THE RELATIONSHIP BETWEEN ELECTRICITY SUPPLY, POWER OUTAGES AND ECONOMIC GROWTH IN SOUTH AFRICA

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DECLARATION

In accordance with Rule G4.6.3, I declare that

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is my own work, that all the sources used of quoted have been identified and acknowledged by means for complete references, and that I have not previously submitted this dissertation for assessment to another university or for any other qualification

Hlalefang Khobai

Signature:……..

Date: November 2013

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ABSTRACT

The economic boom in South Africa following the 1994 democratisation led to increased welfare of the citizens and their purchasing power. This further resulted in increase in electricity consumption. The electricity supply did not increase proportionally to the increase in electricity consumption leading to the 2008 shortage of electricity which nearly damaged the power generating circuit.

The literature review has shown that electricity supply and consumption have a positive impact on economic growth. It further showed that employment enhances economic growth. Conversely, it showed that power outages negatively affect economic growth.

The research serves to investigate the relationship between electricity supply and economic growth in South Africa and to examine the impact of power outages on economic growth. It also seeks to find the appropriate structure for electricity supply industry that will lead to increase in economic growth.

The autoregressive distributed lag (ARDL) bounds approach was used to find the relationship between economic growth, electricity supply, power outages and employment using quarterly data from 2000 to 2012. The ARDL technique was chosen over the conventional models such as Johansen technique for the research because it uses a single reduced form of equation to examine the long run relationship of the variables as opposed to the conventional Johansen test that employs a system of equations. The ARDL technique is also suitable to use to test co-integration when a small sample data is used and does not require the underlying variables to be integrated of similar order.

The Vector Error Correction Model (VECM) Granger causality was also employed in the study to establish the causality between economic growth and electricity supply. It was chosen for its ability to develop longer term forecasting, when dealing with an unconstrained model.

The results from the ARDL bounds test showed that there is a long run relationship between economic growth, electricity supply, power outages and employment. Based on the causality tests, the findings showed a unidirectional causality flowing from

electricity supply to economic growth. This implies that electricity supply affect economic growth in South Africa. The results further showed no causality flowing from economic growth to electricity supply which indicates that when economic growth is booming fewer funds are used for improvement of the electricity generation. Lastly, the results showed that power outages negatively affect economic growth in the long run.

To sum up, electricity supply is an important factor for economic growth in South Africa. It is therefore necessary that South Africa must put in place measures aimed at stimulating electricity supply. One of the measures aimed at increasing output of electricity is to unbundle the electricity sector. This process involves allowing entry of the Independent Power Producers (IPPs), Independent System Operator (ISO) and Regional Electricity Distributors (REDs). This will lead to increased supply of electricity and competitively lower prices of electricity. The study further recommends that renewable energy sources should be used to produce electricity instead of coal and nuclear fuels as they failed to produce enough electricity for the nation.

LIST OF ABBREVIATIONS

ARDL	Autoregressive Distributed Lag Model
CEGB	Central Electricity Generating Board
DME	Department of Minerals and Energy
DSM	Demand Side Management
EC	Electricity Consumption
EG	Economic Growth
ENC	Energy Consumption
ES	Electricity Supply
ESI	Electricity Supply Industry
GC	Granger-Causality
IPPs	Independent Power Producers
ISMO	Independent System and Market Operation
MYPD	Multi Year Price Determination
NERSA	National Energy Regulator of South Africa
PPA	Power Purchase Agreement
REDs	Regional Electricity Distributors
RGDP	Real Gross Domestic Product
SAPP	Southern African Power Pool
VEM	Vector Error Correction Model

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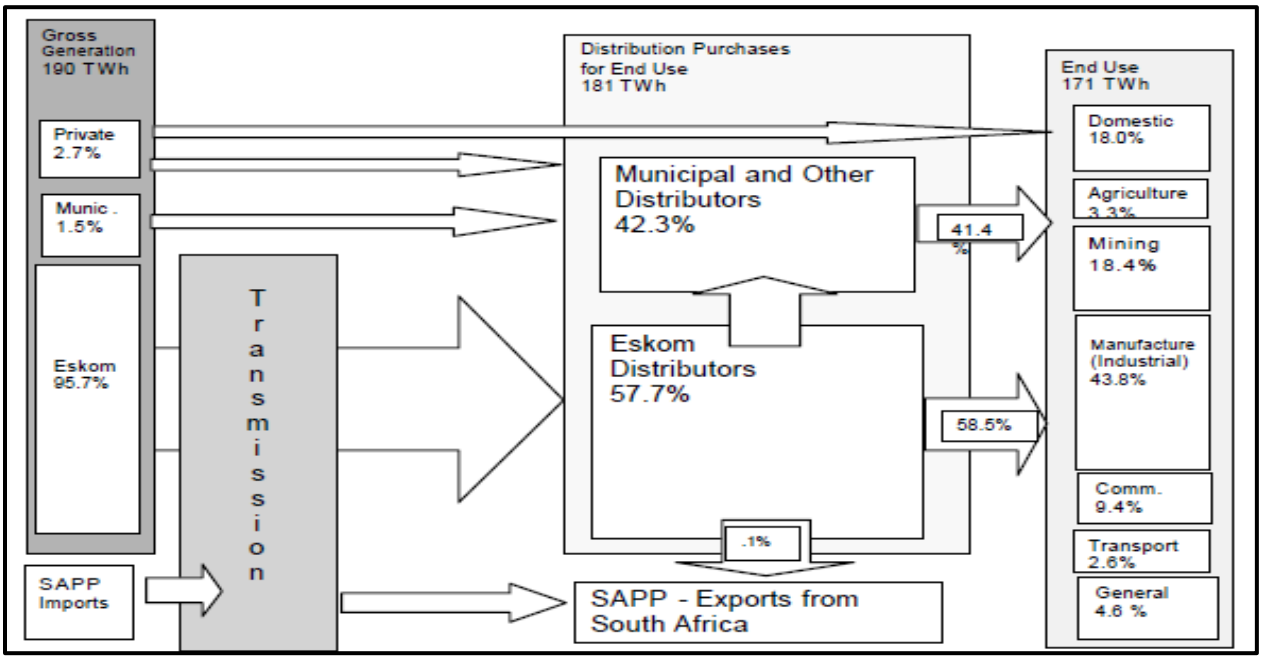
INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 INTRODUCTION

The South African Electricity Supply Industry (ESI) is vertically integrated with a franchise monopoly, the sole supplier of electricity, namely Eskom. The debate to restructure the electricity industry has been going on for more than 20 years, but it has not yet been implemented (Gaunt 2008). As a result Eskom still generates about 95% of electricity in South Africa (Eskom Annual Report 2009). According to (Staartkoerant, 2008), the South African ESI is vertically integrated with Eskom generating 96% (including 5% of imports) of the current requirements, municipalities 1% and the other 3% (inter-alia independent Power Producers: PPAs). According to Figure 1.1 Eskom generates 95.7% of the country's electricity requirement, while municipalities and private organisations produce 1.5% and 2.7% respectively. Eskom controls 57.7% of the requirement for the distribution sector as illustrated in Figure 1.1 whereas only 42.3% goes to municipalities.

Figure 1-1: The South African ESI



Source: Eberhard (2001:1)

In countries such as the UK, Argentina, Chile and Greece, research has shown that a vertically integrated electrical generation, transmission and distribution structure is not the best way to organise electricity generating industries (Letladi 2006). Sarker (2010) stated that in order to formulate policies, such as policies regarding deregulation of an ESI, it is important to know the long run relationship and direction of causality between electricity generation and economic growth.

Many papers have found that electricity and economic growth have a positive long run relationship (Tang 2008; Ouedraogo 2009 and Ankilo 2008). For example, countries with a high per capita GDP have proven to have high per capita electricity consumption. This has led to policy makers becoming interested in investigating whether economic growth stimulates electricity consumption or electricity consumption drives economic growth. The pioneers of the studies on the direction of causality between electricity consumption and economic growth are Kraft and Kraft (1978) and more literature followed thereafter.

Yoo and Kim (2005) stated that there are only a few studies that examined the causality between economic growth and electricity generation. This emphasised the need and

importance for more research to be done. It is possible that causality can flow from electricity generation to economic growth or from economic growth to electricity generation and/or from both directions. It is important for policy makers to know whether electricity generation stimulates economic growth or whether economic growth increases electricity generation.

The direction of causality contains very important policy implications (Jumbe 2004). For instance, Jumbe (2004) stated that the results showing a one-way causality flowing from electricity generation to economic growth means that the country is electricity dependent to the extent that reducing electricity generation may lead to a fall in economic growth. The existence of power shortages in such a country could cause significant harm to its economic growth. On the other hand, a unidirectional causality flowing from economic growth to electricity generation means that the economy is less dependent on electricity in which case a reduction in electricity generation may have less or no effect on economic growth. When there is no causality between electricity generation and economic growth, electricity generation and economic growth are not correlated consequently reducing electricity can not affect economic growth at all.

The policy makers in South Africa have paid less attention to the causality between electricity generation and economic growth. The knowledge of this relationship would play a significant role in the development of the South African electricity supply industry following the electricity power crisis experienced in 2008. The electricity blackouts of 2008 caused severe damage to the industrial sector's production and the loss of leisure time in the household sector. It has led to lower production in most organisations because the parastatal utility, Eskom, instituted electricity conservation policies which forced electricity consumers to use less electricity. It has also led to increases in electricity prices to fund the government's planned increase in electricity generation by building more power stations instead of allowing more players into the industry to generate electricity. Therefore, the purpose of this research is to examine the causality between electricity generation and economic growth and to derive policy implications from the findings.

In the following sections, the problem statement, research objectives and the importance of the research will be discussed. The methods used in the research and the hypothesis will also be reviewed in this chapter.

1.2 PROBLEM STATEMENT

The demand for electricity in South Africa has been increasing very rapidly since the early 1990s (Inglezi 2011). Since democratisation of the country in 1994, the economy underwent significant structural changes. Among these structural changes was electrification for the poor rural areas. Inglezi (2011) showed that during the apartheid era, about two-thirds of the nation lacked access to electricity and hence, provision for electricity to everyone was considered a crucial part of the economic development post 1994. In the study by Odhiambo (2009), it was shown that increasing electricity consumption in South Africa leads to development of the economy.

The CSIR (2010) conducted a study for Eskom to forecast electricity consumption. The study used the following sources of data to examine the behaviour of electricity consumption in South Africa from 1972 to 2009: Statistics SA, Department of Energy, NERSA, South African Energy statistics, Eskom annual reports and Eskom's statistical year book. The results showed that electricity consumption for all the sectors of the economy increased for each sector, but with different magnitude.

The electricity supply did not increase proportionally to the increase in demand. The reserve supply had also been falling over the past years. For example in 2004, the reserve margins were 25 percent, in 2005, it decreased the reserve to 20 percent, in 2006 it fell to 16 percent whilst in 2008 it was 8-10 percent (Government Information 2008). The imbalance in demand and supply of electricity was more extreme in early 2008 when the country experienced power outages. For example, power plants that produced about 8700MW were not available in January 2008 (Government Information 2008). This amounts to a shortfall of 22 percent in electricity supply for that year.

In South African Government (2008), the government planned to increase electricity supply by expanding the electricity power plants and by implementing electricity conservation policies. Consumers and industry were forced to buy less power and this

led to lower production in most industries. The decline in the production of these sectors led to lower economic growth. Another great consequence of the power outages was the increase in the electricity prices. To finance the planned increase in electricity generation, prices had to be increased to meet the cost thereof. NERSA (2008) showed that the expected budget for the new expansion was about R343bn. As a result, electricity prices were anticipated to increase to a level of between 25c/kWh and 30c/kWh (Erero 2010). Eskom requested to increase its price from 14.2% to 53% or at least 60% in nominal terms. If these increases were to continue it was expected that it would double the 2008 prices by the year 2010 (See table 1.1). In 2009/10 the electricity price had increased by 31.30 percent while the inflation rate was only 6.16 percent.

Table 1-1: Eskom's average tariff adjustment for the last 15 years

Year	Average Price Adjustment	CPI
1 January 1996	4,00%	7,32%
1 January 1997	5,00%	8,62%
1 January 1998	5,00%	6,87%
1 January 1999	4,50%	5,21%
1 January 2000	5,50%	5,37%
1 January 2001	5,20%	5,70%
1 January 2002	6,20%	9,20%
1 January 2003	8,43%	5,80%
1 January 2004	2,50%	1,40%
1 January 2005	4,10%	3,42%
1 April 2006/7	5,10%	4,70%
1 April 2007/8	5,90%	7,10%
1 April 2008/9	27,30%	10,30%
1 April 2009/10	31,30%	6,16%
1 April 2010/11	24.80%	5.40%
1 April 2011/12	25.80%	4.50%
1 April 2012/13	16.00%	5.2%

Source: Eskom Tariff and Charges Booklet 2012/13

Table 1.1 shows that the impact of the 2008/9 tariff increases of 14.2% in April and 3.42% in July, led to prices rising above the inflation rate. Schussler (2008) stated that Eskom's price discrimination has led to residential customers being subjected to an increase of about 7.2% per year, which was above the inflation rate (5.7%) between 1996 and 2007. Industrial adjustments however, had always been below the inflation rate. Due to the severe blackouts of 2008, Eskom was forced to make an application to the National Energy Regulator of South Africa (NERSA) for them to review Eskom's prices.

Twine (2010) stated that price hikes will lead to operating margins being cut in many businesses. They will also add to government expenditure as the government is the largest consumer of electricity. OECD (2011) also showed that the price increases impacted negatively on residential property landlords because it would lead to a 30% increase in costs, while mortgage approvals would be badly affected resulting from the fall in potential buyers' disposable income. Odendaad (2010) agreed that the price hikes put the average South African workers at risk of losing their disposable income because a large share of their salaries would be absorbed by electricity cost. Odendaad (2010) believed that this would result in an increase in the interest rate because of the rise in inflation rates. Value added tax (VAT) would also increase as the price increase of an item leads to an increased VAT per item.

Eberhard (2001) stated that in the long run, South Africa's electricity supply industry would face the problem of meeting the ever-increasing demand for electricity because they did not invest in new power generation plants. The last major investment in generation was in the 1970's and 1980's. Proactive electricity utility managers would have realised that there is a need to invest in infrastructure. It was indicated in the South African government's White Paper that there is an imbalance between electricity supply capacity and the ever increasing electricity demand, indicating that there is a need for further investment in the expansion of electricity generating capacity (Erero 2010).

The electricity power outages of 2008 were foreseen and were supposed to have been avoided in time (Eberhard, 2001). Some of the economic indicators, such as

employment, were affected due the power outages which compelled firms to lay off staff as a result of the fall in production. It is therefore important to establish whether electricity generation contributes to economic growth of the country and develop better policies that would promote economic growth.

1.3 THE PURPOSE OF THE RESEARCH

The purpose of this research is to investigate the causality between electricity supply and economic growth in South Africa. It also serves to determine the impact of the power outages on economic growth. Through examining these factors, the guidelines can be given to Eskom and the government on how to ensure secure supply of electricity to avoid power outages.

1.4 RESEARCH OBJECTIVES

The primary objective of the research is to examine the relationship between electricity generation and economic growth in South Africa. The secondary objectives include:

- To determine the impact of electricity outages on economic growth;
- To examine the structure of the electricity supply industry that would be efficient to enhance the country's economic growth, and
- To explore the policy measures that will improve electricity supply.

1.5 IMPORTANCE OF THE STUDY

Electricity is important for labour, capital and other factors of production. It is also essential in modern technology. It is therefore crucial to ensure a good supply of electricity. The experience that South Africa had in power outages triggered the interest of policy makers to invest more in electricity related studies. The way in which the important sectors of the economy were affected by power outages proved the importance of an efficient electricity supply. By improving the electricity supply, production of other sectors is stimulated. This will lead to high levels of employment and betterment of the community as a whole.

The literature available on research with a focus on the relationship between electricity generation and economic growth is limited. The study will therefore add to the literature on the electricity supply side. It will also make policy recommendations for electricity supply in South Africa. The studies by (Odhiambo 2009; Bildirici 2012 and Tang 2008) showed that electricity consumption increased the country's economic growth but Eskom decided to incentify industries to consume less electricity. This indicates that the greatest problem of inefficiency exists in the supply side of electricity in South Africa. Therefore, the major contribution of this research is to use co-integration techniques to examine the relationship between electricity generation and economic growth in South Africa. It also involves investigating the direction of causality by using the Granger-causality test. This would hopefully lead to this research presenting important policy measures that would be useful to Eskom and the economy at large.

1.6 RESEARCH METHODOLOGY

The focus of this dissertation is to examine the causality between electricity generation and economic growth. It will therefore be limited to investigating secondary data and econometric analysis. It will use the Autoregressive Distributed Lag model for testing the long run and short run relationship between electricity generation and economic growth. It will further use the Vector Error Correction Model (VECM) Granger-causality test to determine the direction of causality between the two variables. Labour and power outages variables will be added to the model of this research to form a multivariate framework.

Data for the study for electricity generation will be collected from Statistics South Africa and the data for economic growth and labour will be gathered from the South African Reserve Bank and IMF international financial statistics respectively.

1.7 DIVISION OF CHAPTERS

Chapter One comprises the introduction to this research. Chapter Two will discuss the economic growth of South Africa, its experience of power outages and history of electricity demand and supply. It will be followed by a review of relevant literature in Chapter Three. Chapter Four will discuss the methodology of the research. The main

findings will follow in Chapter Five and the conclusion and recommendations in Chapter Six.

1.8 CONCLUSION

Chapter One consists of the introduction to the research. It first described the importance of electricity to the economy as a driver of labour, capital and other factors of production. It continued to discuss the relationship between electricity generation and economic growth and the relationship between electricity consumption and economic growth. It indicated that the knowledge of the long run relationship and the direction of causality between these variables have significant policy making implications.

The structure of the economy was shown to have changed since the beginning of democratisation of the country in 1994. The economic growth had been increasing which consequently led to an increase in electricity consumption. This showed a positive relationship between electricity consumption and economic growth. The high increases in the electricity consumption caused an imbalance in electricity supply as the supply did not increase proportionate to consumption. This led to the 2008 power outages which caused stoppages in industries and losses in terms of production, hence leading to many employees being laid off.

Chapter One further described the increases in the price of electricity after the 2008 power outages. The power outages increased the electricity prices to an extent where it surpassed the rate of inflation in 2009/2010. The cost of electricity outages and subsequent increase in the price of electricity leads to the statement of the problem from which the research objectives are derived. The research objectives seek to analyse the decision made by Eskom when urging the companies to buy less electricity in trying to establish a balance between electricity supply and demand; this could result in less production in the country and hence low economic growth.

The importance of the research is to add to the existing literature and assist policy making that will increase the supply of electricity that would establish a balance between demand and supply, and not to reduce the demand for electricity. The

research methodology was also discussed in this chapter, showing how and where data will be collected and the methods to be used in analysing and interpreting the data.

In Chapter Two the economic growth in South Africa, electricity supply and demand will be discussed as well as the history of economic growth in South Africa. It will show the relationship of economic growth between both electricity supply and demand. Furthermore, it will discuss the history of power outage and how they affected the production of the household, industrial, mining and farming sectors of the economy, and its impact on economic growth. The potential reforms for the electricity supply industry, the structures which have been proposed, and the structures which can work well for South Africa will be reviewed.

Chapter 2

OVERVIEW OF THE SOUTH AFRICAN ESI

2.1 INTRODUCTION

The 2008 blackouts negatively affected the electricity consumers in South Africa. The electricity outages were the result of the electricity generation capacity failing to meet demand (Hoops 2010). The blackouts threatened to destabilise the national grid and, as a result, the electricity utility (Eskom) was forced to ration electricity to consumers. The consumers of electricity in South Africa include: industrial, agricultural, transport, commercial, mining and residential consumers (see figure 2.2).

The blackouts left the electricity supply utility with no option but to increase the generation capacity. This is going to take time to be accomplished because of the complicated structure of the ESI and the number of players in the industry who are involved in executing the plan. It has been shown, in the previous chapter, that the current monopoly structure is inefficient. This will further be discussed in the current chapter to show how the monopoly structure is costing South Africa. For example, one of the solutions to stop power shortages, decided by Eskom, is to implement the energy saving programmes and the strategies that reduce consumption. This is a typical decision that can be made by a monopolist, resulting into a negative effect to economic growth.

The role players in South Africa will also be highlighted. These role players include: the Department of Minerals and Energy (DME), the National Energy Regulator (NERSA) and the Electricity Distribution Industry Holdings (EDI Holdings) (Hoops 2010). These role players must work together with Eskom to ensure that enough electricity is provided to all the citizens while developing the plan of building a new power station. Eskom must also devise some technological means to keep demand and supply of electricity in balance.

The reform of the electricity supply industry will also play a huge role in increasing generation capacity. Existence of competition will allow more players into the industry

and help to supplement the existing capacity. For example, in South Africa the Independent Power Producers (IPPs) could be given a larger market share and as a result help to reduce the shortage of power. This will lead to the proposed structure for the ESI being reviewed. The objectives that the government hopes to achieve through the electricity industry will be reviewed in this chapter. The chapter will serve to determine whether the existing structure matches with the government's objectives.

Finally, this chapter is going to discuss the crisis that ESI in South Africa has experienced because of the existing structure. It will divide the discussion of the crisis into: the pre-2008 crisis (which led to the 2008 load shedding) and the post 2008 crisis. It will further discuss the utility's decisions that have cost the electricity consumers. For example, the government's decision not to allow Eskom to build more power stations in the early 2000. It is also going to discuss the experience of other countries with power outages and show the means they used to prevent consumers from being affected by power shortages.

2.2 ESKOM

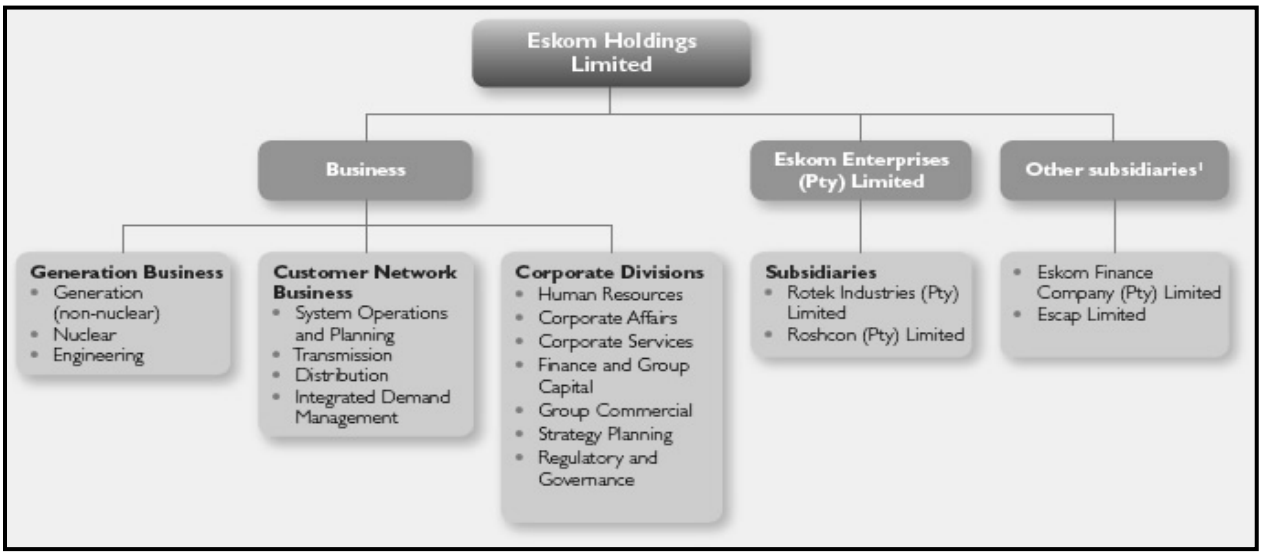
Eskom is a South African electricity state-owned utility. It is the largest producer of power in Africa and in terms of sales and size, ranks seventh globally (Eberhard 2002). Eskom was established in 1923 in terms of Act of 1922 as Electricity Supply Commission (Escom) (Eberhard and Mtepa 2003). In 1985 the Commission recommended that changes be implemented on the organisation and the new Act of 1987 was passed. The name of "Escom" was changed to "Eskom" in terms of this Act (Eberhard and Mtepa 2003). The Minister of Minerals and Energy appointed an electricity council made up of municipal distributors, government representatives and the larger consumers of electricity.

Eskom was freed from requesting for a licence in order to regulate its prices and the Electricity Council Board began to have a little say in the operations of Eskom. Hoops (2010) purported that the Electricity Council Board became answerable to the tariff structures, while Eskom took over the tariff levels. During the 1990s, further changes in the electricity organisational structure were made. A massive electrification programme

was implemented, which led to about two-thirds of the population getting electricity. In this regard, the National Electrification Forum proposed that the distribution sector should be restructured and the Electricity Control Board be changed to the National Electricity Regulator (NER) (Eberhard and Mtepa 2003). In 1995, the NER was formed for the purpose of regulating the whole industry (Hoops 2010). In 2005 the national regulator changed to the National Electricity Regulator of South Africa (NERSA).

Figure 2.1 below shows the current structure of Eskom. The old Eskom, which was formed under the Act of 1987, was replaced by the Eskom Conversion Bill of 2001 and was named Eskom Holdings Ltd (Eberhard and Mtepa 2003).

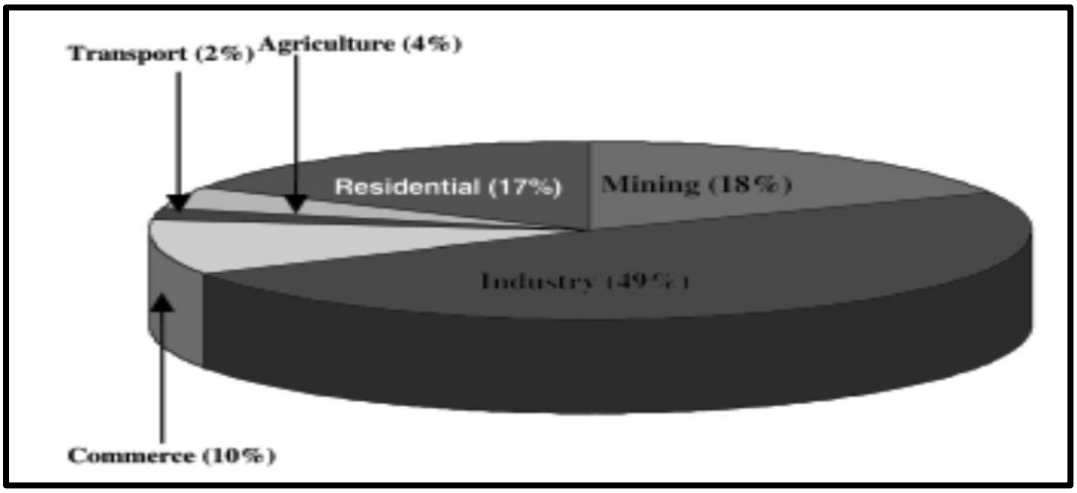
Figure 2-1: Current Structure of Eskom



Source: Eskom (2011)

Bulk consumers of Eskom electricity include large industries, mines and some mineral beneficiaries (Hoops 2010). Figure 2.2 shows Eskom's customers and the percentage of the amount of capacity each buys. It shows that the industrial consumers use more electricity than all other consumers, while the transport and agricultural consumers are the least electricity consumers. Eskom also sells electricity directly to the municipalities, which in turn sells it to its own areas.

Figure 2-2: Categories of electricity consumers

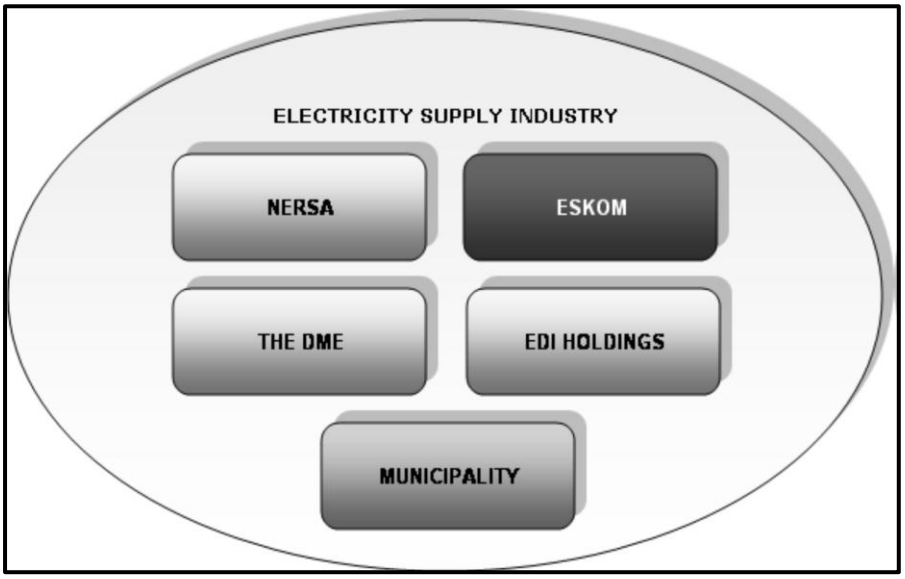


Source: Nortje (2006): Eskom DSM

2.3 ROLE PLAYERS IN THE ESI OF SA

Eskom does not make decisions on its own. There are other role players in the electricity industry who share the responsibility of activities. In South Africa these include: the Department of Energy, the National Energy Regulator, the Electricity Distribution Industry (EDI) Holdings and the Municipalities. See Figure 2.3 below.

Figure 2-3 Role players in the South African ESI



Source: Hoops (2010:27)

2.3.1 Department of Minerals and Energy

The Department of Minerals and Energy (DME) is the government organisation responsible for optimal usage of South Africa's mineral and energy wealth. It also manages the mining and electricity sectors. DME sets the policies for the energy industry (Gaunt 2008). The National Electricity Regulator of South Africa (NERSA) of 2005 was appointed by DME. The Electricity Distribution Industry (EDI) Holdings is also under the ownership of the DME.

