



Electricity adequacy in South Africa

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A thesis accepted in fulfilment of the requirements for the
degree

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Management Sciences

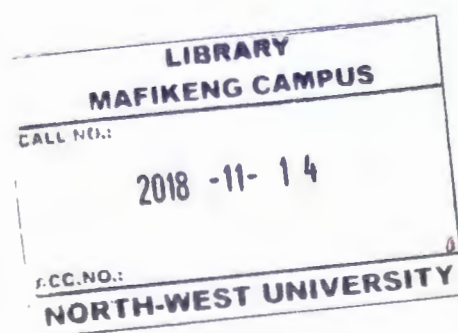
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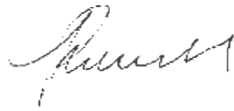
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To whom it may concern,

Re: Letter of confirmation of language editing

The thesis "Electricity adequacy in South Africa" by Benedict Ateba (21994358) was language, technically and typographically edited. The citations, sources and referencing technique applied were also checked to comply with NWU university guidelines. Final corrections as suggested remain the responsibility of the student.

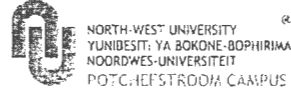
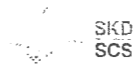


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Precision ... to the last letter

STATISTICS ANALYSIS LETTER



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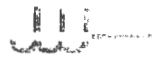
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Kind regards

A handwritten signature in black ink, appearing to read 'E Fourie'.

Dr E Fourie
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DATA COLLECTION LETTER



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TO WHOM IT MAY CONCERN

I, Prof JJ Purkisloo, confirm that Mr Ben Ateba is currently a registered student at the North-West University, Mafikeng Campus. Mr Ateba is studying towards a PhD in Business Management, I also serve in the capacity as promotor to his PhD. The primary focus of his study is towards the designing of an integrated Strategic Management Framework. The aim of this framework is to serve a contributory role towards economic efficiency in South Africa.

His empirical research will be conducted amongst three different market sectors. These mentioned sectors include households, industrial sector and electricity parastatals (NERSA & Eskom). The physical data collection (fieldwork) is planned to be executed during 2016.

It will be highly appreciated if you could assist Mr Ateba in his PhD study with relevant and important data.

Respectfully

Mr Ben Ateba (PhD student)

Prof JJ Purkisloo (PhD) - Promotor

ETHICS APPROVAL CERTIFICATE OF PROJECT



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Based on approval by the **Human Resource Research Ethics Committee (HRREC)** on 30/06/2017, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

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Application Type: Single Study																															
Commencement date: 2017-06-30	Expiry date: 2020-06-30																														
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Special conditions of the approval (if applicable):

- x Translation of the informed consent document to the languages applicable to the study participants should be submitted to the HRREC (if applicable).
- x Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HRREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

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- x The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC via HRREC:
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The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or HRREC for any further enquiries or requests for assistance.

Yours sincerely

Digitally signed by

Prof LA

Prof LA Du Plessis

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Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

DEDICATION

I dedicate this study to my siblings, Ateba Olivia and Ateba Collins for being instrumental to my academic life.

I thank Almighty God for grace and wisdom that enabled me to complete this study.

ACKNOWLEDGEMENTS

- I thank especially my supervisor, Prof JJ Prinsloo, for his guidance and continued support throughout my postgraduate studies, his explicit and constructive criticisms to the study.
- I am deeply indebted to Dr. Fourie at the North-West University's Statistical Consultation Services for all her statistical advice.
- I am grateful to my father and mother, Mr. and Mrs. Ateba, for their continuous encouragement.
- My endless thanks and gratitude to all participants and field workers who made it possible to obtain reliable data for the primary empirical research.

ABSTRACT

The motivation to conduct this study arises from the current uncertainty of electricity security in South Africa (SA). Between the last quarter of 2007 and the first quarter of 2008, South Africa experienced the harshest realities of inadequate electricity in its national grid. This is based on the fact that the capacity of the parastatal which controls over 96% of electricity generation could not meet the South African societal demand. This study was a holistic and comprehensive analysis of the fundamental challenges, associated with the current electricity inadequacy problems throughout four articles. An article approach was utilised.

The first article assessed the effectiveness of strategic management of electricity in South Africa. The empirical research utilised a content analysis methodology. A purposeful reviewing of publications on the most critical concerns was utilised. The analysis was generated through Atlas-ti 8 for windows. The empirical research indicates that strategic management failures and the lack of an integrated strategic management approach to electricity supply and distribution have been a major stumbling block to averting an energy crisis in South Africa.

The second article aimed at contributing to domestic electricity adequacy by assessing four primary factors linked to electricity consistency and analysing consumption behaviours through one primary factor, ten energy intensive domestic appliances and seven commonly used alternative domestic energy sources. The empirical research employed a quantitative survey research design. The target population included Gauteng and North West provinces. A purposive-convenience sampling was employed to select participants for the empirical research. Data collection utilised a closed-ended questionnaire and field workers to gather reliable data. Data collection on factors was collected through a five-point Likert scale and dichotomous questions while analysing consumption behaviours on appliances and alternative energy sources utilised dichotomous questions. The four primary factors linked to electricity consistency reflect that consistency of supply to domestic consumers is ineffective as living standards are affected in general. Results from appliances reflect that energy-intensive appliances are still, in general, being used by society. Beside this tendency, significantly old modelled appliances are also still in use. Despite high electrical energy use and demand, more than a third of alternative energy sources (for example, coal and wood) are used which could result in environmental and physical consequences.

The third article aimed at contributing towards effective industrial electric power supply to achieve sustainable industrial and economic growth. The empirical research utilised a quantitative research design and a survey approach. The empirical research was pursued to identify the association between electricity consistency and industrial growth in South Africa. The empirical research also evaluated the effectiveness of implementing mitigation strategies to prevent interruptions and obstructions in economic activities through electricity disruptions. Intensity control programmes were also accessed, suggesting the importance of electricity control. The geographical area for the empirical included the Gauteng and North West provinces. A purposive-convenience sampling method was employed to target industrial categories reflecting a significant trend of industrial economic development in South Africa. Business categories from the service, manufacturing and mining industries were considered. Data collection utilised a closed-ended questionnaire (Likert scaled questions) and employed field workers to obtain reliable data. Results show that electrical energy is a primary production and operational factor for industrial activities. Findings also reflect that the industrial sector is vulnerable to shocks arising from the inconsistent supply. It was also found that there are limited mitigation strategies to protect the continuity of industrial activities during periods of electricity disruptions. The empirical research also revealed that there is limited electricity control as continuity of supply and efficiency are not effectively legislated.

The fourth article was aimed at determining the steadfastness of the South African electricity grid in meeting consumers' current and future demands. A quantitative research design was employed. A multiple time series research method was utilised. Secondary data was retrieved for key determining variables to electricity generation from the first quarter of 1998 to the last quarter of 2015. The *Eviews* statistical software was employed to obtain regression probabilities through the Ordinary Least Square model (OLS) specification. The Engle-Granger approach was used to establish whether co-integration exists between the independent and the dependent variables. The co-integration analysis reflects that there is a significant long-term relationship between the independent and the dependent variables.

A holistic and comprehensive integrated strategic management framework for electricity adequacy has been recommended. It is hoped that the findings of this paper are used to advise energy policy legislature on priorities towards electricity supply adequacy in South Africa.

RESUME

Cette étude a été motivée par l'insécurité observée dans le secteur de la production de l'énergie électrique en Afrique du Sud ces dernières années. Du dernier trimestre de 2007 au premier trimestre de 2008, l'on a observé les pires inconsistances jamais connues en Afrique du Sud en rapport avec l'inadéquation entre l'offre en production d'énergie et la capacité à produire l'énergie dans l'ensemble du réseau électrique du territoire. Cette étude a donc été menée dans l'optique d'analyser en profondeur et de manière holistique les raisons de cet état des choses à travers quatre articles.

Le premier article évaluait l'effectivité de la gestion stratégique de l'énergie électrique en Afrique du Sud. A cet effet, la méthodologie qui nous a semblée appropriée était l'analyse du contenu. Une revue approfondie des publications ayant effectuées les analyses les plus pertinentes sur des aspects les plus importants a été faite. Les données ont été générées et analysées via Atlas-ti 8 pour Windows. De cette recherche empirique il découle que des manquements dans le management et l'absence d'une gestion stratégique intégrée des structures en charge de la production électrique sont un obstacle majeur à la prévention des crises énergétiques en Afrique du Sud compte tenu de la complexité des grilles.

Le deuxième article visait à souligner l'inadéquation qui existe entre l'utilisation domestique de l'électricité et le comportement des consommateurs à travers l'évaluation de quatre facteurs clés, dix appareils domestiques énergétivores et sept alternatives utilisées couramment pour la production de l'énergie électrique domestique. La recherche empirique menée dans ce cas ci a été basée sur une enquête quantitative. La population cible était les provinces du Gauteng et du Nord-Ouest. Un échantillonnage de commodité proposés a été utilisé pour sélectionner les participants. La collecte de données s'est faite à l'aide d'un questionnaire fermé adressé à des travailleurs sur le terrain pour obtenir des données fiables. La collecte des données sur les facteurs a été réalisée grâce à une échelle de Likert à cinq points et des questions dichotomiques, tout en analysant les tendances de la consommation des appareils et les sources d'énergie alternatives. Les quatre facteurs principaux en matière de consistance de l'énergie électrique montrent que l'approvisionnement en électricité des consommateurs domestiques est insuffisant car le niveau standard de vie sur le plan domestique est en général affecté. En ce qui concerne les appareils électriques, il ressort que les appareils très énergétivores sont très utilisés avec un gout prononcé pour des anciens modèles. Il a également été constaté que malgré une hausse de la demande en énergie électrique, plus d'un tiers des sources d'énergie alternatives qui peuvent entraîner des conséquences dangereuses physiques et

environnementales sont utilisées. Cette recherche empirique souligne la nécessité de prioriser l'amélioration de l'adéquation entre l'approvisionnement en électricité domestique et l'offre de l'énergie électrique.

Le troisième article visait à contribuer à une amélioration de l'offre de l'électricité industrielle pour assurer une croissance industrielle et économique durable. La méthodologie utilisée ici a été la recherche quantitative et le sondage. Elle visait à identifier l'association entre la constance de l'énergie électrique et la croissance industrielle en Afrique du Sud. Elle évalue également l'efficacité de la mise en œuvre des stratégies de mitigations afin de prévenir les entraves aux activités économiques dues aux perturbations de l'énergie électrique. Les programmes de contrôle de l'intensité ont également été consultés, dans le but de souligner l'importance du contrôle de l'électricité. L'étude géographique s'est concentrée dans la province du Gauteng et du Nord Ouest en Afrique du Sud. Un échantillonnage à contingence intentionnelle a été utilisé pour cibler les catégories industrielles reflétant un potentiel important pour le développement économique industriel en Afrique du Sud. Les catégories des industries de la production et de l'exploitation minière ont été examinées. Les données ont été obtenues à l'aide de questionnaires avec des questions conçues dans les paramètres de l'échelle Likert. La collecte de données s'est faite grâce à un questionnaire fermé et des ouvriers ont été approchés sur le terrain pour obtenir des données fiables. Les résultats montrent que l'énergie électrique est un facteur de production essentiel pour les activités industrielles. Il ressort également de cette étude que le secteur industriel est vulnérable à l'approvisionnement inconsistant de l'énergie électrique et qu'il ya des limites au niveau de la pratique des stratégies de mitigations afin d'assurer la continuité des activités industrielles pendant les périodes de d'interruption de l'électricité. La recherche empirique a également révélé qu'il y a un insuffisant contrôle de l'électricité, car l'intensité et l'efficacité de l'électricité ne sont pas légiférées de façon effective.

Le quatrième article visait à déterminer la fermeté du réseau électrique sud-africain pour répondre aux demandes actuelles et futures des consommateurs. La recherche quantitative a été utilisée en plus de la méthode de recherche à plusieurs séries chronologiques. Des données secondaires ont été récupérées pour les principales variables de détermination de la production d'électricité du premier trimestre de 1998 au dernier trimestre de 2015. Le logiciel statistique Eviews a été utilisé pour obtenir des probabilités de régression selon la spécification du modèle de moindre poids ordinaire (OLS). L'approche Engle-Granger a été utilisée pour établir si la co-intégration existe entre les variables indépendantes et dépendantes. L'analyse de la co-

intégration reflète qu'il ya une relation significative de long terme entre les variables indépendantes et dépendantes.

Un cadre holistique et complet de gestion stratégique intégrée pour l'adéquation de l'électricité a été recommandé, dans l'espoir que les résultats de cet article serviront à améliorer la législation en matière de politique énergétique tout en tenant compte des principales priorités dans le secteur de l'énergie électrique en Afrique du Sud afin, d'endiguer les inadéquations observées.

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CHAPTER ONE

INTRODUCTION AND BACKGROUND TO THE STUDY

1. INTRODUCTION

Inglesi-lotz (2011) states that in the last decade, research on energy has received great attention, globally due to the shortage of energy as well as the severe projected consequences to the environment. As stated by Khan *et al.* (2011), ensuring the availability of sufficient, affordable, and environmentally friendly energy, has become one of the major challenges faced by the world in the twenty-first century. It is vital to examine and control energy and more specifically electrical energy and identify its effects on the performance of the economy and industry.

Inglesi and Pouris (2010:1) assert that, by 2007, Eskom, the majority distributor of electricity in South Africa, has experienced a lack of capacity in the generation and supply of adequate electricity. As a result, Bah and Azam (2017) highlight that by the first quarter of 2008, blackouts became commonplace in the country, with damaging effects on households and industries. Sebitosi (2008) had stressed that policy inadequacies before 2008 led to South Africa getting under the grip of an electric power crisis, which was threatening the core of the economy. Sebitosi (2008) posits that such forecasts and predictions should have been followed by the development of reliable alternative strategies to guard against the crises. Trollip *et al.* (2014:3) allude that even when definitive policy statements have been made at the highest-level, implementation has been problematic due to other contingencies and general ineffectiveness.

The negligence also points out that South Africa's lack of decisiveness during the implementation of effective strategic policies to ensure electricity efficiency during its harshest times of electricity constraints have a huge impact on economic development. As stated by Sebitosi (2008) electrical power shortages in South Africa stem from the managerial incompetency in almost all the electricity-related national parastatals, especially those in charge of the administration of electricity in the country. Such entities include the Electricity Supply Commission (ESCOM) and National Energy Regulators South Africa (NERSA). Kenny (2015:6) emphasises that the managerial procedures at Eskom have been ineffective with decision-making mainly based on political agendas. Managers apparently pre-occupy themselves with other goals, such as artificially keeping the price of electricity low, for social purposes with little interest and experience in ensuring adequate future electricity supply.

Altman *et al.* (2010:18) support this observation by mentioning that there have been continuous concerns raised about the business acumen of Eskom's ever-changing top management.

Oberholzer (2008:2) states that only in recent times the public sector accepts the blame for lack of strategic planning for future electricity usage. This came only after it emerged that a White paper drawn up by the Department of Minerals and Energy in 1998 forecasted that electricity would be in short supply after 2007, should expansion plans not be implemented. Inglesi and Pouris (2014:88) emphasize that South Africa should have been highly experienced by now in containing a crisis of this magnitude, prior to steps made during the global financial crisis in 2009.

The primary focus of this study was the effectiveness of strategic activities towards electricity adequacy in South Africa. The study assesses strategic failures and the current inadequacy of supplying electricity to the South African market. An evaluation of supply and consumption of electricity in the domestic and industrial sectors were also conducted. Burlando (2010:1) states that there are significant effects of electricity inadequacy on economic activities and domestic quality of life. The empirical study also conducted an assessment of electricity security in South Africa. Musango *et al.* (2011) assert that electricity demand and consumption in South Africa mainly comes from the domestic and industrial sectors. These sectors have been responsible for over 60% of the energy demand annually.

Bah and Azam (2017) concur that deep-rooted problems in the South Africa electricity sector are currently a primary contributor to elements threatening the core of its economy such as potential state capture. The South African economy is now officially in a recession with a contraction of 0.7 percent. Critical concerns such as demand and supply inconsistency of electricity remains an ongoing and unresolved problem. After the first quarter of 2017, Eskom warned the public on forthcoming temporary load-shedding activities for the rest of 2017.

The aforementioned agendas were essential subjects to identify evidence that could assist towards a successful policy implementation in energy supply and regulation in South Africa. The empirical research seeks to expand the existing electricity supply and distribution policy methodologies to remedy the current electricity insecurity by incorporating a reliable System of System (SOS) integrated strategic management framework. Iskin (2014:5) agrees that an energy organisation's management ideology regarding energy advancement will determine the possibility of an effective strategic management of an electricity grid.

1.1 Motivation

Since 2008, South Africa started experiencing severe electricity shortages. Domestic and industrial electricity users' functioning and production abilities were hampered by widespread rolling black-outs across the country. This disruption became more intense as demand exceeded supply. The question is: how can a country like South Africa, which always had more than electricity supply, suddenly find itself in this predicament? Pouris (2008) argues that the primary reason for the electricity crisis and the difficulties in reaching an effective solution to the current problem is the lack of research on energy management in South Africa in general. Several strategies have been implemented, from load shedding to the most current construction of additional electricity plants. However, these aforementioned strategies have been less effective considering that they are more technically focused with no reliable and tangible outcomes at the moment. To the detriment of Eskom, labour unrest has been the reason for serious stoppages of completing the super energy station like Medupi and Kusile (Van Zyl, 2017:1). National leadership has played a huge role in allowing parastatals like Eskom to make sensible and nimble decisions without political interference (South Africa Risk Report (SARR), 2017:64).

Eskom argues that the lack of adequacy can only be resolved by building new power plants. Concurring with Inglesi (2010), a major question posed is whether or not supplying more electricity would be the solution to the predicament. Kenny (2015:1) agrees that it could take years for the current operational energy sources to meet present demand, let alone future demand. The answer to such a question is that a more reliable strategy and operationalisation should be followed. Strategic variables are envisaged as being of major importance to solve this energy capacity and supply crisis.

Kenny (2015:5) maintains that, in 1969, South Africa faced a brief electricity shortage with electricity demand that threatened to outstrip supply after the national economic growth rate had topped 6%. As far back as the origin of the crisis (1969), a reliable strategic decision framework has not been established, thus no strategic decision-making from both the regime and the democracy. Based on the afore discussions, an integrated strategic planning and implementation is perceived as a possible solution. If implemented effectively, the expected outcome should contribute significantly towards electricity supply and distribution adequacy in South Africa.

1.2 Literature study

The following sections present a brief overview of electricity supply and demand crisis and the administration of the South African electricity industry.

1.2.1 Outlook of the electricity capacity crisis in South Africa

Maasdam (2008:1) traces the events that have triggered the acute electricity crisis in South Africa as dating back to the post-1994 era. Eskom provided cheap electricity to industries, which became the base for economic development. Plans to export cheap energy to the rest of Africa encouraged an investment programme which started in the early 1970s. Koen (2012:5) states that in pursuit of this abundant supply, ESCOM made decisions with far-reaching economic consequences. By the time the new power plants were up and running in the early 1980s, South Africa's economy was in trouble with overcapacity in the energy sector.

In post-1994, the customer base of Eskom grew fast, as the government saw cheap electricity as part of their reconstruction and development programme. Inglesi (2011) states that the electricity demand is on an annual increase of four percent, doubling the total demand and requiring a 40 Gigawatts (GW) additional capacity by 2025. In South Africa, the electricity mismatch of supply and demand has been of major concern to energy policymakers. Eberhard (2006:15b) confirms that electricity supply and demand remain inconsistent. The electricity industry is plagued with uncertainty and insufficiency as regulators have failed to set generation, distribution and capacity standards. A reflection of the nature of the problem is shown in figure 1.1.

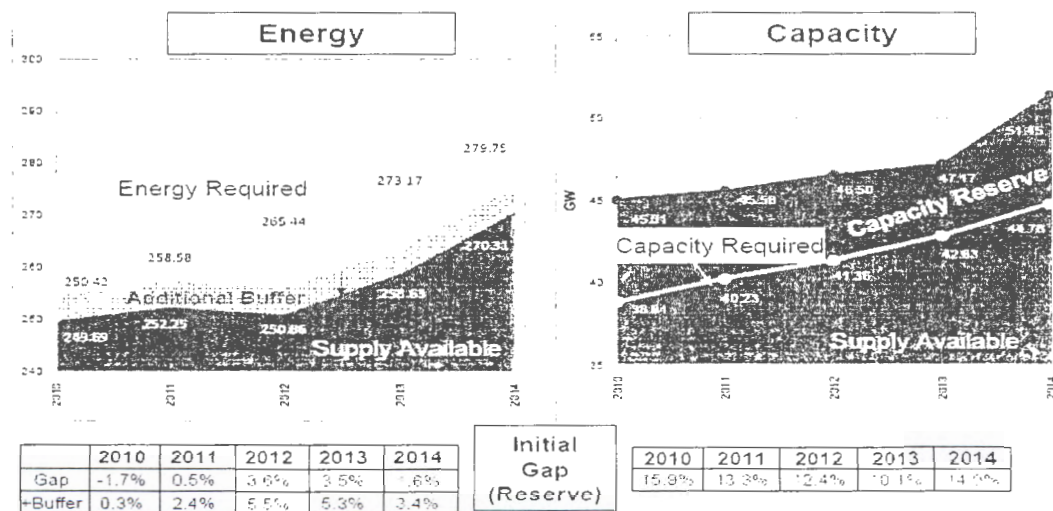


Figure 1.1 Electricity supply and demand capacities in South Africa

Visagie (2014:16)

Wright *et al.* (2017:33) maintain that the demand for electricity is currently on a fast rise and there is a need to grow capacity to sustain the demand gap. The supply and demand balance of the South African grid considering all existing operational production plants as well as plants under-construction and projected plants construction from 2016 to 2040 is reflected in figure 1.2.

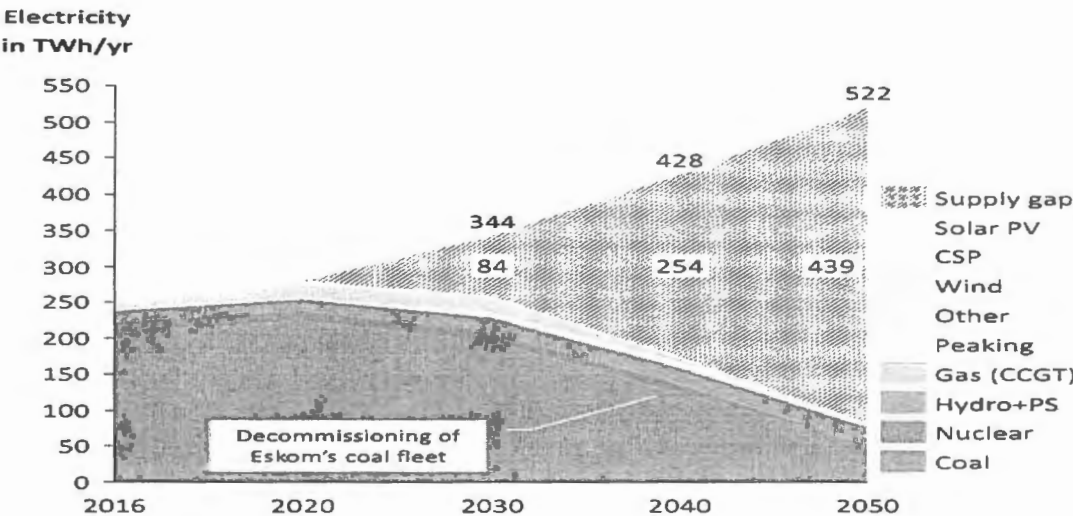


Figure 1.2 Capacity gap from 2016 – 2050

Wright *et al.* (2017:33)

Ingles-i-lotz (2011) highlights that the South African economy has been on an unstable economic growth rate due to decreasing industrialisation as electricity demand rises above available capacity. This very fact has probably played a role in the current recession the country is experiencing with a contraction of 0.7 percent. Martins and McBaid (2013:10) state that out of 94 sampled countries in the world, South Africa was the 78th with regards to the potential of its electricity security. Dinkelman (2011) states that there are difficulties encountered in critically analysing the characteristics of South Africa's electricity inconsistency. The root toward improving electrification in South Africa was more politically motivated. Electricity restructuring projects were very random, ignoring the economic implications and therefore making it very difficult to identify and solve the complexity facing the grid in general. On average Eskom's power plant generators' lifespan are currently at 60%. Eighty percent of Eskom's power plants maintenance interval has expired to date (Van Niekerk, 2015:8). Eskom's power stations' operational life is reflected in figure 1.3.

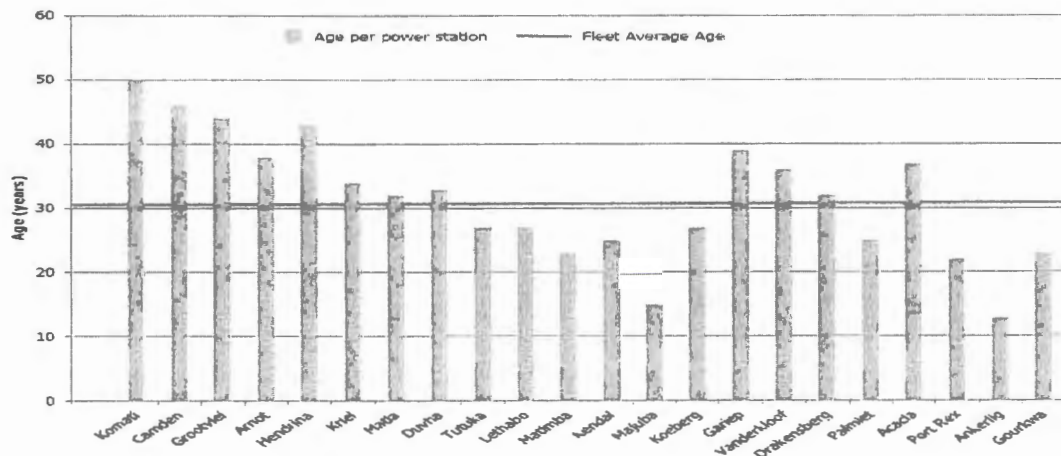


Figure 1.3 Eskom's age cycle of the most important power stations

Van Niekerk (2015:18)

Pegels (2010) maintains that Eskom seeks to improve on its electricity saving capacity through capacity improvement programmes and to promote the increased installation of electrical energy for consumers. Altman (2013:6) maintains that the perspective to improve capacity has so far concentrated on building new technology. It is viewed that such capacity improvement programmes would have prevented a shortfall in generating capacity. Eskom (2015:3) states that electricity generation and transmission projects could unlock additional connection capacity by 2022.

Pegels (2010) however maintains that there are arguments of management short-sightedness to some of these electricity enhancing capacity projects as policies have failed to prioritise the important agenda which entails future electricity security. Kenny (2015:2) argues that the capital costs of Eskom construction of its most important coal station, Medupi, exceeds R100 billion and the capital cost per unit of product (a kWh of electricity) is very low at R1,05/kWh. Medupi's projected life of 40 years or more, will produce an enormous amount of electric energy of 4800 Megawatts (MW). Pegels (2010) highlights that focusing on the current advancement of capacity on coal technology is dangerous as this could aggravate the South African emissions problem and might negatively affect capacity advancement in the long-run. Gross (2012:6) therefore submits that, during 2012, Eskom was ranked as the second highest Carbon-dioxide (Co²) emitting energy company in the world. Laker (2012:33) adds that the newly constructed Medupi coal-fired station alone is estimated to emit over 29.9 million tonnes of carbon-dioxide.

1.2.2 Challenges of the electricity capacity crisis

From the importance of electricity in general, Kenny (2015:1) maintains this commodity is one of the most important new technologies of the 21st century. In households around the world, it is accepted as one of the three essential services along with water and sewerage. Howells *et al.* (2006) state that access to electrification in South Africa deteriorates year-on-year since 2000. Howells *et al.* allude that low-income households such as impoverished settlements in townships have been experiencing a negative pattern in electricity supply. As far back as 2000, Cecile (2000:36-38) submitted empirical findings on the challenges of electrification of South African households, reflecting that electricity access was a major challenge to the domestic sector. The empirical research also determined that significant percentages of electrified households still resort to other forms of energy. Abd'razack *et al.* (2012) agree that poor domestic households in most developing countries tend to be more incapable of acquiring reliable modern electricity due to lack of finance and political will to change the lives of the poorest of the poor. They depend on alternative unclean sources such as wood and kerosene. Research has it on record that four out of five people without electricity live in rural areas in the developing countries (Amadi, 2015). Kojima and Trimble (2016:16) mention that electricity access to households is poor in Africa due to the unreliability of the grids, high initial connection costs and high consumer price. Thopil and Pouris (2013) concluded a study, comparing and ranking global domestic and industrial electricity prices in 17 countries. Within the context of this ranking South Africa is positioned as the 11th least expensive country regarding electricity tariffs. If the real electricity price keeps on increasing in South Africa while that of other sampled countries remain the same, it will take South Africa from 11th to about 15th position. Amadi (2015) argues that electricity promotes economic well-being and makes social life meaningful.

Makgetla (2008:12) maintains that electricity inadequacy is affecting the operationalisation of the South African industrial sector. The mine, chemical, agriculture and nutrition industries have been unable to operate as required due to limited power. The retail cold-chain sector is seriously disrupted due to limited electricity to power fridges and cold houses. In general, Small and medium manufacturing businesses that account for over 60% of South Africa's employment have been seriously injured. Altman *et al.* (2010:28) project that there is a likelihood of electricity supply shortages on the industrial sector stretching beyond 2017. According to Kenny (2015:7) in January 2008, during a period of heavy rains, most coal stations failed tumbling capacity, leading to blackouts and shutting down various gold mines.

A similar situation occurred during the first quarter of 2017 disrupting road transportation of coal to power stations leading to temporary power cuts. These power cuts were primarily experienced by production companies that required high electricity volumes from municipal generators. According to Naidoo (2017:1), four South African provinces have been affected by municipality power cuts, during the first quarter of 2017. Eskom claims that these mentioned power cuts were to alert defaulting municipalities to pay their electricity debts. Unfortunately, this affected the functioning of the industry.

As the crisis proves persistent, Altman (2013:14) points out that electricity rate hikes are worse on industries that are supplied by municipal distributors. After a study (fee structure) done by National Energy Regulators South Africa NERSA (2012:6) amongst 25 municipalities, the results reflected a 39 to 90 percent fee increase during the second quarter of 2008 to the second quarter of 2010. Based on NERSA guidelines, municipal electricity rates for entities should have increased by 49 percent to 59 percent over these mentioned periods. Twelve of these municipalities raised their small business tariffs from 60 percent to 90 percent over this period. NERSA findings also reflected that industries supplied directly by Eskom paid about half the price as compared to municipally supplied businesses. These findings initiated the municipal tariff guideline implemented by NERSA to ensure fair municipal electricity pricing (NERSA, 2017:3).

Von Ketelhodt and Wocke (2008) analyse that effects from the electricity crises are currently felt across the South African business environment. The lack of low priced primary energy sources and increased construction costs for new power stations are all adding pressure to electricity prices for business industries. Baker (2010:3) mentions that the industrial electricity price would have risen by 30% in 2020.

Altman *et al.* (2010:9) point out that there is a real concern that rising electricity prices encourages firms to shut down production or contain expansion with resultant downstream impact on economic growth. However, James (2014:1) reports that the South African business sector is extremely concerned about the short to medium term power inadequacy.

1.2.3 Profile of the South African electricity industry

Electricity was first generated in South Africa around 1882. The creation of the Union of South Africa in 1910 initiated the development of electrical systems under the administration of municipal and private utilities, governed by a range of provincial and municipal laws. By 1920, authorities tabled a coordinated electricity system to support growing industrial demand. A

national transmission grid was established in the early 1970s spawning the long-term institutional and technical pattern of South Africa's electricity industry (Amusa *et al.* 2009). Amusa *et al.* (2009) note that Eskom generates 96 percent of South Africa's electricity while private generators produce around 3.2 percent and municipal authorities generate 0.8 percent. Mushwana (2009:20) states that the creation of the Electricity Regulation Act No. 4 of 2006, called for the establishment of the National Energy Regulator of South Africa (NERSA) as the custodian and enforcer of the regulatory framework provided by the act. Section 3 of the act states that the role of NERSA was to ensure that the interests and needs of present and future electricity consumers and end users are safeguarded and met. Eskom has 27 power plants in South Africa that generate over 42040 GW of the country's 43.9 GW capacity. A representation of Eskom's current generation capacity is reflected in figure 1.4.

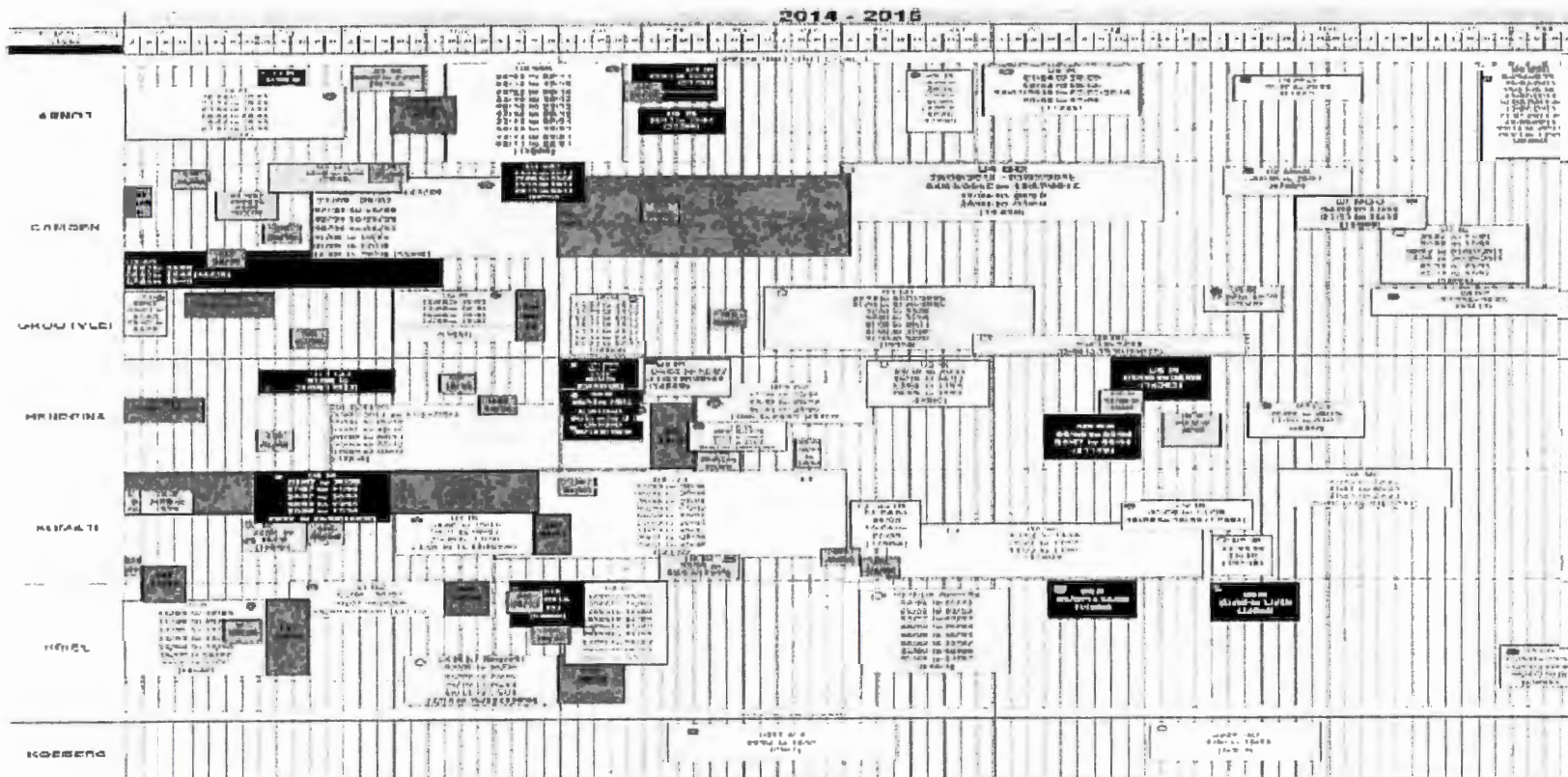


Figure 1.4 Current Eskom generation capacity

Matona (2015:7)

Category A outage
 Category B outage
 Category C outage
 Minor outage
 Secondary outage
 Breakdowns
 Projected outages
 Outages cancelled

The figure represents details of the current position of Eskom's generation capacity. The colours represent the status of the generating plants.

1.2.4 Strategic management in the electricity industry

Brown (2012:5) maintains that an integrated strategic management approach enables an organisation to access additional knowledge, expertise and resources to create a collaborative advantage by linking variables. Geldenhuys *et al.* (2003) state that the *raison d'être* of integrated management decisions involve the establishment of multi-disciplinary transformations. It requires a shift in the manner in which an organisation's operational processes are developed, delivered and managed.

According to Kodama (2010:15) an effective strategic decision-making over the questions of what organisational procedures to implement by large corporations relies on interlinking various functional areas from its internal to the external environment. Such interconnections play a significant role in the value chain. Lalk (2015:5) says a country's energy system is highly complex and its advancement requires an SOS approach. Haskins (2011:6) states that this implies a system-of-interest whose system elements are themselves systems. It consists of large-scale inter-disciplinary problems requiring heterogeneous solutions. Johnson and Suskewitz (2009) say that since energy system planning is dominated by the state, policymakers should also carefully balance state objectives to standard business models with implementation decisions that are cautious of strategic market parameters.

1.2.5 Strategic management of the South Africa utility industry

Gnansounou *et al.* (2008) have produced research in the Economic Organisation of West African States (ECOWAS) electricity crisis, and they found evidence that challenges were rooted in the implementing strategies that are not in line with the fundamentals of effective integrated strategic management. Rue and Holland (1989:31) observe that a strategic model consists of the following elements:

- (1) Status quo analysis.
- (2) Possible opportunities for the future.
- (3) Identifying and mapping the future.
- (4) Implementing strategies.
- (5) Evaluating and management strategies, outlining the fundamental strengths of an effective integrated strategic model.

Dergiades and Tsoulfidis (2008) argue that the electricity supplies industry is highly complex and highly capital intensive. A rigorous analysis of the determinants of electricity supply and its accurate forecasting to demand are of vital importance for sustainable and adequate supply.

Projecting aggregate electricity demand and supply is essential for informing policy developers in the design of an effective energy policy to deal with current and future electricity needs for possible effective electricity sector management and planning.

Rue and Holland (1989:31) point out that an effective strategic plan should survive the test of time. Arguably, South Africa's energy industry has a history in designing deficient strategic frameworks for energy supply and consumption. The development of a deficient strategic plan in the South African energy industry was first manifested in the 1998 Energy White Paper of South Africa. According to Kenny (2015:8), most suggestions in the 1998 South Africa Energy White Paper are perfectly comprehensive. Alternatively, the White Paper failed to address the fundamental problem of electricity generation and supply in South Africa, contributing to the present supply inadequacy predicament.

The South African Government policies and strategic response to supply adequacy and energy crisis are in several publications by the Department of Energy since the crisis from 2007/2008. Lalk (2012:2) outlines documents that have been released that were aimed towards a more secure energy future in South Africa, and these include the Energy Efficiency and Demand Side Management Policy (EEDSM), Nuclear Research (NR), Development and Innovation Strategy (NERDIS) (The NERDIS did not materialise, and its current status is unspecified), Industrial Policy Action Plan (IPAP2), Nuclear Energy Policy (NEP) and the Integrated Resource Plans (IRP).

Lalk (2015:2) demonstrates that the IRP2010 (IRP2) published in 2011 have been the core guidelines for future energy security in South Africa till 2025. Laker (2012:30) states that any energy advancement in South Africa must be within the objectives of the IRP2010. Martin and Atkins (2013:4) say that the IRP in the South African context is an official national electricity plan. Its mandate is to guide and direct the expansion and sustainability of the electricity production and supply in South Africa over the long term. The government views it as ideal for achieving the projected electricity demand with minimum cost. Lalk (2015:1-5) presents constructive criticisms to the fact that even though the IRPs appear to address different challenges, it falls short in many aspects:

- The Department of Energy (DOE) does not clearly understand their policies.
- It is questionable if Eskom who controls over 96 percent of energy administration in South Africa was duly consulted.
- It is not clear whether or not the modelling of plans resulted from a comprehensive and detailed integrated analysis of South African energy needs.

- Implemented models have been based on previously existing government planning parameters with no flexibility for long-term energy plans.
- Policies do not quite match the current energy realities towards a sustainable and environmentally friendly production and usage of energy.
- The nature of a national energy system is very complex and the lack of a systems approach to implementing policy frameworks has resulted in massive mistakes. This is evident in the government's obscure actions.
- The IRP 2010 seems to be the future energy decision policy, but conflicts exist between the IRP2010 and other latest policy release like the National Development Plan (NDP) which has solid government support. There are intense contradictions on the focus towards energy security within these two documents.
- The IRP2010 failed to address the long-term energy security of South Africa. It is evident in its non-consideration of growing modern energy production technologies such as biomass, geothermal and tidal energy.

Laker (2012:30) highlights that a system with no flexibility prevents the opportunity for a radical change. Fisher (2013:18) states that the IRP2010 has been approved by the government to be the future map for the South African grid advancement for the next 25 years, after it was officially launched in May 2011. Fisher (2013:19) therefore agrees that the IRP2010 modelling is a sketchy approach, involving mapping future supply options on historical data and moderate demand predictions structured by Eskom. It is technically a business as usual approach that has just about 2.9 percent yearly growth in electricity for the entire IRP2010 planning horizon. Fascinatingly, an update of the IRP2010 released for public comment in 2013 with a much better effort in attempting to address the bigger picture of the South Africa energy needs was not accepted by the cabinet, leaving the original and flawed IRP2010 as the inept plan of choice (Lalk, 2015:5). Cabinet surely needs to know how to follow systems approaches.

1.2.6 Strategic system development

Throughout the path of the human evolution, systemisation have been prioritise as the most effective concept in solving challenging complex problems. Despite the fact that there have been the emergence of different theories on system development, Cordon (2013) note the following philosophies still underpins the knowledge of system development.

- Evaluating the identified problem as a whole and constructing a system that caters for all sub-problems identified in order to solve the primary problem. This philosophy holds that it is more effective in solving a problems by constructing holistic systems.
- Solving the identified problem by breaking down a large complex problems into smaller manageable portions. The philosophy holds that an identified problem should be solve by constructing separate systems for each identified sub-problems.

According to Cordon (2013), the construction of systems to enhanced wellbeing of humans tend to be the most complicated structures to attain. It is primary to effectively integrate a system development to the objectives of an identified problem in order to construct a system that will attain a sustainable change. Meadows (2009:12), maintains that a system becomes depreciated of its 'system-ness' when all it sub-systems cannot longer function in an integrated fashion. A system problem solving philosophy is underpinned by two rudimentary aspects, which include considering the realities of a problem as units, and acknowledging that the units are essential part of a holistic system environment, as units interacts within the system. Generally commended system thinkers such as Von Bertalanffy (1968), Senge (2006) and Wheatley (2006) have asserted that the world is a unify environment, where everything is inter-related, approaches to solving complex problems by establishing separate manageable elements that cannot be integrated is not sustainable. Element-based systems development has been the case with most structures designed for electricity adequacy in South Africa. The empirical research of the study identified an integrated strategic system framework as the sustainable approach to electricity adequacy in South Africa.

1.3 Problem statement

Several attempts have been made by the government and the energy industry in addressing the problem of electricity inadequacy in South Africa. However, the crisis has been persistent as electricity inconsistency continues, establishing the ineffectiveness of implemented strategies. Matona (2015:9) reports that techniques such as improving electricity plants and load shedding activity, which is considered to be Eskom's primary approach have increased rapidly from 4.3 percent in 2008 to 14.8 percent currently.

The electricity crisis in South Africa shares a similar context as Bangladesh based on a study conducted by Ahmed (2011). Ahmed traces the electricity crisis in Bangladesh to have originated from poor estimation between demand and supply from 1990 by the electricity parastatal, Bangladesh Power Development Board (BPDB), which administers 66 percent of

electricity generation under the Ministry of Power, Energy, and Mineral Resources (MPEMR). Despite several programmes adopted by the Bangladesh government such as incorporating public-private-partnership, the building of power stations and changes in the management structure of the electricity sector and energy department, the Bangladeshi government has not succeeded in mitigating the crisis.

The crisis has become acute with intense load shedding, increasing electricity inefficiency, high debts, inadequate funding to the BPDB and ineffective electricity pricing. Ahmed was very clear that the persistent crisis resulted from ineffective strategic management with regards to every single method that was implemented as a remedy to the crisis. A high percentage of the implemented methodologies were weak and politically motivated to continue the bureaucratic culture of the ruling party, the Awami League.

