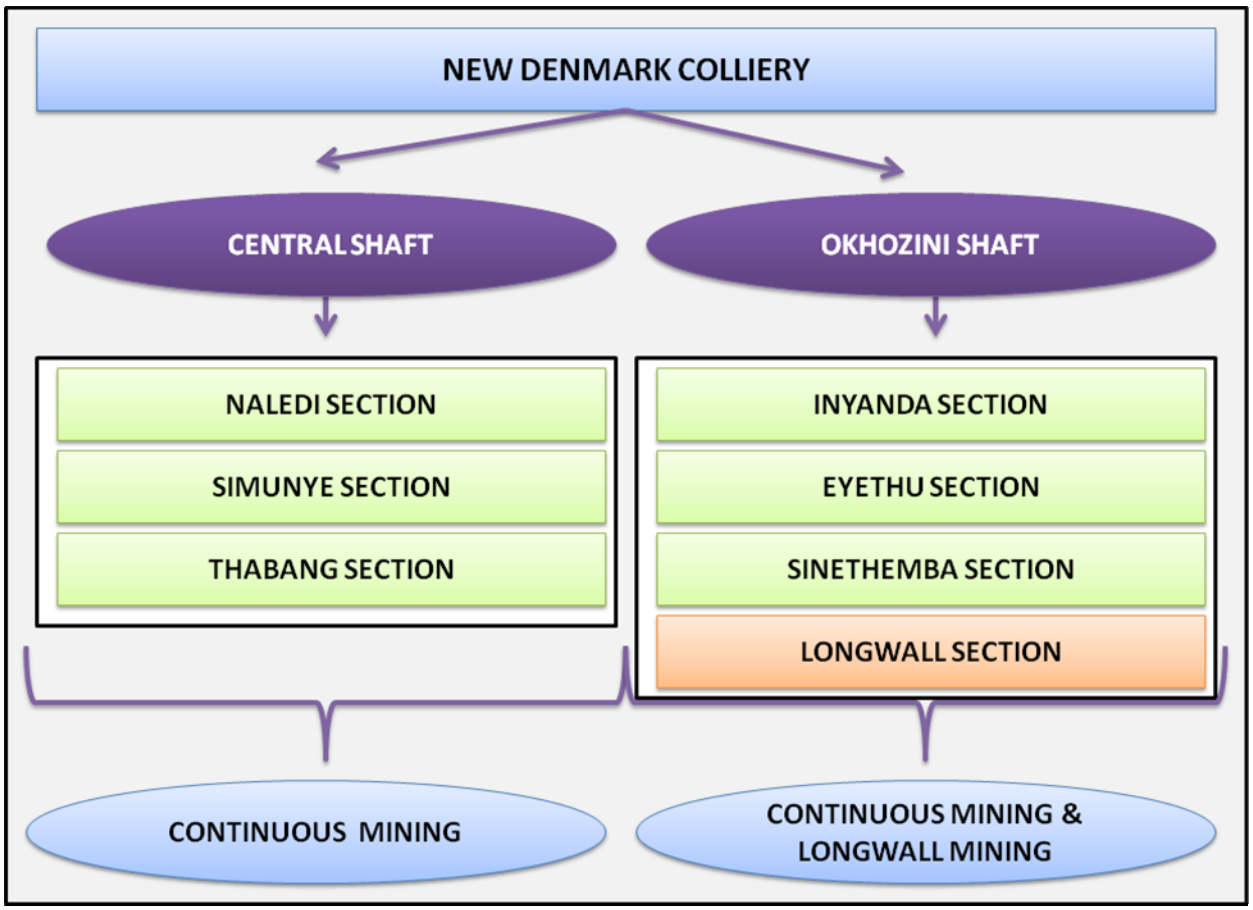


Figure 24: Shafts and sections of New Denmark Colliery.

3.2.3 New Denmark Colliery and Tutuka Power Station

New Denmark is Colliery is the main supplier of coal (approximately 70 percent) to Eskom's power station called Tutuka together with Kriel Colliery, another Anglo American Thermal Coal operation. NDC is linked with the Tutuka Power Station (which is located in close proximity to the mine) through various ways. Firstly, NDC is a feeder mine for Eskom's Tutuka power station. Secondly, due to the depth of the mine, the mine experiences problems of rising groundwater. This groundwater is currently being pumped to Tutuka where it is treated and used by the power station and the mine (NDC, 2010). Figure 25 shows the relative position of New Denmark Colliery (Central Shaft and main offices) and Tutuka Power Station. t



Figure 25: Relative position of Tutuka Power Station and New Denmark Colliery (NDC, 2009).

Table 5 illustrates technical details of Tutuka Power Station. The power station has four electricity generating units with a capacity of 609 MW and a total installed capacity of 2436 MW (Eskom, 2010).

Table 5: Technical details of Tutuka power station (Anglo, 2010).

Technical Details of Tutuka Power Stations	
Installed Capacity	2436 MW
Units	609 MW
Average Production (5 year period)	8962 GWh
Average Availability	93.41%
Design Efficiency at Rated Turbine (Output)	38%
Ramp Rate	33.33%

New Denmark is expected to abide by the contractual ranges of the following qualities of coal, namely: calorific value (CV), ash content, Al and moisture content (NDC,2009). Table 6 shows the contractual qualities of the coal from New Denmark colliery supplied to Tutuka power station.

Table 6: Eskom contractual range qualities (NDC, 2009).

QUALITY	CONTRACTUAL RANGE
CV (MJ/kg)	22.0 – 24.0
Ash (%)	17.6 – 30.0
AI (mg/Fe)	80 – 500
Total Moisture (%)	6.2 – 13.4

3.2.4 Supply, Transmission and Distribution of Electricity to the Mine

NDC is a captive mining operation; as a result all the coal produced by the mine is taken to the power station. Coal is transported through a conveyor belt to the power station which is located 17 km away from the central shaft and 27 km away from Okhozini shaft. Coal received by Tutuka power station is used to generate electricity which is then distributed to NDC, mine villages and Standerton (NDC, 2009). Figure 26 depicts the relationship between the NDC (Anglo American Thermal Coal) and Tutuka power station (Eskom).

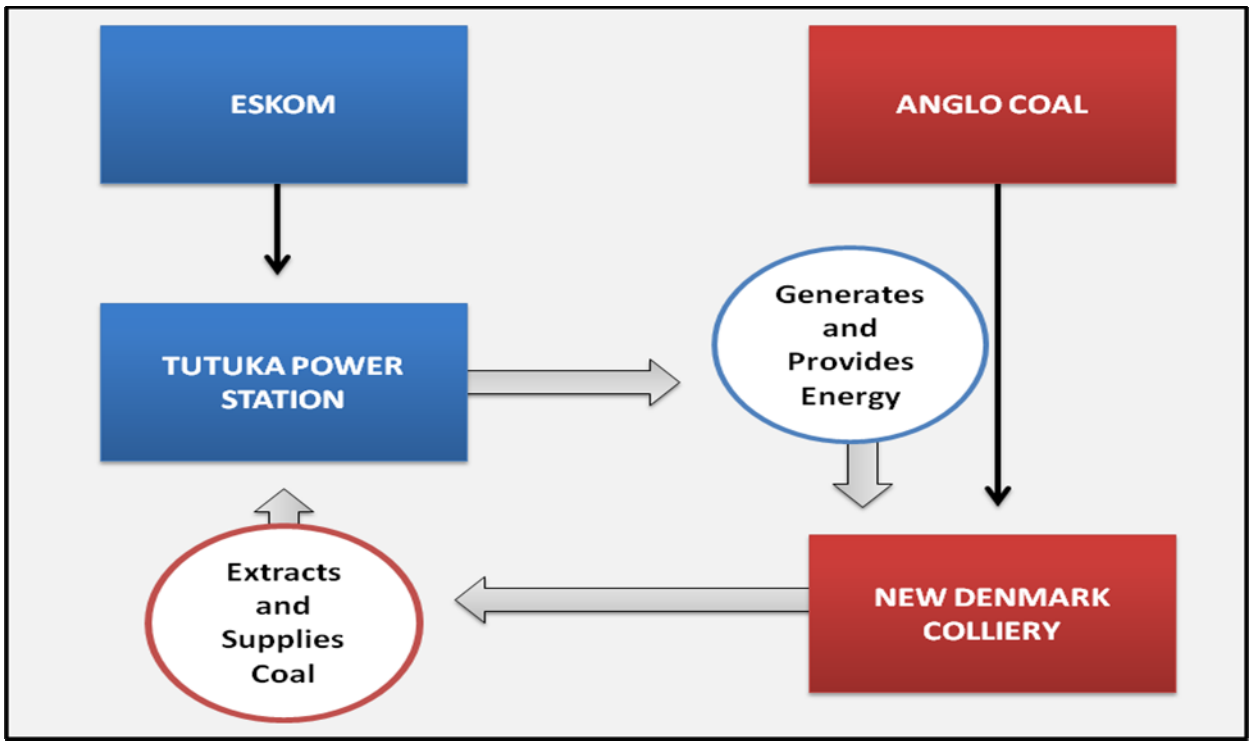


Figure 26: Relationship between New Denmark Colliery (Anglo American Thermal Coal) and Tutuka Power Station (Eskom).

Transmission can be defined as the bulk transfer of electrical power by high voltage links between main load centres. Distribution, on the other hand, is mainly concerned with the conveyance of this power to consumers by means of lower voltage networks (Itseezy, 2010). Electricity is supplied to the NDC sub-station from Eskom (Tutuka power station) sub-station. These sub-stations are used to lower the voltage to an amount that the mining operation can use. Electricity is then distributed to different surface infrastructure, facilities and shafts at the mine. Underground, electrical power is supplied to different sections, construction sites, facilities and working areas underground. From the sub-station, power is controlled by means of circuit breakers. Transformers are used to increase or decrease the voltage (NDC, 2010).

For efficiency and economical reasons overhead power cables are used to supply electricity from the power station to the consumer. Electric power gets sent down the mine by means of cables which are fixed to the hangingwall and sidewall (University of Pretoria, 2010).

These cables supply the underground mobile sub-stations with electricity (University of Pretoria, 2010). Figure 27 shows simplified reticulation (transmission and distribution) system at New Denmark Colliery.

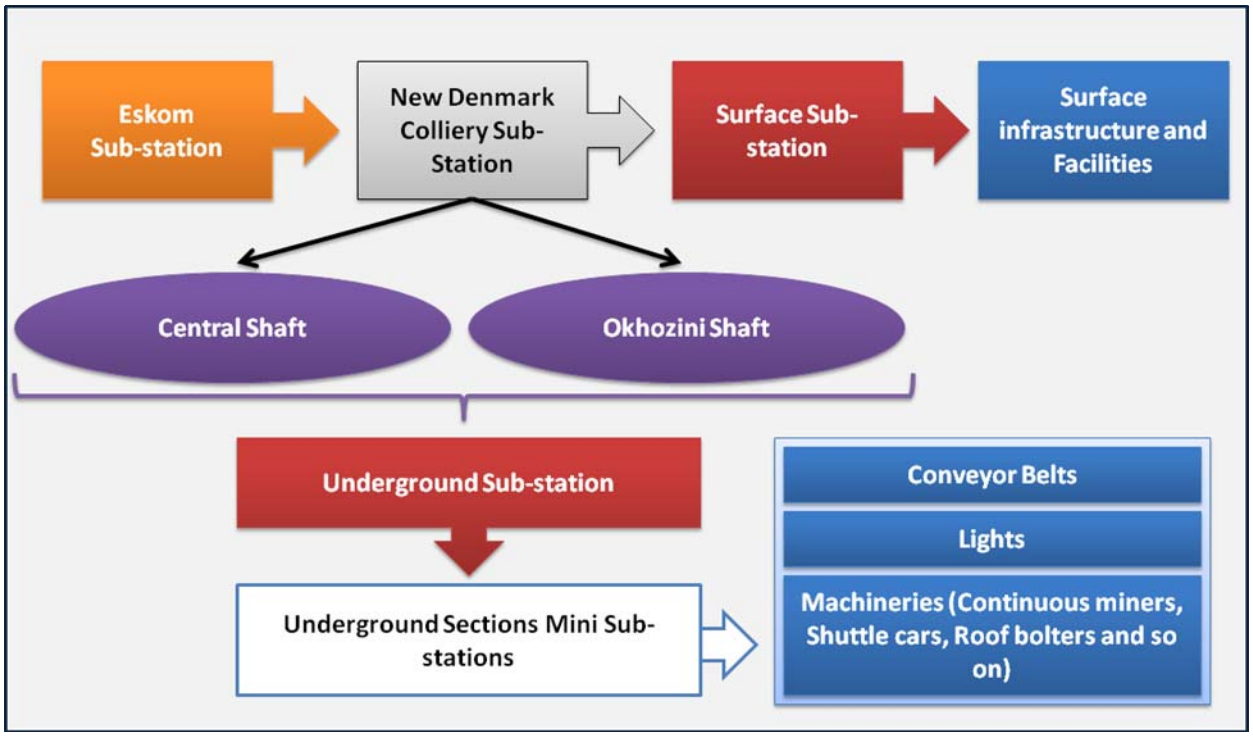


Figure 27: Transmission and distribution of energy at New Denmark Colliery.

3.2.5 Type of Electricity Account

Electricity account of New Denmark Colliery is a megaflex tariff. This type of account is for customers with supplies of 1 MVA and above, who can shift their load to defined time periods and who are not being fed off rural reticulation networks. The mine has the ability to shift load during the day when electricity is charged at a maximum or peak cost (University of Pretoria, 2010). The transmission zone of electricity supply from the power station to the two shafts is less than 300m. The quantity of voltage transmitted to the mine lies between 500 volts (V) and 66 kilovolts (KV) while the maximum demand of electrical power is 17500 KVA (Eskom, 2010). Table 7 shows the certain elements of NDC's electricity account.

Table 7: Electricity account of New Denmark Colliery (Eskom, 2010)

Electricity Account of New Denmark Colliery	
Electricity Supplier	Tutuka Power Station
Tariff	Megaflix
Transmission Zone	≤ 300 km
Voltage Zone	Zone 0
Voltage Level	≥ 500 V and < 66 kV
Notified Maximum Demand	17500 kVA

Figure 28 is a megaflex chart that indicates the number of hours and areas when the demand of electricity demand is at peak, standard or peak; it is used by Eskom to charge NDC. Sunday and Saturday do not have a peak region while weekdays have a total of 3 hours peak period. The cost of electricity during peak hours is very high and it is relatively low during standard and off-peak period. During normal operation of the mine, the load varies substantially from day to day and even hour to hour, depending on the time of the year (University of Pretoria, 2010 and NDC, 2010).

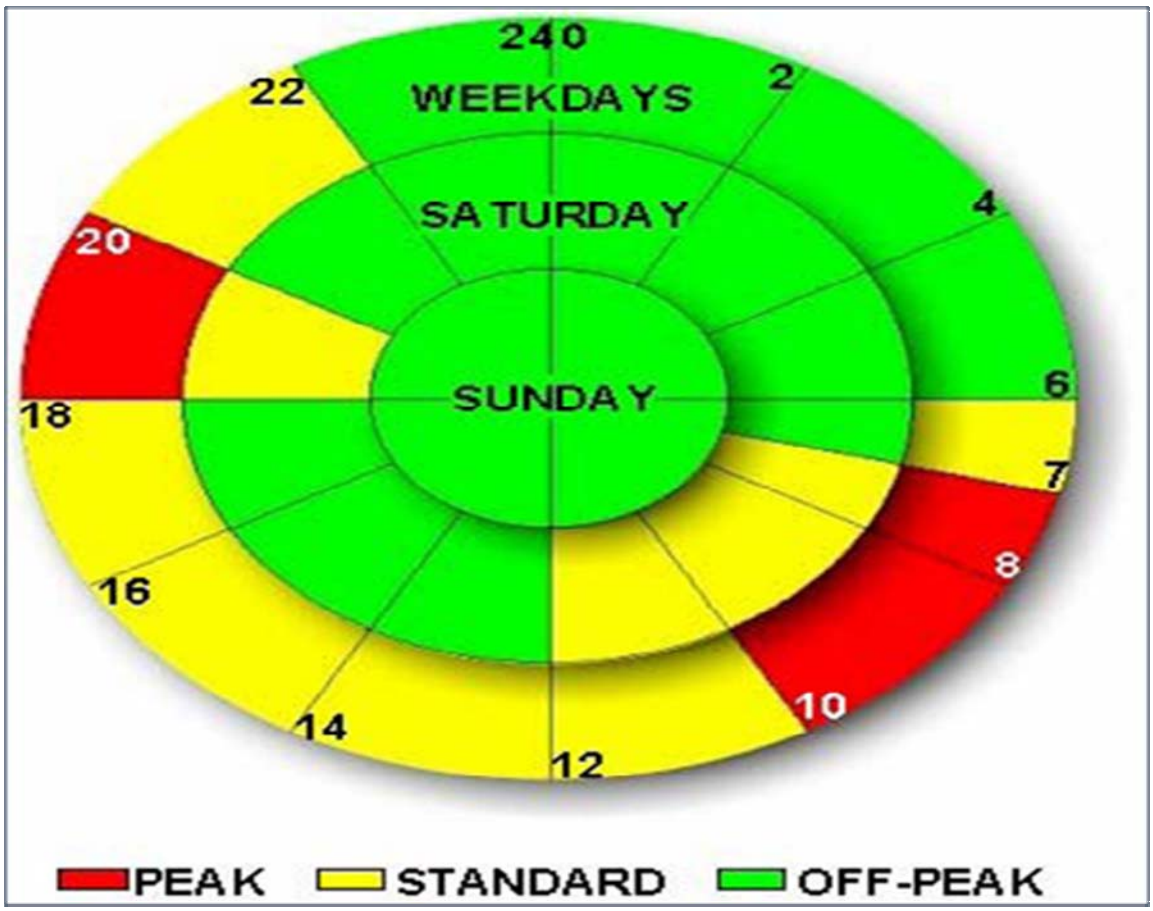


Figure 28: Time of use ratings for Megaflex (Tuks, 2010).

3.2.6 Electricity Demand Load Profile of New Denmark Colliery

A load profile is a graphical plot of the power demand for a specified time period (day, week, month or year). Industrial load profiles of mining operations vary according to the production schedules and amount of energy used. Two essential elements that can be obtained from a load profile are:

- The maximum amount of power consumed (maximum demand); where the point of greatest consumption for the period under consideration and the sum of the area under the profile is the amount of energy consumed during that period; and
- Load profiles also provide an indication of the times that specific loads are being used in order to identify peak demand areas and production hours (Itseezy, 2010).

Electricity demand is the amount of electrical energy required by the consumer (i.e. mining operation) for a certain period of time and it is measured in kilo-volts amps (KVA) (Itseezy, 2010). Figure 29 shows the monthly electricity demand profile of New Denmark colliery for the year 2009 and 2010. On average the amount of energy demanded lies between 15 kVA and 20 KVA. The total amount of energy demanded was approximately 216 000 KVA for 2010 while for the year 2009 it was about 190 000 kVA. NDC was required to cut down on production to save electricity during the year 2009; as a result the electricity demand was comparatively less than in the year 2010.