2.3.2 Electricity Distribution Industry (EDI) Holdings

The Electricity Distribution Industry Holdings was created by the Department of Energy in 2002. In 2003, the Chief Executive Officer and the Board of Directors were appointed (Gaunt 2008). This was established in terms of the Energy White Paper of 1998, with the aim of restructuring the electricity distribution industry (Renewablesb2b 2012). This was also summed up in the Blue Print on the 2001 Electricity Distribution Industry Reform. Coetzee (2009) stated that the process of establishing the Regional Electricity Distributors (REDs) is the responsibility of the EDI Holdings. It restructures and merges the electricity distribution industry into six regional electricity distributors.

The main aims for establishing the Electricity Distribution Holdings include:

i. To establish and administer the REDs to ensure their efficiency and feasibility;
ii. To give strategic advice on restructuring the EDI and best practices that would lead to the success of EDI restructuring;
iii. To plan, manage and implement the establishment of the REDs;
iv. To support the REDs once they have been established;
v. To help meet its objectives, and
vi. To promote the process of restructuring the EDI and gain support from stakeholders to sustain it.

(Renewableb2b 2012)

2.3.3 The National Energy Regulator of South Africa (NERSA)

The National Energy Regulator of South Africa is a regulatory authority formed under the National Energy Regulatory Act 2004 (Act No. 40 of 2004) to operate as a juristic body (NERSA 2009). It took over from the NER (National Electricity Regulator), which in turn took over from the Electricity Control Board in terms of the Electricity Act Amendment of 1995. In 2005, NER was terminated and NERSA took over. NERSA's responsibility is to regulate the pipe-gas, petroleum pipeline and electricity industries (NERSA 2009).

NERSA's mandate is to monitor the energy industry and make necessary changes in its regulations (NERSA 2010). For example, the increases in electricity tariff from 2009 have been approved by NERSA. NERSA's mandate is to regulate the pipe-gas, petroleum pipelines and electricity industries in accordance with the Gas Act 2001 (Act No. 48 of 2001), Petroleum Pipelines Act 2003 (Act No. 60 of 2003) and Electricity Regulation Act 2006 (Act No. 4 of 2006) respectively. Its mission is to follow the government laws and policies, as well as international best practices and standards in regulating the energy industry (NERSA 2010).

NERSA's responsibility is also to monitor, evaluate and then take necessary actions. For example, one of the greatest tasks NERSA faced in the electricity industry was to approve Eskom's Multi-Year Price Determination (MYPD) application for the price increases. Eskom applied for an increase of 34% in their tariffs, but later in the year NERSA approved only 31% as of July 2009. In September 2009, Eskom sent another application requesting an increase of 45%, and in November another request for a 35% increase. NERSA considered some facts and reasons for Eskom's applications, and gave the approval percentages as shown in Table 2.1 below. NERSA also analysed the second Multi-Year Price Determination (MYPD2) and this resulted in the approval of the 25.9% increase in Eskom's electricity tariffs (NERSA 2011).

Table 2-1: NERSA's approved prices increases from April 2010 to March 2013

Year	Average Increase - %	Average Price-c/kWh	Revenue-Rbn
2010/2011	24.8	41.57	85
2011/2012	25.8	52.30	109
2012/2013	25.9	65.85	141

Source: NERSA Annual report 2009/2010 (pp33)

The performance of NERSA is also monitored by the Department of Energy. NERSA is responsible for making quarterly reports on its performance and submits them to the Minister of Energy (NERSA 2010). Table 2.2 shows the performance of NERSA as per the plans drawn and achieved for the 2009/2010 year. In the electricity industry, 67 out of 100 hundred activities were completed by NERSA while 33 of 100 activities were removed from the year plan (refer to Table 2.2). Some activities were not completed because they depended on other role players in the electricity industry and due to delay in the decisions made, affected the plans of NERSA. For example, the restructuring of the Electricity Distribution Industry was not accomplished because of delays in the making of final decisions by other role players (NERSA 2010).

Table 2-2: NERSA performance

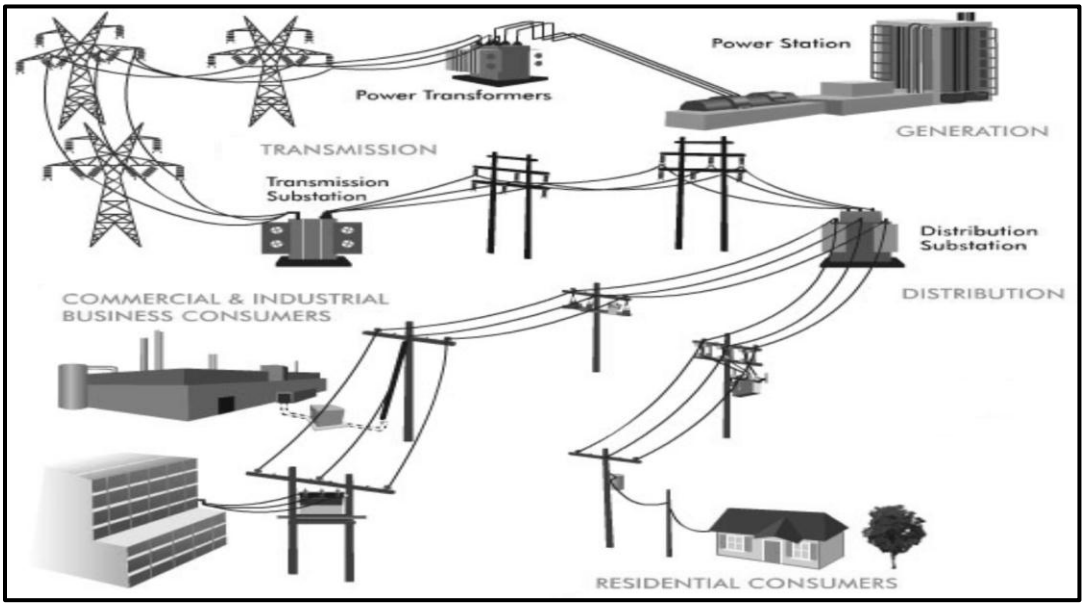
	Completed	On track	Delayed due to external dependencies	Delayed (Other)	Removed	Total*
Electricity industry regulation	19 (28%)	12 (18%)	27 (40%)	9 (40%)	33	67
Piped-Gas Industry regulation	15 (33%)	3 (7%)	10 (22%)	17 (38%)	23	45
Petroleum Pipelines industry regulation	10 (34%)	8 (28%)	4 (14%)	7 (24%)	12	29
Gas-cutting regulatory	8 (28%)	12 (41%)	1 (3%)	8 (28%)	11	29
Organisational	58 (40%)	62 (43%)	5 (3%)	19 (13%)	5	144
Total	110 (35%)	91 (31%)	47 (15%)	60 (19%)	84	314

Source: NERSA annual report 2009/2010 (pp68)

2.4 FUNCTIONAL DECOMPOSITION OF ELECTRICITY INDUSTRY

The electricity supply industry is comprised of three main elements: generation, transmission and distribution. The generation sector is where power is produced using different energy sources and technologies. The transmission sector involves the transportation of high-voltage electricity from the generation power plants to the distributors. The distribution sector sells electricity to the end-users. Figure 2.4 below shows the typical structure of an electricity industry.

Figure 2-4: A typical ESI structure



Source: Hoops (2010: 32)

2.4.1 Generation

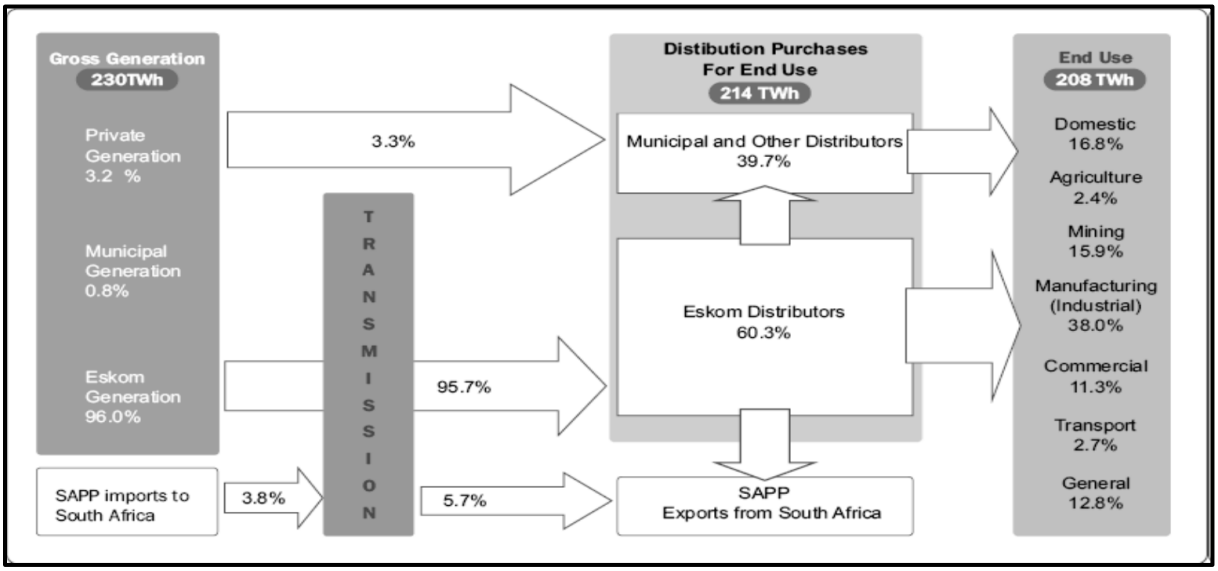
The generation sector entails the changing of one form of energy into electrical energy. From Figure 2.4, it can be seen that energy flows from a power station to power transformers. Eskom owns two national control centres in South Africa. According to Hoops (2010), the control centres serve to organise the generation of electricity, making available sufficient electricity for the country.

Kaseke (2011) stated that the generating technologies differ in terms of the generating input and cost structures. The cost components of the generation sector include fuel, operating, maintenance and capital costs. In the case of South Africa, coal generates about 92 percent of electricity, while 7 percent comes from nuclear energy and the remaining 1 percent is generated from hydro-electricity and the emergence of gas turbines (Eberhard 2002).

Figure 2.5 shows that most of the electricity comes from Eskom generators. About 96 percent of electricity is generated by Eskom, 3.2 percent of it is generated by private

generators known as Independent Power Producers (IPPs) and the remaining 0.8 percent by the municipality generators (refer to Figure 2.5).

Figure 2-5: Flow of energy between the role players



Source: by Mvuleni (2008: 33)

2.4.2 Transmission

Transmission can be defined as the delivering of electricity from the generation sector through the cables to the distribution sector. Electricity is transformed into high voltage electricity after generation in order to minimise energy losses (Kaseke 2011). Eskom is responsible for transforming electricity in South Africa. There are no opportunities for introducing competition in this sector because it is characterised by natural monopoly. Eskom contains about 26 461 km of transmission lines which serve the whole country as well as the neighboring countries (Mvuleni 2008). The amount of electricity capacity transmitted by Eskom distributors is 95.7 percent while the one transmitted by the Southern African Power Pool (SAPP) members in the form of exports is 5.7 percent. Refer to Figure 2.5.

2.4.3 Distribution

This is the last stage of delivery of electricity to the end users. Electricity is converted from high voltage into low voltage for distribution. Kaseke (2011) defines distribution as

a sector where electricity is sold to end users and involves the functions of managing connection, marketing, metering and billing. This is the stage which does not involve maintenance or construction of lines, but cash transactions. Figure 2.5 shows that Eskom distributors supply the municipal and other distributors with 39.7 percent of electricity.

2.5 WHAT THE GOVERNMENT HOPE TO ACHIEVE THROUGH THE ESI

Electricity is an essential input in the development and expansion of the economy. The electricity supply industry is playing an important role in helping the government achieve its objectives. For example, the government achieved the goal of bringing electricity to an additional 2.5 million homes through the Reconstruction and Development Programme (Eberhard 2002). Some of the goals that the South African government hopes to achieve through the ESI include:

i. To achieve global access to electricity;
ii. To provide electricity that will promote incorporated development of rural societies;
iii. To enhance productivity of industries through competitive electricity prices;
iv. To decrease government debt;
v. To promote black economic empowerment, and
vi. To guarantee a secure supply of electricity.

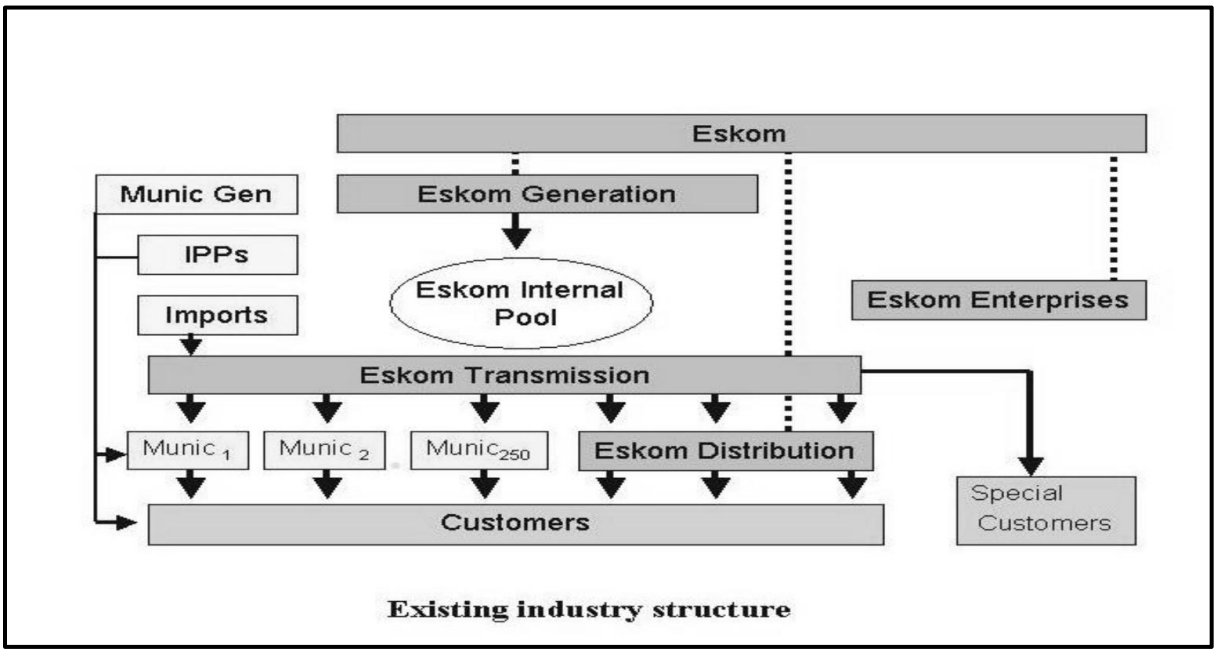
(Eberhard 2002)

The first two objectives are the only ones that can be achieved irrespective of the structure of the electricity supply industry. For example, monopoly industries lead to over-investment and under-investment and in turn, under-investment leads to the power outages and volatility in prices. A competitive industry leads to optimal investment efficiencies. This example serves to argue that the last objective of securing electricity supply in South Africa might not be achieved due to the current monopoly structure of the ESI.

2.6 ELECTRICITY REFORMS IN SOUTH AFRICA

The electricity supply industry in South Africa needs competition and private investments to guarantee the continuity of secured supply. South Africa losses approximately 3.3 % to 3.5% GDP under the current electricity structure (Wait 2012). This will hinder the Government New Growth Path.

Figure 2-6: Current South African ESI structure



Source: Eberhard (2002)

Figure 2.6 above shows that Eskom is enjoying the monopoly of being the only generator of electricity in South Africa. It also shows that the transmission sector is also under full control of Eskom. The distribution sector is dominated by Eskom too, but some distributions are done by the municipalities. Many studies (Eberhard 2002, Letladi 2006 and Gaunt 2006) have been arguing for the reforming of the ESI in South Africa. Most of them focused on introducing competition in the generation sector through the introduction of private generators, namely Independent Power Producers. Pickering (2010) focused on the establishment of the Independent System Operator. The introduction of the Regional Electricity Distributors (REDs) was another focus of these studies to introduce competition in the distribution sector.

2.6.1 Restructuring Opportunities

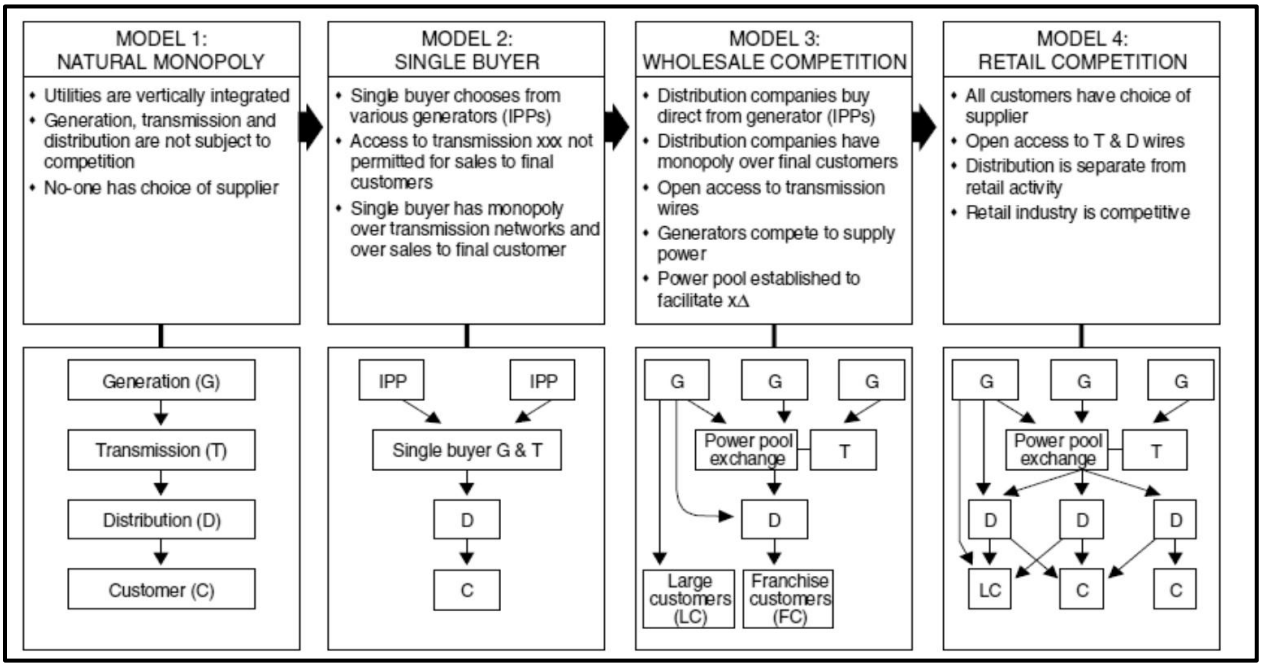
Restructuring of the electricity industry can be done as per the following basic models:

i. The vertical integration monopoly model is one where there is no competition in the industry;
ii. The single buyer model, requires only one buyer or a buying agent to purchase from different producers;
iii. The wholesale competition model is where the distribution companies have an open choice of various suppliers, and
iv. The full consumer choice model is where consumers have a wide choice from among the suppliers. The choice of these models is based on the preference between a competitive and monopolistic industry.

(Vignolo and Monzon 2002)

Figure 2.7 shows the models chosen by the countries which restructured their ESIs when they unbundled electricity structures to introduce competition. The first model is the monopoly model, which indicates the unbundling of the vertical monopoly structures. The second model, the single-buyer model, is used to introduce competition by allowing the IPPs to enter the market. These IPPs secure their future sales of electricity through the Power Purchase Agreement (PPA) (Eberhard 2002). The second model has been followed by the South Asian and other developing countries. The third model is wholesale competition, which involves horizontal unbundling. The generation sector is divided into many competing companies and sells their output to customers through the retailers (Vignolo and Monzon 2002).

Figure 2-7: Single-Buyer model, Wholesale Competition and Retail Competition



Source: Pickering (2010:vi)

The last model, retail competition, is the separation of supply of electricity from the operation and ownership of the distribution wires (Pickering 2010). A number of suppliers or retailers compete to sell electricity to customers hence the customers can choose their suppliers. The operation of this model involves suppliers purchasing electricity from the wholesale market and then paying the transmission and distribution companies a regulated price to transport electricity to customers (Pickering 2010).

The advantages of using the above models facilitate the balancing of planned and actual demand and supply of electricity between individual generators and distributors, more especially the retail competition and wholesale competition models (Vignolo and Monzon 2002). Another advantage is the maintenance of the prices of wholesale electricity, making it simple to regulate the prices (Pickering 2010). Therefore, though most of the parts of the whole structure remain government-owned, the entities will function better if they are separated and can concentrate on their core functions (Eustace, 2011).

The current structure of South African ESI follows the single-buyer model. This is the first step to restructuring an industry. A single-buyer chooses from different generators

and this is what Eskom does by purchasing all generated electricity. The wholesale competition allows the municipalities to also purchase power from competing generator while still serving their specific areas. With wholesale competition, the large consumers are allowed access to purchasing directly from generators. This facilitates competition in the ESI relative to the single-buyer model and allows large electricity consumers the opportunity of entering into long-term purchasing agreements with IPPs directly (DA discussion paper 2008). This will result in the improvement in opportunities for financing new generation capacity and secure electricity supply.

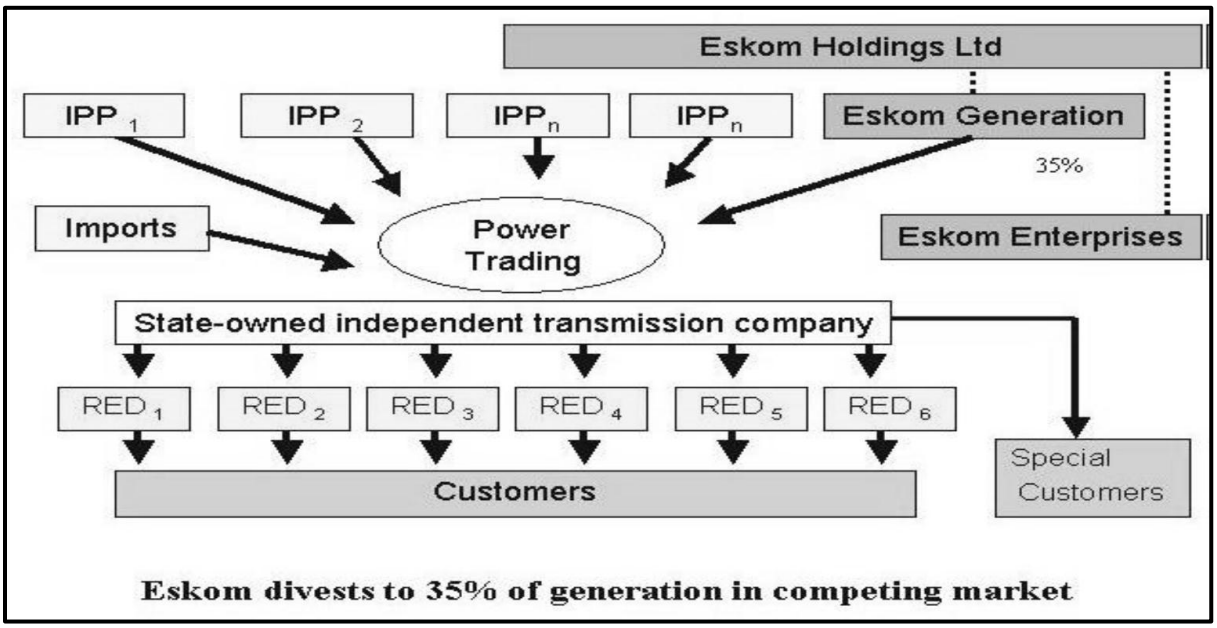
The disadvantages of the single-buyer model include:

i. Government officials are responsible for making decisions on the generation capacity. They make decisions knowing that they are not bound to face the financial problems that may arise as a result of their decisions;
ii. Government intervention is easy in this model. This allows for the special interest groups to use the funds accrued to the generation capacity for their own interests;
iii. In the presence of failure in the economy, this model responds badly, for example, during the economic crisis, and
iv. It hinders trade development with other countries since it is controlled by a state enterprise whose sole purpose is not to make profit.

(Lovei 2000)

The disadvantages of a monopoly structure dominated by Eskom led to different models being proposed to reform this industry. One of the models is illustrated below in Figure 2.8. It shows that for competition to be introduced in the ESI in South Africa, the generation sector should be controlled and managed by Eskom and some private producers. Eskom should hold only 35% of the generating sector. It also shows that the distribution sector could be allocated to the Regional Electricity Distributors (REDs).

Figure 2-8: Proposed market structure for South African ESI



Source: Eberhard (2002:5)

2.6.2 Independent Power Producers (IPPs)

The private sector plays a huge role in the development of a country. It benefits a country by relieving the government of the burden of funding the public entities like Eskom, and relieving Eskom from the burden of supply (Eskom 2012). It will also bring about new generation technologies that Eskom would not have, or even considered within their scope of operation.

The debates on allowing the private sector to participate in the electricity sector first came in the 1998 Energy White Paper. It proposed that the Independent Power Producers (IPPs) should hold about 30% of the generation capacity in the ESI (Creamer Media's Research Channel 2010). Independent Power Producers are also called non-utility generators. They are entities which own facilities to produce electricity for the purpose of selling to the end-users and utilities (Hoops 2010). They are not public utilities.

The proposal of issuing 30% of the market share to IPPs was not taken into consideration until 2007, when the electricity capacity fell. Then the government recommended that the private entities should be allowed entry into the generation

sector. The government's request was that IPPs should be granted 30% of the generation sector. Eskom established three IPP programmes to acquire supply of electricity from the private enterprises. The three IPP programmes include:

i. The pilot national cogeneration programme (PNCP);
ii. The medium-term power purchase programme (MTPPP), and
iii. The multisite base-load independent power producer programme (base-load IPP).

(Creamer Media's Research Channel 2010).

The importance of allowing the IPPs into the industry includes the ability of private sectors to provide new skills and capital into the electricity supply industry and to set the standard for performance and pricing (Eskom 2012). Urbach (2012) stated that if the IPPs are not allowed to help Eskom in generating electricity, household and industrial consumers will encounter severe shortages. The other benefits of introducing IPPs include:

i. Supplementation to the generation capacity of Eskom. Since the IPPs power projects are not restricted to operate only within South Africa, the IPPs can boost power supply by importing from other countries such as Botswana and Mozambique. They can also augment capacity by generating from renewable resources like wind and solar power (Creamer Media's Research Channel 2010);
ii. The ability to operate and enhance generation capacity more efficiently and quicker than Eskom. For example, it can build a new power station in 60% of the time and 80% of the cost relative to Eskom, and
iii. The operation of the IPPs cannot transfer risk to customers.

(Hoops 2010: 43).

The implementation of the IPPs faces economic, policy and institutional barriers. The high increase of electricity demand prior to the 2008 electricity supply crisis is one of the barriers. The others include:

i. Policy barriers: The government has been reluctant or slow in implementing the policies that would govern the IPPs since 2007;
ii. Economic barriers: These barriers depend on the tariff prices the utility will give to the IPPs and whether the utility will be able to cover those costs. For example, in order for a private sector generation utility to be efficient in the industry, Eskom has to be able to pay 65c/kWh for electricity in the region, and
iii. Institutional barriers: This has to do with Eskom being a monopolist and reluctant to share the monopoly benefits with any other utility.

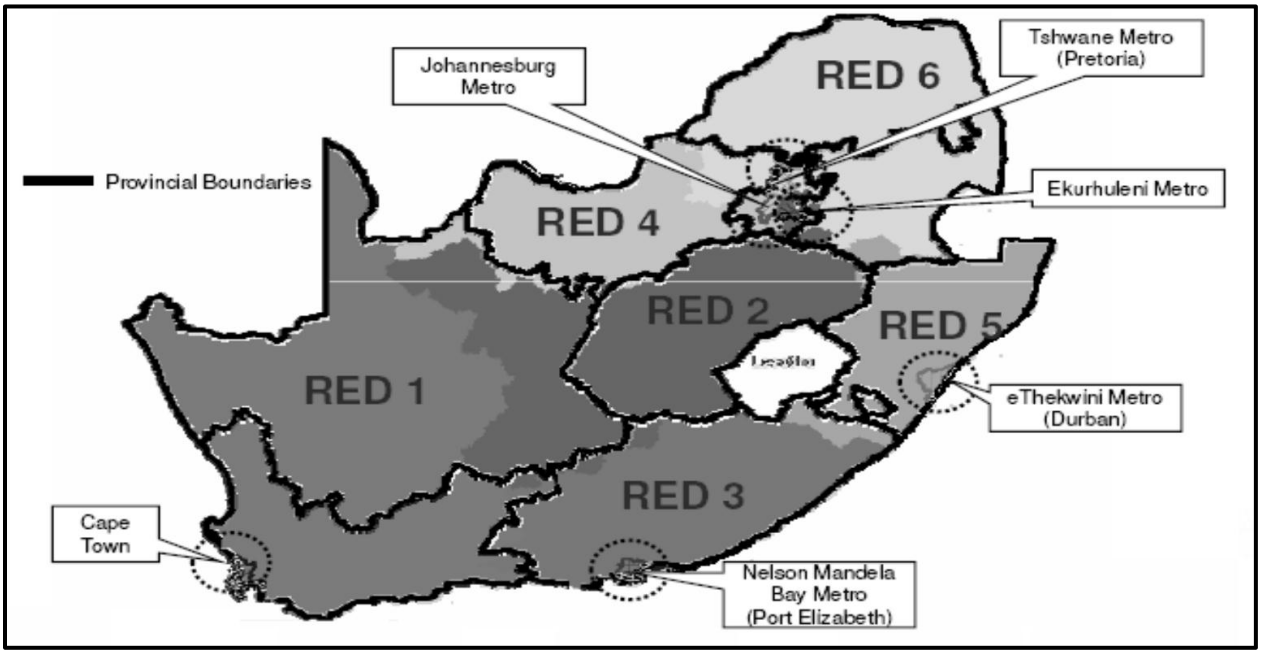
(Creamer Media's Research Channel 2010)

2.6.3 Regional Electricity Distributors (REDs)

Electricity Distribution Industry (EDI) restructuring was first debated in the beginning of the 1990s (Pickering 2010). In November 1994, at the Minerals and Energy Policy Workshop held by the African National Congress, it was decided that the EDI need to be restructured and consolidated urgently (Creamer Media's Research Channel 2010). The electricity distributors were recommended to merge into a single country-wide distributor; or the number of distributors was to be limited but operating separately from the local government. Then, in 2001 the decision to restructure the EDI was finally completed and a regional electricity distributor (RED) model was proposed (Hassen 2006).