Koen (2012:11) observes that the uncertainty by the ruling party, the African National Congress (ANC) unfocused administrative policies on Eskom through the DOE, have all cumulatively affected the smooth functioning of the parastatal, Eskom. Trollip (2014:3) states the electricity crisis is very complex, and an effective integrated strategic approach is most needed to analyse and address challenges to its integrity.

Thus, the problem identified in this study relates to the *lack of a standard integrated strategic system of system (SOS) framework* for the attainment of electricity adequacy in South Africa.

1.4 Research objectives

This study seeks to:

- Investigate the strategic management failures pertaining to the ongoing electricity crisis in South Africa.
- Assess the impacts of the low electricity supply on the South African domestic sector and relating consumption behaviour.
- Evaluate the effect of inadequate industrial electricity supply on industrial growth in South Africa.
- Determine the electricity security by analysing significant determinants to the reliability of the grid.
- Develop a reliable and applicable SOS framework for electricity adequacy in South Africa.

1.5 Research questions

- What are the strategic failures to the ongoing electricity crisis in South Africa?

- What are the impact of the low electricity supply in the South African domestic sector and relating consumption behaviour?
- What is the effect of inadequate industrial electricity supply on industrial growth in South Africa?
- What is the electricity security of supply in South Africa?
- What measures could be established to obtain electricity adequacy in South Africa?

1.6 Research methodology

Wilson (2009:5) refers to methodology as a plan of action that informs and links the methods used to collect and analyse data in a bid to answer postulated research questions. The research design in this study is the multi-method approach as the study followed an article approach utilising both qualitative and quantitative research designs in individual cases. According to Ahmed and Sil (2012) and Matsaganis (2016) a multi-method research design, unlike mixed method, involves conducting a range of relatively independent qualitative and quantitative projects to solve a single main research problem. The independent empirical research is guided by sub-objectives whose outcomes are later incorporated to provide a comprehensive and holistic solution to the main objective of the research project. Buthe and Jacobs (2015) state that the multi-method research design became popular due to continuous calls from the research community on a research method that can handle the complexities involved in certain research agendas. This approach was perceived the most effective strategy in producing a reliable contribution to the research problem.

1.6.1 Primary empirical research methods

The primary empirical research investigated objectives two and three of the study (article two and three respectively).

1.6.1.1 Population

- Bickman and Rog (2009:77) refer to the population as the total group that a researcher conducting an empirical investigation is interested in. The Gauteng and the North West provinces comprised the population for the primary empirical research. Conducting empirical research in Gauteng was driven by the fact that the province is the hub of the South African economy. Gauteng contributes 33.5% to the national GDP. Again out of the 15 million electricity consumers in South Africa, Gauteng alone consists of 10 million electricity consumers. Migration, especially by Africans to South Africa, has had an enormous impact on South Africa's and especially Gauteng's electricity demand.

- The North West province was selected since it was necessary also to target a developing provincial location. In general, it was possible to achieve the sampling objective of the domestic empirical research by utilising the sampled provinces due to the pattern of their settlements.

The target population for the primary empirical investigation included the domestic and industrial electricity consumers in South Africa. The reason for targeting domestic and industrial sectors is because residential and industrial sectors are the major stakeholders in electricity demand and usage in South Africa.

The industrial empirical research was focused towards industrial growth and competitiveness. The empirical research considered the industrial sectors that are the nucleus of industrial development in South Africa. The target industries include mining, manufacturing and commercial organisations. The Industrial development corporation (IDC) (2013:6-7) assessed the economic trends from 1994 and outlined that the services, manufacturing and mining sectors have been the backbone of the South African economy. The services dominate the tertiary industry through financials, wholesale, retailing and motor trade. The secondary industry is dominated by manufacturing through construction. In the primary industry, mining has been a significant growth contributor compared to agriculture, fishing and forestry.

1.6.1.2 Sampling

Alvi (2016:11) defines sampling as actual participants selected from a population for the researcher to conduct an empirical study on. Ross (2005:1) points out that researchers sample to eliminate challenges such as cost and the possible failure to meet research schedules. Sampling also provides the possibility for accuracy as a researcher can perfectly study a manageable size. The primary empirical research employed a purposive-convenience sampling. The guidelines of quota sampling were considered in targeting actual participants to avoid bias and to ensure that sample groups proportionately participated in the empirical research. Cohen *et al.* (2011:156) refer to purposive sampling as a non-probability sampling method which involves purposive selection of particular participants from the sample considered to have the actual information pertinent to the study. According to Farrokhi and Mahmoudi-Hamidabad (2012), convenience sampling entails the targeting of participants based on availability and accessibility, especially with empirical investigations involving a large sample. Through convenience sampling, an adequate participatory size was obtained.

A purposive-convenience sampling approach was most appropriate for domestic and industrial participants. The empirical investigation mainly targeted individuals with knowledge of the respective identified problems of the empirical research. The domestic sector investigation was focused on income earners. The industrial sector empirical research targeted industries with significant patterns and trends in the South African industrial growth. The total sample was determined through the Central Limit Theorem (CLT) technique. According to Filmus (2010:1) and Fisher (2011:1), the CLT holds that the size of the sample will be a function of the accuracy of the sampled population. In the empirical research, accuracy was measured using the margin of error and the level of confidence. A 95% level of confidence and a 5% margin of error was considered for coming up with the total sample. Thus, a 1.64 Z value is considered. The CLT formula considered is denoted as follows:

$$n = Z^2(p.q) h^2 \quad \text{(Formula 1.1)}$$

Z = value from normal distribution table for desired confidence level

p = obtained proportion

q = 1 - p

h = desired precision

The sampled provinces are home to over 5,795,700 households. The domestic sector empirical research reflect that a sample size estimate of 400 households constitutes an accurate sample given the total population size of the target geographies and the type of analysis that was performed, more specifically an exploratory factor analysis. It was estimated that that 50 participants were adequate to represent each group. In the Gauteng province, Johannesburg and Pretoria were the target population. In the North West Province, Potchefstroom and Mafikeng were the actual target population. The selection of sample cities was based on provincial capitals and a large, influential city. The actual data collection targeted different groups from each sampled city as in, Johannesburg (Auckland Park and Soweto), Pretoria (Pretoria North and Soshanguve), Mafikeng (Riviera Park and Extension 39) and Potchefstroom (Potchefstroom town and Ikakeng). A total of 323 questionnaires were gathered from the domestic empirical research.

Sampling for the industrial sector empirical was estimated from available data from the chamber of commerces from the sampled provincial geographies and the Bureau for Economic Research report (2016). An estimated 60,000 formal enterprises are operational across the

investigated sectors in the sampled provinces. The population reflects that a sample size estimate of 300 organisations is an accurate sample for empirical research. It was considered that 100 participants should represent each industrial sector. Sampled organisations from the Gauteng province were identified in Johannesburg and Pretoria. Participants from the North West province came from Rustenburg, Mafikeng, Lichtenburg and Klerksdorp (target cities for industrial empirical for the North West was increased based on spatial economic complexities of the province as compared to Gauteng with a metropolitan setup). The actual data collection targeted different groups from each sample industry: services (financials and cold-chained retail supermarkets), manufacturing (construction and chemicals) and mining (minerals and mining purification). A total of 223 questionnaires were obtained for the industrial empirical fieldwork. A summary of the sampling is reflected in figure 1.5.

Domestic sector empirical research				Industrial sector empirical research					
North-West		Gauteng		North-West		Gauteng			
Mafikeng		Johannesburg		Mafikeng		Johannesburg			
Potchefstroom		Pretoria		Rustenburg		Pretoria			
				Lichtenburg					
				Klerksdorp					
Mafikeng		Johannesburg		Manufacturing		Mining		Commercial	
Extension 39	50	Auckland Park	50	Construction	50	Mineral deposits	50	Supermarkets	50
Riviera Park	50	Soweto	50	Chemicals	50	Mine purification	50	Financials	50
Potchefstroom		Pretoria							
Potch town	50	Pretoria North	50						
Ikakeng	50	Soshanguve	50						
400 participants				300 participants					

Objective two assessed the electricity access and the effect of electricity inconsistency on domestic living standards. It also assessed the consumption behaviours to determine the efficiency and environmentally friendly alternative energy options for the domestic sector. Objective three evaluated the effect of inadequate industrial electrical power supply on industrial growth in South Africa. It also assessed intensity and mitigation programmes for the industrial sector. The questionnaire for the domestic research was structured in five sections (A-E), and the industrial questionnaire was structured in three sections (A-C). Respondents had to complete the questionnaire by ticking the most applicable option, responding to the five-point Likert scale and dichotomous questions as was required by each of the sections. Each of these sections were categorised on considered themes that had to be assessed towards attaining the main objectives. Questionnaire themes and sub-structures for both industrial and domestic sectors empirical research are summarised in Table 1.1

Table 1.1 Summary of objective one and two questionnaires

Domestic sector empirical research		Industrial sector empirical research	
Sections	Themes	Sections	Themes
Section A	Biography and profile	Section A	Biography and profile
Section B	Operational reliability: supply sufficiency	Section B	Supply adequacy: importance electrical energy, supply sufficiency, operational vulnerabilities and business
Section C	Supply Adequacy: service quality, health risk and cost reliability	Section C	Control programmes: mitigation control and intensity control
Section D	Consumption tendencies: Energy saving activities		
Section E	Alternative energy sources		

Access to data was facilitated by a letter signed by the office of the dean. The contents of the letter identified the researcher as a student in the Faculty of Commerce and Administration at the North-West University, Mafikeng Campus. The letter also bore the researcher’s request.

1.6.2 Secondary empirical research methods

The secondary empirical research investigated objectives one and four of the study (article one and four respectively).

Objective one of the study assessed the strategic management failure about the ongoing electricity inadequacy in South Africa. A deductive qualitative content analysis method was employed to respond to objective one.

Objective four was aimed at determining the supply security of the grid based on significant determinants of electricity production. A multiple time series technique was employed in finding co-integration between the dependent variable and the independent variables. Through

objective four, it was possible to evaluate the underlying trends of the electricity security in the South Africa electricity grid by testing significant variables that disrupt electricity generation.

1.6.2.1 *Secondary empirical research data sourcing and description*

Data gathering for objective one was obtained from a purposive review of literature through journals, articles, books, magazines, internet sources and public sector electricity reports. Objective one evaluated the failure of strategic policy implementation to mitigate the electricity crisis towards an SOS approach. It is a large scale inter-disciplinary problem-solving strategy which assesses the performance of an electricity system from an integrated strategic perspective. Through content analysis, empirical research reviewed existing literature in detail to establish the role of electricity policy making strategic failures on current electricity inadequacy.

Objective four data involved obtaining time series data for sampled dependent and independent variables. Electricity production is the dependent variable, while coal price, coal volume, electricity consumption and electricity price are the independent variables. Variables were identified by their capability to significantly disrupt electricity production and negatively affect electricity security in South Africa. Data was collected from Quantec South Africa database. Data collected from variables were done on a quarterly basis. The sampling period was from the first quarter of 1998 to fourth quarter of 2015. The empirical research utilised the measurement units of each variable over the sampled period (1998 to 2015). The empirical research originally targeted asset depreciation of electric machinery as one of the independent variables as it is a measure of a positive electricity security. Asset depreciation was eliminated due to a lack of data that could be mathematically manipulated.

1.7 Data processing and analysis

Alexander (2012:1) defines data analysis as systematically collecting, transforming and analysing data to present meaningful conclusions. Interpretation means relating the results and findings of a study to an existing theoretical framework and showing whether or not these results are supported by existing theories. It also entails the dispelling of rival explanations or interpretations of the empirical data and showing what levels of support the data provides for the preferred interpretation (Mouton, 2002:109).

1.7.1 Primary empirical research data analysis

The primary data collected from both the objective two (article two) and objective three (article three) empirical data was analysed using the IBM Statistical Package for Social Science

statistics version 23.0.0. Arkkelin (2014:10) also argues that the SPSS could permit statistics ranging from simple descriptive numbers to complex analyses of multivariate matrices. With SPSS, data can be presented in different forms such as tables and graphs and much more. It adequately met the approach in the study. The tests conducted on both the domestic and industrial sectors’ empirical research are presented in Table 1.2.

Table 1.2 Summary of primary research data analyses

Conduct tests for domestic sector data analysis (objective 2)		Conduct tests for industrial sector data analysis (objective 3)	
Test Categories	Test types	Test Categories	Test types
<i>Descriptive statistics</i>	Means (M)	<i>Descriptive statistics</i>	Means (M)
	Standard deviations (SD)		Standard deviations (SD)
	Frequencies		Frequencies
<i>Factor analysis</i>	Determinant test	<i>Cronbach alpha</i>	Reliability test
	Kaiser-Meyer-Olkin measure (KMO)	<i>Effect size test</i>	Practical difference estimation
	Bartlett test		
	Communalities test	<i>Independent test</i>	Levene's T-test
	Total variance test	<i>One way test</i>	ANOVA
	Pattern matrix		Welch test
<i>Cronbach alpha</i>	Reliability test	<i>Correlation test</i>	Spearman rank coefficients
<i>Independent test</i>	Mann Whitney test	<i>Chi-Square</i>	Pearson Chi-Square
	T-test		
<i>One way test</i>	ANOVA		
	Welch test		
<i>Correlation test</i>	Spearman rank coefficients		

1.7.2 Secondary empirical research data analysis

This section of the analysis focused on objective one (article one) and objective four (article 4) empirical research studies. A secondary empirical research approach was employed in obtaining outcomes from the two objectives. Objective one utilised a deductive content analysis technique by Atlas-ti 8. Data from the literature were structured to form categories. After categories had been defined, a categorisation matrix was designed to serve as a guideline to perform open coding on literature by placing findings relevant to the structured categories.

According to Elo and Kynge (2008) and Mark and Wright (2008), there are no methodical guidelines that must be adhered to in analysing content data. Analyses are usually performed depending on the research question and a researcher’s intent.

Objective four followed the co-integration analytical technique. Inglesi (2010) highlights that co-integration is the predominantly used method as recommended by international literature modelling electricity generation and supply studies. The Engle Grangerco-integration technique was used in determining co-integration and error correction term (long-run and short-

run relationships among the variables). The most often used Engle Granger specification, the Ordinary Least Squares (OLS), were used in determining regression outcome.

- **Model specification for objective four (Multiple Ordinary Least Square)**

Schmidheiny (2016:2) defines the multiple linear regression models as a linear relationship between a dependent variable y_i and a set of explanatory variables.

Schmidheiny (2016:2) state the formula for Multiple Ordinary Least Square regression is as follows:

Least Square regression is denoted as $y_t = \beta_0 + \beta_1 x_1 + \varepsilon_t$ (Formula 1.2)

y = dependent variable or the explained variable.

β_0 = the intercept of the equation.

β_1 = the slope coefficient of the electricity variable.

x = the independent variable or explanatory variables.

ε = the error term or the disturbance variable.

1.8 Limitations of the study

Due to vast industrial sectors in South Africa, it was impossible to include all existing industries in the study. Just as industries, it was not possible to conduct empirical research on all the households from all provinces. Thus, three industries and four cities were sampled across two provinces in acquiring data for both industries and households empirical research.

1.9 Academic contribution

The initial conception of the empirical research on the problem statement was born out of the need to enhance electricity adequacy in South Africa. Despite the establishment and implementation of different strategies by electricity administrators to solve the electricity inadequacy problem, no feasible and sustainable outcome has been achieved. This study is relevant in the sense that reviewed literature has shown that current electricity crisis mechanisms are not effective. This study focuses on developing a reliable integrated SOS strategic management framework for obtaining electricity adequacy in South Africa. Therefore, this study answers the question of what could be an effective, applicable and reliable integrated strategic management model for electricity adequacy in South Africa. The considered

parameters guiding this study and tentatively reflecting the outcome was the Energy Trilemma by the World Energy Council (WEC). This framework is reflected in figure 1.6.

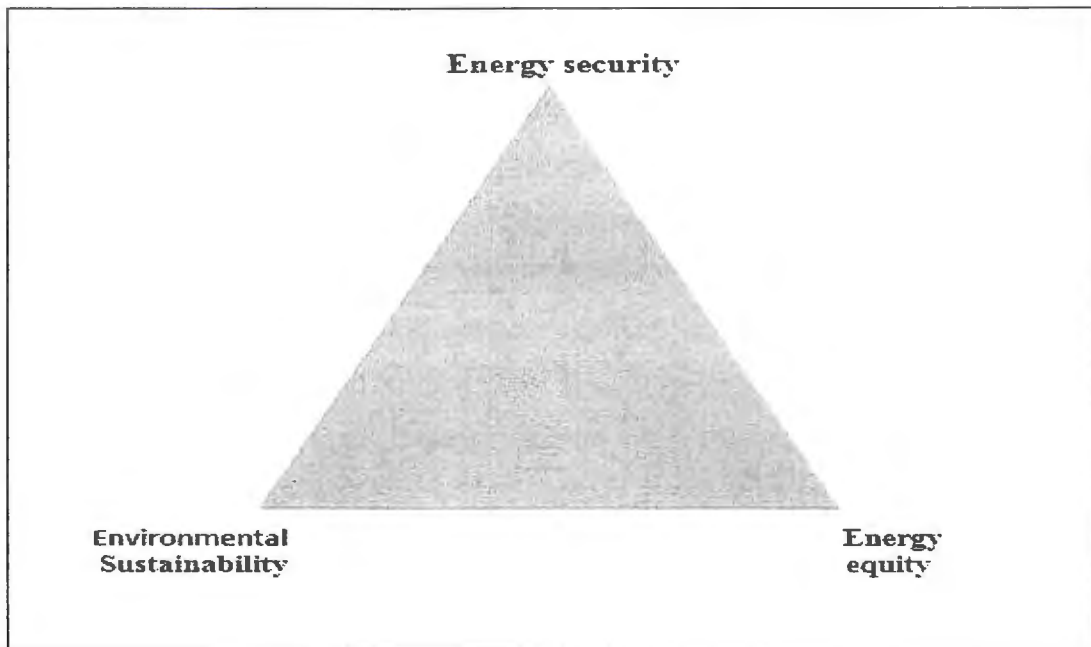


Figure 1.6 Integrated energy trilemma: parameters for electricity adequacy
World Energy Council (2016:25)

Figure 1.6 reflects the dimensions towards developing an integrated strategic management framework for South Africa electricity industry. A brief overview of variables in the figure is explained in the following subsections.

- **Energy security**

Energy security considers management of primary energy production resources and the ability to meet current and future demands through technological advancement.

- **Energy equity**

The focus is on supply accessibility and affordability across all population and industrial competitiveness.

- **Environmental sustainability**

The environmental sustainability covers achievement of energy efficiency and environmentally friendly energy supply and usage.

1.10 Ethical considerations

The ethical considerations in this study followed Trochim's (2006:42) ideas of a perfect ethical consideration of empirical research. It includes the principle of voluntary participation, the requirement of informed consent, the principle of anonymity and guarantee of confidentiality.

1.11 Conclusion

This introductory framework presented a detailed introduction and background to the study. An organisation of the study is represented.

Chapter One: Introduction and background of the study

In this chapter, the statement of the problem, the motivation, background, objectives, research questions, ethical considerations of the study are discussed.

Chapter Two (Article 1): Strategic management failures as a major cause of electricity supply crisis in South Africa.

This section of the study conducted a deductive qualitative content analysis in a literature review to develop a categorisation matrix for the analysis of data through open coding categories. A detailed discussion on the strategic management failure in the South African electricity policymaking was reviewed in detail.

Chapter Three (Article 2): The consequences of inconsistent electricity supply on the South African domestic sector and related consumption behaviours

In this chapter, a quantitative survey was utilised in determining the impact of electricity inconsistency on the residential sector through self-administered questionnaires. Consumption behaviours were also determined to advise on efficient policy to be established by policymakers regarding domestic electricity supply for the sampled consumers.

Chapter Four (Article 3): The effects of the inadequate electrical power supply on the industrial growth in South Africa

In this chapter, a quantitative survey was performed in the industrial sector using self-administered questionnaires in determining the consequences of low electrical power supply on industrial enterprises and the effectiveness of implemented mitigation programmes towards electricity shortfalls.

Chapter Five (Article 4): Electricity security in South Africa: Analysing significant determinants to the grid reliability

In this chapter through time series, co-integration and error correction determined on the dependent variable (electricity production) over independent variables (coal volume, coal price, and electricity price and electricity consumption); through the Engle Granger approach, the electricity supply security in South Africa was computationally determined.

Chapter Six: Conclusions and academic contribution

A summary of the research chapters and outcomes are presented. This chapter also presents a structural framework developed from the empirical data, and it also provides a detailed discussion of its application in answering the main and sub research objectives comprising this study.

CHAPTER 2 (ARTICLE 1)

STRATEGIC MANAGEMENT FAILURE AS A MAJOR CAUSE TO ELECTRICITY SUPPLY CRISIS IN SOUTH AFRICA

Benedict Belobo Ateba and Johannes Jurgens Prinsloo

ABSTRACT

The primary focus of this study is towards the effective strategic management of electricity in South Africa. The empirical research utilised a content analysis methodology. Findings were generated from existing literature review on the electricity inconsistency in South Africa through Atlas-ti 8 for windows. The proposed empirical research points out that strategic management failures and the lack of an integrated strategic management approach have been a major stumbling block to averting energy crises in South Africa. The research focused on exploring the strategic causes of electricity inadequacy and emphasising its heterogeneous nature. The review process followed a purposeful search, selection and review of publications with the literature on the most critical concerns. This paper recommends an integrated strategic management framework as an effective approach towards obtaining electricity adequacy in South Africa.

Keywords: *electricity, inefficiency, crisis, strategic management, integrated management*

2. INTRODUCTION

Inglesi (2011) notes that due to the general global insecurities on energy systems, research on energy creation and consumption has received great attention in the last decade. As stated by Khan *et al.* (2011), the twenty-first century is struggling extremely to safeguard the availability of adequate, inexpensive, and environmentally sustainable sources of energy. It is vital to determine factors that impact upon the electricity system in SA. International Energy Agency (IEA) (2008:78–81) estimates that the global consumption on principal energies will rise to 45 percent by 2030, requiring massive increases in investments for energy enhancement. A proportion of 87 percent of this projection is to be experienced in developing countries. Sarker and Singh, (2009:2) point out that it is important to establish cost-effective programs towards the enhancement of energy security such as efficiency, reduction of environmental emission and extreme reliance on fossil fuel. Figure 2.1 reflects the projected growing gap of regular energy reserves in the world from 1930–2050.

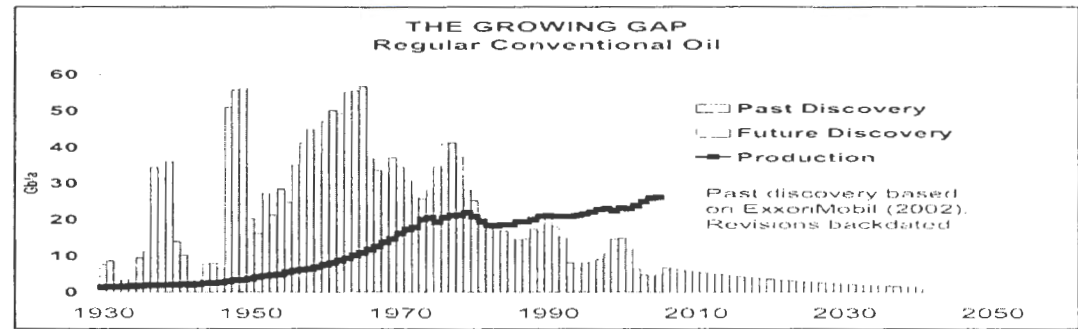


Figure 2.1 The projected growing gap of the world's regular energy reserves
Campbell (2006)

There have been many field research projects undertaken which estimate the global exhaustion time of primary energy reserves by assuming constant production rates. Singh and Singh (2012:171) maintain that most of the research undertaken estimate the rate of fossil fuel consumption to the ratio of reserves. Consequently, Singh and Singh developed a more applicable and accurate formula parameter in estimating energy depletion. The new model outcome of Singh and Singh is reflected in Table 2.1.

Table 2.1 Depletion times of the world's main energy reserves

	Old model ratio of consumption to reserves			New model ratio of consumption to reserves		
Category	Oil	Coal	Gas	Oil	Coal	Gas
Year	40	200	70	35	107	47

Singh & Singh (2012:171)

The DME White Paper on Renewable Energy (2003:3) points out that the reserves margin for South Africa's fossil fuel, which supplies about 90 percent of the country's electricity, was by a 10 percent margin. The White Paper also emphasised that the South African utility would experience tough times by 2007 if major solutions were not in place to ensure energy efficiency. This prediction was allied to that of the 1998 energy White Paper.

Inglesi and Pouris (2010:1) asserted that, by 2007, Eskom, the major distributor of electricity in South Africa, suffered a fall in its electricity supply capacity. This was to prove correct, as the country was plagued with supply inconsistency by the first quarter of 2008 with negative effects on households and industries. Sebitosi (2008) has stressed that a lack of policy oversight before 2008 saw South Africa plunged into an electrical power crisis, which is now threatening the core of the economy. National Treasury (2015:1) reports that the low and unreliable levels of electricity supply are currently the most structural weaknesses constraining the South African economy.

Worch *et al.* (2013) says the managing and usage of energy are yet to be a priority in the research and development policy in South Africa. This has made it difficult in finding an effective solution to the electricity challenges. Steyn (2013:2) agrees that most often, access to reliable information is the main cause of Eskom's glitches because the parastatal operates under unnecessary secrecy. It has a monopoly on information that could provide vital clues to the implications of its decision-making choices. One solution would be for researchers to carry out empirical studies that could recommend practical and implementable solutions contributing towards electricity adequacy in South Africa. Hedden (2015:7) states that since electricity demand began exceeding supply, the true electricity capacity needed to ensure energy security in South Africa is still unknown to date. Thus, the paper examined the literature on:

- (1) The outlook for the developments of the South Africa electricity industry.
- (2) The contribution of strategic management failures towards electricity inadequacy in South Africa.
- (3) Assessing the electricity shortfalls and offering possible solutions from an integrated perspective.

2.1 Introduction to the problem

Sebitosi (2008) posits that predictions on future electricity shortfall, should have been followed up through the development of reliable strategies to safeguard the crises. This negligence also

highlights South Africa's lack of decisiveness in implementing effective strategic policies to ensure electricity efficiency, which led to its harshest electricity shortfall. As stated by Sebitosi (2008), the current electrical power shortages in South Africa stem from the managerial incompetence of the national parastatals in charge of administering electricity supply and output in the country. Such entities include the Electricity Supply Commission (ESCOM) and National Energy Regulator South Africa (NERSA).

Thus, in this paper the problem culminates to the lack of an integrated strategic management assessment of the electricity system – and to identify primary causes to the ongoing electricity inadequacy in South Africa.

2.2 Literature

The following section discusses the South African background regarding geography and economy, the profile of the South African electricity industry and strategic management in the public sector.

2.2.1 Geographical location and environmental implications

South Africa forms part of the Southern African region in Africa and sits at its southernmost tip. The continental shelf forms part of the African highlands, which run from the mountains in the Cape to the Ethiopian highlands in the horn of East Africa. South Africa is bordered by five countries: Namibia, Botswana, Zimbabwe and Mozambique; while Lesotho and Swaziland are two small landlocked countries, territorially encircled by South Africa (Draper & Scholvin, 2012:9–10).

From an energy-generation perspective, the challenge is that South Africa is a water-scarce country, and also the effects of climate change and global warming are beginning to have a visible impact on generation capacity. Kohler (2016:831) says SA stands at 30th in terms of rankings among the driest country in the globe with a 450 mm of mean yearly precipitation. South Africa relies solely on Eskom, a state-owned enterprise, for generating its electricity supply – and as a monopoly, it is heavily reliant on water to generate power. As a result, Eskom has no strategic alternative but to carefully consider the impact and consequences of using water to fuel its current coal-based methods of generating electricity. Does the generation challenge have an answer in embarking on an electricity generation *modus operandi* based on nuclear power? This question is fraught with its complexities and is beyond the scope of this paper. The fact remains that Eskom stands at a watershed moment in its management history –

literally – as it is forced to contemplate heavy reliance on high water consumption in producing energy efficiently (Koen, 2012:12).

2.2.2 Economy

South Africa has enjoyed a relative economic resurgence since democracy in 1994 and has attracted its fair share of global investment (The Presidency bulletin SA, 2014:86). The modest – but steady – upward economic growth since 1994 attests to a robust economy that has been remarkably resilient even in the face of the global financial crises of 2008 to 2009. Certainly, the post-1994 growth is almost opposed to the strained years of not just trade and financial sanctions during apartheid, but virtual economic isolation (Faulker & Loewald, 2008:4). The Presidency bulletin SA (2016:84-86) highlight that the economic indicators speak for themselves: from 1965 to the first quarter of 1994, the economy contracted by 32 percent, compared to just 5 percent by April 1994. Further to that, South Africa endured only four quarters of negative growth between 1994 and 2012.

So what were the internal factors creating this ripe environment for post-'94 economic growth? According to Kearney and Odusola (2011:6–8), the major factors were GEAR, the Growth Employment and Redistribution (GEAR) macroeconomic policy of the time, along with Accelerated Growth Initiative for South Africa (AGISA) initiatives. These programs were instrumental in effecting much-needed economic stability in South Africa.

South Africa was not entirely immune from the global financial crisis of 2008 to 2009, with the economy contracting. The greatest economic reverberations were felt in 2009 but, despite the turmoil, the recession was not a protracted one. The country is still currently recovering from this period of the economic watershed (Bhorat *et al.*, 2013:3). Gordhan (2014:5) points out though that despite the South African economy still being in recovery mode, the rate of recovery is slower than what was projected at the time. Gordhan (2014:5) emphasises that “The economy is currently experiencing the greatest negative impact in the form of a weak currency, resulting from domestic issues such as the electricity crisis and consequent inefficiency nationwide.”

In fact, in real terms, the growth in Gross Domestic Product (GDP) has been slowing down. South Africa's foreign policy has also leaned towards favouring bilateral trade and investment from China, one of the fastest growing economic powers in the world (Grimm *et al.*, 2014:8). These close ties with China and the economically receptive attitude which followed has at times also been a double-edged sword. A classic example was the collateral damage suffered by

South Africa's local currency, the rand, when the Chinese currency, the Chinese Yuan Renminbi, was recently devalued (Amadou, 2015).

2.2.3 The profile of electricity supply in South Africa

This section of the paper gives a detailed report of the South African industry from pre-1994 to post-1994.

2.2.3.1 *Pre-94 developments*

South Africa is among the first nations to have integrated technology into their electricity supply system. Eberhard (2007:216) concurs that electric lights were installed in Cape Town in 1881, a two years interval after the Incandescent Lamp invention in 1879 by Thomas Edison. Bradley (2013:5) adds that the first ever electricity powered streetlights installed in the Southern Hemisphere were in Kimberley city at a time when London was still utilising gas fuel for street lighting. Davidson and Mwakasonda (2004:11) emphasise that in the pre-1994 era, the electricity industry had consequently focused on electricity provision for heavyweight industries such as the gold and diamond mining sectors, and also for the white-dominated residential areas.

According to Eberhard (2004:3), the Rand Central Electric Works (RCEW) in 1897 constructed the earliest commercial power station in South Africa. The RCEW prioritised electricity supply mainly to the mining companies in the vicinity of Johannesburg. Eberhard (2007:217) says the RECW originally paved the way for other corporations like the Victoria Falls Power Company (VFPC) to construct an electricity plant in 1906. The VFPC vision to become a hydroelectric power giant did not reach actualisation as South Africa opted to rely on a coal-fired energy production technology. Joffe (2014:32) states that South Africa electricity production is still heavily dependent on and dominated by coal-fired power. This motivates reasons for transitioning to more diverse sources of supply.

Amusa *et al.* (2009) highlight that the creation of the Electricity Union of South Africa in 1910 followed a more coordinated protocol in the operationalisation of the electricity industry in South Africa. By the 1920's, stakeholders instigated the call for a central electricity system that could cater for the needs of both the industrial and domestic sectors. An interconnected national transmission grid was attained in the 1970s with the vision of protecting a long-term synchronised operational pattern of the electricity industry.

Eberhard (2004:5) says the Electricity Act 1971, No. 3, gave increased administrative rights to Eskom, which were aimed at allowing the parastatal to improve on the capital investments of the electricity industry. The consequences were inappropriate policies such as large price increases and unaccountability, leading to the “De Villiers” enquiry in 1983. Steyn (2013:1) asserts that the commission identified problems related to shaping the managerial model of the electricity industry. However, there were no proposals for an effective strategy to remedy the fragmented nature of the implemented strategic policies within the recommendations.

2.2.3.2 Post-94 developments

Eberhard (2001:8) states that a proposal was tabled for a restructuring in the South African electricity industry in the 1992 African National Congress (ANC) workshop for Energy Development. Lloyd (2011:7) states that during the restructuring phase of the electricity industry in 1995, Eskom, and by then 172 municipalities, took on the task of electrification in South Africa. Currently, the electricity industry is intensely nationalised and largely administered by Eskom. Borenstein and Bushnell (2015:2) mention that one of the main challenges of an electricity industry restructuring is the several competing outlooks on the basis for restructuring. In most economies, a key step in electricity restructuring is to nationalise the power sector. A monopoly retail provider creates a narrower spectrum for achieving effective electricity generation. Eskom generates 96 percent of South Africa’s electricity, while privateers and municipal authorities generate 3.2 percent and 0.8 percent respectively. Figure 2.2 reflects the existing supply structure and energy flow of the South African electricity industry.

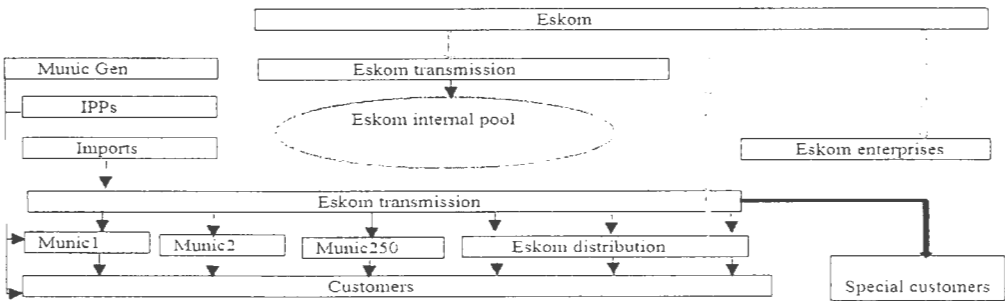


Figure 2.2 Supply structure and energy flow of the South African electricity industry

Eberhard (2004:9)

The figure reflects the generation, transmission and distribution of electricity in South Africa. Eskom seems to monopolised the industry while, participation from private and other independent producers’ (IPPs) is marginal.

2.2.3.3 *National Electricity Regulator South Africa (NERSA)*

Mushwana (2008:20) asserts that the *Electricity Regulation Act* (No. 4 of 2006) calls for the creation of National Energy Regulator of South Africa (NERSA) as the curator of established electricity structures in South Africa. Section 3 of the Act mandates NERSA to implement reliable governance strategies that shall guarantee a sustainable long-term electricity supply and demand consistency.

NERSA's mandates include the regulation of electricity, piped-gas and petroleum pipeline industries regarding the *Electricity Regulation Act, Act No. 4 of 2006*, *Gas Act, Act No. 48 of 2001* and *Petroleum Pipelines Act, Act No. 60 of 2003* (NERSA, 2012/2103:38). Nzimande (2012:9–10) states that in regulating a public utility, the regulator should aim to balance the interests of all stakeholders and the society at large. Olson (2005) states that the bottom line for credible public utility regulation policies is ensuring that all stakeholders associated with a public utility are treated fairly.

Bond (2012:3) points out that it is now evident that NERSA has failed to achieve its regulatory mandate properly. This has led to electricity generation shortfalls which have significantly affected metropolitan areas in the electricity grid. NERSA's current policies seem to be more focused on protecting the best interests of Eskom. Biggar (2011:45) suggests that regulatory policies follow a common tendency over time. Usually, at the onset, policies start by behaving in the public interest, and later the scope of the regulatory body shifts towards the interests of the regulated entity. Nzimande (2012:6) says certainty of a stable regulatory environment is required from an energy regulator through a reputation of credible and standardised principles. Nzimande suggests that transparency is eminent in the manner in which a regulator conducted business and made accountable for all its actions.

2.2.3.4 *Eskom Holdings Limited*

Eskom Holdings Limited is a prominent public entity in the business of electric energy in the African continent in general. Carolus *et al.* (2014:9) state that Eskom supplies power to both end users and distributors. Kenny (2015:5) dates ESCOM's establishment as being 1923 by the South Africa government under the *Electricity Act* (No. 22 of 1922). In 1986 the Afrikaans and the English enunciations were merged to change the operational name to Eskom. Koen (2012:1) points out that Eskom has been through some major periodic concerns since its origins in 1923 from almost absolute self-rule, greater regulation, an oversupply crisis, electricity inconsistency and consequent immense electricity price hikes. Its monopolistic control over

the electricity sector in South Africa incurs enormous pressure on the parastatal. Eberhard (2007:218) says that by 1948, Eskom was totally against the granting of generating licenses to private producers. To secure its monopoly, Eskom initiated an obligatory acquisition of the generation assets of prominent private power producers like the VFPC.

Kenny (2015:1) points out that Eskom is currently a topic of discussion by stakeholders demanding accountability for ongoing operational deficiencies. There have been continuous price hikes to cover up for Eskom's revenue shortfall. Government reports that Eskom will only be able to contain the consequent increase in electricity tariff increases up to 2019. Kahn and Vecchiati (2014:1) say that Eskom requires price increases of about 16 percent a year until 2019 to generate sufficient revenue that would ensure the entity's financial sustainability. Baker (2011:8) mentions that from 27 power plants Eskom produces an estimate of 42 040 Gigawatts (GW) of the country's total capacity of over 43.9 GW. A summary of Eskom energy mix is reflected in Table 2.2.

Table 2.2 South Africa energy mix

Category	Watts
Coal-fired (MW)	35 650
Hydro-electric (MW)	600
Pumped storage (MW)	1 400
Gas turbine (MW)	2 430
Nuclear (MW)	1 860
Wind energy (MW)	100
Total Eskom Generation Capacity (MW)	42 040
dependent Wind Farms (MW)	650
Independent PV Systems (MW)	960

Van Niekerk (2015:6)

Eskom (2015:6) and Baker (2011:9) state that the South African leading power utility parastatal initiated a capacity enhancement programme to attain an additional 20,000 Megawatts (MW) of electricity generation by 2025 in 2005. Pegels (2010) maintains that Eskom seeks to improve on its electricity saving capacity through programmes that would increase the installation of energy for consumers. These projects would improve the capacity of existing Main Transmission Systems (MTS) substations and establish new MTS substations with new transmission lines. Altman (2013:6) maintains that the public sector indecisiveness about adding new base load power stations to the grid fast enough supports the inclination to improve capacity by concentrating on building new technology. It is his view that accelerating the addition of new base load power stations would have prevented a shortfall in capacity and could have avoided the recent electricity supply crisis. These include the construction of the Medupi

(Limpopo) and Kusile (Mpumalanga) power stations, the return to service of mothballed coal-fired stations, a renewable 100 MW Sere wind station, and the establishment of the 352 MW Ingula pumped storage programme. These expansion projects are to be largely financed by the World Bank with costs more than R500 billion by 2017 (Creamer Media, 2011:10). Alternatively, there are arguments of management short-sightedness once again when it comes to some of these electricity enhancing capacity projects. The capital costs per unit of product (Kilowatt-hour) (kWh) of electricity of the newly constructed Medupi coal plant over its 40 years projected life is actually very low (Andrew, 2015:2). Kenny (2015:7) mentions that the Medupi and Kusile will both have a total capacity of 9600 MW. Eskom earlier claimed that Medupi and Kusile would have been on line by 2012 and 2013 respectively despite set deadlines to be 2015. However, neither of the power stations are fully on line yet.

There have been criticisms as stated by Pegels (2010) that most of these technological programmes will obviously aggravate the emissions problem in South Africa. Gross (2012:6) asserts that Eskom was ranked as the second highest carbon dioxide (CO_2) emitting energy company in the world in 2012. Therefore, it is time for government policies to also consider mitigating and reducing Eskom's emission rate. However, Joffe (2014:33–35) holds that there is no doubt that Eskom has made significant progress towards stabilising the power system since the crisis started in 2008. However, there is a need for an implementable decisive strategy to clarify the eventual shape of South Africa's current electricity supply industry.

2.2.3.5 Development of Independent Power Producers (IPP's)

Agboola (2011:1) asserts that the administration and control of the electricity grid by a public entity is a common tendency in most African economies. Despite claims of rebranding by most governments, these agencies have largely failed to meet the obligations and the rising demand of the grid. This discrepancy has offered an opportunity for the integration of IPPs in most African counties.

Woodhouse (2005:1) maintains that a rising wave of private investment in power technology has recently flooded into the developing countries starting from the 1990s. Much of its focus was on electricity generation, known as IPP. By 1996, Africa experienced a massive investment in its electricity industry from private corporations, although the trend has receded rapidly towards the end of the decade. Steyn (2013:5) points out that in 2003, South Africa's cabinet approved a bill for the ongoing call for a public-private partnership in the electricity industry. A resolution arrived at that Eskom generation capacity would be minimised to 70 percent while

30 percent would be controlled by IPPs. Eskom's former generation manager says in an interview:

“If one looks at the future supply-side requirements of the economy of South Africa, it is clear that Eskom, on its own, does not have the resources to meet the demand for electricity in South Africa. The country will need the participation of IPPs” (Yellend, 2009:1).

Volkwyn (2015:1) points out that 90 IPPs have been integrated into the national power grid over the last five years. The Ministry of Energy's recent vision includes the promotion of renewable energy projects through private producers. Montmasson and Ryan (2014) associate the importance of introducing IPPs into the electricity market in South Africa with four grand dynamics:

- (1) Eskom does not have the financial and technical capacity to meet the growing electricity demand and also to ensure energy security.
- (2) IPPs are going to help reduce the cost of electricity in South Africa through the development of competitive delivery strategies.
- (3) IPPs promote renewable energy technologies in the energy industry.
- (4) The development and enhancement of renewable energy are perceived as likely to create a potential industry that supports local economic development objectives.

Montmasson *et al.* (2014:39) agree that a series of programmes have been chronologically established to procure energy from IPPs effectively. Programmes such as the Pilot National Co-generation Programme (PNCP), the Medium-Term Power Purchase Programme (MTPPP) and the Multisite Base-load Independent Power Producer Programme (MBIPPP) has been, in the past, conceptualised by Eskom from 2007 to 2008. However, Yellend (2009:2) states that these programmes experienced setbacks due to a lack of readiness and implementation from stakeholders.

Baker and Wlokas (2014:5; 2015:3) allude to the fact that NERSA created the Renewable Energy Feed-In Tariff (REFIT) mechanism, aimed at procuring quality renewable energy power at nominal prices. Creamer Media (2011:1) states that due to political and legal constraints it was abandoned in favour of an auction system. After a lengthy transition, the government initiated a more focused Renewable Energy Independent Power Producing (REIPP) procurement programme in August 2011. There have been three rounds of auctions

to bidders. Table 2.3 presents a summary to the advancement of the REIPP procurement programme.

Table 2.3 Summary of the total Megawatt awarded per technology, bid responses, preferred number of bidders and success rate in the procurement programme

Awards (MW)	Initial determination (2011-2016)	Second determination (2017-2020)	Round 1 allocation	Round 2 allocation	Round 3 allocation	Total allocation
Wind	1850	1470	634	563	787	1984
Solar	1450	1075	632	417	450	1499
CSP	200	400	150	50	200	400
Small Hydro	75	60	0	14.3	0	14.3
Land fill gas	25	47.5	0	0	18	18
Biomass	12.5	47.5	0	0	16.5	16.5
Total	3612.5	3100	1416	1044.3	1471.5	3931.8
Bid responses	N/A	N/A	53		93	225
Preferred bidders	N/A	N/A	28	19	17	64
Success rate	N/A	N/A	53%	24%	18%	N/A

DoE (2013:11-16) and Eberhard *et al.* (2014:14)

2.2.4 Strategic management in the public sector

Strategic management is a process by which top management determines the long-term direction and performance of an organisation by ensuring that careful formulation, effective implementation and continuous evaluation of strategy take place (Chemengich, 2013). Brown (2012:5) maintains that through strategic management an organisation can enhance its strategic efficiency to become more competitive in its environment. Sulle (2009:2) notes that the public service has been long prioritising on strategic management to effectively implement missions of organisations.