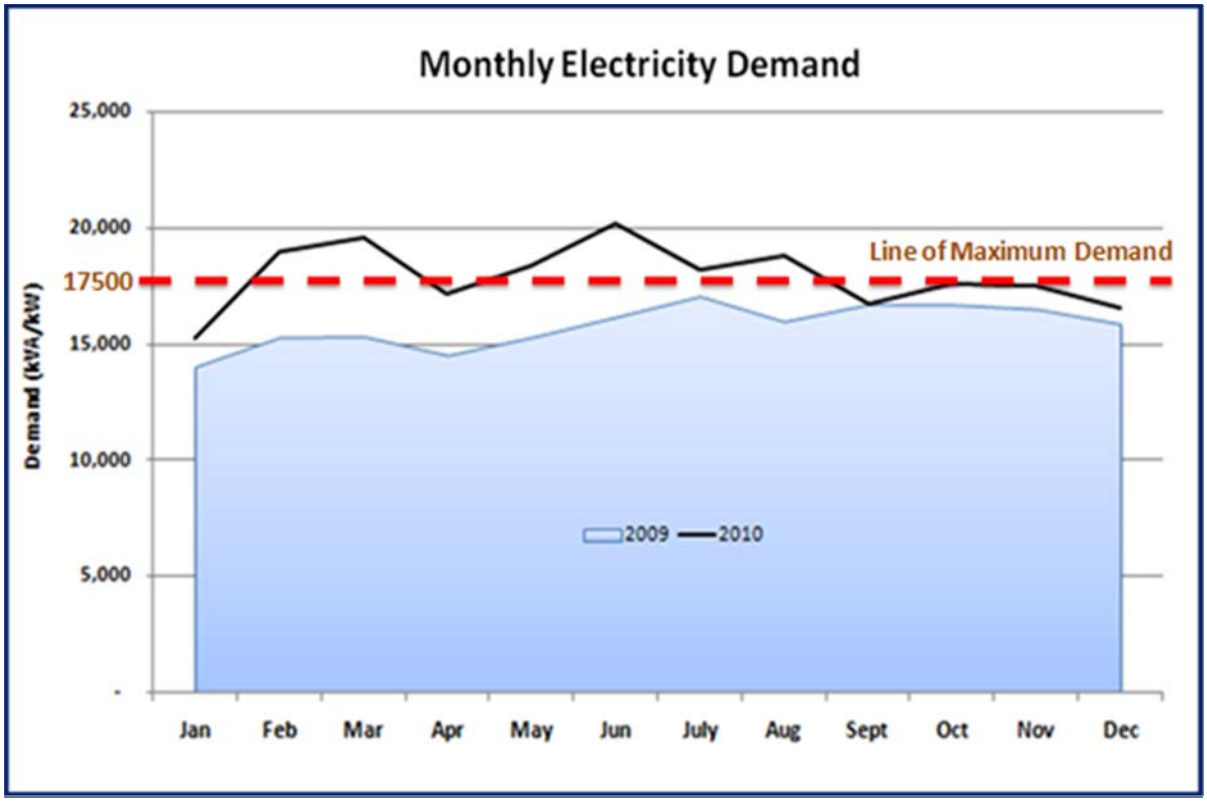


Figure 29: Monthly electricity demand profiles of NDC for the year 2009 and 2010 (NDC, 2011 and NDC, 2010).

Appendix B shows a table of NDC's electricity demand (in KVA), consumption (in KWh), maximum demand (in KVA) and the cost of electricity (in Rands) for the year 2009 and 2010.

The maximum demand (MD) is defined as the greatest of all demands which have occurred during a given period of a week, month or year (Itseezy, 2010). New Denmark Colliery has monthly maximum demand of 17500 KVA.

3.2.7 Electricity Management at New Denmark Colliery

Energy management is the process of monitoring, controlling, and conserving energy in a in an organisation or company. According to its principles, the main objective is to optimise the benefits derived from efficient energy including energy conservation through reduction of consumption (Energylens, 2011 and Tshisekedi, 2008). The concept of energy management is still in developmental stage at New Denmark and other Anglo American Thermal Coal mining operations. The mine has an energy policy (adapted from Anglo American Thermal Coal) however it does not have mechanisms, tools or systems in place to optimally manage energy. There is also inadequate organisation structure and culture to promote energy management initiatives at the mine. The following are not well defined or set at New Denmark Colliery:

- A framework for understanding significant energy uses in a mining operation;
- Targets for energy costs and consumption;
- Systems to measure and monitor performance;
- Action plans for improving energy performance;
- Improvement opportunities are not identified; and
- The reporting system for energy management (Anglo, 2010 and Lawrence, 2011).

Before any energy management mechanisms/initiatives can be introduced in a mine it is first necessary to conduct comprehensive study on historic and current state energy consumption, financials and standards that already in place. It is also necessary to analyse factors that affect and influence the above energy consumption and costs (Beggs, 2002). The next chapters of the study will focus on energy consumption, economics and management with reference to NDC.

3.3 Summary

This section provided a discussion on the area of study for the research project by focusing on the mining company and operation, Anglo American Thermal Coal and New Denmark Colliery respectively. Anglo American Thermal Coal is a division of Anglo American that owns and operates nine collieries and a washing plant. The strategy of the company is focused on serving the power generation and industrial sectors from large, low cost coal basins. The level of production of the company is expected to ramp from the year 2013, as a result the level of energy demand and consumption will also escalate.

The company was affected by power cuts negatively. The power crisis had impacted not only on production but also on profitability, safety standards and international competitiveness of the company. The company is currently modeling strategies to enhance energy security in the future. It is looking into short and long term initiatives or mechanisms to ensure that energy is used productively and efficiently in its mining operations.

There are good financial and strategic reasons why Anglo American Thermal Coal and its mining operations need to address the energy issue. The concept of energy management is still in developmental stage at New Denmark and other Anglo American Thermal Coal mining operations. Many opportunities exist to improve energy efficiency, lower capital cost, and mitigate supply-side risk through management interventions. It becomes necessary for Anglo American Thermal Coal to conduct studies in its mining operations in order to reduce energy consumption and costs. The next chapters of the paper will focus on electricity consumption, economics and management at NDC.

CHAPTER 4: ENERGY CONSUMPTION

4.1 Introduction

This chapter provides a discussion on energy consumption at New Denmark Colliery. It takes a look at the following subsections: use of energy; factors influencing and affecting electricity consumption; electricity consumption per geographical area; yearly and monthly electricity consumption; carbon dioxide per electricity consumed; and estimation of electricity consumption in the mere future (forecast).

4.2 Use of Energy

Energy Consumption can be defined as the total energy used to produce a particular product. Depending on the source, energy consumption is measured in various units such as: kilo Watt hours (kWh) for electricity; litres of diesel, petrol and oils (l); and kilograms of explosives. All these are converted into Joules (J) and added to give a total consumption. Different forms of energy sources are used in a mining operation for various segments of the value chain such as: coal extraction, transportation and ventilation. Energy is also used by surface facilities (mine offices, workshop, mine store, change houses and so on), mine village and underground facilities (lights, workshop, waiting areas, water pumps, belt conveyors, machinery and so on) (Anglo, 2010). Figure 30 illustrates different forms of energy used at NDC and areas where they are used.

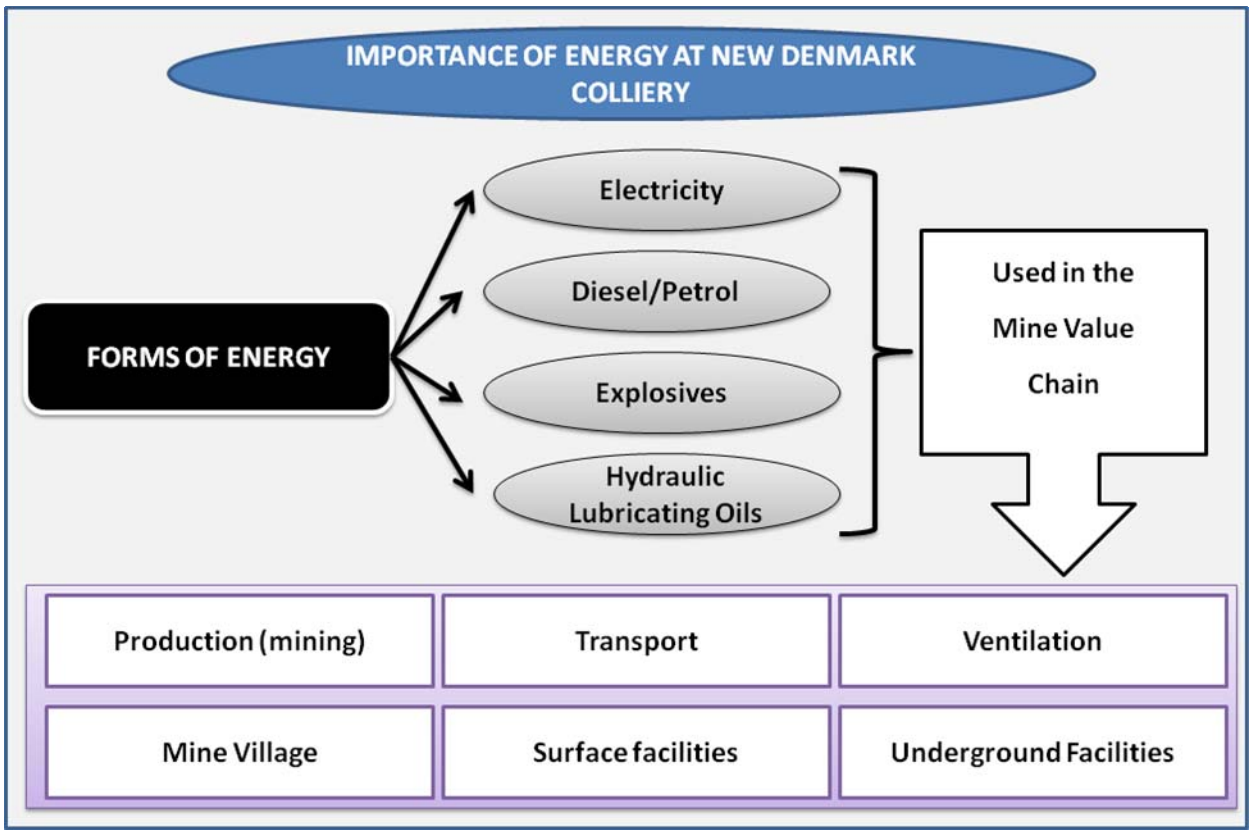


Figure 30: Different forms of energy and their application at New Denmark Colliery.

Electricity is a major source of energy in the mining industry and manufacturing sectors. In underground mining, electricity is used to operate the machines, lighting, ventilation, transport of people (cage), equipment, use of electric locomotives and so forth. In surface mining, electric power is used for drilling, loading shovels, trolley assist on the trucks and so on. It is also used for pumps, conveyor belts, crushers, mills, compressors, workshops, housing and offices (Tuks, 2010). Three main forms of energy used at NDC are: electricity, diesel and petrol. Table 8 illustrates the level of energy consumption at NDC for the year 2010. Electricity accounts for more than 90 percent of the energy type consumed, while diesel and petrol constitute for 8.87 percent and 0.81 percent respectively.

Table 8: Forms of energy and quantity used at New Denmark Colliery in the year 2010 (NDC, 2011).

	Absolute Consumption	Percentage of Energy Breakdown
Electricity (MWh)	88867	90.32%
Diesel (m^3)	820	8.87%
Petrol (m^3)	73	0.81%

4.3 Factors Influencing and Affecting Electricity Consumption

This section defines factors influencing and affecting the level of energy consumption in a mining operation. Consumption of energy in the mining industry is related to operational practices. The amount of electricity consumed is influenced by the following factors: size of operation; depth of operation; mining method; type of equipment used; actual production time; degree of mechanisation and automation; differences in mining and processing operations; layout of the mine; and production rate of the operation. Electricity consumption is measured in kilowatt-hour (kWh) units, which is the quantity of energy when 1 kW of energy is used for one hour (University of Pretoria, 2010).

Figure 31 shows energy consumption of different Anglo American Thermal Coal collieries for the year 2010. The total amount of electricity consumed by the company is 736538 MWh. New Denmark, Goedehoop, New Vaal and Kriel Colliery consumed approximately over 70 percent of the total electrical energy in the year 2010. NDC consumed 95750 MWh, which is about 13 percent of the total electricity consumption of Anglo American Thermal Coal.

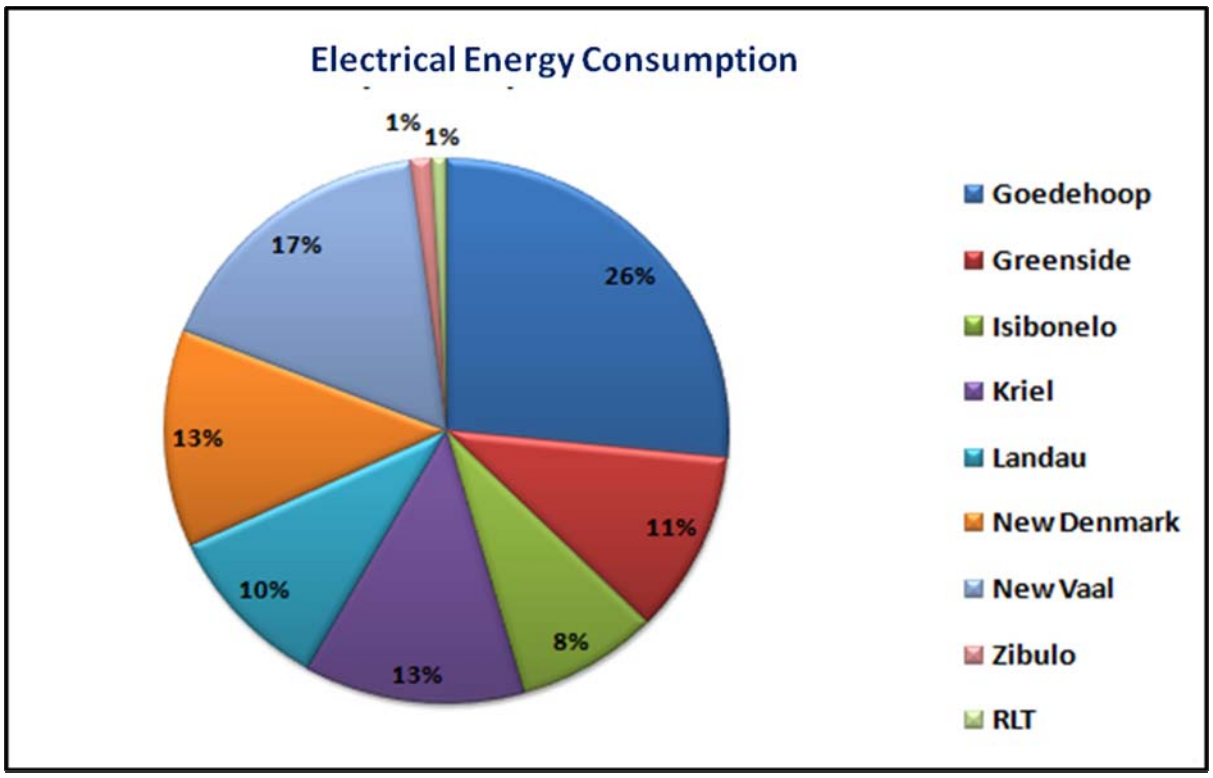


Figure 31: Electricity consumption of different Anglo American Thermal Coal collieries for the year 2010 (Anglo, 2010).

The amount of coal produced by an operation affects the level of energy consumption and demand. Table 9 illustrates the production data (in tonnes) and consumption rates of different Anglo American Thermal Coal operations. It can be deduced from table 9 and figure 31 that the higher the production profile of a mine the higher the quantity of electricity consumption. It can be seen from the figure 31 and table 9 that NDC is one of the major consumers of electricity at Anglo American Thermal Coal.

Table 9: Production and energy consumption rates of different Anglo American Thermal Coal operations (Anglo, 2010).

Collieries	Tonnes (t)	Total Energy Consumed (MJ)	Electricity Consumed (MWh)	Electricity per tonne (kWh/t)
Goedehoop	6905000	888840	201757	29.22
New Vaal	17553700	1110445	117680	6.70
Isibonelo	5061900	417330	59292	11.71
Greenside	3294600	337582	67389	20.45
Kriel	11161700	944351	87970	7.88
NDC	3342624	327340	80447	24.07
Mafube	2212800	676870	38530	17.41
Kleinkopjie	4414000	765438	125247	28.37
Landau	4231500	647613	73218	17.30

4.4 Electricity Consumption per Specific Area/Activity at NDC

The main objective of this sub-section was to determine the relative electricity consumption of different areas and activities at New Denmark Colliery. NDC has the following geographical areas: mine village, Okhozini shaft, Central shaft, surface facilities, ventilation fans, pumps and conveyor belts. Electricity provided by Eskom is transmitted to these areas where it is used for various functions. Figure 32 shows the estimated electrical energy consumption at NDC per specific area or activity for the year 2010. It can be seen from figure 32 that mining, ventilation and coal transportation consume relatively more electricity compared to other activities/areas at the mine. Okhozini shaft consumed approximately 33.4 percent of the total electricity because of different mining methods and machineries used at the shaft. It has one longwall section and 3 continuous miner sections. The mine uses multiple ventilation system which uses 9.7 percent of the total electricity. Central shaft has three continuous miner sections and it consumes 16.9 percent of electricity.

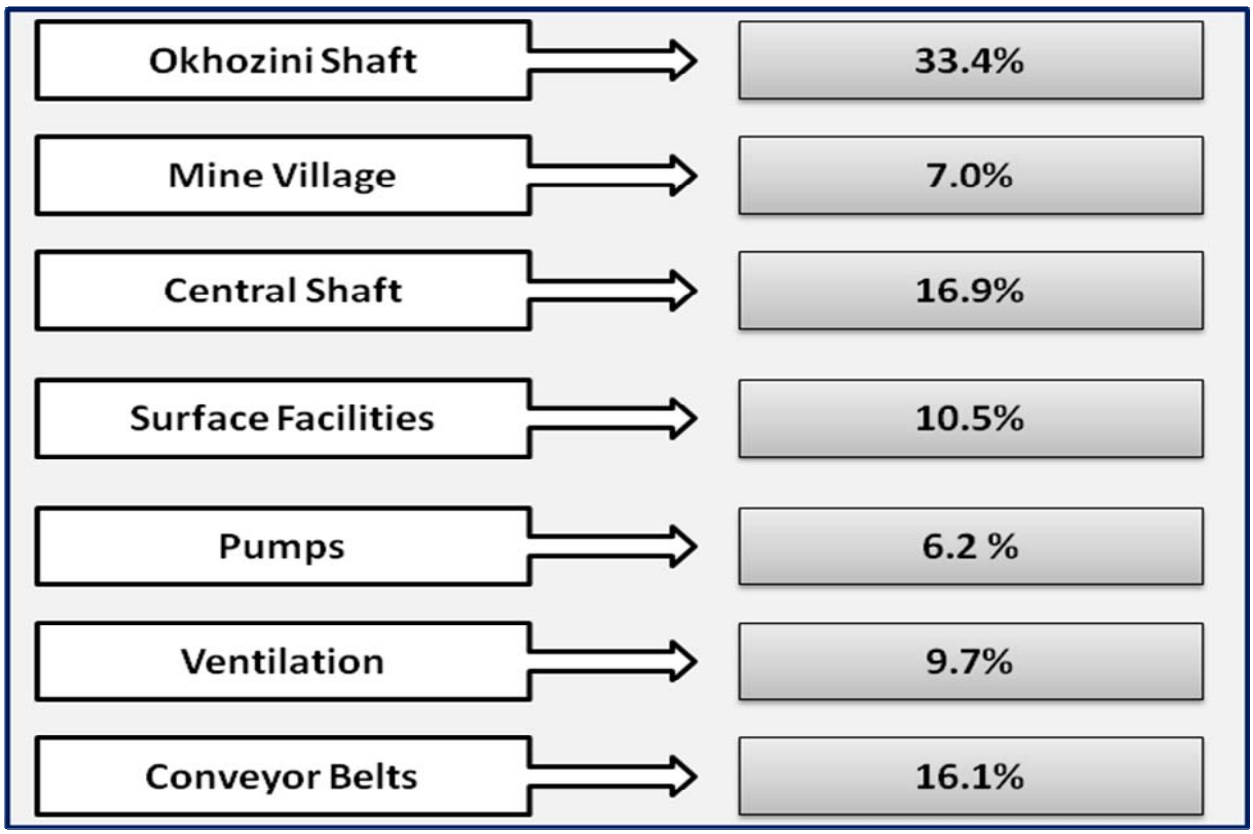


Figure 32: Estimated electricity consumption per specific area at NDC (NDC, 2010)

4.5 Year Electricity Consumption versus Production Rate

The main objective of this subsection was to conduct a yearly comparative study of electricity consumption in relation to production rate at NDC. The level of electricity used by the mine has been changing over the years due to section moves, change in machineries, production schedule and so on (Hunter, 2011). Table 10 shows the New Denmark Colliery's production (in tonnes), electricity consumption (in mega watts hour) and electricity consumption per tonnes produced (in KWh/t) from the year 2004 to 2010.

The amount of electricity consumed per tonne of coal produced has been fluctuating over the years between range 15-22 kWh/t. The higher the production, the lower is the electricity consumed per tonne produced. In the year 2009 maximum electricity per tonne produced was reached (approximately 22 kWh/t) with a corresponding production of 3.4 Mt.

In the year 2010, the highest amount of energy was consumed by NDC is approximately 95700 MWh. In the year 2009, the mine experienced power cuts due to load-shedding; as a result the quantity of electricity consumed was comparatively lower.