The president at the time, Thabo Mbeki, stated in 2004 that by June 2005, the first RED would have been established and by 2008, all the six Reds shall be completed (Hassen 2006). The six REDs were planned to be regulated by the Electricity Regulation Act and Public Finances Management Act and would operate as a public body. The EDI holdings were to oversee the process of restructuring, while the distributing municipalities and Eskom were to give ownership of their distribution businesses to the REDs (Hoops 2010). Figure 2.9 below shows the areas where the REDs were planned to be situated. The first Red was planned to be established in Cape Town, Red 2 in Ekurhuleni, Red 3 in Port Elizabeth, Red 4 in Johannesburg, Red 5 in Durban and Red 6 in Tshwane (Pretoria).

Figure 2-9: Areas where the Reds are to be situated



Source: Mvuleni (2008: 57)

The aim for establishing REDs was to end disintegration and do away with inefficiency in the electricity industry (NERSA 2008). It was also hoped to promote governance of sectors and ensure that consumers are treated equally through a national pricing system (NERSA 2008). The REDs were also expected to facilitate access to all as it consists of Eskom distributors and the local authorities (Hoops 2010). The supply of electricity is also expected to be reliable, providing a top quality of consumer service and competitive electricity prices. Some of the objectives are listed in Table 2.3 below. Table 2.3 shows how the objectives of the REDs are related to what the ESI in South Africa is hoping to achieve.

Table 2-3: Restructuring objective

EDI Restructuring Objective	EDI Holdings
Energy white paper objectives (1998)	EDI Restructuring Blueprint Objectives (2001)
• Ensure electricification targets are met	• Achievement of government's electricification programme • Universal access to electricity for all South Africans
• Provide low-cost electricity • Facilitate better price equality	• Sustainable electricity supply to low-income consumers, regardless of location, at affordable prices
• Improve the financial health of the industry	• Future REDs to operate on a sustained, financially variable basis as independent business
• Improve service quality and supply • Foster proper co-ordination of operations and investment capital	• Acceptable and sustainable levels of supply security and quality
• Attract and retain competent employees	• Future REDs to provide secure employment to their employees, provide skills development and training consistent with a high technology, modern distribution business
	• Planned and manage transition

Source: De Beer (2007:3)

EDI Holdings claim that there is progress in the restructuring of the EDI and the implementation of the REDs. The Strategic Implementation Plan (SIP) was established to ensure the smooth transfer of assets from 188 owners to six wall-to-wall public entity REDs (Creamer Media's Research Channel 2010). The EDI Holdings have stated that, of the 187 electricity distributing municipalities, 147 have already signed the Accession to Cooperative Agreement as a sign of guaranteeing support to the transfer of ownership to the REDs (Creamer Media's Research Channel 2010).

The challenge which was faced in implementing the REDs is the need for associated legislation in supporting the restructuring process (NERSA 2008). The structure of the EDI and the delays in the restructuring process was costing the country about R2.9 billion to R8 billion, while maintenance and renovation costs about R27 billion per annum (Yelland 2009). It was also discovered that the EDI Holdings were busy with

other issues except restructuring, such as preparing the electricity infrastructure for the World Cup of 2010. The Minister in the Presidency, Collins Chabana reported that the EDI restructuring needed to be stopped immediately (Sapa 2010). The Cabinet suggested that the EDI Holdings should be responsible until the end of the financial year 2010/2011, after which the DME will take over the activities which were previously conducted by the EDI Holdings.

2.6.4 Independent System Operator (ISO)

The electricity industry faces a problem of mismatch between demand and supply. Some of the characteristics of electricity make its trade to be complicated. For example, electricity is not storable. But electricity, like any other commodity, can be traded. It is important to ensure that a proper demand supply balance for this commodity is kept. The independent transmission system operator serves to coordinate the mismatch between electricity supply and demand (Urbach 2012). The independent system operator will help change the structure of Eskom, which is outdated and slow to respond to the changes in the market. It will dismantle generation, transmission and distribution to improve and introduce competition (Urbach 2012).

The establishment of an independent system and market operator will modernise the South African electricity market (Lakmidas 2011). Table 2.4 below shows the functions possible for the independent system operator. Eskom needs to give out the functions of planning, procurement, system operations and allocation to the ISO (Pickering 2010). The ISMO Bill aims to change the ESI to allow the IPPs the opportunity to generate electricity and invest together with Eskom. The aim is to have Eskom's transmission and distribution assets transferred to the ISMO (Lakmidas 2011).

Table 2-4: Potential functions for ISO

Planning	• Undertake/facilitate new generation capacity planning
Allocation	• Allocate new capacity opportunities between Eskom, other SOEs and IPPs
Procument	• Procure new IPPs (on behalf of the buyer)
Buyer	• Enter into PPAs with generations, on behalf of the distributor/s • Aggregate the wholesale cost of power
System Operator	• Ensure short-term security of supply • Dispatch generation and dispatchable load • Operate the transmission network
Transmission	• Build, own and maintain transmission infrastructure

Source: Pickering (2010: ix)

The challenge Eskom faces to secure supply is the core reason for the establishment of the ISMO. Pickering (2010) stated the following challenges that Eskom faces: firstly, the country has not had enough supply for a long time and from the projections, it is clear that supply will be short further in the future. Secondly, Eskom is having a problem with financing the power stations and this will mean a further shortage of capacity. This will put South Africa in danger of facing continuing power outages. According to Pickering (2010), all the above problems faced by Eskom, will be addressed without doubt if ISO can be established.

In summary it can be seen that the Independent Power Producers have a small share in the generation. The REDs are not yet in operation. The ESI in South Africa is still in the hands of the monopoly state-owned utility (Eskom).

2.7 RENEWABLE ENERGY SOURCES

The electricity supply industry should resort to the use of the renewable energy sources in order to ensure security of supply. One of the factors that led to deficiencies in the electricity supply is the fall in coal production and the increase in its price (SA

Government information 2008). Eskom had to import coal and was exposed to the fluctuations in the exchange rates.

Coal and nuclear fuels have been critised for their inefficiencies in the production of electricity (Gets and Mhlanga 2013; Greenpeace 2013 and Teske *et.al,* 2011). Firstly, coal is the core source of the world's CO_2 emissions and the highest polluting energy source on earth (Greenpeace 2013). The impact of climate changes caused by coal affects other industries such a water industry. For instance, Acid mine drainage from deserted mines impacts the quality of water in South Africa and threatens supply of the scarce water resources (Gets & Mhlanga 2013). Gets and Mhlanga (2013) further showed that Eskom utilises about 10000 litres of water per second washing coal as well as operating power stations.

Climate change caused by the greenhouse gases result in real damage to the people's lives. According to Teske *et.al* (2011) approximately over 150000 additional deaths are caused by climate change per annum. People's lives are also in risk because there will be lower production which will lead to hunger and malaria.

The following are the advantages of using renewable energy sources as opposed to coal and nuclear energy sources:

i. Job creation: Renewable energy sources are more job intensity than fossil fuel power (Greenpeace 2013). This shows that to achieve high levels on employment in South Africa, the investments should be channeled towards renewable energy sources.
ii. Energy access and security: The electricity powered by coal and nuclear fuels has failed to provide the South African citizens with enough electricity and millions of the South Africans are still without electricity. According to Teske *et.al* (2011), it is projected that renewable energy resources could supply 94% of electricity demand in the country by 2050.
iii. Climate change: Coal and nuclear energy sources entail expenses resulting from climate change and owes to the citizens good health because of pollution (Gets & Mhlanga 2013).

iv. Renewable energy is cheaper. The cost of Renewable energy has been decreasing overtime while the cost of coal and nuclear fuels has been increasing (Teske *et.al.* 2011). This is on account that supply of coal and nuclear fuels are decreasing while renewable energy sources are increasingly accessible globally. This increasing cost of coal and nuclear fuels is been transferred to customers in terms of high tariffs for electricity. Gets and Mhlanga (2013) stated that it is cheaper to supply electricity from new wind farm compared to new coal plant and the costs are shown as R747.32MWh for new wind farm and R1335.82 for new coal plant.

v. Decentralised renewable resources: This will involve construction of renewable micro grids which will focus on supplying power to the rural areas (Greenpeace 2013). Greenpeace (2013) further showed that investing in climate infrastructure like smart interactive grids and super grids, will help supply electricity in large cities. Therefore, decentralisation will lead to increase in supply of electricity.

The countries like China, Indonesia and Columbia have experienced a massive growth since the 1990s after they changed to renewable energy sources (Greenpeace 2013). This shows that if South Africa needs to achieve the objectives it has about the ESI in terms of electricity access and supply security and to realise economic growth, the production of electricity should be transformed from coal and nuclear fuels to renewable energy sources.

It has been realised that if South Africa needs economic growth from electricity supply, the solution is detailed, replace coal and nuclear fuels with renewable energy and energy efficiency. Teske *et.al.* (2011) stated that the importance of this transition is to minimise the negative social and economic impacts and at the same time maximising the opportunities for innovation, high levels of employment and investment. The building of Kusile power station will not be necessary and hence this could lead to saving Eskom the high costs they are incurring in this project. Greenpeace (2013) indicated that it would only take three and half years to recover investments from damage cost of Kusile.

The potential for the use of renewable sources differs from one country to another. South Africa is one of the countries with the highest potential to have giant renewable energy sources. Teske *et.al* (2011) indicated that if the government could commit to renewable energy sources, South Africa would become a leading country in the renewable energy sources in the continent of Africa. South Africa is placed in a way that it can be energy efficient and reduce both the costs of energy and CO_2 emissions.

South Africa has abundant solar energy supply and is ranked among the highest in the world (Teske *et.al* 2011). South Africa is also amongst the highest in the world in terms of solar radiation levels. This shows that the resources are been under utilised as free energy sources are not fully exploited. Comparing solar radiation averages for South Africa with countries such as USA and Europe, Teske *et.al* (2011) found that in USA, an annual 24-hour solar radiation averages 150W/m^2 and 100W/m^2 for Europe while in South Africa, it averages to about 220W/m^2. This rankings show that South Africa has a high potential and this can be achieved only if the government would commit to the transition from coal and nuclear fuels to renewable energy resources.

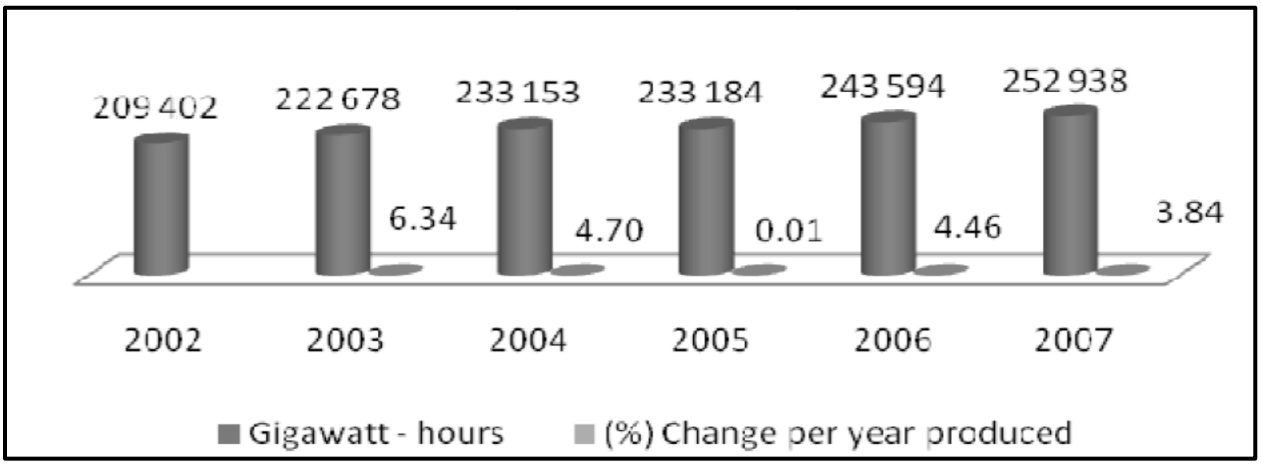
The western side of Kwazulu-Natal is endowed with the South Africa's best wind resources more especially in the mountainous regions. Other wind resources are placed along the east coast. The wind energy is already been used by the farmers through the use of wind powered water pumps and approximately 30000 systems have already been installed (Teske *et.al* 2011).

South Africa in ranked the world's top sixth largest producer of coal (Sourcewatch 2013). This has limited the nation's potential for large scale hydroelectricity because of shortages of water it has caused. Teske *et.al* (2011) stated that few rivers are suitable for hydroelectricity because South Africa is water-stressed but there is a potential for growth of 3500 to 5000 sites for mini-hydropower production. Therefore, shifting from coal will reduce shortages of water and in turn increase hydroelectricity. The existence of this variety of renewable energy sources will ensure security of electricity supply.

2.8 ELECTRICITY CRISIS IN SOUTH AFRICA

During the late months of 2007, South Africa was hit by extensive rolling blackouts. The demand for electricity rose above supply and nearly distabilised the national grid (Calldo 2008). This led to the discussion of the trends in the supply of electricity and the reasons and causes of the electricity crisis. Figure 2.10 shows the trends of electricity supplied by Eskom from 2002 to 2007, when the shortages began. There have always been increases in the supply as shown in Figure 2.10. For instance, from 2002 to 2003 there was an increase of 6.34 percent of power produced and from 2006 to 2007, there was an increase of 3.84 percent.

Figure 2-10: Total volume of electricity produced by Eskom for the year



Source: Calldo (2008:2)

The South African electricity exports have also been increasing between 2002 and 2007. Table 2.5 illustrates the trends in the electricity supplied by Eskom to the international sectors. It shows that from 2002 to 2003, exports increased from 6950 Gigawatt-hours to 10136 Gigawatt-hours, while from 2006 to 2007, exports increased from 13766 to 14217 Gigawatt-hours.

Table 2-5: Total electricity exported for the year by Eskom from 2002 to 2007

Total volume of electricity exported for the year by Eskom: 2002 to 2007						
	2002	2003	2004	2005	2006	2007
Gigawatt-hours	6950	10136	12543	12884	13766	14217
(%) change per year exported		45.84	22.86	3.46	6.85	3.28

Source: Calldo (2008:3)

The imports have also been increasing from 2003 to 2007. In comparing the imports and exports of the electricity industry, it is clear that in 2002, South Africa imported more electricity than it exported. From 2003 to 2007, more electricity was exported and less imported (refer to Table 2.6). From the above information, it can be concluded that there has been an increase in electricity provided to other countries, while the electricity provided to the South Africans declined.

Table 2-6: Total electricity imported for the year by Eskom from 2002 to 2007

Total volume of electricity imported for the year by Eskom: 2002 to 2007						
	2002	2003	2004	2005	2006	2007
Gigawatt-hours	7873	6739	8026	9199	9782	11318
(%) change per year imported		-14.40	19.10	14.62	6.34	15.70

Source: Calldo (2008:3)

The South African economy experienced high levels of growth from 2004. This resulted in an increase in consumption of electricity. Following economic growth, the levels of electricity consumption increased up to 60 percent (South African Government 2008). Electricity consumption increased by 4.31 percent between 2006 and 2007, and 4.9 percent during peak hours (South African Government 2008).

Table 2-7: Electricity supply: 1996 vs. 20007

Electricity supply: 1996 vs. 2007		
	1996	**2007**
Mining	19%	15%
Agriculture	2%	2%
Transport	2%	1%
International	3%	6%
Municipalities	42%	40%
Households	3%	5%
Commercial	0%	4%
Industries	29%	27%

Source: Calldo (2008: 6)

In the late months of 2007, South Africa experienced shortages of electricity supply. Table 2.7 shows how the electricity supply has been declining. The only increases that were realised were in the household and the commercial consumer categories, while the Mining, Municipalities and industrial consumer categories has been reduced.

The South African Government (2008), in analysing the causes of the shortage, identified pricing of electricity as a key issue. The price of electricity is very low compared to other countries and hence it becomes difficult for the country to raise enough money to fund new generation capacity. The Round Table Report states that the other causes of the electricity shortage in South Africa in 2008 include:

i. The delay of Eskom in building the new generation station and as a result, leading to lower amount of capacity available. It was indicated in the White Paper of 1998 that the country will experience shortage of power by 2007, and Eskom requested for a budget to build a new power station (Calldo 2008). The government denied Eskom the budget to build the new power station in 1998 because it was in the process of privatising the electricity supply industry;
ii. The reserve margins fell from 15 percent to 7 percent between 2001 and 2007. This is below the international standard level (15 percent).

iii. Eskom has been unable to maintain its existing kit running efficiently. The planned availability of capacity for Eskom had always been 90 per cent, 3 per cent for the breakdowns and the remaining 7 per cent for planned maintenance. But Table 2.7 shows that the only capacity which was available in 2008 was 78 per cent. This is a result of the aging of the plant, which needed more capacity for maintenance and for breakdowns.

iv. Another problem was that the quality of coal Eskom used was deteriorating. In the world market, coal has increased and more coal started to be exported and less was left for Eskom. Jacob Maroga stated that Eskom does not have a dedicated supplier of coal, and as a result is forced to import some of the coal. This exposes Eskom to the international prices of coal and the high cost of transportation.

v. Eskom has a shortage of skill. Eskom reported that it is short of technical staff and engineers. This was also a challenge because Eskom had to incur the costs of holding workshops to recruit skilled labour and also hold training sessions to improve the skills of current employees.

vi. The private companies were also expected to supplement the capacity shortage but did not. This is because the market was not open for the private investors. Eskom wanted to retain 70 percent of the market, thus deterring the entry of private producers.

(Bernstein & Dagut 2008)

Calldo (2008) identified the following as the possible solutions for electricity shortages in South Africa: Building more power stations and allowing participation of private firms into the industry. Other possible policy implications to stop electricity shortages include:

i. Investment in power sector: to enhance reliability of supply in the electricity sector and to avoid unsupplied electricity costs lead to a strong case for expansion of generation capacity.

ii. Load management strategy: the priorities given to customers during load shedding should be transparent and clear. The losses differ according to the

industries. For example, in continuous-process industries, losses are very high compared to other industries.

iii. Information Flows and Customer Education: the distribution firms often make customers aware of load shedding well in advance, hence limiting firms the chance to adjust to load shedding. The customers outreach programmes should also be implemented to educate customers on how to conserve energy.

(Ghaus-Pasha n.d)

The measures of controlling the high levels of demand include:

i. Load Shedding;
ii. Running all available generation at maximum rating;
iii. Implementing gas plants;
iv. Utilising emergency water resources, and
v. Switching the power off for consumers with interruptible contracts.

(IEA 2011).

2.9 POWER OUTAGES IN SOUTH AFRICA

The electricity power outages can undermine South Africa's financial muscle and lead to increases in cost to consumers and uncertainty of the electricity industry. Power outages occur as a result of high level demand and maintenance closure relative to available generation capacity (IEA 2011). It was projected that, in 2007, South Africa will run out of peaking capacity due to the growth in demand (Urbach 2006). Power outages affect all consumers, and cost each of them more especially the industrial, agricultural, household and mining consumers.

The power outages in South Africa commenced in the third week of January 2008 (Bernstein & Dagut 2008). It lasted until mid-2008. This nearly led to the crash of the national grid. In responding to the problem of the shortage of power, the Department of Energy, NERSA and Eskom Holdings decided to ration electricity for the citizens. The focus was on the whole economy, but mostly on the industrial sector.

The CEO of Eskom, Jacob Maroga stated that Eskom had to start load shedding because there was a shortage of electricity, especially during peak hours (Bernstein & Dagut 2008). Peaking plants had to be used harder. This led to high levels of unplanned outages because equipment was extremely stressed and some of them failed. For example, unplanned power outages led to unavailability of over 5000 MW of power plants in mid-January 2008 (South African Government 2008). There was also a capacity of 3700MW which was put aside for maintenance. This implies that about 8700MW of capacity, which was supposed to meet demand, was unavailable. For example, in Table 2.8 below, it can be seen that on Monday about 22% of capacity was unavailable for meeting demand, while on Tuesday and Thursday 23% of capacity was unavailable.

Table 2-8: Amount of capacity available to meet demand

	Generating capacity	Plant Unavailable		Available capacity	
		Unplanned	Planned		
	(MW)	(MW)	(MW)	(MW)	
14/01/2008 (Mon)	39 194	4 824	3 675	30 695	78%
15/01/2008 (Tue)	39 194	5 342	3 675	30 177	77%
16/01/2008 (Wed)	39 194	5 647	3 695	29 852	76%
17/01/2008 (Thu)	39 194	5 380	3 695	30 119	77%

Source: South African Government (2008)

Load shedding affected the entire economy, but mostly the industrial sector and the mines. The platinum and gold mines had to go for about five days without production. The emergence of 'Black Friday' at the mines emanated from the occurrence of load shedding and its effect on production (Bernstein & Dagut 2008). An output of about 22 per cent was lost in the mines, while 5000 employees were retrenched. The country was losing R75/kWh for every kilowatt hour of unserved electricity (Wait 2012). Wait (2012) further stated that South Africa was shot of 5000MW of energy and this costs the country close to R3.3 trillion a year.

A study by Zietsman (2012) estimated costs for the three months of 2008 load shedding. The study found the cost to be between R50billion and R119 billion. This is

an equivalent of 2.5% to 6% of a fall in the nominal GDP growth and 8.5% of unserved electricity (Zietsman 2012).

2.10 ESKOM'S CAPACITY EXPANSION PROGRAMME

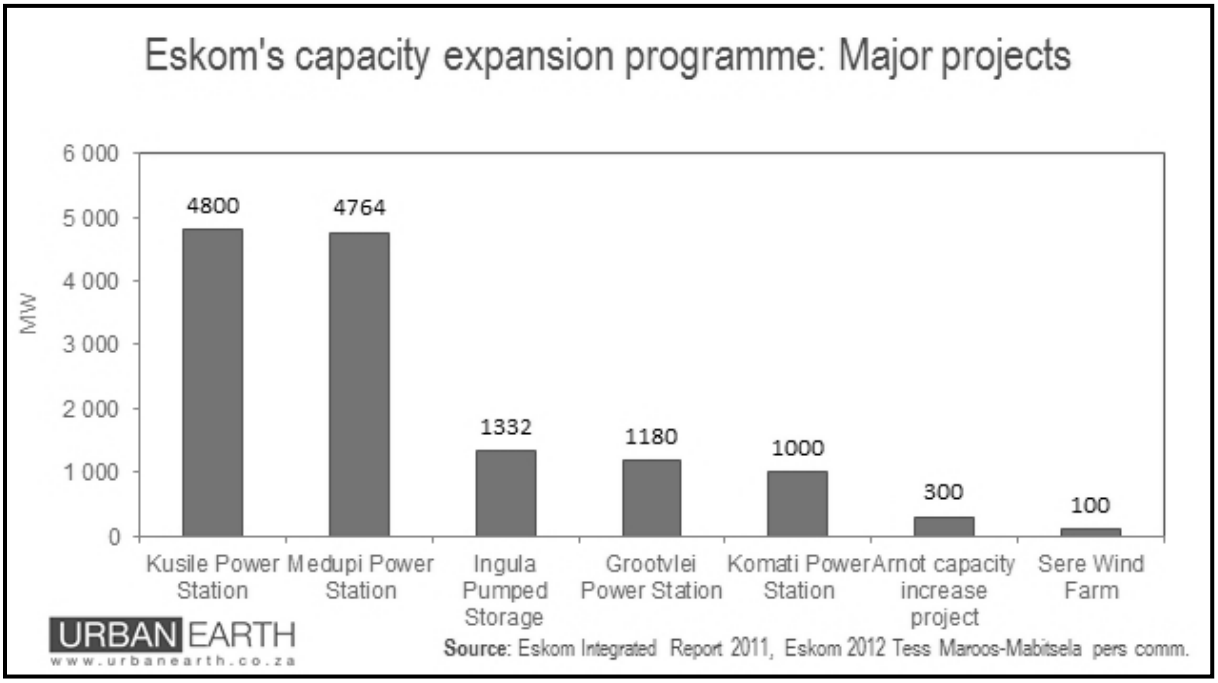
Eskom's capacity expansion programme began in 2005. It is the largest in the history of Eskom's projects and it was expected to raise its transmission lines by 4700 KM while the generation capacity would increase by 17120MW (Eskom 2012b). The main objective of the capacity expansion programme was to meet the ever increasing demand and also diversify Eskom's energy sources (Eskom 2012b). Eskom has budgeted R385 billion for its capacity expansion programme up to 2013 and it was anticipated to increase to a trillion or more by 2026, with a double capacity of 80000MW (Eskom 2012a). For the six years of its operation, the capacity expansion programme had already cost R140 billion and is estimated to cost R340 billion when it is completed in 2018. The amount of new generation capacity which has already been installed currently is 5500MW, in addition to the existing capacity of 39794 MW (Botes 2012).

Eskom has committed to the following tasks:

i. To build the two coal-fired power station: the Medupi and Kusile, a pumped storage plant: Ingula and the two new gas-turbine plants;
ii. To improve other existing plants;
iii. To return-to-service three coal-fired plants (Camden power station, Grootvlei and Komati) which were previously mothballed, and
iv. To build new infrastructure together with two renewable energy plants and new transmission plants.

(Eskom 2012b)

Figure 2-11: Projects Eskom is investing in capacity expansion



Source: Botes (2012)

The above projects which Eskom is investing in as part of the capacity expansion programme are illustrated in Figure 2.11 below. Figure 2.11 also shows the electricity capacity which will be generated from each plant. For example, Kusile power station is expected to generate 4800 MW of electricity.

The economic slowdown has worked in favour of Eskom in terms of reducing demand for electricity. This will help Eskom in running the projects of expanding electricity capacity without high levels of consumption. As it stands, Eskom's capacity expansion programme is still doing well and in spite of the uncertainties about the future, Eskom is determined to support the projects which are currently in progress (Eskom 2012c). The new build programme is expected to create up to an approximate level of 100,000 new jobs (Eskom 2012c). Table 2.9 below shows the current planned capacity expansion and shows the schedules of installing the stations and the times they are expected to be completed. For example, with Medupi power station, the first unit is expected to have been installed by the first quarter of 2012, but has not, while the last unit will be completed by the end of 2015.

Table 2-9: Current planned capacity expansion (MW)

MW	F2009/2010	F2010/2011	F2011/2012	F2012/2013	F2013/2014	F2014/2015	F2015/2016	F2016/2017	Total
Grootvei (coal fired)	800								800
Komati (coal fired)	125	325	300						750
Arnot (coal fired)	70	30							100
Medupi (coal fired)				1588	794	1588	794		4764
Kusile (coal fired)					1600	800	1600	800	4800
Ingula (pumped storage)				338	1014				1352
Annual total MW	995	355	300	1926	3408	2388	2394	800	12566

Source: Eskom (2012c)

2.11 PERSISTENT THREATS OF POWER SHORTAGES POST 2008

The electricity generation expansion programme, on its own, might lead to the 2008 crisis repeating itself. The power outages continue to this day though not as frequent as they were in 2007/2008 (Urbach 2012). The construction of the power stations is increasingly costing South Africa in terms of the budget and delays in building. For example, the prices of household consumers went up by 137 percent in 2011, following the 2010 approval of the Medupi Project (Sourcewatch 2012). Over and above, Eskom proposed another increase of 25 percent increase in order to finance the Kusile power station. The electricity industry consumers are unaware of the current crisis. This is because “the lights are still on” (Urbach 2012).

The persistent delays and increases in the budget for the construction of the power stations date back to 2006. Medupi power station’s first unit was planned to be produced by January 2010 with an initial cost estimated to be R17bn, which is equivalent to R9.4m/MW for the expansion of 1800MW (Urbach 2012). The trends of the size, budget and the delays in the construction of Medupi power station are as follows:

i. In March 2006, the expansion of 1800MW budget price increased from R17bn to R20bn which is between R9.4m/MW and R11.1m/MW on average.
ii. In January 2007, the Medupi power station size was changed to 4500MW, costing over R52bn and the first unit was reported to be commissioned in mid-2011.
iii. In February 2007, the price was confirmed to be R56bn (which is equivalent to R12.44m/MW on average) and delayed by one and half years.
iv. Late February 2007, the budget was announced to have increased to R70bn, but was confirmed to cost R66bn (an equivalent of R14.67m/MW on average) in May.
v. In October 2007, the station was announced to be expanded to 4700 and then to 4800 in the same month, with the cost increasing to R78.66bn (equivalent of R16.37m/MW on average). The first unit was then to be commissioned to the third quarter of 2011, a delay of 2 years.
vi. As of March 2011, the budget increased to R120bn from R78.6bn in October 2007. The date of commissioning the power station was postponed to June 2012, a delay of two and a half years, with a budget price equivalent to R26.15m/MW.
vii. In July 2012, the size was 4764MW, costing R91.2bn when excluding interest during construction (IDC). The commission date has been postponed to December 2013. By December 2013, it is projected that the power station will be costing R130bn including IDC. This is now gone to 3 years.

(Urbach 2012)

From the above changes in the size, budget and time scheduled for completion of the Medupi power station, it can be seen that billions of rands are being lost on the construction of the power station alone. It can also be seen that the times for commissioning have been postponed, which means there is still lack of enough capacity generated for consumers. Eskom is now depending on the demand side electricity to ensure consumers use less electricity. The consumers are discouraged to buy more power by increasing electricity costs. This made savings to exceed the expectations

(Steyn 2012). For example, the mining sector saved 406MW. Eskom incurs costs to pay the bulk users of energy to not use electricity.

Eskom has also chosen to buy back electricity from the large users of electricity. A power buy-back programme has cost Eskom R1.8 billion between March and May (Steyn 2012). Eskom had to pay back the bulk consumers who volunteered to stop producing in order to save power. The government, in May 2011, announced that it is running out of funds to contribute to the financing of the expansion of the Medupi and Kusile projects (Sourcewatch 2012).

The South African ESI goes through a lot of supply pressure as it awaits the completion of the Medupi and Kusile power stations. Most of the South African power components are nearing the lifespan. Most of the distribution networks currently have an average of 47 years while their lifespan was 50years (Sapa 2012). This shows that if a maintenance backlog is not considered, most distribution components will start collapsing from 2015. The Eskom and the municipalities distribution networks need R35 billion for maintenance (Sapa 2012). This shows that the South African electricity industry is in crisis.