Chemengich (2013) says that during the 1980s, the World Bank structural adjustment programmes campaign instituted reform programmes which required an obligatory strategic plan of influential institutions from developing countries. However, current public management reforms have been driven by a combination of administrative challenges, triggered by the quest for the efficiency of delivering public services. Sulle (2009:2) states that public organisations are increasingly utilising strategic management in their planning policies. It has become an attractive management tool to reformers. Bovaird (2009:61) asserts that an organisation would be perceived as very incompetent if strategic planning is not used as the basis for decision making. McBain and Smith (2010:1) assert that the growing complexities in

public management and governance, strategic management has become a standard instrument for public personnel to create value for organisational planning. Christensen and Laegreid (2007) recommend that in times of crisis, public officials can implement a collaborative public sector management approach that critically entails management's involvement in the active use of formal and informal networks across the different agencies within that government (OCED, 2006:10). McGuire (2006) agrees that the approach helps to acquire effective strategies in solving obstinate problems.

2.3 Research method

A qualitative content analysis research design was employed in this article. Neuman (2014:173) states that content analysis is a method of analysing the content of texts and written documents, themes, verbal or visual communication messages. A conventional qualitative content analysis was utilised as categories are derived directly and inductively from reviewed publications. Polit and Beck (2004:31) hold that content analysis is a very multifarious and tricky research method when compared to other research methods as it has no prescribed standard protocols. Hoskins and Mariano (2004:62) agree that obtaining reliable results relies on author competence and research experience. Elo *et al.* (2014) argue that currently obtaining reliable content analysis totally depends on the obtainability of appropriate and well-saturated data to an investigated phenomenon. However, Mayring (2014:10) disagrees that a content analysis still involves the collection of relevant data to conclude an identified phenomenon. Hence, processes have to be within the acceptable guidelines of a social science research. Elo and Kynge (2008) highlight that an advantage of utilising this research method is that different data sources can be used to substantiate and build more foundation to evidence.

2.3.1 Data collection

Data collection was purposive in nature. Hashemnezhad (2015) says with a qualitative purposive content analysis; the empirical research focused on specific data from which adequate categories and themes to the investigated phenomenon could emerge. This paper reviewed pertinent electricity policy documents from Eskom, the South African Department of Energy and NERSA. The paper focused on reviewing literature related to the aforementioned government entities because they are dominant role-players in electricity policy formulation, and their history of being forerunners in the transformation of the electricity industry in South Africa is well-documented. The paper also reviewed relevant literature sources on public electricity administration in South Africa. Reports from newspapers and other research

documents relating to the South African electricity industry as well as other economies with cases comparable were also reviewed.

Retrieving relevant data followed a systematic approach. Data collection from the empirical research was obtained from 133 publications. The publications were imported into Atlas-ti and then exported into Excel to obtain variables with the highest frequencies. Two hundred and twenty factors were obtained from the Excel analysis (see Appendix 1). The 150 factors with the most frequencies were coded in the Atlas-ti program to perform an Atlas-ti word cloud. Figure 2.3 present outcomes from the Atlas-ti analysis.

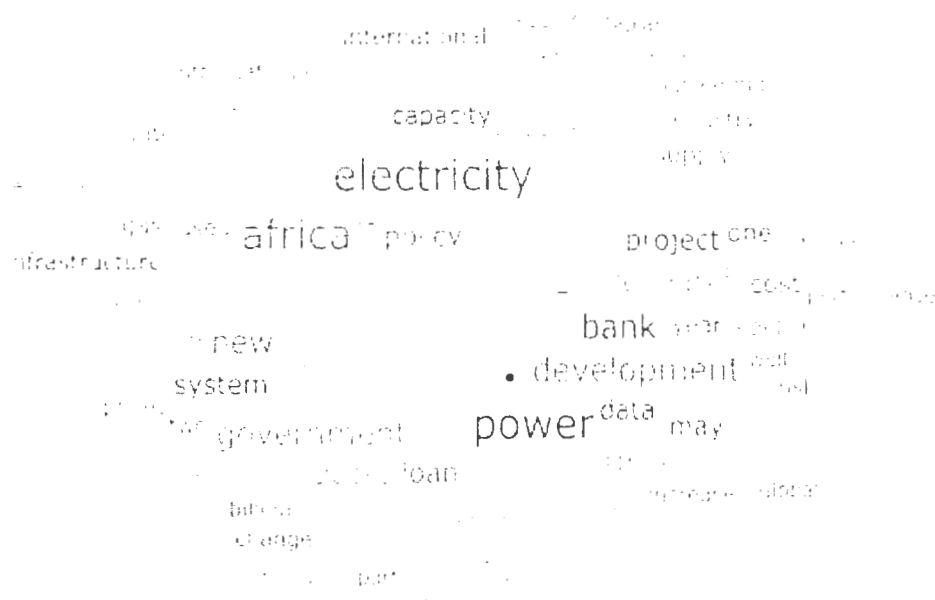


Figure 2.3 Word cloud results

Themes of relevance to the article were developed, and these guided the analysis of information from the word cloud.

2.4 Analysis and discussions

The analysis of data guided the discussion from two main perspectives:

- (1) The impact of strategic management malfunctions to low electricity supply in South Africa.
- (2) Evaluating the current challenges from an integrated management perspective.

Lalk (2015:5) says a country's energy system is highly complex and its advancement requires a system of systems (SOS) approach. Haskins (2011:6) states that this implies a system-of-interest whose system elements are themselves systems. It consists of large-scale interdisciplinary problems requiring heterogeneous solutions. Nine themes of primary importance

were developed from the word cloud under this section. Data analysis is further reflected in Table 2.4.

Table 2.4 A description of empirical research

(1): The impact of strategic management failures to low electricity supply in South Africa	
Themes	Question
Demand and supply estimation	What strategic failures have primarily contributed to electricity crisis in South Africa?
The Department of Energy White Paper of 1998	
Strategic renewal of utility supply	
Eskom's coal supply decision	
Administrative effectiveness	
(2): Assessing the causes to low electricity supply from an integrated perspective	
Human resources	What are the general factors contributing to electricity crisis in South Africa?
Policy regulation	
Environmental concerns on emission	
Revenue and profitability	
Financing and investments	
Asset management	
Demand-side management	
Research and development	

Table 2.4 presents the structure of the empirical research reported in this article. The analysis and discussion of data from publications followed a categorisation matrix procedure. Categorisation matrix ensured that the interpretations of publications were logically supported by published words as the analysis progressed. Through the method that was utilised in the article, it was possible to address the objectives in a systematic and detailed way. The reviewed process made it possible to develop applicable and reliable conclusions about the impact and role of integrated strategic management to electricity crisis in South Africa.

2.4.1 The impact of strategic management failures upon low electricity supply in South Africa

This section of the analysis determined and assessed the impact of significant strategic management foresight upon electricity inconsistency and crisis in the South African context. Under this section, five important themes were developed from the word cloud. Figure 2.4 presents the data analysis of this section.

Mahmoudi *et al.* (2014) agree that recent developments in the electricity utility industry have created several challenges that require effective strategic decision-making to accomplish all compliance requirements. This demands that public utilities, in particular, must excel right from the strategic decision-making frameworks that they put in place. Organizational planning and improving service quality are fundamental challenges for the South African utility industry at this juncture and these need to be urgently addressed (National Planning Commission, 2011:2).

Roos (2015:27) agrees that most South Africans are affected by power interruptions, and he also acknowledges that there is a crisis in the supply of electricity. Khan *et al.* (2011) agree that it is vital to examine those factors affecting the effective advancement of electric energy in South Africa. Kenny (2015:6) emphasises that the management model at Eskom has been ineffective in developing sound decisions, and that decision-making has often been based on political agendas. Management frameworks seemed to focus less on the core goal, which entails rectifying the current inconsistent electricity supply in South Africa. According to Barnard (2010:25), Eskom, as a public utility, shows serious managerial and strategic shortcomings. The unreliable supply of electricity in South Africa is not due to unforeseen circumstances. The problem is a lack of planning and strategic foresight (Hedden, 2015:3). The following section discusses the role of strategic management failures in contributing to the low electricity supply in South Africa by elaborating on themes in figure 2.4.

2.4.1.1 Demand and supply estimation

Maasdam (2008:1) traces events that have triggered acute electricity inefficiency in South Africa back to pre-1994. Eskom provided relatively cheap electricity to industries, which contributed effectively to the economic development of South Africa. Eskom ambitions to trade at relatively low price utility to its neighbouring countries led to the development of a programme that was projected to increase electricity capacity during the early 1970s. Koen (2012:5) alludes to the fact that in pursuit of this projected abundant supply, ESCOM made decisions with far-reaching economic consequences. By the time the new power plants were operational in the early 1980s, South Africa's economy was in trouble with over-capacity in the energy sector.

During post-1994, electricity demand grew faster than expected due to the government's adoption of an affordable electricity policy as part of their development programme. Also, advancement in industrialisation has also significantly contributed to the heightened electricity

demand. It is anticipated that South Africa's electricity demand is likely to increase by four percent per annum. Demand is likely to grow twice its size, requiring an extra capacity of 40 GW by 2025. The ongoing demand and supply inconsistency remains a major concern as policymakers are still unable to provide a reliable long-term recommendation (Inglesi, 2011). The generation, transmission and distribution of electricity is a very intensive capital undertaking. It requires large budget spending to construct plants with quite long waiting periods to start getting operational. For this reason, Dergiades and Tsoulfidis (2008) point out that implementing accurate strategic programmes that can effectively cater for future electricity misbehaviours and uncertainties is an essential undertaking at the corporate and national levels.

The electricity crisis in South Africa is similar in context to that of Bangladesh, according to a study conducted by Ahmed (2011). Ahmed traces the electricity crisis in Bangladesh and establishes that it originated in poor estimation of demand and supply from 1990. The electricity parastatal, Bangladesh Power Development Board (BPDB), which administers 66 percent of electricity generation, and the Ministry of Power, Energy, and Mineral Resources (MPEMR), experienced a drop in capacity. Despite several programmes adopted by the Bangladeshi government such as incorporating public-private partnerships, building power stations and changing the management structure of the electricity sector and energy department, the government of Bangladesh has not succeeded in mitigating the crisis.

This crisis has become acute, leading to load shedding, increased electricity inefficiency, high debts and inadequate funding to the BPDB, and ineffective electricity pricing. Ahmed (2011:11) was very clear that this crisis would persist due to ineffective strategic management with regards every single methodology that has been implemented as a remedy to the crisis by the government. Koen (2011:11) also highlights that similarly, in South Africa, the uncertainty and unfocused administrative policies about Eskom by the ruling party, the African National Congress (ANC), returns to affect the effective operation of the parastatal. Thus, it is essential to evaluate the impact that managerial malfunctions have on electricity inadequacy in South Africa.

2.4.1.2 *The Department of Energy White Paper of 1998*

In 1998, the Department of Energy released its *White Paper* on the policy vision for all energy categories for the Republic of South Africa. This document outlined the department's ideas and proposals for strengthening existing policies for all energy system categories in South Africa, including electricity. Njikelana (2014:2) asserts that the policy calls for the

restructuring of underdeveloped systems and a proposed extensive change on performance issues with critical concerns in the energy sector. The DME White Paper (1998:41) has since identified the following challenges that were classified as being primary ones:

- Most underprivileged South Africans still live without access to basic electricity.
- There was a lot of fragmentation in the distribution sector of the industry with inconsistent pricing from over 400 distributors.
- Default payments by electricity consumers were at intolerably high levels.
- Coal-based electricity generation significantly increased the emission rate, with possible long-term environment concerns.
- There was a complete disregard for electricity efficiency on energy policies and by consumers.
- Growth in electricity demand was projected to exceed capacity generation by approximately 2007; hence, no programmes exist towards the capacity expansion of generation to contain the growing demand.

The prediction of the 1998 White Paper was so exact that the concerns outlined in the paper would have been followed by effective long-term management strategies that would have prevented intense forth-coming electricity crisis. Sebitosi (2008) posits that such predictions should have been followed and reliable strategies developed to safeguard against the dawn of the crises. Oberholzer (2008:2) states that the public sector accepts the blame for not strategically planning for future electricity usage. This came only after it emerged that a white paper drawn up by the Department of Minerals and Energy in 1998 predicted that electricity would be in short supply after 2007, should expansion plans not be implemented. Kenny (2015:8) points out that there is a confusion of thought in certain paragraphs, which has resulted in further alarming confusion around a policy aimed towards creating adequate electricity supply after 1998.

- The White Paper of 1998 made the unfortunate mistake of classifying uranium as a fossil fuel. Taylor *et al.* (2008:7) state that fossil fuels are the primary energy sources for producing electrical energy in the world and that these fuels consist of coal, gas and oil. As earlier pointed out, coal generation caters for over 90 percent of South Africa's electricity production. This was a major failure from a document that was to the basis for making strategic undertakings regarding the future supply and consumption of energy. Misleading information on electricity production capacity was reported.

- The policy recommended a change in attitudes towards private partnership but failed to propose any practical implementation, and this has been discussed as completely contrary to the operational constitution of the government.

Kenny (2015:8) states that most suggestions in the White Paper are perfectly sound. However, they failed to address the fundamental problem of electricity generation and supply in South Africa, therefore leading to the present crisis.

2.4.1.3 Strategic renewal of utility supply

Strategic renewal is a process of substantial change concerning key organizational attributes to sustain a firm's long-term prospects and viability (Agarwal & Helfat, 2009). Strategic renewal principally requires an organization to accept a complete reform of its existing operations and systems in place. Worch *et al.* (2012) point out that the spine of strategic renewal in utility firms involves the transformation from one strongly engineering dominated environment toward a more management-oriented organization. Altman (2013:6) maintains that to improve capacity and efficiency in South Africa, it is necessary to build new technology. Worch *et al.* (2012) say that modern infrastructure services, such as engineering restructuring in the utility industry, require excellent management know-how. As stated in United Nation Habitat (2011:1), strategic renewal is yet to be welcome in the South Africa utility industry owing to the aggressive requirement of the programme. Major issues requiring strategic renewal in the South African electricity industry can be attributed to:

- The monopoly of Eskom since 1948 as a majority generator of electricity (96 percent) in South Africa. This was contrary to the 1998 energy White Paper proposal of increasing private sector participation in the South African electricity grid by 30 percent.
- The need to transform older machinery with more modern technologies. The electricity industry in South is overly dependent on traditional coal electricity generation despite the introduction of modern sources of electricity production. Eskom (2013:7) states that the South African electricity industry is likely not to have a competitive disadvantage until it can implement certain changes such as reliance on coal. However, government's decision to prevent Eskom from constructing more reliable and new power stations possibly prevented Eskom's ability to provide consistent and efficient electricity. Dagut and Bernstein (2008:26) maintain that although Eskom was prevented from building new power stations, as a utility parastatal, they should have motivated the need to construct additional power stations. Dagut and Bernstein (2008:26) assert that this decision by the government affected the reserve margins of Eskom. Capacity fell to dangerously low levels leading to

breakdowns and blackouts by 2007, as earlier predicted. Alternatively, Capron and Mitchell (2009) note that the nature in which a particular change unfolds is critical to the success of strategic innovation. Worch *et al.* (2012) say a strategic change is capable of having destructive effects or causing a decline in an entity's performance if not well planned. About the afore phrase, Eskom's action to trade cheap energy to its neighbours in the early 1970s encouraged an investment programme that has now become responsible for the ongoing demand and supply crisis in South Africa.

2.4.1.4 Eskom's coal supply decisions

Dagut and Bernstein (2008:7) point out that traditionally, the national utility had coal procurement contracts with major coal suppliers and therefore received a regular supply of cheap and quality coal through such contracts. Spicer (2008:9) supports the notion that Eskom's policy choice in January 2008, when the electricity crisis hit, which favoured buying coal from small Black Economic Empowerment (BEE) contractors, was a poor strategic move. These coal products were expensive, of poor quality, and transportation was mostly via road transit. Trollip *et al.* (2014:22) state that the challenges found with the new supply contracts related to the fact that new contractors were unable to meet the required demand of power stations, compared to previously contracted suppliers that had sufficient coal. Unreliability was a major setback since new contracted mines stopped deliveries during the holiday season.

As highlighted by Kenny (2015:8), the origin of the problem was a reckless decision by Eskom's accountants to scale down coal stockpiles at power stations. This decision was motivated by possible financial savings on stock expenses. Dagut and Bernstein (2008:26) state that Eskom management defended their decision by stating that it had been based on the rising prices of the world's coal. This exposed Eskom's gross negligence in coal contracting with suppliers that have in the past offered the entity some low-priced coal resources. No effort was made to bargain for a more amenable cost to secure existing long-term contracts with such suppliers. Poole and Mathu (2011) argue that the poor responsiveness of domestic coal suppliers who significantly depend on Transnet for transporting their resources has only increased the burden for efficient coal delivery for power stations. Transnet has been very inefficient in its freight supplies and delivery on time and in required quantities has significantly become an intractable challenge.

2.4.1.5 Administrative effectiveness

In line with the 1922 *Electricity Act* (No. 42 of 1922), Koen (2012:16) concurs that Eskom was created relatively as an autonomous entity, exempted from any form of government supervision. Importantly, Eskom provided electricity to consumers for neither a profit nor loss. It was due to this autonomy and freedom that the parastatal developed a business operation that was focused on serving mainly the mining industries and white residential areas in its early days. Eskom's earlier commitment to satisfying industries most was on the basis that they were responsible for the economic success of the country. Newbery and Eberhard (2008:6-7) claim that:

- (1) The cost of connecting previously un-electrified rural areas is rapidly increasing.
- (2) The electricity grid is currently very vulnerable should there be a radical shift in policy, since the industrial sector is becoming more service intensive.

There was no vision to include previously disadvantaged citizens as part of the electricity grid in the future and, consequently, no provision was made for the increasing demand that has arisen as a consequence of getting these formerly marginalised consumers connected to the Eskom grid. Hedden (2015:4) agrees that the competence of energy planners in estimating the current and future demand and supply levels for electrical generating capacity is the first step towards ensuring the long-term security of an electricity grid. Kenny (2015:5) points out that the coming to power of the ANC brought with it unpremeditated changes at Eskom. Some of these changes were based on radical and racialised philosophies, political interference and political appointments. Experienced and skilled white executives and experts were offered attractive packages to surrender their positions in what was known as "space creation" for the recently disadvantaged.

Černiauskiene (2014:88) maintains that it is crucial to identify and analyse even indirect trends that may have had an impact on an institution's resource supply and demand. It allows for effective scrutiny of all possible factors to a strategic failure. Trollip *et al.* (2014:3) state that the electricity crisis is very complex. An effective inspection of electricity crisis dynamics requires integrated strategic tools as the standards for analysing and addressing issues to solving the problem. The next section provides an integrated outlook into the cross-functional causes of electricity inefficiency in South Africa.

2.4.2 Assessment of multi-factors contributing to the electricity supply crisis in South Africa

This section assesses factors contributing to electricity inadequacy from an integrated perspective. Figure 2.5 presents the data analysis of this section.

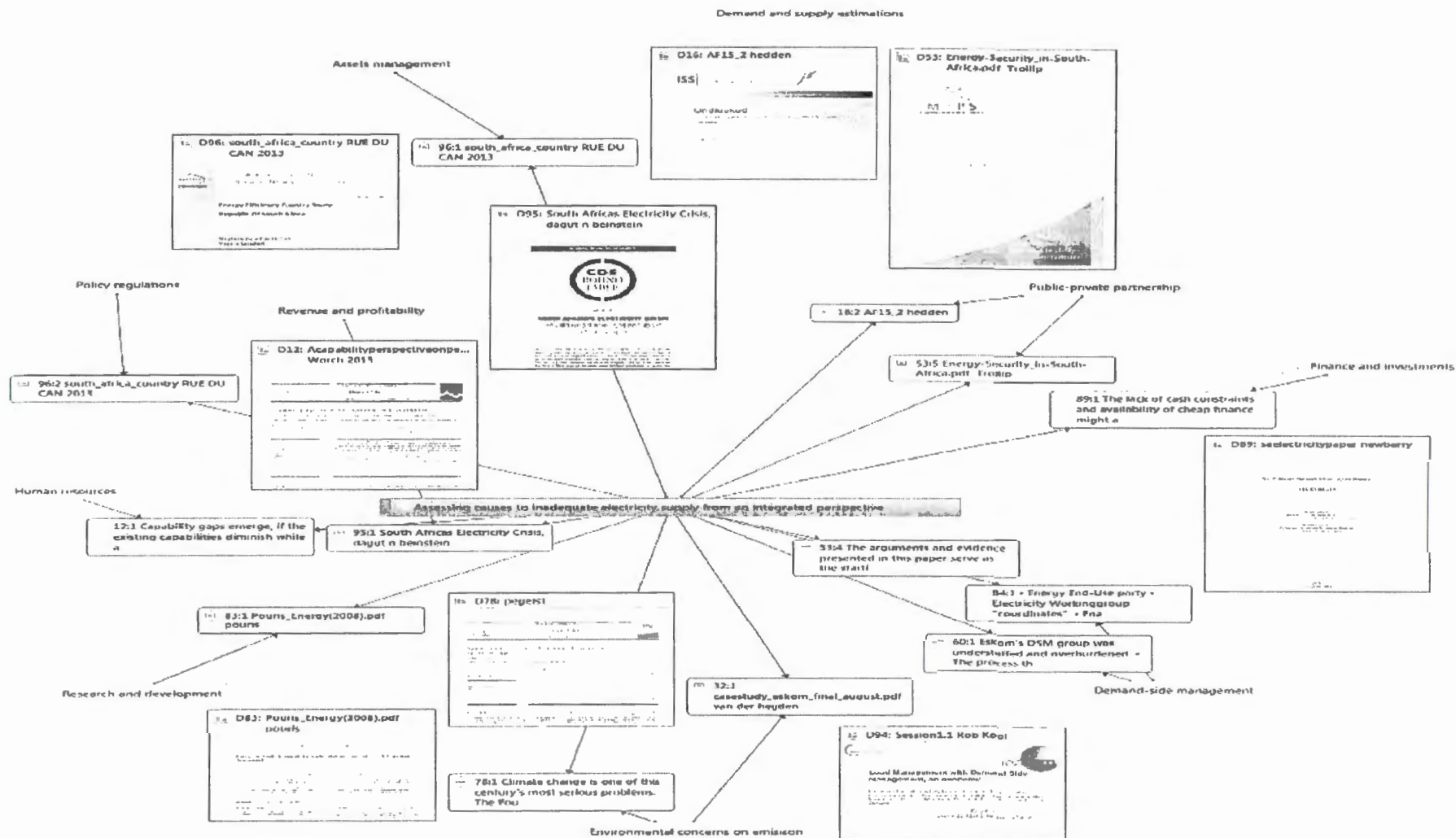


Figure 2.5 Categorisation matrix for causes of inadequate electricity supply from an integrated perspective

Geldenhuys *et al.* (2003) state that the *raison d'être* or rationale for integrated management decision-making involves establishing a multi-disciplinary approach to transformation. It requires a shift towards the manner in which an organisation's operational processes are developed, delivered and managed.

Kodama (2010:15) states that over and above the questions of what organisational procedure entails, effective strategic decision-making by large corporations involves implementing, and indeed, relying on interlinking various functional areas from its internal to the external environment, which plays a role in the value chain. Jin and Gao (2010) support the view that it is essential to analyse various internal and external functional areas of an electrical power network in the context of an electrical crisis. Trollip *et al.* (2014:3) asserts that a multifunctional approach is vital to diagnose and address challenges to an electricity grid. Concerns on the South African grid are extremely complex, requiring a multi-assessment of impacting variables and an integrated management perspective towards ascertaining a solution to a capacity struggling grid. The following section further elaborates on the themes on figure 2.5.

2.4.2.1 Human resources

Lomey and McNamara (2008:35–36) state that the capability gap has been the primary skill capacity deficiency posing a major challenge to Eskom. Capability gap is the deficiency of required competent expertise within an organisation (Worch *et al.*, 2013). There has been an exodus of skills from Eskom, and they now have to import technicians to perform highly skilled procedures. Many former Eskom staff members are now working offshore and have to be brought back at great cost to service equipment and the high voltage lines (Eskom, 2013:1). The view of Kenny (2015:7) is that the long delays in bringing the Medupi and Kusile power stations online is a result of a severe shortage of artisan skills and also the lack of skilled technicians to handle the technological sophistication of the station's design.

2.4.2.2 Regulatory policies

Von Hirschhausen *et al.* (2011) point out that the continuous execution of regulatory compliance has been identified as a primary problem for the South African utility industry. Alternatively, it cannot be a trade-off as institutional frameworks are needed to improve performance. In agreement with De la Rue du Can (2013:18) the last decade saw the government implement numerous energy regulations, adding more pressure on the energy industry. Government actions have been primarily motivated by the general global call for

utilities to meet required economic and environmental compliances. Worch *et al.* (2013) hold the view that regulatory implementations can affect utilities by:

- Increasing uncertainties.
- Adding new objectives or changing the priority of objectives that utilities have to pursue.
- Limiting the options for strategic planning and decision-making.

Spiller (2010) highlights the fact that the government itself can be a possible threat to utilities, by pressuring utilities to pursue prioritised specific goals by intimidation of penalties on utilities that do not adhere to government goals. Worch *et al.* (2013) state that the early 2000's saw South Africa implementing electricity policies which negatively affected electricity supply. Njikelana (2014:7) also adds that policy uncertainty and an unstable regulatory electricity industry framework have resulted in a detrimental impact on the sector and the economy as a whole, increasing the risk profile in the industry. Singh (2008:32) therefore logically states that electricity policy in South Africa is characterised by uncertainty. This uncertainty is likely to lead to the next big electricity crisis, which could be more difficult to resolve.

2.4.2.3 Public-private partnership

Hedden (2015:10) mentions that according to Eskom's general manager of grid planning, there are complexities involved in a complete IPPs integration into the electricity industry. Public-private partnership requires a long-term reliable strategic plan. This is because Eskom claims that the projects that make it flexible for IPPs to connect to the electricity grid have been selected during the first IPP bidding rounds between 2012 and 2016. Dagut and Bernstein (2008:7) disagree with the view that the problem is challenging public-private partnerships is pinned down to ineffective contracting procedures, pointing out that bid processes are awfully slow and complex. The Department of Minerals and Energy (DME) has failed to secure contracts with international companies to build and run new private power stations. Trollip *et al.* (2014:13) says it was normal that Eskom would resist or not provide voluntary active support to implement any policy which involved the integration of private corporations into the electricity industry. The proposal was perceived as a strategy to reduce its monopoly. Nhlanhla (2015:7) specifies that a research study on restructuring policies in South Africa has proven that the option of employing private investment to strengthen the balance sheets of state-owned companies is a milestone. Hedden (2015:11) views that the integration of private corporations into the electricity grid would create room for price competition. As a consequence, the Eskom autonomous access to the grid would also be reduced.

2.4.2.4 Revenue and profitability

The National Energy Efficiency Strategy identified that a significant barrier to electricity profitability is the undervalued retail price compared to the quality of electricity supply. Newbery and Eberhard (2008:5) agree that if prices are raised to sustainable levels, some of the pressure on capacity would have been eased. De la Rue and du Can (2013:23) highlight that electricity tariffs primarily determine the advancement potentials of an electricity grid. Dagut and Bernstein (2008:8) concur that effective electricity pricing is essential for the advancement of generation capacity. Eskom (2015:10) points out that its financial health has been influenced by its profit margins that have been declining over the years, mainly due to the electricity price which does not reflect the input costs.

Van der Heijden (2013:19) states that Eskom's profitability is further constrained by default payments from users. Ineffective revenue collection increases Eskom's cost of debt and their delivery ability (Dagut & Bernstein, 2008:10). Eskom launched a shocking campaign in January 2017 where over eight municipalities experienced severe power cuts due to large outstanding accounts. Newbery and Eberhard (2008:7) allude to the fact that higher electricity prices encourage less wasteful consumption and help stimulate the industry. The South African Local Government Association (SALGA) (2013:18) says price increases do present some of the possible causes for social unrest that plague the country. The introduction of price policies has caused unrest in some areas based on the perceptions of unfairness.

2.4.2.5 Environmental concerns on emission

There is currently intense pressure on Eskom to reduce the carbon-intensity of its electricity generation. Pegels (2010) remarks that carbon emissions in South Africa are on the rise as the energy industry environmental pollution intensifies. Improving capacity through efficient programmes is necessary. Van der Heijden (2013:14) asserts that the World Bank (WB) announcement in April 2010, granting Eskom a loan of \$3.75billion to fund the construction of its biggest coal-fired plant, received a negative response from environmental organisations. Rastello (2010:354) notes with concern that the initiative was turned down on several occasions by the committees overseeing the operations of the World Bank's policy and funding. The bank opposed financing Eskom by its lack of concern for environmental compliance in its capacity advancement ventures. Swilling (2010:326) highlights that some environmental societies and some western trade unions also supported the campaign with allegations that Eskom is among

the top carbon dioxide emitters in the world. Arguments were also tabled that the carbon dioxide per unit of GDP in South Africa is greater than in any other country in the world.

Reddy (2013:4) states that South Africa can henceforth burn just 20 percent more of fossil fuel to avoid going above the obligatory global warming average of two degrees. Eskom’s long-term plan to invest in massive coal plants also put off the possibilities of introducing cleaner generation technologies. Bond (2012:7) mentions that there was progress only when South African finance minister, Pravin Gordhan, raised the issue that the World Bank should establish a relationship with South Africa through the request as the country has not been its regular borrower. Alternatively, the World Bank 1999 to 2008 Country Assistance Strategy (CAS) report showed that it was the fifteenth credit request from the World Bank Group. As policies claim, electricity production from coal is considered as the best short-term option, while the long-term plan is in favour of renewable and nuclear energy, Eskom’s long-term plans still considers coal as its major source of energy production. Ferrer (2017) conduct an empirical research to assess the strength of solar energy in South and found that there is a significant irradiation potential in most provincial geographies. Solargis (2015) recent census on Global Horizontal Irradiation (GHI) average reflecting the strength of solar energy generation in kWh/m² in South Africa is reflected on figure 2.6

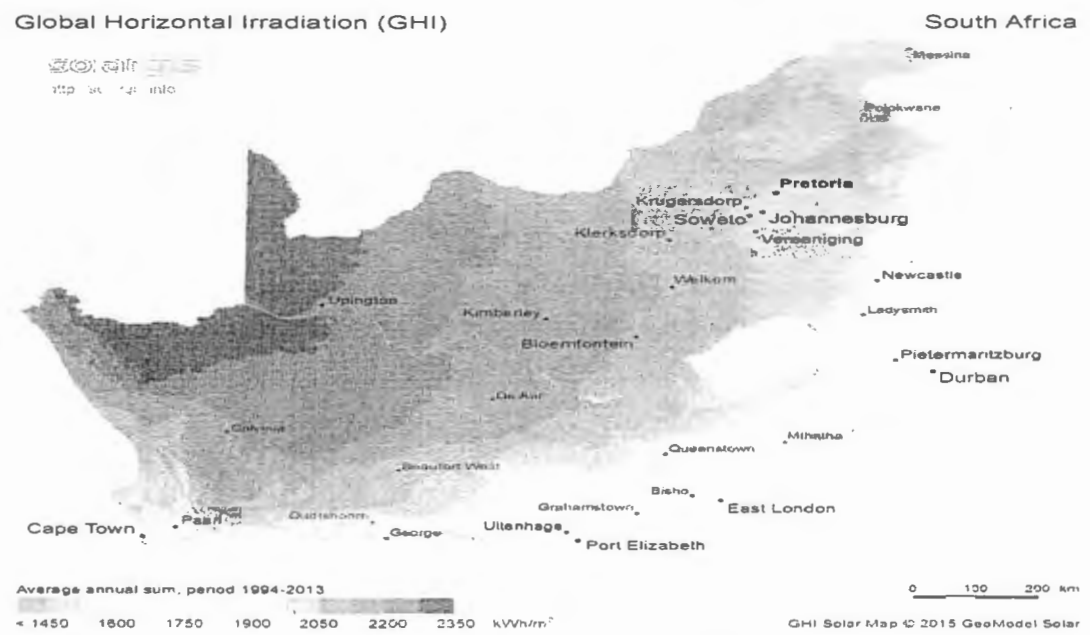


Figure 2.6 Average yearly GHI for South Africa, between 1994 and 2013
Solargis.com (2015)

Wright *et al.* (2017:29) further report that over 70 percent of the suitable land area in South Africa, aiming at possible wind energy generation possibilities, has a 35 percent capacity factor or higher. Prohibiting zones with a more difficult landmass still, has the minimum potentials for effective wind energy generation. Spatial wind energy potentials of South Africa is reflected in figure 2.7

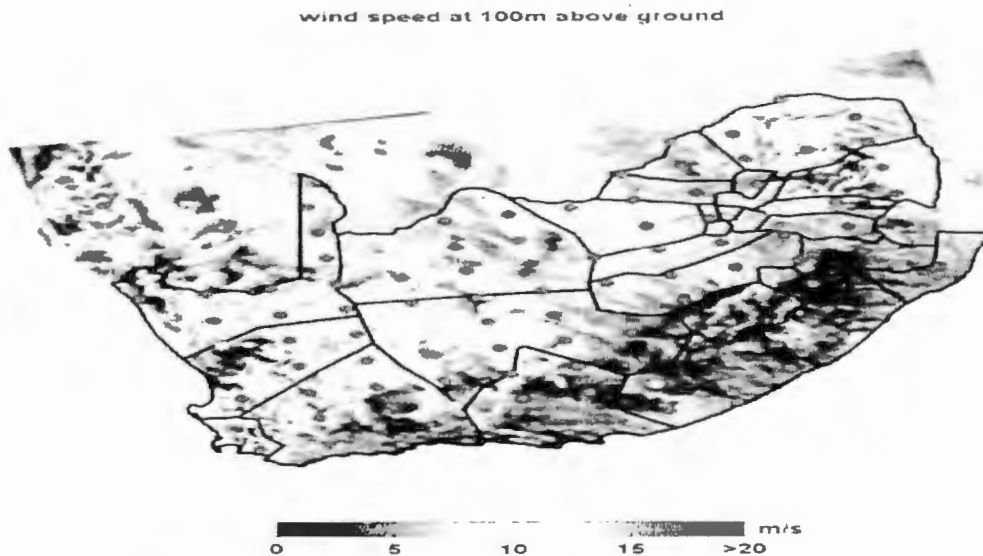


Figure 2.7 Wind energy potentials for South Africa

Wright *et al.* (2017:29)

Despite the reflected strengths and potentials to enhance the generation of energy from more sustainable sources, Musango *et al.* (2011) point out that South Africa is still to explore its potentials of renewable energy generation.

2.4.2.6 Financing, investment and debts

According to Eskom (2014:36), the parastatal's financial health continuously gets worse to support its projects and possible growth. Eskom's struggling liquidity has been restraining strategic implementations. Newbery and Eberhard (2008:7) state that the lack of efficient cash flow and availability of cheap finance has been a major obstacle and reason for dalliance to implement recommended improvements in the electricity industry. Pressly (2010:2) says despite the world Bank granting huge loans and the continuous increases in electricity price, approximately R200 billion is still required by Eskom to finance its capacity advancement projects up to 2017. Eskom indicates that its profit margin declined while its assets capacity grew (Eskom, 2015:10).

Nhlanhla (2015:4) is of the opinion that operational failures like the inadequate asset repairs cause performance flaws, resulting in higher maintenance costs and more pressure on finances. According to Eskom (2015:11), Moody and Standard & Poor downgraded its credit rating from 2014, and this act has increased its cost of debt. The downgrades might reduce funding available for future borrowing and investments based on investor and trustee mandates. Major investors are calling on Eskom to work on their credit ratings or face stricter loan covenants in future. Ensor (2010:7) notes that an earlier research study by Eskom regarding the downgrade of its credit rating reflects an increased stress on its financing costs. Based on Eskom’s calculations, this downgrade would result in additional finance costs of R4.3billion to R15.9 billion being incurred. Financial malpractices such as irregular, fruitless, wasteful expenditures and fraud reported in the most recent audited financial statement of Eskom is presented in Table 2.5.

Table 2.5 Eskom’s financial losses for 2015

Financial Malpractices'	Amount of losses
Irregular expenditure below materiality threshold	R25 million
Fruitless and wasteful expenditure below the materiality threshold	R51 million
Fruitless and wasteful expenditure exceeding material threshold	R25 million.
Occupational theft	R102 million
Fraud financial misconduct	R40 million.

Eskom Annual Financial Statement (2015:110)

2.4.2.7 Asset management

Newbery and Eberhard (2008:4) say that despite inadequate generation, recent blackouts have also been caused by unprecedented breakdowns and failures at electricity generation plants. Joffe (2014:33) says that some of Eskom’s electricity-producing power plants require continuous routine maintenance to keep electricity generation at the required rate. Currently, most of these plants cannot cope with increased electricity demand, which leads to too much stress on plants and more frequent breakdowns. De la Rue and du Can (2013:9) state that about 85% of Eskom electricity generation fleet is currently over 20 years old. Govender (2013:6–8) states that repairs of plants have often had to be altered or delayed to ensure continuous capacity. This approach is not sustainable because systems remained unhealthy, needing significant refurbishment works. Govender insists that it is essential that planned maintenance be done to enable power station sustainability. Alternatively, there is a risk to systems generation as units are taken out for servicing. Matona (2015:7) presents the current challenges to Eskom’s electricity generation assets available at

https://www.teraco.co.za/content/Eskom_SystemStatusPresent.pdf. The figure paints a very bleak picture of the depreciation levels on Eskom generation and transmission assets. It is evident that Eskom's current asset capacity is highly depreciated.

2.4.2.8 Demand-side management

Shen (2011:4) describes Demand-Side Management (DSM) as an important component required to meet the increasing demands of electricity supply. DSM aims to achieve energy efficiency and load management. Energy efficiency is designed to reduce electricity consumption throughout an estimated period. Alternatively, load management seeks to reduce consumption during periods of peak demand within intervals from minutes to hours (Kool, 2011:2). Wang *et al.* (2011:8) state that some major issues are hindering the effective functioning of the DSM in the South African electricity industry as follows:

- Eskom's DSM group was understaffed.
- The implemented DMS frameworks by Eskom have been non-pragmatic.
- There is no transparency to the approval of projects and procedures by Eskom.
- There is no clarity to evaluation processes leading to inadequate feedback as Eskom's evaluation teams have been more concerned with less necessary issues.

Eskom (2011:5) states that new capacity advancement projects are likely to struggle to contain future demand, except an effective DSM program, is implemented.

2.4.2.9 Research and development on utility

Pouris (2008) asserts that the primary reason leading to the electricity crisis and difficulties in resorting to an effective solution to the current problem is the general lack of research within energy management in South Africa. The South African utility industry needs substantial financial investments in research and development, focusing on the areas of alternative utility sources and resources. Bond (2012: 9) emphasises that there is continuous pressure from environmentalists on Eskom to carry out research and development on how to transform its generation technology to more environmentally cautious energy alternatives - that would palpably reduce its significant reliance on coal technology.

2.5 Conclusion

This paper was based on evaluating the effects of strategic malfunctions and inadequacies within the South African electricity suppliers network. The paper revealed that strategic management failures are a major challenge in obtaining required supply capacity. The electricity shortfall has negatively affected both domestic and industrial end users, incurring

devastating financial and material losses. The cause and effect strategic theory of a problem is the most standardised approach to resolving the electricity system challenges currently staring at Eskom. This will enable the development of a reliable and applicable solution to the utility shortfall in South Africa. Jin & Gao (2010) state that the generation and development of an effective strategic management mechanism could be critical in avoiding power insecurity and challenges that might threaten the operation of the power network.

2.6 Final statement

The strength of an electric power network depends on its ability to cater for the power needs of its environment. Electricity inadequacy has become a widespread concern for the South African society in general. The paper revealed that to strengthen an electric power grid, especially in times of growing insecurities, holistic and comprehensive analyses of all associating factors are imperative. It is essential for informing the energy policy legislature on primary policy aspects of priority for effective energy policy. This will ensure current and future electricity needs and possible effective electricity sector management and planning. The development of an effective integrated strategic management system is critical for obtaining electricity adequacy and advancement in the South African electricity system.

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CHAPTER 3 (ARTICLE 2)

THE ADEQUACY OF ELECTRICITY SUPPLY TO THE DOMESTIC SECTOR AND RELATED CONSUMPTION BEHAVIOURS IN SOUTH AFRICA

Benedict Belobo Ateba and Johannes Jurgens Prinsloo

ABSTRACT

Electrical energy is a major resource for domestic livelihood throughout the world. In South Africa, the domestic sector is a major electricity end-user. Low-efficient electricity is a current plague impacting on the livelihood of domestic electricity consumers. This inefficiency massively affects the day to day household activities on consumers, negatively affecting living standards. Adopting an approach towards energy growth, conservation and efficiency on a troubled electricity grid, understanding how electricity is being used and consumed is a primary undertaking. This empirical research employed a quantitative research design. This article aimed at contributing to domestic electricity adequacy by assessing four primary factors towards electricity consistency and analysing consumption behaviours through one primary factor, ten energy most intensive domestic appliances and seven commonly used alternative domestic energy sources. The target population was Gauteng and North West provinces. A purposive-convenience sampling was employed to select participants for the study. However, quota sampling guidelines were considered in targeting actual participants. Data collection utilised a closed-ended questionnaire, employing field workers to obtain reliable data. Data collection on factors was through a five-point Likert scale and dichotomous questions while analysing consumption behaviour on appliances and alternative energy sources utilised dichotomous questions. The four primary factors towards electricity consistency reflect that consistency of electricity supply to domestic consumers is ineffective as living standards are affected. Results from appliances reflect that energy-intensive appliances are used more with significantly old modelled appliances in use. It was also found that despite electrical energy being highest in demand, more than a third of alternative energy sources that result in physical and environmental hazardous consequences is used. The priorities for effective domestic electricity supply adequacy are highlighted.

Keywords: *Electricity inconsistency, consumer behaviour, electricity efficiency, alternative energy sources.*

3. INTRODUCTION

Olufemi (2015) points out that energy is an essential component for survival and has immensely contributed to shaping living conditions. Energy production and consumption are among the most important activities in the society. Kenny (2015:1) affirms that energy is among the three household essentials along with water and sewerage in the world. Gotz *et al.* (2016:2) note that South Africa is currently affected by severe bottlenecks in the supply of electricity, resulting from weaknesses in the electricity grid. Matona (2015:9) gives an account that there is increased uncertainty on consistent electricity in the South African environment as load shedding has rapidly increased from 4.3 percent in 2008 to 14.8 percent by 2015, incurring constraints on residential consumers. Eberhard *et al.* (2011:1-7) postulate that electricity inconsistency is a major impediment on the sub-Saharan African economy in general. Current trends reveal that the region has a reputation for over 40 percent of its power supply being very unreliable. This region has the worst and lowest generation capacity compared to all regions in the world. In general, the domestic sector in Sub-Saharan Africa has a total electricity access of 30 percent, compared to other developing regions like South and East Asia with 65 percent and 90 percent respectively.

Marquard *et al.* (2008) point out that the main consequence of low domestic electrification has been a drop in living standards. Poor domestic electrification has resulted in inadequacy and households' reliance on low-quality energy. Balmer (2007) states that the domestic sector contributes 65% to local air pollution from other sources of energy in South Africa. Adam (2010:9) highlights that an approximately 80,000 children suffer from the use of unclean energy sources every year. Malzbender and Kamoto (2005:17) agree that it is important that electricity access ought to benefit the society by improving their living conditions. Referring to the Department of Energy (DOE) (2012:23), electricity is considered to be the cleanest energy source for standard households. Thus, the focus on households in this paper is to identify the access to electricity by households. It also assessed consumption behaviours towards appliances and alternative energy sources.

3.1 Introduction to the problem

Consistent evidence from energy supply studies conducted in South Africa confirms that South African households are seriously affected by limited electrical energy to ensure that their daily

electricity requirements are adequately met. This phenomenon characterises households, irrespective of social or electrification status (DOE, 2012:18). Adam (2010:7) emphasises that socio-economic growth and development can only be attained if there is access to safe, clean, convenient, and cheap energy for citizens.

Davis *et al.* (2010:103-104) highlight the importance of identifying electricity consumption behaviours as well as tendencies towards energy efficiency. Davis suggests that continuous research into the primary challenges in the electricity industry is likely to achieve the integration of their knowledge into society. According to Gallachóir *et al.* (2007), researching on energy supply and end-use are a prerequisite for developing policies and initiating a change towards increased sustainability and efficiency.

Thus, the problem identified in this paper is the ongoing electricity inadequacy characterised with inconsistencies that affects the electricity demand required by households for their daily activities. The domestic standard of living has been negatively affected. Efforts to balance demand and supply through efficient consumption is increasingly challenged by the insufficient control on domestic consumption tendencies.

3.2 Literature review

The following section outlines literature on the development of the South African domestic electrification. This section also discusses the current plague of low efficient electricity and how it has affected the livelihood of domestic electricity consumers.