Table 10: NDC's production and electricity consumption for the year 2004 – 2010 (NDC,2011)

Year	Production (t)	Electricity (MWh)	Consumption per tonne (kWh/t)
2004	4,974,454	74,949	15
2005	4,160,269	72,290	17
2006	5,510,936	80,924	15
2007	5,140,705	82,803	16
2008	5,276,150	86,552	16
2009	3,342,624	73,594	22
2010	5,209,734	95,750	18

4.6 Monthly Electricity Consumption

This subsection provides a comparative study of changes in electricity consumption levels on a monthly basis for the year 2009 and 2010. Figure 33 depicts monthly electricity consumption (in kilowatt hour) for the year 2009 and 2010. The mine consumed more electricity in 2010 than it did in year 2009. The average quantity of electricity consumed in 2009 and 2010 are 6437667 kWh and 7148451 kWh respectively (as illustrated by Appendix B).

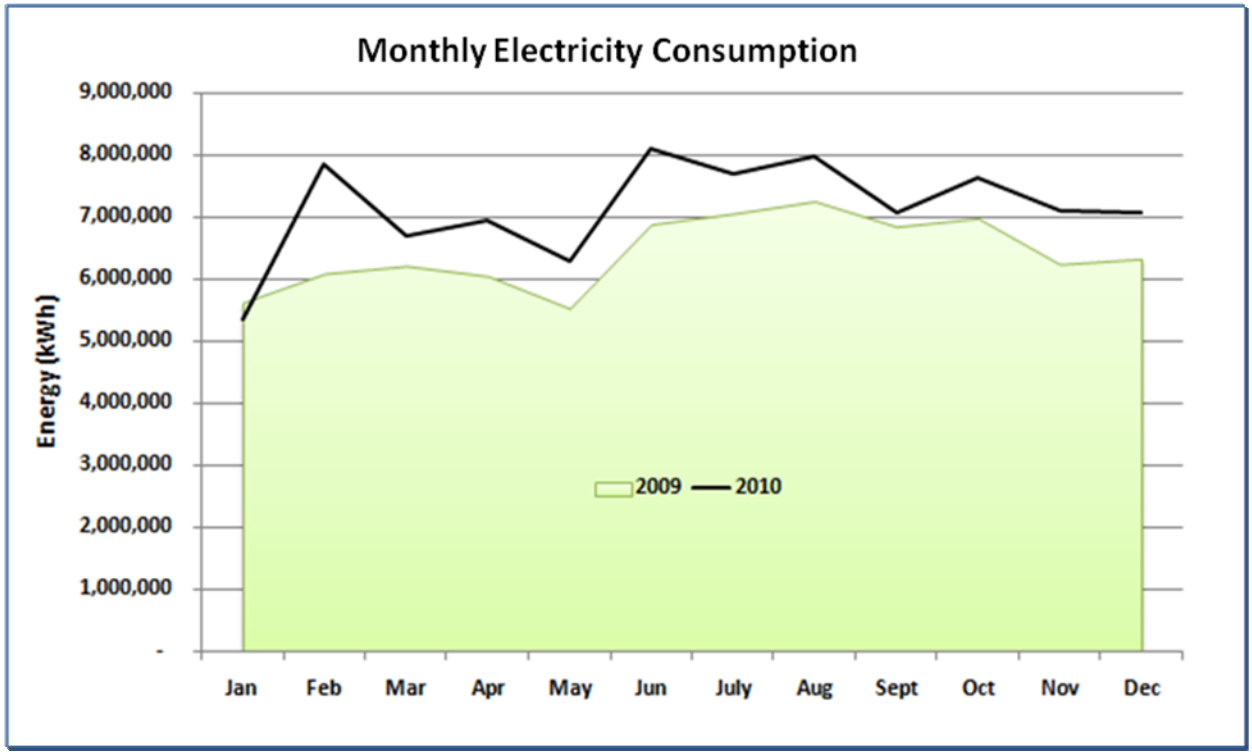


Figure 33: Monthly electricity consumption (NDC, 2010 and NDC, 2011).

Figure 34 illustrates the electricity consumption profile (in kWh) in relation to the production (in kilo-tonnes) trend on a monthly basis for the year 2010. Electricity consumption is also partly dependent on weather conditions. During the cold season more energy is consumed in order to maintain a consistent internal temperature of surfaces buildings and machines than in a warmer season. In January, April, May, August and November the longwall section was moved, as a result the mine produced less coal. The average electrical power consumed per tonne of coal produced is 18 kWh/t for the year 2010.

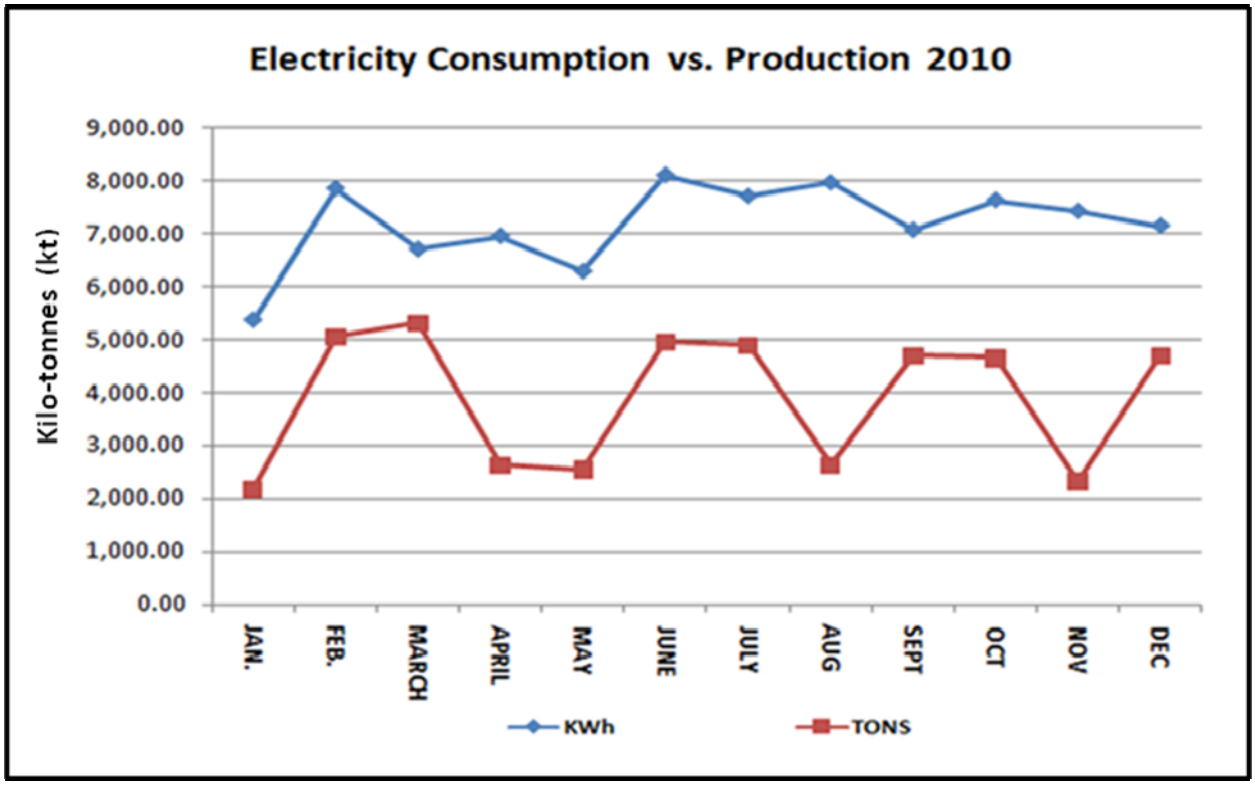


Figure 34: Production versus electrical power consumed for the year 2010 (NDC, 2010)

4.7 Carbon Dioxide Emissions

This sub-section provides a discussion on carbon dioxide emission in relation to the amount of electricity consumed by New Denmark Colliery. Energy used in different mining activities contributes directly or indirectly to climate change and the environmental impact through greenhouse gases (GHG) and carbon dioxide (CO_2) emissions. The higher the energy consumption; the higher the level of GHG and CO_2 emissions (Jean, 2009). Total CO_2 emissions consist of both energy and non-energy related sources. Figure 35 shows the 2011 breakdown of the Anglo American Thermal Coal collieries according to their carbon footprint (indicating the contribution from energy and non-energy sources). Comparatively, NDC has the fourth largest carbon footprint in relation to other Anglo American Thermal Coal operations (Anglo, 2011).

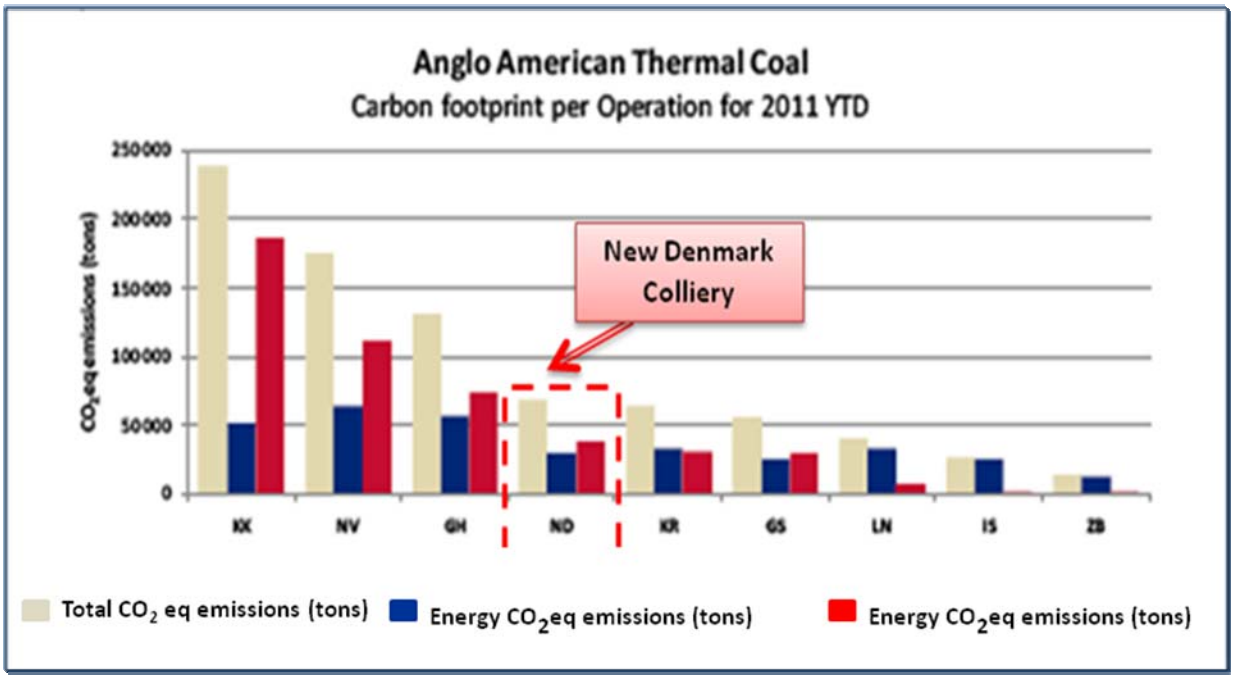


Figure 35: Anglo American Thermal Coal carbon footprint per operation for year 2011 YTD (Anglo, 2011).

Table 11 illustrates calculated (estimated) carbon dioxide emissions per quantity of electricity consumed (in MWh) by New Denmark Colliery from the year 2007 to 2010. It can be deduced from the table that the amount of electricity consumed is directly proportional to quantity of carbon dioxide emitted. The amount of energy consumed in 2010 was high, as a result the level of carbon dioxide was also high.

Table 11: Electricity consumed versus CO_2 emission for the year 2007 – 2010 (NDC, 2011)

Years	Electricity Consumed (MWh)	CO2 emissions per Electricity Consumed (tonnes)
2006	80,924	83351.72
2007	82,803	85287.09
2008	86,552	89148.56
2009	73,594	75801.82
2010	95,750	98622.50

4.8 Future Studies - Electricity Consumption

This sub-section provides a discussion on electricity forecasts (future studies) at New Denmark Colliery. It was done to determine the level of electricity consumption/requirement of NDC in the future based on production schedule mine. Forecasting is the process of estimating future business performance or the behaviour of a certain variable under different conditions. It is important for production planning and future expansion projects of the mining operations. Forecasting also provides an important benchmark for mines which have a long-term perspective of operations. Electricity consumption forecast is useful for planning strategy, determining organisational policy that relates to financial projection and budget; and setting up electricity tariff structure (Torbaghan, 2010 and Investopedia, 2011).

The trend projections method was used in the study to forecast the level of electricity that might be required by NDC in the future. Electricity consumption data of the previous years (historic data) was used to estimate future level of energy consumption. Electricity consumption historic data and future production schedule of the mine were used to determine the direction of future electricity trend at NDC.

Figure 36 shows the electricity consumption (in MWh) trend projection from the year 2011 to 2016. The electricity consumption is expected to increase due to expansion of sections, change in layout of the working areas and section moves. On average electricity consumption is expected to be 90000 MWh per annum, with the given production profile of the Life of Mine (LOM).

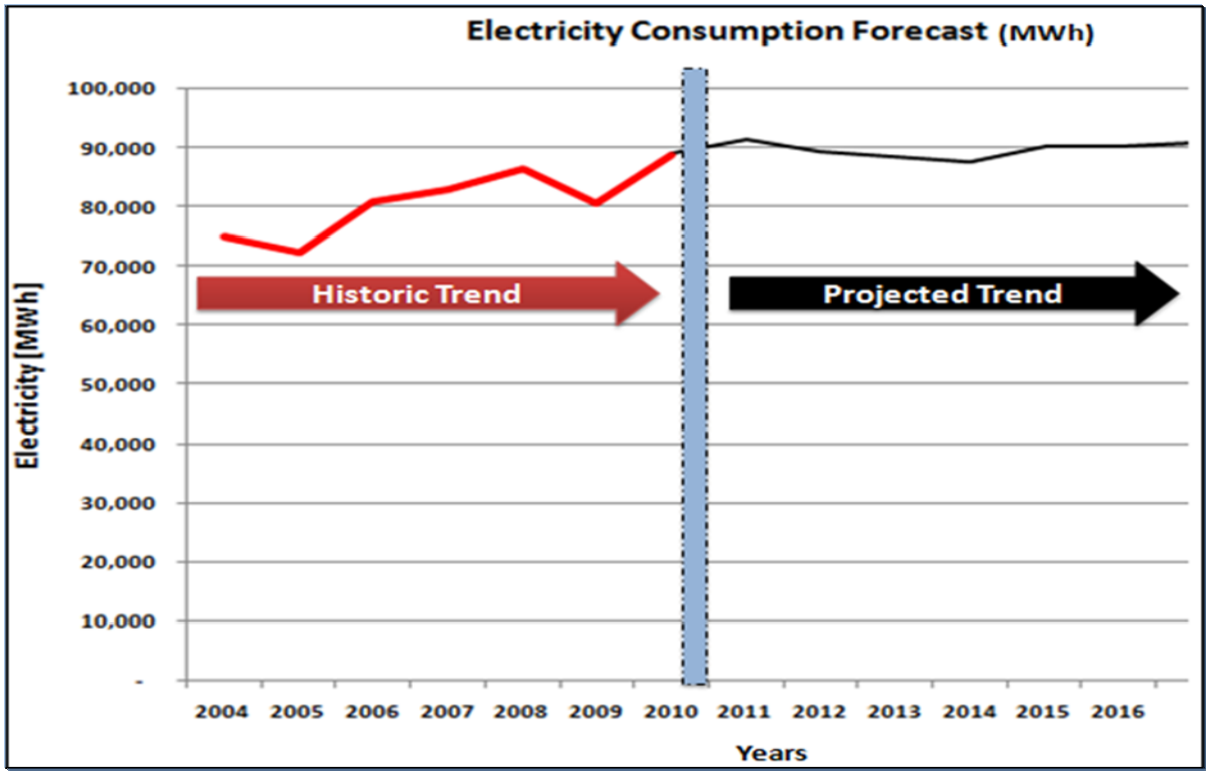


Figure 36: Electricity consumption projection for New Denmark Colliery

4.9 Summary

This chapter provided a discussion on energy consumption at New Denmark Colliery. It defined the following: factors influencing and affecting the level of electricity consumption; level of electricity consumption per area or activity; yearly and monthly comparative study of electricity consumption; carbon dioxide emission in relation to the amount of electricity consumed; and it also estimated the amount of electricity the mine should expect to consume in the future based on production schedules of the operation. The next chapter will focus on financial economics of energy at the mine.

CHAPTER 5: FINANCIAL ECONOMICS OF ENERGY

5.1 Introduction

The aim of this chapter is to provide a discussion on financial economics of energy at New Denmark Colliery and the following sub-sections were considered: Cost of energy; energy cost break down; tariff; monthly electricity cost distribution; yearly electrical energy cost versus production and electricity consumption; monthly electricity cost versus production and electricity consumption; electricity cost and tariff forecast.

5.2 Cost of Energy

Energy sources such as electricity, fuel oil, natural gas are supplied as inputs to production chain of minerals commodities. The price of electricity, like the price of mineral commodities, has a significant influence on the national economy of any country and plays an important role in societies all over the world. The cost of energy in mining operations influence both availability and price of commodities on the market but also profitability of the company. In order to maintain competitive and profitable landscape, companies must find ways of minimising costs (the cost of energy is an input into operating cost of a mine). Electrical energy constitutes a significant amount of the total mining cost. Because of the high cost of diesel, most mining operations use electrical operating machines (Tuks, 2010; Jean, 2009 and Itseezy, 2010).

Figure 37 shows the total electricity cost (in Rmillion) and average electricity cost (in c/kWh) of different Anglo American Thermal Coal operations. The total cost of electricity is approximately R306 million with an average electricity cost of R0.30 per kilowatt hour. The cost of electricity per operation is affected by the size of a mining operation, mining method, production rate, machinery used and so forth. The Total cost of electricity at NDC was approximately R36 million in the year 2010; with an average cost of R0.40 per kilowatt hour. NDC constituted 10 per cent of the total cost of electricity at Anglo American Thermal Coal (as shown by figure 38).