2.12 CONSERVING ELECTRICITY

Eskom planned to reduce peak demand in mid 2008 by 10 per cent, which is about 3000MW. The programme, called Power Conservation, was formed to deal with the 10 per cent decrease in demand. This programme is a key initiative by the government to deal with the challenges born by the demand-side (Eskom 2010). Its sole purpose is to balance the supply and demand in the short run. The programme targeted mostly the industrial consumers, mines and smelter (IEA 2011). The targeted consumers were requested to reduce electricity consumption in the following ratios: industrial (10%), commercial (15%), agricultural (5%), residential (10%) (South African Government 2008). The report from Eskom showed that 1500MW of demand was reduced by January 2009 because of the Power Conservation Programme.

The power conservation programme consists of two basic elements: the Energy Conservation Scheme (ECS) and Electricity Growth Management (EGM). The Energy

Conservation Scheme is about the government's target to reduce electricity consumption by 10 per cent, while the Electricity Growth Management is for managing new electrical connections using available supply capacity (Eskom 2010).

The following are the benefits hoped to be achieved from the Power Conservation Programme:

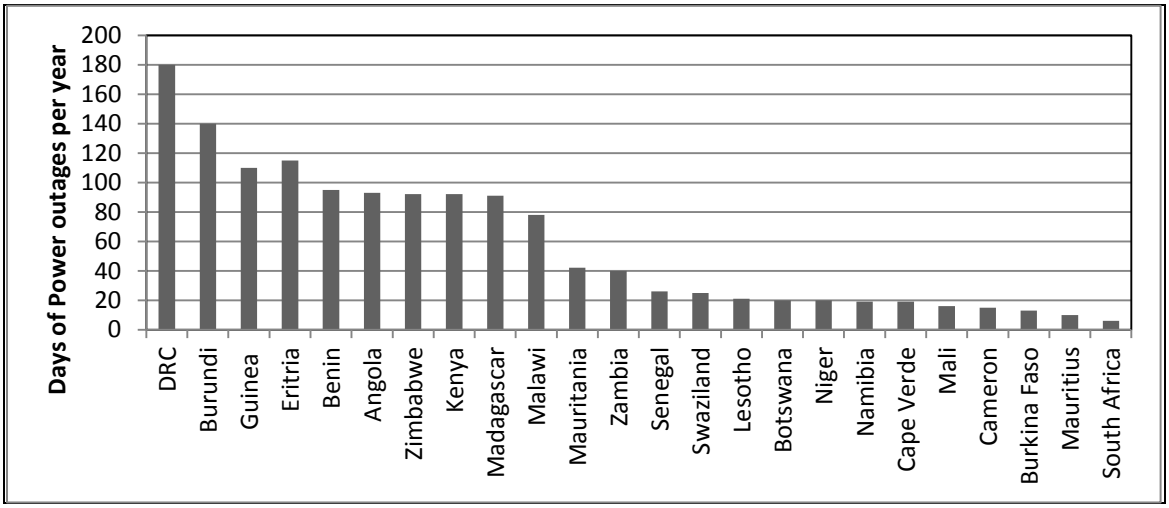
i. Improvement in the reserve margin;
ii. Reduction in the need for load shedding or bring it to a stop;
iii. Improvement in Energy efficiency viability;
iv. Improvement in Climate change, and
v. Production will be enhanced because wasteful energy usage will stop.

(South African Government 2008)

2.13 INTERNATIONAL EXPERIENCE WITH ELECTRICITY POWER OUTAGES

The supply of electricity is unreliable in Sub-Saharan African countries. In developing countries, unreliability of electricity supply has become a custom and most countries experienced electricity supply shortages between 2008 and 2010 (Kaseke 2011). For example, in South Africa, shortages of supply were heavily experienced in 2008, in 2009 in Zimbabwe. Senegal and Tanzania experienced power outages in 2007. Figure 2.12 below shows the Sub-Saharan African countries which experienced power shortages and the frequency and duration of time that power shortages lasted in a year. For instance, the electricity consumers in Senegal experienced electricity power shortages of about 45days, while Burundi and Tanzania went for 144 and 63 days without electricity respectively. It can be seen that South Africa is one of the countries that went for few days without electricity. This does not justify the effect on power consumers.

Figure 2-12: Selected countries that experienced power outages



Kaseke (2011:53)

The power outages date back to 2005. The outages back then were severe because most countries faced outages without having been given notice prior to the outage. This resulted in fewer days of outages leading to greater impact on a firm's production and household leisure times. Table 2.10 shows a selected number of countries which experienced power outages in the year 2005. It shows all important features of power outages: the duration, frequency and the down time. Congo is still shown to be leading with 182 days of power outages in a year while South Africa is still the lowest with only six days per year. Tanzania has experienced a decrease from 67 days of power outages per year in 2005 to 63 in 2007 while the opposite happened for Senegal with 44 days in 2005 and increased to 45 days in 2007.

Table 2-10: The 2005 power outages in selected countries

	Outages (days/year)	Average Duration (hours)	Outages (hours per year)	Down time (% of year)	Suppressed demand in 2005 (GWh)
Southern African Power Pool					
Angola	92	19.31	1, 780.8	20.3	435
Congo Dem. Rep	182	3.63	659.2	7.5	351
South Africa	6	4.15	24.5	0.3	602
Zambia	40	5.48	219.9	2.5	157
East African/Nile Basin Power Pool					
Kenya	86	8.20	702.6	8.0	366
Tanzania	67	6.46	435.9	5.0	208
Uganda	71	6.55	463.8	5.3	84
Western African Power Pool					
Cote d'Ivoire	46	5.94	1101	13	365
Ghana	61	12.59	1465	17	979
Nigeria	46	5.94	1101	64	10803
Senegal	44	5.67	1052	17	250
Sierra Leone	46	5.94	1101	82	189
Central African Pool					
Cameroon	26	4.03	613	7.0	241
Congo Rep.	39	4.33	924	10.6	616
Gabon	40	5.20	950	10.8	134

Source: Eberhard et al (2011:56)

The other selected studies with estimated electricity power outages include USA, Israel, and Japan. Refer to Table 2.11 below. Table 2.11 shows that the estimates of the cost of power outages within a country may differ according to the studies. This is on account of the different methods used by different authors. It also can be on account of the sectors studied. For example, Kaseke (2011) focused on the residential, industrial, mining and agricultural sectors to estimate the cost of power outages in Zimbabwe.

Table 2-11: Selected studies that estimated costs of power outages

Country	Cost (US$) per kWh	Source
Israel	0.21	Bental and Ravid(1982)
United States of America	1.16	Bental and Ravid(1982)
United States of America	11-20	Caves, Herriges and Windle (1992)
Japan	118-149	Matsukawa and Fujii (1994)
Israel	7.20	Beenstock, Goldin and Haitovsky (1997)
USA	4-9.60	Eto, Koomey, Lehman, Martin, Mills, Webber and Worrell (2001)
Netherlands	12-20	de Nooij, Koopmans and Bijivoet (2006)

Kaseke (2011:34)

2.14 CONCLUSION

This chapter discussed a comprehensive structure of the electricity supply industry in South Africa. It started with the dominating role player, Eskom, which holds 95 percent of the electricity market share. It also discussed other players in the industry, namely: the Department of Minerals and Energy (DME), the National Energy Regulator (NERSA) and the Electricity Distribution Industry (EDI) Holdings.

It further discussed the elements of the industry and showed that they are vertically integrated and owned by a monopoly utility. This led to the discussion of the reforms in the electricity industry. The possible structures for unbundling the electricity industry were also discussed and showed the future benefits of introducing competition in the industry. The transition from the usage of coal and nuclear fuels to renewable energy sources to produce electricity was also reviewed.

The history of the supply of and demand for electricity was also examined. This led to the discussion of the electricity crisis that was experienced in South Africa. The causes of this crisis were reviewed, as well as the possible solutions. The core cause of this crisis was shown to be a shortage of supply and the solution to it was to introduce Eskom's Capacity Expansion Programme. From the demand side management, Eskom pays large users of electricity to stop producing. This has a negative impact on employment and economic growth.

The solutions that Eskom management has come up with concerning the power outages include: increasing the electricity tariffs and discouraging large firms from producing. These are typical features of a monopoly firm, which is increasing prices and restricting output. This will be discussed further in Chapter three. In a normal business operation, the firms advertise to attract more customers and to persuade them buy more of the firm's products. As a result, the firm makes more profits and increases its supply. But, with Eskom, the opposite is true.

The following Chapter will discuss in depth the theories of power outages and the causality. The causes of power outages and costs imposed on the electricity consumers will be reviewed. Power outages in other countries will be discussed. This will be followed by the measures of estimating the cost of power outages to the consumers. The solutions of eradicating electricity shortages will be highlighted. The focus of solutions to power outages will be more on increasing private participation, introducing competition into the industry and discouraging increases in prices. The increase in prices is the main focus of the Eskom utility.

The causality theory will also be discussed. This will focus on investigating the relationship between electricity generation and economic growth. The discussion will entail the co-integration techniques to determine the long run relationship between the variables and the Granger-causality framework to find the direction of causality between the variables.

Finally, the models of unbundling the electricity industry will be further discussed. This is because it was indicated in chapter two that the current model (the single-buyer) adapted in South Africa, allows too much of government intervention and its harmful to economic growth. In chapter two, it was realised how much government intervention cost the economy. The government led to the current electricity crisis and the 2008 power outages by not allowing Eskom to increase the generation capacity as early as 2004.

Chapter 3

LITERATURE REVIEW

3.1 INTRODUCTION

Chapter Two dealt with the experience of South Africa's disequilibrium in the supply and demand of electricity. This has been shown by the 2008 blackouts in South Africa. The Chapter further discussed the effect of power outages on production in the industrial, residential, farming and mining sectors. These sectors contribute significantly to the country's economic growth. It can therefore be concluded that such power outages will have an adverse effect on the country's economic growth.

This chapter comprises a literature review with the focus on relevant theory and empirical studies that investigated the relationship between the variables: electricity supply and economic growth and electricity demand and economic growth. Most studies in the literature focused on electricity demand while a few focused on electricity supply (Gupta 2009). The debate around the relationship between these variables examines the existence of both long run and short run relationships using co-integration techniques. The other studies, for instance Sarker (2010), Tang (2008), Jumbe (2004) and Ghosh (2002) focus on the direction of causality between the two variables. The direction of causality can be defined in four categories: firstly, one is where there is unidirectional relationship running from economic growth to electricity consumption termed *conservation hypothesis*; secondly, where there is a unidirectional causality running from electricity consumption to economic growth named *growth hypothesis*; thirdly, where there is bidirectional causality between electricity consumption and economic growth called *feedback hypothesis* and lastly a *neutral hypothesis* where there is no causality between electricity consumption and economic growth (Mehrara and Musai 2012).

There are other factors that affect the relationship of the variables (mentioned above) which led to some studies adding a third variable to the model to form a trivariate framework. For instance, Adebola (2011) and Ouedraogo (2009) added capital

formation as the third variable while Ghosh (2009) and Acaravci and Otzurk (2012) added labour; the reason being that the bivariate system has been found to suffer from variable bias and lead to overestimation of the results (Morimoto & Hope 2001). Morimoto and Hope (2004) also recommended in their study that for further research capital and labour should be added to complete the production function as this increases reliability of the results.

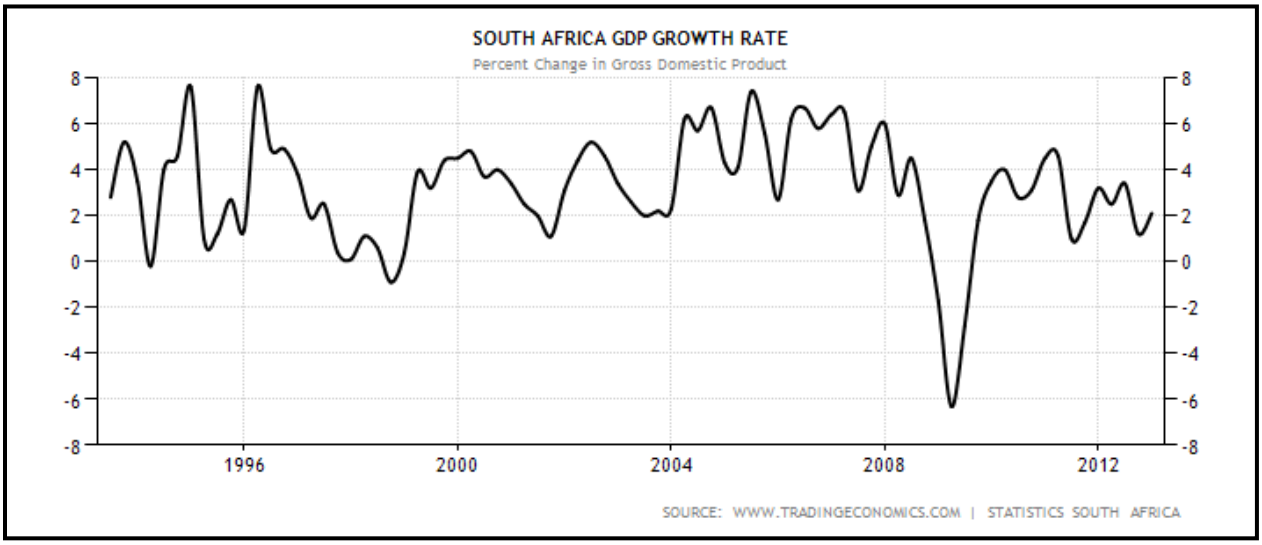
Other studies used a multivariate framework including variables such as exports, remittance, electricity prices, imports, financial development and power crises. Examples of these studies include that of Muhammad *et al.* (2012), Tang, Shahbaz and Halicioglu (2007) and Lean and Shahbaz (2012). Sadorsky (2012), Sarker (2010) and Yang (2000) focused on the aggregate energy consumption instead of doing only electricity. The disaggregated energy includes factors such as fossil fuel, gas, oil and electricity.

The following section comprises a discussion of the history of economic growth in South Africa, the impact of power outages to the industrial, farming, mining and household sectors and the relationship between electricity consumption/generation and economic growth.

3.2 GDP AND ECONOMIC GROWTH HISTORY

Historically, South Africa's GDP growth rate averaged 3.22 percent from 1993 to 2012 (Trading Economics 2013). During that same period, the GDP growth rate reached its highest at 7.60 percent in December 1994 and its lowest point in March of 2009 of -6.30 percent. Figure 3.1 below shows the GDP growth rates from 1993 until 2012. It shows that from 2002 to 2008, the averaged growth rate of GDP increased to 4.5 percent on a yearly basis. The fastest growth rates have been realised since the beginning of democracy in 1994 (Trading Economics 2013).

Figure 3-1: The growth rate of South African GDP



Source: Statistics South Africa

Trading Economics (2013) reported that in the first quarter of 2012, the real GDP at market price rose by 2.7 percent quarterly. This increase is subject to the contribution of the manufacturing industry which added 1.2 percentage points of the growth of 7.7 percent; the transport, storage and communication industry which contributed 0.2 percentage points of the 2.5 percent of growth and lastly, the wholesale, retail, motor trading, and catering and accommodation industry which contributed 0.4 percentage points of the growth of 3.0 percent (Trading Economics 2013).

3.3 POWER OUTAGES STUDIES

An electricity outage or power failure is a short-term or long-term loss of electricity supply to a region. This may be the result of the overloading of the electricity grid, faults at the generation plants and small capacity generated to meet system load levels (Shaalan 2000). For instance, South Africa, in 2008 and 2009, New Zealand in 2008 and Chile in 2007 and 2008 experienced electricity shortages resulting from high growth in demand, fuel disturbances and drought (Linares & Rey 2012). In 2011, Japan also ran out of electricity capacity due to the earthquake and tsunami which led to a closure of a number of power stations (Linares & Rey 2012). High increases in demand were experienced by countries like France, Germany and Europe, where the hot summer days led to an increase in demand for air conditioners.

Power outages are defined as interruptions on the supply of electricity, incorporating both planned load shedding and unplanned power cuts (Kaseke 2011:35). Power outages are critical mostly where the environment and the people end up at risk. For example being stuck in the lifts or walking in the dark streets. In this regard, some institutions plan for such situations by having backup power sources and demand-side measures. The power outages lead to revenue losses and high maintenance and repair losses (Shaalan 2000).

The theory behind estimating the power outages is that the presence of electric power failure leads to the consumer welfare loss and loss of output to the industrial customers. This will as a result lead to a fall in the country's economic growth. The impact of electricity power outages to consumers can be classified into three categories: Firstly, the direct economic costs. These refer to damages that occur during or after the power outage that include costs such as Loss of production, equipment damage, restart costs and raw material spoilage (Kaseke, 2011). It refers to the time lost during the power outage, that is, the time the firm could have been in production but that time was lost because of the power outage (Ghaus-Pasha n.d). Kaseke and Hoskings (2012) stated that direct costs go beyond output loss and include consequences such as material destruction cost, labour cost in the form of overtimes and paying idling labour force, equipment destroyed and time.

Secondly, the indirect economic costs. These costs refer to adjustment costs (Ghaus-Pasha n.d). This is because firms often make adjustments in their operations, either after or during the power outage, to recover those costs (Ghaus-Pasha n.d). The typical adjustments that firms make involve working overtime, acquiring self-generation capacity, working additional shifts, more intensive utilisation of capacity and changing shift timings (Ghaus-Pasha n.d). The study by Bental and Ravid (1982) was the first to discover that to infer the cost of outages, backup generators can be used (Beenstock 1991). In the presence of outages, consumers invest in backup generators to minimise the expenses incurred during outages. Therefore, to compute the costs of outages, the investments in backup generators to mitigate costs incurred during outages are used (Beenstock 1991). The indirect costs are costs incurred in buying the backup materials

such as solar systems, generators and insurance premiums paid to cover risks incurred by power outages (Kaseke 2011).

Lastly, the social impact costs. These are costs borne mostly by the residential consumers. They include costs of high temperatures at home or at work which hinder the domestic or work activities (Munasinghe 1980). These are normally borne in the hot summer days where the use of air conditioners will not be working because of the power outages. Other costs include the lost leisure time by the residential consumers, where power outages can stop them from watching television and reading news papers (Munasinghe 1980). Consumers are also at risk of bad health and safety.

The elements of power outages costs differ according to the customer category. The main categories of power consumers include commercial, industrial and residential consumers (Munasinghe 1980). The greater cost of outages is borne by the consumers. The different classes of consumers face different costs at different times. For example, the residential consumers face a high degree of hardship when engaged in domestic work, while the industrial consumers bear the consequences during the production process (Shaalan 2000).

Table 3.1 illustrates the categories of consumers affected by power outages. It also shows the costs borne by each category of consumers. For instance, industrial, commercial and agricultural consumers face direct costs of shutting down machines during production and the costs of restarting the machines when the power returns. The indirect costs incurred include the delay in the production of other firms because of the delay in the delivery of raw materials for production. This leads to a decrease in production in all sectors of the economy which will have an adverse effect on economic growth.

Table 3-1: The primary electricity users and the type of costs they incur

Primary Electricity User	Direct Components of Outages costs	Indirect Components of Outage Costs
Residential	a. Inconvenience, lost leisure, stress et. b. Out-of-pocket costs • Spoilage • Property damage c. Health and safety effects	Costs to other households and firms
Industrial, commercial and Agricultural firms	a. Opportunity cost off idle resources such as labour, land and capital b. Shutdown and restart costs c. Spoilage and damage d. Health and safety effects	a. Cost on other firms that are supplied by impacted firm (Multiplier effect) b. Costs on consumers if impacted firm supplies a final good
Infrastructure and Public service	a. Opportunity cost of idle resources b. Spoilage and damage	a. Cost of public users of impacted services and institutions b. Health and safety effects c. Potential for social costs stemming from looting, vandalism

Source: Munasinghe and Sanghvi (1988)

The magnitude of the impact of power outages is further determined by its unique characteristics that include the frequency of outages, the time duration, the time of day, season of year and warning time (Adenikinju 2005). The relationship between costs of outages and frequency of power interruption is inversely proportional. This means that an increase in the frequency of power interruption results in the decline in the consequences of interruptions (Adenikinju 2005). This is because the customer get to adapt to the power outages the more frequent the outages occur and make adjustments to reduce costs incurred (Spiegel *et al*. 2005).

The longer the duration of the power outages, the greater the costs to the consumers. Some damages proportional to the length of time include loss of working hours. Some damages are incurred in short length of power interruption e.g. computer files, while others occur when the length of interruptions is longer e.g. food getting spoiled in the refrigerators (Bijvoet *et al.* 2005). This is illustrated in the study by Lineweber and McNulty (2001) where a relationship between cost of outages and duration of

interruption was determined using one-second interruption, three-minute interruptions and one hour interruption. The results showed an average cost of $1,477, $2,848 and $7,795 for one-second, three-minute and one-hour interruptions respectively.

The time for the occurrence of power outages is important. This refers to the day of the week, season and time of day (Bijvoet *et al.* 2005). The time of day affects the different consumers in different ways. For example, residential consumers are less affected by power outages during the day - more especially the wage earners because they are not at home. On the other hand, commercial and industrial consumers are normally badly affected during the day because that is when production takes place. The household consumers are affected more in the evening during their leisure time and activities like watching television would be affected. An outage occurring during winter causes more costs to household consumers than the ones occurring in summer with the same duration and time of day (Spiegel *et al.* 2005). The costs of outages borne by industrial and commercial consumers do not have an orderly seasonal pattern (Spiegel *et al*. 2005).

The electricity utility provider knows well in advance when the power shortages are going to occur and it is the utility's duty to notify the customers in advance. A warning of an interruption prior to its occurrence lowers the damage to consumers (Bijvoet *et al.* 2005). The advance notice give the customers an opportunity to prepare for the outages. For example, the residential customers can cook meals in advance if the power outage is going to last for a short time. The length of time of notice does not matter but what matters is whether the advance notice is definite about the occurrence of the outage. In the study by Lineweber and McNulty (2001), the findings showed that one day advance notice and one hour advance notice gave the same results of $6918. It also showed that the cost of outages increased to $7795 without an advanced warning of the same interruption duration.

Table 3.2 shows the studies conducted on power outages. It shows the experience of both developed and developing countries. The different methods of calculating the costs of power outages are mentioned in the table and different customer categories are also included.

Table 3-2: Studies on power outages

Study	Country	Sector	Methodology
Munasinghe (1980)	Brazil	Residential sector	Survey
Shaalan (2000)	Saudi Arabia	Residential Sector	Survey
Bose et al (2005)	India	Agricultural and Industrial sectors	Survey
Kaseke and Hosking (2012)	Zimbabwe	Mining sector	Survey
Adenikinju (2003)	Nigeria	Manufacturing sector	Survey
Caves et al (1992)		Industrial sector	Survey
Beenstock et al (1997)	Egypt	Business and public sectors	
Spiegel et al (2005)	California	Residential and Non-residential	Survey
TERI (2001)	India	Manufacturing and agricultural sectors	
Kaseke (2010)	Zimbabwe	Mining sector	Survey
Sullivan et al (2009)	United States	Industrial, commercial and residential	Survey
Kaseke (2011)	Zimbabwe	Residential, Mining, farming and industrial	Survey
Bental and Ravid (1982)	USA and Israel	Industrial	Proxy method
Gaunt and Herman (2008)	South Africa	Residential and Commercial	Survey

Source: Own construction

Adenikinju (2003) studied the effects of power outages in the manufacturing industry in Nigeria. The data used in the study was drawn from the 1998 nationwide survey. Nigerian firms were experiencing power outages about seven times a week. The objective of the study was to find the willingness of manufacturing companies to pay to avoid power outages. The production function approach was used to estimate the cost of power outages.

The study used a stratified random sampling method to select the manufacturing firms to use in the survey. The survey included 300 manufacturing firms in the country. The sample selection was based on the size, industry and location. For example, the zones selected contributed over 80% of manufacturing output in Nigeria and over 60% of power consumption in the country. The survey served to determine the consumers'

responses regarding the following issues: Sources and amounts of electricity consumption, cost of provision of back-up, characteristics of outages, types and amount of losses incurred from power failures, perceptions about the effectiveness of National Electric Power Authority (NEPA) as well as that of the firms.

The findings of the study were that 792 working hours were lost by firms in 1998, which is about 88 working days assuming firms operate 9 hours a day. Thirty-five percent of the firms were forced to stop their production in that year. Firms experience outages that lasted for over an hour, between 5 to 10 times a week. The total cost on destruction of raw materials, lost output, restart costs and damage of equipment was over half a million naira. A large number of respondents preferred long interruptions with less frequency to higher frequency with a lower duration. Sixty six percent of the respondents indicated that they had to pay employees to work overtime. To end these chronic power outages, the Nigerian president Goodluck Jonathan pledged to privatise the electricity supply sector (Brock 2013). In April 2013, the government accepted five distribution companies and ten generation companies which were established to dismantle the electricity supply sector. Brock (2013) further reported by end of 2013, these companies will be controlled by the private firms. This sell-off is estimated to raise $2.5 billion for the Nigerian government.

Kaseke (2011) conducted a study to compute the costs of power outages to the residential, industrial, farming and mining consumers in Zimbabwe. The methods of power outage costs estimation used in the study were direct cost (welfare loss) and indirect cost (backup cost) methods. The data was collected through the use of questionnaires. The findings of the study showed that the total outage cost incurred by the industrial sector had the highest impact on GDP (22.1%). The other sectors followed with 7.7%, 1.5% and 1.24% for mining, agriculture and household consumers respectively. The total outages costs for the four sectors in 2009 were found to be US$1.76 billion.

Gaunt and Herman (2008) performed a pilot study to determine the impact that power outages have on consumers in South Africa. The pilot study focused on residential and commercial consumers. The study used the direct and the indirect assessment methods

to compute the costs. The results for the residential consumers showed that the direct costs were (in Rands) 56.5; 34.88; 31.85 and 46.5 for 0.25; 1.25; 4 and 11 hours respectively. The results also indicated that the consumers gave responses which were inconsistent even though they were from the same residential area. The results for the commercial sectors were captured by categorising the consumers into retail, hotel and restaurant and monetary intermediation. The results were captured for outages of 2 seconds to 8 hours duration. The retail, hotel and restaurants and financial sectors showed an increase in costs as the hours of interruptions increased. For instance, the retail sectors incurred costs of R182 for 2 seconds, R6,398 for 20 minutes, R16,303 for 1 hour and R67,111 for 8 hours.

Bose *et al.* (2006) carried out a study of the agriculture and industrial sectors in India. The survey method was used. It targeted a sample size of 500 manufacturing consumers and 900 farmers. The contingent valuation method was used to determine the consumers' willingness to pay to avoid the power outages. The direct cost and indirect cost estimations were also used and the results of the three methods were compared. The industrial sector was divided into High-Tension (HT) and Low-Tension (LT) and the findings from the three models were as follows: For HT, the direct assessment, indirect assessment and willingness to pay methods resulted into R1.7billion, R0.9billion and R1.7billion respectively of cost of power outages. For LT, the cost estimations were R0.4 billion, R0.4 billion, and R0.5 billion for direct assessment, indirect assessment and willingness to pay methods respectively. The agricultural sector produced results for the direct and indirect assessment methods as R34 billion and R18 billion respectively.

In general, the estimated costs for the agricultural consumers ranged from 1.9 % to 3.6 % of the gross domestic product of the country. This is equal to R950 billion using the 1999/2000 prices. The estimated costs for the industrial consumers ranged between 0.04% and 0.17 % of the gross domestic product.

Tata Energy Research Institute (TERI) did a study to estimate the cost of unserved energy. TERI (2001) focused on the industrial (manufacturing only) and agricultural consumers. This study followed three methods of estimation: the production loss

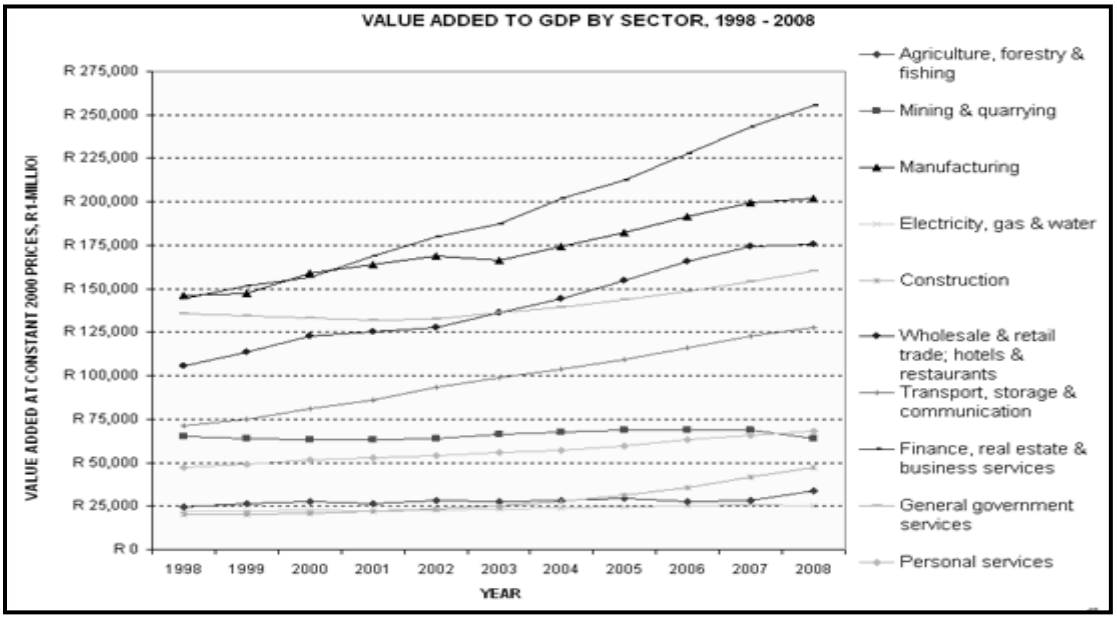
method, captive generation method and contingent valuation method. A sample size of approximately 500 manufacturing industries and 900 farmers was used and collected in each state in India. The three methods produced different results for the manufacturing industry. The production loss method resulted in (R7.15/kWh), willingness to pay method (R5.16/kWh) and captive generation method (R3.38/kWh) for Haryana. The estimates for Karnataka were R24.7/kWh, R5.22kWh and R3.74kWh respectively.