3.2.1 Developments of domestic electrification in South Africa

McDonald (2009:14) holds that Africa is the most electricity under-supplied region in the world, while its economies depend on it. This undersupply is mostly experienced by its domestic sector, explained by the inequalities in electricity supply. Most governments prioritise cheap electricity access to industries while the continent's residents remain off the grid. Madubansi and Shackleton (2007) hold that during the pre-1994 days, providing basic services such as electricity to most of the population was not a priority for the South African government. Inglesi-Lotz (2010) highlights that the political and economic instability before 1994 encouraged unequal development within different segments of the population. Ogunlade and Winkler (2006:6) point out that electricity supply during this period was focused on industries and white residential areas, which covered just 12 percent of the total population.

Referring to Ziramba (2008) a majority of the South African population were without electricity by 1994. Marquard *et al.* (2008) hold that electricity is an essential element of

modernisation, as the core features of modern social and economic sectors are not reachable to citizens without the effective accessibility to electrical energy. Bekker, Eberhard *et al.* (2008) and Ferrer (2017) point out that the political restructuring of 1994 and the transition to democracy started eliminating inequalities and providing electricity to the majority of South Africans. However, there is still need for significant development as Sustainable Energy Africa (SEA) (2014:8) states that over 7 000 000 households in South Africa depend on unsafe energy sources ranging from paraffin, biomass and coal.

3.2.2 Developments on domestic electrification policy framework

Referring to Marquard *et al.* (2008) two main historical electrification campaigns have been identified as the initial call for all states to be fully involved in the operations of electricity systems:

- (1) The first wave of electrification.
- (2) The second wave of electrification.

The first wave involved the electrification of the economy as a whole, in recognition of electrical energy as a choice. The second wave called for institutional innovations providing electricity to formerly disadvantaged classes that did not meet criteria for electrification under colonial norms. This second wave started with the electrification of rural households in developed countries by the 1930s.

Referring to Dinkelman (2011) the American rural electrification campaign in the 1930s was a historical episode of a widespread campaign calling for all economies to adopt the electrification agenda. In the 1960s a campaign with similar emphasis was launched for rural households in developing countries. Kojima and Trimble (2016:22) say that factors such as gender and place of residence determine the probability of getting connected to the grid. Male-headed households are more likely to have access to electricity than female households, likewise more developed residential dwellings are more likely to get connected than poorer ones. Gaunt (2005) notes that the second wave required electrification policies to view access to electricity as a major interest to the general public, portraying existing institutional protocols as inadequate about access to electricity as a national goal.

In the South African scenario, the pre-1994 administration energy policies did not view energy poverty as an agenda of priority, due to its exclusion of most of the disadvantaged population groups. Referring to Marquard *et al.* (2008) electricity supply policy and institutional

development in South Africa is guided by the South African electrification programme described in three phases as follows:

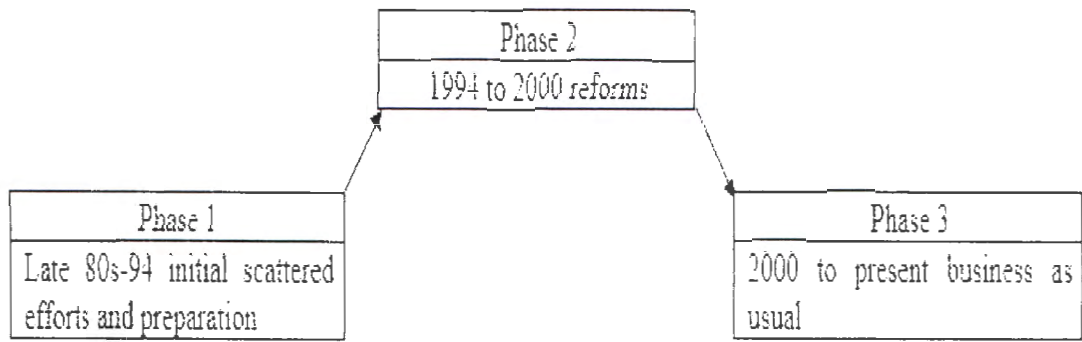


Figure 3.1 Policy and institutional electrification development
Marquard *et al.* (2008)

3.2.2.1 Phase one of electrification programme in South Africa

This stage marks the initial efforts and processes underpinning the strong appeals for electrification programmes as a vital policy agenda. Kessides (2006:37-38) highlights that after the African National Congress (ANC) had won the first democratic elections 1994, it expressed a strong commitment to redress the social and economic inequities of apartheid policies. Access to electricity was an important goal in its Reconstruction and Development Programme (RDP). Gaunt(2005) states that with access to electricity being one of the ANC’s major agenda, Eskom initiated an “electricity for all” campaign by 1992 parallel to the political negotiation process in the early 1990s. This campaign addressed the backlogs and severe inequities in electricity supply in South Africa.

Referring to Eberhard (2003:3), the meeting organised by the Energy and Development Research Centre (EDRC) of the University of Cape Town (February 1992) on electrification (under the auspices of the Department of Economic Planning) was a milestone in a positive progress on electrification. The meeting brought together policymakers and members of the different civil societies to discuss parameters to guide the South African electrification process. Marquard *et al.* (2008) state that the EDRC paved the way to convening the national conference on electrification and the launch of the National Electrification Forum (NELF) in 1993. This facilitated the consultative process and development of an implementable strategy to increase access to electricity services in the underdeveloped urban and rural areas.

3.2.2.2 Phase two of electrification programming in South Africa

The second phase achieved the connection of thousands of households to the electricity grid. The ANC administration converted the “electricity for all” campaign into the RDP. Ogunlade and Winkler (2006:7), show that Eskom working under the electricity for all slogan provided 2.5 million electricity connections during 1994-1999. Prasad *et al.* (2006:61) estimated that the total cost was over R7 billion. The “electricity for all” campaign contributed to a 66 percent of households’ electrification in South Africa. Thousands of rural domestic public facilities such as schools, clinics and households were connected to the national grid. By 2000, phase two was launched with an objective to access electricity to 300 000 households annually. By 2001, thousands of households across the country were connected to the grid. Dinkelman (2011) says the second phase connection success rate is comparable to the first five years of Roosevelt's Rural Electrification Act in the United States of America. According to Prasad (2006:61-62), the success rate encouraged the Department of Minerals and Energy to budget an additional R1.1 billion for electrification finances in 2003.

3.2.2.3 Phase three of electrification programming in South Africa

This era begins in 2004 when electricity rates dropped to low levels through a programme formally institutionalised in the government policy. Malzbender and Kamoto (2005:2) hold that policies in the electrification programme were focused on improving electricity access for the poor during this phase. Inglesi (2010) points out that the government interest in electrification, especially for the poor, led to the implementation of the Free Basic Electricity (FBE) Programme introduced by Eskom and the DME in 2001. The government argued that a typical poor household in South Africa consumes less than 50 kWh (kilowatt per hour) of electricity per month. The government further recommended that 50 kWh of free electricity should be offered to low-income households across South Africa. Adam (2010:15) views that the research conducted by the University of Cape Town suggesting that 56 percent of households in South Africa operate sufficiently with 50 kWh of electricity on which the government based its conclusions was misleading. This is because the research failed to critically evaluate if households would not consume above 50 kWh due to affordability. Recent research in Limpopo and Eastern Cape provinces by Azimoh *et al.* (2016) found that a basic low-income household requires a minimum of 72 kWh of electricity a month to ensure sustainability.

De la Rue du Can (2013:16) states the FBE has been an important social welfare policy in South Africa, ensuring that a basic low-income household has access to a decent supply of electricity. Makonese (2012:2) points out that FBE applicants have to meet the following criteria to qualify:

- The household should be residing in a property with a municipal value not exceeding R150 000.
- Household members should not exceed two state old age pensions in gross monthly income.
- The applicant household should be able to prove limited services and will not show the ability to survive without the programme for at least six months.
- The applicant household will agree to the installation of a prepaid meter on their property.
- The misinformation by an applicant will result in forfeiting benefits.

In accord to IMF prescriptions (2008:56), the considerable quantity of electricity consumed and not connected to price remains a major setback in the electrification system of South Africa. It originally started with a cost of over R600 million and increased by R80 million every year. Makonese *et al.* (2012:12) say it is fair to agree that the FBE has delivered basic electrification services to previously marginalised communities. However, the system remains unsustainably inefficient as service backlogs continue to add up. Makonese (2012:2-3) expresses the view that FBE policy is currently in a state of total disorder without any uniqueness of implementation across the country. For instance, large cities like Tshwane and Johannesburg offer a 100 kWh per month instead of the 50 kWh as stated in the policy. The DME (2005:37) states that the FBE failures are consequences of a lack of capacity and inefficiency on the part of local electricity administrators and the state's involvement in under-funding numerous infrastructural development programmes.

According to Koen (2012:9), despite the large-scale electrification of numerous households in South Africa since 1990, there still exists a relatively high overall electricity inequality in the country. Ruiters (2009:248) points out that the FBE has not been a very lucrative programme due to the following:

- The kilowatts per-month is inadequate for meeting basic domestic needs and thus, does not do much in attaining a meaningful development and assistance of the poor.
- It targets citizens with installed prepaid meters primarily. The situation is further complicated by the fact that large proportions of the poor do not have any electricity infrastructure.

- The current issues with accessing electricity such as an increase in tariffs have reduced the impact of the FBE to minimal.

The Department of Energy (DoE) (2011:3) reported that the NEP has been on a decline primarily because of finance and infrastructure constraints. The DOE allege that approximately 3 388 156 households' connections were affected in the 2011 ineffective operationalisation of the programme. Winkler (2006:23a) views that the future of the NEP is unsure as uncertainty surrounds RDP in South Africa due to growing tension between macro-economic policies. However, successes of the FBE cannot be overlooked, and it remains a policy foundation for domestic electricity supply in South Africa.

3.2.3 Current supply position

Debba *et al.* (2010:6) hold that assessing domestic electricity supply performance in South Africa has been problematic due to limited research. Winkler (2006a:23) states that access to quality and affordable electricity supply is still a major difficulty to a large proportion of the population. De la Rue du Can (2013:10) concurs that South Africa's households still significantly live without access to electricity supply. De la Rue du Can (2013:8) views that the widespread rolling blackouts by 2008 were due to insufficient generation capacity as households demand created more pressure on the grid. Winkler *et al.* (2011) say's the usage of different energy sources is still a common practice in South Africa across all income levels even after electrification. Balmer (2007) says an estimated 950, 000 South African households significantly rely on coal for energy, especially in winter every year. Adam (2010:9) concurs that over four million households use different sources of energy for cooking, while over two million households rely on candles for lighting.

Bekker, Gaunt *et al.* (2008) states that in 2004 president Mbeki announced universal access to electricity by all households by 2012. This has not been achieved to date due to struggling grid capacity. Bekker also concurs that the programme did not take into consideration the growth rate of households. On the contrary Winkler (2006b:34) states recent estimates suggest that by 2025 a large proportion of South African households will still be un-electrified. Bekker, Gaunt *et al.* (2008) highlight that the increasing pattern of new households poses a challenge to electricity suppliers. Winkler *et al.* (2011) hold that the off-grid electrification programme initiative has not been successful due to ineffective implementation. DME (2008:38) highlights that the general quality of electricity service provided to customers is not at an acceptable level.

Adam (2010:9) argues that regardless of the increased electrification in South Africa, the poor are still incapable of acquiring adequate electricity to alter the quality of their living standards.

3.2.4 Electricity consumption and efficiency

DME (2008:35) highlights that the domestic sector presents significant challenges for South African electricity suppliers because of their numbers in different categories with diverse needs. Horacek (2014:1) says analysing consumer behaviour regarding electricity is usually complex. It is of principal importance for electricity administrators to establish patterns of electricity consumption behaviour for government policy concerning optimal taxation, energy infrastructure, nature-friendly legislation and electricity security. Utilities that understand and leverage the perceptions, behaviours and values of their consumers ultimately generate the most value in this new energy era (Guthridge, 2010:3). Understanding consumer behavioural changes are essential in achieving greater energy efficiency (Makgetla, 2008:13).

Von Ketelhodt and Wocke (2008) agree that electricity consumption has moved closer to a critical situation and electricity administrators have been appealing to the public to reduce the use of appliances that overload the grid. Appliances with high consumption such as hot water cylinders and pool pumps have directives to switch off during peak hours to stabilise consumption and capacity. According to Diederichs *et al.* (2014:26) a typical low-income household in South Africa still primarily utilises old appliances that are not energy efficient. Covary *et al.* (2014:6) maintain that old modelled appliances have less functionality and consume high energy. This is contrary to upper-income households' tendency of upgrading their appliances as latest models are available on the market. Inefficient appliances will effectively be exterminated only by 2024. Tholen *et al.* (2015:20) highlight that energy efficiency has been identified as a critical action to overcome the pervasive shortage of supply and the energy consumption intensity in South Africa.

Gotz *et al.* (2016:1-2) state that the development of a basic energy efficiency policy framework began in 2005 considering only refrigerators. This initially pioneered the development of the South African National Standards (SANS 941) for monitoring energy efficiency for electrical and electronic devices in 2008. The SANS 941 programme identified reliable energy efficiency requirements, labelling and measurement procedures for introducing an obligatory parameter. Long waiting periods to implement the policy due to funding and negligence to the initiative has characterised the programme as poor standard. SAN941 became only operational in

2015/2016 to monitor refrigerators, washing machines, dryers, dishwashers, electric water heaters, ovens, air conditioners and heat pump appliances.

Gotz *et al.* (2016) point out that the lack of information and knowledge on the programme remains a barrier for successful marketing. Procedures are still not in compliance with acceptable standards and no evaluation procedures exist. The policy in practice needs effective frameworks and policy evaluation.

Bah and Azam (2017) emphasise that the delivering and consuming electricity sustainably and efficiently still remains a major problem in South Africa. Inglesi and Blignaut (2011:6) say there have been calls by administrators towards reasonable consumption tendencies for efficiency improvements. In agreement with Von Ketelhodt and Wöcke (2008), South African consumers need to embrace efficient electricity consumption tendencies to prevent future electricity constraints such as price increases and inconsistency in supply. Altman *et al.* (2011:43) project an on-going shortfall in supply capacity if exceptional efforts are not established in energy-saving practices.

3.3 Methodology

Wilson (2009:5) maintains that methodology involves the planned schedule in obtaining and analysing data to answer suggested research objectives. A quantitative research design was utilised in this paper. As explained by Creswell (2009:3), research design provides a proper guideline for a researcher to follow and develop a reliable framework for solving an identified problem. Punch (2009:112) suggests that research design initiates a connection between a researcher and the empirical world, while Edmonds and Kennedy (2013:20) say a quantitative research fundamentally entails the application of quantitative properties in social science.

3.3.1 Population and sampling

Bickman and Rog (2009:77) refer to the population as the total group that a researcher conducts an empirical investigation on. Despite that the research is centred on South Africa in general, the population for the empirical research was on households from the North West and Gauteng provinces. Gauteng province was considered essential because of its urban growth when compared to other provinces in South Africa. The North West province was selected as it was necessary to also target a developing geographical location to represent the spatial geography of South Africa.

The focus was on specific sampled geographies from each of the selected provinces. In the North West province, Mafikeng and Potchefstroom were targeted, while Pretoria and

Johannesburg for the Gauteng province. A purposive-convenience sampling technique was used in this paper. The four aforementioned geographies were selected because of the nature of their settlements as it complied with the intention of the paper's objectives. The nature of settlements in the four selected towns is characterised by extremes of high-income groups and low-income group settlements. Thus, quota sampling guidelines were utilised to avoid any biases that might occur and to ensure that target groups are proportionately represented. Cohen *et al.* (2011:156) holds that the purposive sampling technique involves the deliberate selection of particular participants with relevant and reliable information to the empirical research. Target participants were income earners in households. According to Farrokhi and Mahmoudi-Hamidabad (2012), convenience sampling entails the targeting of participants based on availability and accessibility, especially with empirical investigations involving a large sample. Through convenience sampling, an adequate participatory size was obtained.

According to Maree and Pietersen (2016:177) quota sampling guidelines entails targeting relevant participants to reflect an adequate representation for each sampled sub-groups. This made it possible to discover the heterogeneity and deliver better results compared to probability sampling in research investigations with a population containing groups with distinct characteristics. De Rada and Martin (2014) opine that it is very relevant in utilising quota sampling guidelines for household studies. The paper sampled participants from eight individual groups from two different quotas.

The empirical research only considered sampling formal settlements. Formal settlements make over 80% of electricity consumers in South Africa. Alternatively, targeted low-income groups are characterised by the RDP housing projects in which informal settlers are majority benefactors. This was done to limit bias. It was estimated that 50 participants should be appropriate representatives of each group. Field (2014: 915) suggests a major research requires 100 respondents from main groups and 20 to 50 respondents per sub-group. A further elaboration of the empirical research is reflected in figure 3.2:

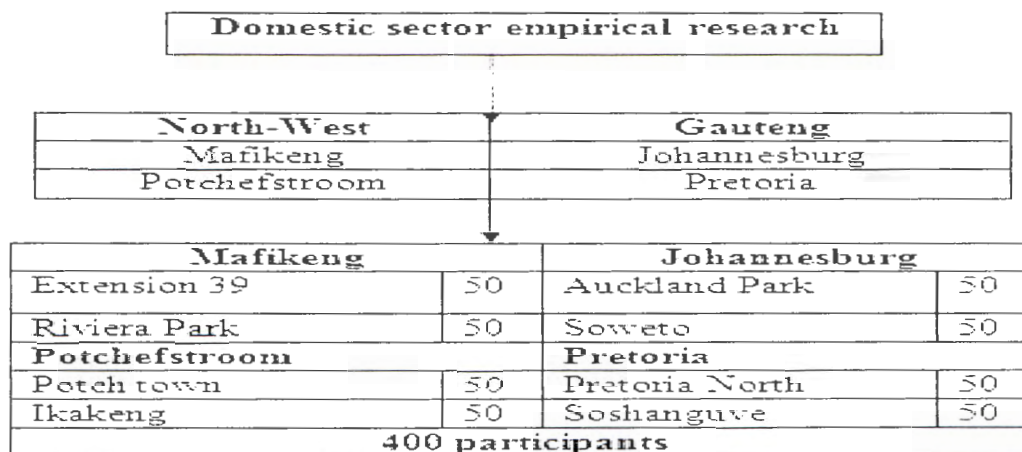


Figure 3.2 Summary of population and sampling

3.3.2 Data collection method

The data collection employed closed-ended questionnaires with defined categories to establish the effect of electricity supply and consumption on the South African domestic sector and related electricity consumer behaviours. Tait (2017) recommended that a detailed household energy study in South Africa should prioritise focus on affordability, safety, reliability, appliance usage and consumptions of alternative energy fuels. The questionnaire used was developed within the recommended parameters by Tait (2017). The questionnaire was structured under five main themes and with each having sub-categories. Questions were designed from a nominal (participants had to tick on the appropriate option), dichotomous (participants had to select from options; yes, no or don't know) and a Likert scale (participants had to rank their opinions on statements on the five-point Likert scale). Due to the massive undertaking here, field workers were utilised for the data collection exercise. Field workers were strictly post-graduate students with sufficient background on social science empirical research data collection. Training sessions were held with field workers to advise on what was required of them in the fieldwork.

3.4 Data analysis

The IBM Statistical Package for Social Science statistics version 23.0.0 as prescribed by SPSS Inc (2016) was used in analysing data. According to SPSS Inc (2016), the SPSS software is an advanced and professional application in analysing data. To enable analyses, questions had to be coded.

3.4.1 Presentation and interpretation of results

The following section presents results and interpretation of the data. Results for all tests that were conducted have been presented in tables to aid understanding of outcomes. Outcomes from the empirical research have been supported by data from existing literature in the conclusions.

Table 3.1 Percentages for return of questionnaire per target location

Code	Target location	City	Frequency	Percentage
1	Pretoria North	Pretoria	51	15.80%
2	Soshanguve	Pretoria	50	15.50%
3	Auckland	Johannesburg	50	15.50%
4	Soweto	Johannesburg	49	15.20%
5	Reviera park	Mafikeng	49	15.20%
6	Extension 39	Mafikeng	50	15.50%
7	Potchefstroom town (Potch)	Potchefstroom city	15	4.60%
8	Ikakeng	Potchefstroom city	9	2.80%
			323	100%

Table 3.1 reflects the number of percentage of responses returned from each sampled group. In total, 323 participants responded to questionnaires that were distributed. Results reflect that Gauteng Province (Johannesburg and Pretoria) made up 62% of the total sample. The North West Province (Mafikeng and Potchefstroom) made up 38%.

Table 3.2 Biographic outcome of participants

<i>Code</i>	<i>Biographic category</i>	<i>Percentage</i>	<i>Summary</i>
Gender			51.7% was made up of female participants, while males participants made up 48.3%
1	Male	48.30%	
2	Female	51.70%	
		100%	
Household participant			Fathers and mothers were majority participants with 80.3%
1	Father	40.30%	
2	Mother	40%	
3	Child	8.40%	
4	Tenant	8.20%	
5	Grand parents	3.10%	
		100%	
Marital Status			44.8% of the participants were married. A 13.9% and 7.3% are in a relationship and divorced respectively. 34.1% of the participants were singles
1	Married	44.80%	
2	Single	34.10%	
3	In a relationship	13.90%	
4	Divorced	7.30%	
		100%	
Qualification			A total of 64.2% of the participants have an educational level from diploma and above. A 35.8% represent Grad 12 and below
1	Grade 12 and below	35.80%	
2	Diploma	17.10%	
3	Degree	28.80%	
4	Post Graduate	18.40%	
		100%	
Income contribution			The empirical research effectively achieved its sampling plan ensuring that primary income earners were majority participants. Primary income earners were represented by 76.7%
1	Primary income earner	76.70%	
2	Not the primary income earner	23.30%	
		100%	

Table 3.2 reflects the outcome from the biographic responses. The majority of the sample was made up of female (51.7%), fathers and mothers (80.3 %) as well as primary income earners (76.70%).

Table 3.3 Household profile

<i>Household Profile</i>	<i>Code</i>	<i>Individuals per range</i>	<i>percentage</i>	<i>Summary</i>
Household members 18 years and younger	1	1 to 3 members	83.60%	The majority (83.6%) of the households that participated had 1-3 members 18 years and younger
	2	4 to 6 members	16%	
	3	7 to 9 members	0.40%	
	4	10 and more	0%	
			100%	
Household member 19 years and older	1	1 to 3 members	83.30%	The majority (83.3%) of households that participated had 1-3 members older than 18 years
	2	4 to 6 members	14.80%	
	3	7 to 9 members	1.60%	
	4	10 and more	0.30%	
			100%	
Total household size	1	1 to 3 members	40.60%	Almost half of the total households participated had a total household size of 4 to 6 members, 40.6% had only 1-3 members. Less than 10% had 7-9 total household members and only 1.3% had 10 or more
	2	4 to 6 members	48.80%	
	3	7 to 9 members	9.40%	
	4	10 and more	1.30%	
			100%	
Type of electricity meter	1	Prepaid	70.80%	Outcome reflects that most electricity users utilised a prepaid connection
	2	Conventional	29.20%	
			100%	
Monthly electricity expenditure of households	1	R10 – R50	2.80%	The outcome reflects that 55% spent above R301 monthly on electricity cost
	2	R51 – R100	6.20%	
	3	R101 – R150	8.70%	
	4	R151 – R200	11.50%	
	5	R201 – R250	8.70%	
	6	R251 – R300	7.10%	
	7	Above R301	55%	
			100%	
Total Gross Monthly Income of household	1	Less than R15, 000	41.80%	41.8% live on a monthly income under R15, 000 while, 58.2% live on an income above R15,000
	2	R15,001 – R25, 000	19.90%	
	3	R25,001 – R34,000	16.10%	
	4	R34,001 – R46,000	11.70%	
	5	Above R46 000	10.40%	
			100%	

Table 3.3 shows the household profiles. The majority (83.6%) of the households that participated had 1-3 members, 18 years and younger. The majority (83.3%) of households that participated had 1-3 members, older than 18 years. Almost half of the total households participated had a total household size of 4 to 6 members, while 40.6 % had only 1-3 members. Less than 10% had 7-9 household members, and only 1.3% had 10 or more. A significant 29.2 % of the participants still utilised the conventional metering system. Results also indicate that over 41% of the sampled individuals live on a monthly income of R15, 000 and lower while 55% of the participants spent above R301, 00 on their monthly electricity needs.

Table 3.4 Descriptive statistics for supply sufficiency

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1. The supply of electricity in South Africa is:					
a) Sufficient	1 Strongly disagree	15.60%	2.48	1.02	15.6% and 42.2% strongly disagreed and disagreed respectively that electricity supply is sufficient. Thus, participants who disagree made up a total of 57.8%
	2 Disagree	42.20%			
	3 Neutral	23.80%			
	4 Agree	15.30%			
	5 Strongly agree	3.10%			
b) Consistent (low voltage)	1 Strongly disagree	12.50%	2.55	1.00	12.5% and 42.3% strongly disagreed and disagreed respectively that electricity supply is consistent. A total of 54.8% of the participants strongly disagreed and disagreed
	2 Disagree	42.30%			
	3 Neutral	24.80%			
	4 Agree	17.90%			
	5 Strongly agree	2.50%			
c) Without interruptions (blackouts)	1 Strongly disagree	19.40%	2.33	1.01	19.5% and 45.5% strongly disagreed and disagreed respectively that electricity supply is without interruptions. A total of 64.9% of the participants disagreed
	2 Disagree	45.50%			
	3 Neutral	20.70%			
	4 Agree	11.30%			
	5 Strongly agree	3.10%			
d) Allows household to perform basic household activities	1 Strongly disagree	9.80%	2.89	1.13	41.8% participants on total disagreed that electricity supply is adequate. 25.6% of the participants where neutral and a total of 32.6% agreed
	2 Disagree	32%			
	3 Neutral	25.60%			
	4 Agree	24.40%			
	5 Strongly agree	8.20%			
2. Future electricity supply will be without interruptions	1 Strongly disagree	18.50%	2.4	0.96	18.5% and 38.7% participants strongly disagreed and disagreed respectively, summing up to 57.2%. 28.1% of the participants where neutral and a total of 14.7% of the participants agreed
	2 Disagree	38.70%			
	3 Neutral	28.10%			
	4 Agree	14.10%			
	5 Strongly agree	0.60%			
3. Electricity supply strength allows for effective functioning of household	1 Strongly disagree	9.70%	2.57	0.97	9.7% and 45.8% participants strongly disagreed and disagreed respectively summing up to 55.5%. 25.1% of the participants where neutral and 19.4% of the participants agreed
	2 Disagree	45.80%			
	3 Neutral	25.10%			
	4 Agree	16.60%			
	5 Strongly agree	2.80%			

Table 3.4 presents results for supply sufficiency. The results reflect that a significant proportion of the participant's view was that the supply is not sufficient. Respondents tend to disagree with supply sufficiency (Statement 1: a, b, c, 2 and 3 ($M = 2.48$, $SD = 1.02$), ($M = 2.55$, 1.00), ($M = 2.33$, 1.01), ($M = 2.4$, $SD = 0.96$) and ($M = 2.57$, $SD = 0.97$) respectively. They tend towards neutral on supply sufficiency statement d ($M = 2.89$, $SD = 1.13$).

Table 3.5 Descriptive statistics for supply sufficiency (dichotomous questions)

Statements	Yes	No	Don't know	Conclusions
1.Are you aware of the government scheduled free monthly electricity (FBE 50 kwts per household)?	25.70%	53.90%	20.40%	A total of 74.34% participants respondent negative of being aware of the FBE
2.Do your household make use of the government scheduled free monthly 50kwts electricity?	11.20%	64.20%	24.60%	A total of 88.8% gave a negative response on utilising the FBE
3.Is 50kwhs electricity enough to meet your household demand?	5.90%	70.30%	23.80%	70.3% participants said 50kwhs of electricity cannot meet their household demand
4.Has your residential area experienced electricity interruptions (black-outs) in the last 6 months?	59.80%	25.70%	14.60%	59.8% of the participants agreed to have experienced interruptions in the last 6 months in their residential area. 25.7% and 14.6% disagreed and do not know respectively

Table 3.5 presents the descriptive statistics for supply sufficiency (dichotomous questions). The dichotomous section tested the awareness and utilisation of the Free Basic Electricity (FBE). Results reflect that consumers lack both usage parameters and awareness of the FBE. Also, a significant portion of the consumers of 70.3 % points out that 50kWh is inadequate to meet household demand. Another important outcome was that 59.8 % participants indicated that they experienced supply interruptions within the last six months.

Table 3.6 Descriptive statistics for service quality

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1.Electricity supply volumes meet the households in South Africa's demand	1 Strongly disagree	12.40%	2.48	0.94	12.4% and 45.3% of the participants strongly disagreed and disagreed respectively that supply does not meet households demand. 25.2% are neutral and 17% agreed that electricity supply meets demand
	2 Disagree	45.30%			
	3 Neutral	25.20%			
	4 Agree	15.80%			
	5 Strongly agree	1.20%			
2.Multiple electric appliances (e.g. stove, geyser & kettle) can be used simultaneously in your house	1 Strongly disagree	7.20%	3.85	1.21	A total of 29.9% strongly disagreed and disagreed to the ability to simultaneously use multiple appliances. A majority of the participants agreed that multiple appliances are used simultaneously making up a total of 57.7%
	2 Disagree	22.70%			
	3 Neutral	12.50%			
	4 Agree	39.90%			
	5 Strongly agree	17.80%			
3.Load shedding has an effect on household functioning (e.g. study time for school children)	1 Strongly disagree	4.30%	3.95	1.08	A total of 73% participants agreed and strongly agreed that load shedding affects household functioning. 15.2% where neutral, while a total of 11.1% strongly disagreed and disagreed
	2 Disagree	6.80%			
	3 Neutral	15.20%			
	4 Agree	36.80%			
	5 Strongly agree	36.80%			
4.Unannounced load shedding destroys home appliances	1 Strongly disagree	1.60%	3.93	1.13	A total of 72.9% of the participants agreed and strongly agreed that load shedding causes damages on electrical appliances. 9% where neutral, while a total of 18.1% strongly disagreed and disagreed that load shedding causes damages
	2 Disagree	16.50%			
	3 Neutral	9%			
	4 Agree	32.70%			
	5 Strongly agree	40.20%			
5.Domestic family comfort (watching Tv, heating water, security lights, and pool pumps) has been influenced negatively by inconsistent electricity supply	1 Strongly disagree	2.20%	3.68	1.01	31.9% and 24.7% of the participants agreed and strongly agreed respectively that inconsistent supply has impact on domestic comfort 32.2%. where neutral and 11.3% on total disagreed
	2 Disagree	9.10%			
	3 Neutral	32.20%			
	4 Agree	31.90%			
	5 Strongly agree	24.70%			

In general, the respondents agreed with the statements provided, thus indicating that multiple electrical sources could be used ($M = 3.85$, $SD = 1.21$). Households agreed load shedding has an effect on their household functioning ($M = 3.95$, $SD = 1.08$), participants agreed unannounced load shedding destroys their home appliances ($M = 3.93$, $SD = 1.13$) and households also agreed domestic family comfort had been influenced negatively by inconsistent electricity supply ($M = 3.68$, $SD = 1.01$). Households also felt that South Africa's household demand is not met by the electricity supply ($M = 2.48$, $SD = 0.94$). Supply and demand inconsistencies have remained a setback to electricity suppliers starting from the last quarter of 2007. The country at large is faced with uncertainties regarding reliability in electricity supply. Currently, there are concerns towards suppliers' ability to meet constantly increasing demand. The monopoly of coal technology has generally been criticised of its capability to stand the test of time as the world is gradually moving towards more competent production technologies.

Table 3.7 Descriptive statistics for health risk

Statements	Scale points	percentage	Mean	Standard deviation	Conclusions
1. Alternative sources for heating and cooking (e.g. paraffin and wood) cause health problems	1 Strongly disagree	3.10%	4.00	1.05	40% and 32% % participants strongly agreed and agreed respectively that unclean source of energy causes health damage. Thus, 72% participants on total feel usage of traditional sources of energy affects health
	2 Disagree	6.20%			
	3 Neutral	18.30%			
	4 Agree	32%			
	5 Strongly agree	40%			
2. Alternative sources for heating and cooking could contribute to hazardous consequences (e.g. accidental arson)	1 Strongly disagree	2.80%	4.00	1.00	40.7% and 37.3% strongly agreed and agreed respectively that unclean source of energy causes peril. The afore scale points made up 78% of the respondents
	2 Disagree	5.60%			
	3 Neutral	13.70%			
	4 Agree	37.30%			
	5 Strongly agree	40.70%			
3. The usage of unclean sources of energy causes air and environmental pollution	1 Strongly disagree	4.10%	4.21	1.07	A majority of the participants of 53.1% and 27.2% strongly agreed and agreed respectively that usage of unclean energy increases environmental concerns
	2 Disagree	4.40%			
	3 Neutral	11.30%			
	4 Agree	27.20%			
	5 Strongly agree	53.10%			

Table 3.7 shows the results for perceived health risk. In general, the respondents agreed with the statements provided indicating that alternative sources of energy cause health problem (means = 4.00, $SD = 1.05$), alternative sources of energy contribute to hazardous consequences (mean = 4.00, $SD = 1.00$) and usage of unclean sources of energy causes environmental pollution (mean = 4.21, $SD = 1.07$). This implies that alternative sources of energy which are the usually unclean impact on domestic consumers negatively.

Table 3.8 Descriptive statistics for cost reliability

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1.Electricity price increases is relatively higher than increases to your household's disposable income	1 Strongly disagree	3.80%	3.88	0.99	45.6% and 27% participants strongly agreed and agreed respectively that increases in electricity cost is not consistent to growth in disposable income, making up 72.6%
	2 Disagree	5.30%			
	3 Neutral	18.20%			
	4 Agree	45.60%			
	5 Strongly agree	27%			
2.Increased electricity fees impact on domestic electricity purchasing ability	1 Strongly disagree	1.30%	3.92	0.81	61% participants agrees that increases in electricity cost affects their electricity purchasing capacity. A 20% strongly agreed
	2 Disagree	6%			
	3 Neutral	11.70%			
	4 Agree	61%			
	5 Strongly agree	20%			
3.The current cost of electricity is acceptable	1 Strongly disagree	21.10%	2.48	1.15	A 21.1% and 36.8%, of the participants strongly disagreed and disagreed respectively. Thus, 57.9% in total felt that the current electricity cost is not acceptable. However, it is noteworthy that 21.1% participants were neutral
	2 Disagree	36.80%			
	3 Neutral	21.40%			
	4 Agree	14.80%			
	5 Strongly agree	6%			
4.Future electricity price increases is a threat to domestic electricity purchase ability	1 Strongly disagree	7.60%	3.75	1.15	A 25% and 49.4% participants strongly agreed and agreed respectively that the increases in electricity price create concerns to their future purchasing capability
	2 Disagree	9.20%			
	3 Neutral	8.90%			
	4 Agree	49.40%			
	5 Strongly agree	25%			
5.Due to the increasing high cost of electricity, you tend to rely on alternative energy sources (wood, paraffin or candles)	1 Strongly disagree	6.60%	3.41	1.28	Results reflects that a 25.2% and 26.4% of the participants agreed and strongly agreed respectively summing up to a total of 51.6%. 30.5% disagreed and 17.9% were neutral in relying on alternative energy sources due to increasing electricity cost
	2 Disagree	23.90%			
	3 Neutral	17.90%			
	4 Agree	26.40%			
	5 Strongly agree	26.40%			

Table 3.8 presents results for cost reliability. In general, the respondents agreed with the statements provided in most cases. Results reflect that electricity price increases are not factored to cater for households' disposable income ($M = 3.88$, $SD = 0.99$), increased electricity fees impact on domestic electricity purchasing ability ($M = 3.92$, $SD = 0.81$) and future electricity price is a threat to domestic electricity purchase ability ($M = 3.75$, $SD = 1.15$). Households also felt neutral that due to increasing high cost of electricity, consumers tend to rely on alternative energy sources ($M = 3.41$, $SD = 1.28$). Participants also disagreed that the current cost of electricity is acceptable ($M = 2.48$, $SD = 1.15$). The MYPD pricing technique applied by NERSA and Eskom has constantly been criticised as non-pragmatic. A critical review of the methodology reflects that it does not consider market forces in implementing periodic increases. Thus, there is a need for a more dynamic and applicable methodology towards standardised electricity pricing in South Africa.

Table 3.9 Descriptive statistics for energy saving activities

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1. In your household you switch off lights when leaving a room	1 Strongly disagree	2.20%	3.92	1.06	40.3% and 34.3% participants agreed and strongly agreed respectively that they switch off lights when living a room in the house
	2 Disagree	11.90%			
	3 Neutral	11.30%			
	4 Agree	40.30%			
	5 Strongly agree	34.30%			
2. In your household you switch off geyser at certain times	1 Strongly disagree	5.50%	3.49	1.19	A reasonable 38% and 21.4% of the participants agreed and strongly agreed on using their geyser efficiently. Alternatively, it is important to note that a significant 25.8% disagreed
	2 Disagree	20.30%			
	3 Neutral	14.80%			
	4 Agree	38%			
	5 Strongly agree	21.40%			
3. In your household you use warm clothing or blankets instead of a electric heater	1 Strongly disagree	6.60%	3.35	1.22	A total of 54.4% of the participants agreed and strongly agreed to the usage of warm cloths instead of electric heater. However, a total of 31.3% of the participants disagreed
	2 Disagree	24.70%			
	3 Neutral	14.20%			
	4 Agree	35.40%			
	5 Strongly agree	19%			
4. In your household you switch appliances (e.g. routers and modems) on standby mode when not in use	1 Strongly disagree	5%	3.45	1.11	A proportion of 39.9% and 16.5% of the participants summing up to a total of 56.4% agreed to switch off appliances when not in use. 20% and 23.3% gave a neutral and negative response respectively
	2 Disagree	18.30%			
	3 Neutral	20.10%			
	4 Agree	39.90%			
	5 Strongly agree	16.50%			
5. You report members of society that gain electricity illegally	1 Strongly disagree	12.30%	3.11	1.3	A total of 35.9% of the participants tend to disagree and strongly disagree. A 39.8% agree and strongly agree respectively. 24.3% were neutral
	2 Disagree	23.60%			
	3 Neutral	24.30%			
	4 Agree	20.40%			
	5 Strongly agree	19.40%			
6. Itemised billing could contribute to more effective electricity usage	1 Strongly disagree	5.90%	3.48	1.05	A total of 57.2% of the participants agreed and strongly agree; while a total of 17.1% disagreed and strongly disagreed that itemised billing will assist them to be cautious on electricity usage. A 25.7% were neutral
	2 Disagree	11.20%			
	3 Neutral	25.70%			
	4 Agree	43.10%			
	5 Strongly agree	14.10%			

Table 3.9 presents results from energy saving factors. This construct was aimed at determining consumers' behaviour towards energy saving activities. In general, respondents were neutral to statements provided except for statement 1, reflecting that participants agreed that lights are switched off when leaving a room (mean = 3.92, SD = 1.063).

3.4.1.1 Factor analysis

An exploratory factor analysis was conducted in this article. Bartholomew *et al.* (2011:24) assert that the factor analysis applies to concepts that are measurable and observable variables that can be summarised to lesser latent variables with a common variance. A factor analysis is normally performed to establish the fundamental relationship among factors. Factor analysis elements considered in this article are elaborated according to Yong and Pearce (2013) and Cornish (2007:3) as follows:

- **Determinants:** This test assesses that the correlations between the items are not too high within an individual factor. The *determinant* should be ≤ 0.0001 to indicate that there are no severe correlations between the items.
- **Kaiser-Meyer-Olkin:** The KMO measures the sampling adequacy. The KMO has an acceptance range from 0.5 to above 0.9. The range between 0.5 and 0.7 is medium, 0.7 to 0.8 is good, 0.8 to 0.9 is very good and >0.9 is superb.
- **Bartlett's test:** This test estimates if the correlation between items is high enough to be categorised under a particular factor. A *p* value <0.05 is considered to be significant.
- **Communalities:** Communalities assess the proportional variance of each item to be explained by the extracted factor. Communalities should be >0.3 to be considered sufficient.
- **Variance explained:** This requires that at least 50% of the total variance should be explained by the extracted factors.
- **Pattern matrix:** The pattern matrix indicates the factor loadings.

Table 3.10 Factor analysis results for operational reliability

<i>Determinant</i>		0.62	
<i>KMO</i>		0.849	
<i>Bartlett's Test</i>	Sig.	≤0.0001	
Code	Statements	Communalities	Total variance
B1.1a	The supply of electricity in South Africa is sufficient	0.75	59.60%
B1.1b	The supply of electricity in South Africa is consistent (low voltage)	0.60	
B1.1c	The supply of electricity in South Africa is without interruptions (blackouts)	0.46	
B1.1d	The supply of electricity in South Africa allows household to perform basic household activities	0.61	
B1.2	Future electricity supply will be without interruptions	0.26	
B1.3	Electricity supply strength allows for effective functioning of household	0.44	

Table 3.10 reflects factor analysis results for the operational reliability factor. All tests adhered to the guideline values. All the communalities for this analysis were close to the guideline value of 0.3. Results also reflect that 59.6% of the variance is explained by the extracted factor. The KMO and Bartlett determinants are 0.62, 0.849 and ≤ 0.0001 respectively.

Table 3.11 Factor analysis results for supply adequacy

<i>Determinant</i>				0.037		
<i>KMO</i>				0.75		
<i>Bartlett's test</i>			<i>Sig.</i>	≤0.0001		
<i>Code</i>	<i>Statements</i>	<i>Communalities</i>	<i>Total variance</i>	<i>Pattern matrix</i>		
				<i>Service quality</i>	<i>Health risk</i>	<i>Cost reliability</i>
C1.1	Electricity supply volumes meet the households in South Africa's demand	0.51	51.80%		0.48	
C1.2	Multiple electric appliances (e.g. stove, geyser & kettle) can be used simultaneously in your house	0.17			-0.33	
C1.3	Load shedding has an effect on household functioning (e.g. study time for school children)	0.31			-0.39	
C1.4	Unannounced load shedding destroys home appliances	0.53			-0.57	
C1.5	Domestic family comfort (watching Tv, heating water, security lights, and pool pumps) has been influenced negatively by inconsistent electricity supply	0.40		0.76		
C2.1	Alternative sources for heating and cooking (e.g. paraffin and wood) cause health problems	0.64		0.83		
C2.2	Alternative sources for heating and cooking could contribute to hazardous consequences (e.g. accidental arson)	0.77		0.67		
C2.3	Continues coal usage by electricity producers causes air and environmental pollution	0.49				
C3.1	Electricity price increases is relatively higher than increases to your household's disposable income	0.61				0.76
C3.2	Increased electricity fees impact on domestic electricity purchasing ability	0.52				0.70
C3.3	The current cost of electricity is acceptable	0.11				-0.28
C3.4	Future electricity price increases is a threat to domestic electricity purchase ability	0.34				0.30
C3.5	Due to the increasing high cost of electricity, you tend to rely on alternative energy sources (wood, paraffin or candles)	0.14			-0.26	

Table 3.11 presents factor analysis results for the supply adequacy factor and its sub-factors namely: service quality, health risk and cost reliability. Results also reflect that 51.8% of the variance is explained by the three extracted factors. The pattern matrix indicates the factor loadings. The determinant, KMO and Bartlett test are 0.037, 0.75 and ≤0.0001 respectively, thus within the guideline values.

Table 3.12 Factor analysis results for energy saving factor

Determinant			0.458		
KMO			0.737		
Bartlett's test		Sig.		≤0.0001	
Code	Statements	Communalities	Total variance	Pattern matrix	
				Energy saving activities	Energy saving alert
D1.1	In your household you switch off lights when leaving a room	0.33	55%	0.4	
D1.2	In your household you switch off geyser at certain times	0.58		0.84	
D1.3	In your household you use warm clothing or blankets instead of a electric heater	0.30		0.47	
D1.4	In your household you switch appliances (e.g. routers and modems) on standby mode when not in use	0.31		0.97	
D1.5	You report members of society that gain electricity illegally	0.22			0.46
D1.6	Itemised billing could contribute to more effective electricity usage	0.42			

Table 3.12 reflects factor analysis results for energy saving activities. All the communalities for this analysis were close to the guideline value of 0.3. Results also reflect that 55% of the total variance is explained by the extracted factors. The pattern matrix indicates the factor loadings. The determinant, KMO and Bartlett test are 0.458, 0.737 and ≤0.0001 respectively, thus falling within the guideline values

3.4.1.2 Cronbach's alpha and factors summary

Tavakol and Dennick (2011) state that the Cronbach's Alpha measures the internal consistency within all the items of a test or a scale. Tavakol and Dennick (2011) and Tavakol and Dennick (2008) also say it is fundamental to evaluate the reliability of data scores as Cronbach's alpha does. For an exploratory study reliability measured by Cronbach's Alpha of >0.5 and <0.7 is good. However, reliability is considered as very good or excellent if it is >0.7. Field (2014: 708 - 709) states that due to several dynamics relating to what should be actually accepted as a reliable Alpha for an analysis, values of 0.5 or above are deemed sufficient.