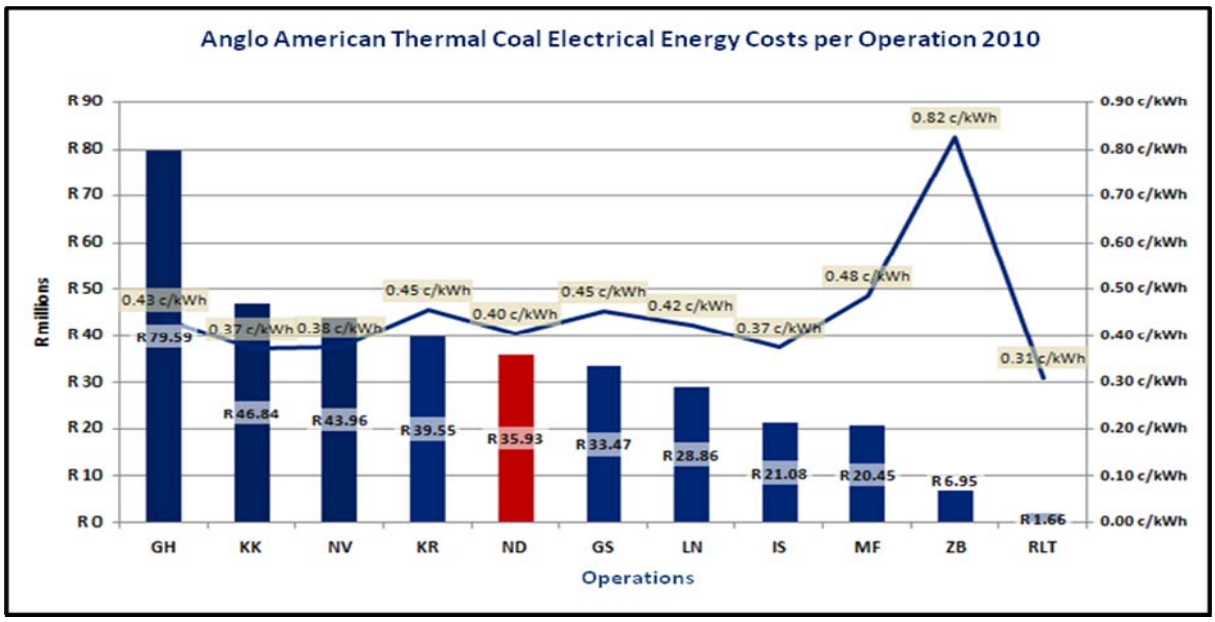


Figure 37: Anglo American Thermal Coal electricity cost per operation (Anglo, 2010)

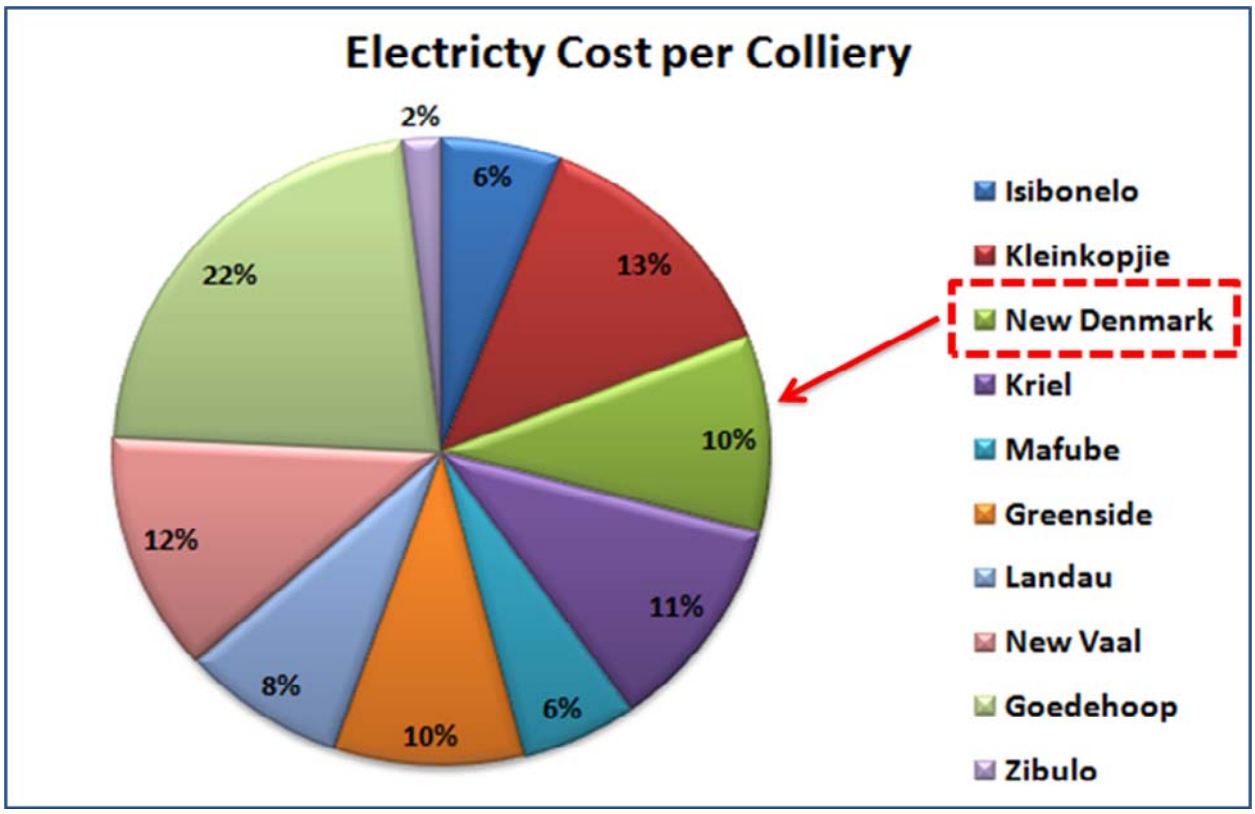


Figure 38: Comparative study of Anglo American Thermal Coal electricity cost per operation (Anglo, 2010)

5.3 Energy Cost Break Down

The manner in which mining operations consume electricity affects their average cost of electricity. Sporadic consumption of electricity by the mine elevates the average cost of electricity, while a constant, even consumption of electricity leads to a lower average cost to the mining operation. If the area under the maximum demand graph (load profile) is big, it indicates that the amount of electricity used and the average cost of electricity will decrease if the load remains constant (Dahl, 2004). The main objective of this sub-section is to evaluate the financial aspect of electricity at New Denmark Colliery.

Figure 39 shows energy cost breakdown of New Denmark Colliery for the year 2010. Total cost of energy for 2010 year was approximately R39 million. Electricity constituted 87 percent of the cost while diesel and petrol accounted for 12 percent and 1 percent respectively. The main source of energy used at NDC is electricity; as a result it constitutes a larger percentage of the total cost.

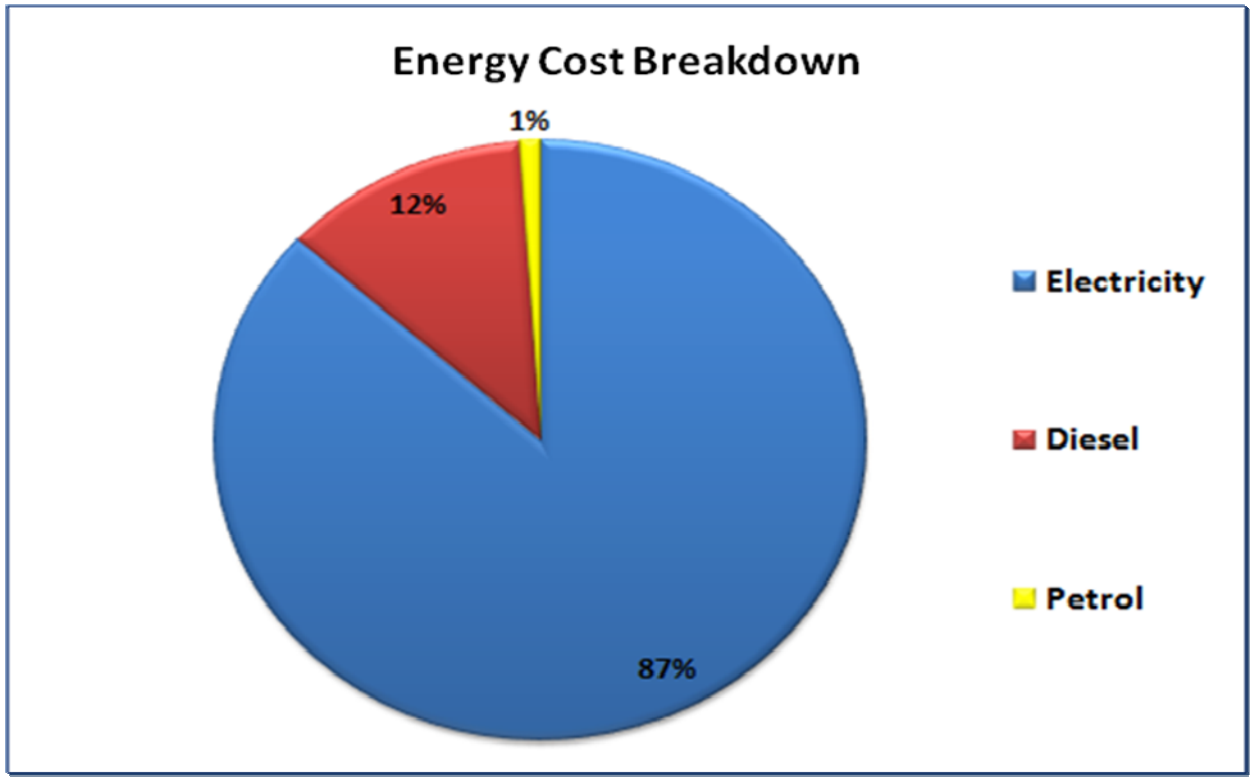


Figure 39: 2010 energy costs breakdown for New Denmark Colliery (NDC, 2011).

5.4 Yearly Electricity Cost versus Production and Electricity Consumption

This subsection was done in order to do a comparative study of the yearly electricity cost as a function of electricity consumption and production rate over a certain period of time at NDC. Table 12 shows the yearly electricity cost coupled with total production (in tonnes), electricity consumption (in MWh) and demand (in kVA) for the year 2007 till 2011. The total cost of electricity has been increasing over the years. The following factors influenced the increase in electricity costs over the years: tariff rates, tariff structure, inflation, structure of the production schedules and mining conditions (Hunter, 2011). It can be deduced from the table that the total cost of electricity is directly proportional to the electricity consumption and total production of the mining operation.

Table 12: Yearly electricity cost versus power (NDC, 2010 and NDC, 2011).

	Electricity Consumption (MWH)	Max Electricity Demand (kVA)	Total production (tonnes)	Total Cost of Electricity (Rands)
2007	79611.36	201917	5134749	14056374
2008	84320.84	192653	5262168	17855918
2009	77252.91	189966	3342624	21893524
2010	86148.2	215409	4657000	33479455
2011	88445.17	221152	4812608	45798041

Figure 40 illustrates the average electricity cost for New Denmark Colliery. The rate of average cost of electricity (in R/kWh) has been escalating over the years. It increased by over 65 percent in a period of 4 years, from R0.18/kWh in the year 2007 to R0.52/kWh in 2010. The global increase in fuel price, new Eskom tariff rates and inflation had an impact on the price of electricity.

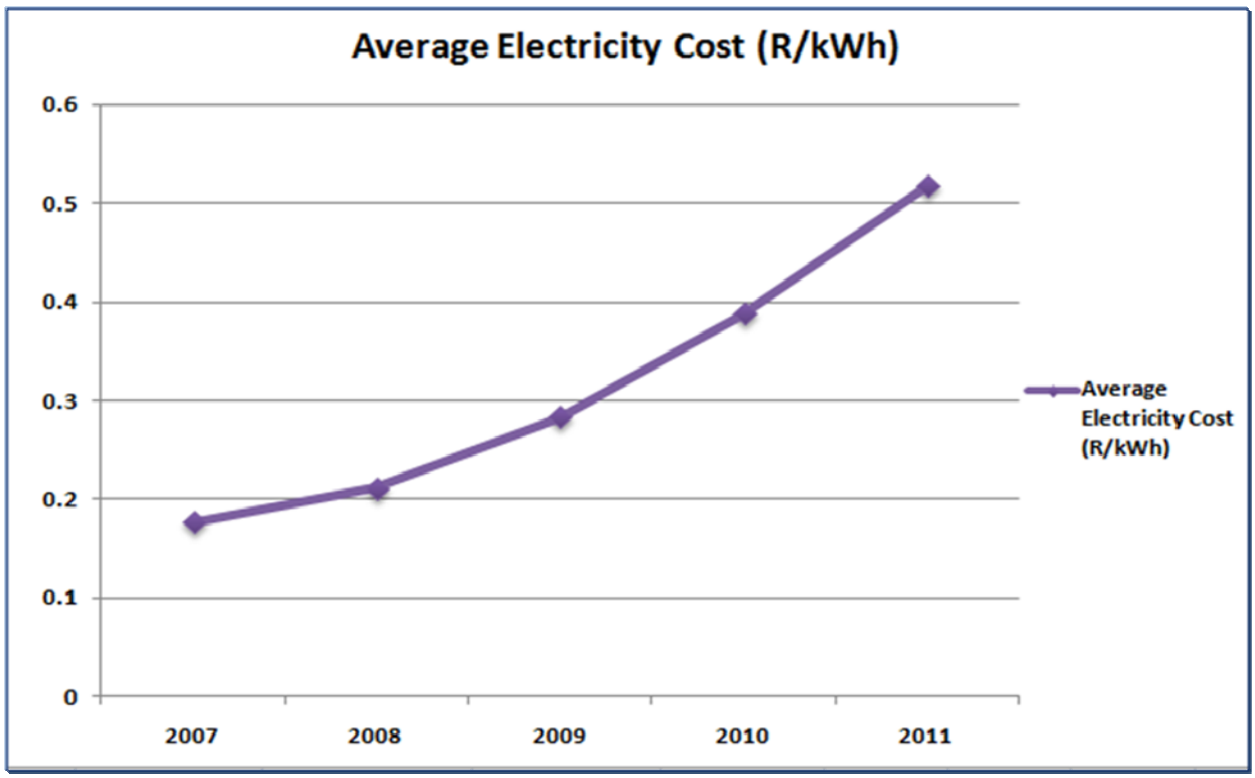


Figure 40: Yearly average electricity cost for New Denmark Colliery (NDC, 2010 and NDC, 2011).

5.5 Monthly Electricity Cost versus Production and Electricity Consumption

The main objective of this subsection was to do a comparative study of the monthly electricity cost as a function of electricity consumption and production for the year 2009 and 2010. Figure 41 illustrates monthly electricity cost for the year 2009 and 2010. It can be deduced from figure 33 that more electricity was consumed in the year 2010 than 2009; as a result cost of electricity was relatively higher in 2010 than 2009 (figure 41). The cost of electricity is high during 'high demand season' (June, July and August) as opposed to 'low demand season' due to level of electricity consumed during that period. The total electricity cost for the year 2009 and 2010 were R21.9 million and R32.5 million respectively. The tariff increase between the year the year 2009 and 2010 contributed significantly to the increase in electricity cost between the two years.

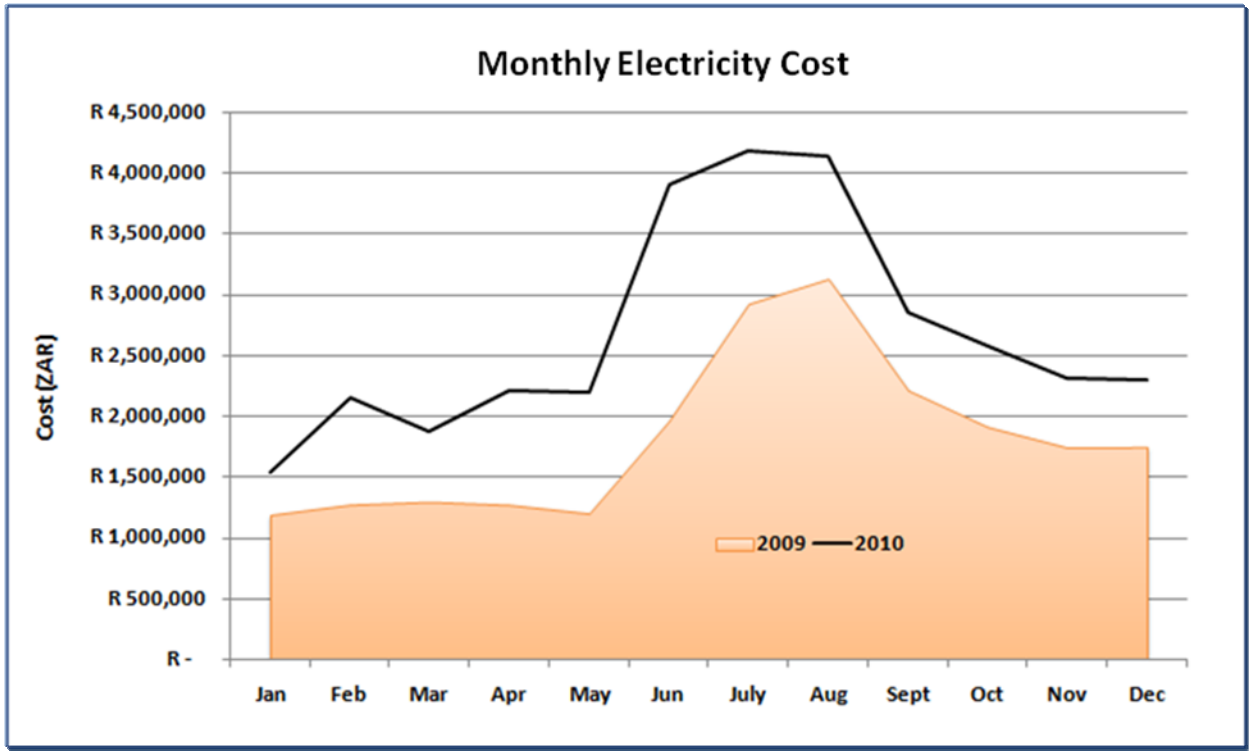


Figure 41: NDC monthly electricity increase between the year 2009 and 2010 (NDC, 2010 and NDC, 2011).

Figure 42 shows NDC electricity cost curve versus the production trend for the year 2010. The electricity consumption (in MWh) profile correlates with costs (in Rands) trend. In some regions of the graphs (April, May and August) the trends do not correlate due to section moves at the mine.

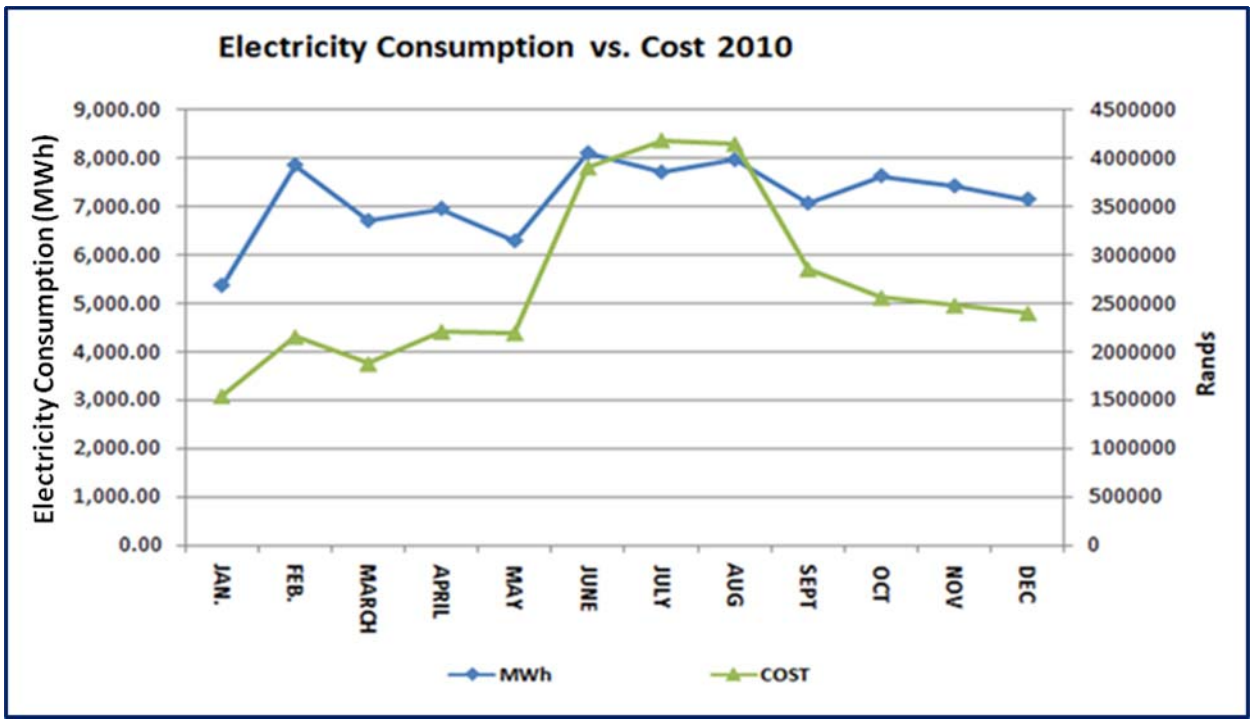


Figure 42: NDC Electrical power versus cost for the year 2010 (NDC, 2011)

5.6 Monthly Electricity Cost Distribution

Monthly electricity rates are a function of the total access network, distribution demand, total energy, peak period energy, standard period energy, excess reactive energy, rate rebalancing levy, environmental levy, service charge and administration charge. The rates will vary on a seasonal basis and are also influenced by the amount of energy consumed. Some of the parameters are fixed rates while others are semi-variable (Lawrence, 2011 and NDC, 2011). Figure 43 shows the cost distribution of average monthly electricity rates for the year 2009/2010. The rate of total energy accounted for 33 percent of total cost while peak energy accounted for 18 percent. Administration cost accounts for the lowest component of the total cost. The total cost of peak, standard and off-peak energy constituted for approximately 48 percent of the total cost.