The estimates for the agricultural sector were based on a sample size of 908 farmers from Haryana and 910 farmers from Karnataka. The results vary with the methods of estimations and are as follows: the production loss approach, for Haryana was R1.32/kWh and R3.28/kWh for Karnataka, the captive generation method resulted in R2.25/kWh and only 2 percent of farmers in Haryana and about 3 percent in Karnataka were willing to pay more on a per kWh basis.

Wijayatunga and Jayalath's (2003) study in Sri Lanka aimed to determine the cost of power outages to the industrial sector. They employed the survey method to evaluate the cost of power outages to the country's GDP. The findings of the study showed that approximately US$81 million was lost in 2001 and this is equivalent to 0.65 percent of the country's GDP. Breaking it down into planned and unplanned outages, the results showed that about US$45 million was lost; about 0.3 percent of GDP.

The studies above showed that the inequality between electricity supply and demand amounted to the loss of millions to the countries' economy. Figure 3.2 shows the value added by each economic sector to the GDP in South Africa. For example, the sectors like manufacturing rank second to the highest contributing sectors to GDP and is highly affected by power outages. It is therefore certain that the effect from power outages to these sectors negatively affect the countries' GDP. In the following section the long run and short run relation between electricity supply and economic growth, as well as electricity demand and economic growth will be discussed.

Figure 3-2: Value added by sector



Source: Trading Economics (2013)

3.4 CAUSALITY STUDIES

The debate concerning the causalities studies is whether electricity consumption Granger-causes economic growth or economic growth Granger-causes electricity consumption. The importance of knowing the direction of causality between electricity consumption and economic growth is to formulate accurate electricity policies and appropriate energy conservation measures (Bildirici 2012). According to Adebola (2011), the pioneers of the debate on causality between electricity consumption and economic growth are Kraft and Kraft (1978). The models used in the literature were mostly the Error correction model (ECM) and the standard granger causality (GC) model (Liang-qi 2007).

The interpretations of causalities were given by Adebola (2011) and Odhiambo (2009) as follows: “A unidirectional causality running from electricity demand to economic growth means that a country’s economic growth is dependent on its electricity demand” (Adebola 2011). This shows that decreasing electricity consumption will surely result in a decrease in economic growth (Odhiambo 2009). Therefore, if a country has policies on electricity conservation, it could be harmful to its economic growth. This also applies

to South Africa, as it is still developing and aiming to have higher growth rates (10 percent) by 2020.

A unidirectional causality running from economic growth to electricity consumption implies that a country's economic growth is not solely dependent on electricity (Odhiambo 2009). This way, the policies on energy conservation can cause a modest or undesirable impact on economic growth (Adebola 2011). No causality in either direction is said to mean that policies for changing electricity supply do not have an impact on economic growth (Odhiambo 2009). By implication, a country can carry on with the energy conservation policies without being concerned about the effect on economic growth because they do not affect it at all.

Table 3.3 shows the studies which investigated four categories of relationships: firstly, between electricity consumption and economic growth; secondly, between electricity generation and economic growth; thirdly aggregated energy consumption and economic growth and lastly, energy consumption and GDP per sector of the economy. The table further shows the periods of study and the different countries which were studied. It also indicates that some studies focused on single countries while others focused on multi-countries studies. The results of these studies as well as the methodologies used by these studies are also illustrated in table 3.3.

Table 3-3: Studies on Causality

Study	Country	Period	Methodology	Main variables	Causality
Ghosh (2002)	India	1950 – 1997	Granger Causality	GDP, electricity consumption	ES →EC
Mahadevan and Asafu-Adjaye (2007)	Multi-countries	1971 – 2002	-	GDP growth, prices and Energy consumption	ES ↔ ENC
Adebola (2011)	Botswana	1980 – 2008		Electricity consumption, real GDP, capital formation	EC → RGDP
Ouedraogo (2009)	Burkina Faso	1968 – 2003		Electricity consumption, real GDP, capital formation	EC ↔ RGDP
Liang- qi (2007)	China	1980 – 2005	Granger Causality	Electricity consumption, real GDP	EC → RGDP
Wolde-Rufael (2009)	Multi-countries	1971 – 2001		Electricity consumption, Economic growth, labour, capital	EG → EC(Egypt, Ivorycoast, Morrocco, Nigeria, Senegal, Sudan) EC→EG (South Africa, Benin, Algeria)
Ankilo (2008)	11 Sub-Saharan African countries		Granger Causality	Electricity Consumption, Economic growth	EC↔EG (Senegal, Ghana, Gambia) EC→EG (Zimbabwe, Sudan) No causality (Kenya, Togo, Code d'Ivoire, Nigeria)
Yoo and	Indonesia	1971 – 2002		Electricity	EG→ EC

Study	Country	Period	Methodology	Main variables	Causality
Kim (2006)				consumption, Economic growth	
Gupta (2009)	India	1960-67-2006-07	Granger causality	Electricity supply, Economic growth	ES → EG
Sarker (2010)	Bangladesh	1973 – 2006	Granger causality	Electricity generation,RGDP	ES→ RGDP
Yusuf and Metehan (2011)	30 OECD member countries	1980 – 2007	Holtz-Eakin causality test	Electricity generation, economic growth	ES↔ RGDP
Ghosh (2009)	India	1970 – 2005		Electricity supply, RGDP,employment	No causality between ES & RGDP
Razzaqi and Sherbuz (no date)	D8 Countries	1980 – 2007	VAR granger causality	Energy use, economic growth	EG ↔ ENC except Indonesia
Muhammad et al (2012)	Kazakhstan		VECM granger causality	Electricity consumption, economic growth, capital, labour, trade openness	EC → GDP
Atif and Siddiqi (2010)	Pakistan	1971 – 2007	Standard granger causality and MWald test	Electricity consumption, GDP	EC → EG
Bildirici (2012)	Cote d'Ivoire	1970 – 2010	Switching granger causality	Electricity consumption, economic growth	EC ↔ EG
Tang and Shahbaz	Portugal	1970 – 2009	Granger causality	Electricity consumption, economic - growth, financial development, foreign trade, population	EC ↔ EG

Study	Country	Period	Methodology	Main variables	Causality
Tang (2008)	Malaysia	1972 – 2003	Standard granger causality	Electricity consumption, economic growth	EC ↔ EG
Madhavan et al (2009)	Malaysia	1971 – 2003		Electricity consumption, economic growth, price	EC → EG
Jumbe (2004)	Malawi	1970 – 1999	Granger causality	Electricity consumption, economic growth	EC ↔ GDP
Altinay & Karagol (2005)	Turkey	1950 – 2000	Standard granger causality	Electricity consumption, real GDP	EG→ EC
Lise and Montfort (2007)	Turkey	1970 – 2003		Economic growth, energy consumption	GDP → ENC
Yuan et al (2007)	China	1978 – 2004		Electricity consumption, real GDP	EC → RGDP
Halicioglu (2007)	Turkey	1968 – 2005		Residential energy demand, income, prices urbanization,	EG→ EC
Sadorsky (2012)	7 South American countries	1980 – 2007		Energy consumption, output, trade	No causality
Yang (2000)	Taiwan	1954 – 1997		Energy consumption, GDP	ENC ↔ GDP
Lim and Shiu (2004)	China	1971 – 2000		Electricity consumption, economic growth	EC → RGDP
Jamil & Ahmad (2010)	Pakistan	1960 – 2008	VECM	Electricity consumption, prices, real GDP	RGDP → EC
Lean and Shahbaz (2012)	Tunisia	1971 – 2008	Granger causality	Energy consumption, Economic growth, industrialization, financial devpt,	EG → ENC

Study	Country	Period	Methodology	Main variables	Causality
				urbanization	
Smyth and Lean (2010)	Malaysia	1790 – 2000		Economic growth, electricity generation, exports, prices	EG → ES
Hossain (2012)	SAARC countries	1976 – 2009	Panel Granger F-test	Economic growth, electricity consumption, export, remittance	EG→ EC in Pakistan
Kwakwa (2012)	Ghana	1971 – 2007		Energy consumption, overall growth	EG → ENC
Awan (2013)	Pakistan	1971 – 2008		Real GDP, electricity consumption	EC → RGDP
Acaravci and Otzurk (2012)	Turkey	1968 – 2006	Granger Causality	Electricity consumption, real GDP, employment ratio	EC → RGDP

Source: Own construction

The discussion in this section starts with the studies which considered the relationship from a demand perspective between electricity consumption and economic growth or energy consumption and economic growth. It will also focus on the studies that focused on single countries and then proceed to multi-countries studies before a discussion on supply perspective of electricity.

3.4.1 Electricity Consumption Vs. Economic Growth for Single Countries

The studies of these countries produce different results even though using the same tests. Narayam and Smyth (2005a) carried out a study to investigate the factors that determine residential demands for electricity in Australia. The study used data for the period from 1969 to 2000. The study used the following variables to test their relationship with per capita residential electricity consumption, real residential electricity

prices, temperature, real per capita income, electricity consumption for the previous year and real natural gas prices. The study found that a one percent rise in GDP results from a 0.41 percent of a long run increase in residential energy consumption.

Narayan and Smyth (2005b) took a study to determine the relationship between electricity consumption, employment and real income. This Australian study used both causality and co-integration systems to examine relationship between the variables. A positive long run relationship is found between the electricity consumption, employment and real income. The Granger-causality tests show a unidirectional causality flowing from real income and employment to electricity consumption. The results show that electricity conservation policies can be implemented without affecting economic growth. These policy implications are found to be very crucial for Australia as it was in the process of reforming its electricity supply industry.

A similar trivariate study to Odhiambo's (2009) was carried out by Adebola (2011). In this study, instead of including the employment variable, it uses capital formation. The aim of the study was to examine the relationship between real GDP and electricity consumption in Botswana. The data covered a period from 1980 to 2008. This study also aimed to fill the gap left by African studies of not taking into consideration the structural breaks when testing for unit root tests. This is harmful in the sense that it lessens the unit roots test power which could result in bias that will in return affect inferences derived from co-integration and causality tests (Adebola 2011). Therefore, the study used Zivot and Andrews' (1992) method to determine structural breaks. The findings of the study were that, in the long run, there would be existence of unidirectional causality running from electricity consumption to real GDP. This reveals that, in the long run, electricity consumption is related to real GDP.

Another trivariate study that used capital formation, as one of the variables, is the study by Ouedraogo (2009). The study sought to examine the relationship between real GDP and electricity consumption for Burkina Faso. The data period was from 1968 to 2003. The findings of this study differ from Adebola (2011) but are similar to Odhiambo's (2009) results in that they showed existence of a bidirectional relationship between real GDP and electricity consumption both in the short and the long run. The study further

showed an existence of a positive nexus between capital formation and Real GDP but no causal relationship between capital formation and electricity consumption.

Liang-qi (2007) studied the relationship between electricity consumption and GDP for the Period of 1980 to 2005 in China. The computation of electricity consumption in the study was not based on total electricity consumption that incorporates the residential consumption but only consumption from a production perspective. Therefore, the relationship investigated in the study was between intermediate electricity consumption and ecomomic growth, using the Error Correction Model (ECM) and the Granger causality test. The results suggested the existence of cointegration between GDP and intermediate electricity consumption. The causality was shown to flow from electricity to real GDP. This implied that the electricity power outages would restrain the increase in GDP in China. The findings further indicated that an increase of one percent in electricity intermediate consumption will lead to 1.21 percent increase in the real GDP. The study recommended that, since China's electricity consumption supported economic growth, it was of paramount importance to ensure restructuring of the electricity industry and improving efficiency in the supply of electricity.

Lim and Shiu (2004) also conducted a study for China to analyse the relationship between electricity consumption and economic growth using the Error Correction Model (ECM) for the period of 1971 to 2000. The study used the Johansen Maximum likehood test and ADF test to examine co-integration and unit root. The findings of the research were similar to the results of Ling-qi (2007) showing the existence of a one-way relationship flowing from electricity consumption to real GDP. This implied that electricity consumption affected GDP such that increasing electricity consumption would lead to an increase in GDP but not the other way around.

Another study for China was done by Yuan *et al*. (2007) sought to find the relationship between electricity consumption and economic growth for the period 1978 to 2004. The results indicated the existence of cointegration between these variables. The findings further showed a unidirectional causality flowing from electricity consumption to real GDP. The last study for China was by Zhong-fu *et al.* (2008) who investigated the relationship between electricity consumption and economic growth and included the

electricity retail price as the other variable; contrary to the other three studies that used only two variables. The data for the study covered the period of 1978 to 2006.

The results indicated a long run relationship between real GDP, electricity retail price and economic structure. The estimates for long run income elasticity, electricity price elasticity and economic structure are 0.85, -0.13 and 1.26 respectively. The results from the Vector Error Correction model (VECM) showed that a rise in the average retail prices and a fall in the proportion of heavy industrial structure will lead to a fall in electricity demand.

Saleheen *et.al* (2012) conducted a multivariate study for Kazakhstan. The study aimed to investigate the relationship between electricity consumption and economic growth by including capital, labour and trade openness as the additional variables. To test the relationship between the variables, the VECM granger causality and ARDL bounds testing models were used. The results showed that in the long run, the relationship between these variables are realised. It further showed that both electricity consumption and trade openness enhanced economic growth. Capital and labour also stimulate economic growth. The results from VECM Granger-Causality showed a unidirectional causality flowing from electricity consumption to GDP. There also existed feedback hypothesis between economic growth and trade openness. Bidirectional relationship was found between economic growth and labour and also between trade openness and labour.

A Pakistan study by Atif and Siddiqi (2010) investigated the relationship between electricity consumption and GDP. The data used in the study covered the period from 1971 to 2007. The study used the following tests: Augmented Dickey-Fuller, Phillips-Perron, Engle and Granger co-integration, Standard Granger-causality and Modified Wald tests. The results from Engle and granger co-integration revealed no relationship between the variables while Modified Wald and Standard Granger causality exhibited a unidirectional granger causality running from electricity consumption to economic growth without any feedback effect. This implied that there was a need in Pakistan to increase their electricity supply.

Jamil and Ahmad (2010) also carried out a study for Pakistan to examine the relationship between electricity consumption, electricity prices and real GDP at both aggregate and disaggregate sectoral levels. The study also included the agricultural, household, manufacturing and commercial sectors. The study used annual data covering the period from 1960 to 2008. The results for co-integration showed the long run relationship between all the variables. The Vector Error Correction Model (VECM) results showed a one-way causality flowing from real GDP to electricity consumption for all the sectors. This implied economic growth positively affected electricity consumption in the long run. The results also showed a one-way causality running from real economic growth to electricity consumption in commercial and household sectors. It further showed a one-way relationship flowing from output to electricity consumption and electricity prices in the manufacturing sector and also a bidirectional relationship between output and electricity prices in the short run for the manufacturing sector. The study recommended that all sectors of the economy should use electricity efficiently.

Awan (2013), in a study for Pakistan investigated the causality between real GDP per capita and electricity consumption. The data of the study covered the period 1971 to 2008. The results showed the existence of co-integration between the variables. The causality results showed a one-way flow from electricity consumption to real GDP per capita. This implied that electricity consumption restricted economic growth such that crises that may occur to the supply of electricity will adversely affect economic growth. Awan's (2013) study showed the same results as Atif and Siddiqi's (2010) but differed from Jamil and Ahmad's (2010) study, that showed that adding a single or more variables to the bivariate model can lead to a change in the results. This was because for Jamil and Ahmad (2010), the direction of causality changed even when considering all sectors of the economy.

The study by Sultan (2012) attempted to investigate the relationship between export and GDP, and the relationship between electricity and GDP. This study for Mauritius used data for the period of 1970 to 2009. The study used Johansen's co-integration and ARDL bounds tests to examine the long run relationship between the variables. The results showed that in the long run electricity and exports affected economic growth.

This implied that electricity conserving policies may restrict economic growth and exports in the long run.

Tang and Shahbaz (n.d) undertook a study for Portugal to examine the relationship between electricity consumption, financial development, economic growth, foreign trade and population. The data used in this study was for the period of 1970 to 2009, using Granger-Causality test to determine the direction of causality between the variables and bounds testing framework to ascertain the presence of co-integrating relationship. The findings suggested the existence of co-integration between consumption and other variables which implied that there existed a long term relationship between the variables. The granger causality results showed a bidirectional relationship between electricity consumption and economic growth. Financial development and population were found to granger cause economic growth. This implied electricity on its own was not enough to boost economic growth.

Tang (2008) performed a study to re-examine the nexus between electricity consumption and economic growth for the period of 1972 to 2003 for Malaysia. To examine the long term relationship between the variables, the study used the ARDL model. The results of the study showed no long term relationship between electricity consumption and economic growth in Malaysia. The results of the Standard Granger-Causality and MWald tests showed the existence of a bidirectional relationship between electricity consumption and economic growth. This showed that electricity consumption was an important factor in the economic growth of Malaysia. The study recommended that since it had been shown that electricity consumption was important for Malaysia's economic growth, policies on electricity supply should be formulated in a way that it supported economic development.

Another Malaysian study to determine the relationship between electricity consumption and economic growth was carried out by Madhavan *et al.* (2009). The study applied multivariate systems using a time series data from 1971 to 2003. To determine the co-integration between the electricity consumption, economic growth and price, the study used the bounds test. The results, contrary to Tang (2008) results, found that co-integration between electricity consumption and economic growth existed in Malaysia.

This change in the results was caused by excluding important variables; as Tang (2008) used a bivariate framework and Madhavan used multivariate framework. The results showed that electricity consumption had a positive impact on the economy. The study estimated that increasing electricity consumption by one percent raised economic growth by between 0.68 to 0.79 percent. The results further showed existence of a unidirectional causality flowing from electricity consumption to economic growth in the short run. This showed that electricity is important in Malaysia.

Jumbe (2004), in a study for Malawi to investigate co-integration and causality between GDP and electricity consumption, used data for the period of 1970 to 1999. To examine co-integration between the variables, the Error Correction Model (ECM) technique was used while causality was examined by using the Granger-causality test. The GDP applied in the study was divided into agricultural GDP and non-agricultural GDP. The results showed co-integration between electricity consumption and GDP and non-agricultural GDP but no co-integration with agricultural GDP. The findings from the Granger-causality test demonstrated bidirectional causality between electricity consumption and GDP. A unidirectional causality flowing from Non-agricultural GDP to electricity consumption was also found. In applying the Error Correction Model, the study found a unidirectional causality flowing from GDP to electricity consumption and also from non-agricultural GDP to electricity consumption.

Odhiambo (2009) studied the relationship between electricity consumption and economic growth for Tanzania using a newly developed Autoregressive Distributed Lag (ARDL) bounds test of Pesaran *et al*. (2009). Two categories were used for energy consumption, the total energy consumption per capita and electricity consumption per capita. The bounds test results demonstrated existence of a long-run relationship between the variables while the causality test results suggested a unidirectional relationship flowing from total energy consumption to economic growth both in the long and short run. The results further showed a unidirectional causality flowing from electricity consumption to economic growth. Generally, the results showed that energy consumption affected Tanzanian economic growth.

3.4.2 Electricity Consumption Vs. Economic Growth in Multi-Countries

A multi-country study was performed by Ankilo (2008). This study seeked to find the causal relationship between economic growth and electricity consumption for eleven Sub-Saharan African countries. The study utilised both the Autoregressive Distributed Lag (ARDL) bound tests and Granger-Causality tests within the context of Vector Error Correction Model (VECM). The two tests resulted in different findings for different countries. Starting with ARDL bound tests, the findings were that electricity consumption is co-integrated with economic growth in Senegal, Ghana, Cote D'Ivore, Gambia, Zimbabwe and Cameroon. The results on the Granger-causality test portrayed bidirectional causality between economic growth and electricity consumption for Senegal, Ghana and Gambia. The results also showed a unidirectional causality flowing from economic growth to electricity consumption in Zimbabwe and Sudan. Finally, no causality was found for Cameroon, Kenya, Togo, Code D'Ivore and Nigeria.

Squalli (2007) did a multi-country study focusing on the Organisation of Petroleum Exporting Countries (OPEC). The paper investigated the relationship between electricity consumption and economic growth utilising the bounds test by Persaran *et al.* (2001) and non-causality test by Toda and Yamamoto (1995). The results from the causality test showed that in five of the countries, economic growth was dependent on electricity demand. It further showed that in three of these countries, economic growth showed less dependence on electricity consumption and independent on the last three. The bounds test showed the existence of a long-run relationship between consumption of electricity and economic growth for all the countries.

In Squalli (2007), it was observed that of the countries in which economic growth was independent of electricity consumption include Algeria, Lybia and Iraq. These results were found to be questionable with regard to these countries' economic and political stress. This has led to the conclusion that there was a possibility of mismanagement of resources in these countries such that those resources were not used in a way that added value to economic growth. This could be possible if the resources were not applied in energy intensive sectors. Lastly, the results showed a neutral hypothesis for

Kuwait, Saudi Arabia and the UAE, which indicated that energy conservation policies for these countries did not affect economic growth

Mehrara and Musai (2012) undertook a multi-country study to investigate the electricity consumption-GDP nexus in a panel of eleven Oil exporting countries. It added on oil revenues variable in the bivariate model of electricity consumption and GDP to form a trivariate framework. The study applied the panel co-integration method by Pedroni (1995) to test the availability of a long run relationship between these variables. It also used panel Granger-Causality tests to investigate the direction of the relationship of these variables. Time series data were used in the study for the period of 1970 to 2010. The findings showed the existence of causality flowing from Oil revenues and GDP to electricity consumption without any feedback effect. It was also found that in the short run oil revenues significantly impacted on GDP. This showed that electricity conservation policies could be made without any impact on economic growth.

Smyth and Narayan (2008) conducted a study for a panel of Middle Eastern countries using a multivariate framework to investigate the relationship between electricity consumption, exports and GDP. The findings of the study showed that there was existence of co-integration between the variables. The estimates showed that increasing electricity by one percent raised GDP by 0.04 percent while increasing exports by one percent increases GDP by 0.17 percent. The study further showed that increasing GDP by one percent on the other hand raised electricity consumption by 0.95 percent.

Hossain (2012) analysed the causal relationship between economic growth, electricity consumption, export and remittance for South Asian Association of Regional Cooporation (SAARC) countries. The study considered a time series data from 1976 to 2009. This study used Johansen Fisher co-integration and Kao tests to examine the long run relationship between the variables and panel Granger F-test for causality direction between the variables. The findings of the study showed that all the variables were co-integrated. The results further showed a bidirectional relationship between export and economic growth in the short run. The results also showed a unidirectional causality flowing from export values and remittance to economic growth in Bangladesh

in the short run, a one-way causality flowing from economic growth to export in India in the long run and a causality running from economic growth to electricity consumption in Pakistan in the short run.

3.4.3 Energy Consumption Vs. Economic Growth in Single Countries

Some studies did not only focus on electricity consumption but also the aggregate energy consumption. The study for Turkey to determine the relationship between economic growth and aggregated energy consumption was done by Lise and Montfort (2007). The annual data of 1970 to 2003 was used in this study. The study found existence of co-integration between energy consumption and GDP. Contrary to the study by Altinay and Karagol (2005), this study found a unidirectional causality flowing from GDP to energy consumption. This implied that the policies for energy saving would not harm economic growth in Turkey.

Another study for Turkey by Halicioglu (2007) sought to determine the relationship between residential demand for energy and income. The study used data for the period of 1968 to 2005 and utilised the bounds-test framework to determine the long term relationship between the variables. The variables used in the study included residential electricity demand, income, urbanisation and prices. The findings showed that, in the long run, causality flowed from price, income and urbanisation to residential energy consumption.

Yang (2000) undertook a study for Taiwan to re-investigate the relationship between energy consumption and GDP for the period of 1954 to 1997. The relationship investigated different categories of energy and aggregated energy with GDP. The results showed that the direction of causality differed according to the different categories of energy. It further showed bidirectional causality between GDP and aggregate energy consumption.

Qasi, Ahmed and Mudassar (2012) performed a study in Pakistan to examine the relationship between disaggregate energy consumption and industrial output for the period from 1972 to 2010. The paper used Johansen’s co-integration test to examine the long run relationship of the variables. The findings showed that disaggregate energy

affected industrial output. The results further determined a bidirectional relationship between oil consumption and industrial output, a one-way causality flowing from electricity consumption to industrial output and unidirectional relationship flowing from industrial output to coal consumption. There was a neutral hypothesis between gas consumption and industrial output. The study recommended the government to develop innovative energy policies to meet the demand for energy and not to implement energy conservative policies as they would hamper industrial production.

Another study for Pakistan by Aqeel and Butt (2001) purposed to determine the relationship between energy consumption, economic growth and employment. The study used Hsiao's Granger-causality to test for the direction of causality between the variables. The findings show that economic growth Granger-causes aggregate energy consumption. The study further disaggregated energy consumption into Petroleum, gas and electricity consumption. The results demonstrated that economic growth stimulates petroleum consumption but no relationship was found between economic growth and gas consumption. The electricity consumption, on the other hand, was found to Granger-cause economic growth without feedback effect. Finally, the findings showed that energy consumption Granger-causes employment directly. The policy implications for this study indicated that policies on electricity and gas consumption should be done in a way that promotes economic growth while policies concerning petroleum consumption will not affect economic growth.

Kwakwa (2012) investigated the relationship between disaggregated energy consumption (fossil fuel and electricity consumption) and overall growth which was divided into agricultural and manufacturing growth. The data used in the study was for the period 1971 to 2007 for Ghana. The results from the Johansen test suggested the presence of long run relationship between the variables. The results from the causality test demonstrated a one-way causality flowing from overall growth to disaggregated energy consumption. It also showed a one-way causality flowing from agriculture to electricity consumption both in the long and short run but feedback causality between electricity consumption and manufacturing. The general results implied that energy did not seem to be a core factor in the agricultural sector but in the manufacturing sector

proved to be highly necessary. In this regard, it would be of great importance that resources be allocated to sectors in which they are mostly useful, which is manufacturing at this point.

The study by Wesseh and Zoumara (2012) examined the relationship between energy consumption and economic growth in Liberia for the period from 1980 to 2008. The study applied a bootstrap methodology and included employment in the model to form a trivariate framework. Bidirectional Granger-causality was found between energy consumption and economic growth. The findings also demonstrated a unidirectional relationship running from employment to economic growth. The policy implications show that energy consumption has an impact in the employment generation.

Lean and Shahbaz (2012) analysed the relationship between energy consumption, economic growth, industrialisation, financial development and urbanisation for the period from 1971 to 2008 for Tunisia. This study used the Granger-causality test for testing for direction of causality between the variables and the ARDL bounds tests for the long run relationship between the variables. The findings showed the existence of co-integration of the variables. The findings also showed bidirectional relationships between financial development and energy consumption, financial development and industrialisation and, industrialisation and energy consumption. A unidirectional causality flowing from economic growth to energy consumption was also found. The results further showed a bidirectional relationship between economic growth and energy consumption in the short run. This implied that the energy conservation policies should not be used in the short run as they could potentially restrict economic growth. In general, the results of the study showed that electricity consumption on its own was not enough for economic growth but industrialisation, urbanisation and financial development do impact economic growth.

3.4.4 Energy Consumption Vs. Economic Growth in Multi-Countries

The study by Mahadevan and Asafu-Adjaye (2007) investigated the relationship between GDP growth and energy consumption. The study used a panel error correction model, with annual data from 1971 to 2002. This is a multi-country study of 20 nations.

To test for unit roots, co-integration and Granger-causality Mahadevan and Asafu-Adjaye (2007) used panel methods for the following reasons: firstly, it prevented low power problems which existed in the traditional unit roots and co-integration tests; secondly, it entailed pooling which increased the sample size considerably. This led to more reliable and accurate statistical tests because the increase in sample size resulted in higher degrees of freedom. Lastly, the panel method lessened collinearity between the regressors and enabled heterogeneity among the countries. They used a trivariate model which proxied energy prices because price changes have been hypothesised to have a direct impact on both energy consumption and income.

The findings of their research were different for developing and developed countries. It was observed that bidirectional causality existed between economic growth and energy consumption for developed countries both in the short and long run. The results for developing countries showed that bidirectional causality existed only in the short run.

Razzaqi and Sherbuz (no date) conducted a study for the D8 countries for the period of 1980 to 2007. The aim of the study was to examine the relationship between energy use and economic growth. In their research to find the long run and short run relationship between economic development and energy they used the Johansen co-integration, VAR Granger-causality and VECM tests. The results showed bidirectional causality for all the countries in the short and long run, except Indonesia. In Indonesia a neutral hypothesis was found in the short run.

Sadorsky (2012) studied the relationship between energy consumption, output and trade in South America. The period of data used in the study was from 1980 to 2007 for seven South American countries. The study used the panel co-integration technique to examine the long run relationship between the variables. The findings of the study demonstrated a long run relationship between capital, output, exports, labour and energy and a long run relationship between output, labour, capital and imports. The results for causality direction showed a two-way causality between energy consumption and exports, output and exports and also output and imports. There was also a unidirectional relationship flowing from energy consumption to imports in the short run.

3.4.5 Electricity Supply Vs. Economic Growth in Single Countries

The research proceeds to consider the supply side of electricity. The supply side has been rarely investigated in the literature. The few studies that considered the supply side attempted to apply causality direction to indicate which variable takes precedence over the other (Yoo & Kim 2006). This means that the studies sought to investigate whether electricity supply stimulated economic growth or whether economic growth improved electricity supply.

Knowledge of the direction of causality from either side has a significant importance for policy recommendation for the following reasons: firstly, a one-way causality flowing from electricity generation to economic growth shows that policies of reducing electricity generation should not be made as they would adversely affect economic growth; secondly, a one-way causality flowing from economic growth to electricity generation shows that policies to reduce electricity could be made without affecting economic growth or could have a small effect; lastly, no causality between the two would mean that electricity generation could be reduced without affecting economic growth at all (Yoo & Kim 2006).

The research further considers the work of Ellahai (2010) who studied the relationship between industrial sector development, electricity supply and economic growth. This study used the Autoregressive Distributed Lag (ARDL) approach and the endogenous growth model. The study used a model to find relationship between economic growth and five independent variables, namely, industrial sector development, electricity supply, labour, capital and electricity shortages. The findings of the research was that capital, labour, electricity supply and industrial sector development played an important role in improving economic growth. It further showed that electricity shortages had an adverse effect on economic growth.