Table 3.13 The reliability test

Factor	Cronbach Alpha
Supply sufficiency	0.86
Service quality	0.71
Health risk	0.84
Cost reliability	0.70
Energy saving activities	0.72

Table 3.13 reflects Cronbach alpha values for all factors. Results show that the Cronbach's alpha values for all factors were 0.70 and above and thus the factors are deemed reliable. Although the factor analysis indicated that two sub-factors can be extracted for the energy saving activities factor, based on the reliability it was decided to extract only one factor. Thus, it was decided to consider only one factor going forward.

Table 3.14 A summary of the means and standard deviations of factors

Factors	Mean	Standard deviation	Conclusions
Supply sufficiency	2.54	0.79	Results reflects that participants generally disagree that supply sufficiency is effective
Service quality	3.53	0.67	Results reflect that participants are generally neutral to service quality
Health risk	4.09	0.91	Results reflect that participants generally agree that there is health risk towards the usage of unclean sources of energy
Cost reliability	3.69	0.65	Results reflect that participants generally agree that the increase in the cost of electricity affect their electricity purchased capability
Energy saving activities	3.49	0.71	Results reflect that participants are generally neutral towards energy saving behaviours

Table 3.14 presents a summary of participants' general responses on the five extracted factors. The results reflect that participants generally disagreed tending towards feeling neutral that supply sufficiency from the Eskom grid is adequate ($M = 2.54$, $SD = 0.79$). Participants had neutral opinions tending towards agree on the service quality ($M = 3.53$, $SD = 0.67$). Participants agreed that unclean sources of energy have significant associations with health risk ($M = 4.09$, $SD = 0.91$). Participants agreed that electricity cost is not reliable ($M = 3.69$, $SD = 0.65$) and are neutral tending towards agree that they practice energy saving activities in households and appliance acquisition ($M = 3.49$, $SD = 0.71$).

3.4.1.3 Independent T-test

The *T*-test analyses the difference between the means derived from the different groups' scores. Schlomer (2009:3) says the independent samples *T*-test is used to compare two groups from a sample whose means are not dependent on one another. IBM (2016:33) states that descriptive statistics for equality of variance for each group are reflected through the Levene's *p*-value test. The independent *T*-test involves comparing the means by effect size of two groups with possible unique individual characteristics from the other. The effect size explains practical differences between the means. Values >0.2 , >0.5 and >0.8 reflect small, medium and large differences respectively. The independent *T*-test was utilised in comparing the (Low-income and the high-income groups' responses). The *p*-values are reported for the purpose of

completeness sake, but are not interpreted since a purposive-quota sample was used and not random sampling.

Table 3.15 Results of T-test between low-income and high income groups

Factors	Groups	Income class	Mean	Standard deviation	Levene's P values	Effect size
Supply sufficiency	Pretoria, Auckland, Riviera and Potch	High income	2.83	0.78	<0.001	0.75
	Soshanguve, Soweto, Extension 39 and Ikakeng	Low-income	2.24	0.68		
Service quality	Pretoria, Auckland, Riviera and Potch	High income	3.34	0.64	<0.001	0.62
	Soshanguve, Soweto, Extension 39 and Ikakeng	Low-income	3.74	0.64		
Health risk	Pretoria, Auckland, Riviera and Potch	High income	4.12	1.01	0.48	0.07
	Soshanguve, Soweto, Extension 39 and Ikakeng	Low-income	4.05	0.79		
Cost reliability	Pretoria, Auckland, Riviera and Potch	High income	3.69	0.67	0.86	0.02
	Soshanguve, Soweto, Extension 39 and Ikakeng	Low-income	3.68	0.62		
Energy Saving	Pretoria, Auckland, Riviera and Potch	High income	3.50	0.68	0.85	0.02
	Soshanguve, Soweto, Extension 39 and Ikakeng	Low-income	3.48	0.75		

Table 3.15 contains the results of the independent t-test when considering the low-income and high-income groups of all the cities simultaneously. Results reflect that medium and tending towards large differences exist between the two groups' means for the factors supply service quality (0.62) and the supply sufficiency (0.75) respectively. This might be explained by the fact that there are noticeable differences between low-income and high-income groups regarding supply sufficiency and service quality. Supply sufficiency reflect that high-income groups opinion tended towards neutral and low-income disagreed that electricity supply is sufficient (high-income, $M = 2.83$, $SD = 0.78$ and low-income, $M = 2.24$, $SD = 0.68$). Service quality with (high-income, $M = 3.34$, $SD = 0.64$ and low-income, $M = 3.74$, $SD = 0.64$) reflect that high-income quotas' opinion was tending towards neutral and low-income disagreed that service quality is at the level of the required standards.

Table 3.16 Description of T-test between groups

Factors	Groups	Income class	Mean	Standard deviation	Levene's p values	Effect size	Mann Whitney p values	Mann Whitney effect size
Supply sufficiency	Auckland	High-income	3.03	0.85	<0.001	1.01		
	Soweto	Low-income	2.17	0.76				
Service quality	Auckland	High-income	3.18	0.68	<0.001	1.18		
	Soweto	Low-income	3.99	0.64				
Health risk	Auckland	High-income	3.54	1.13	0.11	0.29		
	Soweto	Low-income	3.87	0.84				
Cost reliability	Auckland	High-income	3.49	0.85	0.84	0.04		
	Soweto	Low-income	3.46	0.70				
Energy saving	Auckland	High-income	3.37	0.94	0.38	0.17		
	Soweto	Low-income	3.22	0.82				
Supply sufficiency	Pretoria North	High-income	2.67	0.51	0.003	0.51		
	Soshanguve	Low-income	2.27	0.77				
Service quality	Pretoria North	High-income	3.67	0.51	0.98	0.00		
	Soshanguve	Low-income	3.68	0.50				
Health risk	Pretoria North	High-income	4.43	1.04	0.12	0.28		
	Soshanguve	Low-income	4.14	0.82				
Cost reliability	Pretoria North	High-income	3.89	0.6	0.57	0.11		
	Soshanguve	Low-income	3.83	0.55				
Energy saving	Pretoria North	High-income	3.75	0.55	0.26	0.42		
	Soshanguve	Low-income	3.47	0.65				
Supply sufficiency	Potch town	High-income	3.13	0.73	<0.001	1.86	<0.001	0.73
	Ikakeng	Low-income	1.75	0.46				
Service quality	Potch town	High-income	2.97	0.40	0.01	1.29	<0.001	0.58
	Ikakeng	Low-income	3.82	0.65				
Health risk	Potch town	High-income	4.42	0.51	0.02	0.86	0.04	0.41
	Ikakeng	Low-income	3.81	0.7				
Cost reliability	Potch town	High-income	3.58	0.49	0.17	0.53	0.25	0.23
	Ikakeng	Low-income	3.26	0.60				
Energy saving	Potch town	High-income	3.37	0.43	0.06	0.61	0.05	0.4
	Ikakeng	Low-income	2.85	0.85				
Supply sufficiency	Reviera	High-income	2.7	0.90	0.02	0.36		
	Extension 39	Low-income	2.37	0.45				
Service quality	Reviera	High-income	3.27	0.64	0.05	0.39		
	Extension 39	Low-income	3.54	0.68				
Health risk	Reviera	High-income	4.31	0.69	0.4	0.17		
	Extension 39	Low-income	4.20	0.68				
Cost reliability	Reviera	High-income	3.73	0.53	0.33	0.19		
	Extension 39	Low-income	3.84	0.54				
Energy saving	Reviera	High-income	3.40	0.50	<0.001	0.82		
	Extension 39	Low-income	3.86	0.55				

Table 3.16 presents the independent *T*-test for low-income and high-income groups per city. Results reflect some practically significant difference in the opinions between the different groups of sampled cities. Auckland Park and Soweto reflect large differences in supply sufficiency (1.01) and service quality (1.18). Households from Auckland tend towards neutral that supply is sufficient while households from Soweto tend to disagree (Auckland, $M = 3.03$, $SD = 0.85$ and Soweto, $M = 2.17$, $SD = 0.76$). For service quality, households from Auckland tend towards neutral, and those from Soweto tend to agree (Auckland, $M = 3.18$, $SD = 0.68$ and Soweto, $M = 3.99$, $SD = 0.64$). Pretoria North and Soshanguve reflect differences tending towards medium in supply sufficiency (0.51) and energy saving (0.42). Households from Pretoria North tend towards neutral on supply sufficiency while households in Soshanguve

disagree (Pretoria North, $M = 2.67$, $SD = 0.51$ and Soshanguve $M = 2.27$, $SD = 0.77$). Households from Pretoria North tend towards agree on energy saving while households from Soshanguve tend towards neutral (Pretoria North, $M = 3.75$, $SD = 0.55$ and Soshanguve $M = 3.47$, $SD = 0.65$). Potch and Ikakeng reflect differences in supply sufficiency (1.86), service quality (1.29), health risk (0.86), cost reliability (0.53) and energy saving activities (0.61), while Riviera and Extension 39 reflect differences tending towards large for energy saving (0.82) (Riviera, $M = 3.40$, $SD = 0.50$ and Extension 39, $M = 3.86$, $SD = 0.55$).

The Mann Whitney *T*-test was also performed on Potchefstroom town and Ikakeng. Nachar (2008) says that the Mann-Whitney test answers questions about the irregularity from small data acquired from limited numbers of participants and also validates the reliability of the independent test outcomes for such data. Just 15 and nine questionnaires were acquired from Potchefstroom town and Ikakeng respectively, giving a total of 24 questionnaires out of 100 distributed questionnaires. The Mann Whitney requires an effect size >0.1 , 0.3 and 0.5 to indicate small, medium or large differences. Mann Whitney test reflects large effect sizes for supply sufficiency (0.73) and service quality (0.58). Households from Potchefstroom town tend towards neutral that supply is sufficient while households from Ikakeng tend towards strongly disagree (Potch, $M = 3.13$, $SD = 0.73$ and Ikakeng, $M = 1.75$, $SD = 0.46$). Households from Potchefstroom are tending to neutral on service quality while households from Ikakeng tend towards agree (Potch, $M = 2.97$, $SD = 0.40$ and Ikakeng, $M = 3.82$, $SD = 0.65$). In general, factors also reflect noticeable small and medium effect sizes in some cases. This implies that the low-income and high-income households reflect significant differences in opinions towards their feelings on the provided factors.

Table 3.17 T-test comparisons for gender, income status and meter type

Factors	Elements		Mean	Standard deviation	Levene's P values	Effect size
	Gender					
Supply sufficiency	1	Male	2.56	0.78	0.61	0.06
	2	Female	2.52	0.79		
Service quality	1	Male	3.48	0.67	0.13	0.17
	2	Female	3.59	0.66		
Health risk	1	Male	4.03	0.95	0.24	0.12
	2	Female	4.15	0.87		
Cost reliability	1	Male	3.67	0.63	0.66	0.05
	2	Female	3.7	0.67		
Energy saving activities	1	Male	3.42	0.71	0.07	0.2
	2	Female	3.56	0.71		
Income						
Supply sufficiency	1	Primary earner	2.54	0.8	0.66	0.06
	2	Not Primary earner	2.58	0.75		
Service quality	1	Primary earner	3.55	0.68	0.62	0.06
	2	Not Primary earner	3.5	0.63		
Health risk	1	Primary earner	4.04	0.92	0.11	0.21
	2	Not Primary earner	4.24	0.86		
Cost reliability	1	Primary earner	3.67	0.63	0.39	0.11
	2	Not Primary earner	3.74	0.7		
Energy saving activities	1	Primary earner	3.46	0.74	0.12	0.19
	2	Not Primary earner	3.61	0.6		
Meter type						
Supply sufficiency	1	Prepaid meter	2.47	0.76	0.009	0.3
	2	Conventional meter	2.72	0.83		
Service quality	1	Prepaid meter	3.59	0.62	0.01	0.28
	2	Conventional meter	3.38	0.75		
Health risk	1	Prepaid meter	4.09	0.86	0.96	0.01
	2	Conventional meter	4.08	1.03		
Cost reliability	1	Prepaid meter	3.72	0.62	0.25	0.13
	2	Conventional meter	3.62	0.72		
Energy saving activities	1	Prepaid meter	3.51	0.67	0.44	0.08
	2	Conventional meter	3.44	0.82		

The results in table 3.17 present opinions of participants based on gender, income status and the installed meter type in their houses. The results reflect that there are only small or practical insignificant differences in the different groups' opinions.

3.4.1.4 ANOVA

Analysis of Variance (ANOVA) tests were also performed to test for any differences in the opinions according to academic status and household size. According to Karp (2010:24), the ANOVA test compares the mean scores of more than two groups. An effect size of >0.2, >0.5 and >0.8 reflect small, medium and large differences respectively. The aim was to determine if the academic status and the household size affect participants' feelings towards the tested factors. The *p*-values are reported for completeness sake but are not interpreted since a non-probability sample method was used and not random sampling.

Table 3.18 Effect sizes for the ANOVA tests for qualification and household size

Factors	Level of qualification		Mean	Standard deviation	ANOVA	Welch	Effect size		
							Grade 12 & below with...	Diploma with..	Degree with...
Supply sufficiency	1	Grade 12 & below	2.34	0.61	<0.001	<0.001			
	2	Diploma	2.38	0.79			0.05		
	3	Degree	2.63	0.84			0.34	0.29	
	4	Post graduate	2.93	0.81			0.73	0.68	0.36
Service quality	1	Grade 12 & below	3.69	0.59	0.004	0.003			
	2	Diploma	3.59	0.63			0.15		
	3	Degree	3.45	0.73			0.32	0.19	
	4	Post graduate	3.33	0.67			0.54	0.39	0.17
Health risk	1	Grade 12 & below	4.1	0.87	0.92	0.91			
	2	Diploma	4.13	0.84			0.03		
	3	Degree	4.06	1.03			0.04	0.07	
	4	Post graduate	4.02	0.89			0.09	0.12	0.04
Cost reliability	1	Grade 12 & below	3.77	0.59	0.02	0.03			
	2	Diploma	3.81	0.6			0.06		
	3	Degree	3.64	0.68			0.2	0.25	
	4	Post graduate	3.49	0.71			0.4	0.45	0.21
Energy saving	1	Grade 12 & below	3.66	0.69	0.006	0.006			
	2	Diploma	3.6	0.77			0.08		
	3	Degree	3.36	0.7			0.42	0.31	
	4	Post graduate	3.35	0.66			0.44	0.32	0.01
	Household size		Mean	Standard deviation	ANOVA	Welch	household members 1-3 with...	household members 4-6 with...	
Supply sufficiency	1	1 to 3 members	2.49	0.76	0.19	0.17			
	2	4 to 6 members	2.63	0.83			0.17		
	3	7+ members	2.43	0.64			0.08	0.25	
Service quality	1	1 to 3 members	3.58	0.66	0.39	0.40			
	2	4 to 6 members	3.48	0.67			0.15		
	3	7+ members	3.57	0.67			0.02	0.13	
Health risk	1	1 to 3 members	4.1	0.93	0.97	0.97			
	2	4 to 6 members	4.07	0.86			0.03		
	3	7+ members	4.08	1.08			0.01	0.01	
Cost reliability	1	1 to 3 members	3.79	0.59	0.01	0.01			
	2	4 to 6 members	3.57	0.71			0.31		
	3	7+ members	3.8	0.51			0.01	0.32	
Energy saving	1	1 to 3 members	3.55	0.63	0.25	0.03			
	2	4 to 6 members	3.38	0.76			0.23		
	3	7+ members	3.7	0.73			0.21	0.42	

Table 3.18 reflects results of ANOVA, including the effect sizes for qualification and household size. For qualification, results reflect that opinions differ for postgraduates and grade 12 and below, tending towards large (0.73) and postgraduates and diploma tending towards large (0.68) for supply sufficiency (postgraduate, $M = 2.93$, $SD = 0.81$ and grade 12 & below, $M = 2.34$, $SD = 0.61$ and diplomas, $M = 2.38$, $SD = 0.79$). Postgraduates tend towards neutral for supply sufficiency while grade 12 and below tend towards disagree. This might be explained by the fact that postgraduates are skilled in acquiring jobs that sustain their domestic needs as opposed to grade 12 and below or diplomas who are normally not skilled with the minimum requirements for most high-income jobs to acquire sufficient electricity. Postgraduates and grade 12 and below reflect a medium effect size (0.54) for service quality. Postgraduate tend towards agree, while grade 12 and below are tending to neutral (postgraduates, $M = 3.33$, $SD = 0.67$ and grade 12 & below, $M = 3.69$, $SD = 0.59$).

3.4.1.5 Correlation

Harmon (2011:33) states the Spearman's rank correlation is a nonparametric statistic which measures the strength of an association between two variables. Hauke and Kossowski (2011) say that the Spearman coefficient assesses how the relationship between two variables can be best described. The Spearman rank coefficient also indicates if a practical significant relation exists between variables. A coefficient >0.1 , >0.3 and >0.5 represents a small, medium and large relationship respectively. The Spearman's rank correlations were calculated between households' monthly electricity spending and monthly income as well as between monthly spending, monthly income and the different factors.

Table 3.19 Correlation estimation between household size, spending, and income

	Household size	Spending	Income
Household size		0.15	0.1
Spending	0.15		0.47
Income	0.1	0.47	

Table 3.19 presents correlations coefficient for household size, spending and income. Results reflect that spending on electricity has a large association with monthly income indicated ($r = 0.47$).

Table 3.20 Correlation estimation between monthly electricity spending and monthly income over factors

Factors	Monthly spending on electricity	Monthly income
Supply Sufficiency	0.26	0.30
Service quality	-0.25	-0.21
Health risk	0.13	0.00
Cost reliability	0.01	-0.15
Energy saving activities	-0.6	-0.22

Results reflect medium positive correlations for both monthly spending ($r = 0.26$) and income ($r = 0.30$) with supply sufficiency. Thus the more respondents spend and earn the more likely they are to agree that electricity supply is sufficient. A negative correlation, tending towards medium, was found to exist between service quality and monthly spending on electricity. This indicates that the more the respondent's expenditure, the more likely they are to disagree with the negative statements made regarding service quality.

3.4.1.6 Measuring the usage of energy-intensive appliances and alternative sources of energy

This section presents participants' responses to the usage of energy-intensive appliances and alternative sources of energy. The results reflect the percentages of participants who selected the (yes) option for each appliance at each of the questions.

Table 3.21 Descriptive statistics on the usage of domestic energy-intensive appliances

	1	2	3	4	5	6	7	8	9	10
Indicate which of the following appliances....	<i>Fridge</i>	<i>Geyser</i>	<i>Cooking stove</i>	<i>Air-conditioner</i>	<i>Pool pump</i>	<i>Space heater</i>	<i>Iron (clothing)</i>	<i>Kettle</i>	<i>Washing machine</i>	<i>Micro wave</i>
1. are being used in your household?	96%	73.40%	95.40%	31.30%	16.10%	41.80%	93.80%	95%	78%	86.70%
2. usage has been reduced due to electricity cost and supply?	18.90%	48.60%	26.60%	23.30%	16.70%	30.70%	14.60%	14.60%	17.30%	14.60%
3. do you demand all day?	85.10%	29.10%	27.20%	8.40%	4.30%	5%	15.80%	22.30%	11.50%	20.10%
4. used in your household are older than 5 years?	78.60%	57%	63.50%	17%	14.20%	27.90%	58.80%	63.50%	53.30%	59.10%
5. can you function without?	16.40%	22.60%	23.20%	31.90%	29.40%	36.50%	23.20%	27.90%	29.70%	31.30%
6. are being used during warmer summer months?	86.40%	48.30%	60.10%	25.40%	13.60%	9.30%	47.40%	47.10%	41.50%	44.30%
7. are being used during colder winter months?	74.60%	62.50%	66.90%	9%	5.30%	41.50%	50.20%	59.80%	55.10%	57.60%

Table 3.21 presents results on the usage behaviour of selected energy-intensive domestic appliances that are commonly used in households. The selection process followed specifications in accordance to the SANS 941. From the results, there is a high usage rate from most of these energy-intensive appliances. Appliances that are not in high usage are luxury categories such as pool pumps and air-conditioning devices. However, low daily usage rates cannot guarantee effective efficiency as a large proportion of the participants also stated that the utilisation of these appliances has not been reduced in general. In most cases, respondents said "yes" on owning these appliances (statement 1). A large proportion of participants utilise appliances that are older than five years (statement 4). Pool pumps, air-conditioning and space heaters recorded the lowest outcomes of 17%, 14.1% and 27.9% respectively for the age of the appliances utilised more than five years old. The rate at which seasonal changes impact on an appliance usage rate was also assessed (statements 6 and 7). The summer and winter months were the considered seasons. Results reflect that fridges, cooking stoves and geysers have a high usage rate in winter as well as during summer months. In general, results reflect that fridges, cooking stoves and geysers have a high usage rate and thus, officials should focus on stabilising efficiency on such appliances which also have a high energy consumption rate.

Table 3.22 Description of percentages on the usage of other sources of energy

Indicate the main source of energy for the following activities	1	2	3	4	5	6	7
	<i>Electricity</i>	<i>Paraffi</i>	<i>Gas</i>	<i>Solar</i>	<i>Generator</i>	<i>Wood</i>	<i>Coal</i>
1 Lighting	95%	3.10%	1.20%	1.90%	6%	9%	1.50%
2 Cooking	82.70%	9%	26%	6%	6%	14.60%	5%
3 Heating	75.20%	5%	17.30%	3.40%	1.20%	14.90%	8.40%

The table 3.22 presents results to the usage of energy mix sources for household consumption. These results reflect that 75.2 % and above of the participants utilise mostly electrical energy for household activities (lighting, cooking and heating). Because a majority of the participants utilise electrical energy, other sources are marginally utilised. Other notable sources are gas and wood usage for cooking (26 % and 14.6%) respectively and gas, wood and coal for heating (17.3%, 14.9% and 8.4%) respectively.

3.5 Conclusion

This paper assessed the electricity supply inconsistency in the South African domestic sector. Supply sufficiency, service quality, health risk and cost reliability were considered to assess the effects of electricity inconsistency on the domestic sector. The study also conducted empirical research on the consumption behaviours by evaluating statements on energy saving activities and usage rate of energy-intensive domestic appliances. The empirical research also assessed the use of alternative sources of energy by the domestic sector. The following section presents a conclusion from each objective of this paper.

3.5.1 Electricity supply and inconsistency on the South African domestic sector

Gotz *et al.* (2016:2) note that South Africa is currently affected by severe bottlenecks in the supply of electricity resulting from weaknesses in the electricity grid. The empirical research sampled five factors (supply sufficiency, service quality, health risk, cost reliability and energy saving) to determine participants' opinions on the aforementioned factors regarding the grid supply. In general, empirical research supports that electricity supply consistency and access is inadequate. For supply sufficiency, opinions were essentially that supply is insufficient ($M = 2.54$, $SD = 0.79$). Opinions reflect the population still experiences load shedding and constant interruptions of supply. Load shedding remains a necessary option for Eskom to regulate demand and supply. Matona (2015:9) gives an account that load shedding in South Africa has increased rapidly from 4.3 percent in 2008 to 14.8 percent by 2015 incurring constraints on residential consumers. Marquard *et al.* (2008) point out that the main impediment to low domestic electrification is the drop in living standards. The FBE aimed at improving the lives

of low-income groups is ineffective, with most participants noting that they are not aware of the FBE. Makonese *et al.* (2012:2-12) says the FBE programme is not sustainable and is currently in a state of total disorder due to poor implementation.

Service quality was rated towards neutral ($M = 3.53$, $SD = 0.67$). However, “statement 1” of service quality, stating that electricity supply meets household demands showed cumulative disagreement ($M = 2.48$, $SD = 0.94$). Opinions reflect that unannounced load shedding has led to damage of house appliances and domestic comfort has been negatively affected due to inadequate available electricity. Participants also agreed that alternative energy sources of energy are strongly associated with environmental and health risk ($M = 4.09$, $SD = 0.91$). Balmer (2007) states that the domestic sector contributes 65% to local air pollution from other sources of energy in South Africa. Adam (2010:9) highlights that approximately 80, 000 children suffer from the domestic usage of unclean energy sources every year. Adam (2010:7) has stated that socio-economic growth and development can only be attained if there is safe, clean, convenient and cheap energy for citizens.

Opinions for cost reliability tend towards agreeing that electricity cost is unacceptable ($M = 3.69$, $SD = 0.65$). Participants noted that the increase in electricity prices is not in tandem with disposable income, threatening their current and future purchasing abilities. Winkler (2006a:23) highlights that quality and affordable electricity supply is still a major difficulty to a large proportion of the South African population. There was a significant difference between the high-income and low-income groups on electricity supply and service quality. High-income groups were largely neutral on electricity supply sufficiency while low-income groups disagreed that electricity supply was sufficient. In general, opinions are tending towards neutral on service quality. Adam (2010:9) mentions that the poor are still incapable of acquiring adequate electricity to impact the quality of their living standard in South Africa.

There are also significant differences in supply sufficiency and service between quotas of sampled cities. A noticeable difference was reflected between Potchefstroom and Ikakeng amongst all factors. It was also reflected that significant differences exist between primary and non-primary income earners in supply sufficiency and service quality and males and females on supply sufficiency and cost reliability. Significant differences in opinion were also reflected in household size and qualification level of health risk.

3.5.2 Electricity consumption tendencies by domestic consumers

Electricity consumption was assessed to establish consumers' tendencies. Understanding consumer behavioural changes were essential in achieving greater energy efficiency (Makgetla, 2008:13). In general, participants' opinions reflect neutrality towards practising energy saving activities with ($M = 3.49$, $SD = 0.71$). Usage of energy-intensive appliances reflect that in most cases a majority of the participants utilised most the appliances with a large proportion agreeing to have used a particular appliance for more than five years. Diederichs *et al.* (2014:26) have pointed out that a typical low-income household in South Africa still primarily utilises old appliances that are not energy efficient.

Results also reflect that consumer's still heavily uses appliances such as fridges, geysers and cooking stoves regardless of seasonal changes. It is important for administrators and suppliers to educate the public on the contribution of energy saving gadgets to attain electricity adequacy. To develop a reliable solution to a capacity challenge grid, it is only practical in determining the consumption tendencies of its consumers. Guthridge, (2010:3) says energy structures with systems in place for monitoring consumption tendencies are capable of solving energy challenges resulting from consumption tendencies. BigEE report (2013) states that regulating the efficiency level of appliances, already on the market was long identified as a potential starting point towards efficiency improvement. However, there have been no policy amendments to implement the initiative. Gotz *et al.* (2016) mention that there have been consistently fewer quality models of gadgets and appliances on the South African market between 2010 and 2014. Bah and Azam (2017) agree that the challenge of delivering and consuming electricity efficiently still remains a major problem in South Africa.

3.5.3 The usage rate of alternative sources of energy

Consumer tendencies towards using alternative sources of energy (electricity, paraffin, gas, solar, generator, wood and coal) for household activities were also assessed. In most cases, a large proportion of the participants noted a significant reliance on electrical energy. Referring to the Department of Energy (DOE) (2012:23), electricity is the cleanest energy storage for households and for maintaining a quality living and environmental standards. Electricity prevents the usage of unclean energy sources. Despite the large dependence of most of the population on electrical energy, at least a third of other sources of energy, are marginally used. Winkler *et al.* (2011) concur that the use of different energy sources is still a common practice in South Africa across all income levels, even after electrification. Results also reflect that

alternative energy sources with biomass (wood and paraffin) are greatly used. Tait (2017) concurs that there is a wide usage of alternative energy sources in South Africa. However, there has been little attention in addressing the consequences of traditional energy sources to the environment. Gevaart-Durkin *et al.* (2014) report that there is environmental and physical peril associated with the usage of alternative energy sources with biomass. Gevaart-Durkin alludes to paraffin stoves, and candles make up over 70 % of fire disasters in South Africa.

3.6 Final statement

This article assessed the dynamics of electricity supply, consumption and efficiency in the South African domestic sector. Electricity inconsistency is a global problem that affects all economies in the world. It is important that policy prioritise crisis management plans to reduce the impact of electricity inconsistency on domestic quality of life. South Africa has considerably implemented electricity policy frameworks towards attaining secure electricity supply and access among its citizens. Policies have been successful in most cases. However, loopholes still exist. It is important that policy-makers focus policy objectives towards attaining policy specific goals. The supply and access to adequate electrical energy in the domestic sector are of primary importance as it contributes positively to social development and economic growth. Efficiency is a very important programme towards improving electricity savings. South Africa has implemented mandatory standards to control efficiency on appliance groups. The programme experiences significant loopholes compared to other countries and energy policies only recently prioritised on domestic market energy regulations such as required standards of domestic appliances for consumers. However, implemented policies are struggling to initiate and foster a broad market transformation towards the most energy-efficient products. It is important that policy-makers prioritise the domestic sector's most consumed energy-intensive appliances such as refrigerators. Establishing minimum energy standards for appliances could successfully persuade valuable domestic appliances energy savings. The long absence of energy saving programmes in South Africa implies that limited energy efficiency has been attained over the years. Gotz *et al.* (2016:9) exposed that the current standard and labelling programme is archaic and futile for achieving energy transformations in the domestic appliance market. Policies should be revised to harness progress in appliance efficiency.

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CHAPTER FOUR (ARTICLE 3)

ELECTRICITY POWER SUPPLY AND INDUSTRIAL GROWTH IN SOUTH AFRICA

Benedict Belobo Ateba and Johannes Jurgens Prinsloo

ABSTRACT

The industrial sector is the most consuming electricity end user in South Africa. Inconsistencies in supply have incurred devastating shocks on the industrial sector in general. The current business environment is also characterised by supply uncertainties owing to continuous threats to the grid. These challenges have large economic implications on the country's capacity to achieve both its industrial short and long-term goals. Industrial growth decline in South Africa is directly associated with decreasing economic development. Economic growth continuously drops drastically as industrial performance falls, considering that the industrial sector is the main economic contributor to the Gross Domestic Product (GDP) in South Africa. This paper seeks to outline the shocks of the low (inconsistent) electricity supply on the South African industrial sector. The paper also evaluates the effectiveness of strategies used to mitigate disruptions from inconsistent electricity supply. Intensity control programmes were also assessed, aiming to point out the importance of efficiency. The empirical research utilised a quantitative research design, and a survey approach was used. The study geography was focused in the Gauteng and North West provinces of South Africa. A purposive-convenience sampling was utilised. However, quota sampling guidelines were considered in targeting actual participants. Enterprises across the service, manufacturing and mining industries were sampled. Data was acquired using questionnaires with questions designed within the parameters of the Likert scale. Results reflected inadequate electricity power supply has an impact on industrial growth in South Africa. Results also note that most businesses is challenge in instituting mitigation strategies such as Small, Micro, Medium Enterprises (SMME's) across industries. The phenomenon tends to impact electricity intensive and non-electricity-intensive industries differently.

Keywords: Electricity supply, low-efficiency, business performance, industrial growth

4. INTRODUCTION

From the importance of electricity in general, Kenny (2015:1) maintains that the commodity is one of the most important new technologies of the 21st century. It changed the world extremely and entirely for the better. It is now the stamina of every modern economy. Ahmad and Othman (2014) point out that electricity is the most demanded necessity currently in the world, in general. The global applications of electricity have been advanced rapidly with industries utilising large amounts of electrification for generating power to all technologies that are needed for production while domestically for the powering of daily electrical appliances.

Ahmad and Othman (2014) state that, globally, electricity consumption has advanced rapidly for industry consumers who utilises large amounts of electricity in heating, lightening and generating power to all other technologies that are needed for industrial production. Olufemi (2015) says industrial growth is vital since industrialisation is responsible for manufacturing consumer and capital goods which tend to create the necessary social overhead capital that would stimulate the development of other sectors of the economy. Aladejare (2014) mentions that an accurate supply of modern electricity for the commercial sector now signify high economic prominence of a country.

Doyle (2015:22) note unreliable power supply that threatens extended periods with no power over the course of several years is characterised with load-shedding occurrences as a predictable certainty in the future. Thoughtful enterprises need to implement mitigation strategies to deal with it, and they also need to implement successful strategies they need to understand what are the risks and implications of low electricity supply.

4.1 Introduction to the problem

Von Ketelhodt and Wocke (2008) analysed that constraints are now starting to impact on the South African business environment prior to the electricity shortages that have brought on electricity outages. Attigah and Mayer-Tasch (2013:4) note that quantitative evidence about the impact of electricity on economic activities hardly exists. Von Ketelhodt and Wocke (2008) have executed one of the most extensive studies about the performance of the South African commercial industry as a result of the electricity crisis. They sampled 250 businesses in the Western Cape region across 29 different industrial sectors. The empirical outcomes reflect that the electricity inconsistency has extensively affected the operations of the South African businesses sector in general. Albert (2015:34) agrees that even though the electricity supply has been fairly stable in recent months, there is no assurance that Eskom can keep up with the

ever-increasing demand for power. This paper seeks to elaborate the importance of an efficient electrical energy supply as a major factor for industrial growth in South Africa. A statistical overview of the GDP growth from key industrial sectors is reflected on table 4.1

Table 4.1 Gross domestic product growth for key sectors in South Africa

Economic sectors	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture, forestry & fishing	-0.3	1.3	0.6	1.5	5.6	-8.4	-7.6	3.4
Mining	5.3	-0.7	-2.9	4.00	-1.6	3.00	-2.9	0.1
Manufacturing	5.9	2.9	1.9	0.7	0.00	0.1	-0.1	1.4
Electricity, gas & water	2.4	1.4	-0.1	-0.6	0.00	-1.00	-0.5	2.1
Construction	0.7	0.4	2.1	2.7	2.9	1.9	0.4	1.3
Wholesale, catering & accommodation	4.4	3.8	3.6	1.9	1.3	1.4	1.00	1.1
Transport, storage & communication	1.7	3.00	2.5	2.00	2.3	1.4	0.5	0.9
Finance, insurance & business services	1.2	4.1	3.00	3.00	2.2	2.8	1.9	2.00
Community, social & personal services	0.4	2.4	2.1	1.8	1.4	1.1	1.00	1.2
General government	2.7	2.4	3.6	3.1	3.00	0.9	1.1	0.6
Total GDP growth	2.9	4.5	2.2	2.3	1.6	1.2	0.4	1.2

This paper's problem identified relates to low electricity supply for the industrial sector - which has led to a decline in industrial efficiency impacting on the role of electrical energy as a potential driver for meeting up new industrial pressures. This result from domestic and global markets tendencies. It also relates to limited mitigation strategies towards low industry electricity supply by enterprises.

4.2 Literature review

This section will present a brief discussion on the contribution of electrical energy to global industrialisation, the connexion between electricity supply and industrial performance in South Africa and the importance of electricity supply adequacy for industrial competitiveness.

4.2.1 The contribution of electrical energy to industrial growth

Industrial growth or industrialisation is the deliberate and sustained application and the combination of appropriate technology, infrastructure, managerial expertise, and other important resources in the production of output (Olufemi, 2015). Attigah and Mayer-Tasch (2013:4) state that of all modern energy types, electricity is the most undisputable category that is much considered in the strategic objectives of industrial growth. Hedden (2015:11) states that an electricity grid system was designed in the image of the "First Industrial Revolution", with the grid modelled, to enable mass production and to attain economies of scale.

Zhang *et al.* (2017) highlight that electric power was a key contributor during the "Second Industrial Revolution" by the last quarter of the 19th century and the beginning of the 20th century. The revolution was pioneered by electrical generation, the transformation of the chemical industry and the advancement of the internal combustion engine. It made available new technological opportunities for industrialisation in the world.

Jucker *et al.* (2008:3) states that industrial and economic growth for all developing economies is strongly dependent on the supply levels of electrical energy and access to reliable supplies of electricity. Electrical energy savings have a direct impact on the bottom line of industrial plants and commercial businesses (Jucker *et al.*, 2008:5). Isaksson (2009:1) agrees that the most direct role of electrical energy is that it serves as the main input to industrial production. A world without electricity amounts to non-mechanized production. Unreliable supplies of electricity disrupt production, and voltage fluctuations negatively affect the durability of machinery.

As electricity cannot be economically stored on a large scale, it has to be produced at the same moment and in the same quantity that is requested and has to be transmitted instantaneously from the power generator to the user through transmission lines. Because of these special features, the electricity supply system has to be designed for the maximum expected demand to be able to sustain industrial activities (Aoki *et al.*, 2009).

4.2.2 Electricity supply and industrial performance in South Africa

Asafu-adejaye (2000), investigated the drivers of industrial productivity in Singapore and Indonesia and found that there is causativeness between electricity supply and economic growth. Asafu-Adjaye state that electricity adequacy is an indispensable component of industrial productivity. Nkomo (2006:77) says the relationship between energy supply and industrial growth is complex and can be elaborated upon from different angles. The most important are the volume effect, which determines different tendencies in the production level of economic activities based on the quantity of energy supply.

Inglesi (2010) points out that, from 2007, Eskom, the national parastatal who is in charge of the administration of about 96 percent of South Africa's electricity, experienced a lack of capacity in the generation and reticulation of electricity supply for South Africa in general. As a result, by the fall of 2008, domestic and industrial electricity users had to suffer from blackouts all over the country with damaging effects on the economy. Oxford (2015:12) states that as load-shedding first hit South Africa from April 2008, businesses have been battling to

deal with its impacts. The power supply has been on a short leash as Eskom fights to manage an ageing grid, and alongside steadily increasing consumer demand.

Oxford (2015:12) points out that Eskom agrees that the challenge of a constrained power system and the issues of supply and demand are not likely to end if sufficient capacity to meet required demand remains pending. South Africa's insufficient and unstable electricity supply leading increased input costs and difficult industrial relations are affecting the performance of business enterprises and their investment plans (Industrial Development Corporation, 2015:2). Inglesi and Blignaut (2012) maintain that electricity is an essential input for production in South Africa, hence an important factor for the competitiveness of the country's industrial performance. Calculating the electricity intensities, South Africa's electricity intensity has more than doubled when considered on time series bases. The sectoral analysis also confirms that a majority of South African sectors are becoming electricity intensive. To improve its industrial competitiveness, South Africa will have to improve its sectoral electricity efficiency levels.

Referring to Von Ketelhodt and Wocke (2008) constraints caused by low energy has an impact on the performance of the South African industrial and business sector. A reliable and low priced supply of electricity is critical to the success of the business sector in South Africa. Altman *et al.* (2010:9) point out that there is a real concern that, rising electricity prices will encourage firms to shut down production or contain expansion with resultant downstream impacts on economic growth. Altman *et al.* (2010:28) highlight that it is now clear that there is a likelihood of electricity supply shortages stretching to 2017 for the industrial sector. James (2014:1) affirms that the South African business sector is extremely concerned about the short to medium term power crisis.

4.2.3 Electricity supply adequacy and industrial competitiveness

Naude and Maastricht (2012:20) view the structural transformation of economies from traditional to modern economies driven by high-productivity industrial manufacturing activities, have been a defining feature of economic development. In this 21st century industrial age, development remains relevant for developing countries trying to catch up with more advanced economies and to provide increasing standards of living for their populations. Industrialization is a catalyst that accelerates the pace of structural transformation and diversification of economies, enabling a country to fully utilise its factor endowment for its sustenance (Olufemi, 2015). Fedderke (2014:6) notes that the main setback to the struggling

South African economy is linked to the declining industrial sector, resulting mainly from shortages of electrical energy. Carew (2015:16) points out that the economic impact of load-shedding in 2015 alone was equivalent to the loss of an entire industry.

Referring to Makgetla (2008:12) the electricity shortfall has incurred devastating consequences on the industrial sector in South Africa. Kumo *et al.* (2016:4) state that severe electricity inefficiency which precipitated frequent load-shedding, lead to low business confidence. Kenny (2015:7) notes in January 2008, during a period of heavy rain, a large number of the big coal stations failed, plunging much of the country into blackouts and shutting down all the gold mines. Mines have to close down, chemicals and food processing lose if blackouts are scheduled, coal chain seriously disrupted, farmers lose crops, small manufacturing retail and restaurants which are important for employment are seriously damaged (Andrew, 2015:7). According to Jackson (2015:28), being able to guarantee business operations under the current environment of unreliable electricity supply doesn't stop at installing generators, it demands the ability of electricity administrators to keep on the lights even when the power is off. Most needed skills to guarantee such security is a major challenge for Eskom. Burrows (2015:14) views that the dynamics towards low power is very complex to the extent that there is no point for some business sectors to even mitigate electricity shortage to be up and running, while clients cannot buy services since power shortages from their side will avert purchase. Alternatively, mitigation strategies are very expensive, adding to the operational cost. Mannak (2015:3) highlights that Shoprite, South Africa's largest supermarket chain, report an R168 million spend to run diesel generators for just 2014 December alone.

4.2.3.1 Economic implications

Bah and Azam (2017) mention that there is a significant relationship between electricity and economic growth in South Africa. The IDC (2015:8) and Hedden (2015:7) concur that the economy is seriously constrained with the impact of insufficient and unreliable electricity supply. Stat SA (2015:2) points out that the low electricity supply immensely affected the production chain, causing a sharp contraction in major industries such as mining, manufacturing and service industries, lowering the economic growth. Tesfachew *et al.* (2015:2) note that the service sector is not only a key player in economic development but also on social development. Kumo *et al.* (2016:2) agree that economic growth decline by 1.5 percent in 2014 to 1.3 percent in 2015, while growth is forecast to further weaken by 0.7 percent in 2016 as low-efficient electricity and business confidence continue to restrain the growth of economic activity. The South African Reserve Bank (SARB) (2016:1) points out that economic growth

has decelerated markedly since 2011. During 2015, forecasts suggest growth will be less than 1 % during 2016. It is the most sluggish pace of expansion since the Great Recession and such only experienced last during the emerging-market crisis of 1998.

SARB (2016:1) highlights this disappointing growth outcome has been mostly traceable to shocks from the electricity crisis. Consumer and business confidence reached a 24 year-low in historical perspective by the first quarter of 2016. Laubscher (2008:14) says dealing with electricity-related shocks cannot be the sole responsibility of the monetary authority. For the good of the economy all individuals, entities and the public sector need to play a role. Van der Nest (2015:1) states that the effect of low electricity supply has caused a decline in industrial performance, which is greatly felt in the South African economy. Makgetla (2008:10) says a major concern of the electricity crisis was experienced within the export industries, especially the mining sector. The mining value comprises close to 60 percent of all South African exports. Van der Nest (2015:1) agrees that South Africa relies strongly on the exports of some of its industrial commodities which most are energy intensive, such as precious metals to finance its current account deficit. Disruptions from load shedding have negatively impacted on production and consequently economic growth.

Several rating agencies have also downgraded the country's credit rating, which has had a negative impact on the outlook of the country as an investment destination. Green (2017:1) reports that rating agencies, Fitch, Standard & Poor (S&P) downgraded South Africa to junk status for the first quarter of 2017. Green alludes the rating agencies perceive the South African economic environment as characterised with uncertainties affecting creditworthiness and the willingness of investors to consider South Africa as an investment destination. Brown and Van Rensburg (2016:1) highlight that Moody's existing ratings are just two marks above junk status. Should there be any more downgrades, the rand might move to a historic low. Bloomberg (2017:20) states that J.P. Morgan has already announced that it will be removing South Africa from its investment grade emerging market bond indexes following the downgrades. Oxford (2015:12) says electricity administrators' failure to recognise the growing threat about electricity adequacy has cost the country billions of Rands and it is yet to incur the country's economy the harshest financial loss should there be any occurrence of blackouts ahead.

Van der Nest (2015:1) says Chris Yelland, a South African energy expert, gave a press release on the estimated cost of blackouts on the South Africa economy. Yelland points out that Stage 1 load shedding resulting in 10 hours of blackouts per day for 20 days a month results in losses

of R20 billion per month. Using the same parameters, Stage 2 load shedding costs the economy R40 billion per month and Stage 3 was estimated to have cost R80 billion per month. Mike Schussler presented a different view on an interview by Biz4Afrika in August 2015, highlighting that load shedding on industries cost the economy R15 to 20 million for every five hours of lights out. This slow industrial growth is also felt in the utility industry as reflected in figure 4.1.