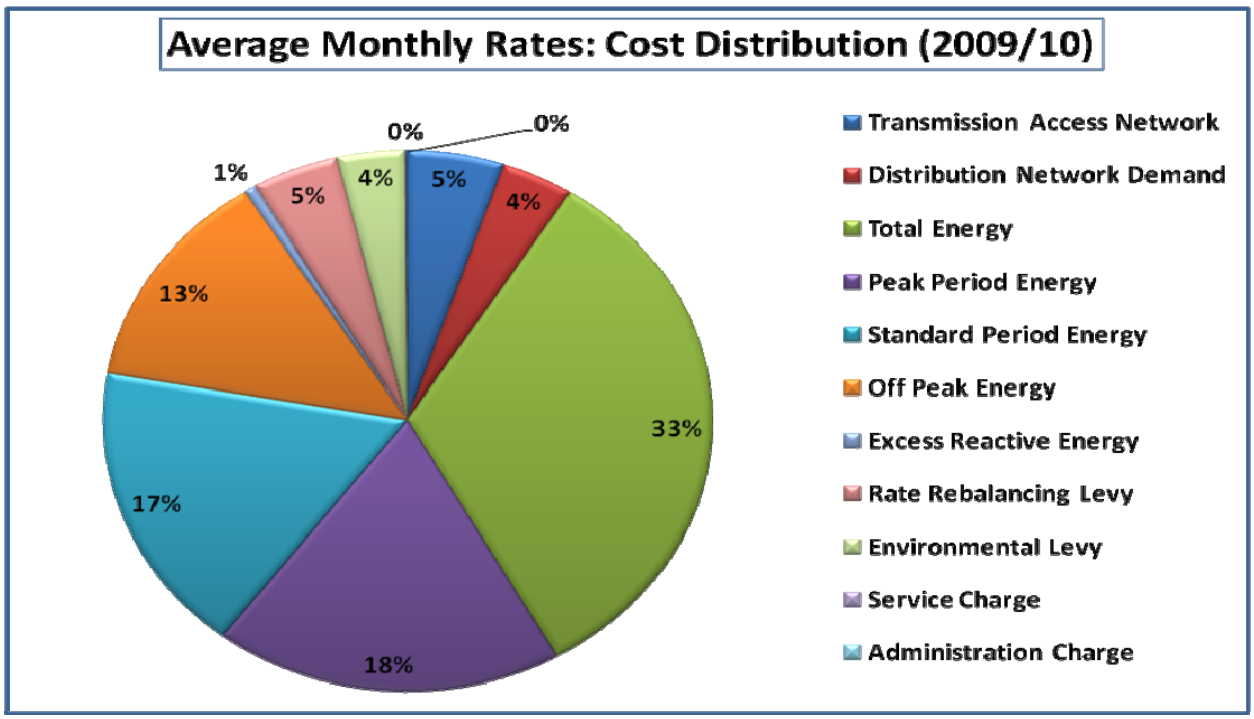


Figure 43: Cost distribution of average monthly electricity charge rates for the year 2009/ 2010 (Eskom, 2010).

5.7 Tariff

Tariff can be defined as a combination of charging parameters applied to recover measured and unmeasured quantities such as consumption and capacity costs, as well as service costs. Eskom sets the energy tariff in order to raise sufficient revenue to meet the financial requirements of the utility, and in the process be simple enough to facilitate understandable billing with available technology. Costs are allocated among customers according to the burden they place on the energy system. Tariffs are dynamic and depend upon system load patterns and developments in metering technology (Itseezy, 2010).

Figure 44 shows how electricity costs are derived or calculated. The algorithm involves the system load profile of the mining operation and the tariff package. Tariff package is comprised of tariff rates, tariff structure and other charges (like distance, environmental levy, number of consumers on the line and so on); which when applied to consumption profile gives the electricity cost (Itseezy, 2010).

Tariff structure commonly used fixed charge, single energy rate, block rate, demand tariff, time of use tariff, real time pricing and demand side management (Itseezy, 2010).

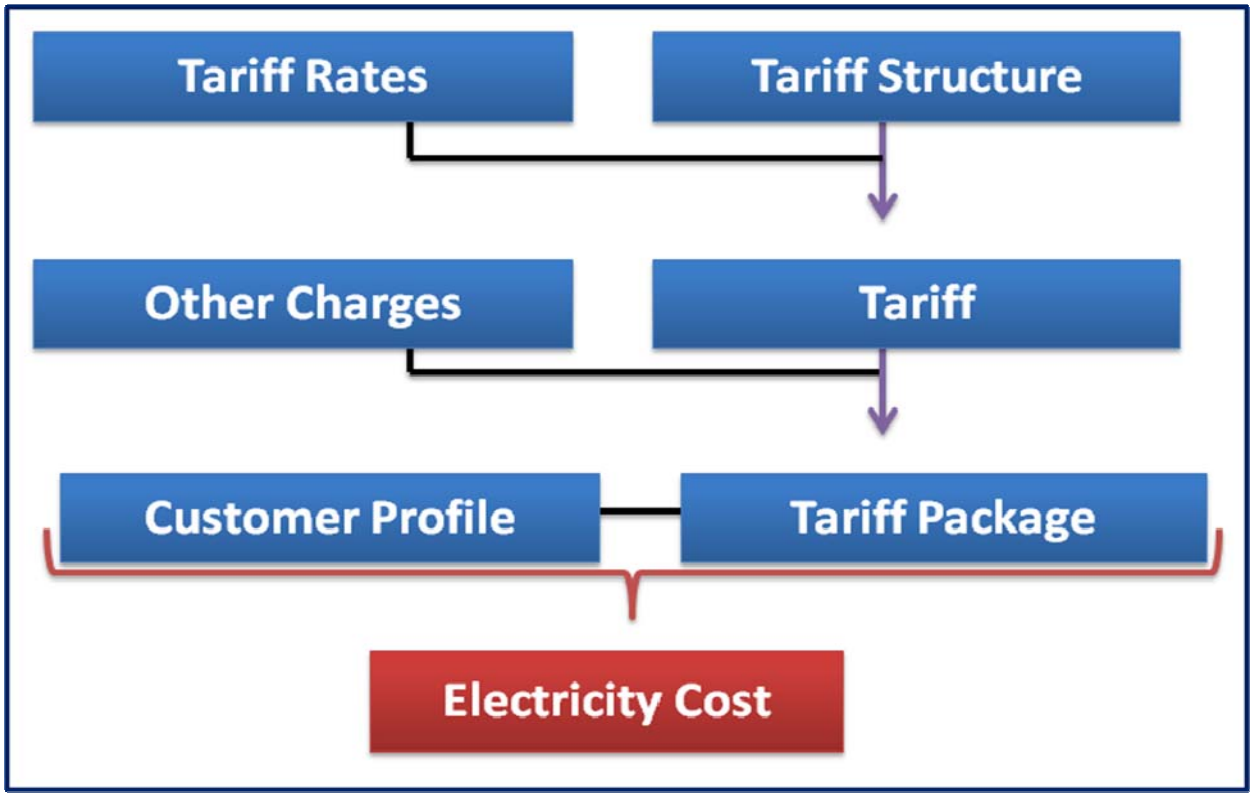


Figure 44: Algorithm of deriving or calculating the electricity cost (Itseezy, 2010).

Table 13 illustrates NDC tariff rates for the year 2008/2009 and 2009/2010. The mine is charged for service, administration, transmission and network distribution charge; off-peak, standard and peak energy; reactive energy charge; and environmental levy (Lawrence, 2011). The rates are high during high demand season because the level of electricity consumption and demand are high.

Table 13: NDC electricity monthly charge rate for the year 2008/2009 and 2009/2010 (Eskom, 2011)

		2008/9 rates	2009/10 rates	Difference	%
Low-Demand Season	January	R 428,916	R 460,154	R 31,237	7.28%
	February	R 452,895	R 489,157	R 36,262	8.01%
	March	R 1,304,134	R 1,736,050	R 431,916	33.12%
	April	R 1,271,470	R 1,692,287	R 420,817	33.10%
	May	R 1,201,627	R 1,585,798	R 384,171	31.97%
High - Demand season	June	R 2,130,982	R 2,912,383	R 781,401	36.67%
	July	R 2,303,717	R 3,152,547	R 848,830	36.85%
	August	R 2,288,398	R 3,137,395	R 848,996	37.10%
Low-Demand Season	September	R 1289,743	R 1475,419	R 185,676	14.40%
	October	R 1361,934	R 1593,809	R 231,875	17.03%
	November	R 1348,856	R 1515,572	R 166,716	12.36%
	December	R 1370,184	R 1582,290	R 212,106	15.19%

Figure 45 shows the NDC 2010 megaflex hourly energy charges profile for peak, standard and off-peak time-slots in a day (high and low energy seasons). The high demand season starts on the 1st of June and continues to the 31st August. The energy charges are high during energy demand season. It can be deduced from the diagram that major power consuming activities are during peak periods in a day (06:00 – 10:00 AM and 05:00 – 08:00 PM). The biggest impact on electricity charges (kWh) is during high demand season peak periods; there is an increase of over 210 percent in energy charges (an increase from R0.3604/kWh to R1.4283/kWh).

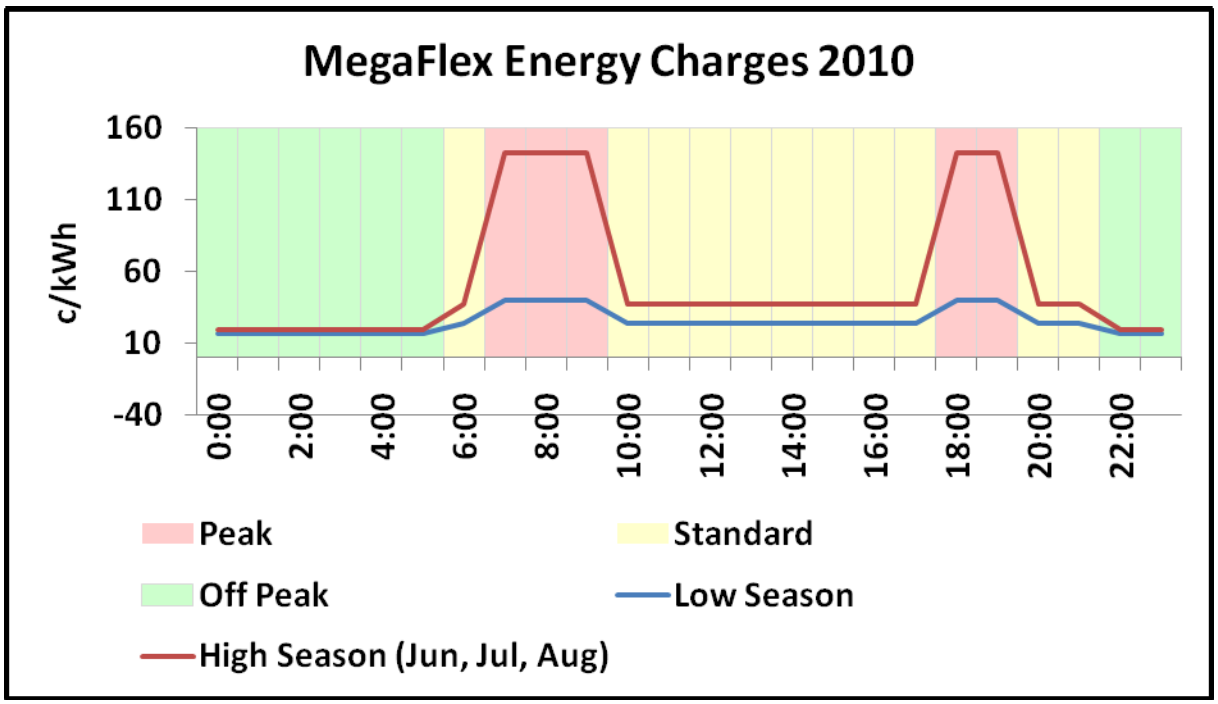


Figure 45: NDC hourly electricity charges profile for different season in the year 2010 (Anglo, 2010)

5.8 Electricity Cost Forecast

The main objective of this section was to forecast NDC electricity costs based on the electricity consumption (projected in section 4.8) and also tariff structure of Eskom. Figure 46 shows the Anglo American Thermal Coal electrical energy cost for the year 2010, 2011 and forecast for the year 2012 for different collieries. The energy forecast is based on the size of operation, production rate, tariff rate and expected load profile of each mining operation. The costs are expected to escalate due to increase in tariff rates, inflation, expansion of operations and tariff structure (Anglo, 2011 and Lawrence, 2011). In the year 2012, New Denmark is expected to pay approximately R55 million for electricity.

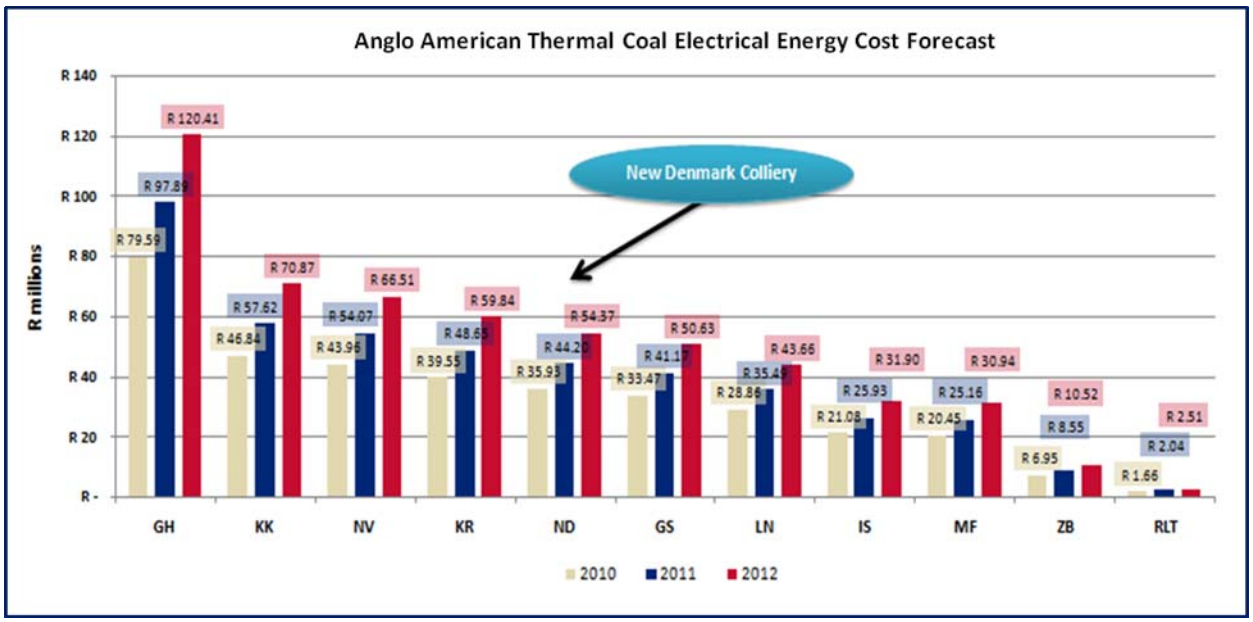


Figure 46: Anglo American Thermal Coal electrical energy cost forecast (Anglo, 2011).

Figure 47 shows the historical and forecast total and average electrical energy cost of Anglo American Thermal Coal from the year 2006 to 2020. The total cost of electricity (in R million) and average cost of electricity (in R/KWh) are expected to increase linearly over the years.

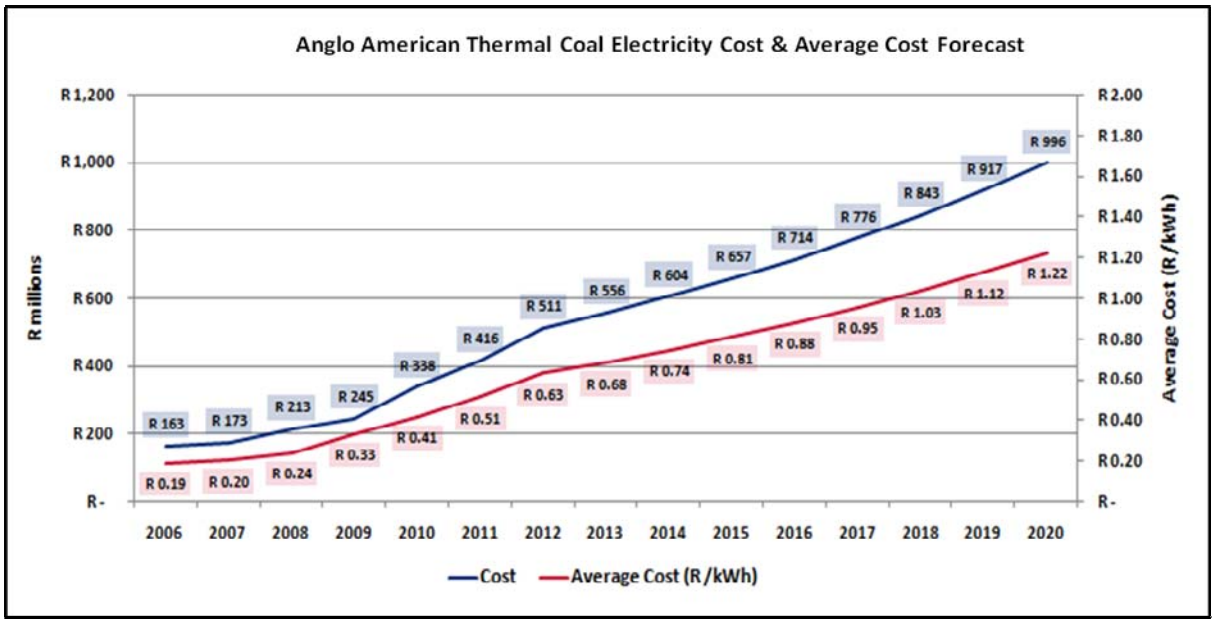


Figure 47: Anglo American Thermal Coal electricity cost and average cost forecast (Anglo, 2011).

5.8.1 Electricity Tariff Forecast for New Denmark Colliery

Following the July 2010 tariff increase, Eskom's (Tutuka power station) annual average power cost was R0.389 per kW hour, equivalent to R3 404 per annum, based on the Eskom megaflex cost structure and other costs (energy, network charges and capital charges). The cost of power is expected to increase drastically over the next five years, due to uncertainty regarding the magnitude of the pending Eskom tariff increases. Predicted electricity increase rate and electricity cost (in c/kWh) were used by the author to calculate the annual electricity cost per KW. Table 14 shows the calculations where figures were adjusted for 'Present Value' at 6 percent. Total estimated five year present value for one kilowatt supplied to the mine is approximately R23000.

Table 14: Electricity tariff forecast

Calendar Year	**2010/2011**	**2011/2012**	**2012/2013**	**2013/2014**	**2014/2015**
Period Year	0	1	2	3	4
Predicted Electricity Increase (%)	24.8%	25.8%	25.9%	10.0%	10.0%
Comment: Electricity Cost (current year) = Electricity Cost (previous yr) x (1 + predicted % increase)					
Electricity Cost (c/kWh)	38.86	48.89	61.55	67.70	74.47
Comment: Assumed operational time of 365 days per annum and 24 hours a day					
Annual Electricity Cost per kW (R)= Electricity Cost (c/kWh) x 24 2 365					
Annual Electricity Cost per kW (R)	3404.14	4282.40	5391.55	5930.70	6523.77
Comment: Assumed 6% adjustment percentage for the present value					
Formula for PV factor = 1/(1+adjustment factor)^period					
Present Value (PV) Factor	1.00	0.94	0.89	0.84	0.79
Comment: PV Value for each year = PV factor x Annual Elecity Cost per kW®					
Present Value (PV) for each year	3404.14	4040.00	4798.46	4979.53	5167.44
Five year PV cost for one KW (Sum)	**22389.56**				

5.8.2 Electricity Cost Forecast for New Denmark Colliery

The author estimated the average cost of electricity (in c/kWh), total cost of electricity (in Rands), carbon dioxide emissions (in tonnes) and cumulative electricity cost (in Rands) for a period of 6 years, using 2011 as a base year. The author used the production schedule provided by the mine, predicted electricity cost increase (discussed in section 5.8.1) and also forecast electricity consumption (discussed in section 4) to do the forecast. Appendix D shows the electricity cost forecast for New Denmark Colliery from the year 2011 till 2016.

The total electricity cost forecast over 6 years is approximately R434 million and the normalised annual cost is R72 million. It can be deduced from the forecasts that the cost of electricity will escalate over the upcoming years, as a result this will have a negative impact on profitability of NDC. There is a need for New Denmark Colliery to look into different ways or mechanisms of managing energy in order to minimise electricity consumption and costs for optimal production of coal, profitability and long term sustainability.