Yoo and Kim's (2006) study examined the relationship between economic growth and electricity generation in Indonesia. The study used data from 1971 to 2002. The study tested for stationarity and co-integration and estimated the error correction model. The findings suggested the existence of unidirectional causality flowing from economic growth to electricity generation. This implied that economic growth has an impact on

electricity generation such that reducing economic growth would lead to a fall in electricity generation. Furthermore, the results indicated no causality flowing from electricity generation to economic growth. Therefore, in Indonesia, policies on increasing or decreasing electricity generation could be made without affecting economic growth.

Another similar study that focused on the supply side of electricity is by Morimoto and Hope (2004). The aim of the study was to investigate the impact of electricity supply on economic growth in Sri Lanka. The study followed the research by Yang (2000) which examined the impact of electricity consumption on economic growth. The cost benefit analysis was used in this study and the findings indicated that electricity supply had a positive impact on economic growth. Numerically, the study showed that an increase of 1 Mwh of electricity supplied at time t led to an increase in economic growth by Rs38 200, and while at time *t*-1, economic growth increases by Rs30 000 and at time *t*-2, economic growth increases by Rs44 100. Generally, this implied that the past and the current changes in electricity supplied have a significant effect on economic growth in Sri Lanka.

Sarker (2010) investigated the relationship between electricity generation and economic growth in Bangladesh. The data used in the study covered the period 1973 to 2006. The study used the Granger-causality test to examine the relationship between electricity generation and economic growth. The study followed the model by Yoo and Kim (2006) who used a bivariate model with electricity generation and real GDP as the variables. The unit root test was examined by ADF and PP tests while co-integration was examined by Johansen's co-integration test. The results indicated a unidirectional relationship flowing from electricity generation to real GDP. This implied that a change in the policies for electricity generation would affect economic growth. The results of this study differed from Yoo and Kim (2006) results in that Yoo and Kim's (2006) found a unidirectional relationship running from economic growth to electricity generation. These two studies further show the inefficiency of using a bivariate system. In the case of Bangladesh, it was important for electricity generation to be increased as it would lead to an increase in economic growth.

Ghosh (2009) carried out a study in India that investigated the relationship between employment, electricity supply and real GDP. The data used in the study was for the period from 1970 to 2006. The research employed a multivariate system and utilised Autoregressive Distributed Lag (ARDL) bounds tests for co-integration. The long and short causality was established flowing from electricity supply and real GDP to employment without feedback effect. This showed that real GDP and electricity supply had an impact on employment in India. There was no causality flowing from electricity supply to real GDP, implying that electricity generation policies could be made in India without affecting economic growth. Further, in the short run, the study suggested a unidirectional causality flowing from economic growth to electricity supply.

Gupta (2009) researched the causal relationship between electricity supply and economic growth in India for the period of 1960 to 2006. The study used the Granger causality model to examine the relationship between electricity consumption and economic growth. The findings showed existence of a unidirectional causality between electricity supply and economic growth, flowing from electricity consumption to economic growth. The panel regression model was also used in the study to investigate the relationship between economic growth and electricity supply across major states. The data used was for the period of 1990 to 2004. The results showed that, in the backward states, an inverse relationship between electricity supply and economic growth existed whereas in the developed states the opposite was true.

Smyth and Lean (2010) added to the studies of the electricity supply side by studying the relationship between electricity generation, economic growth, exports and prices for Malaysia during the period 1970 to 2008. The study found a one-way causality flowing from economic growth to electricity generation. The relationship relating to exports and trade were not supported. The study also found a neutral hypothesis for prices and economic growth. The results implied that policies concerning increases in electricity generation could be implemented without fear of affecting economic growth.

3.4.6 Electricity Supply Vs. Economic Growth in Multi-Countries

A multi-country study from the supply side of energy was done by Yusuf and Metehan (2011) who studied the relationship between renewable electricity generation from renewable resources and economic growth for 30 OECD member countries. The study used data for the period 1980 to 2007 for the OECD member countries. The aim of the study was to examine the direction of causality (if it existed). The panel-data methodology was used in the research. The study applies Pedroin, Kao and Fischer's co-integration tests and the Holtz-Eakin causality test.

The Pedroin, Kao and Fisher co-integration tests suggested that there is a long term significant relationship between electricity generation and economic growth. Holtz-Eakin causality test demonstrated bidirectional causality between economic growth and electricity generation. The study recommended that the countries should aim at improving on their electricity generation as it would have a positive impact on economic growth.

The research of Halkos and Izeremes (2009), studied the impact of electricity generation on countries' economic efficiency. The data in the study was collected for 42 World and East Asian countries for the period 1996 to 2006. The econometric panel techniques and Data Envelopment Analysis (DEA) window analysis were used in the study. The DEA window analysis was used in the study to measure the countries' economic efficiency, and the impact of electricity on their economic efficiency was tested by the panel technique. The findings of the study showed an inverted U-shape relationship between electricity generation and economic efficiency. This implied that electricity generation affected economic efficiency positively to a certain extent and which after a certain period of time, the effect changes to negative.

3.4.7 The South African Studies

Inglesi (2009) and Odhiambo (2009) undertook their South African studies to examine the relationship between electricity consumption and economic growth. Inglesi (2009) used the Engle-granger test and Error correction models to test the long run relationship between electricity demand, electricity prices and economic growth. The study used

annual data covering the period from 1980 to 2005. The results showed co-integration between the variables, meaning that in South Africa, there is evidence of a long run relationship between electricity demand and prices of electricity and also economic growth.

Odhiambo (2009) used employment as the third variable for testing relationships between electricity consumption and economic growth whereas Inglesi (2009) used electricity prices. This was because employment impacts on both electricity consumption and economic growth. Odhiambo (2009) also mentioned that employment was included because the use of bivariate framework can lead a study suffering from the omission of variables bias. The results of this study showed distinct bidirectional causality between economic growth and electricity consumption in South Africa.

From these two studies, it can be viewed that electricity consumption does affect economic growth and on the other hand economic growth affects electricity consumption in South Africa. These results showed that to deal with the increasing electricity demand, the country's resources should be used to increase supply of electricity. For instance, the electricity generation plants and infrastructure should be expanded. This will in return avoid the power outages which affect the production of the industrial sector and hence negatively affect the country's economic growth.

The study by Okafor (2012) investigated the relationship between energy consumption and economic growth in South Africa and Nigeria. The energy consumption was disaggregated into oil, hydro and coal consumption. The study used the Hsiao's Granger causality because of the restrictions on stationarity the features of data. The results showed a unidirectional causality running from economic growth to aggregate energy consumption in South Africa while a unidirectional causality running from energy consumption to economic growth was evidenced in Nigeria. The findings show that in South Africa energy policies have impacts on economic growth as a result they should be made in such a way that they stimulate economic growth.

The Wolde-Rufael (2009) study investigated multi-countries and compared the causal relationship between economic growth and electricity consumption for 17 African

countries. The study used a multivariate framework including both labour and capital variables. The data used was for the period from 1971 to 2001. The study also incorporated the bound test for cointegration.

The findings of the study showed different results for different countries. The findings showed a unidirectional relationship flowing from economic growth to electricity consumption for Egypt, Ivory Coast, Morroco, Nigeria, Senegal, Sudan, Tunisia and Zambia. For South Africa, Benin and Algeria, the findings showed a unidirectional causality flowing from electricity consumption to economic growth. This showed that in the three countries, a decrease in energy consumption can lead to a decline in economic growth. This implies that these countries should be careful when making energy conservation policies because they could negatively affect economic growth. Finally, the results showed that as much as electricity consumption is an important factor to economic growth, labour and capital contribute more to economic growth than electricity consumption.

Bildirici (2012) researched the causality between electricity consumption and economic growth for the following countries: Code d'Ivoire, Cameroon, Nigeria, Brunei, Togo, South Africa and Zimbabwe. The Markov Switching Vector Auto Regression (VAR) and Switching Granger-Causality tests were used for the period 1970 to 2010. The findings showed existence of bidirectional causality between electricity consumption and economic growth. The study recommended that the ongoing restructuring policies should be implemented because electricity consumption proved important for economic growth.

3.6 CONCLUSION

This chapter discussed the theory and empirical studies concerning the impact of electricity power outages. Electricity shortages affect production of the industrial, farming and mining sectors and also the leisure time of the household sector. The impact of power outages on the country's economic growth has also been reviewed.

The chapter has also discussed the literature on studies that focus on the relationship between electricity consumption and economic growth, electricity generation and

economic growth as well as energy consumption and economic growth. The general consensus regarding the findings is still mixed. This means that some studies found causality flowing from economic growth to electricity generation, others suggested causality flowing from electricity generation to economic growth and even some determined bidirectional and/or no causality between these variables.

The differences in the findings of these studies result from the period of sample, country specific features, the chosen variables and methodologies used. Most studies used a sample period of 20 to 40 years. The choice of variables ranged from two variables, termed bivariate framework to three variables, named trivariate system and to more than three called multivariate models. The increase in the number of variables used in the studies is ascribed to the deficiencies of using few variables. For instance, bivariate framework was shown to suffer from lack of variable bias as a result overestimating the results. The other problem found in the studies is that the majority used cross-sectional data which does not cater for country specific characteristics.

Against these backdrops, the research uses a multivariate framework following from the study by Odhiambo (2009) who investigated the relationship between electricity consumption, economic growth, and labour. The study differs from the research in that, it uses electricity generation instead of electricity consumption because few studies concentrated on electricity generation. The model will also incorporate a dummy on electricity power outages, because power outages affect economic growth and this has been the major problem of electricity supply since 2008 in South Africa. The study will use the standard Granger-causality and ARDL bounds tests to determine the direction of causality between the variables and the existence of the long run relationship between the variables respectively.

The following chapter describes the methodology of the study and discusses the econometric models that are used to assess the viability of the study. It also discusses the sample size chosen for the study, the method of data collection, and the places where the data was collected.

Chapter 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

Chapter Three has discussed the literature review. It reviewed the studies on the impact of electricity consumption, energy consumption and electricity generation to economic growth. It showed that to test for causality or non-causality between the variables, the unit root and co-integration have to be tested apriori. The following tests for unit root were used by different studies; Phillips and Perron (PP) test, Augmented Dickey-Fuller test and KPSS.

The tests for co-integration were also carried out using the following techniques; bounds test by Persaran *et al.* (2001), Johansen co-integration test, Pedroin Kao and Fischer co-integration test, Autoregressive Distributed Lag (ARDL) bounds testing and Engle and Granger co-integration test. The results in most studies showed existence of co-integration e.g. Lise & Montfort 2007; Yuan *et al.* 2007; Sadorsky 2012; Awan 2013 and Lim & Shiu 2004. The results showing no co-integration were rarely found. This includes study by Wolde-Rufael (2006) for Algeria, Congo, South Africa and Sudan.

Then finally, the causality between the variables was examined using the following tests; Hsiao's granger causality test, Vector Autoregressive (VAR) Model, Holtz-Eakin causality test, VECM granger causality, Modified Wald test and Markov Switching VAR model. The results from those tests demonstrated different findings: some showed bidirectional causality, others one way causality while others showed no causality between the variables. The examples of these studies include; Atif and Siddiqi (2010), Bildirici (2012), Tang (2008) and Jamil and Ahmad (2010).

This leads to Chapter Four focusing on the methodology to be used in the research. The research methodology discusses the process, tools and steps used in the research. This section is going to discuss the method of data collection, the period of study and analysis of the data. It will show how data collection and analysis add value to the study. Generally, the chapter will be organised in the following manner: firstly, it will discuss

the model specification; secondly, data sources and variables description; thirdly, the unit root tests to be used in the study; fourthly, the co-integration tests to examine the long run relationship between the variables and lastly, causality tests to determine the direction of causality between the variables.

4.2 MODEL SPECIFICATION

In investigating the relationship between economic growth and electricity supply, the research follows the work of Ghosh (2009) and Odhiambo (2009). The study by Odhiambo (2009) was carried in South Africa to investigate the relationship between electricity consumption and economic growth. In Odhiambo's (2009) model, labour was added as the third variable to form a trivariate framework. The study showed that there is a long run relationship between electricity consumption, labour and economic growth in South Africa. Most importantly, bidirectional causality between electricity consumption and economic growth was found in the study and that labour Granger-causes economic growth. In this regard, the research follows Odhiambo's (2009) study but instead of using electricity consumption, it utilises electricity supply. This is because the literature review has shown that very few studies focused on electricity supply and so far in South Africa no study has been done on the relationship between electricity supply and economic growth. The aim of the research is therefore to fill the gap.

The adoption of electricity supply is in line with the study by Ghosh (2009) that also examined the causality between electricity supply and economic growth in India. The study also added labour as the third variable to form a trivariate system. The study found existence of a long run relationship between the variables and a causality running from electricity generation to real GDP. The choice of the third variable also emanates from the fact that a bivariate framework leads to unreliable results (Adebola, 2011). This led to some studies adding a third variable, while others included more than three variables in their models. For instance, Adebola (2011) and Ouedraogo (2009) added capital formation as the third variable in addition to electricity consumption and real GDP.

The other studies included labour as the third variable (Ghosh 2009; Acaravci and Otzurk 2012; Madhavan *et al.* 2010; Narayan 2005 and Odhiambo 2009). The addition of the third variable was shown to lead to changes in the results and this led to studies such as Sadorsky (2011) and Wolde-Rufael (2009) adding both labour and capital to their models. The choice of labour as the third variable for the current study is because from Odhiambo (2009), it was discovered that in South Africa, labour affects both electricity consumption and economic growth. Acaravci and Otzurk (2012); Madhavan *et al.* (2010); Narayan (2005), and Narayam and Smyth (2005) also showed in their respective countries that labour Granger-causes economic growth and electricity consumption. Ghosh (2009) specifically demonstrated that labour affects both economic growth and electricity generation in India.

Consistent to the literature and the studies by Ghosh (2009) and Odhiambo (2009), the research adopts a standard log-linear functional specification of the nexus between electricity supply, real GDP and employment as follows:

$$GDP_t = \alpha_1 + \alpha_2 DUM\,08 + \alpha_3 ES_t + \alpha_4 EM_t + \varepsilon_t \qquad (4.1)$$

Where; *GDP* represent the real gross domestic product (using constant prices of 2005), *DUM08* is the dummy variable for the power outages from 2008, *ES* is the electricity supply measured in Gigawatt-hours and *EM* is the total labour force. The research's model is different from Ghosh's (2009) model in that it includes a dummy variable on electricity outages. The year 2008 is chosen because that is when South Africa experienced high levels of power outages. It has been observed in the literature that power outages have a significance influence on real GDP hence, its inclusion in the model. The choice of power outage dummy variable also follows from Ellahai's (2011) study which used a model with a dummy variable of power outages from 2007. Ellahai's (2011) study evidenced that power outages affect economic growth. The variables are all expressed in logarithmic form to stimulate stationarity of the mean, variance and covariance as a result reducing heteroscedasticity (Acaravci & Ozturk 2010).

4.3 DATA SOURCES AND VARIABLES DESCRIPTION

The empirical study uses quarterly data for the period first quarter of 2000 to the second quarter of 2012. The data for South African GDP is sourced from the South African Reserve Bank while data for Labour is found from IMF international financial statistics. In the research, electricity generation is expressed in terms of Gigawatt hours and it is obtained from the Statistics South Africa data base. The nominal GDP of South Africa is deflated by the GDP deflator to compute the figures for real GDP taking 2005 as the base year. Following the studies by Narayan (2005) and Odhiambo (2009) labour is calculated as the total number of people who are employed in the manufacturing industry. The research also included people employed in the mining sector because it also employs a significant amount of labour in South Africa. The choice of the manufacturing sector is also because it employs more people than all the other sectors in the economy (Statistics South Africa, 2013).

4.4 UNIT ROOT TESTS

The unit root tests serve to determine the stationarity of the variables. Yuan, Zhao and Hu (2006) stated that a series that contain mean, variance and auto-covariance that are non-constant over time is referred to as non-stationary. A non-stationary series has to be differenced a certain number of times in order to be stationary. For instance, if it is differenced *d* times to be stationary, it is said to be integrated of order *d*, denoted as I(d). Lise and Montfort (2006) purported that non-stationary series have repercussions if they have unit root, therefore it is important to find order of integration of the variables. The behaviour of non-stationary series can be random walks, cycles, trends. Non-stationary series have a problem of heteroscedasticity, as a result cannot be forecasted (Lise & Montfort 2006). They may also give results which are spurious (Odhiambo 2009). This means non-stationary series can indicate existence of a relationship between the variables where it does not exists. It can therefore be concluded that to have reliable results, stationary series have to be established.

The Augmented Dickey-Fuller test, by Said and Dickey (1984) and Phillips and Perron tests by Phillips and Perron (1988) were conventionally used to investigate the unit root (Adebola, 2011). The conventional tests have been criticised by many studies in

literature. For instance, Tang (2008) citing from Cambell and Perron (1991) showed that when the root of the autoregressive polynomial is near unity, the tests have low power such that it is difficult to distinguish when unit root exists or if it is a near unit process. Hu and Lin (2008) indicated that the conventional unit roots tests contain a problem of size distortion which highly affects the selection of an autoregressive truncation lag k. To tackle these critiques, KPPS test was also used because it can powerfully differentiate between the variables which appear to be integrated and stationary and the variables which are not very informative about having unit root or being stationary (Hu and Lin 2007).

4.5 CO-INTEGRATION TESTS

Yoo and Kim (2005) define co-integration as “a systematic co-movement among two or more economic variables over the long run”. Engle and Granger (1987) indicated that a combination of non-stationary variables may be stationary and this is a necessary situation for the existence of co-integration and it implies that there is a long run relationship between the variables. Following from the studies of Adebola (2011), Tang (2008) and Madhavan *et al.* (2009), the research uses the Autoregressive Distributed Lag (ARDL) approach to test for co-integration. The ARDL technique was established by Pesaran and Shin (1999) and extended by Pesaran, Shin and Smith (2001).

The ARDL technique was chosen over the conventional models such as Engle and Granger (1987) and Johansen (1988) for the research for the following reasons: firstly, ARDL uses a single reduced form of equation to examine the long run relationship of the variables as opposed to the conventional Johansen test that employs a system of equations (Adebola 2011). Secondly, it is suitable to use to test co-integration when a small sample data is used (Ellahai 2011). Thirdly, it does not require the underlying variables to be integrated of similar order e.g. integrated of order zero I(0), intergrated of order one I(1) or fractionally integrated, for it to be applicable (Madhavan *et al.* 2009). Lastly, it does not rely on the properties of unit root dataset and this makes it possible for the Granger causality to be applied in testing the long run relationships between the variables (Ellahai 2011).

The application of ARDL in investigating the long run relationship between the variables involves estimating an Unrestricted Error Correction Model (UECM) in first difference form (Madhavan *et al.* 2009). The research utilises the following UECMs:

$$\Delta LGDP_t = \alpha_{0GDP} + \alpha_{1GDP} DUM\,08 + \sum_{i=0}^{q} \alpha_{2GDP} \Delta LGDP_{t-i} + \sum_{i=0}^{q} \alpha_{3GDP} \Delta LES_{t-i} + \sum_{i=0}^{q} \alpha_{4GDP} \Delta EM_{t-i}$$

$$\theta_{1GDP} LGDP_{t-i} + \theta_{2GDP} LES_{t-i} + \theta_{3GDP} LEM_{t-i} + \varepsilon_{1i} \qquad (4.2)$$

$$\Delta LES_t = \alpha_{0ES} + \alpha_{1ES} DUM\,08 + \sum_{i=0}^{q} \alpha_{2ES} \Delta LES_{t-i} + \sum_{i=0}^{q} \alpha_{3ES} \Delta LGDP_{t-i} + \sum_{i=0}^{q} \alpha_{4ES} \Delta EM_{t-i}$$

$$\gamma_{1ES} LGDP_{t-i} + \gamma_{2ES} LES_{t-i} + \gamma_{3ES} LEM_{t-i} + \varepsilon_{2i} \qquad (4.3)$$

$$\Delta LEM_t = \alpha_{0EM} + \alpha_{1EM} DUM\,08 + \sum_{i=0}^{q} \alpha_{2EM} \Delta LEM_{t-i} + \sum_{i=0}^{q} \alpha_{3EM} \Delta LGDP_{t-i} + \sum_{i=0}^{q} \alpha_{4EM} \Delta LES_{t-i}$$

$$\phi_{1EM} LGDP_{t-i} + \phi_{2EM} LES_{t-i} + \phi_{3EM} LEM_{t-i} + \varepsilon_{3i} \qquad (4.4)$$

The Δ is defined as the first difference operator and all the variables are expressed in logarithmic form. The null hypothesis of no co-integration is then conducted for each of the three equations above. For instance in equation 4.2, the null hypothesis of no co-integration is as follows:

$$\mathrm{H}_0 : \theta_{1GDP} = \theta_{2GDP} = \theta_{3GDP} = 0$$

Against the alternative hypothesis of co-integration:

$$\mathrm{H}_1 : \theta_{1GDP} \neq \theta_{2GDP} \neq \theta_{3GDP} \neq 0$$

For equation 4.3, the null hypothesis of no co-integration is shown as

$$\mathrm{H}_0 : \gamma_{1ES} = \gamma_{2ES} = \gamma_{3ES} = 0$$

Against the alternative hypothesis of co-integration:

$$\mathrm{H}_1 : \gamma_{1ES} \neq \gamma_{2ES} \neq \gamma_{3ES} \neq 0$$

And the same procedure is carried for equation 4.4

The F-test is used to determine the long run relationship among the variables by examining the significance of the lagged level of the variables. If F-statistics is greater than the upper critical value, this implies existence of co-integration (Narayam 2005). If F-statistics is smaller than the critical value, then there is no co-integration and lastly, if the F-statistics falls within the upper and lower critical values, the test will be inconclusive (Narayan, 2005).

4.6 CAUSALITY TESTS

The presence of co-integration relationship indicates the existence of causal relationship but does not show the direction of causality between the variables. It therefore, leads the research to examining the tests used to investigate the direction of causality between the variables.

Madhavan *et al*. (2009) indicated that the Granger-causality as a Vector Autoregressive (VAR) is applied in the first differenced form if the variables were not co-integrated. On the other hand, if the variables are co-integrated, the Granger-causality which entails the lagged Error Correction Term (ECT) is used in the equation as an additional variable. The information pertaining to long run relationship between the variables is contained in the ECT while the short run information is determined by the lagged terms of individual coefficients (Adebola 2011). Adebola (2011) further shows that the long run relationship is depicted by a negative sign on the coefficient of the ECT. For the purpose of the research, the following equations will be used.

$$\Delta LGDP_t = \alpha_{10} + \sum_{i=1}^{q} \alpha_{11} \Delta LGDP_{t-i} + \sum_{i=1}^{r} \alpha_{12} \Delta LES_{t-i} + \sum_{i=1}^{s} \alpha_{13} \Delta LEM_{t-i} + \psi_1 ECT_{t-1} + \varepsilon_{1i} \quad (4.5)$$

$$\Delta LES_t = \alpha_{20} + \sum_{i=1}^{q} \alpha_{21} \Delta LES_{t-i} + \sum_{i=1}^{r} \alpha_{22} \Delta LGDP_{t-i} + \sum_{i=1}^{s} \alpha_{23} \Delta LEM_{t-i} + \psi_2 ECT_{t-1} + \varepsilon_{2i} \quad (4.6)$$

$$\Delta LEM_t = \alpha_{30} + \sum_{i=1}^{q} \alpha_{31} \Delta LEM_{t-i} + \sum_{i=1}^{r} \alpha_{32} \Delta LGDP_{t-i} + \sum_{i=1}^{s} \alpha_{33} \Delta LES_{t-i} + \psi_3 ECT_{t-1} + \varepsilon_{3i} \quad (4.7)$$

The direction of causality can be differentiated between long run and short Granger-causality effects. The *t*-statistics is used to test the significance of the lagged error correction term. The significance of ECT will prove the existence of long run Granger-causality (Ghosh 2009). The short run Granger causality is tested by the F-statistics and testing the significance of the lagged independent variables (Odhiambo, 2009).

4.7 CONCLUSION

Chapter Four discussed the methodology of the study. It commenced with the model specification. This section gave details on the choice of the model for this study and explained the importance of each variable. The model serves to investigate the granger causality between electricity supply and economic growth. But since, the literature has shown that using a bivariate model weakens the results, the model included the third variable, namely, labour. This is because labour was proven to affect both electricity consumption and economic growth in South Africa (Odhiambo, 2009). It was also shown in studies such as Acaravci and Otzurk (2012) Madhavan *et al.* (2010); Narayan (2005), and Narayam and Smyth (2005) that labour affects electricity consumption and economic growth in other countries e.g. Pakistan and Turkey. In relation to what the current study serves to investigate, Ghosh (2009) showed that labour affects both electricity generation and economic growth in India.

Chapter Four continued to discuss data sources and the period of the study. It showed that quarterly data from 2000 to 2012 will be used in the study and will be sourced from Statistics South Africa, South African Reserve Bank and IMF international financial statistics. The proxies for economic growth, electricity supply and labour was shown to be real gross domestic product, electricity generated and available for distribution and total number of people employed by all the sectors, respectively.

Following the literature review, it was shown that before testing for the Granger-causality between the variables, it is important to find the order of integration of the variables first. This will show whether the variables are stationary or non-stationary. The importance of testing for stationarity is because non-stationary variables suffer from heteroscedasticity and give spurious results and hence cannot be used for forecasting. Co-integration of the variables also has to be tested first before Granger-causality. This determines whether there is existence of long run relationship between the variables. The study used the ARDL model to test for co-integration for the reasons provided above.

Finally, the Chapter Four discussed the Granger-causality between the variables. This serves to determine the direction of causality between the variables and to test whether it is a long run or short run Granger-causality impact. The VECM Granger-causality was chosen for the current study. To test the short run Granger-causality between the variables, the F-statistics is used while the *t*-statistics is used to test the long run Granger-causality impact.

Chapter Five is going to discuss the analysis and interpretation of the results. The regression analysis of the models will be reviewed in Chapter Five. In general, the empirical findings of the study will be shown in this chapter.

Chapter 5

ANALYSIS OF THE EMPIRICAL FINDINGS

5.1 INTRODUCTION

Chapter One discussed the main objectives of the dissertation, namely, to determine causality between electricity and economic growth as well as the impact of power outages on economic growth. Chapter Two investigated the relationship of these variables as experienced by South Africa and other countries. The theoretical and empirical literature on economic growth and electricity supply nexus were examined in Chapter Three while Chapter Four described the models used in the dissertation to investigate this relationship. The analysis and estimations of the findings are discussed in this chapter.

The econometric models developed in Chapter Four are analysed in the current chapter using quarterly time series data. This chapter is divided into three main sections: The first section focuses on testing the stationarity of the variables to ensure that the model yields reliable results. The second section examines the existence of the long run relationship between the variables and the third section determines the direction of causality between the variables.

This chapter commences with the summary statistics of real GDP, employment, electricity supply and power outages for South Africa. The summary statistics are presented for data which has been converted into logarithmic form. The chapter will continue to discuss the stationarity of the variables using the traditional unit root tests, Augmented Dickey-Fuller (ADF) and Phillips and Perron (PP). The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root test will also be conducted to supplement the traditional unit roots tests because of the problem of low power of these tests.

The analysis of co-integration follows after determining the order of integration of the variables. This serves to determine the existence of a long run relationship between economic growth, electricity supply, power outages and employment, using the Autoregressive distributed lags (ARDL) technique. The Johansen co-integration

technique will also be used to confirm the robustness of the long run relationship between these variables. The importance of choosing the right lag length in conducting co-integration will lead to consideration of lag order selection criterion prior to co-integration tests. The study will use Akaike information criteria (AIC) as the major determinant of the lag length supplemented by LR, FPE, SC and HQ.

The diagnostic tests of the models are also discussed. This involves testing the model for serial correlation, heteroscedasticity and normality. The stability of the long run parameters will be determined by the use of the cumulative sum of recursive residuals (CUSUM) and the CUSUM of squared residuals (CUSUMSQ).

Finally, the direction of causality between the variables will be analysed using the Vector Error Correction Model (VECM) granger causality. The analysis will include both the short run and long run causalities. The model will be tested for stability by using the unit circle, impulse response and variance decomposition.

5.2 DATA DESCRIPTION

Table 5.1 shows the correlation matrices and descriptive statistics for real GDP, power outages, employment and electricity supply. The results shown by Jarque-Bera estimates confirm that all series are normally distributed. The correlation matrices indicate the existence of a positive correlation between electricity supply and economic growth, electricity supply and employment, economic growth and employment.

Table 5-1: Summary statistics the real GDP, Electricity supply and Employment

	RGDP	ES	EM	DUM
Mean	6.205414	4.745341	4.105904	0.00800
Median	6.213295	4.754228	4.115527	0.00000
Maximum	6.290668	4.798409	4.141262	1.00000
Minimum	6.108469	4.671737	4.066699	0.00000
Std. dev	0.058111	0.034523	0.024340	0.274048
Skewness	-0.204581	-0.594909	-0.289138	3.096281
Kurtosis	1.559973	2.351602	1.568165	10.58696
Jarque-Bera	4.668941	3.825177	4.967825	199.8119
Probability	0.096862	0.147698	0.083416	0.00000
Sum	310.2707	237.2671	205.2952	4.00000
Sum Sq. Dev.	0.165467	0.058399	0.029030	3.68000
Observations	50	50	50	50
RGDP	1.00000			
ES	.0874022	1.00000		
EM	0.864561	.0732692	1.000000	
DUM	.0263182	.0265837	0.359224	1.00000

Source: Own construction

5.3 UNIT ROOT TESTS

This section tests the unit root properties of economic growth, electricity supply, power outages and labour. The ADF, Phillips and Perron and KPSS unit root tests are used to determine the order of integration of these variables. This is done to ensure that none of the variables are integrated of order beyond one. As indicated in chapter four, the ARDL test for cointegration is applicable even when the variables are intergrated of order one or zero or both. But according to Muhammad, Ahmad and Saleheen (2012) the order of integration is not supposed to go beyond the order one for the ARDL method to be applicable e.g. I(2) and above.