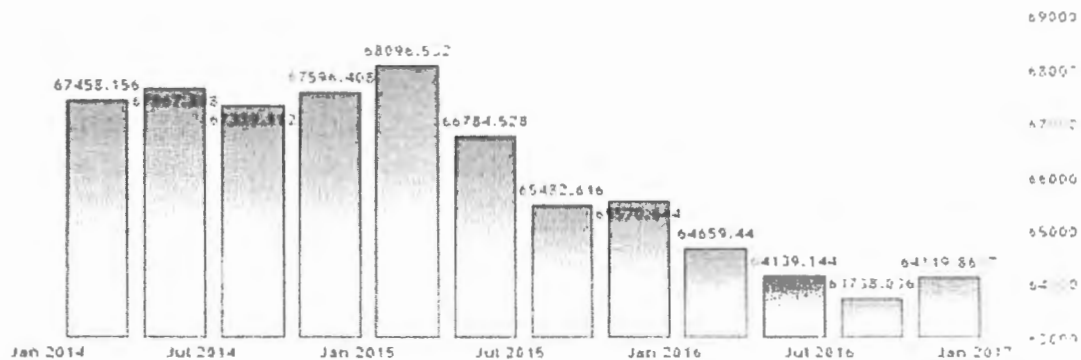


Figure 4.1 South African GDP from utilities from 2014 to 2017
Trading economic (2017)

Figure 4.1 reflects that GDP from utilities has been on a constant decrease since the first quarter of 2014.

4.3 Methodology

According to Prasad (2015), research methodology is the preferred research procedures utilised in achieving the research goals. It involves methods and techniques for an empirical research and holds the most important role in knowledge development to an empirical investigation. The research design used in this paper was the quantitative research design. Kumar (2011:74) points out that a research design is important as it set the procedures to be applied by a researcher in answering postulated empirical research questions accurately. Pandey and Pandey (2015:18) concur that the research design is the developed map out a plan to guide an empirical research study. Punch (2009:112) highlights that the research design situates the researcher in the empirical world and connect the research questions to data. Creswell (2013:3) states that quantitative research design achieves research objectives by investigating the association between variables. Variables are measured, with the aid of instruments with numbered data, to conduct analyses using statistical procedures.

4.3.1 Population and sampling

Prasad (2015) points out that in social science research, a population is a unit of which a sample is to be developed, with consideration of the characteristics of the population. Mason (2014:140) identifies sampling to be selected respondents from the larger population under survey. The empirical research in this paper is based on the industrial sectors of the Gauteng and North West provinces. However, the Gauteng and the North West province was the considered geography for participating entities. Conducting empirical research in Gauteng was based on the provincial economic strength and its role as the stamina of the South African economy, contributing 33.8 % to the national GDP. Gauteng is currently rated as the economic hub in South Africa. The North West province was selected since it was necessary to also target a provincial location with a slow-paced economic growth. This made it possible to determine the impact of supply inadequacy on entities' operating in a more economically viable environment as compared to a less viable economic environment. The North West economy is among the lowest contributors to the economic growth with a GDP of just 6.8 %. The empirical research focused on specific sampled geographies from each of the selected provinces. In the North West province, Mafikeng, Rustenburg, Lichtenburg and Klerksdorp were targeted, while Pretoria and Johannesburg were target cities for the Gauteng province.

The industrial empirical research was focused towards industrial growth and competitiveness. The empirical research mainly considered the industrial sectors that are the nucleus towards industrial development in South Africa. The target industries include the mining, manufacturing and commercial organisations. Industrial development corporation (IDC) (2013:6-7) assessed the economic trends from 1994 and outlined that the services, manufacturing and mining sectors have been the spine of the South African economy. The services dominate the tertiary industry through financials, wholesale, retailing and motor trade. The secondary industry is dominated by manufacturing through construction. In the primary industry, mining has been a significant growth contributor compared to agriculture, fishing and forestry.

The non-probability sampling method, purposive-convenience sampling was used in targeting participating industries. Patton (2015:264) says purposive sampling involves the targeting of participants with the relevant knowledge to the subject under inquiry to acquire reliable data. This approach was employed to target industrial categories with the significant industrial trend to the South African industrial growth and employees with reliable information on the operationalisation of organisations. Etikan *et al.* (2016) refer to convenience sampling as a non-

probability sampling, in which information from the target population is based on elements such as a participant accessibility, willingness to participate and availability to the researcher. Through convenience sampling, an adequate participatory size was obtained. However, the quota sampling guidelines were utilised to enable a proportionate representation of each target group. This made it possible for the empirical research to discover the heterogeneity among the different enterprise categories within an industry.

Yang and Ahmad (2014) say targeting participants by the quota sampling guidelines ensure sufficient representation of target sub-groups in the population and enables the possibility to identify heterogeneous characteristics on each group about the identified agenda of the empirical research. The sampled enterprise categories per industry includes Services (Financials and cold-chain supermarkets), Manufacturing (construction and chemicals) and Mining (Minerals and mine purification).

Sampling for the industrial sector empirical research was estimated from available (secondary) data sources from the chamber of commerce's based on sampled provincial geographies. The National Bureau for Economic Research outlined that the focused geographies have an estimate of 60,000 formal entities from the sampled sectors. Thus, sampling was generated based on indications from an appropriate Systems of National Accounts (SNA). McCulla *et al.* (2015:1) highlight that these are statistical databases that provide consistent historical time series measures of a nation's production, income, saving, investment and also comparisons of economic activity across a country's regions to determine economic developments. It was considered acceptable that 100 enterprises should represent each industrial sector. Participants per groups were considered to be 50 per industry category summing up to a total sample of 300. A total of 223 questionnaires were obtained from the fieldwork. It should be noted that empirical research only targeted the mining industry in the North West, due to limited mining activities in the Gauteng province. Mining in the North West is responsible for over 40% of total mining in South Africa. However, over 70% of mining activities in the area is solely conducted by three large mining conglomerates (Anglo Gold, Ashanti Gold and Impala Mines). This account for a low representation of the mining industry in the empirical research.

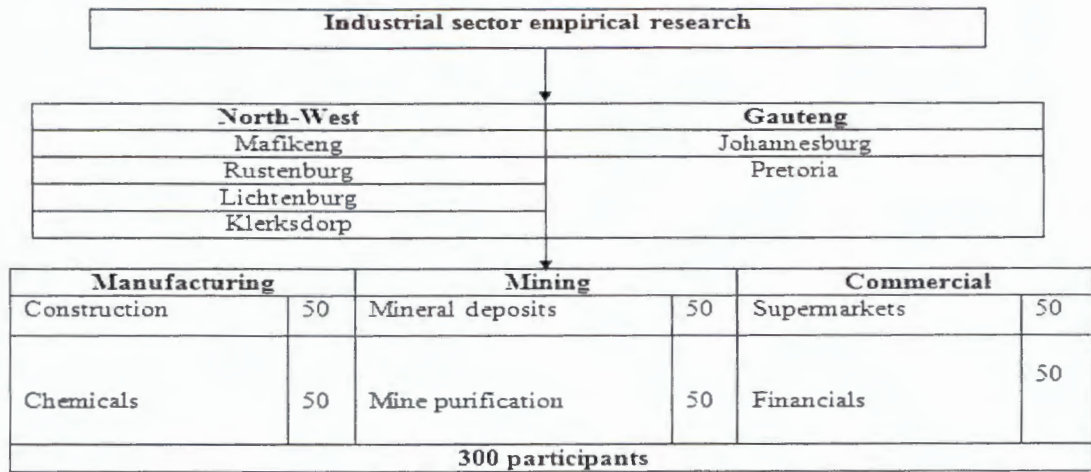


Figure 4.2 Summary of population and sampling

4.3.2 Data collection method

The data collection employed close-ended questionnaires with defined categories to examining the effect of low electrical power supply on the industrial growth in South Africa. The Questionnaire was structured under biography and profile and two main themes with each having sub-categories as reflected in Table 4.2.

Table 4.2 Questionnaire structure for industrial sector empirical research

Industrial sector empirical research	
Sections	Themes
Section A	Biography and profile
Section B	Supply adequacy: importance electrical energy, supply sufficiency, operational vulnerabilities and business performance
Section C	Control programmes: mitigation control and intensity control

Items on the questionnaire included nominal, dichotomous and Likert scaled questions. Field-workers were utilised due to the massiveness of the empirical research study. Selection of field workers was based on academic fieldwork experience. Field-workers were strictly postgraduate students with a well-experienced background on data collection for social science empirical research. Physical discussions were held with field-workers to advise on the data collection procedures. Due to the complexity of the empirical investigation, reliability of data was very important. Only filled questionnaires with a business stamp from participating enterprises were considered for data analysis.

4.4 Data analysis

The IBM Statistical Package for Social Science statistics version 23 as prescribed by SPSS Inc (2016) was used in analysing data. According to SPSS Inc (2016), the SPSS software is an advanced and professional application in analysing data. To enable analyses, questions had to be coded. The various analytical tests performed in the article is presented in Table 4.3.

Table 4.3 Conduct tests for industrial sector data analysis

Conduct tests for industrial sector data analysis (objective 3)	
Test Categories	Test types
<i>Descriptive statistics</i>	Means (M)
	Standard deviations (SD)
	Percentages
	Frequencies
<i>Cronbach alpha</i>	Reliability test
<i>Independent test</i>	Effect size
<i>One way test</i>	ANOVA
	Welch test
<i>Correlation test</i>	Spearman rank coefficients
<i>Chi-Square</i>	Pearson Chi-Square

Table 4.3 reflects a break-down of all analyses performed in this article. Conducted tests are presented in the following sections.

4.4.1 Presentation and interpretation of descriptive results

The following section present results and the interpretation of data for all analysed test results mentioned on table 4.2. Results are presented in tables containing required tests for every individual section.

4.4.1.1 Descriptive statistics for biography and profile

This section of data presentation and interpretation will discuss results based on frequencies, percentages, means (M) and standard deviation (SD)

Table 4.4 Description of participants across sampled provinces

Code	Province	Frequency	Percentage
1	Gauteng	124	55.60%
2	North West	99	44.40%
			100%

Table 4.4 reflects the total participants per sampled province. In total, 223 enterprises responded to questionnaires. Results reflect that Gauteng province contributes to 55.6% of the total sample. The North West province contribute to 44.4% of the sample.

Table 4.5 Description of participating enterprise categories per sampled industries

Code	Sector	Industry	Frequency	Percentage
1	Supermarkets	Services	82	36.80%
2	Financials	Services	41	18.40%
3	Constructions	Manufacturing	53	23.80%
4	Chemicals	Manufacturing	41	18.80%
5	Minerals	Mining	2	0.90%
6	Mining purification	Mining	4	1.80%
			223	100%

Table 4.5 reflects the outcome from the different sampled enterprise categories per industry. The services and manufacturing industries were the most represented industries with a total of 55.2% and 42.2% respectively. The mining industry was the least represented with 2.7% in total.

Table 4.6 Profile description of participants

Code	Profile category	Percentage	Summary
Capacity in the organisation			Managers and owners were the main participants with 73.4% and 11.7% respectively
1	Owner	11.70%	
2	Manager	73.40%	
2	Director	9.90%	
3	CEO	1.80%	
4	Sole proprietor	3.20%	
		100%	
Gender			Male participants were most represented with a total of 65.5%
1	Male	65.50%	
2	Female	34.50%	
		100%	
Highest qualification			A majority of the participants had diploma and degree with a total of 38% and 32.1% respectively
1	Grade 12 and below	18.10%	
2	Diploma	38%	
3	Degree	32.10%	
4	Post Graduate	11.80%	
		100%	
Years of employment			A majority of the participants have been on their employment from 0-5 years and 6-10 years
1	0 to 5	38.20%	
2	6 to 10	29.10%	
3	11 to 15	17.90%	
4	16 to 20	10.30%	
5	More than 20	4.50%	
		100%	
Business size			Medium and large businesses were significant participants making up a total of 39.2% and 29.2% respectively. Small and micro business only made up 31.6%
1	Small	15.80%	
2	Micro	15.80%	
3	Medium	39.20%	
4	Large	29.20%	
		100%	
Monthly expenditure on electricity			Majority of the participants spend within R5,001 - R10,000 and R10,001 - R15,000 on electricity. The expenditure ranges reflect percentages of 38.1% and 28.7% respectively
1	R5,001 - R10000	38.10%	
2	R10,001 - R15,000	28.70%	
3	R15,001 - R20,000	11.70%	
4	R20,001 - R25,000	7.20%	
5	R25,001 - R30,000	5.40%	
6	More than R30,000	9%	
		100%	
Cost per unit of electricity			In most cases participants note that their expenditure per unit of electricity is R1.5cent - R2 and R3.1cent to R4. These costs per unit reflect percentages of 21.1% and 25.1% respectively
1	0.8cent - 0.16 cent	16.10%	
2	0.17 cent - R1.50cent	13%	
3	R1.5cent - R2	21.10%	
4	R2.1cent to R3	9%	
5	R3.1cent to R4	25.10%	
6	More than R4	15.70%	
		100%	
Electricity meter			A majority of the 83.4% utilises the conventional meter system
1	Prepaid meters	16.60%	
2	Conventional meters	83.40%	
		100%	

Table 4.6 reflects the responses of participants' profile. Owners and managers were the majority of participants adding up to a total of 85.1%. Most participants have been employed 0 to 5 years (38.2%) and 6 to 10 years (29.1%). Medium sized enterprise's representation contributes 39.2% of the participants. Most enterprises spends between R5 000 to R10 000 on monthly electricity purchases. Eighty-four point four (84.4%) of the participants utilises the conventional metering system as opposed to prepaid meters.

4.4.1.2 Description statistics for levels of supply adequacy

The following section shall present results for supply adequacy section and its sub-elements; electrical energy importance, supply sufficiency, operational vulnerability and business performance.

Table 4.7 Importance of electrical energy

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1. Electrical energy is mainly used as energy source	1 Strongly disagree	0.10%	4.43	0.65	45.7% and 49.8% of the participants agreed and strongly agreed that electrical is the main energy source for business operations
	2 Disagree	2.20%			
	3 Neutral	2.20%			
	4 Agree	45.70%			
	5 Strongly agree	49.80%			
2. Electricity disruptions has a negative effect on your company's production levels	1 Strongly disagree	0.40%	4.39	0.76	37.7% and 52% agreed and strongly agreed. 7.6% of the participants were neutral while a total 2.6% gave a disagreed response
	2 Disagree	2.20%			
	3 Neutral	7.60%			
	4 Agree	37.70%			
	5 Strongly agree	52%			
3. Consistency in electricity supply is necessary for your business growth	1 Strongly disagree	0.40%	4.50	0.70	35.9% and 58.7% of the participants agreed and strongly agreed that electricity consistency is necessary for business growth
	2 Disagree	2.20%			
	3 Neutral	2.70%			
	4 Agree	35.90%			
	5 Strongly agree	58.70%			

Table 4.7 presents results for participants' opinions to the importance of electrical energy as an energy source for business operations. The majority of the participants gave a positive response that electrical energy is the main energy source ($M = 4.43$, $SD = 0.65$). Participants agreed that electricity disruptions affect their production levels ($M = 4.39$, $SD = 0.76$). The majority of the participants agreed that consistency in electricity is necessary for business growth ($M = 4.50$, $SD = 0.70$).

Table 4.8 Supply sufficiency

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1.Electricity supply volumes is sufficient to meet business demand	1 Strongly disagree	22.40%	2.37	1.17	44.8% and 22.4% of the participants disagreed and strongly disagreed that electricity supply volumes is sufficient to meet demand
	2 Disagree	44.80%			
	3 Neutral	13.90%			
	4 Agree	10.80%			
	5 Strongly agree	8.10%			
2.Your organisation is optimistic about future consistency in electricity supply	1 Strongly disagree	19.30%	2.43	1.13	44.4% and 19.3% of the participants disagreed and strongly disagreed that they are not optimistic on future consistency in supply
	2 Disagree	44.40%			
	3 Neutral	16.10%			
	4 Agree	13.90%			
	5 Strongly agree	6.30%			
3.Currently in South Africa, businesses are operating in an energy crisis environment	1 Strongly disagree	8.10%	3.42	1.27	31.4% and 23.8% of the participants agreed and strongly agreed that South Africa business environment is characterise by energy crisis
	2 Disagree	20.60%			
	3 Neutral	16.10%			
	4 Agree	31.40%			
	5 Strongly agree	23.80%			

Table 4.8 reflects results for electricity supply sufficiency to industries. The majority of the enterprises felt that electricity supply volumes are not sufficient to meet business demand ($M = 2.37$, $SD = 1.17$). Participants tend to disagree regarding being optimistic on future electricity consistency ($M = 2.43$, $SD = 1.13$). The majority of participants tend towards agreeing that South Africa are operating in an energy crisis environment ($M = 3.42$, $SD = 1.27$).

Table 4.9 Operational vulnerabilities

Statements	Scale points	Percentage	Mean	Standard deviation
1.Your organization's production reliability is affected negatively by inadequate electricity supply	1 Strongly disagree	0.40%	4.13	0.76
	2 Disagree	2.70%		
	3 Neutral	12.60%		
	4 Agree	51.60%		
	5 Strongly agree	32.70%		
2.Your organization have experienced industrial equipment damages due to inconsistent electricity supply	1 Strongly disagree	3.10%	3.68	0.95
	2 Disagree	8.50%		
	3 Neutral	21.50%		
	4 Agree	50.70%		
	5 Strongly agree	16.10%		
3.Electricity supply inconsistency contributed towards a reduced workforce (labour) in your organisation	1 Strongly disagree	4.90%	3.55	1.10
	2 Disagree	16.60%		
	3 Neutral	13.90%		
	4 Agree	48.00%		
	5 Strongly agree	16.60%		
4.Production deadlines have been influenced negatively by electricity supply inadequacy	1 Strongly disagree	1.30%	3.92	0.93
	2 Disagree	9.40%		
	3 Neutral	11.70%		
	4 Agree	51.10%		
	5 Strongly agree	26.50%		
5.Electricity inconsistency has a negative effect on employee motivation levels in your organisation	1 Strongly disagree	1.80%	3.86	0.91
	2 Disagree	8.10%		
	3 Neutral	14.80%		
	4 Agree	52.90%		
	5 Strongly agree	22.40%		
6.a. Productive working hours are being reduced due to electricity supply inadequacy	1 Strongly Disagree	2.70%	3.75	0.91
	2 Disagree	7.60%		
	3 Neutral	17.90%		
	4 Agree	55.20%		
	5 Strongly agree	16.60%		
6.b. Productive working hours are being reduced due to electricity supply disruptions	1 Strongly disagree	2.20%	3.89	0.95
	2 Disagree	8.10%		
	3 Neutral	13.90%		
	4 Agree	50.20%		
	5 Strongly agree	25.60%		
7.Electricity supply inadequacy caused a decline in your product range (product lines closure etc.)	1 Strongly disagree	1.80%	3.77	0.92
	2 Disagree	9.90%		
	3 Neutral	16.10%		
	4 Agree	53.80%		
	5 Strongly disagree	18.40%		
8.a.Electricity supply inadequacy had a negative influence on communication technology infrastructure in your organisation	1 Strongly disagree	2.70%	3.86	0.93
	2 Disagree	7.20%		
	3 Neutral	13.50%		
	4 Agree	55%		
	5 Strongly disagree	21.60%		
8.b.Electricity supply inadequacy resulted in a loss of data in your organisation	1 Strongly disagree	3.60%	3.73	0.99
	2 Disagree	9%		
	3 Neutral	17.60%		
	4 Agree	50.50%		
	5 Strongly disagree	19.40%		
9.Electricity supply inadequacy has a negative effect on investments possibilities in your industry	1 Strongly disagree	3.20%	3.86	0.99
	2 Disagree	8.10%		
	3 Neutral	13.60%		
	4 Agree	49.80%		
	5 Strongly disagree	25.30%		
10.a.Electricity supply inadequacy has a negatively effect on financial market behavior in your industry in the short-term	1 Strongly disagree	2.30%	3.79	0.88
	2 Disagree	7.20%		
	3 Neutral	16.20%		
	4 Agree	58.10%		
	5 Strongly disagree	16.20%		
10.b.Electricity supply inadequacy has a negatively effect on financial market behavior in your industry in the long-term	1 Strongly disagree	2.30%	3.87	0.98
	2 Disagree	8.10%		
	3 Neutral	17.10%		
	4 Agree	45%		
	5 Strongly disagree	27.50%		
11.Your company have lost direct investment possibilities due to electricity uncertainties	1 Strongly disagree	6.80%	3.64	1.12
	2 Disagree	9.90%		
	3 Neutral	16.70%		
	4 Agree	45.90%		
	5 Strongly agree	20.70%		
12.Electricity cost has a significant effect on profit margins in your organisation	1 Strongly disagree	3.60%	3.82	0.97
	2 Disagree	6.30%		
	3 Neutral	17.60%		
	4 Agree	50%		
	5 Strongly agree	22.50%		
13. Electricity price increases are being spiraled down to the final consumer (business's)	1 Strongly disagree	3.20%	3.85	0.98
	2 Disagree	6.30%		
	3 Neutral	18.90%		
	4 Agree	45.90%		
	5 Strongly agree	25.70%		

Table 4.9 contains operational vulnerability results. Results reflect that a total of 84.3% agreed that production reliability is affected ($M = 4.13$, $SD = 0.76$). A total of 66.8% agreed that equipment damages had been experienced in their enterprise due to inconsistency in electricity supply ($M = 3.68$, $SD = 0.95$). Sixty-four point six percent (64.6%) of participants agreed that electricity inconsistency has contributed towards a reduced workforce in their enterprises ($M = 3.55$, $SD = 1.10$). A total of 77.6% agreed that production deadlines had been influenced negatively by electricity inadequacy ($M = 3.92$, $SD = 0.93$). A total of 75.3% agreed that electricity inconsistency affected employees motivation to work ($M = 3.86$, $SD = 0.91$). A total of 71.8% and 75.8% of participants agreed that working hours are reduced due to electricity inadequacy and disruptions ($M = 3.75$, $SD = 0.91$) and ($M = 3.89$, $SD = 0.95$) respectively.

A total of 72.2% agreed that electricity supply inadequacy has caused a decline in product range (product line decline) ($M = 3.77$, $SD = 0.92$). Seventy-one point six percent (71.6%) and 69.9% respectively agreed that electricity supply inadequacy has affected communication technology infrastructure ($M = 3.86$, $SD = 0.93$) and loss of data ($M = 3.73$, $SD = 0.99$). A total of 75.1% agreed that electricity inadequacy has a negative effect on investment possibilities in the industry ($M = 3.86$, $SD = 0.99$). Seventy-four point three percent (74.3%) and 70.5% agreed that electricity inadequacy has affected the financial markets in the short term ($M = 3.79$, $SD = 0.88$) and long term and ($M = 3.89$, $SD = 0.98$) respectively. A total of 66.6% agreed that there have been losses of direct investments due to electricity uncertainty ($M = 3.64$, $SD = 1.12$). A total of 72.5 % agreed that electricity cost has a significant effect on enterprises' profit margins ($M = 3.82$, $SD = 0.97$). A total of 71.6% agreed that electricity price increases are being spiraled down to enterprises ($M = 3.85$, $SD = 0.98$).

Table 4.10 Business performance

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1. Your business growth (linked to performance) has declined since 2007 due to instability of electricity supply	1 Strongly disagree	4.50%	3.73	1.02	53.2% and 19.4% of the participants agreed and strongly agreed that business growth has decline since 2007 due to electricity crisis
	2 Disagree	9.90%			
	3 Neutral	13.10%			
	4 Agree	53.20%			
	5 Strongly agree	19.40%			
2. Your business growth (linked to performance) has declined since 2007 due to the general economic downturn	1 Strongly disagree	3.60%	3.78	1.02	51.4% and 22.1% of the participants agreed and strongly agreed that business growth has decline since 2007 due to economic downturn
	2 Disagree	10.40%			
	4 Agree	51.40%			
	5 Strongly agree	22.10%			

Table 4.10 presents results on the assessment of electricity inconsistency and economic downturn on business performance from 2007. The majority of the participants agreed that

electricity inconsistency had affected business performance since 2007 ($M = 3.73$, $SD = 1.02$). The majority of the participants also agreed that economic downturn had affected business performance as of 2007 ($M = 3.78$, 1.02). Results reflect that electricity consistency is eminent for economic growth as supported in the literature review.

Table 4.11 Organizational electricity inconsistency mitigation programmes

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1. Your organisation have an adequate understanding of electricity crisis management programs (e.g alternative power sources)	1 Strongly disagree	7.20%	3.47	1.17	47.3% and 16.2% of the participants agreed and strongly agreed respectively that their organisation understands electricity crisis management. Is note worthy that a total of 25.7% gave a negative response
	2 Disagree	18.50%			
	3 Neutral	10.80%			
	4 Agree	47.30%			
	5 Strongly agree	16.20%			
2. Electricity crisis management programs have been successfully implemented in your organisation	1 Strongly disagree	10.80%	2.84	1.24	40.5% and 10.8% of the participants disagreed and strongly disagreed respectively on their organisations successfully implementing crisis management programs
	2 Disagree	40.50%			
	3 Neutral	15.30%			
	4 Agree	20.30%			
	5 Strongly agree	13.10%			
3. Alternative electricity generating systems (for example solar power and generators) have been adopted successfully	1 Strongly disagree	18.90%	2.65	1.24	35.1% and 18% of the participants disagreed and strongly disagreed respectively that alternative electricity generating systems have been adopted in the organisation
	2 Disagree	35.10%			
	3 Neutral	17.10%			
	4 Agree	19.80%			
	5 Strongly agree	9%			
4. The organization's alternative power systems is capable of solving any form of grid short-fall	1 Strongly disagree	18.90%	2.43	1.13	47.3% and 18.9% of the participants disagreed and strongly disagreed respectively that alternative power sources is capable of solving grid short-fall
	2 Disagree	47.30%			
	3 Neutral	10.40%			
	4 Agree	18.50%			
	5 Strongly agree	5%			
5. Your organisation have been able to acquire investors to sponsor your energy mitigation programmes	1 Strongly disagree	25.70%	2.24	1.07	A total of 69.4% of the participants disagreed, while 20% of the participants agreed that they able to acquire investors to sponsor their mitigation programmes
	2 Disagree	43.70%			
	3 Neutral	14%			
	4 Agree	14%			
	5 Strongly agree	2.70%			
6. Trade unions are involved with the stabilizing of electricity supply (strategic discussions with suppliers)	1 Strongly Disagree	26.10%	2.17	0.96	A total of 68.4% of the participants disagreed that trade unions get involved in stabilising electricity supply to industries
	2 Disagree	42.30%			
	3 Neutral	21.20%			
	4 Agree	9%			
	5 Strongly agree	1.40%			
7. Commercial business forums are involved with the stabilising of electricity supply (strategic discussions with suppliers)	1 Strongly disagree	19.40%	2.42	1.09	A total of 61.3% of the participants disagreed that business forums get involved in stabilising electricity supply to industries
	2 Disagree	41.90%			
	3 Neutral	20.70%			
	4 Agree	13.10%			
	5 Strongly agree	5%			

Table 4.11 presents descriptive statistics for the electricity inconsistency mitigation programmes section. Results reflect that participants felt neutral tending to agree that their enterprises have an adequate understanding of electricity crisis management ($M = 3.47$, $SD = 1.17$). Participants also tend towards being neutral that enterprises have successfully

implemented electricity crisis management programs ($M = 2.84$, $SD = 1.24$). Respondents felt neutral tending towards disagreeing that alternative electricity generating system has been adopted successfully ($M = 2.65$, $SD = 1.24$). More than half of the participants noted that alternative power sources are not capable of solving shortfalls of the grid ($M = 2.43$, $SD = 1.13$). Participants mostly disagree to have acquired investors to sponsor energy mitigation plans ($M = 2.24$, $SD = 1.07$). Participants disagree that trade unions and business forums are involved in stabilising electricity supply to the industrial sector ($M = 2.17$ and $SD = 0.96$) and ($M = 2.42$ and $SD = 1.09$) respectively.

Table 4.12 Industrial electricity intensity control

Statements	Scale points	Percentage	Mean	Standard deviation	Conclusions
1.Electricity efficiency within your industry is important to the public sector (NERSA / DME).	1 Strongly disagree	9%	3.19	1.24	Results reflect neutral with 25.2%, 23.9% and 23.9% of the participants agreeing, disagreeing and neutral respectively
	2 Disagree	23.90%			
	3 Neutral	23.90%			
	4 Agree	25.20%			
	5 Strongly agree	18%			
2.a.Electricity distribution control programs have been introduced successfully to stabilize intensity in high demand industries	1 Strongly disagree	12.20%	3.00	1.26	Results reflect neutral. A total of 41.5% and 40.1% of the participants gave an agreed and disagreed opinion respectively
	2 Disagree	29.30%			
	3 Neutral	18.50%			
	4 Agree	26.10%			
	5 Strongly agree	14%			
2.b.Electricity distribution control programs have been introduced successfully to stabilize intensity in low demand industries	1 Strongly disagree	11.30%	2.77	1.12	A total of 47.3% of the participants gave a disagreed opinion
	2 Disagree	36%			
	3 Neutral	23.40%			
	4 Agree	22.50%			
	5 Strongly agree	6.80%			
3.Conservation of available power has become a major focus in your business strategy	1 Strongly disagree	18%	2.61	1.23	Most participants of 50.9% disagreed towards considering the conservation of available power as a major focus in their business strategies
	2 Disagree	39.20%			
	3 Neutral	17.10%			
	4 Agree	15.30%			
	5 Strongly agree	10.40%			
4.a.Your organisation take part in efficiency programmes such as reducing electricity consumption	1 Strongly disagree	26.60%	2.38	1.21	A total of 64.4 % of the participants disagreed in regulating their electricity consumption
	2 Disagree	37.80%			
	3 Neutral	12.60%			
	4 Agree	17.10%			
	5 Strongly agree	5.90%			
4.b.Your organisation take part in programmes such as instituting guidelines towards emission control	1 Strongly Disagree	23.40%	2.35	1.11	A total of 64.4% of the participants do not have guidelines towards emission control
	2 Disagree	41%			
	3 Neutral	17.10%			
	4 Agree	14%			
	5 Strongly agree	4.50%			
4.c.Your organisation take part in efficiency programmes such as facing-off energy intensive operational activities	1 Strongly disagree	23.90%	2.55	1.24	A total of 54.5% of the participants note that their organisations have not considered facing off energy intensive activities
	2 Disagree	30.60%			
	3 Neutral	18.90%			
	4 Agree	19.40%			
	5 Strongly agree	7.20%			
5.a.Administrators (Eskom, NERSA);levy penalties in cases of non-compliance to efficiency control policies	1 Strongly disagree	15.80%	2.51	1.05	A total of 56.3% of the participants disagreed that administrators levy penalties on non-compliance to efficiency control
	2 Disagree	40.50%			
	3 Neutral	24.30%			
	4 Agree	15.80%			
	5 Strongly disagree	3.60%			
5.b.Administrators (Eskom, NERSA);ensure administration in cases of levy to non-compliance to efficiency control policies	1 Strongly disagree	21.20%	2.30	0.98	A total of 64% of the participants disagreed that administrators ensure administration to non compliance to efficiency control
	2 Disagree	42.80%			
	3 Neutral	21.60%			
	4 Agree	14%			
	5 Strongly disagree	0.90%			
6.There is a general corporate awareness towards efficient use of electricity	1 Strongly disagree	18.50%	2.53	1.14	A total of 57.7% of the participants disagreed that the is general corporate awareness to the efficient use of electricity
	2 Disagree	39.20%			
	3 Neutral	18.90%			
	4 Agree	18%			
	5 Strongly disagree	5.40%			
7.a.The general organisation attitude towards energy control is positive	1 Strongly disagree	12.60%	2.91	1.24	A 45.5% of the participants disagreed that is general positive organisation attitude towards energy control
	2 Disagree	32.90%			
	3 Neutral	18%			
	4 Agree	24.30%			
	5 Strongly disagree	12.20%			
7.b.The general organisation attitude towards energy control is negative	1 Strongly disagree	8.60%	3.26	1.12	A total of 48.9% agreed that general organisational attitude is negative on energy control
	2 Disagree	16.30%			
	3 Neutral	26.20%			
	4 Agree	38%			
	5 Strongly agree	10.90%			
8.Do you think that controlling industrial energy consumption is important	1 Strongly disagree	5.40%	3.47	1.21	A total of 57.6% of the participants feels controlling industrial energy consumption is important, while a 27.9% responded disagreed
	2 Disagree	22.50%			
	3 Neutral	14.40%			
	4 Agree	35.10%			
	5 Strongly disagree	22.50%			
9.Administrators have established guidelines towards emission control	1 Strongly disagree	16.70%	2.60	1.14	A total of 55% of the participants opinion that administrators have not establish guidelines towards emission control
	2 Disagree	38.30%			
	3 Neutral	18.50%			
	4 Agree	21.60%			
	5 Strongly agree	5%			

Table 4.12 presents outcomes for industrial electricity intensity control. Respondents were neutral towards the importance of industrial electricity efficiency to the public sector ($M = 3.19$, $SD = 1.24$). The respondents were neutral towards the statements ‘electricity distribution programmes which have been introduced successfully to stabilise intensity in high demand industries ($M = 3.00$, $SD = 1.26$), as well as that electricity distribution programmes, have been introduced successfully to stabilise intensity in low demand industries ($M = 2.77$, $SD = 1.12$). Respondents tend toward feeling neutral in the conservation of available power that has become a major focal point in business strategies ($M = 2.61$, $SD = 1.23$). Participants disagreed that organizations take part in efficiency programs such as [(4a): reducing electricity consumptions ($M = 2.38$, $SD = 1.21$), (4b): emission control ($M = 2.35$, $SD = 1.11$) and (4c): facing-off energy-intensive activities ($M = 2.55$, $SD = 1.24$)].

Respondents tend to disagree that electricity administrators levy penalties (5a) and ensure administration of penalties (5b), to non-compliance of efficiency control policies ($M = 2.51$, $SD = 1.05$) and ($M = 2.30$, $SD = 0.98$) respectively. Opinions tend towards disagreeing that there is a general corporate awareness towards the efficient use of electricity in enterprises ($M = 2.53$, $SD = 1.14$). Participants disagreed tending towards neutral on (statement 7a), that enterprises’ attitude towards energy control is positive ($M = 2.53$, $SD = 1.14$) and tend to be neutral on (statement 7b), that enterprises’ attitude towards energy control is negative ($M = 2.91$, $SD = 1.24$). Opinions were neutral respectively for (statement 8), the importance to control industrial energy consumption ($M = 3.26$, $SD = 1.12$) and (statement 9), administrators efficiency on establishing emission guidelines ($M = 3.47$, $SD = 1.21$).

Table 4.13 Dichotomous outcome to intensity control

Statements	Yes	No	Partially
Would you be interested in participating in energy saving activities	42.60%	18.40%	39%

Table 4.13 reflects results to the dichotomous question as being interested in participating in energy-saving activities. Surprisingly just over 42.6% gave a positive response. Eighteen point four percent (18.4%) note that their organisations will not, while 39% note a partial interest.

4.4.2 Reliability test (Cronbach Alpha)

Cronbach (1951) says Alpha reliability is a type of internal consistency coefficient that evaluates items scored in multiple answer categories. Ritter (2010:3-4) points out that the Cronbach definition implies that the Alpha measures their reliability of consistency of the

individual's scores across equivalent measurement forms. Sharma (2016) concurs and highlights that reliability exists if there is a transverse consistency on measurement forms. For an exploratory study such as this, reliability >0.5 and < 0.07 is good. However, reliability is considered as very good or excellent if it is >0.7 . Field (2014:708-709) states that due to several dynamics relating to what should be accepted as a reliable Alpha for analysis, values of 0.5 or above will be sufficient.

Table 4.14 Reliability test results

Variables	Cronbach's alpha
Electrical energy importance	0.75
Supply sufficiency	0.31
Operational vulnerabilities	0.81
Business performance	0.76
Mitigation control programs	0.74
Intensity control programs	0.74

Table 4.14 reflects Cronbach alphas for all constructs as indicated by the sections of the questionnaire. Results show that the Cronbach's alpha for all factors was deemed reliable with a result of 0.74 and above except for the supply sufficiency construct with a low Cronbach's alpha of 0.31. Due to this henceforth each statement from supply sufficiency construct will be considered separately. Spiliotopoulou (2009) argues that a low Cronbach alpha estimate does not imply problems with the construction of the tool. Likewise, large estimates do not necessarily suggest adequate reliability, as Cronbach's alpha is related to internal consistency of data scores. Spiliotopoulou suggests that Cronbach's estimates should be evaluated by taking into account the specificities of an empirical research before concluding on measures with an insufficient alpha. Basto and Pereira (2012) concur that inconsistency might be bound to happen as different sampling groups might lead to differences in opinion. An empirical research, with groups of different characteristics, has the tendency to reflect low consistency measures. Palant (2010:100) also states that for scales with a small number of items of less than 10, it is often difficult to get a decent Cronbach alpha value. Such was the case with the supply sufficiency construct. Due to the low-reliability score of supply sufficiency variable, it should be noted that the analysis henceforth shall consider each statement from supply sufficiency separately.

Table 4.15 Descriptive summary of factors

Factors	Mean	Standard deviation
Importance of electrical energy	4.43	0.58
Supply sufficiency (statement1)	2.37	1.17
Supply sufficiency(statement2)	2.43	1.13
Supply sufficiency (statement3)	3.42	1.27
Operational vulnerability	3.81	0.49
Business performance	3.75	0.92
Mitigation control	2.60	0.71
Intensity control	2.70	0.56

Table 4.15 presents a summary of participants' responses on constructs. The results reflect that participants, in general, agree that electrical energy is important for business operations ($M = 4.43$, $SD = 0.58$). Respondents had different views to the statements on the sufficiency of supply. Results reflect that organisations disagree with statement 1, ($M = 2.37$, $SD = 1.17$) and statement 2, ($M = 2.43$, $SD = 1.13$). Respondents were neutral on statement 3, ($M = 3.42$, $SD = 1.27$). Opinions tend to agree that enterprises are vulnerable ($M = 3.81$, $SD = 0.49$) and business performance is dropping ($M = 3.75$, $SD = 0.92$), due to electricity inconsistency. Outcome reflects opinions tending towards neutral on mitigation control ($M = 2.60$, $SD = 0.71$) and intensity control ($M = 2.70$, $SD = 0.56$). It should be noted that due to the small sample obtained from the mining industry, it is excluded from analysis henceforth.

4.4.3 ANOVA (*F*-test)

The one-way Analysis of Variance (ANOVA) test was conducted to assess whether or not there are differences in the opinions within the different business categories (supermarkets, financials, construction and chemicals) and the different industrial business size classifications (small, micro, medium and large) for sampled industries. Since a non-probability sample method was used and thus statistical inferences conclusions cannot be drawn effect sizes were used to determine the practical significance of any differences that might exist as suggested by Ellis and Steyn (2003). Effect sizes >0.2 , >0.5 and >0.8 reflect small, medium and large differences respectively. These can also be referred to as practically non-significant, practically visible and practically significant differences. A p -value <0.05 reflects that a significant statistical difference exists. The p -values are reported for completeness sake, but won't be interpreted since a non-probability sampling procedure was used and not probability sampling.

Table 4.16 ANOVA test for industrial sectors on variables

Factors	Business categories	Mean	Standard deviation	ANOVA p values	Welch p values	Effect sizes		
						Supermarket with...	Financials with...	Construction with...
Importance of electrical energy	Supermarket	4.54	0.48	0.04	0.08			
	Financials	4.48	0.44			0.13		
	Construction	4.26	0.71			0.40	0.31	
	Chemicals	4.42	0.61			0.20	0.10	0.23
Supply sufficiency(statement1)	Supermarket	2.55	1.39	0.21	0.21			
	Financials	2.29	0.98			0.18		
	Construction	2.28	1.08			0.19	0.01	
	Chemicals	2.10	0.90			0.32	0.20	0.17
Supply sufficiency (statement2)	Supermarket	2.62	1.20	0.17	0.19			
	Financials	2.46	0.97			0.13		
	Construction	2.23	1.05			0.33	0.23	
	Chemicals	2.28	1.17			0.29	0.16	0.04
Supply sufficiency(statement3)	Supermarket	3.13	1.25	<0.01	<0.01			
	Financials	3.98	0.85			0.67		
	Construction	3.09	1.41			0.03	0.62	
	Chemicals	3.90	1.19			0.61	0.06	0.57
Operational vulnerabilities	Supermarket	3.81	0.43	0.49	0.51			
	Financials	3.76	0.43			0.11		
	Construction	3.78	0.57			0.04	0.05	
	Chemicals	3.91	0.51			0.21	0.30	0.22
Business performance	Supermarket	3.71	0.90	0.82	0.80			
	Financials	3.72	0.99			0.01		
	Construction	3.83	1.04			0.12	0.11	
	Chemicals	3.83	0.68			0.14	0.11	0.00
Mitigation control	Supermarket	2.65	0.68	0.04	0.05			
	Financials	2.77	0.56			0.16		
	Construction	2.50	0.65			0.23	0.41	
	Chemicals	2.36	0.90			0.32	0.44	0.15
Intensity control	Supermarket	2.71	0.47	0.01	<0.01			
	Financials	2.89	0.34			0.39		
	Construction	2.67	0.66			0.05	0.33	
	Chemicals	2.46	0.62			0.39	0.69	0.32

Table 4.16 reflects results of the ANOVA for business categories. Results indicate effect sizes are tending towards medium for chemicals and financials sectors (0.44) and construction and financial sectors (0.41) for mitigation control. This implies respondents from the chemical sector tend to disagree ($M = 2.36$, $SD = 0.90$), while respondents from the financial sector ($M = 2.77$, $SD = 0.56$) tend towards neutral with statements on mitigation. Respondents from the construction sector tend more towards neutral ($M = 2.50$, $SD = 0.65$) contrasting the financial sector that tends towards neutral. Effect size differences indicating medium tending towards large is reflected between sectors for supply sufficiency construct. The financial and supermarket sectors reflect an effect size of 0.67, with financial sector tending towards agree on supply sufficiency (statement 3) ($M = 3.98$, $SD = 0.85$) and supermarket sector tending towards neutral ($M = 3.13$, $SD = 1.25$). The chemical and supermarket sectors reflect an effect size of 0.61, with respondents from the chemical sector tending towards agreeing ($M = 3.90$, $SD = 1.19$), unlike the supermarket sector that tends towards neutral. The construction and finance

sectors reflect an effect size of 0.62, with respondents from the construction sector tending towards neutral ($M = 3.09$, $SD = 1.41$), unlike the financial sector with responses tending toward agreeing. The chemical and construction sectors indicate an effect size of 0.57, as respondents from the chemical sector tend to agree on the statement, while construction respondents tend towards neutral. Intensity control reflects medium tending towards large (0.69) for chemicals and financials. The respondents from the chemical sector disagreed with the statements regarding intensity control ($M = 2.46$, $SD = 0.62$). The respondents from the financial sector in general felt neutral ($M = 2.89$, $SD = 0.34$).

Table 4.17 ANOVA test for enterprise size on factors

Factors	Business categories	Mean	Standard deviation	ANOVA p value	Welch p value	Effect sizes		
						Small with...	Micro with...	Medium with...
Importance of electrical energy	Small	4.34	0.59	0.51	0.50			
	Micro	4.51	0.50			0.29		
	Medium	4.41	0.58			0.11	0.18	
	Large	4.49	0.60			0.25	0.04	0.14
Supply sufficiency (statement1)	Small	2.09	0.91	0.02	0.03			
	Micro	2.09	0.95			0.00		
	Medium	2.36	1.13			0.24	0.24	
	Large	2.71	1.40			0.44	0.44	0.25
Supply sufficiency (statement2)	Small	2.20	1.02	0.51	0.46			
	Micro	2.54	1.22			0.28		
	Medium	2.52	1.10			0.29	0.02	
	Large	2.40	1.19			0.17	0.12	0.10
Supply sufficiency (statement3)	Small	3.29	1.34	0.25	0.24			
	Micro	3.14	1.28			0.11		
	Medium	3.40	1.28			0.09	0.20	
	Large	3.65	1.19			0.27	0.39	0.19
Operational vulnerability	Small	3.74	0.45	0.76	0.75			
	Micro	3.79	0.47			0.09		
	Medium	3.84	0.49			0.20	0.11	
	Large	3.79	0.51			0.09	0.01	0.10
Business performance	Small	3.88	0.65	0.56	0.51			
	Micro	3.84	0.87			0.05		
	Medium	3.75	0.92			0.15	0.10	
	Large	3.63	1.06			0.23	0.19	0.10
Mitigation control	Small	2.39	0.65	0.01	0.01			
	Micro	2.37	0.68			0.02		
	Medium	2.66	0.71			0.38	0.40	
	Large	2.76	0.70			0.53	0.55	0.14
Intensity control	Small	2.54	0.48	0.01	0.01			
	Micro	2.54	0.56			0.01		
	Medium	2.73	0.57			0.33	0.34	
	Large	2.85	0.56			0.54	0.55	0.20

Table 4.17 reflects the results of the ANOVA for the different industrial enterprise size classifications. Results reflect medium effect sizes for mitigation control between large and small enterprises (0.53) and between large and micro enterprises (0.55). Large enterprises tended toward neutral ($M = 2.76$, $SD = 0.70$), while small enterprises tended toward disagreeing on the construct ($M = 2.39$, $SD = 0.65$). Micro enterprises tended towards disagree ($M = 2.37$, $SD = 0.68$), unlike large enterprises that tends more towards neutral. Intensity control also

reflects medium effect sizes between large and small enterprises (0.54) and also for large and micro businesses (0.55). Large enterprises tend towards being neutral ($M = 2.85$, $SD = 0.56$), while small businesses are tended more towards disagree ($M = 2.54$, $SD = 0.48$). Micro enterprises reflect to be tending more towards disagree ($M = 2.54$, $SD = 0.56$), unlike large enterprises that tend's towards neutral.