5.9 Summary

This chapter provided a discussion on financial economics of energy at New Denmark and under that the following sub-sections were considered: cost of energy, energy cost break down; yearly and monthly electricity costs versus production and electricity consumption; monthly electricity cost distribution; tariff and electricity consumption; and electricity cost and tariff forecast. The next chapter will focus on different mechanisms which can be used to manage electricity at NDC in order to optimise minimise electricity consumption and save costs.

6. SUMMARY OF DISCUSSIONS AND RECOMMENDATIONS (ENERGY MANAGEMENT)

This section focuses on two subsections namely: summary of different chapters (literature review; area of study; energy consumption and financial economics of energy) and recommendations (energy management - different initiatives, mechanisms and standards that New Denmark Colliery can adopt in order to optimally manage electricity consumption and costs).

6.1 Summary of Discussions

6.1.1 Literature Review

A review from literature shows that South Africa is a comparatively energy and carbon intensive country with respect to other African countries and developed nations. It is mainly dependent on fossil fuels for its total energy needs and it consumes more electricity per capita compared to other African countries and world-wide average. The major energy use sectors in the South African economy are: transport, agriculture, industrial, commerce, residential and mining.

South Africa is a developing country hence the energy demand is expected to increase considerably in the coming years due to rapid industrialization, mass electrification programme and strong economic growth. Electricity demand continues to rise in South Africa and in recent years, it has outstripped the available supply infrastructure to the point where the country suffered rolling blackouts. It became clear from events towards the end of 2007 and into 2008 that there is an inadequate supply-demand balance in the country.

The mining industry is one of the major consumers of energy and it was severely affected by power cuts. The impact of electricity crisis reduced national production of commodities in South Africa by 10.7 percent. The power crisis had impacted negatively not only on production but also on profitability, beneficiation strategy, safety standards and international competitiveness of mining companies in South Africa.

The energy crisis has provided Eskom, the Department of Energy, the National Energy Regulator of South Africa, mining industry and other sectors of the economy an opportunity to deal positively with energy efficiency and management in a decisive manner. It has allowed the country to take a closer look at how to use energy effectively and productively. This will accelerate innovation on demand side management and energy technologies. It also provides a platform to focus on climate change mitigation and an opportunity to make appropriate decisions on alternative forms of energy. Based on the findings of the literature review, it becomes critical for studies to be conducted in mining operations to determine the amount of energy consumed, costs and management techniques in order to establish energy standards, identify improvement opportunities, set-up energy management systems, enhance operational efficiency and secure long-term energy supply.

6.1.2 Area of Study

Chapter 3 provided a discussion on the area of study, which is New Denmark Colliery, an Anglo American Thermal Coal (AATC) operation. The chapter outlined the following aspects of AATC: general company background, energy consumption and energy strategy of the company. The second leg took a look at the mining operation which is the area of study, NDC. It defined the mine background and general information; structure of the mine; supply of the electricity to the mine; shafts, mining methods and equipment; relationship between the mine and power station; type of electricity account used; supply, transmission and distribution of electricity; and electricity demand profile of the mine.

Anglo American Thermal Coal is a division of Anglo American that owns and operates nine collieries and a washing plant. The company uses energy in the form of electricity, liquid fuels and explosives in order to extract coal from underground and opencast cast operations. Coal produced by Anglo American Thermal Coal in South Africa has three market streams, namely: thermal sector, metallurgical industry and Eskom. The production level of the company is expected to ramp-up from the year 2013; as a result the amount of energy consumption and demand will also increase.

The energy vision of the company entails the following: Reducing the amount of energy used during production; saving on the total energy bill; causing less damage to the health and environment; and ensuring that there are sustainable resources for future generation. Electricity costs of AATC have been escalating over the years. It becomes necessary for the company to conduct studies in its mining operations in order to reduce energy consumption and costs.

The area of study of the research is NDC, an AATC operation with an annual production of approximately 5.4 Mt. The operation has three shafts, namely: Central shaft, Okhozini shaft and North shaft. The North Shaft is mothballed; and Central and Okhozini Shafts are in operation and have a total of 7 continuous miner sections and 1 long wall section. NDC is the main supplier of coal (approximately 70 percent) to Eskom's power station called Tutuka together with Kriel Colliery, another Anglo American Thermal Coal operation. NDC is a captive mining operation; as a result all the coal produced by the mine is taken to the power station.

The concept of energy management is still in developmental stage at New Denmark and other Anglo American Thermal Coal mining operations. The mine has an energy policy (adapted from AATC) however it does not have mechanisms or systems in place to achieve the vision and objectives of the policy. There is also inadequate organisational structure and culture to promote energy management initiatives at the mine. The following are not well defined or set at New Denmark Colliery: targets are not well defined (energy consumption, costs, etc); there are no systems in place to measure and monitor performance; and improvement opportunities are not identified.

Energy consumption and costs are often erroneously viewed as unavoidable, resulting in their inadequate control when, in fact, effective energy management can have a significant impact on profit of the mining operation. Before any energy management mechanisms/initiatives can be introduced in a mining operation it is first necessary to conduct comprehensive study on historic and current state energy consumption, costs and standards that are already in place.

It is also necessary to analyse factors that affect and influence the above discussed energy consumption and costs.

6.1.3 Energy Consumption at New Denmark Colliery

Chapter 4 provided a discussion on energy consumption at New Denmark Colliery by focusing on the following subsections: Use of energy; factors influencing and affecting electricity consumption; electricity consumption per geographical area; yearly and monthly electricity consumption; carbon dioxide per electricity consumed; and forecasting of electricity consumption in the mere future.

Energy consumption can be defined as the amount of energy used by a mining operation for coal extraction, transportation and ventilation in addition to surface and underground facilities. Three main forms of energy used at NDC are: electricity, diesel and petrol. Electricity accounts for more than 90 percent of the energy type consumed, while diesel and petrol constitute for 8.87 percent and 0.81 percent respectively. It can be inferred from the findings that mining, ventilation and transportation consume relatively more electricity compared to other activities at NDC.

The amount of electricity consumed by NDC has been fluctuating over the years due to the following factors: production schedule of the mine; section moves; introduction of new equipment and so on. It can be deduced from the findings of the study that the higher the amount of coal produced the higher the quantity of electricity consumption.

Electricity consumption is also partly dependent on weather conditions. During the cold season more energy is consumed in order to maintain a consistent internal temperature of surface buildings and equipment than in the warmer season. Winter season is considered high demand season; as a result the electricity consumption and costs electricity are high.

It can be deduced form the findings that the amount of electricity (energy) consumed is directly proportional to quantity of carbon dioxide emitted. Comparatively, NDC has the fourth largest carbon footprint in relation to other Anglo American Thermal Coal operations.

Trend projection method was used in the study to estimate the amount of energy that will be consumed by NDC in the future based on historic electricity consumption data and future production profile. Electricity consumption data of the previous years (time series data) was used to estimate future level of energy consumption from the year 2011 to 2016. The electricity consumption is expected to increase due to expansion of sections, change in layout of the working areas and section moves. On average electricity consumption is expected to be 90000 MWh per annum.

6.1.4 Financial Economics of Energy at New Denmark Colliery

Chapter 5 provided a discussion on financial aspect of electricity at New Denmark Colliery by taking a look at the following subsections: Cost of electricity; energy cost break down; tariff; monthly electricity cost distribution; yearly electrical energy cost versus production and electricity consumption; monthly electricity cost versus production and electricity consumption; electricity cost and tariff forecast.

The price of electricity has a significant influence on the production cost of a mining operation and consequently the profitability of the company. The total cost of electricity at Anglo American Thermal Coal for the year 2010 was approximately R306 million with an average electricity cost of R0.30 per kilowatt hour. NDC constituted 10 percent of the total cost of electricity at Anglo American Thermal Coal. The Total cost of electricity at NDC was approximately R36 million in the year 2010; with an average cost of R0.40 per kilowatt hour. The total cost of energy in the year 2010 at NDC was R39 million; electricity constituted 87 per cent of the total cost while diesel and petrol accounted for 12 per cent and 1 per cent respectively.

The author conducted a comparative study of yearly electricity cost of electricity as a function of production and electricity consumption. It was found that although the consumption of energy has been fluctuating over the years, the cost of electricity has been escalating at an alarming rate. The average cost of electricity has been escalating over the years; it increased by over 65 percent in a period of 4 years, from R0.18/kWh in the year 2007 to 0.52/kWh in 2010. This is mainly due to changes in tariff structure in addition to other factors such as inflation. It can be deduced that the total cost of electricity is directly proportional to the electricity consumption and total production of the mining operation.

The comparative study of the monthly electricity cost as a function of electricity consumption and production for the year 2009 and 2010 was also conducted. It was found that more electricity was consumed in the year 2010 as a result the electricity costs were also relatively higher than in 2009. The energy charges are high energy demand season (June, July and August) because the level of electricity consumption is high during that period. It can also be inferred that major power consuming activities are during peak periods on weekdays (06:00 – 10: 00 AM and 05:00 – 08:00 PM).

Monthly electricity rates are a function of the total access network, distribution demand, total energy, peak period energy, standard period energy, excess reactive energy, rate rebalancing levy, environmental levy, service charge and administration charge. The rates vary on a seasonal basis and are also influenced by the amount of energy consumed. Some of the parameters are fixed rates while other are semi-variable.

The author estimated the NDC electricity costs forecast based on estimated electricity consumption and tariff structure of Eskom. The costs are expected to escalate due to increase in tariff rates and structure. The total electricity cost forecast over 6 years is expected to be approximately R434 million; with normalized annual cost of R72 million. The escalating costs will affect the profitability of NDC.

The next sub-section section of the report will focus on different initiatives, mechanisms and standards that New Denmark Colliery can adopt in order to optimally manage electricity consumption and costs.

6.2 Recommendations (Energy Management)

This sub-section section of the report focuses on different initiatives, mechanisms and standards that New Denmark Colliery can adopt in order to optimally manage electricity consumption and costs.

Energy management is the process of monitoring, controlling and conserving energy in an organisation or company. According to its principles, the main objective is to optimise the benefits derived from efficient energy including energy conservation through reduction of consumption. It takes into account consumption of energy in all its forms, their environmental impact and furthermore costs associated with the usage (Energylens, 2011 and Tshisekedi, 2008). The concept of energy management is still in a developmental phase at New Denmark and other Anglo American Thermal Coal mining operations.

Effective energy management does not only cut energy costs and consumption but it can improve energy supply reliability and security. Advances in information systems, technology and management techniques have provided new opportunities to control the use of energy in mining operations (Villiers, 1996). Energy management is the key to saving energy in mining operations. Much of the importance of energy saving stems from the national need to save energy, this affects energy prices, emissions targets, and legislation, all of which lead to several compelling reasons why mining operations should save energy. Monitoring, control and reduction of energy is important to mining operations because it enables them to:

- Reduce costs – this is becoming increasingly crucial as the cost of energy rises;
- Reduce carbon emissions and environmental damage they cause, in addition to the cost related implications of carbon taxes and environmental charges; and
- Reduce risk – the more energy an operation consumes, the greater is the risk that there will be supply shortages or energy price increases that could affect profitability. Energy

management helps an organisation to reduce this risk by minimising its energy demand and by controlling it so as to make it more predictable (Energylens, 2011).

NDC has an energy policy (adapted from AATC) however it does not have mechanisms in place that can be used to achieve the energy management objectives. Operational practices are not well aligned to AATC energy strategy because there are no management systems to do so (Anglo, 2011). Figure 48 shows tools that can be used by New Denmark Colliery to manage its electricity consumption levels and reduce costs, namely: applying energy management standards; energy management processes; energy accounting and auditing; educational programs and training; energy efficient technology; energy saving strategies and policies. These tools can be used to align the energy strategy of a company to operational practice in a mine.

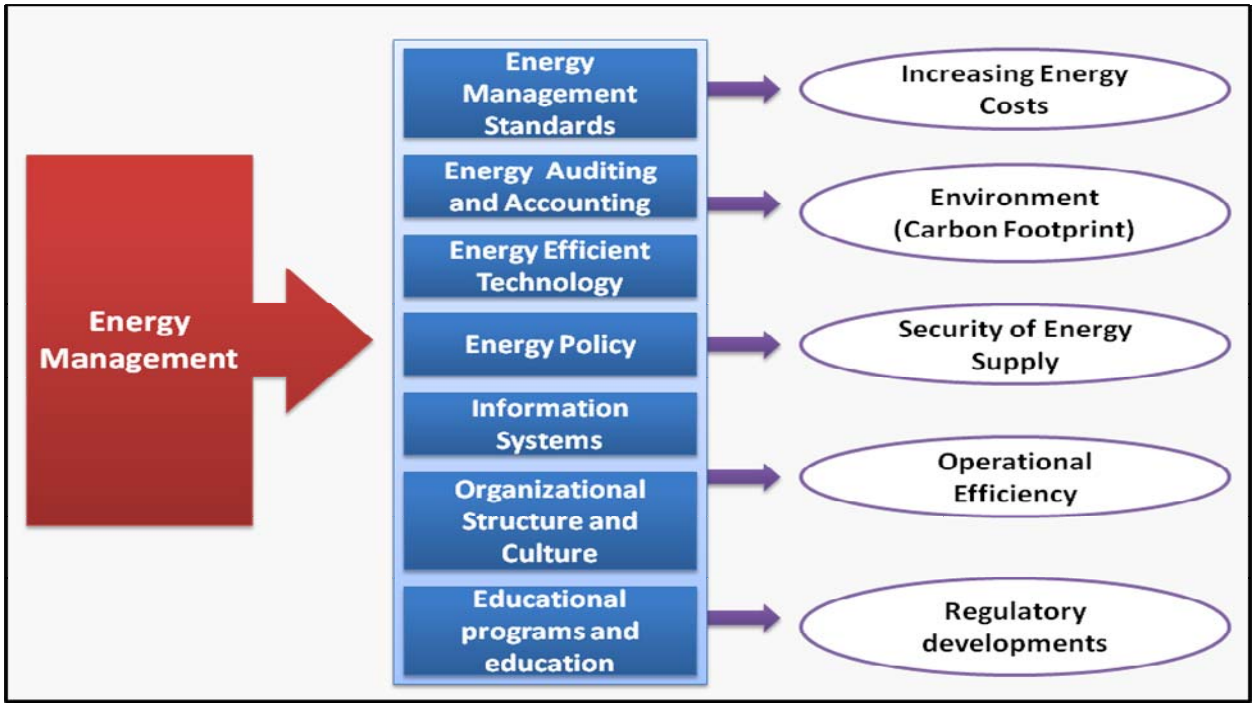


Figure 48: Energy management mechanisms or tools that can be used by New Denmark Colliery

6.2.1 Energy Management Standards

Energy management standards can be defined as a set of features, policies and mechanisms that are used to establish best practices for the emerging area of energy efficiency in different sectors. The purpose of an energy management standard is to provide guidance, and best

practice methodologies for mining industry in integrating different mechanisms into their management and operational practices (Tshisekedi, 2008 and Anglo, 2010).

The following energy standards must be clearly outlined at New Denmark Colliery in order to optimally manage energy and save costs:

- A framework for understanding significant energy uses in a mining operation;
- Action plans for improving energy performance;
- Organizational framework and structure to sustain energy performance improvements over time and change of personnel;
- Energy policies and training procedures; and
- Identified key performance indicators to measure progress and optimize energy and costs (Tshisekedi, 2008 and Lawrence, 2011).

6.2.2 Management Capacity and Organizational Structure for Energy Management

The management capacity and organisational structure at New Denmark Colliery should be structured in such a way that it promotes energy management initiatives. The first phase of energy management programme should start with top management defining the goals; establishing the organizational structure; and providing the necessary resources to integrate energy management initiatives in operational practice of the mine. The core of an effective energy programme is the energy action group, coordinated by an appointed experienced line manager or energy manager in a mining operation. The energy manager's job is to ensure prompt follow-up of all actions taken, accountability for the effectiveness of the programme and overall responsibility for carrying out the programme. The energy manager must have direct access to senior management, mining operators and engineering crew at the mine to discuss and establish targets for the programme; and should liaise with relevant government department, professional bodies, energy suppliers (Eskom) and consultants (Lawrence, 2011 and Villiers, 1996). Figure 49 shows an organisational structure that can be used to promote energy management at NDC.

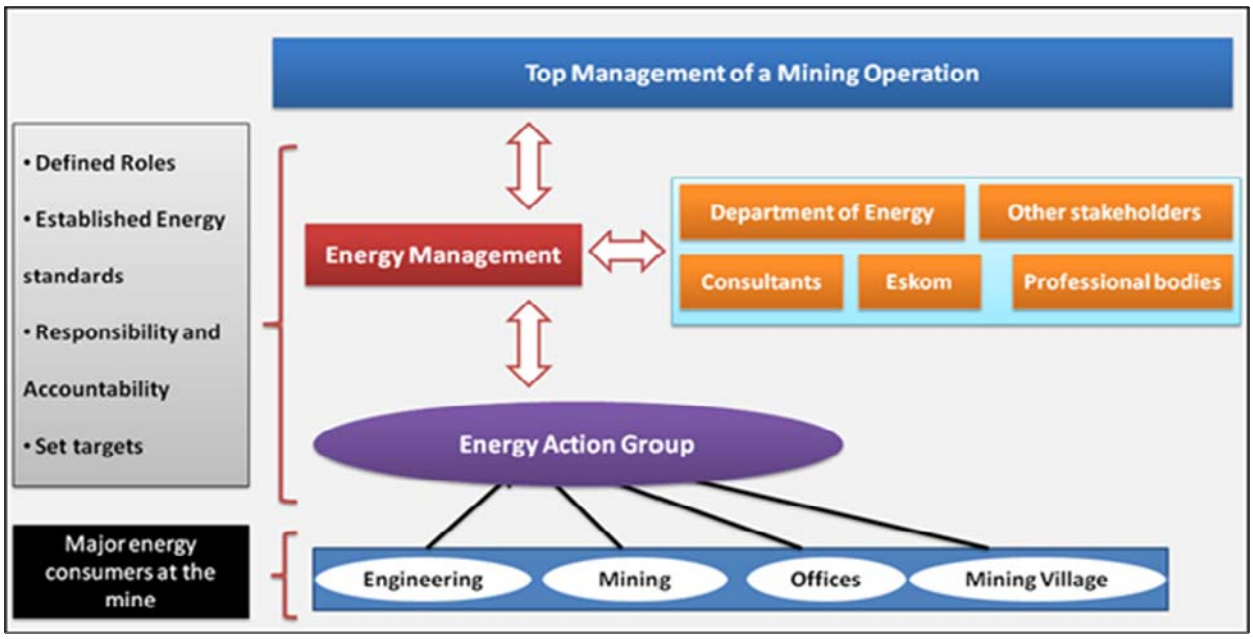


Figure 49: Organisational structure that can be used by NDC to promote energy management.

Depending on the size and structure of the mining operation, the energy action group should include senior members from major energy-consuming departments (mining, ventilation, engineering and so on). Specific accountable responsibilities should be assigned to the member of action groups, and they should make recommendations affecting their areas of responsibility. Members of the group may form sub-committees in their own departments in order to identify energy saving opportunities and delegate responsibility (Hunter, 2011 and Villiers, 1996).

6.2.3 Energy Accounting and Auditing

Energy accounting and auditing should be used by New Denmark Colliery to manage energy. Energy accounting entails book keeping management systems including records, reports and analysis for energy costs and accounting on a regular basis. Figure 50 shows what energy accounting entails. It will help NDC to compare energy consumption and costs amongst different facilities and to monitor the trend of energy use over time. It can also help the mine to evaluate potential energy savings limits to incorporate in future program success by identifying energy intensive areas and the peak energy use period or sudden unexplained increase in consumption that requires investigation. It is an important step towards effective management by providing quantity of energy a mining operation uses and the costs (Tshisekedi, 2008).