Table 5-2: The Augmented Dickey-Fuller unit root test

Variable	Model	Levels	First Difference
RGDP	None	2.4823	-1.7251***
	Intercept	-0.8019	-3.0886**
	Intercept and trend	-1.9127	-3.1002
ES	None	2.1737	-2.1930**
	Intercept	-1.7173	-17.6596*
	Intercept and trend	-0.6150	-18.0307*
EM	None	0.9773	-6.8083*
	Intercept	-1.2927	-6.8749*
	Intercept and trend	-1.7665	-6.8139*

Note:

1. *, ** and *** represent significance at 1%, 5%, and 10% levels respectively.
2. The null hypothesis is that the variable has a unit root
3. The Akaike information criteria is used to select the optimal lag order of variables

Source: Own construction

Table 5.2 shows the unit root results for the ADF unit root test. The variables are tested for stationarity at level form and that takes into consideration the inclusion of trend and constant or constant only. The Schwarz information criteria will be used to determine the number of lags to be used.

The null hypothesis states that the variable possesses unit root, meaning that the variable is not stationary. The results showed that the null hypothesis is rejected at all levels of significance at level form. This implies that electricity supply, economic growth and employment are all non-stationary at levels. The results for first difference of electricity supply, economic growth and employment reported that all these variables are stationary. This means that electricity supply, economic growth and employment are integrated of order one.

Table 5-3: Phillips and Perron unit root test

Variable	Model	Levels	First Difference
RGDP	None	6.0647	-1.5114
	Intercept	-0.9060	-3.5744**
	Intercept and trend	-1.2464	-3.0810
ES	None	1.7488	-8.3762*
	Intercept	-2.4507	-9.7240*
	Intercept and trend	-4.1349	-13.0140*
EM	None	1.0656	-6.8088*
	Intercept	-1.2970	-6.8883*
	Intercept and trend	-1.7665	-6.8217*

Source: Own construction

The test for stationarity was taken further using Phillips and Perron unit root test. The results are shown in Table 5.3. Similar to the ADF unit test results, the PP unit root test found electricity supply, economic growth and employment to be non-stationary at level form and stationary at first difference. In Chapter four, it was found that the two traditional unit root tests, ADF and Phillips and Perron have problems of low power, in such that they cannot identify unit root and near unit root results. These inefficiencies of the two techniques have been solved by using the KPSS. This technique has the power to identify the variables that look stationary and integrated and those which are not highly informative about the stationarity properties (Hu & Lin 2008).

Table 5.4 shows the unit root results using the KPSS technique. The null hypothesis states that the variables are stationary. Commencing with real GDP at levels, the *t*-statistic is greater than the critical values at the 5% level of significance in the case of only constant, but including both trend and constant, the *t*-statistic is greater than the critical values at both the 1% and 5% level of significance. The null hypothesis of stationarity thus is rejected. The results therefore report that real GDP is not stationary at levels. These results are similar to the results shown by ADF and Phillips and Perron unit root test.

Table 5-4: The Kwiatkowski-Phillips-Schmidt-Shit unit root test

Variable	Model	Levels	First Difference
RGDP	Intercept	0.9258	0.1616*
	Intercept and trend	0.1589	0.1005*
ES	Intercept	0.8100	0.3490*
	Intercept and trend	0.2301	0.2349
EM	Intercept	0.7020	0.1012*
	Intercept and trend	0.1216	0.0893*

Note:

1. The Null hypothesis of KPSS is stationarity
2. The critical values for KPSS test statistics are 0.216, 0.146 and 0.119 at 1%, 5% and 10% level of significance respectively for constant and trend
3. The critical values for KPSS test statistics are 0.739, 0.463 and 0.347 at 1%, 5% and 10% level of significance respectively for constant and no trend
4. *, ** and *** indicate significant at 1%, 5% and 10% levels respectively

Source: Own construction

The results for electricity supply report that the null hypothesis is rejected at both 1% and 5% levels of significance in the case of constant and no trend, and when both trend and constant are included. For employment, the null hypothesis is rejected at the 10% level of significance when both constant and trend are included. When including only constant, the null hypothesis is rejected at the 5% level of significance. From both the results of electricity supply and employment, it can be concluded that at levels, employment and electricity supply are not stationary. These results are consistent to the findings suggested by ADF and Phillips and Perron.

This research proceeds to take the first difference of the real GDP, electricity supply and employment because they were found to be non-stationary at levels. The results for real GDP and employment shows that *t*-statistics are smaller than the critical values at both the 1% and 5% level of significance where both constant and trend are excluded, as well as including only the constant. This implies that the null hypothesis of stationarity cannot be rejected and as a result, employment and real GDP are stationary at first difference. The results of electricity supply differ when a trend is included, that is the null

hypothesis is rejected even at first difference. Excluding the trend and only including the constant, the results reveal that the null hypothesis cannot be rejected. This means that at first difference electricity supply is stationary. Since the trend is not significant, it can be excluded and the results show that at the 1% and 5% levels of significance, electricity supply is stationary.

To illustrate stationarity of the variables, the line graphs of levels and first difference are plotted as shown in figures A.1 and A.2 (in Appendix A). Figure A.1 shows the results for stationarity of these variables at level form. The graphs do not show a constant mean and variance. This indicates that at level form, electricity supply, employment and real GDP are non-stationary. Figure A.2 reports the results for first difference of the variables. The graphs demonstrate that a series has a constant mean and variance. This implies that at first difference the variables are stationary. It can therefore be concluded that the variables are integrated of order one I(1) as proven by ADF, PP and KPSS unit root tests.

In summary, a comparison of the three results for unit root reveal that real GDP, electricity supply and employment are non-stationary at level form. This shows that these possess variables have unit root. Taking the first difference of all these variables makes them stationary. This means that real GDP, electricity supply and employment are integrated of order one I(1).

5.4 CO-INTEGRATION TEST

This section tests for co-integration between the variables, that is, whether there is a long run relationship between the variables. The ARDL procedure is used. It is applicable since a series is found to be integrated of order zero or one I.e. I(0) or I(1). The ARDL model needs an appropriate choice of the lag order of the variables (Muhammad *et.al* 2012). The different lag length criteria are shown in Table 5.5. The Akaike Information Criteria (AIC) has been proven to be powerful in selecting the number of lags (Muhammad, Ahmad &Saleheen 2012). This leads to the choice of the (AIC) to select the number of lags. The number of lags that show the minimum AIC

value indicates an optimal model, this implies that the lower the value of AIC, the better the model.

Table 5-5: Lag Order Selection Criteria

VAR Lag Order Selection Criteria						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	454.7704	NA	2.34e-14	-20.0342	-19.8737	-19.9744
1	474.6572	35.3543	1.98e-14	-20.2070	-19.4040	-19.9077
2	523.8335	78.68217*	4.61e-15*	-21.6815*	-20.2362*	-21.1427*
3	537.7247	19.7563	5.30e-15	-21.5878	-19.5001	-20.8095
4	549.1179	14.1782	7.11e-15	-21.3830	-18.6530	-20.3653

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5%)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Source: Own construction

Table 5.5 indicates a number of criteria to choose the maximum number of lags namely: LR, FPE, AIC, SC and HQ. The results are indicated with a star which demonstrates the maximum number of lags that each criterion chooses. All the lag order criteria in Table 5.5 highlighted two as the appropriate lag length. As indicated earlier, the AIC is the most powerful in terms of choosing the number of lags. As a result, this led to the selection of two as the maximum number of lags to be used.

The following procedure was to test for co-integration between the variables. This means determining the existence of a long run relationship between economic growth, electricity supply, power outages and employment. The F-statistics will be used to determine the presence of co-integration. The procedure is such that the F-statistics is compared to the upper critical bound and lower critical bound at the 5% level of significance. The null hypothesis is that there is no co-integration against the alternative hypothesis that co-integration exists. The decision is that if the F-statistics is less than

the lower critical bound, then the null hypothesis cannot be rejected which implies that there is no co-integration. On the other hand, if the F-statistics is greater than the upper critical bound, then the null hypothesis is rejected, meaning that there is co-integration. If the F-statistics falls between the lower critical bound and the upper critical bound, the results become inconclusive.

The chapter commenced by performing diagnostic tests for the models where real GDP, electricity supply and the dependent variables. This involved testing for non-normality, serial correlation and heteroscedasticity. Table 5.6 presents the estimated values for the following tests. The probability values are compared to the 5% significant level to find the results of the tests. For normality, the null hypothesis is that residuals are normally distributed against the alternative hypothesis that residuals are not normally distributed. The same procedure is done for heteroscedasticity and serial correlation, whereby the null hypothesis states that there is no heteroscedasticity and there is no serial correlation, respectively.

Table 5-6: Testing the model

F_{rgdp}(rgdp/es, em, dum)		
	Probability value	**Test**
Normality test	0.7253	Jarque-Bera test
Heteroscedasticity	0.1548	Breusch-Godfrey serial correlation LM test
Serial correlation	0.5399	Breusch-Pagan-Godfrey
F_{ES} (es/rgdp, em, dum)		
Normality test	0.1285	Jarque-Bera test
Heteroscedasticity	0.5884	Breusch-Godfrey serial correlation LM test
Serial correlation	0.0535	Breusch-Pagan-Godfrey
F_{EM} (em/rgdp,es, dum)		
Normality test	0.1351	Jarque-Bera test
Heteroscedasticity	0.1606	Breusch-Godfrey serial correlation LM test
Serial correlation	0.3372	Breusch-Pagan-Godfrey

Source: Own construction

Table 5-7: F-statisitics for co-integration

Critical value bound of the F-statistic						
K	90% level		95% level		99% level	
	I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
3	**2.022**	**3.112**	**2.459**	**3.625**	**3.372**	**4.797**
4	**1.919**	**3.016**	**2.282**	**3.340**	**3.061**	**4.486**
Calculated F-statistics F_{RGDP}(RGDP/ES, EM, Dum) = 4.8175 F_{ES}(ES/RGDP, EM, DUM) = 0.4084 F_{EM}(EM/RGDP, ES, DUM) = 1.6921 Note: the critical bound values were taken from Table 1 of Narayam and Smyth (2005: 470)						

Source: Own construction

Table 5.7 presents the results of the ARDL tests for co-integration. The test serves to determine whether co-integration exists when economic growth, electricity supply or employment is the dependent variable. Starting with economic growth as dependent variable, the F_{RGDP}(RGDP/ES, EM, Dum) is 4.8175 and greater the upper bound critical values at both 1% and 5% levels of significance. The evidence of this results is that co-integration between these variables exists. It means that there is a long run relationship between real GDP, electricity supply, power outages and employment. The diagnostic tests are shown in Table 5.6 and the model passed all the tests.

This chapter further considered the results when electricity supply is the dependent variable. The diagnostic tests of normality, heteroscedasticity and serial correlation were taken and the model passed all tests (refer to Table 5.6). The results from Table 5.7 indicate that the calculated F-statistics for electricity supply is 0.4084 and this value is less than the lower critical bound of 2.459 at the 5% level of significance. This means that when electricity supply is the dependent variable, there is no co-integration.

The employment variable was also considered as the dependent variable. The diagnostic test of normality, serial correlation and heteroscedasticity was also done and all the tests were passed as shown in Table 5.6. The calculated F-statistic is also shown

in table 5.7 as smaller than the lower critical bound at the 5% level of significance. This implies that there is no co-integration.

In general, it can be accepted that there is a long run relationship between electricity supply, economic growth, employment and power outages in South Africa when real GDP is the dependent variable. The results of the ARDL technique revealed that there is only one co-integrating relationship when economic growth is the dependent variable. These results are consistent with those of Ellahai (2010), Morimoto and Hope (2004), Ghosh (2009) and Yosuf and Metehan (2011) that showed a long run relationship between electricity supply and economic growth for Pakistan, Sri Lanka, India and OECD members respectively. However, these results differ from Sarker's (2010) estimates that found no co-integration between electricity supply and economic growth in Bangladesh.

To confirm the robustness of the long run relationship between the variables, the Johansen co-integration test was also taken. The results are shown in tables 5.8 and 5.9

Table 5-8: Trace

Hypothesis	Trace statistics	0.05 critical values	Probability values
None	61.937	47.856	0.0014
At most 1	20.958	29.797	0.360
At most 2	5.536	15.495	0.750
At most 3	0.438	3.842	0.508

Source: Own construction

Table 5-9: Maximum Eigen value

Hypothesis	Max-Eigen statistic	0.05 critical values	Probability values
None	40.980	27.584	0.0005
At most 1	15.422	21.132	0.2604
At most 2	5.098	14.265	0.7294
At most 3	0.438	27.584	0.5082

Source: Own construction

The null hypothesis of no co-integration is tested using both the trace statistics (λ_{trace}) and Maximum Eigen Value statistics (λ_{max}) at 5% level. The null hypothesis which states that none of the variables are integrated is rejected from both trace statistics and maximum Eigen Value statistics because the calculated values are greater than the critical values. The null hypothesis of at most 1, 2 or 3 variables are co-integrated and cannot be rejected. This merely implies that there is a long run relationship between economic growth, electricity supply, power outages and employment.

Having determined the long run relationship between the variables, the next step was to estimate the long run and short run coefficients of the impact of electricity supply, power outages and employment on real GDP. The results for long run and short run elasticities are reported in Table 5.10. The findings demonstrate that electricity supply positively affects economic growth and is significant at the 1% level. It is such that a one percent increase in electricity supply leads to 0.87 percent increase in economic growth, where all other variables are held constant.

These results are in line with the findings the two Indian studies by Ghosh (2009) and Gupta (2009). Gupta found a positive relationship between electricity supply and economic growth in developed states of India and but for less developed states the opposite was true. The other studies that found a positive relationship between electricity supply and economic growth include Yoo and Kim (2009) for Indonesia, Morimoto and Hope (2004) for Sri Lanka and Ellahai (2010). Halkos and Izeremes (2009) found electricity supply to positively impact on economic growth in 42 World and East Asian countries.

The results further revealed that employment has a positive impact on economic growth and is significant at the 1% level. This shows that a one percent increase in employment is associated with 1.2 percent rise in economic growth keeping other variables constant. The results of this research are similar to the study by Muhammad *et.al* (2012) who served to investigate the relationship between electricity consumption and economic growth in Kazakhstan incorporating labour and capital as additional variables. The results showed that labour stimulates economic growth. The other studies with similar results include the Pakistan study by Aqeel and Butt (2001), Liberian study of Wesseh and Zoumara (2012), Sadorsky (2012) and Ghosh (2009). The South African study by Odhiambo (2009) also found a positive relationship between employment and economic growth.

The results on electricity power outages showed that it negatively affects economic growth but is not significant. The results suggest that a 1% increase in power outages results in economic growth falling by 1.2%, when holding other variables constant. The two South African studies that found parallel results to the research's results include Zietman's (2012) and Gaunt and Herman's (2008) studies. Kasake (2011), Bose *et.al* (2006), Wijayantunga and Jayalath (2003), Ellahai (2010), Munasinghe (1980) and Adenikinju (2003) also found that power outages negatively affect economic growth in Zimbabwe, India, Sri Lanka, Pakistan, Brazil, Nigeria, respectively.

Table 5-10: Long run and short run analysis

Dependent variable = Ln RGDP			
Long run results			
Variable	**Coefficient**	**Standard Error**	**T-statistics**
Constant	-2.8843*	0.5505	-5.2398
Ln ES	0.8748*	0.1289	6.7889
Ln EM	1.2030*	0.1888	6.3720
Dum	-0.0119	0.0118	-1.0028
R-squared	0.8751		
F-statistics	107.4746*		
D.W test	0.7294		
Short run results			
Variable	**Coefficient**	**Standard Error**	**T-statistics**
Constant	0.0035*	0.0004	9.1515
Ln ES	0.0382***	0.0208	1.8348
Ln EM	0.1157**	0.0463	2.5011
DUM	0.0003	0.0013	0.1998
ECM_{t-1}	-0.0427**	0.0193	-2.2061
R-squared	0.2056		
F-statistics	2.8468**		
D.W test	0.9346		
Short run diagnostic test			
Test	**F-statistics**	**P-value**	
Normality	22.0972	0.0000	
Heteroscedasticity	6.2612	0.1805	
Serial correlation	29.8419	0.0725	
Note: *, ** and *** represent 1%, 5% and 10% significance levels respectively			

Source: Own construction

The Error Correction Model (ECM) was employed to determine the short run effects of electricity supply, employment and power outages on economic growth. The short run results demonstrated that electricity supply has a positive impact on economic growth and is significant at the 10% level. Employment also has a positive effect on economic growth in the short run and is significant at 5% level. Contrary to economic theory, electricity power outages have a positive impact on economic growth in the short run but it is not significant. The model is not spurious as the R-squared was less than the Durbin-Watson statistics.

The long run relationship is confirmed by the negative sign of the lagged ECM_{t-1} which is also significant at the 5% level. The results of ECM indicate that the short run deviation in economic growth is corrected by 4.3% every quarter towards long run equilibrium.

The problem with time series regressions is that the estimated parameters alternate over time (Narayam & Smyth 2005). The instability of the parameters leads to misspecification, which in turn leads to biased results. The stability of long run parameters is examined by applying cumulative sum of recursive residuals (CUSUM) and CUSUM of recursive squares (CUSUMSQ). Figure 5.3 and figure 5.4 (in Appendix B) shows the CUSUM and CUSUMSQ when real GDP is taken as the dependent variable, respectively. Unfortunately there is evidence of instability in the coefficients because the CUSUMSQ diagram does not lie between the 5% critical bounds of parameter stability. This shows that there is a possibility of structural break in 2008 and 2009. The reason for this could be the 2008 power outages. The economic crisis of 2008 could also be an explanation for this as it was learned in Chapter three that South Africa reached its lowest GDP growth rate of -6.20 in March 2009.

5.5 CAUSALITY TEST

The existence of a long run relationship between real GDP, electricity supply and employment shows that causality exists between these variables but does not show the direction of that causality. This leads to the need to conduct Granger-causality to determine the direction of causality. The short run and long run causality is shown in Table 5.11 below using the Error Correction Model (ECM). “The F-statistics on the lagged coefficients of the independent variables of the ECM indicate the significance of the short-run causal effect” (Narayam& Smyth 2005). The *t*-statistics on the coefficients of the lagged error correction term indicates the significance of the long run causal effect. This section will first determine the long run causality commencing with the model where real GDP is the dependent variable.

5.5.1 Model where Real GDP is the dependent variable

The results in Table 5.11 present the coefficient of the lagged error term which is used to determine the existence of the long run causality between the variables. This

coefficient of the lagged error term shows the speed of adjustment of the endogenous variables to explanatory variables and determines the long run causality. It has to be negative and significant to suggest existence of long run causality (Chapter four). Table 5.11 illustrates that the coefficient of the lagged error term is negative and significant. This suggests that there is a long run causality flowing from electricity supply, employment and power outages to real GDP.

The chapter further serves to determine whether there is a short run causality flowing from electricity supply, employment and power outages to real GDP. Commencing with electricity supply, the null hypothesis stating that there is no short run causality flowing from electricity supply to GDP is rejected at the 5% level of significance, meaning that there is a short run causality flowing from electricity supply to real GDP.

The results for employment demonstrate that the null hypothesis cannot be rejected. This implies that there is no short run causality flowing from employment to real GDP. The results for power outages show that the null hypothesis of no short run causality running from power outages to real GDP is rejected at the 5% level of significance. This means that there is a short run relationship flowing from power outages to real GDP.

In summary, when real GDP is the dependent variable, the results show existence of a long run causality flowing from electricity suppy, employment and power outages to real GDP. The results further demonstrated a short run causality flowing from electricity supply and power outages to real GDP but no short run causality flowing from employment to real GDP.

The model tested whether any statistical errors existed where real GDP is the dependent variable. The R-squared value from Table 5.7 is very high and the F-statistics is significant. The tests for heteroscedasticity, normality and serial correlation were also considered and the tests were all passed. The following section considers a model where electricity supply is the dependent variable.

5.5.2 Model where electricity supply is the dependent variable

Table 5.11 reports the results for both short run and long run causality when electricity supply is the dependent variable. The coefficient of the error correction term in this case is shown to be significant at the 5% level of significance but has a positive sign. This means that there is no long run causality flowing from real GDP, employment and power outages to electricity supply. This leads to consideration of the short run causality to determine the existence of short run causality flowing from economic growth, employment and power outages to electricity supply.

At first, the causality flowing from real GDP to electricity supply is considered. The results indicate that the null hypothesis cannot be rejected at the 5% level of significance. This means that economic growth does not have impact on electricity supply. Therefore, there is no short run causality flowing from economic growth to electricity supply. Similar results were found for power outages and employment. This means that there also is no short run causality flowing from power outages to electricity supply and from employment to electricity supply.

In summary, when electricity supply is the dependent variable both short run and long run causality results fail. This means that there is no long run causality flowing from economic growth, employment and power outages to electricity supply. The results further report no short run causality flowing from economic growth, employment and power outages to electricity supply.

The model was also tested for heteroscedasticity, non-normality and serial correlation and all the tests were passed. The R-squared value is also high indicating the good fit of the model. Lastly, the F-statistics is also significant at the 5% level of significance.

5.5.3 Model where Employment is the dependent variable

In this section the model results where employment is the dependent variable is discussed. The results are illustrated in Table 5.11. The coefficient of the error correction term is negative but not significant. Therefore, there is no long run causality flowing from real GDP, electricity supply and power outages to employment. This leads

to the discussion of the short run causality running from real GDP, electricity supply and power outages to employment.

The null hypothesis that there is no short run causality flowing from real GDP, electricity supply and power outages to employment was tested. The results show that there is no short run causality flowing from electricity supply to employment and from power outages to employment. The null hypothesis of no causality is rejected at the 10% level of significance, meaning there is a weak short run causality flowing from real GDP to employment.

In summary, when employment is the dependent variable, causality flowing from real GDP, electricity supply and employment was not found. The short run causality was also not found flowing from power outages and electricity supply to employment. The results only found a weak short run causality streaming from real GDP to employment.

The model was tested to determine whether there were any statistical errors in it. This was done by testing heteroscedasticity, normality of residuals and existence of serial correlation and all the tests were successful except the normality test.

The general results of causality demonstrated a long run causality flowing from electricity supply, employment and power outages to real GDP. These results are contrary to the findings of Yoo and Kim (2006) , and Smyth and Lean (2010) who found one way causality from economic growth to electricity supply. Yoo and Kim (2006) used a bivariate framework and this might be resulting from the omission of other important variables. Similar results of causality flowing from electricity supply to economic growth were found by Sarker (2010). This shows that electricity supply has an impact on economic growth in as much that an increase in electricity supply will also increase economic growth.

The findings further reported a unidirectional causality streaming from electricity supply to real GDP and from power outages to real GDP in the short run. Again the short run causality flowing from electricity supply to real GDP is contrary to the results by Gosh (2009) who conducted a study for India. Weak short run causality was also found to flow

from real GDP to employment whereas no causality was found flowing from real GDP to electricity supply.

Table 5-11: VECM Granger causality analysis

Long run Granger causality			
Dependent variable	**Error Correction Term**	**Sign of ECT**	**Probability values**
Real GDP	0.0583	Negative	0.0000*
Electricity supply	0.0199	Positive	0.0443**
Employment	0.0076	Negative	0.8214

Source: Own construction

Table 5-12: VECM Granger causality analysis

Short run Granger causality		
Hypothesis	**Chi-square**	**Probability values**
ES does not Granger cause RGDP	10.9938	0.0041*
EM does not Granger cause RGDP	0.7568	0.6850
PO does not Granger cause RGDP	19.8377	0.0000*
RGDP does not granger cause ES	0.7319	0.6935
EM does not granger cause ES	3.9493	0.1388
PO does not Granger cause ES	1.3856	0.5002
RGDP does not Granger cause EM	5.2794	0.0714***
ES does not Granger cause EM	0.3571	0.8365
PO does not Granger cause EM	0.0397	0.9804

Note:

1. PO is power outages
2. *, ** and *** show significant at 1%, 5%, and 10% level.

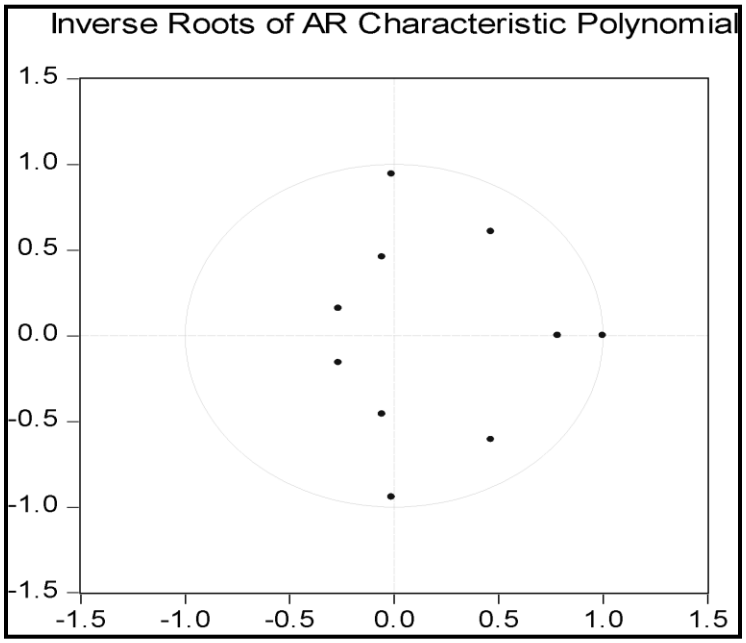
SOURCE: OWN CONSTRUCTION

5.6 THE STABILITY TESTS OF THE MODELS

5.6.1 Unit Circle

The stability of the VAR model is tested using the unit circle in figure 5.1. The results show that all the lagged variables fall within the unit circle. This provides evidence of the stability of the VECM model.

Figure 5-1: Unit circle



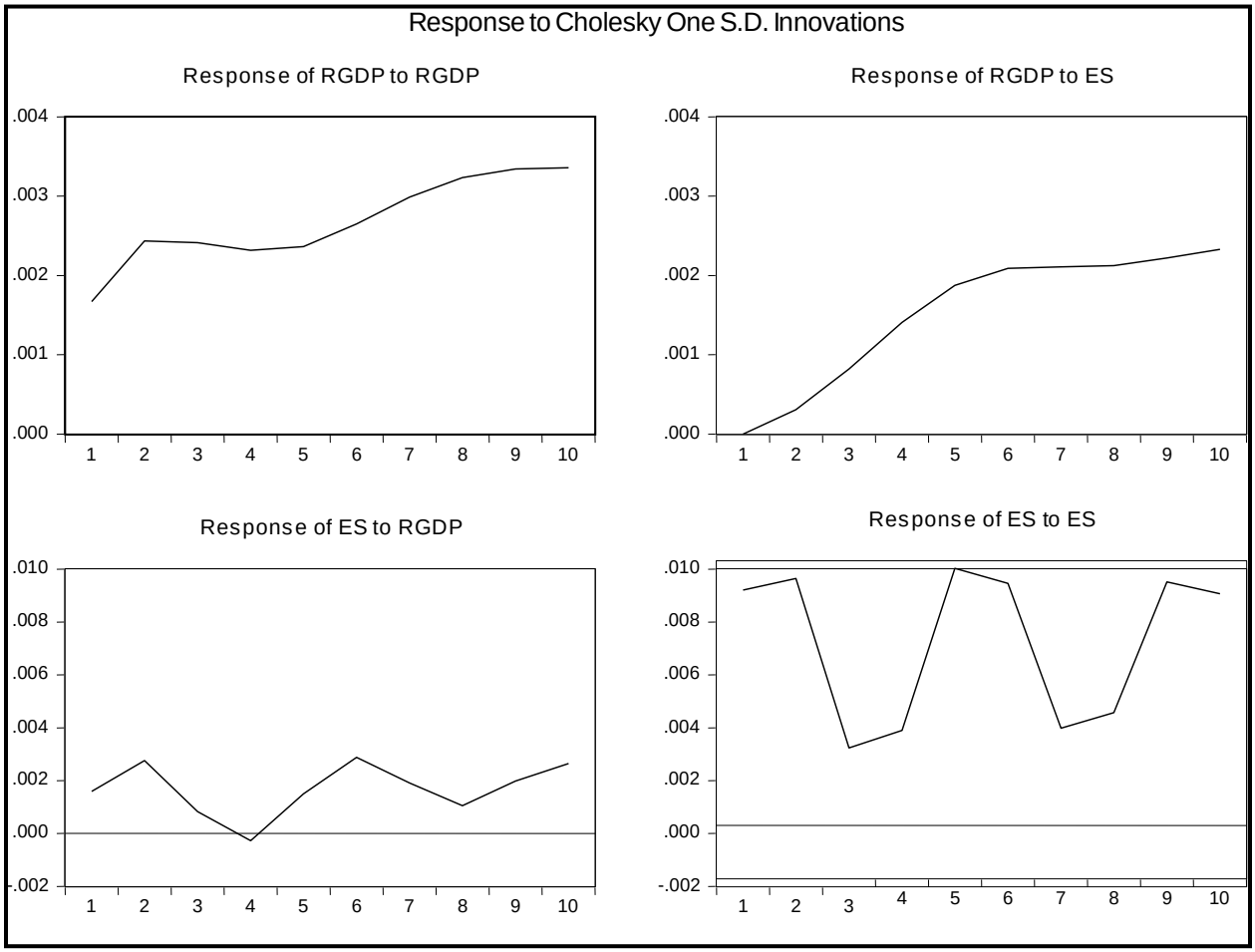
5.6.2 Impulse Response

To further test the stability of the VAR model, the impulse response function was employed. Figure 5.2 shows the impulse response function of real GDP and electricity supply. The cholesky-dof adjusted was employed to order the variables. The response of real GDP to real GDP is shown in the first graph in figure 5.2. The figure demonstrates that imposing a positive shock to real GDP causes real GDP to go up. A positive shock in real GDP caused real GDP to increase in the first quarter and remained steady until the fifth quarter where it started to increase again. This shows that there is a positive relationship between real GDP and itself.

There is also evidence of a positive relationship between electricity supply and real GDP. A one standard deviation positive shock in electricity supply leads to a steady increase in real GDP (refer to figure 5.2). But a positive shock in real GDP leads to an increase in electricity supply in the first quarter and starts to fall from the second quarter until it reaches zero and becomes negative in the fourth quarter. It begins to increase again towards the fifth quarter until it becomes positive again to the tenth quarter.

Finally, a positive shock in the electricity supply leads to electricity supply itself going up in the first quarter, down in the second quarter and keeps alternating within the quarters but it never reaches zero. This shows that there is a positive association between electricity supply and itself.