4.4.4 Independent *T*-test

The *T*-test analyses the difference between the means derived from the different groups' scores. Schlomer (2009:3) states that the *T*-test identifies that two groups have significant differences in means. Allen *et al.* (2009:36) concur that *T*-test determines whether the variability between two groups from a targeted sample is larger than the expected natural variability present. The independent *T*-test was utilised in comparing the business sectors per sampled province. The effect size explains practical differences between the means of sampled clusters. Values >0.2 , >0.5 and >0.8 reflect a small, medium and large effect sizes respectively. The *p*-values will also be reported. *The p-values are reported for completeness sake, but won't be interpreted since a non-probability sampling method was used and not a probability sampling.*

Table 4.18 T-test results on chemical sector for sampled provinces

Factors	Province	Mean	Standard deviation	Levene's p value	Effect sizes
Importance of electrical energy	Gauteng	4.33	0.72	0.30	0.28
	North-West	4.53	0.44		
Supply sufficiency (statement1)	Gauteng	2.18	0.90	0.53	0.2
	North-West	2.00	0.90		
Supply sufficiency(statement2)	Gauteng	2.45	1.22	0.29	0.33
	North-West	2.06	1.11		
Supply sufficiency statement3)	Gauteng	3.64	1.32	0.12	0.44
	North-West	4.22	0.94		
Operational vulnerability	Gauteng	3.74	0.50	0.01	0.76
	North-West	4.12	0.45		
Business performance	Gauteng	3.72	0.81	0.26	0.30
	North-West	3.97	0.46		
Mitigation control	Gauteng	2.55	0.70	0.16	0.38
	North-West	2.14	1.09		
Intensity control	Gauteng	2.63	0.47	0.06	0.51
	North-West	2.26	0.73		

Table 4.18 contains the results of the independent *T*-test when considering the chemical sector per sampled province. Operational vulnerability (0.76) and intensity control (0.51) reflect large and medium effect sizes respectively. The operational vulnerability construct reflect that

respondents from Gauteng tended towards ($M = 3.74$, $SD = 0.50$) while respondents from North West agreed, tending towards strongly agree ($M = 4.12$, $SD = 0.45$). Load shedding statistics for 2014 to 2015 concur that there were more lights cut in the North West province compared to Gauteng in the mentioned period. The intensity control construct reflect that respondents from Gauteng tend towards neutral on statements ($M = 2.63$, $SD = 0.47$) while respondent from North West tend to disagree ($M = 2.26$, $SD = 0.73$).

Table 4.19 T-test results on supermarket sector for sampled provinces

Factors	Province	Mean	Standard deviation	Levene's p value	Effect sizes
Importance of electrical energy	Gauteng	4.59	0.51	0.26	0.25
	North-West	4.46	0.41		
Supply sufficiency (statement1)	Gauteng	2.61	1.45	0.57	0.13
	North-West	2.43	1.28		
Supply sufficiency(statement2)	Gauteng	2.72	1.20	0.29	0.24
	North-West	2.43	1.20		
Supply sufficiency statement3)	Gauteng	2.72	1.28	<0.01	0.94
	North-West	3.93	0.71		
Operational vulnerability	Gauteng	3.74	0.40	0.04	0.43
	North-West	3.94	0.47		
Business performance	Gauteng	3.63	0.98	0.30	0.22
	North-West	3.85	0.73		
Mitigation control	Gauteng	2.75	0.65	0.08	0.38
	North-West	2.47	0.71		
Intensity control	Gauteng	2.74	0.42	0.34	0.19
	North-West	2.64	0.55		

Table 4.19 contains the results of the independent *T*-test when considering supermarket sector per province.

Supply sufficiency (statement 3: Currently in South Africa business are operating in an energy crisis environment) reflect a large effect size of 0.94 for Gauteng ($M = 2.72$, $SD = 1.28$) and North West ($M = 3.93$, $SD = 0.71$). The large difference reflects that participants tend towards neutral in Gauteng, while participants in the North West agreed to the statement.

Table 4.20 T-test results on financial sector for sampled provinces

Factors	Province	Mean	Standard deviation	Levene's p value	Effect sizes
Importance of electrical energy	Gauteng	4.62	0.48	0.03	0.59
	North-West	4.33	0.35		
Supply sufficiency (statement1)	Gauteng	2.14	1.03	0.27	0.33
	North-West	2.47	0.90		
Supply sufficiency(statement2)	Gauteng	2.59	1.05	0.37	0.26
	North-West	2.32	0.88		
Supply sufficiency statement3)	Gauteng	3.73	0.88	0.04	0.61
	North-West	4.26	0.73		
Operational vulnerability	Gauteng	3.62	0.41	0.02	0.71
	North-West	3.92	0.41		
Business performance	Gauteng	3.40	1.15	0.02	0.61
	North-West	4.11	0.58		
Mitigation control	Gauteng	2.64	0.54	0.13	0.48
	North-West	2.92	0.56		
Intensity control	Gauteng	2.93	0.39	0.38	0.24
	North-West	2.84	0.25		

Table 4.20 contains the results of the independent *T*-test when considering financial business sector per sampled province simultaneously.

The importance of electrical energy reflects a medium effect size (0.59). Gauteng tend towards strongly agree ($M = 4.62$, $SD = 0.48$) and North West tend towards agree ($M = 4.33$, $SD = 0.35$). Effect sizes tending towards large, reflect for supply sufficiency, (statement 3) (0.61), operational vulnerability (0.71) and business performance (0.61). Respondents tend towards agreeing for supply sufficiency (statement 3: currently in South Africa enterprises are operating in an energy crisis environment) for Gauteng ($M = 3.73$, $SD = 0.88$), while respondents from North West tend towards strongly agree ($M = 4.26$, $SD = 0.73$). Operational vulnerability reflect that respondents from Gauteng tend towards agree ($M = 3.62$, $SD = 0.41$) and respondents from North West agree ($M = 3.92$, $SD = 0.41$). Business performance reflect that respondents from Gauteng tend towards neutral on statements ($M = 3.40$, $SD = 1.15$) while respondents from North West tend to agree ($M = 4.11$, $SD = 0.58$).

Table 4.21 T-test results on construction sector for sampled provinces

Factors	Province	Mean	Standard deviation	Levene's p value	Effect sizes
Importance of electrical energy	Gauteng	4.08	0.91	0.07	0.38
	North-West	4.42	0.42		
Supply sufficiency (statement1)	Gauteng	2.2	1.08	0.60	0.14
	North-West	2.36	1.09		
Supply sufficiency (statement2)	Gauteng	2.24	1.05	0.93	0.02
	North-West	2.21	1.06		
Supply sufficiency (statement3)	Gauteng	2.16	1.14	<0.01	1.55
	North-West	3.93	1.08		
Operational vulnerability	Gauteng	3.62	0.61	0.04	0.52
	North-West	3.93	0.51		
Business performance	Gauteng	3.54	1.29	0.04	0.44
	North-West	4.10	0.67		
Mitigation control	Gauteng	2.57	0.65	0.45	0.21
	North-West	2.43	0.66		
Intensity control	Gauteng	2.68	0.59	0.95	0.01
	North-West	2.67	0.73		

Table 4.21 contains the results of the independent *T*-test when considering the construction sector per province.

Operational vulnerability reflects medium effect size (0.52) while supply sufficiency (statement 3) showed a very large effect size (1.55). Respondents for Gauteng tend towards agreeing on statements for operational vulnerability ($M = 3.62$, $SD = 0.61$), while respondent from North West tended a little stronger towards agreeing ($M = 3.93$, $SD = 0.51$). Supply sufficiency (statement 3) reflect respondents tend to disagree on statements for Gauteng ($M = 2.16$, $SD = 1.14$) and tend to agree for North West ($M = 3.93$, $SD = 1.08$).

4.4.5 Correlation

Harmon (2011:33) states that the Spearman's rank correlation is a nonparametric statistic which measures the strength of an association between two variables. Hauke and Kossowski (2011) say that the Spearman coefficient is not a measurement of a linear relationship between two variables as most statistical analyses assert. It assesses how the relationship between two variables can be best described. The Spearman rank coefficient also indicates if a practical significant relation exists between variables. A coefficient >0.1 , >0.3 and >0.5 represents a small, medium and large relationship respectively. The Spearman's rank correlation was performed between business size, monthly expenditure of electricity and cost per unit of electricity.

Table 4.22 Correlation between business size, electricity monthly spending and cost per unit of electricity

Factors	Measurements	Business size	Monthly expenditure on electricity	Cost per unit of electricity
Business size	Coefficient	1.00	0.48	0.15
	Sig.		0.00	0.02
Monthly expenditure on electricity	Coefficient	0.48	1.00	0.24
	Sig.	0.00		0.00
Cost per unit of electricity	Coefficient	0.15	0.24	1.00
	Sig.	0.02	0.00	

Results reflect a positive correlation, tending towards medium, between cost per unit of electricity and monthly expenditure on electricity ($r = 0.24$). A positive correlation tending towards large exist for business size and electricity monthly spending ($r = 0.48$). Thus, it indicates that large enterprises will spend more on electricity compared to smaller enterprises.

4.4.6 Chi-square test

The Chi-square test was employed to identify if an association exists between enterprise category, monthly expenditure on electricity and cost per unit of electricity. Turner (2014:2) says the Chi-square analysis identifies if two categorical variables are independent (no relationship). Waller and Johnson (2013:2) agree Chi-square examines whether equality exists between two or more categorical variables. Bolboacă *et al.* (2011) highlight that the Pearson Chi-square is the most appropriate in samples sizes with a minimum of 20 to 50 participants. The Pearson Chi-square was used to identify statistically significant associations. Cramer's value was used to indicate practical significant associations (effect size differences). A coefficient <0.05 indicates a significant statistical relation. Cramer's values of >0.1 , >0.3 , >0.5 indicates small, medium and large associations respectively. *The p-values are reported for completeness sake, but won't be interpreted since a non-probability sampling method was used and not a probability sampling.*

Table 4.23 Pearson Chi-square and symmetric measures for industries and monthly expenditure on electricity

Chi square test			Symmetric measures		
	df	Sig.		Values (effect size)	Sig.
<i>Pearson</i>	15	0.04	<i>Phi</i>	0.34	0.04
<i>Likelihood ratio</i>	15	0.02	<i>Cramer's V</i>	0.19	0.04
<i>Linear-by-linear association</i>	1	<0.001			

Table 4.23 reflects the Chi-square test between industry and monthly expenditure on electricity. Results also reflect a small association effect (Cramer's V (CV) = 0.19).

Table 4.24 Pearson Chi-square and symmetric measures for industries and cost per unit of electricity

Chi square test			Symmetric measures		
	df	Sig.		Values (effect size)	Sig.
<i>Pearson</i>	15	<0.001	<i>Phi</i>	0.65	<0.001
<i>Likelihood ratio</i>	15	<0.001	<i>Cramer's V</i>	0.37	<0.001
<i>Linear-by-linear association</i>	1	<0.001			

Table 4.24 reflects the Chi-square test between industry and cost per unit of electricity. Results reflect a medium tendency toward large effect size ($CV = 0.37$). This indicates that industrial energy pricing per unit cost is regulated across different industrial sectors in South Africa.

4.5 Conclusion

This article has critically examined the effect of low power supply on industrial growth in South Africa. The importance of electrical energy to businesses, supply sufficiency, operational vulnerability and business performance were used to measure the aggregate relation between electrical energy and industrial growth in South Africa. The article also assessed the mitigation control programs instituted by industrial enterprises to ensure no-disruption in production and operational activities. An evaluation was also done to determine the level of intensity control to advice on reliable policies for efficiency and emission that comes with increased intensity in the industrial sector. The service industry (financials and cold-chained supermarket), manufacturing (constructions and chemicals) and mining (mineral deposits and mine purification) were the sampled industries. Stats S.A. (2015:2) points out that the low electricity supply immensely affected the production chain, causing a sharp contraction in major industries such as mining, manufacturing and service industries, lowering economic growth. The following section will elaborate on the papers’ research objectives.

4.5.1 Importance of electrical energy to businesses

A majority of the participants gave a positive response that electrical energy is very important for their operations energy source ($M = 4.43$, $SD = 0.58$). Attigah and Mayer-Tasch (2013:4) state that of all modern energy types, electricity is the most undisputable category that must be considered in the strategic objectives of industrial growth. Enterprises also noted that electrical energy consistency is necessary for their business growth and competitiveness in general. The results reflect indications from the literature review that despite the availability of alternative sources of energy, electrical energy sustainability is primary for industrial growth and advancements in economic activities. This is very essential in the case of South Africa with an

energy-intensive economy. Isaksson (2009:1) agrees that the most direct role of electrical energy is that it serves as the main input to the activities of industries. There were indications of a medium difference in opinion between manufacturing and the service industry about importance of electrical energy for business activities.

4.5.2 Supply sufficiency

Organisations disagreed that supply sufficiency levels are adequate. Statement one was assessing if supply volumes are sufficient to meet industrial demand, while statement 2 was assessing the optimism of organisations on the consistency of future electricity supply. Aforementioned statements reflect $M = 2.37$, $SD = 1.17$ and $M = 2.43$, $SD = 1.13$ respectively. Nkomo (2006:77) points that the most important relationship between energy supply and industrial growth is the volume effect, which determines different tendencies in the production level of economic activities based on the quantity of energy supply.

Statement 3 was assessing whether the South African business environment is characterised by the energy crisis. James (2014:1) affirms that the South Africa business sector is extremely concerned about the short to medium-term power crisis. Albert (2015:34) agrees that even though the electricity supply has been fairly stable in recent months, there is no assurance that Eskom can keep up with the ever-increasing demand for power. Oxford (2015:12) highlights that Eskom even agrees that the challenge of a constrained power system and the issues of supply and demand are not likely to end if sufficient capacity to meet required demand remains pending. Enterprises' response tended towards neutral ($M = 3.42$, $SD = 1.27$). It was found that there are significant differences in opinions on the business environment being characterised with the energy crisis between the different business categories and industries from Gauteng and North West provinces. In general, there were medium to large effect sizes for supply sufficiency across industries, business categories and provincial geographies. This implied that electricity supply confidence varies across enterprise sectors, classification and provincial locations. Jucker *et al.* (2008:3) states that industrial and economic growth for all developing economies is strongly dependent on the supply levels of electrical energy and access to reliable supplies of electricity.

4.5.3 Operational vulnerability and business performance

Enterprises agreed that there have been operational vulnerabilities and business performance is dropping due to electricity inconsistency ($M = 3.81$, $SD = 0.49$ and $M = 3.75$, $SD = 0.92$) respectively. There were small differences in opinions across industries. Provincial differences

were very significant, with chemical and financial sectors tending towards large differences. Enterprises note that there has been a drop in productivity, increased overhead cost due to price, damages on equipment, failures to meet deadlines due to limited working hours, financial markets are affected in the long term and short term and the loss of investments. It was also discovered that there is a significant association on electricity spending, cost per unit of electricity to industrial sectors and classifications. Hence, the higher the cost per unit of electricity of an enterprise, the greater it spending on electricity demand for operational activities. Alternatively, an organisation's size or operational nature will determine its electricity spending.

Von Ketelhodt and Wocke (2008) state that a reliable and low priced supply of electricity is critical to the success of the business sector in South Africa. Altman *et al.* (2010:9) point out that there is a real concern that, rising electricity prices will encourage firms to shut down production or contain expansion with resultant downstream impacts on economic growth. Kumo *et al.* (2016:4) state that severe electricity inefficiency precipitated frequent load-shedding, with a resultant outcome to low business confidence from investors. Organisations point out that electricity inconsistency and the consequent economic downturn has led to decreasing profit margins as business growth is on a decline since the start of the crisis from 2007. Inglesi and Blignaut (2012) maintain that electricity is an essential input for production in South Africa, hence an important factor for the competitiveness of the country's industrial performance.

4.5.4 Mitigation control

In general, the South African business environment is surrounded by uncertainties of electricity consistency. Altman *et al.* (2010:28) highlight that it is now clear that there is a likelihood of electricity supply shortages stretching to 2017. There have been cases of completely light cuts in some parts of South Africa for weeks. Doyle (2015:22) note that unreliable power supply threatens extended periods with no power over the course of several years, characterised with load-shedding occurrences as a predictable certainty in the future. Thoughtful enterprises need to implement mitigation strategies to deal with it and to implement successful strategies, they need to understand what are the risks and implications of low electricity supply. It was thus, important to evaluate industrial and enterprises readiness in ensuring operational continuity with limited disruption on activities during the occurrence of load shedding. Enterprises' responses were neutral towards establishing mitigation control systems and strategies ($M = 2.60$, $SD = 0.71$). Medium differences in opinion reflected across the different business

classifications. Burrows (2015:14) says mitigation strategies are very expensive especially for smaller enterprises, adding up to operational cost.

4.5.5 Intensity control

Industrial energy consumption is the highest among other sectors in South Africa. Pegels (2010) remarks that carbon emissions in South Africa are on the rise as the energy industry environmental pollution intensifies. Gross (2012:6) asserts that Eskom itself was ranked as the second highest carbon dioxide emitting energy company in the world by 2012. Outcome reflects opinions tending towards neutral on industrial intensity control ($M = 2.60$, $SD = 0.71$ and $M = 2.70$, $SD = 0.56$). There were medium differences in opinion on intensity control by business classifications (SMMLs). Oxford (2015:12) says electricity administrators have failed to recognise the growing threat about electricity adequacy in South Africa. There is a need for effective industrial sector intensity and efficiency control. Electrical energy savings have a direct impact on the bottom-line of industrial plants and commercial businesses (Jucker *et al.*, 2008:5). Inglesi and Blignaut (2012) assert that South Africa's electricity intensity has more than doubled when considered on a time series basis. The sectoral analysis also confirms that a majority of South African sectors are becoming electricity intensive. To improve its industrial competitiveness, South Africa will have to improve its sectoral electricity efficiency levels. Inglesi and Blignaut (2014) assert that enforcement of sectoral industrial energy intensity control has a direct benefit to electricity efficiency.

4.6 Final statement

To strengthen the international competitiveness of industries, electricity suppliers must ensure fair energy access and security. Insufficient energy supply for industrial operations will significantly impact on industrial competitiveness and consequently industrial growth. Arguably the South African business environment is characterised with uncertainties on energy security. It is very important for industry stakeholders to establish their microgrid to reduce the impact of low supply of electrical power and to prevent disruptions in industrial activities due to electricity inconsistency. To ensure substantial energy savings, consumption control should be effective across all sectors in the economy. Paredis and Black (2012:189) emphasise that technological efficiency improvement measures are key strategy towards minimising environmental pollution. The public sector should apply the good governance framework to ensure policies are effectively implemented and stakeholders adhere to compliance requirements on efficiency and intensity control. It is important to proceed by addressing the

lack of motivation to practice energy control by industries. The lack of effective intensity control can be viewed as the public sector's unwillingness to trade-off short-term industrial economic implications for a long-term attainment of industrial energy control objectives. A policy fostering heavy sanctions should be instituted to ensure compliance.

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CHAPTER FIVE (ARTICLE 4)

THE ELECTRICITY SECURITY IN SOUTH AFRICA: ANALYSING SIGNIFICANT DETERMINANTS TO THE GRID RELIABILITY

Benedict Belobo Ateba and Prinsloo Johannes Jurgens

ABSTRACT

South Africa has been suffering from low electricity supply for decades now, dating back to the first occurrence during 1983. Another crisis struck by the fall of 2007, which shocks from the crisis still affect the economic growth. The country's fossil fuels, which serve as a major contributor to its electricity generation, are depleted by 1% every year. Other determining variables such as increases in domestic consumption and industrial intensity as domestic and industrial consumption rise, increase in coal prices, drop in the production volumes of coal, depreciation in machinery remain continuous dangers to the future reliability of supply of the grid. This has led to inflation of consumer prices, as end users' future access to adequate electricity supply is not guaranteed. This paper aimed at determining the steadfastness of the South African electricity grid in meeting consumers' demands. A quantitative research design was employed. A multiple time series research method utilising secondary data from key determining variables to electricity supply from the first quarter of 1998 to the last quarter of 2015 was employed in this study. The Eviews statistical software was employed to obtain regression probabilities through the multiple Ordinary Least Square model (OLS) specifications. The Engle-Granger approach was used to establish whether or not co-integration exists between the independent and the dependent variables. The co-integration analysis reflects that there is a significant long-term relationship between the independent and the dependent variables.

Keywords: *Electricity security, supply determinants, grid sustainability, future electricity access*

5. INTRODUCTION

Winkler (2006a:23) notes that energy has been a very instrumental feature in shaping the South Africa economy. Supplying consistent electricity to the mining industry, to boost economic growth was the primary supply objective of the public sector throughout the early quarters of the twentieth century. The intensive dependence on the imported energy resources raised concerns about energy security during the 1950s. The government of the time initiated projects to meet the demand for electricity by constructing massive power stations in the 1960s and 1970s. The previous abundant electricity reserves are gradually getting exhausted. A major concern as viewed by Winkler and Marquand (2009) is that international standards currently rank the South African economy extremely energy intensive.

Hameed and Khan (2016) say electricity is prime on the hierarchy among energy resources of priority for every modern economy. It is essential for an economy to generate and distribute a sufficient supply of electricity if sustainable economic growth is to be attained (Kohler, 2013:5). Ojeaga (2014) states that issues about energy sustainability should be of paramount importance to every economy since it mostly determines the possibility of economic growth and productivity. Kohler (2013:5) alludes that the availability and reliability of energy is an important determinant of economic productivity. Conceptualising energy security differ depending on the perspective taken, ranging from the international to regional, national to local, and also differ across stakeholders such as industry, communities and individuals (Chester, 2010). This paper views that, it is of core importance to evaluate the security of electricity supply in South Africa, considering recent low supplies caused by influential determinates to electricity production and supply.

5.1 Introduction to the problem

Hedden (2015:7) agrees that South Africa's electricity demand currently exceeds supply. Von Keltchodt and Wocke (2008) note that if electricity demands exceed supply, the cost and the unreliability of electricity supply increases. Hameed and Khan (2016) assert that an electricity grid is under siege if production potentials are not comparative to the constantly increasing demands of the industrial and domestic sectors. This paper seeks to call attention to the responsibility of supply security in the electricity market and to demonstrate the most effective parameters that can be incorporated as the standards for measuring the security of supply.

The problem in this paper relates to electricity security in South Africa that is threatened by elements that significantly determine electricity production and supply. The increasing pressure of demand over supply reflects the unsustainability of over-reliance on coal technology reflecting a potential threat to future electricity security. There is a limited policy advancement towards significant electricity security in South Africa.

5.2 Literature review

The following section discusses energy security, South Africa's grid security and factors that have been considered as influencing variables.

5.2.1 Energy Security

Knox-Hayes *et al.* (2013) agree that security and reliability of energy have become increasingly important in energy policy debates, driving an agenda towards a change in energy systems. Chester (2010) notes that there has been little discussion of the notions which underpin the meaning of the term 'energy security'. As a result, it is often referred to as the threats to a continuous supply of energy resources, failing infrastructure and depletion of energy resources. Consequently, these risks lead to price hikes and shortages, initiating a negative impact on demand. Recently, researchers in the field of energy have been creating awareness on the dangers of poor energy security. Burgess and Nye (2008) agree that a diminished 'energy security' is primarily experienced through fuel deficiencies resulting in electricity cuts, as well as increases in the price for power.

Glyn *et al.* (2014) conducted a study on the energy security of Ireland and revealed findings that Ireland's electricity grid is very vulnerable due to: import dependency by 88 % of its energy requirement, its limited energy mix and wobbly pricing. Glyn *and others* further forecast that Ireland will encounter possible disruptions in electricity supply if strategic implementations are not established soon enough. Demski *et al.* (2014) say in the United Kingdom (UK), there is a proposal from the general public for a change in the energy system that is solely dependent on gas to more advanced 21st century energy generation technologies. High concerns regarding the dependence on fossil fuels, high imports of energy resources to more immediate issues ranging from insufficient reserves to meet demand and price increases has relatively low concerns for possible disruptions to electricity supply.

Reverting to electricity security, Raillon (2010:2) notes that there is no common definition of electricity supply security. Electricity supply security can be attributed to the capability of an electricity grid in meeting up the electricity needs of final consumers with a defined quality

and at a transparent and cost-oriented price. In line with afore context, electricity security is the capability of an electrical system to supply electricity to consumers with a definite level of continuity and quality in a sustainable manner, according to generally acceptable delivery standards (Gábor & Lipponen, 2006:6).

5.2.2 South African electricity grid security

Clark *et al.* (2005:29) maintain that the effective provision of electricity services to consumers significantly depends on price and supply reliability. Thus, security of electricity is threatened if the physical quantity of available electricity is insufficient and prices that are not affordable for consumers. Clark *et al.* (2005:13) emphasise that assessing and improving on the security of supply to meet future demand has always been a primary agenda for power sectors reform in South Africa. Wilson and Adams (2006:5) note that the rate of growing insecurity of supply in the South African electricity industry is a major challenge to suppliers. Wilson and Adams allude that a major threat to supply security is the inadequate generation of required capacity that is secure enough to deliver power to all regions of the country. Ojeaga *et al.* (2014) extensively evaluate constraints to energy security ranging from the availability of natural resources for a generation, size of regions, regional temperature level, income, population density, cost of accessing energy, consumption demands both domestic and industrial and spend on technology. Threats that were identified as a matter of concern to energy security include; the cost of accessing energy, availability of natural resources for a generation, domestic and industrial electricity consumptions.

In accord with Newberry and Eberhard (2008:10) neither the Department of Energy (DOE), Eskom nor National Energy Regulators South Africa (NERSA) has ever critically looked into the country's supply security nor set standards establishing a procedure for measuring electricity security in South Africa. Wilson and Adams (2006:6) state that, in the past, Eskom mostly utilised the criterion of determining the cost of unserved energy, which is assumed to represent the value to customers of system security. Previously, this approach has been widely used in most countries but is now recognised as not being an adequate basis for determining power system security. Wilson and Adams (2006:5) have the viewpoint that variables that impact on the reserve margin is probably the most appropriate deterministic criterion to factors that pose a threat to the South African grid security.

Determining the security of an electricity grid involves the complexity of assessing the proper functioning of its independence to its dependent factors. The focus of this paper is about factors

that cause a significant interruption to electricity supply with a material consequence. There might be many aspects that affect the security of electricity supplies in South Africa. However, this paper focuses primarily on aspects of fossil fuel, supply price, consumption growth and depreciation on machinery. That is not to say other elements are inferior, but to specify that, after an extensive review of the literature, the mentioned variables significantly determine the occurrence of a threat to the South Africa electricity grid.

5.2.3 Coal energy

Focusing mainly on coal electricity generation and not from all energy sources, in general, is because the energy sector is too diverse for comparative analysis. South Africa's electricity generation is 95 percent dependent on coal. An intensive investment in coal energy assets has historically been the country's electricity development path (Kohler, 2013:2).

Antin (2013:6) posits that the South African mining industry seems well-established, but a closer inspection reveals severe productivity issues. Prevost (2003:102) points out that the coal sector has reached its threshold and will soon experience stagnation. Coal production is at a recession as output and exports steadily decrease. Prevost alluded that 2020 is the 'target year' when most coal factories might have shut-down and reserves will be close to attaining exhaustion.

British Petroleum (BP) Statistical Review of World Energy (2005:30) version estimated South Africa's coal reserve is at 5.4% of the world's total, matching up the Department of Minerals and Energy (DME) evaluation of 31 Metric Tons (Mt) by 2005. BP Statistical Review of World Energy (2016:30) state that the South African coal reserves are constantly at a decrease, with current levels estimates at 3.4 % of the world's total. Fourie (2009:1) stated that, despite that the Waterberg coalfields are expected to cater for future crisis, it is dangerous to rely on, since estimates of its total quantity of resources are highly uncertain as it has been relatively under-explored. Jeffrey (2005) and Fourie *et al.* (2009:28-29) maintain that the current estimations of the Waterberg fields predict low productivity. It is also endangered by some geological setbacks from past tectonic activities with no guarantee of effective exploitation of the Waterberg coal deposits.

Baxter (2015:19) points out that a decline in productivity adds to the headwinds of the industrial progress as a capital injection from activities such as coal exports dropped due to reduced volumes of production. Antin (2013:1) highlights that the mining industry has undergone a major unrest since the beginning of the 2008 global financial crisis, with workers inter-alia

demanding better wages. Antin posits that 2012 experienced a fast decreasing productivity prior to turmoil by mineworkers. Altman (2013:6) notes that poor management of available coal stocks adds to the challenges to attaining coal adequacy for the electricity industry.

Mayet *et al.* (2012:3-4) view that Eskom believes it can use coal resources as a competitive advantage to improve production capacity failed to consider the implications of future coal prices. Prices of coal at present are on a constant increase and very unstable. There is anticipation that situations will get worse in the future. Mayet *et al.* (2012:4) says pricing is furthermore challenged by the competition of the Broken Hill Proprietary (BHP) Billiton group, which controls the largest coal produced in South Africa. An estimated US\$800 billion is required by Eskom to acquire Billiton coal deposits. A pricing agreement does not seem to entirely reflect the interests of the public as Eskom's agenda is towards protecting its monopoly as primary administrator to energy resources. In South Africa, coal prices are mostly a 25-30 % of the electricity consumer price since coal price variations are highly reflected in the electricity production cost (Inglesi, 2010).

5.2.4 Consumer price of electricity

Inglesi and Pouris (2014:1) say there have been continuous debates on whether increases in electricity tariffs will affect the energy sector and if it is necessary. Altman (2013:6) maintains that there are similar consistent debates as to whether South Africa's protocol for the consumer electricity price increase is effectively aligned to global standards. Kohler (2013:5-6) states that South African electricity regulators technically determine electricity prices, instead of the forces of demand and supply in the market. Kohler further views that the absence of an appropriate pricing determination instrument is likely to cause imbalances in the demand and supply, particularly in cases when regulators are not well experienced in responding to market signals. Eskom (2012:5) states that the South Africa pricing technique follows a Multi-Year Price Determination (MYPD), in which Eskom applies to NERSA for a periodic electricity price adjustment plan. Altman (2013:6) agrees that the electricity selling price should reflect its full production cost. Alternatively, the ongoing proposals for multiple inflation type increases that are currently discouraging global investment in South Africa, is not realistic. Thopil and Pouris (2013) performed an empirical research study of the state of electricity consumer price in South Africa and the following outcomes were ascertained:

- The industrial sector is under-priced while the residential sector suffers immensely from high percentage increases. This was questionable as to why price increases are not equally executed on both sectors considering that their benefits are not proportionate.

- Multi-Year Pricing Determination (MYPD) has been seriously criticised to be a non-pragmatic pricing technique. MYPD has a history of unfairness traced from the prevailing electricity pricing inequality in South Africa. Thopil and Pouris suggest that a more appropriate standard that would ensure transparency in all sectors should be introduced.

Mayet *et al.* (2012:5) confirm Eskom agrees that the MYPD makes it too complicated to establish a 100% precise cross-subsidy plan from industrial to residential users. Such finding is proof enough to introduce a new tariff structure that will guarantee electricity accessibility to the poor. Mayet *et al.* allude that Eskom's decision to apply the MYPD approach, instead of exploring a more appropriate and reliable alternative can be attributed to Eskom's managerial convenience policies.

Alternatively, literature points out that price is a very complex variable to conclude electricity tendencies in South Africa. Blignaut *et al.* (2014) conducted a comparative investigation to assess the elasticity of electricity price for years, 2002 to 2011 in South Africa. Outcomes from empirical research found a statistically insignificant elasticity for periods pre-2007 agreeing with over 90% of similar studies. Alternatively, post-2007 results were statistically significant across 9 out of 11 sampled sectors. Policy implications point out that tariff restructuring might influence future consumer behaviour and might be a significant threat to electrification potentials. Inglesi and Pouris (2014:1) carried out a similar investigation evaluating the causality of price and income on electricity demand in South Africa with similar findings. Inglesi (2011) view that price is becoming relatively weaker over the years as a perfect explanatory variable for electricity consumption tendencies. A consensus regarding the significance of electricity price as a determinant to electricity tendencies in South Africa is currently in a dilemma due to conflicting findings from researchers.

5.2.5 Consumption growth

Marquard *et al.* (2008) note concerns on the implications of the steady increase in population growth. These increases result in roughly 350 000 new South African households per year. The annual growth in household formation is a primary challenge on the electricity grid. Hameed and Khan (2016) agree that there is a significant positive relationship between population growths, which consequently caused a drastic change in electricity consumption. The South African Energy Efficiency Report (2011:2) points out that South Africa has high energy consumption per capita of 2.7 averages, compared to the regular global consumption of 1.8

average. Energy consumption between 1990 and 2002 increased by 1.1 percent yearly; after 2002, increases have been at a very rapid rate of 4 percent yearly.

Kohler (2013:2) highlights that there has been a constant growth in electricity consumption and intensity in South Africa from 1971, implying that the South African electricity efficiency instruments are not implemented effectively based on the required international standards. Inglesi and Blignaut (2011:4) maintain that the constant increase in grid electricity consumption in South Africa is prior to major transformation programmes. According to Kohler (2013:2), electricity transformation programmes such as historically low prices initiated a substantially low electricity efficiency environment relative to other countries. Winkler and Marquand (2009) say electricity efficiency implementation in the industrial sector is still significantly poor and considerably lower than global averages.

Hedden (2015:5) says the Council for Scientific and Industrial Research (CSIR) modelled and forecast that the energy intensity of the South African economy will decrease over time. The underlying logic behind the model assumption is on the basis that South Africa is transitioning away from energy-intense industries to a more service-oriented economy. Hedden disagrees that it is not completely factual since as the country demands for electricity increases as well. This means that, even if the energy intensity of the country decreases, the size of the economy is also growing the overall energy consumption.

5.3 Research methodology

The research methodology of this paper was a quantitative research design. A quantitative design was the most appropriate approach because analyses had to take account of occurrences of behaviour between tested variables and to record correct answers and errors in quantity. The research technique was the multiple time series approach. Schmidheiny (2016:2) defines a multiple linear regression models as a linear relationship between a dependent variable y_t and a set of explanatory variables x . According to Mohod (2012) the independent variable is the variable which researchers measure while the dependent variable is the assumed effect. Data for the empirical investigation was collected from secondary sources. All data was retrieved from Quantec South Africa. The data gathering process involved obtaining time series data of sampled variables. Data was categorised into 1 dependent variable (electricity production) and 4 independent variables (electricity price, coal price, coal production, electricity consumption and depreciation of machinery).

Empirical research was affected by the non-availability of data for depreciation of machinery as scheduled to be part of the empirical research. The factor was eliminated from the empirical research since even an appropriate proxy could not be ascertained. Data frequency was all on a quarterly basis for both the dependent and the independent variables. The study period was considered from the first quarter of 1998 to the last quarter of 2015. All variables produced 68 individual observations. The only exception was the electricity price with an observation of 63 since there was no data available from the first quarter of 1998 to the last quarter of 2002. Information obtained was used to determine regressions' effects of the dependents over the independent variable. The dependent variable (electricity production) was measuring the electricity supply security such as disruptions should production decline (grid reliability). The independent variables measured the impact on electricity production. The total number of observation occurrences accumulate to 471.

5.3.1 Hypotheses

The hypothesis is a good guess at the best answer to a question, based on the most reliable facts available (Chesterman, 2008:10). Bulajic *et al.* (2012) assert that a hypothesis condenses the general focus of empirical research to aid research framework or model. A hypothesis is mostly designed to prove false than prove true because it is not possible to test all the viable combinations and conditions that a hypothesis can cover (Bulajic *et al.*, 2012). Levine *et al.* (2008) agree that testing the significance of the null hypothesis is the most common method that is applied to a statistical inference research. To develop an effective and applicable model for the empirical research, hypotheses were developed to guide model construction by the following assumptions:

- 1: If the production of coal decreases, electricity supply capacity will decrease.
- 2: If electricity prices increase, electricity supply capacity will increase.
- 3: If coal price increases, electricity supply capacity will decrease.
- 4: If the increase in consumption is not relative to production, supply capacity will decrease.

5.3.2 Model specification

The Ordinary Least Square (OLS) model was employed in performing linear regressions. Varmuza and Filmer (2009:124) state that multiple linear regressions can utilise the OLS model. A multiple OLS model is denoted as follows:

$$Y_t = \beta_o + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \varepsilon_t \quad (\text{Formula 5.1})$$

Concerning formula (5.1) indications represented are as follows:

Y_t = Dependent variable.

β_0 = The intercept of the equation.

β_{1-4} = The slope coefficient of the independent variables.

$X_{1/-4,t}$ = The independent variable that is used to predict the dependent variable.

ε_t = The error term.

The slopes all convey information about the conditioned association between an independent variable and the dependent variable. Conditioned association, for instance, means: β_1 is the association between X_1 and Y_t holding $X_2 - X_4$ constant.

The model specification (causality between the dependent variable to independent variables) of this paper was then equated as:

$$EPV_t = \beta_0 + \beta_1 EPR_t \beta_2 CV_t \beta_3 CP_t \beta_4 ECI_t + \varepsilon_t \quad (\text{Formula 5.2})$$

Concerning formula (1.2) indications represented are as follows:

EPV = Electricity Production Volumes.

EPR = Electricity consumer price.

CV = Coal production volumes.

CP = Coal price.

ECI = Electricity consumption intensity.

β_0 = The intercept of the equation.

$\beta_1 \text{ to } \beta_4$ = The slope coefficient of the independent variables.

ε = The error term or white noise. The error term includes other variables that can also influence on EPV .

t = The sampled period.

The OLS was seen to be the best suited and most robust model specification in acquiring the objective of this paper.

5.4 Analyses and discussion

The multiple time series was the analytical approach used in this paper. Varmuza and Filmoser (2009:124) state that a multiple linear regression time series measures a single *Y* variable with several *X* variables. A multiple time series analysis was superlative in conducting the research analysis as it simultaneously considers the dependent variable to a range of possible independent variables that can significantly affect the dependent variable. It was the most appropriate technique to effectively attain a reliable outcome to the objective of this paper. Neuman (2014:421) states that a very important element of the multiple regression is that it has been recognised by most time series researchers, as an effective approach in confirming the accuracy predictions between the independent or control variables over the dependent variable through the R-Squared.

The objective was to assess the level to which significant electricity production determinants are increasingly negatively affecting electricity security of supply in South Africa. Because all variables had their measurement, they had to be logged to make them all similar to avoid permeability. To draw an applicable and reliable conclusion to assumed hypotheses, different time series regression tests were performed. Tests were performed in a systematic order as follows: unit root tests, model estimation tests, Jansen co-integration, Granger causality and the diagnostic tests. A summary of tests conducted is reflected in Table 5.1.

Table 5.1 Regression tests

Test Categories	Test type
Unit root test	Phillip Peron(PP)
	Augmented Ducker fuller (ADF)
Estimations	OLS estimation
	Residual test for co-integration
	Error Correction Term (ECT)
	Causality
Diagnostic tests	Serial correlation
	Normality
	Heteroscedasticity
	Stability test

Results were interpreted according to the outcomes from regressions. Results were accurately interpreted to avoid any possibility of fallacy in the analysis. All the time series data tests as indicated were done strictly and all procedures followed. The *p*-value is the most important element from regression results. This is because it determines the probability of whether the null or the alternative hypothesis is to be rejected or not. Performed tests seek for a *p*-value

<0.05 in order not to reject the null hypothesis. Likewise, the alternative hypothesis is accepted if the p -value is >0.05. The rule is different for the normality and serial correlation and the heteroscedasticity tests (diagnostic tests). The diagnostic tests require a p -value >0.05 to establish that regression residuals are normally distributed and not serially correlated. Alternatively, residuals are considered to be abnormal distributed and serial correlated if results are <0.05. The p -values are marked as $[*]$, $[**]$ and $[***]$ to denote significance levels at 10%, 5% and 1% respectively. It should also be noted that results were rounded up to three decimals. It should be noted that in the analysis process, sampled series were given individual codes to be able to identify variables during the analysis (See model specification or appendix 1).

5.4.1 Unit root tests

According to Westerlund and Breitung (2013), a standard econometric empirical research requires testing the stationarity of data. A unit root test was conducted for all independent and dependent variables separately to determine their stationarity. The focus unit root test in this paper was the PP and the ADF tests. Augmented Dickey-Fuller (1981) modelled a protocol for testing stationarity by utilising logarithmic series at the 1st difference, denoted as:

$$(Ly_t) = \log(y_t) \quad (\text{Formula 5.3})$$

The following hypotheses are assumed for the ADF unit root test:

$H_1 : L_y$ is non stationary against the

$H_0 : L_y$ is stationary

Bento (2011:3) says the ADF has the potential to overcome the problem of autocorrelation frequently found in time series modelling. ADF was estimated at no intercept or trend. However, the ADF has encountered some insignificant criticisms. The PP was also utilised to establish reliability that, data are stationary.

Phillips and Peron (1988) modelled a nonparametric approach to testing unit root for a wide range of data. This test uses fitted drift and time trend to determine between unit root stationarity and non-stationary in a model. The PP is conduct based on the following model:

Let $\{y_t\}$ be a time series generated by:

$$y_t = \alpha y_{t-1} + u_t \quad (t = 1, 2, \dots) \quad (\text{Formula 5.4})$$

$$\alpha = 1$$

Castro *et al.* (2013:3) says the PP and the ADF differ as the ADF perform stationarity on residuals free of serial correlation. Alternatively to the ADF, the PP is utilised on models with

weakly dependent errors. It was important to establish if the tested data series were stationary or non-stationary. It was important to utilise stationary data in the estimation of models to avoid spurious regressions. Spurious regressions lead to spurious results that are misleading in terms of inferences drawn. Results from unit root test are presented in Table 5.2

Table 5.2 Unit root test

Variables	ADF P-Values	PP P-Values	Conclusion
CP	0.0000***	0.0000***	H_0 is rejected
CV	0.0001***	0.0001***	H_0 is rejected
ECI	0.0283**	0.0001***	H_0 is rejected
EPV	0.0062***	0.0001***	H_0 is rejected
EPR	0.0000***	0.0000***	H_0 is rejected

Both the ADF and PP tests were conducted on each series. All conduct unit root test produced a stationary outcome at the 1st difference. The *p*-values from all series were below 0.05. The *p*-value results in the various unit root tests for all series confirmed positive at a 1% level of significance. Thus, the null hypothesis that data are autoregressive (non-stationary) for each series against the alternative that each series is stationary was accepted.

5.4.2 Ordinary Least Square estimation

The OLS estimation test is a test for co-integration in the OLS model. The independent variables Coal Price (CP), Coal Volume (CV), Electricity Consumption Intensity (ECI) and Electricity Consumption Price (EPR) were tested over the dependent variable Electricity Production Volumes (EPV) to establish if the independent variables can influence the dependent variable. Bento (2011:3) points out that stationarity of data is the only requirement to implement an OLS regression method.

Table 5.3 Ordinary least square estimations

Variables	t-statistics	P-value	Conclusion
CP	19.67969	0.0000***	H_0 is accepted
CV	3.001454	0.0042***	H_0 is accepted
ECI	2.086586	0.0419*	H_0 is accepted
EPR	-2.278119	0.0269*	H_0 is accepted

The outcome from regression reflects that a significant relationship exists between all the independent variables with the dependent variable. The results reflect that the hypotheses and model specification used in the investigation of the problem of the empirical research is reliable. Outcomes from all independent variables produced a *p*-value results <0.05, with all series reflecting a positive outcome at a 1% level of significance. The regression analysis further confirmed reliability by obtaining a 97% R-squared. The results from the price of

electricity reflect similarly to outcomes of Blignaut *et al.* (2014) and Inglesi (2011). The outcome from price was significant, confirming that price elasticity of electricity in South is becoming increasingly lower through the years and can consequently affect future electricity potential as consumers become very alert to the pricing of electricity.

5.4.3 Co-integration

On this paper, co-integration was performed through the Engle Granger OLS non-stationarity tests. Ssekuma (2011:3) views that, it is faulty for econometric to accept differencing of OLS series during unit root. It causes a material influence by reducing non-stationary series to stationary as opposed to if tested at levels. Engle and Granger (1987) point out that stationarity is precise when no deterministic component is attached to perform stationarity on a data series. Engle and Granger proposed a method which involved performing the ADF test from OLS estimation residuals.