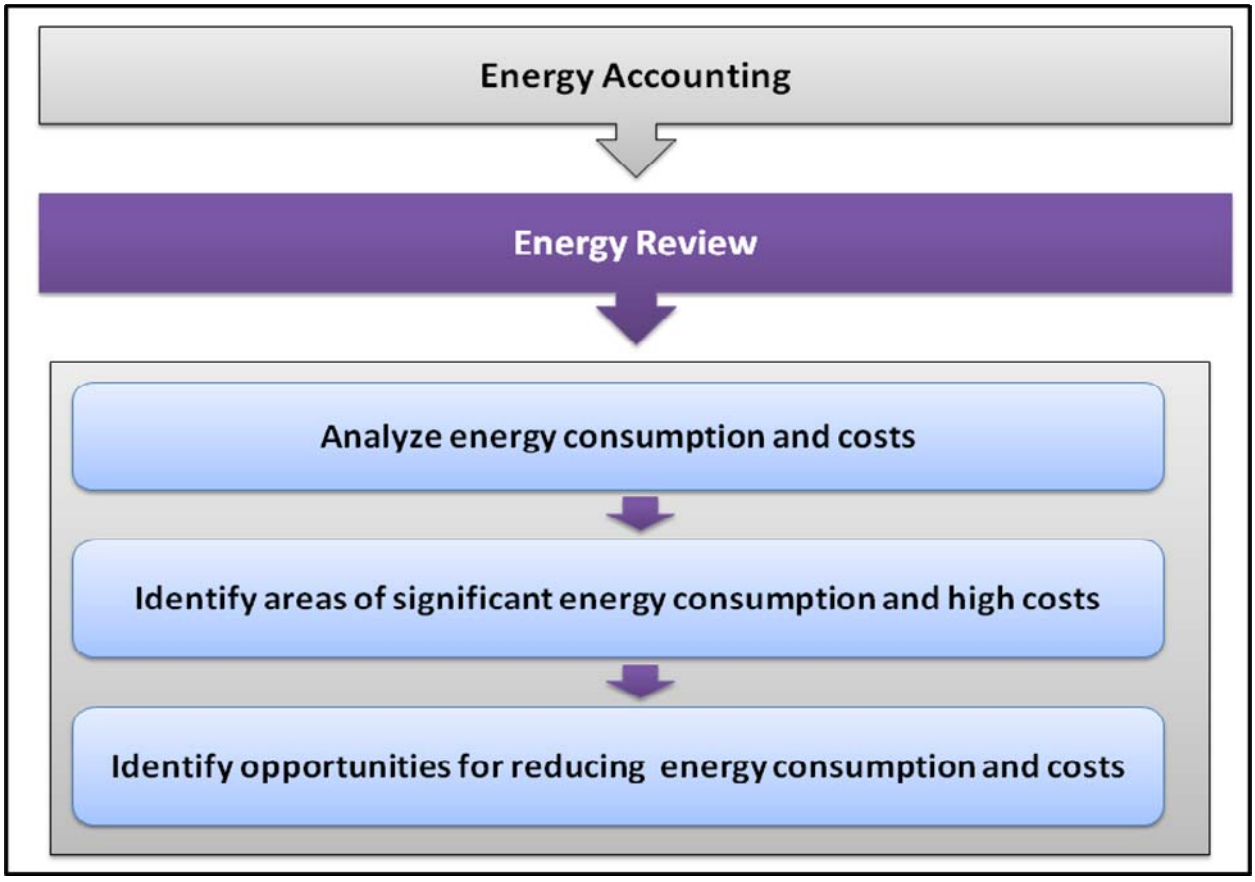


Figure 50: Different aspects of energy accounting.

Energy audit can be defined as the feasibility study to establish and quantify the cost of various energy inputs and flows within a mining operation over a given period. The main objective of an energy audit is to identify viable and cost effective energy measures which will reduce electricity costs and consumption. Energy audit process usually involves collecting data from energy invoices and meters. It must be conducted at different specific areas at NDC such as Central Shaft, Okhozini Shaft, mine villages, sections, workshops, offices and so on. It forms a foundation in which an energy management programme is built. Depending on the depth of the study, there are three types of energy audits, namely: preliminary, targeted and comprehensive energy audit (as illustrated by figure 51) (Beggs, 2002).

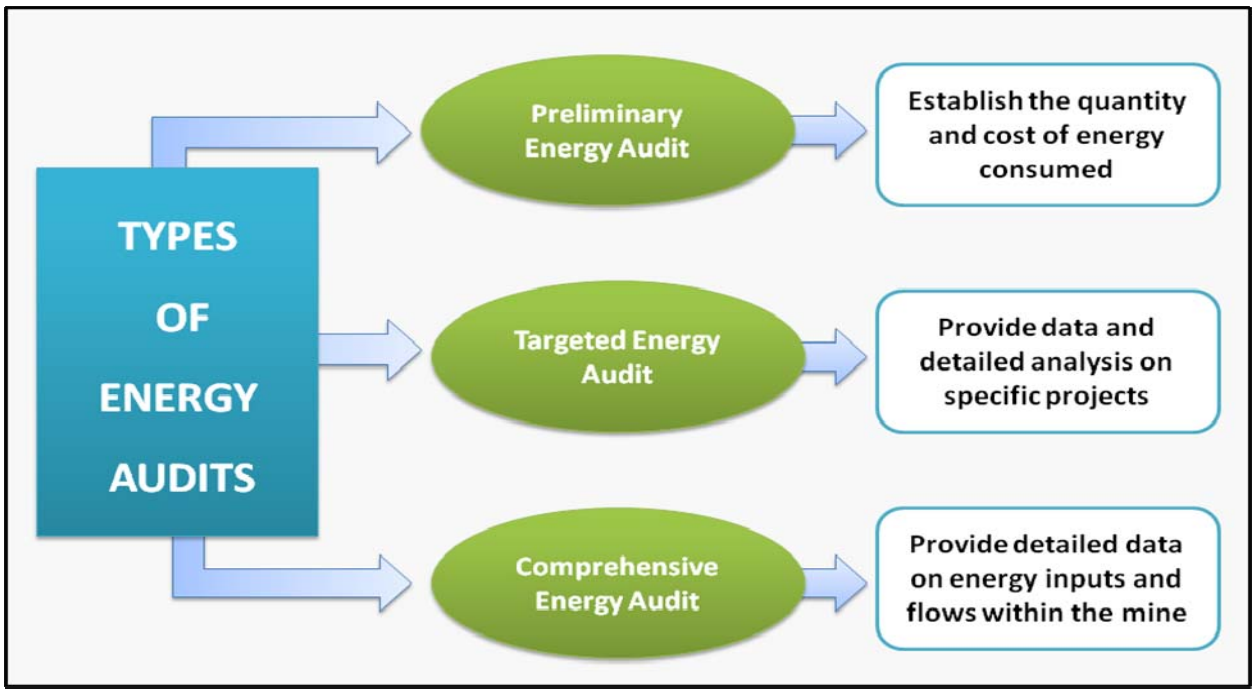


Figure 51: Types of energy audits.

Preliminary energy audit establishes the quantity and cost of energy used in a mining operation they are concerned with obtaining data from energy invoices and meter readings for a given period, which often corresponds to the most recent financial year. They are relatively quick to conduct and are designed to determine a project's potential. Targeted energy audits seek to provide data and detailed analysis on specific targeted projects. They involve detailed surveys of the target subjects and also analysis of the energy flows and costs associated with the targets. Comprehensive energy audits provide detailed data on the energy inputs and flows within a mining operation. They produce detailed energy project implementation plans through detailed energy surveys; and may involve the use of complex energy simulation computer software (Beggs, 2002).

6.2.4 Energy Management Mechanisms

Four energy management steps that can be used by NDC to optimise the use of energy and save energy includes the following: metering energy consumption and collecting the data; finding opportunities to save energy; taking action to target the opportunities to save energy and tracking progress by analyzing the meter data (Energylens, 2011).

Priority should be given to specific activities that consume most of the energy such as: mining, ventilation and transportation. Okhozini shaft should be given more priority than Central Shaft since it has relatively high electricity consumption. Figure 52 shows sequence of energy management mechanisms that can be used by NDC to minimise energy consumption and costs.

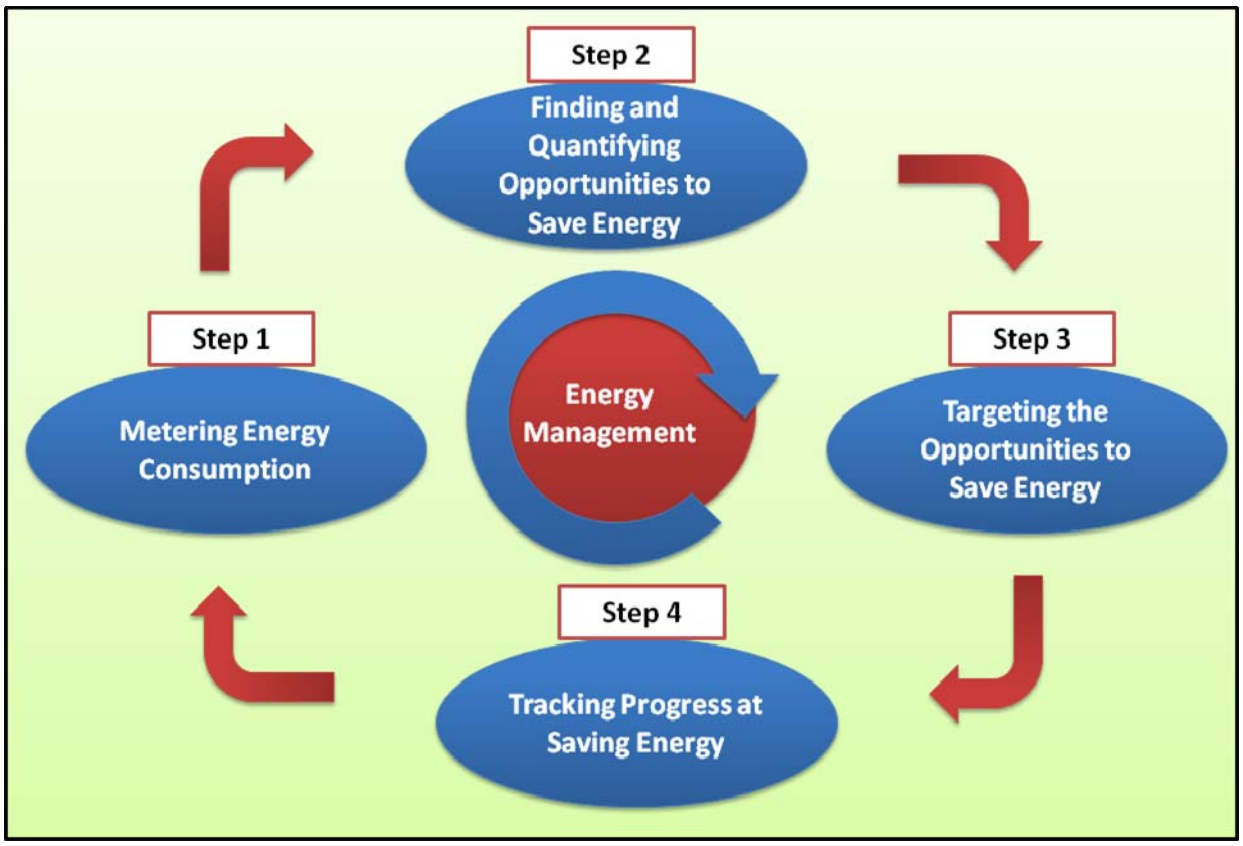


Figure 52: Energy management mechanisms that can be used by NDC.

6.2.4.1 Metering Energy Consumption and Data Collection

This step involves metering the amount of electricity consumed by means of instruments and collecting the data. Metering devices or instruments should be installed on high energy consuming facilities, machineries and equipment at NDC such as the continuous miners, conveyor belts, shuttle cars, long wall equipment, workshops facilities and so on. As a rule of thumb; the more data one captures, and the more detailed it is, the better (Energylens, 2011).

Interval-metering systems should be fitted to automatically measure and record energy consumption at short regular intervals such as every 15-minutes or half hour. Detailed interval energy consumption data makes it possible for the mining operation to see electricity waste patterns that would be impossible to see otherwise. For example, there is no way that weekly or monthly meter readings can show how much electricity is used at different times of the day, or on different days of the week. Seeing these patterns will make it easier for NDC to find areas where energy is wasted at the mine (Energylens, 2011).

6.2.4.2 Finding and Quantifying Opportunities to Save Energy

This step entails finding and quantifying opportunities to save energy. The detailed meter data collected will not assist one to find and quantify energy-saving opportunities. Detailed interval data allows one to estimate how much energy is being wasted at different times. Total energy used is calculated from which proportion of energy being wasted can be estimated. The detailed meter data will not necessarily help the mining operation to find equipment or facility-related opportunities; it will be useful for quantifying the potential savings that each opportunity could bring. Meter data could be analyzed to find and quantify routine energy waste, and also investigate the electricity savings that the mine could make by replacing equipment (Energylens, 2011 and Hunter, 2011).

6.2.4.3 Targeting the Opportunities to Save Energy

This step involves targeting the opportunities to save electricity at the mine. Energy saving opportunities will require the energy manager at NDC to motivate employees and upgrade the equipment, facilities or devices used. New Denmark is currently working on a number of projects in order to save energy, such as fan optimization and so forth (Lawrence, 2011).

6.2.4.4 Tracking Progress at Saving Energy

Energy data should be analysed regularly to check that things are not getting worse. At a minimum energy data should be analysed once a week to ensure that nothing has gone horribly wrong (Energylens, 2011).

Ideally, energy-management drive will be an ongoing effort to find new opportunities to target (step 2), to target them (step 3), and to track progress at making ongoing energy savings (step 4) (Energylens, 2011).

6.2.5 Energy Security

Energy security is of paramount importance in order to ensure long-term sustainability of New Denmark Colliery. Eskom has raised different initiatives that can be used by mines to reduce the need for peak power demand. Demand Side Management (DMS) can be used to limit the growth of energy demand. This initiative can be used by NDC in order to minimise energy demand. DMS is a measure used to secure energy for short term in a mine by reducing electricity consumption during peak consumption periods. It is achieved through energy efficient measures and technologies, energy conservation, load shifting (load management) and load shedding (illustrated by figure 53) (Govender, 2011). This will allow NDC to receive a constant and reliable supply of electricity; simultaneously saving energy costs.

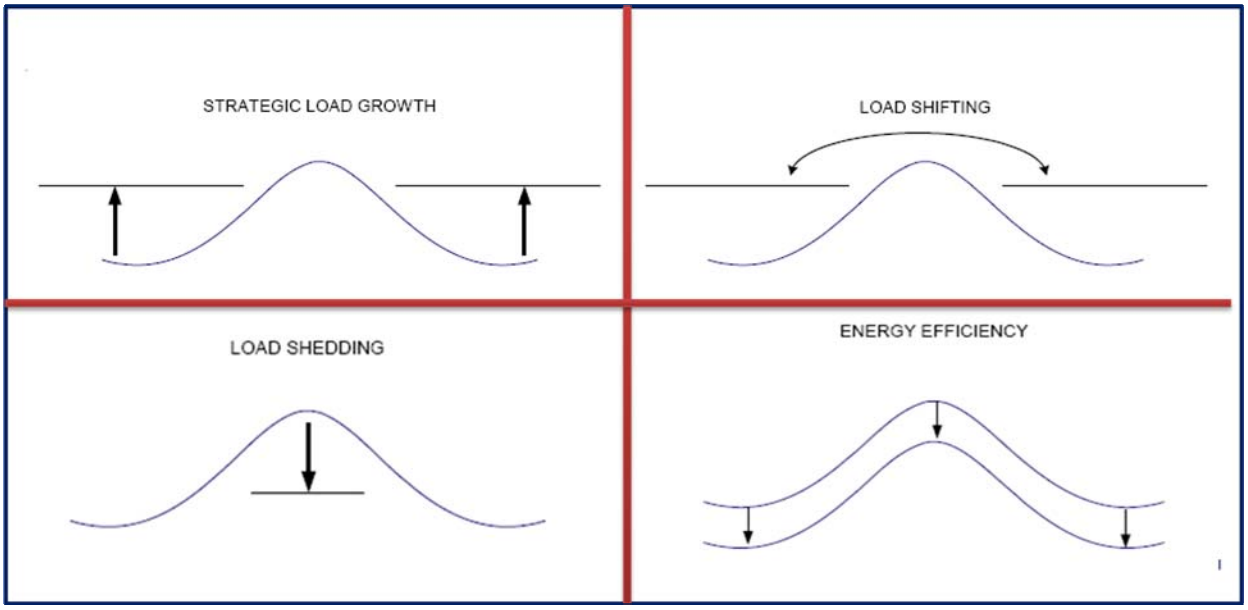


Figure 53: Demand Side Management (DSM) options (Govender, 2011).

Strategic load growth involves the creation of additional electricity sales through growth initiatives which utilities use if they have surplus power. Load shifting or load management refers to a strategic scheduling plan in which the mine reduces its usage of energy during peak hours when energy is most expensive and in short supply, into standard and off-peak hours, when the demand is not as great. This has the effect of lowering peak demands of the country and assists Eskom to avoid mandatory load shedding in order to meet escalating demands. Energy Efficiency is the decrease of energy consumption of a particular end-use with the intention of reducing the peak load demand. DMS options can be used by NDC to lower its energy consumption and enhance energy security (Govender, 2011 and Anglo, 2010).

Based on the findings of the report, major consuming activities at the mine (NDC) are during peak periods in a day (06:00 – 10: 00 AM and 05:00 – 08:00 PM). It can be recommended that NDC should shift its load such that during peak hours to lower the level of electricity consumption. This gives the mine an opportunity to reduce the electricity costs. The author further recommends that the electricity consumption should be kept to a minimum during the high demand season in order to save costs.

6.2.6 Educational Programs, Communication and Training

Energy savings that come from behavioural changes can be achieved through educational programs, training and communication. The main objective of training sessions is to create new competencies within the company; and the primary purpose of communication is to raise awareness. Training sessions created through informal/formal meetings, workshops, documents, courses and documents should be used by the NDC to create competencies with regards to energy management. Communication tools that can be used to promote energy management initiatives include the following: internal newsletters, announcements from senior management, work groups, special events days such as “Energy Days”, e-mail posters, calendars and stickers (Anglo, 2010).

6.2.7 Energy Efficient Technology

One of the ways in which New Denmark Colliery and other Anglo American Thermal Coal operations can accomplish electricity management is through the promotion of energy efficient technologies (machineries, facilities, energy efficient lighting, appliances and so on). Energy efficient technologies use less electrical power as a result the overall electricity consumption (load profile) will be lower; this will reduce operational costs of the mine. Energy efficient technologies should be used for activities that consume most of the electricity such as: mining, ventilation and transportation. A certain amount of capital will be required in order to invest in energy efficient technologies (Anglo, 2010 and Wisegeek, 2011). The biggest electricity consumers at NDC include ventilation, mining and transportation; thus they should be given more priority than other activities at the mine.

6.2.8 Other Tools (Information Systems and Investment)

Other tools that can be used by the NDC to promote energy management strategies include the following: information systems and investment. Information systems should be used to monitor, set targets and report on energy consumption level at the mine. Industry experience shows that monitoring, targeting and reporting alone can lead to significant reductions of electricity consumption. The architect of the information systems should be able to illustrate energy consumption and costs trends, comparisons and daily changes; this will help the energy management team to monitor and identify opportunities for improvements (Anglo, 2010).

Energy management is not free and neither should it cost the colliery an insuperable sum of money. Investment will be required for process improvements, new equipment, and upgrading old energy inefficient technology. Investments in marketing, training, and upgrades of information systems will also be vital. Eskom has incentive programmes in place for energy saving projects (Anglo, 2010).

6.2.9 Energy Policy

The energy policy is a formal written policy acting as a public expression of the colliery's commitment to energy management. It is also a working document to provide for and ensure sustainability in energy management practices. Energy management is likely to be more successful and supportive in saving energy if there is a clear statement of the goal; it is adequately staffed and funded; and has backing by top management. An energy policy sets the standard for taking action by establishing clear roles and accountabilities. It has three major functions in a mining operation: to harmonize energy improvements internal to the organization; helps to improve productivity and provides entry to new business opportunities; and to prepare the organization for outside scrutiny and opportunities, such as compliance and market development (Anglo, 2010 and Energy pathfinder, 2011).

NDC should structure its energy policy such that it is aligned to operational practice of the mine and also energy strategy of Anglo American Thermal Coal. The energy policy should be reviewed on an annual basis and it should also be accompanied by action plans for achieving its objectives.