Figure 5-2: The impulse response function



Source: Own construction

5.6.3 Variance Decomposition

The results in Table 5.12 shows that in the tenth period, one standard deviation shock in electricity supply, employment and power outages explain 14.81%, 0.84% and 47.57% respectively of the forecast error variance of real GDP. A greater percentage of 36.78 of variation in real GDP is explained by itself after ten periods. On the other hand, forecast error variance of electricity supply is explained by 4.94% of real GDP, 1.49% of employment and 18.79% of the power outages in the tenth period. The remaining 74.77% of variations in electricity supply is explained by itself.

Table 5-13: Variance decomposition of RGDP

Period	S.E	RGDP	ES	EM	DUM
1	0.001670	100.0000	0.0000	0.0000	0.0000
2	0.002974	98.59984	1.054352	0.299658	0.046147
3	0.003928	94.17171	4.951056	0.765311	0.111925
4	0.004974	80.43672	11.08436	1.527185	6.951742
5	0.006431	61.59803	15.12185	1.694547	21.58557
6	0.008184	48.51636	15.85312	1.419280	34.21124
7	0.009913	42.15400	15.32952	1.14059	41.37441
8	0.011476	39.38474	14.86390	0.970316	44.78105
9	0.012889	37.94373	14.74460	0.883963	46.42771
10	0.014214	36.77820	14.80571	0.841374	47.57472

Source: Own construction

Table 5-14: Variance Decomposition of ES

Period	S.E.	RGDP	ES	EM	DUM
1	0.009047	3.095895	96.90410	0.0000	0.0000
2	0.013320	5.697689	93.85775	0.187538	0.257026
3	0.013978	5.519821	89.63998	1.200895	3.639299
4	0.015086	4.771819	82.62460	1.985064	10.61852
5	0.018592	3.789754	81.73750	1.508208	12.96454
6	0.021412	4.661828	79.91045	1.197512	14.23021
7	0.022348	5.008630	76.06936	1.713447	17.20857
8	0.0023219	4.844706	73.84994	1.949642	19.35571
9	0.025393	4.655750	74.89846	1.709045	18.73674
10	0.027360	4.940706	74.77036	1.496325	18.79260

Source: Own construction

Generally, the results demonstrate that electricity supply has a large positive impact on economic growth relative to employment. On the other hand, real GDP has a larger

positive impact on electricity supply relative to employment. The impact of electricity supply to itself has also been found to be greater than the impact of other variables on itself. The same results were found with real GDP.

5.7 CONCLUSION

Chapter Five examined the relationship between electricity supply and economic growth. It has also analysed the impact of electricity power outages on economic growth in South Africa. The analyses commenced by testing for stationarity of the variables using the Augmented Dickey-Fuller, Phillips and Perron and Kwiatkowski-Phillips-Schmidt-Shit unit root tests. The results of the three tests showed that employment, electricity supply and economic growth are non-stationary at level form but stationary at first difference. This implies that these variables are all integrated at order one I(1). The levels and first difference of the variables were also plotted on the graphs.

Furthermore, the optimal lag length of the variables using the following lag selection information criteria: AIC, LK, FPE, SC and HQ were determined. A lag length of two was found to be most suitable by all the criteria. The investigation of the long run relationship between the variables followed using the ARDL model. The findings indicated that the variables have a long run relationship when economic growth is the dependent variable. The Johansen test of co-integration was also employed to confirm the robustness of the long run relationship of the variables. The findings showed the same results as the ARDL results. This implies that there is a long run relationship between electricity supply, economic growth, power outages and employment in South Africa.

The diagnostic tests were conducted to test for the reliability of the models. This involved testing for existence of serial correlation, heteroscedasticity and normality in the models and all the tests were passed. This means that there was no serial correlation, no heteroscedasticity and residuals were normally distributed. The stability of the long run parameters was also examined using CUSUM AND CUSUMSQ and the parameters were found to be unstable.

The existence of a long run relationship between economic growth, electricity supply, power outages and employment led to an investigation of the direction of causality

between these variables using the Vector Error Correction Model (VECM) Granger causality. The findings demonstrated a long run causality flowing from electricity supply, power outages and employment to economic growth. The results further showed a short run causality flowing from electricity supply and power outages to economic growth. No causality was found to flow from economic growth to electricity supply. In addition a weaker short run causality flowing from economic growth was also found.

The parameter stability of the VAR model was verified by employing unit circle, impulse response and variance decomposition. The lagged variables fell within the unit circle indicating the stability of the model. The following chapter discusses the conclusion and recommendations of the dissertation. It is going to review the appropriate structure of the electricity supply industry in South Africa as the results of this research has shown that electricity supply affect economic growth both in the short run and long run.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

The primary objective of this research was to investigate the relationship between electricity supply and economic growth in South Africa. The focus was to determine whether economic growth causes electricity supply or electricity supply causes economic growth (Chapter one). A further aim was to examine the impact of power outages on economic growth. The surge in economic growth after democratisation in 1994 in South Africa caused a disequilibrium in the demand and supply of electricity. The changes in the economic policies stimulated South Africa's economic growth which in turn resulted in a significant increase in the demand for electricity, whilst electricity supply increased by a smaller margin. This led to the 2008 power outages which affected the industrial, farming, household and mining sectors in the country adversely (Chapter two).

The research evaluated the relationship between electricity supply and economic growth, electricity consumption and economic growth as well as energy consumption and economic growth in South Africa, as well as the experience of other countries such as Pakistan, India, Turkey, Nigeria, Malaysia and Bangladesh (Chapter three). The research further reviewed the costs of power outages to the industrial sector and to the economy as a whole for South Africa. The econometrics models testing the nexus between electricity supply and economic growth incorporating employment and power outages to form a multivariate framework were also considered (Chapter four).

The analysis of the model developed in chapter four was examined for stationarity by ADF, PP and KPSS unit root tests (Chapter five). The model was further tested for co-integration, to determine the long run relationship between the variables using the ARDL technique which was supplemented by the Johansen co-integration technique. The causality between the variables was investigated by applying the Vector Error

Correction Model (VECM). In the following sections, conclusion, policy recommendations and the limitations of the research are discussed.

6.2 CONCLUSION

The two hypotheses that this research intended to investigate have been established. The first was to examine the causality between electricity supply and economic growth. The second hypothesis was formulated to determine the impact of power outages on economic growth in South Africa. The research employed the data obtained from the first quarter of 2000 to the second quarter of 2012 to investigate the relationship between electricity supply and economic growth.

The findings based on South African data demonstrated that economic growth, employment, electricity supply and electricity power outages move together in the long run. The relationship is such that power outages have a negative impact on economic growth in the long run while employment and electricity supply have a positive effect on economic growth. The impact is such that increasing employment and electricity supply by one percent leads to economic growth increasing by 1.2% and 0.87% respectively whereas a one percent increase in power outages decreases economic growth by 1.2%.

These results are in line with economic theory. Commencing with electricity supply, an increase in electricity supply leads to good welfare of the household consumers and this will in turn lead to increased productivity in the work place. Electricity supply facilitates other factors of production such as labour and capital and therefore increases in electricity supply will lead to an increase in production and hence economic growth. On the other hand, an increase in employment, one of the factors of production, will certainly lead to high levels of production resulting in an increase in economic growth. Lastly, the power outages have an adverse effect on economic growth in the sense that it limits the production of industries and put the labour force and other factors of production at risk. For example, employees may get stuck in lifts during power outages or materialsmay be lost through damage of in process goods.

The Vector Error Correction Model results reported a unidirectional causality from electricity supply to economic growth in South Africa. This implies that electricity supply plays a crucial role economic growth and that South Africa is an electricity dependent country. This shows that in South Africa, occurrence of power shortages causes significant damage to economic growth. Therefore, the policies of achieving high levels of economic growth in South Africa should be paralleled with electricity supply. It can be viewed that sufficient electricity as such, should be supplied to boost the production of industrial, farming and mining sectors to improve the economic growth of the country.

The results further showed a unidirectional causality flowing from employment to economic growth. This showed that electricity supply on its own cannot increase economic growth but that employment is also an important factor to boost economic growth. The results of short run causality also demonstrated that electricity granger causes economic growth. This means that even in the short run it is dangerous for energy conservation policies to be applied in South Africa. It is therefore of paramount importance that electricity supply should be sustained as any incidence of power outages affects economic growth in South Africa. The policies on electricity supply should be formulated in such a way that it supports economic growth.

There was no causality found flowing from economic growth to electricity supply either in the long run or short run. This implies that an increase in economic growth in South Africa does not have an impact on electricity supply. This indicates that even when economic growth is booming in the country, no significant investment goes to creating electricity supply infrastructure. This explains the low supply of electricity even when economic growth was flourishing since democratisation in 1994. According to Odhiambo (2009), there is a bidirectional relationship between electricity consumption and economic growth. The increase in economic growth in South Africa leads to an increase in electricity consumption. This explains the high increases in demand resulting from the increase in economic growth compared to electricity supply since 1994. Finally,this imbalance resulted in the 2008 power shortages, which according to Zietsman (2012) caused a loss of about 2.6% to 6% of nominal GDP.

6.3 POLICY RECOMMENDATIONS

It has been stated in the research that the importance of establishing the direction of causality between electricity supply and economic growth is to formulate the most reliable energy conservation measures and appropriate electricity supply policies. Bildirici (2012) citing from Nondo, Kahsai and Schaeffer (2010) stated that poverty in African countries is caused by the lack of investment in energy infrastructure. The research shows that electricity supply in South Africa plays a significant role in boosting economic growth. This therefore calls for sufficient investment in the electricity supply industry in South Africa.

The type of electricity supply structures as in South Africa, where Eskom has the monopoly power, is one of the major reasons for the inefficiency of electricity supply in the country. As discussed in Chapter One, vertically integrated electricity generation, transmission and distribution system, is not the best way to organise the electricity industry. This was proven by countries such as Nigeria, United Kingdom, Chile and Argentina. This, therefore, calls for deregulation of the electricity supply industry in South Africa. The current South African structure, which is a single buyer, has been criticised for its opening up for too much Government intervention. Chapter two showed that too much Government intervention affected South African electricity supply industry where government did not increase electricity generation until it was too late and the country experienced severe power outages. The other problem with this single buyer model is that government officials make policies knowing that they will not face consequences as their term might be over by the time problems arise. It also responds badly during crisis. This is because the private investors who could help with supplementing supply during outages are deterred entry.

An additional problem that the country experienced as a result of the current monopolistic structure is the decision concerning electricity conservation policies. This research and the study by Odhiambo (2009) showed that electricity supply and demand does have an impact on economic growth. Therefore, when electricity supply and demand impact on economic growth, the electricity conservation policies become harmful to economic growth. But Eskom, the monopolist power producer, opted for

power conservation measures in 2008 when the country was faced with power shortages. This led to a fall in production levels of many companies that had to cut production because of selling back the electricity to Eskom and some being limited to purchase a prescribed amount of electricity.

Countries such as Nigeria, which were having frequent power outages every year have resorted to privatisation of the electricity industry. Nigeria planned to dismantle its electricity supply sector by privatising 10 more state owned power plants by the middle of 2014 (Brock 2013). The government opened up biddings for the private firms to submit their proposals to show their interest in taking over by July 2013 and its expected that by June 2014 all the successful bidders would have taken over (Brock 2013). The sell-off of the state owned electricity power sector is expected to double the current capacity while raising around $2.5 billion for the government. The advantage of privatisation is shown as increasing the number of participants in the market and hence increases supply and a potential of reducing the prices.

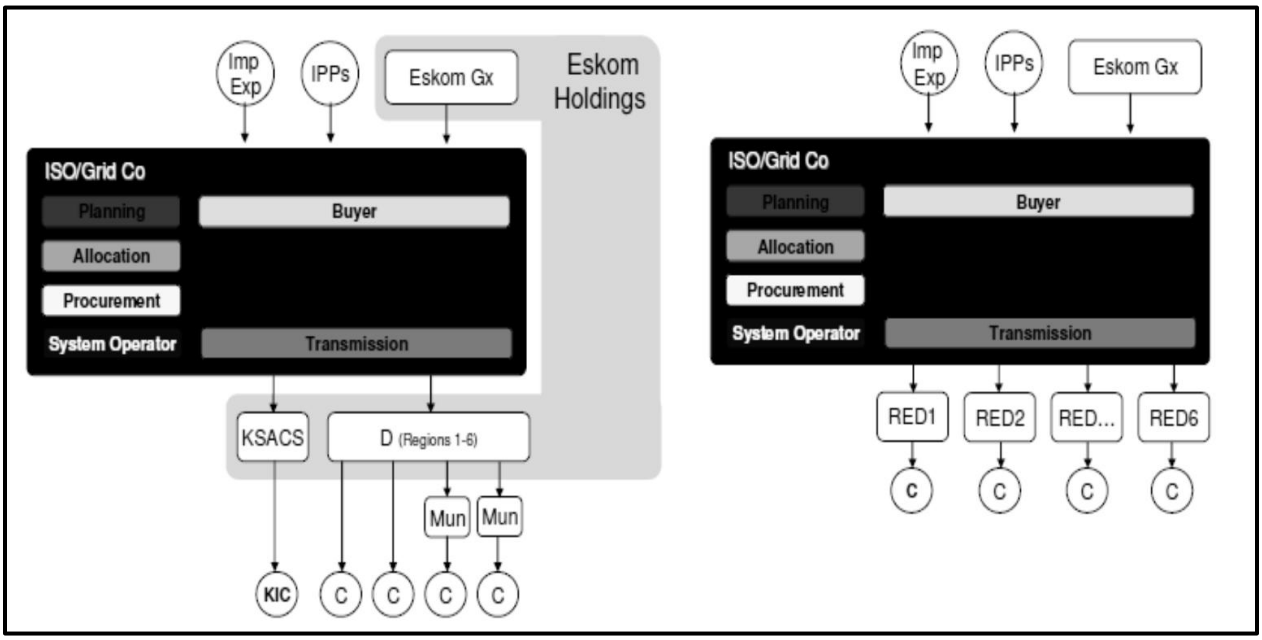
Since the 19th century, the pace of reform and change in the electricity sector has increased immensely. These reforms have led in part to lower costs, gave consumers safer and cleaner electricity power, enhanced the economy and maintained development of the states (Camacho 2003). The electricity industry was believed to be a natural monopoly, but technological change has made small-scale power generation increasingly cost-effective by reducing economies of scale (Harris 2004). As a result, electricity generation, transmission, distribution and retail sales are no longer viewed as natural monopolies.

Harris (2004) further stated that getting rid of geographical restrictions on the sale of generated electricity and deregulating prices encouraged remarkable changes in competitive small-scale generation. The natural monopoly rationale is further weakened by the separation of the charges for using transmission grids and metering of the retail energy commodity. Even though the regulators are flexible, the issue of a natural monopoly makes them reluctant to deregulate their electricity supply industries. It is important, therefore, to eliminate the traditional idea of regulation so that competition in electricity is enhanced to benefit consumers, the environment and the economy as a

whole. The electricity systems will, as a result, adapt more readily in response to changing market conditions and demands. A priority to electricity industry deregulation is ensuring the existence of reliability.

In Chapter Two, the potential structure for South Africa ESI was shown in figure 2.8. Figure 6.1 below adds to the introduction of the IPPs, REDs and the ISMO. This structure shows how much the electricity supply industry structure can be unbundled in South Africa in order to do away with electricity power outages. The importance of the IPPs will be to relieve the SA government of the burden of budget which it uses to fund Eskom and other state owned entities. The IPPs will further bring about new production technologies which will be efficient, quicker and less costly and also supplement the electricity produced by Eskom. This will eliminate the power outages.

Figure 6-1: Recommended ESI model incorporating the ISO – pre-REDS and post-REDS



Source: Pickering (2010: 74)

The REDs on the other hand, will ensure equal distribution of electricity to consumers and ensure that all consumers have access to electricity. It will further ensure competitive prices to the consumers. The IMSO will modernise the ESI which is

outdated and slow to respond to the changes in the market. It will ensure a balance between electricity supply and demand which has been the major problem since 2008.This proposed structure will lead to a secured supply of electricity and the objective that the government serves to achieve through the ESI will be fulfilled.

Considering the major goals that the government strives to achieve through the electricity supply industry, which is, to achieve global access to electricity- the more private investors in the ESI, the more interaction there will be with the outside world. This will lead to increased use of the modern technologies to connect with other nations of the world and more research will be done on how to trade well internationally.

Secondly, to provide electricity that will promote incorporated development to rural societies. Privitisation brings competition into the industry. This should therefore lead to each private investor striving to be the best in order to win a large market share and giving back to the community. As a result, this will lead to the development of rural societies and the entire economy.

Thirdly, enhancing the productivity of industries through competitive prices, private ownership will lead to many suppliers striving to attract customers by cutting prices. According to economic theory, monopolists charge higher prices than competitors. The change in the structure from a monopoly to a competitive structure will certainly lead to lower prices. This would be in line with what South Africa needs as from 2008, the electricity tarrifs have been increasing at an alarming rate.

Fourthly, the government debts will decrease. The government of South Africa spent large sums of money in the building of power stations to the extent that it ran out of budget. The private investors will relieve the government of this burden if allowed entry into the industry.

Fifthly, black economic empowerment in South Africa will be promoted. To promote black economic empowerment can be more effective if black private investors are allowed to invest in the electricity supply infrastructure. Lastly, the secure supply of electricity will be guaranteed. It has been discussed in the earlier chapters of this research that electricity capacity will increase if the electricity industry structure allows

more investors to participate. For example, in Nigeria, it was established that by admitting the 10 private investors will lead to the electricity capacity to increase by 5000 megawatts.

This structure will allow the IPPAs the opportunity to invest in the electricity industry and attract many distributing companies to become involved in the electricity supply industry. Eskom will be relieved of the burden of building the power generation stations on its own and it will reduce government expenditure on electricity supply infrastructure.

Furthermore, in the problem statement it was stated that since the 2008 power shortages and government's plan to build more power stations, the price of electricity has been increasing at an alarming rate. This affected production of many companies and individual households. Economic theory shows that a monopoly structure leads to high prices while competition works to alleviate the problem of high prices. Therefore, the structure proposed in this research could lead to lower competitive prices.

Finally, Chapter Two indicated that one of the electricity supply deficiency is the increase in cost coal and increase in its scarcity in South Africa. It was also stated that about 92% of electricity in South Africa is produced from coal. Since, the coal produced electricity failed to supply millions of citizens in South Africa, there research further recommends that the renewable energy sources, such as wind, solar and hydropower, should be used to produce electricity instead of coal. The transition is further motivated by the fact that coal causes pollution and climate change, which is what the world is trying to avoid.

There is variety of renewable resources. This will therefore ensure security of electricity supply. It will also lead to higher levels of employment as renewable energy industry is employment intensity. Lastly, it will lead to a fall in electricity prices following from enough supply.

6.4 SCOPE FOR FURTHER RESEARCH

The normal production function includes both capital and labour, so the results above may be overestimated as the model did not include capital. It is therefore recommended

that in future research, capital should be included in the model to improve it. For further research, it can be benefial to focus on other forms of energy such as coal, gas and fuel instead of only focusing on electricity to get a clear picture as approximately 92% of electricity in South Africa is generated by coal. One of the factors that led to a fall in the generation of electricity was found to be the deteriorating quality of coal. This shows that the other sources of energy are also worth been examined.

Another aspect that warrants attention is the increase in the price of electricity which has been experienced in South Africa since 2008. The model of this research has a potential of investigating the relationship between electricity supply and economic growth incorporating electricity prices as another variable. This would help examine the impact of the electricity price on economic growth and provide policy recommendations on the regulation of the prices.

The importance of renewable energy resources have been discussed briefly in the research. There is a need to examine the relationship between electricity generated from renewable sources and economic growth following Yusuf, Metahan and Sefer (2011). This is because renewable energy sources contribute to reduction of climate change, poverty and shortages of water.

The major problem encountered in the research was finding statistical data on the cost of electricity power outages. This led to this study using dummy variable for power outages following from Ellahai's (2010) study. Therefore, it is recommended that for future research, the cost of electricity power outages should be computed.

Lastly, the lack of security in the supply of electricity affects different industries differently. Therefore, the effect of an unstable electricity supply should be conducted per sector. For example, the loss of production in the mining industries is highly affected by power outages than in the farming industry which is not highly electricity dependent.

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Appendix A: Unit root results at levels and at first difference

Figure A-1 Unit root results at levels

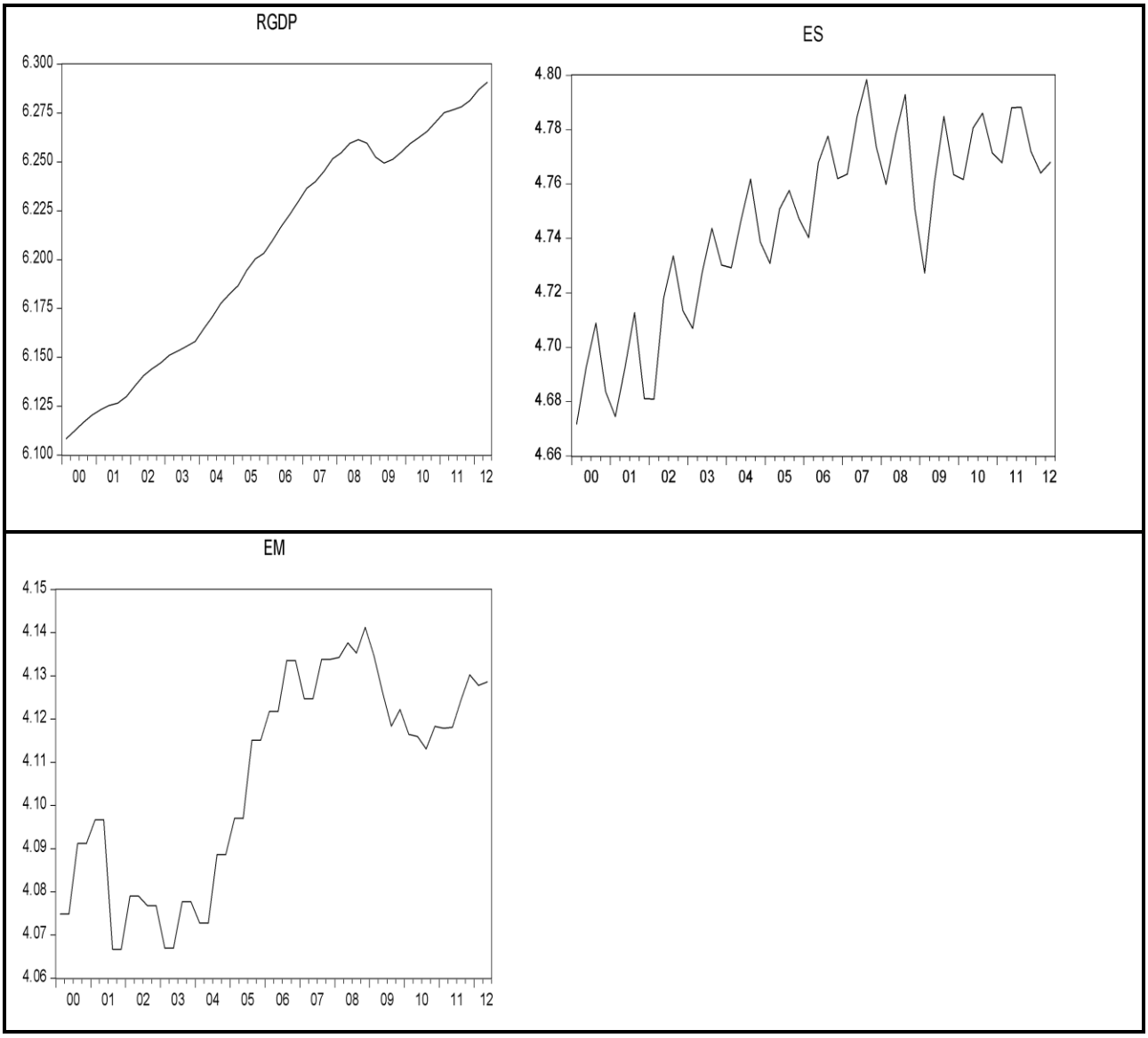
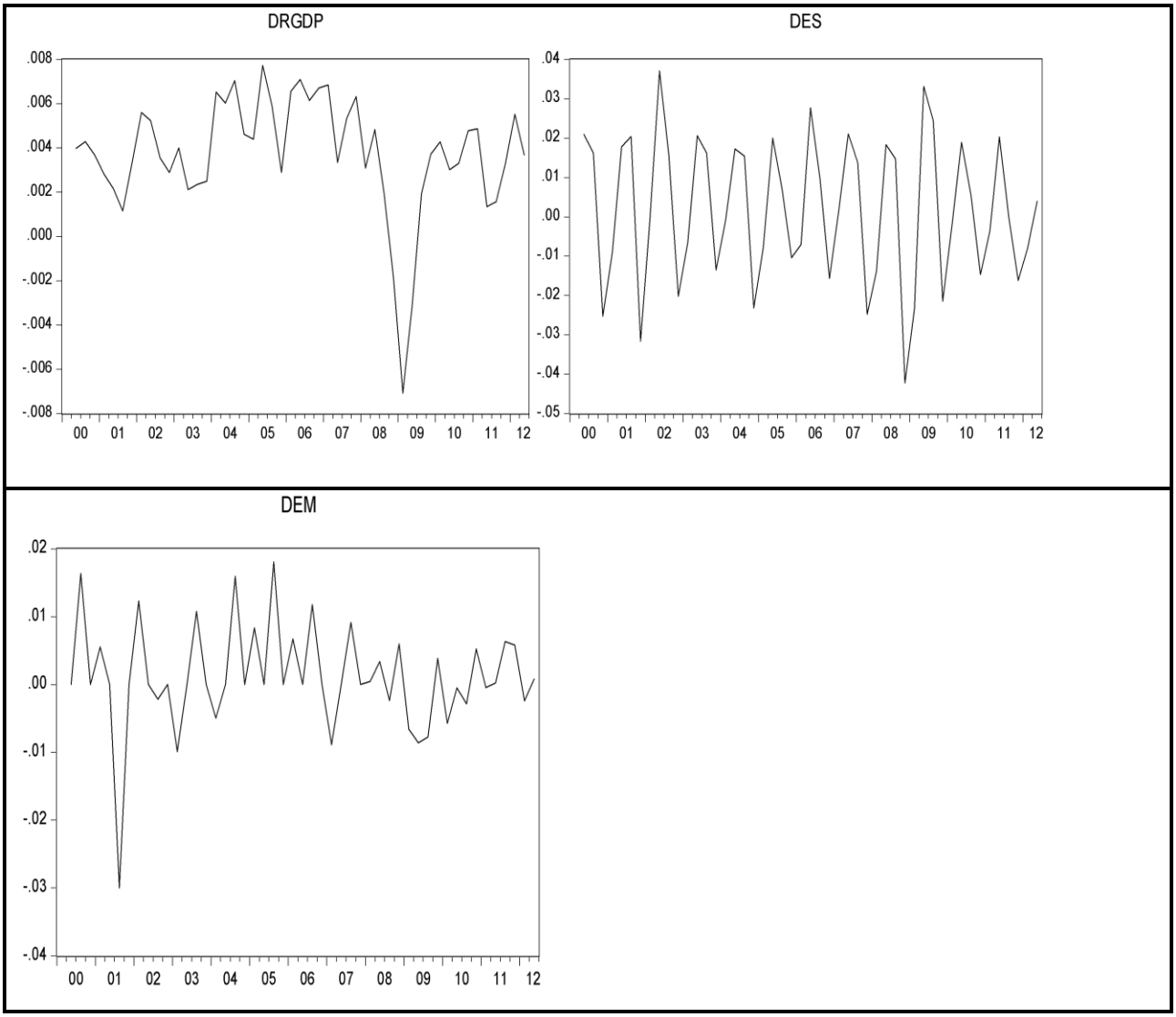


Figure A-2 Unit root results for first difference



Appendix B: CUSUM and CUSUMSQ

Figure B-1: CUSUM

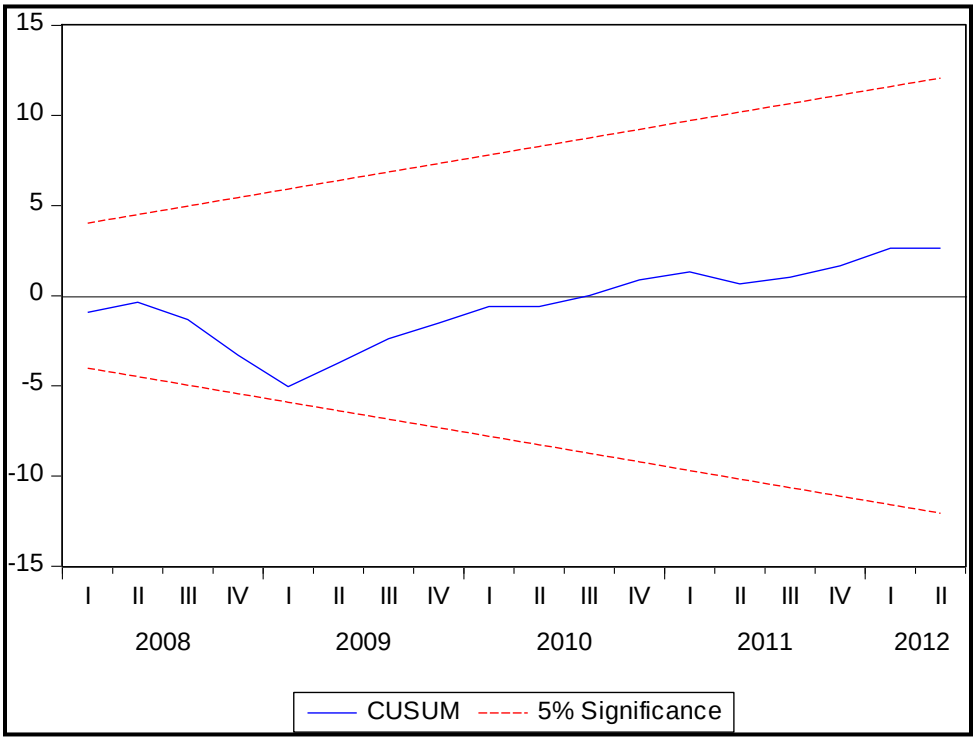


Figure B-2: CUSUMSQ