6.2.10 Benefits of Energy Management

Implementation of energy management techniques at New Denmark Colliery will have number of benefits, such as: operational efficiency; optimisation of electricity consumption and costs; and reduction of carbon footprint. The author did a scenario analysis in order to estimate the financial gain that the operation will achieve if it reduces quantity of electricity used through energy saving initiatives. If NDC reduces its energy consumption by 5 percent per annum; based on that target; the production schedules of the mine; and electricity forecast in section 5; the author estimated the financial saving and reduction of carbon footprint that the operation will achieve. The results are presented in appendix E. The mine will potentially save up to R18.2 million over a 5 year period (year 2012 to 2016) and approximately R3.6 million per annum. Carbon dioxide emissions will be reduced by 4596 tons per annum.

7. CONCLUSION

Energy is an essential driving force behind industrial activities and other sectors of economic development across the globe. The importance of energy is much more than its direct contribution to the national product because it does not only serve as a basic input but also acts as a catalyst for development and growth. Based on the findings of the literature review it can be inferred that South Africa is a comparatively energy and carbon intensive country with respect to other African countries and developed nations. The mining industry is one of the major consumers of electricity in South Africa; accounting for approximately 17.4 percent. The demand of electricity in South Africa has been increasing over the years, towards the end of 2007 and into 2008 it outstripped the available supply infrastructure to the point where the country suffered rolling blackouts.

The power crisis affected the production, profitability, safety standards, productivity of operations, beneficiation strategy and international competiveness of mining companies in South Africa. It became imperative for mining companies to do detailed studies at an operational level on the critical aspects of energy economics and management in order to identify potential areas of improvement, establish energy standards, reduce energy consumption and secure long term energy supply.

The case study of the research was New Denmark Colliery, one of the major electricity consumers in Anglo American Thermal Coal; accounting for more than 13 percent of the total electricity consumption. NDC is a domestic operation which is tied to Eskom (Tutuka Power Station) on a contract basis. It can be inferred from the findings of the study that electricity is the main source of energy used at NDC accounting for more than 90 percent of the energy type consumed. It can be concluded that mining, ventilation and coal transportation consume relatively more electricity compared to other activities at the mine. It can be further submitted that the higher the level of production the higher the quantity of electricity consumption.

The amount of electricity consumed per tonne of coal produced has been fluctuating over the years due to section moves, change in machineries, production schedule and so on. It can be further concluded from the monthly comparative studies that more electricity is consumed during high demand season (May, June, July and August). It can be submitted that the level of energy consumption is directly proportional to the amount of carbon dioxide emissions. Comparatively, NDC has the fourth largest carbon footprint in relation to other Anglo American Thermal Coal operations.

The manner in which mining operations consume electricity affects their average cost of electricity which in turn affects the profitability of the mine. It can be concluded that electricity constitutes larger percentage (more than 90 per cent) of energy cost at NDC. The mine constitutes more than 10 percent of the total cost of electricity at Anglo American Thermal Coal. It can be inferred that the total cost of electricity has been increasing over the years; influenced by the following factors: tariff rates, inflation, structure of the production schedules and mining conditions. In a period of four years, the average cost of electricity increased by more than 65 percent. The increase in the cost of energy has the potential to affect the financial viability of New Denmark Colliery in the future because it will increase the operating cost of the mine. High electricity costs will make it expensive for the mine to extract coal.

It can be deduced from the forecast (estimated using trend projection method) that the level of electricity consumption will increase in the upcoming years. It can further be concluded that the electricity costs will increase at an alarming rate due to annual increase in tariff rates, inflation and changing tariff structure; among other factors. It becomes necessary for New Denmark Colliery to find ways of cutting electricity costs through operational practices that optimises consumption of electricity.

The study recommended number of tools and mechanisms that can be used by New Denmark Colliery and other mining operations to decrease energy consumption, minimise energy costs

and secure long term sustainability; namely: energy management standards; energy management processes; energy accounting and auditing; educational programs and training; energy efficient technology; Information systems and investment; and energy saving strategies. It is further recommended that these tools should be aligned to company policies and operational practice in mines. The following must be clearly defined and outlined in mining operations:

- A framework for understanding significant energy uses in a mining operation;
- Action plans for improving energy performance;
- Organizational framework and structure to sustain energy performance improvements over time and change of personnel;
- Energy policies and training of procedure; and
- Identified key performance indicators to measure progress and optimize energy and costs.

The author further recommends that additional studies should be conducted on financial analysis (cost benefit analysis) of how investment in energy management initiatives, facilities, etc can affect the micro and macroeconomic structure of mining operations and companies.

As the mining industry expands, consumption will grow proportionately but the costs associated with energy will grow faster, resulting in a potentially negative impact on profit margins. Risks associated with reliability and securities of supply; as well as the emerging international and national environmental legislations, are also likely to increase. The mining industry can become part of the energy solution by managing its energy consumption levels optimally. This will promote long term sustainability of the industry and its role in developing the economy of South Africa.

8. APPENDICES

Appendix A: South African energy gap and capacity reserve statistics (Anglo, 2011).

ENERGY					
	2010	**2011**	**2012**	**2013**	**2014**
Energy Required (GW)	250.42	258.58	265.44	273.17	279.75
Supply Available	254.92	258.58	258.26	266.02	277.84
Comment: Energy Gap = (Energy required - Supply available)/(Energy required)					
Energy Gap (GW)	-1.80%	0.00%	2.70%	2.62%	0.68%
CAPACITY					
	2010	**2011**	**2012**	**2013**	**2014**
Capacity Required	38.84	40.23	41.36	42.83	44.78
Supply Available	45.21	46.19	48.33	49	52.26
Comment: Capacity Reserve = (Capacity required - Supply available)/(Capacity required)					
Energy Gap	-16.40%	-14.81%	-16.85%	-14.41%	-16.70%

Appendix B: Electricity Demand, Consumption and Cost for the year 2009 and 2010 (NDC, 2010 and NDC, 2011).

		2009			**2010**		
Months	**NMD**	**Max kVA**	**kWh**	**Cost**	**Max kVA**	**kWh**	**Cost**
January	17500	14063	5636067	1189773	15289	5358853	1540990
February	17500	15328	6100757	1274198	19009	7850931	2151114
March	17500	15372	6225035	1297844	19607	6697670	1875138
April	17500	14559	6061027	1271603	17183	6949348	2206953
May	17500	15333	5537570	1201495	18442	6280936	2191703
June	17500	16215	6899684	1964188	20219	8099898	3903036
July	17500	17106	7071459	2930845	18194	7702352	4183445
August	17500	16018	7269939	3136783	18851	7959794	4144802
September	17500	16756	6861817	2217602	16752	7061016	2849190
October	17500	16745	6993847	1915482	17623	7628270	2570491
November	17500	16554	6253285	1744550	17547	7105619	2307577
December	17500	15917	6341515	1749161	16583	7086730	2297249
	Total	189966	77252002	21893524	215299	85781417	32221688
	Minimum	14063	5537570	1189773	15289	5358853	1540990
	Maximum	17106	7269939	3136783	20219	8099898	4183445
	Average	15830.5	6437667	1824460	17941.58	7148451	2685141

Appendix C: Predicted Eskom tariffs increase for the next five years (Source of Data – Anglo, 2010)

Calendar Year	**2010/2011**	**2011/2012**	**2012/2013**	**2013/2014**	**2014/2015**
Period Year	0	1	2	3	4
Predicted Electricity Increase (%)	24.8%	25.8%	25.9%	10.0%	10.0%
Comment: Electricity Cost (current year) = Electricty Cost (previous yr) x (1 + predicted % increase)					
Electricity Cost (c/kWh)	38.86	48.89	61.55	67.70	74.47
Comment: Assumed operational time of 365 days per annum and 24 hours a day					
Annual Electricity Cost per kW (R)= Electricity Cost (c/kWh) x 24 2 365					
Annual Electricity Cost per kW (R)	3404.14	4282.40	5391.55	5930.70	6523.77
Comment: Assumed 6% adjustment percentage for the present value					
Formula for PV factor = 1/(1+adjustment factor)^period					
Present Value (PV) Factor	1.00	0.94	0.89	0.84	0.79
Comment: PV Value for each year = PV factor x Annual Elecity Cost per kW®					
Present Value (PV) for each year	3404.14	4040.00	4798.46	4979.53	5167.44
Five year PV cost for one KW (Sum)	**22389.56**				

Appendix D: Electricity cost forecast for New Denmark Colliery.

Appendix E: Financial benefit (savings) of electricity management (reduction) forecasts

REFERENCES

AMEU Conference Stellenbosch (2010) *Electricity Supply versus Demand for the Medium Term*, Internet Site: http://www.google.co.za/search?hl=en&q=AMEU+CONFERENCE+%E2%80%93+STELLENBOSCH%3B+SEPTEMBER+2010%3BELECTRICITY+SUPPLY+vs+DEMAND+SCENARIOS+FOR+THE+MEDIUM+&btnG=Search&aq=f&aqi=&aql=&oq=, Date accessed: 19 February 2011

Anglo American Thermal Coal, *Energy Matters to You*, Energy Booklet of Anglo American Thermal Coal, Internal and Unpublished Document, Page 1-6

Anglo American Thermal Coal (2010) *Production Analysis and Forecasts*, Mining and Planning Department, New Denmark Colliery, Page 2-4

Anglo American: The Source (2008) *CEO News: Electricity Supply and its Impact on Anglo Coal South Africa,* Internet site: http://thesource.anglo.local/bu/thermcoal/news/News/Pages/e5a06c4ca02b683.aspx; Date accessed: 13 January 2011

Anglo American Thermal Coal (2009) *Anglo American Energy Booklet* ; Internal and Unpublished

Anglo American Thermal Coal (2010) *Company Overview: Anglo American Thermal Coal*; Internal and Unpublished ; Page 8-15

Anglo American Thermal Coal (2010) Electricity and Mining, The source: Energy; Internal and Unpublished; Page 14-19

Anglo American Thermal Coal (2010) *Quarterly Energy Meeting Presentation*; Internal and Unpublished Document; Slide 4 - 8

Anglo American Thermal Coal (2009) *Review on Energy Presentation*; Internal and Unpublished Document; Slide 16 - 19

Anglo American Thermal Coal (2011) *Bau Energy Projection*; Internal and Unpublished Document; Page 2-10

Anglo American Thermal Coal (2011) *Climate Change and Energy*; SHE Divisional Committee & Environmental Co-ordinators; Monthly Report; Internal and Unpublished Document; Page 6-15

Anglo American Thermal Coal (2011) *Eskom Budget Presentation*; Internal and Unpublished Document; Page 2 - 7

Anglo American Thermal Coal (2010) *Production Analysis and Forecasts*, Mining and Planning Department, New Denmark Colliery; Page 2-4

Anglo American Thermal Coal (2012) *Production and Financials Report*, Internal and Unpublished Document; Page 1-2

Beggs, C (2002) *Energy and the Environment*; Energy Management, Supply and Conservation; Page 15-18

Beggs, C (2002) *Energy Auditing and Surveying*; Energy Management, Supply and Conservation; Page 114-128

Business Wire (2009) *Research and Markets: A Strategic Analysis of South Africa's Coal Mining Industry* Internet Site: http://www.businesswire.com/news/home/20091027006156/en/Research-Markets-Strategic-Analysis-South-Africas-Coal; Date accessed: 18 March 2011

Davis, S (2010) A South African Case Study: Measuring the Rebound Effect of Energy Efficiency Initiatives for the Future; Page: 1-7; Internet Site: http://www.erc.uct.ac.za/Research/publications/10-Davis_Rebound_effect.pdf; Date accessed: 15 May 2011

Department of Planning and the Environment (1977)*The Outlook for Energy in South Africa*, A Report for a Subsidiary Committee of the Prime Minister's Planning Advisory Council, Republic of South Africa, Page 18-39

Department of Minerals and Energy (2008) Energy Balance for South Africa; International Workshop on Energy Statistics; Slide: 16 - 25; Internet site: http://unstats.un.org/unsd/energy/meetings/mexico2008/Presentations/Session%207%20-%20South%20Africa.pdf; Date accessed: 10 April 2011

Doug, L (2008) *What Future for Coal in South Africa?* Page: 1-8; Internet Site: http://www.lincenergy.com/data/media_news_articles/news-18.pdf; Date accessed: 15 May 2011

Dahl, C (2004) Energy Lessons from the Past to the Future; International Energy Markets – Understanding Pricing, Policies and Profits; Page 24

Energy Lens (2011) Energy Management; Internet site: http://www.energylens.com/articles/energy-management; Date accessed: 22 June 2011

Eskom (2010) Information Sheet: Climate Change; Page: 3-8; Internet Site: www.eskom.co.za/content/GI%200099ClimateChange~1.doc; Date accessed: 15 May 2011

Eskom (2010) Coal in South Africa; Page: 1-2; Internet Site: http://www.eskom.co.za/content/CO_0007CoalSARev9.pdf; Date accessed: 20 May 2011

Eskom (2010) Financials – New Denmark Colliery Presentation; Tutuka Power Station; Internal and Unpublished Material; 4-7

Electricity Governance Initiative of South Africa (2010) *The Governance of Power: Shedding a Light on the Electricity Sector in South Africa;* Page 3-5; Internet Site: http://electricitygovernance.wri.org/files/egi/EGI-SA%20report%20-%20The%20Governance%20of%20Power%20(Feb2010)-cover.pdf; Date accessed: 14 May 2011

Eskom (2010) *Coal Power*; Internet Site: http://www.eskom.co.za/c/article/200/coal-power/; Date accessed: 18 March 2011

Eskom (2010) *Information Sheet: Climate* Change; Page: 2-8; Internet Site: www.eskom.co.za/content/GI%200099ClimateChange~1.doc; Date accessed: 15 May 2011

Eskom (2010) Coal in South Africa; Page: 1-2; Internet Site: http://www.eskom.co.za/content/CO_0007CoalSARev9.pdf; Date accessed: 2010

Eskom (2010) *Company Profile: Eskom*; Page: 1-2; Internet Site: http://financialresults.co.za/2010/eskom_ar2010/downloads/01_profile.pdf; Date accessed: 18 March 2011

Eskom (2010) *Fact Sheet of Eskom : Transmission and Distribution of Electricity;* Page: 1-2; Internet Site: http://recruitment.eskom.co.za/content/TD_0003TxDxelecRev4.pdf; Date accessed: 03 March 2011

Eskom (2010) Generation Business; Integrated Report; Page 1-13 Internet Site: http://financialresults.co.za/2010/eskom_ar2010/downloads/08_generation_business.pdf; Date accessed: 03 March 2011

Eskom (2008) *Developing a Power Conservation Programme for South Africa*; PCP Integrated Strategy; Page 1-3

Eskom (2010) *Fact Sheet: The Formation of Coal*; Page: 1-2; Internet Site: http://www.eskom.co.za/content/CO_0009FormCoalRev4~1.pdf; Date accessed: 18 March 2011

Exxaro Resources (2008) *Energy and Mining: The Impact of One on the Other*; SANEA Business Breakfast Meeting; Page 3-18; Internet Site: http://www.exxaro.com/pdf/sanea_may_08.pdf; Date accessed: 14 May 2011

Govender, S (2008) Energy Saving Mechanisms in The Mining Industry: A Case Study of Switching off Non-Essential Power; University of Stellenbosch; Page 5 – 12; Internet site: http://scholar.sun.ac.za/bitstream/handle/10019.1/843/govender_energy_2008.pdf?sequence=1; Date accessed: 06 June 2011

Hunter, M. (2011) *Personal Communication with the Author;* November 2011

Investopedia (2011) What Is Forecasting; Internet Site: http://www.investopedia.com/terms/f/forecasting.asp; Date accessed: 14 October 2011

Itseezy (2009) Economics of Power Supply and Generation of Power; Internal and Unpublished Document; Page 3-11

Itseezy (2009) Supply Systems; Internal and Unpublished Document; Page 2-7

Lawrence, C. (2011) *Personal Communication with the Author;* November 2011

Marx, W (2009) Initial Assessment of Main Fan Energy Saving Potential For Anglo Coal; Mine Ventilation and Refrigeration Specialists; BBE Consulting; Page 16

Mtegha, H (2011) *Personal Communication with the Author;* October 2011

Nakata, T and Matsumoto, J (2008) The Energy System Analysis And Forecasts of the Republic of South Africa; Page 1-3; Internet Site: http://active.cput.ac.za/energy/web/ICUE/DOCS/353/Paper%20-%20Matsumoto%20J.pdf; Date accessed: 30 June 2011

National Energy Regulator of South Africa (2008) *NERSA Consultation Paper: Power Conservation Programme (PCP) Rules;* Page 4-9; Internet Site: http://www.nersa.org.za/Admin/Document/Editor/file/Consultations/Electricity/Documents/Consultation%20Paper%20Power%20Conservation%20Programme%20(PCP)%20%20Rules.pdf; Date accessed: 15 May 2011

New Denmark Colliery (2010) Power and Production Presentation; Internal and Unpublished Document; Slide 10-24

New Denmark Colliery (2009) Five Year Production Profiles; Internal and Unpublished Document; Page 3 - 9

New Denmark Colliery (2011) Financials of New Denmark Colliery; Internal and Unpublished Document; Page 2- 11

New Denmark Colliery (2010) Environmental Management Programme; Internal and Unpublished Document; Page 1-3

New Denmark Colliery (2011) Production, Electricity and Financials of New Denmark Colliery; Internal and Unpublished Document; Page 13- 21

Wise Geek (2011) What is Electricity Management; Internet site: http://www.wisegeek.com/what-is-electricity-management.htm; Date accessed: 09 June 2011

Oliver, H (2009) *The Demand for Green Electricity amongst residential consumers in the Cape Peninsula*; University of Stellenbosch; Page: 1-9; Internet Site: http://scholar.sun.ac.za/bitstream/handle/10019.1/921/oliver_green%20electricity_2009.pdf?sequence=1; Date accessed: 14 May 2011

South Africa Government (2000) *How Energy Generation Causes Environmental Change in South Africa*; Internet Site: www.environment.gov.za/soer/nsoer/drivers/general/Energy.doc; Date accessed: 14 May 2011

South Africa Energy Data (2010) *Statistics Analysis of Oil, Gas Electricity and Coal*, Country Analysis Brief, Internet Site: http://fayzeh.com/South%20Africa.htm, Date accessed: 19 February 2011

South Africa Information (2010) *South African Energy Supply*, Internet site: http://www.southafrica.info/business/economy/infrastructure/energy.htm; Date accessed: 21 March 2011

South Africa Newyork (2007) *Year Book: Minerals, Energy and Geology;* Page 421-443 Internet Site*:* http://www.southafrica-newyork.net/oldconsulate/about%20south%20africa/2007%20Yearbook/mineral%20enery%20and%20geology.pdf; Date accessed: 20 June 2011

Sterling, V. A (2009) Electric Capitalism: Recolonising Africa on the Power Grid; Page 234; Internet site: http://www.worldcat.org/title/electric-capitalism-recolonising-africa-on-the-power-grid/oclc/255016437; Date accessed: 18 May 2011

The South African National Energy Association (2010) *Renewable Energy in South Africa and the Outlook for Growth*; Page: 13-25 Internet Site: http://www.sanea.org.za/CalendarOfEvents/2010/SANEALecturesCT/Nov17/CornelisVanDerWaal.pdf; Date accessed: 15 May 2011

The World Bank (2010) *The World Eskom Support Program,* Internet site: *http://electricitygovernance.wri.org/news;* Date accessed: 19 April 2011

Tshisekedi J.R.N (2009) Energy Consumption Standards and Costs in South African Gold and Platinum Mines; University of the Witwatersrand Page 4-22; Internet Site: http://wiredspace.wits.ac.za/bitstream/handle/10539/7043/Dissertation.pdf?sequence=11; Date accessed: 20 May 2011

University of the Witwatersrand (2009) *Mining and Energy*; Page 4-22; Internet Site: http://wiredspace.wits.ac.za/bitstream/handle/10539/7043/Dissertation.pdf?sequence=11; Date accessed: 20 June 2011

University of Pretoria (2010) Electricity and the Mining Environment; Chapter 3; Class Notes; Department of Mining Engineering; Internal and Unpublished Document; Page 2-8

Villiers, M (1996) *Effective Energy Management: Opportunity for Increased Profitability*; Energy Research Institute; University of Cape Town; Page: 23 - 26

Winkler, H (2009) *Cleaner Energy Cooler Climate: Developing Sustainable Solutions for South Africa*, Internet Site: http://www.hsrcpress.ac.za/product.php?productid=2237&freedownload=1, Date accessed: 03 March 2011