Testing for co-integration on this Engle-Granger approach involved performing the ADF tests on OLS estimation residuals at levels, with the MacKinnon critical values adjusted on variables to determined stationarity. The co-integration approach evaluates if $\hat{u}_t$ is stationary. If stationarity exists, the OLS estimator is said to be co-integrated. This approach for co-integration assumed the following expression:

$$\hat{u}_t = y_t - \hat{\alpha}_0 - \hat{\delta}_1 x_t \tag{Formula 5.5}$$

Table 5.4 Engle-Granger ordinary least square co-integration test

		t-Statistic	P value	Conclusion
ADF test statistic		-4.907166	0.0002***	<i>H₀ is rejected</i>
Test critical values	1% levels	-3.555023		
	5% levels	-2.915522		
	10% levels	-2.595565		

ADF estimation obtains a *p*-value of 0.0002 and a t-statistic of -4.907166. Results reflect that the independent variable and the dependent variable are highly co-integrated. This implies that there is long-term relationship between the dependent and the independent variables.

5.4.4 Engle Granger “Error Correction Term” (ECT)

Engle and Granger (1987) point out that if two variables *y* and *x* are co-integrated, the error correction term should be defined between the co-integrating variables. Co-integration and ECM verify if a long-run and short-run relationship exist between variables respectively. An elementary ECT model is as follows:

$$\Delta y_t = \chi_0 + \chi_1 \Delta x_t - \tau(u_{t-1}) + \varepsilon_t \tag{Formula 5.6}$$

The generated residual series derived from the the simple OLS co-integration estimation are lagged to act as the ECT. The ECT, which is a symbol as u_{t-1} , is expressed as $(y_{t-1} - x_{t-1})$. The ECT is only statistically significant when the coefficient is a negative and the p -value is <0.05 . The ECT measures reverse rate of adjustment to equilibrium following an exogenous shock.

Table 5.5 Error Correction Term results

Coefficient	t-statistics	P value
-0.442332	3.523117	0.0009***

Error correction was estimated to present short-term dynamics that exist between influencing factors and the grid. Results from the ECT regressor reflect that the model is balanced. The ECT coefficient was found to be negative (-0.442332) and statistically significant with a p -value of 0.0009. The result reflects that the speed of adjustment on any shock by the dependent variables on the independent variables will be approximately 44%. This indicates that over 44% of the disequilibrium in the previous quarter is adjusted to their long-run equilibrium in the current quarter.

Table 5.6 Causality test

Null hypothesis	F-Statistic	P-Value	Conclusion
ECI does not granger cause EPV	3.08677	0.0524*	H_0 is rejected
CV does not granger cause EPV	4.11640	0.0207**	H_0 is rejected
CP does not granger cause EPV	1.83146	0.0583*	H_0 is rejected
EPR does not granger cause EPV	10.1456	0.0002***	H_0 is rejected

After the OLS estimation, a uni-lateral causality test was conducted to establish if the independent variables granger causes the dependent variables. H_0 (Null hypothesis) assumed that the independent variables do not granger cause or impact the dependent variable. Regression outcome from ECI, CV, CP and EPR rejected H_0 with the aforementioned variables producing p -value results <0.05 . Thus, independent variables, ECI, CV, CP, EPR, test significance to have an impact on EPV.

5.4.5 Diagnostic test

Dalla *et al.* (2015:1) state that it is customary to perform a diagnostic assessment to properties from data used for empirical research in time series modelling. Brooks (2009:43) brings to light that the diagnostic tests seek to assess the degree of fairness from regression outcomes. These tests require p -values >0.05 to be considered significant.

5.4.5.1 Normality test

The Jarque-Bera (J-B) test was used in testing for normality. According to Brooks (2008:57) the J-B estimate normality through the skewness and Kurtosis statistics. The J-B assumes that the null hypothesis is normally distributed against the alternative hypothesis that other distributions are present. Referring to Cameron (2005:238), the J-B test combines the skewness and the kurtosis according to the following formula:

$$J-B = n[(S^2/6) + \{(K - \frac{3}{24})^2\}] \quad (\text{Formula 5.7})$$

Cameron elaborated on the equation, n is the sample size, S the skewness and K the kurtosis. If skewness slopes to the right or the left, then the distribution is not normally distributed. Kurtosis measures how steeply values are rising to the most likely value in the distribution curve. According to Gujarati (2004:148) under the J-B test, if the computed p -value is sufficiently low, the alternative hypothesis should be accepted that residuals are not normally distributed. Alternatively, if p -values are reasonably high, the normality assumption is not rejected.

5.4.5.2 Serial correlation

The Serial correlation test provides evidence if error term values within sampled periods are systematically dependent (Studenmund 2011:304). Baltagi (2008:92) warns that is biased in ignoring serial correlation if detected in analysed data. Regression will provide required but unethical estimates if serial correlation is detected and ignored. The Correlogram test was used in detecting serial correlation among data series. Referring to Nopiah *et al.* (2010) the Correlogram test, aim at sensing the presence of serial correlation in a specified order in the autocorrelation tested lags. Gujarati and Porter (2009:434) highlight that the advantage of the Correlogram test is that it detects the presence of higher-order serial correlation.

Hypotheses developed in testing for serial correlation are:

$$H_0: \rho = 0 \text{ and } H_1: \rho \neq 0.$$

The hypothesis H_0 denotes that no serial correlation exists while the alternative, H_1 , on the other hand assumed that there was serial correlation. Data were tested for serial correlation because in general, econometrics established the OLS is commonly inconsistent in the presence of lagged dependent variables and serially correlated errors. Even though Wooldridge (2006:415) holds that most of such assumptions are false, it was necessary to test for serial correlation to prove the precision of coefficient estimates.

5.4.5.3 Heteroscedasticity

Wooldridge (2009:278) states that the test for heteroscedasticity investigates whether or not heterogeneity exists among estimates. Baltagi (2005:99) elaborates that the test assumes that disturbances from regressions are homoscedastic with the same variance across time and individuals.

In this paper, the White's cross section and the Arch tests were used. Studenmund (2011:350) says the White test detects the heteroscedasticity by considering the squared residuals as the dependent variable when performing regression. The following hypotheses were developed:

$H_0: \sigma_t^2 = \sigma$ (the null hypothesis assuming homoscedastic errors) and

H_1 : *not equal for all t*, (the alternative hypothesis assuming heteroscedastic errors).

In agreement with Asteriou (2011:127), the White's cross-section test was employed in this study because it does not assume any determination of heteroscedasticity.

Table 5.7 Diagnostic tests results

Test	Measurement	Hypothesis	P-values	Conclusion
Normality	Jarque-Bera	H_0 : all t is normally distributed H_1 : not all t is normally distributed	0.8382	Errors were normally distributed.
Serial correlation	Correlogram test at (1 st difference)	$H_0: \rho = 0$ $H_1: \rho \neq 0$	0.15	Serial correlation was not detected
Heteroscedasticity	White's test	$H_0: \sigma_t^2 = \sigma$	0.0690	The white and Arch test reflects that series are homoscedastic.
	Arch test	H_0 : <i>not equal for all t</i>	0.1330	

All series acquired a p -value >0.05 for the normality, serial correlation and heteroscedasticity tests respectively. Thus, diagnostic results acquired a positive significance for tested series.

5.4.5.4 Stability test

Brown *et al.* (1975), developed the recursive stability test for OLS models under the following parameter:

$$y_t = x_t b_t + u_t \quad (\text{Formula 5.8})$$

where, y_t is the observation on the dependent variable, x_t , is a $K \times 1$ column vector of non-stochastic regressors, b_t , is a $K \times 1$ vector of regression coefficients, u_t , is a disturbance term, with mean zero and variance σ_t^2 .

Farhani (2012) alludes that the recursive value also estimates the level of stability significance at a 5% critical line benchmark. The test is referred to as the Cumulative Sum (CUSUM) of squares test, and it uses the sum of squared recursive residuals, as reflected by an estimation graph. It tests the null hypothesis under the assumption that the dependent variable “ s_m ” follows a *Beta* distribution with a mean, equals to independent parameters, $E(s_m) = [(m - K)/(T - K)]$.

The OLS recursive stability test assumes a negative result if the constructed forecasting model is stable over the sample period and remain stable over the forecast period. If the model’s parameters are different during the forecast period than the sample period, the model estimation will be viewed as irrelevant regardless of how perfectly it was estimated.

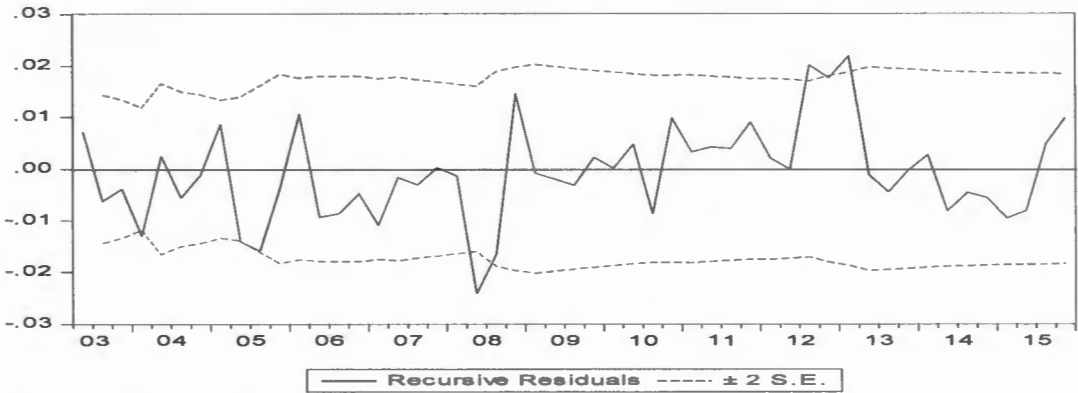


Figure 5.1 Recursive residual test

Figure 5.1 reflects the recursive residual test. It is evident that none of the model’s parameters changed at one or more points in the sample period. Results reflect that the regression model is stable over time because as t increases the recursive parameter estimates stabilise at level. A conclusion can be made that the stability of CP, CV, EPR and ECI is of crucial importance for consistent electricity supply.

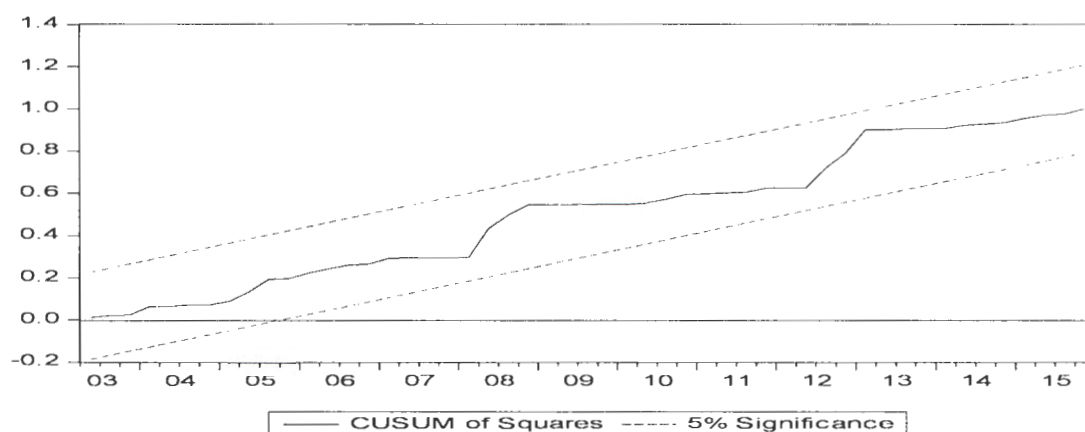


Figure 5.2 The CUSUM estimation test

Figure 5.2 reflects the significance level of the CUSUM estimation. The CUSUM test falls within the accepted critical value of 5%. Results reflect that the model parameters are stable over the tested time periods.

5.5 Conclusion

The empirical research of this paper was assessing the sustainability of the electricity grid in meeting the pressure of current and future demand. Von Keltchodt and Wocke (2008) note that if electricity demands exceed supply, the unreliability of electricity supply increases.

This paper has provided reliable evidence of the significant threats to the electricity security in South Africa. The Engle-Granger co-integration test concurs that both the short and long-term relationship between the dependent variable and the independent variables. Stability tests confirm that the tested independent variables, electricity price, coal price, coal volume and increase in grid consumption have a consistent pattern to the dependent variable. Causality test also confirms that the independent variables can cause an impact on the dependent variable. This has a direct consequence on electricity supply in general because as production falls, supply is adversely affected in high proportions. Hameed and Khan (2016) assert that an electricity grid is under siege if production potentials are not comparative to the constantly increasing demands of the industrial and domestic sectors. Thus, Clark *et al.* (2005:29) concur the security of electricity is threatened if the physical quantity of available electricity is insufficient for consumers. Considering that South Africa is an energy-intensive economy, developing sustainable electrical energy frameworks should be a major element for strategic policymakers.

5.6 Final statement

The *raison d'être* behind this article was to encourage research on electricity security and to recommend applicable policy guidelines in attaining a secure electricity environment in South Africa. It is acknowledged that initiative programmes have been established to ensure the security of electricity supply in South Africa. However, initiatives are still to be effectively prioritised and applied. Policy makers are still to develop reliable and applicable dynamic parameters towards electricity security in South Africa. Current efforts show that the focus has been on coal generation, which has proven to be unsustainable. South Africa should explore new sustainable and energy efficient technology generation sources such as renewable energies with more security potentials compared to other sources. Electricity security can be attributed to the capability of an electricity grid in meeting up the electricity needs of final consumers (Raillon, 2010:2). Energy security will turn around the negative social and economic development in South Africa. Energy strategies should consider renewable energy as the most effective option for future South Africa electricity needs and energy systems advancement.

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CHAPTER SIX

RECOMMENDATIONS AND CONCLUSION

6. INTRODUCTION

By 2007/2008 electricity inconsistency had become common in the South African environment with serious impact on domestic living standards and industrial growth. There is a general concern about electricity security in South Africa as load shedding is still experienced in most parts of the country. The effects of electricity inadequacy have a far-reaching effect on the economy in general as economic growth has been greatly affected. Implemented policy frameworks to advance the energy system and the electricity grid have not attained desired targets due to non-prioritization of an integrated management approach that shall assess the challenges of the grid as an SOS. It is acknowledged that researchers have conducted empirical researches into the electricity shenanigans in South Africa. However, this study is unique, as no study has attempted to examine the scope applied in this study critically. The empirical research assessments examined the following: electricity crisis, inconsistency, adequacy, emission and efficiency which constitute the foundation for the advancement and solutions to the challenges of an energy system and electricity grid such as that in South Africa.

To achieve the core objective of this study, designing an integrated strategic management framework with capabilities for electricity adequacy in South Africa, the following sub-objectives were considered:

- Investigating the strategic management failures pertaining to the ongoing electricity crisis in South Africa.
- Assessing the impacts of the low electricity supply on the South African domestic sector and resulting consumption behaviour.
- Evaluating the effect of inadequate industrial electrical power supply on industrial growth in South Africa.
- Determining the electricity security by analysing significant determinants to the reliability of the grid.

The objectives were addressed through relevant articles. Addressing these objectives through an article approach provided an opportunity to formulate a conceptual framework that would reliably contribute to the advancement of the South African electricity system. The framework

has integrated the results of the empirical research to provide reliable and applicable steps that would need to be followed to ensure electricity adequacy and advancement in South Africa.

6.1 Investigating the strategic management failures relating to an electricity crisis in South (Article 1)

This objective (article 1) primarily focused on the assessment of strategic management and integrated strategic management of the electricity system in South Africa. The empirical research utilised a qualitative content analysis. Findings were generated from a reliable existing literature review on the low electricity supply in South Africa. The empirical research considered two main categorical concepts with themes under each category.

Category concept 1: *The impact of strategic management failures to low electricity supply in South Africa.* This category considered the following themes: Demand and supply estimation, Department of Energy White paper of 1998, strategic renewal, Eskom coal supply decision and administrative effectiveness.

Category concept 2: *Assessing challenges to low electricity supply from an integrated perspective.* The category addressed causes of low electricity supply from an integrated management perspective. This section was aimed at bringing to light the fact that an electricity grid is a complex network consisting of large-scale inter-disciplinary problems requiring heterogeneous solutions. Themes discussed in this section include human resources, policy regulation, a public-private partnership, environmental concerns on emission, asset management, demand-side management and research and development.

The empirical research revealed that strategic management failures and the lack of an integrated strategic management approach had been major stumbling blocks to averting energy crises in South Africa. Thus, it is important for policy developers to prioritise strategic management and a multi-factor approach in assessing the challenges of the South Africa, unlike the current philosophy of strictly technological investments.

The significance of the empirical research: The article creates awareness about the importance of viewing the causes and solutions towards solving the current electricity crisis from an integrated strategic management perspective.

6.2 Consequences of inconsistent electricity supply on the South African domestic sector and related consumption behaviours (Article 2)

This objective (article 2) was to address electricity access the effects of electricity inconsistency on the living standards of the domestic sector. Electrical energy is a primary factor for social development in an economy. Challenges to electricity supply affect the quality of life of the domestic sector. The empirical research was quantitative and was conducted on the low-income and high-income bracket households in the economy by applying a purposive quota sampling technique targeting residential environments from both income groups in cities in Gauteng and North West provinces. The empirical research was aimed at bringing to light the ineffectiveness of electricity access and to demonstrate how electricity inconsistency affects the quality of life of South Africans. The empirical research also investigated the current electricity consumption tendencies in the domestic sector. Determining the pattern in which electricity is consumed by the population ultimately provides advice for policy officials on developing reliable strategies towards domestic sector efficiency.

The empirical research was structured into three principal sections: Electricity supply and inconsistency and consumption behaviour. Conclusions from the two sections were drawn as follows:

Electricity supply and inconsistency: This section considered the following factors to develop a reliable contribution on a Likert and dichotomous scale questions: Supply sufficiency, service quality, health risk and cost reliability.

Consumption behaviour: This section considered a Likert scale energy saving factor, the usage rate of domestic energy intensive appliances and the use of alternative sources of energy for domestic households.

The empirical research reflects that electricity inconsistency has led to supply insufficiency, poor service quality, cost unreliability and health risks. Results also reflect that participants practice energy-saving activities to some extent. Results also reflect that energy-intensive appliances are used more, and there are severe limitations towards the efficient use of energy-intensive appliances.

The significance of the empirical research: The empirical research has contributed towards identifying the impact of electricity inconsistency across the different income groups in the South African society. It has also identified important domestic consumer tendencies that

should inform policy developers on important elements to prioritise in developing policies towards obtaining electricity efficiency in the domestic sector.

6.3 The effects of the inadequate electrical power supply on industrial growth in South Africa (Article 3)

The objective (article 3) addressed the effects of the inadequate electrical power supply on industrial growth in South Africa. The industrial sector uses electrical energy as a primary input for powering production technologies and activities. Currently, in South Africa, the business environment is fraught with uncertainties in electricity supply as industries continue to experience a shortfall in supply capacity. The effects of electricity supply and demand inconsistency for industries are also felt in the economy as the industrial sector is a principal sector towards attaining advancement in economic growth.

A quantitative design was employed. The empirical research used a purposive-quota sampling to target the three main industries that have been fundamental to the industrial growth in South Africa after 1994 (mining, service and manufacturing industries). Comparisons were made between business categories from sampled industries as well as the different business industrial classifications (SMMLES). Even though the empirical research was investigating the effects of low industrial power supply on industrial growth; the empirical investigation also assessed electricity mitigation and intensity control in the industrial sector. The empirical research main sections and factors are as follows:

Electricity supply and industrial growth: This section considered the following factors towards achieving a reliable outcome through Likert scale questions: the importance of electrical energy, supply sufficiency, operational vulnerabilities and business performance.

Mitigation control: This section used Likert scale questions in assessing participants' understand and implementations of mitigation strategies to enable the non-interruption of production and business activities due to low, poor supplies.

Intensity control: This section used a Likert scale and dichotomous questions in assessing intensity control policies by administrators and efficiency practices by organisations towards obtaining an industrial electricity efficient environment.

Findings reflect that the low supply of electrical power to the industrial sector is affecting industrial growth. However, there is variability between energy intensive and less energy-intensive industries. Results also reflect that there is a general concern in the industrial sector

on the electricity security in the South African business environment. It was also shown that there is the limited implementation of mitigation policies. Smaller businesses with limited resources struggle to implement mitigation strategies compared to larger businesses. Results also reflect that there is limited prioritisation in the implementation of intensity control programmes by administrators, especially on low-energy demand businesses. Industries tend towards negative on intensity control and efficiency practices even on industrial operations with emission implications.

The significance of the empirical research: The empirical research analysed the relationship between electrical energy and industrial competitiveness in South Africa. The findings have contributed enormously on advising the public sector to note that negligence on stabilising electricity supply and demand for the industrial sector consequently has a massive impact on the economy in general. The empirical research also created awareness on the uncertainty surrounding electricity security in the South African business environment and the need for industries to establish standby power sources to ensure the continuity of industrial activities when inconsistency occurs.

6.4 Determining the electricity security by analysing significant determinants to the reliability of the grid (Article 4)

The objective was aimed at assessing the electricity security in South Africa by analysing significant determinants to the grid reliability and to project future implications if measures are not implemented. Electricity security is currently the fundamental concern of utilities around the world. Insecurities in the electricity system directly threaten the future capacity of the grid. It is important to attain a secure electricity environment as it leads to supply confidence and economic growth.

The empirical research was quantitative and employed a multiple time series approach. The Engle-Granger OLS technique was utilised in running a regression between the dependent and independent variables. The dependent variable is electricity production in GW, and the independent variables are coal volume, coal price, electricity consumption and electricity price. Depreciation of electricity machinery was also considered to be a significant determinant, but could not be included in the empirical research due to unreliable data.

The empirical outcome reflects that co-integration exists between the dependent and the independent variables. It was also found that there is causality between the dependent and the independent variables.

The significance of the empirical research: The empirical research conducted estimations to project future relations to establish the sustainability of the grid in the short and long-run. The findings identified the primary elements to consider for improving electricity security potentials in South Africa.

6.5 An integrated strategic management system framework for electricity adequacy in South Africa

The main objective of this study was to design an integrated strategic management system framework with capabilities for ensuring electricity adequacy and advancement in South Africa. The design of the framework considered a systematic and coherent approach from its development stage to its finalisation to ensure an effective model construction. According to Sinclair (2007), the construction of a theoretical framework commences with reviewing existing literature to identify relevant theories that guide the framework development. This is important as it assists in constructing fundamental questions that describe and propose potential relationships links of factors in the empirical research to reflect a solid outcome for the modelling tentatively.

Sinclair (2007) outlined that in selecting an effective theory to guide the development of a robust framework, researchers should consider the following fundamentals questions:

- What are the relevant aspects of the phenomenon of the study?
- What types of knowledge are available on the phenomenon (empirical, non-empirical)?
- What theory best guides the development of a practical system?
- Is the design backed by theory-linked research?
- What are alternative relevant theories to the phenomenon?
- How can the theory be applied in empirical findings?

The main agenda answers the question of what could be an effective, applicable and reliable integrated strategic management model to direct the development of a concrete electricity adequacy framework in South Africa. After a coherent assessment of the recommended question by Sinclair, the Energy Trilemma reflected to be the most effective tool to gear the construction of a reliable and practical framework. As already discussed in detail in Chapter one, the energy trilemma is recommended by the WEC with proposed parameters that should underpin developmental direction for electricity systems studies. The WEC argues that the trilemma is a fundamental tool for countries to utilise as a parameter for integrated strategic assessment of challenges and solutions to electricity systems.

6.5.1 Relevance of the framework

After a thorough review of existing empirical research on electricity policy frameworks in South Africa, there was no research found to have explored parameters within the scope of this study. A detailed evaluation of the current implemented integrated strategic policies in South Africa has been elaborated upon in Chapter one. Major concerns are the following:

- The modelling of a strategic plan for future electricity advancement has not considered a comprehensive and detailed integrated analysis of South African energy needs.
- Policies do not quite match the current energy realities towards a sustainable and environmentally friendly production and usage of energy.
- The nature of a national energy system is very complex, and the lack of a systems approach to implemented policy frameworks has resulted in limited rewards in the progress of the South African electricity system.

According to Laitner (2007:3-4), the scope of energy systems analysis has been significantly limited to technological dimensions hindering the prevalence of comprehensive, integrated approaches. Technological dimensions do not appropriately apply to the real world realities of energy needs because it does not identify humans as active energy users. Integrated models further advance knowledge on energy systems compared to technical models as it considers human decisions regarding energy usage (Farsi & Pachauri, 2007 and Gundimeda & Kohlin, 2008). The designed framework is capable of overcoming identified loopholes on policy implementation aimed towards electricity adequacy and advancement in South Africa. Its parameters effectively provide policy developers with important considerations for both short and long-term electricity policy implementation. The framework practically reflects the direction of electricity policy priorities in South Africa. An integrated strategic management framework with capacity for electricity adequacy in South Africa is diagrammatically reflected in figure 6.1.

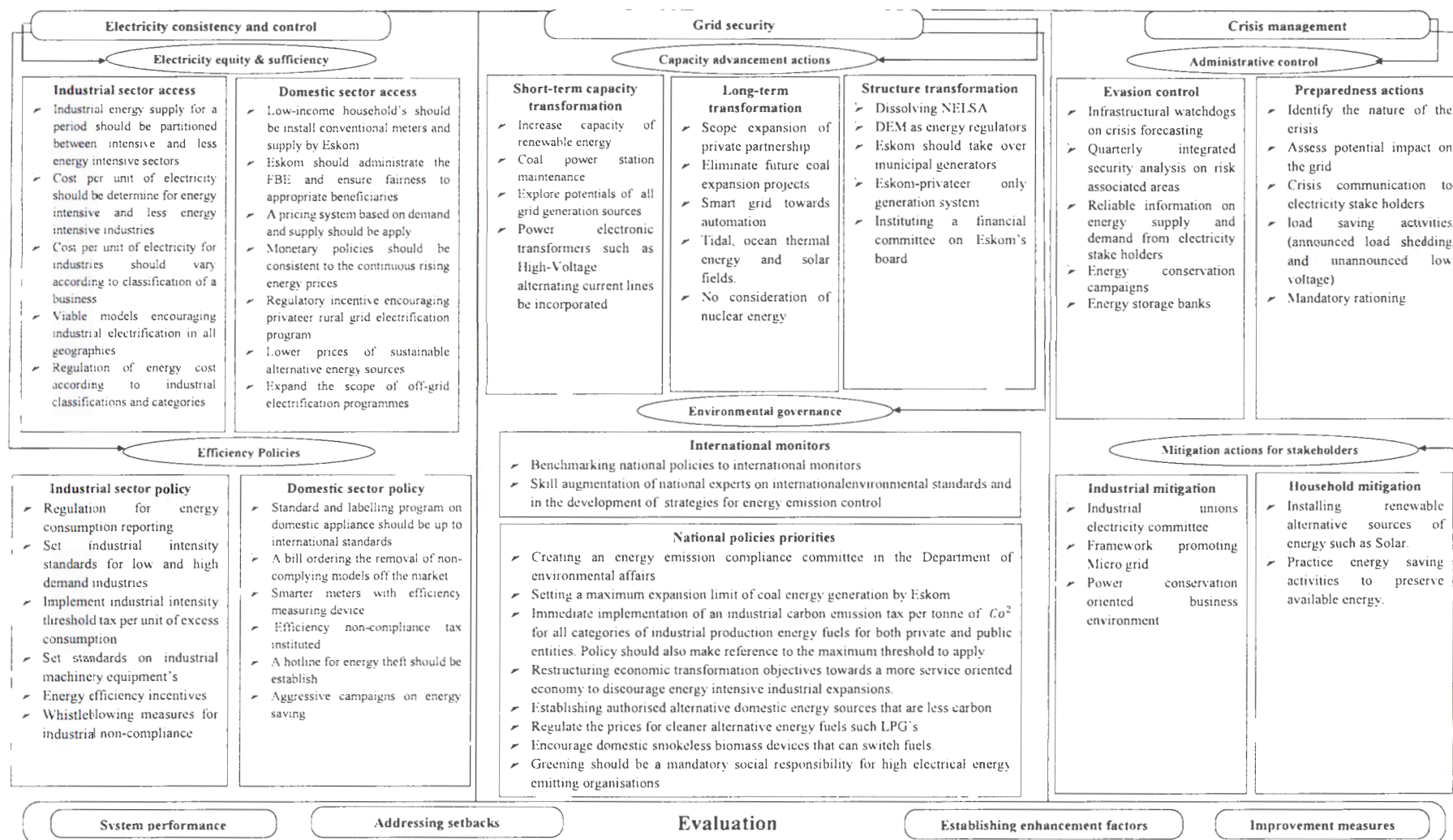


Figure 6.1 Holistic integrated strategic management system framework for electricity adequacy in South Africa

The holistic approach of the study brings together all fundamental aspects of electricity adequacy in South Africa. The systems are practical and inter-related. To analyze the integrated nature of the framework, a more simplified version is provided in figure 6.2.

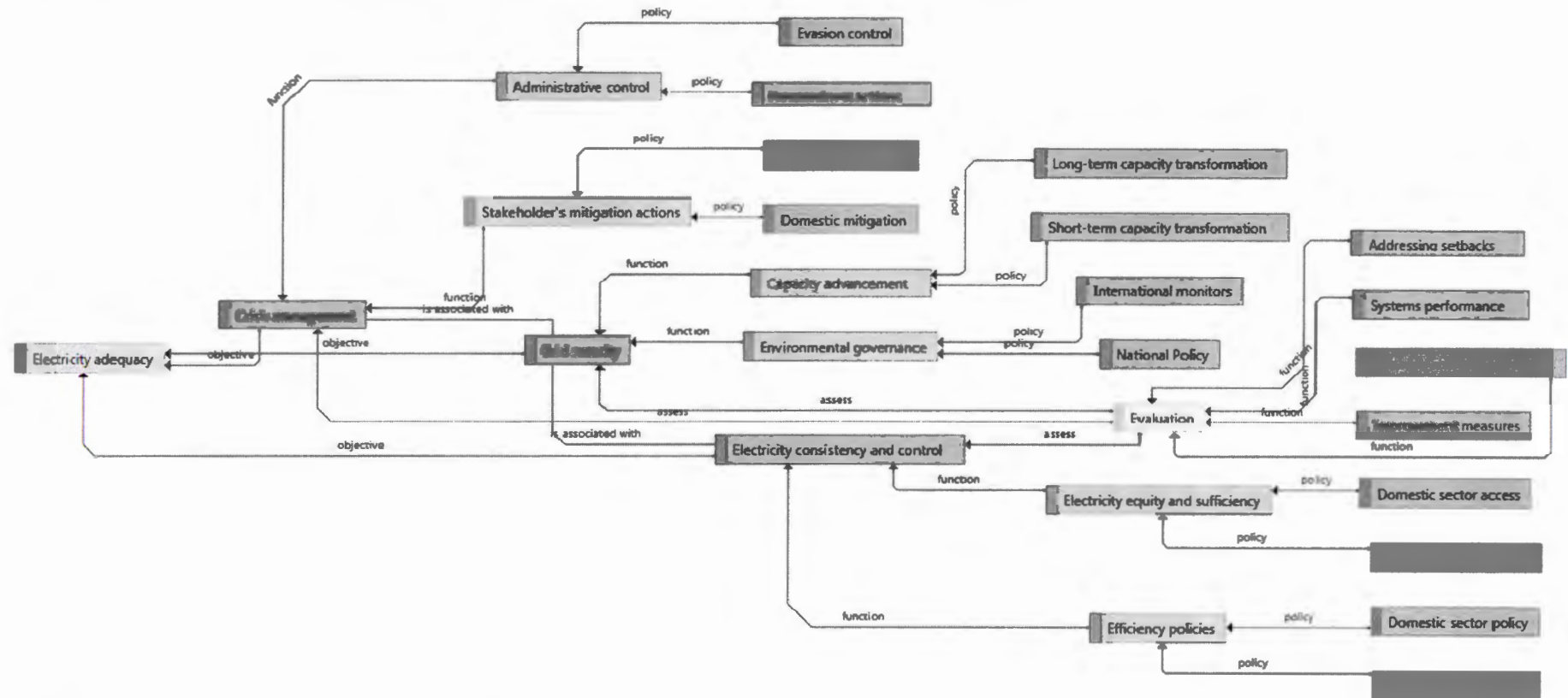


Figure 6.2 Project-oriented integrated strategic management system structure for electricity adequacy in South Africa

The structure is a four-phase design with three critical objectives: Electricity consistency and control, grid security and crisis management. Each of the objectives consists of a two-system function network. Each of the systems contains a two-structure policy implementation platform. Evaluation is the final phase of the framework and has equal strength as any of the objectives. The four phases are unified, which implies none of the systems can operate individually towards achieving a solution to the identified phenomenon without the effectiveness of the other systems. An electricity grid is complex and requires a thorough holistic approach towards its stability.

The electricity supply to consumers is determined by the grid security. The unreliable state of the current grid supply consequently affects electricity consistency. This implies that it is important to prioritise grid capacity advancement to guarantee the reliability of the grids to achieve consistency between demand and supply and energy required and energy reserves. The South African electricity grid has been venerable over the years with significant impact on the grid generation capacity and the government legislation in 1995 calling for a suspension to the capacity advancement of any kind. By the last quarter of 2007, electricity inconsistency has been plaguing the society in general. Intensive load shedding has been experienced to date. The electricity industry has identified this particular objective. Alternatively, policy implementation towards its improvement are non-comprehensive.

Equity of supply and sufficient demand levels for all sectors in the economy is required for complete electricity access for all consumers. Alternatively, the capability of the grid to supply sufficient electricity to consumers requires effective and reliable control measures. Sufficient supply is usually characterised by wastefulness and ineffective electricity efficiency. Inefficiency in electricity generated and consumed leads to the insecurity of the grid. The efficiency of electricity is a major objective towards attaining stability on the grid. South Africa currently, still cannot institute efficient generation and end-use of energy. A vulnerability of the grid will be followed by a crisis. In general, the insecurities in global electricity systems are highest in sub-Saharan Africa compared to other world regions. It is essential that both administrators and consumers accept the realities of the current insecure electricity environment of South Africa. The current crisis by 2007 that was adequately predicted by the DME White Paper of 1998 reflects the non-prioritisation of electricity crisis plans in South Africa.

The evaluation phase consists of four fundamental elements that would steer the framework to effectiveness. The evaluation process will provide the opportunity to strengthen the framework

further to guarantee the reliability of its applicability. In general, the evaluation of energy policies in South Africa is still at a crossroads. It is without a doubt that the framework mirrors a reliable and applicable way forward to electricity adequacy and advancement in South Africa. The framework represents the general recommendation of all aspects of the study. Further elaboration to the features of each phase is discussed in the following section.

6.5.3 Recommendations on framework characteristics

The following section discusses the characteristics of the framework and related recommendations.

6.5.3.1 *Electricity equality and electricity control*

The objective was aimed at developing systems for electricity access and sufficiency and efficiency policies for domestic and industrial sectors. The framework considered electricity access and sufficiency and efficiency as an important first step towards supply sufficiency and adequacy.

- **Electricity access and sufficiency**

The focus was on strategies toward supply accessibility and sufficiency across all classes of the domestic population and the industrial sectors. Domestic and industrial sectors empirical results (Objective 2 and 3) did conduct an assessment of electricity access and sufficiency. The empirical outcomes reflect that supply access is not effective and sufficiency is still at a minimum and this has greatly affected the operational activities in the domestic and industrial sectors. Results reflect that electricity sufficiency varies across different income groups and industrial sectors. The framework (figure 6.1) has outline strategies to ensure improvement in electricity access and sufficiency in both the domestic and industrial sectors.

- **Efficiency policies**

The first step to possible electricity adequacy advancement to an electricity grid is through electricity efficiency. To recommend potential efficiency policies for the domestic sector, the empirical research sampled ten most intensive electrical appliances to determine consumption tendencies. Critical energy saving activities were also used to evaluate participants' habits. Empirical research reflects that consumers need awareness of energy efficiency practices. There is a high usage of most intensive appliances with most participants owning appliances older than five years. It is important for a more dynamic approach to the standard and labelling programme with the flexibility to permit radical policy implementations. The lack of effective

practice of energy saving activities by domestic consumers implies that more aggressive energy saving campaigns are of the essence.

Empirical outcomes also reflect that there is increasing intensity within industries and there is the limited incorporation of electricity efficiency in organisation strategies. The framework (figure 6.1) has recommended critical regulatory priorities to ensure electricity efficiency in the industrial sector.

6.5.3.2 Grid security

The grid security is a very important objective in the framework. It reflects the most effective approach towards the short and long-term transformation of the grid and constitutes a reliable procedure for environmental control.

- **Capacity advancement actions**

The framework has considered capacity advancement in the short term as also very important. Capacity advancement policies have prioritized long-term security. Eskom has over-focused its resources towards the realisation of the Kusile and Medupi new power stations, ignoring the importance of effective assets. Repair circles are continuously altered as Eskom fears the impact of trading off continuous supply for asset maintenance. Alternatively, the operational cycle of most capital generation assets of Eskom are at their break-even point. Thus, trading off periodic supply disruption for asset management is a better choice. Eskom can also capitalise on the potentials of its supporting generation sources such as wind and solar to advance its renewable energy objective.

The long-term capacity advancement approach is a major concern in the South African society today. There have been several debates on what is the best approach towards energy capacity advancement in South Africa. The energy policy cabinet is currently promoting an agenda towards nuclear energy. An advantage of nuclear energy as an alternative energy generation carrier is that capacity will be improved. Alternatively, it will hinder all efforts towards sustainable energy generation. Nuclear energy generation is not the most reliable future pathway for South Africa as it entails similar disadvantages as any other environmental concern energy generation sources. Nuclear energy contains the following disadvantage for South Africa:

- Uranium, the most important and effective resource for fission process, is scarce in South Africa.

- Nuclear energy generation reactors are highly fragile requiring effective maintenance schedules which South Africa currently lacks in this regard.
- An incidence of operational failure can cause a radioactive explosion with serious environmental consequences.
- Radioactivity from fission is high-level nuclear waste that requires sufficient and adequate water sources to eliminate waste. South Africa is currently ranked the 31st driest land in the world.
- To attain a competitive nuclear energy dominant electricity grid, an electricity system should have been strategically positioned towards that direction in its long-term goals. South Africa's future electricity generation policies are currently more inclined towards coal generation advancement.

The framework has suggested ocean energy as a turning point towards electricity adequacy in South Africa. South Africa is still to explore its potential of ocean energy. The Cape currents are a major contributor to the Agulhas ocean currents, which produce the strongest tides in the world. The Cape Ocean is a meeting point between the cold Atlantic waters and the hot Indian Ocean. The Cape Ocean has the potential for hybrid thermal energy as it has the potential for both closed and open-cycle energy generation. Closed-cycle involves using the heat from the surface of the ocean collected from the sun to convert energy. Open-cycle involves generating steam from the hot ocean waters from the earth crust. Ocean energy has the following potentials for South Africa electricity adequacy;

- A major challenge to electricity adequacy in South Africa is capacity. Ocean energy naturally increases capacity without any cost input.
- Since ocean energy involves natural geological activities of the earth, it is practically inexhaustible.
- Ocean energy is “smart electricity” generation approach.
- Ocean energy is the appropriate pathway towards exploiting extreme potentials of the DME objectives towards renewable energy.

The framework has also suggested the exploration of solar and wind energy to full capacity as it would also solve adequacy deficiencies experienced by off-grid consumers. Wright *et al.* (2017:53) recent findings on the South African energy system found that the IRP (2010) has significant gaps in the capacity of effective renewable energy attainment. Wright *et al.* empirical findings revealed the following:

- Solar PV and wind fields will be the cheapest energy enhancement option into the South African energy grid.
- Renewal energy expansion has a lifetime cost of R90 billion per year cheaper, reflecting 70 percent less costly compared to coal and nuclear energy.

Full exploration of the potentials of renewable energy will reduce CO^2 emissions by 65 percent by 2050.

In general, the framework emphasises that the renewable road path is the most reliable, but there is a need for the DME to expand the scope of the renewable energy objective. The framework also suggests a general structural change in the electricity industry in general towards a more Eskom-private generators oriented structure. Bayrak *et al.* (2017) say renewable energy is the solution for energy sustainability of all economies of the world. It offers unique competitive advantages such as environmental-cautiousness, inexhaustibility and are the cleanest electrical energy carrier in the modern world.

- **Environmental governance**

The framework advocates that national policies should be benchmarked by international standards. It has also outlined important national energy environmental policy priorities for South Africa. Environmental challenges are primary obstacles to achieving electricity adequacy in South Africa. There is a general global campaign from most environmental societies against Eskom's non-prioritisation of the future transformation of its generation plans to an environmental friendly energy generation sources. It is important that policy effectively prioritises on energy emission and control to meet internationally acceptable standards. Industrial energy carbon compliance and sustainable domestic alternative energy sources will significantly impact efforts towards the control of energy pollution in South Africa. A major obstacle to achieving green energy production in South Africa is its utilisation of coal as a primary energy production resource. Mezghan and Haddad (2017) and Liddle and Sadorsky (2017) concur that there is both a long-term relationship between energy production fuel of a country to its emission levels. Armaroli and Balzani (2011) conducted an empirical research study to establish the possibility of a complete electricity powered world. The findings from empirical research pointed out that a general global accord towards a transformation of electricity generation from fossil fuels to carbon-free sources such as solar and wind is a fundamental action to ascertaining a total electricity powered world.

6.5.3.3 Crisis management

The objective has considered electricity crisis management in South Africa from two dimensions. The framework considered the importance of crisis management from an administrative and consumer perspective.

- **Administrative control**

Administrative control is the actions liable to electricity administrators towards crisis avoidance and preparedness. Conservation of energy requires administrators to provide for continuous assessments and conservation of energy through intensive research on high probability risk areas. It is also important for administrators to be aware that electricity inconsistency cannot be easily eliminated especially in developing economies like the sub-Saharan Africa. It is important to establish effective measures for effective control of electricity crisis occurrences. The South African electricity grid has proven to be obstinate over the decades with periodic occurrences of the electricity crisis. Recommendations on critical functions are reflected in the framework

- **Mitigation actions for stakeholders**

The South Africa environment is characterised by periodic electricity inconsistencies and electricity insecurities. There is ongoing tension between demand and energy reserves as reflected in figure 1.1. It is important for consumers to develop back up plans to guarantee continuity of their sectoral activities in times of supply disruptions. Industries should be prone micro-grid. Most developed economies are promoting an industrial micro-grid environment to maintain continuity of economic activities. Industrial electricity unions are also important in protecting the interests of industries during periods of inconsistency. Domestic consumers should consider renewable alternative energy storages such as solar. Practicing the saving and conservation of available energy is important.

6.5.4 Advantages of the structure

- The structure is self-explanatory. The design is flexible to understand and implement. The framework took into consideration that public sector policy developers, in most cases, are political experts rather skilled field experts with experience in the strategic decision of a phenomenon.
- Cost effective. An important element of South Africa public sector for electricity projects as stated even in its IRP is towards low-cost implementations. The framework entails low-cost practical recommendations with potentials for maximum outputs.

- The framework implementation has recommended the importance of national skill development which paves the way for employment.
- The model is holistic, comprehensive and integrative.

6.5.5 Limitations of the framework

- The context has limitations for systems with adequacy challenges only comparable to South Africa.
- There is still need for effective experts for technical suggested recommendations.

6.6 Conclusion

There is a pattern of previous electricity studies recommending further research on the identified problem (the need for a standard integrated strategic management system framework for electricity adequacy in South Africa). Existing empirical research reflect a systematic approach towards a strictly technical solution to the recommendations from previous researches. The non-comprehensive nature of the existing models would raise doubts if the structuring of recommended parameters resulted from a detailed integrated analysis of South African energy needs. There is a continuing failure of implemented plans to address the fundamental problem of electricity adequacy in South Africa, contributing to the present ongoing supply inconsistency and insufficiency predicament. Tait (2017) concur that policies to the advancement of grid electricity in South Africa remain almost exclusively non-conceptual. This is evident in the government recent obscure electricity advancement legislations and contest bills.

Parameters of existing models, plans and policies did not quite match the current energy adequacy realities such as towards grid security, electricity consistency and control, effective crisis management, efficient and environmentally friendly production and usage of energy. The nature of a national energy system is very complex, and the lack of an integrated strategic system approach to policy frameworks will result in immense errors. To achieve an applicable and reliable contribution to the identified gap, empirical research was holistic as it focused on critically analysing the major agenda towards electricity adequacy in South Africa. Thus, the study was extremely exploratory as there is no trace of any previous empirical research within the scope of this study. It is without any reasonable doubt that the recommended framework has been developed from a comprehensive, integrated analysis of the primary issues on the phenomenon and has the capacity to a solution to electricity inadequacy in South Africa.

6.7 Further research

Studies on energy are now fundamental in the society considering the increasing importance of energy for social and economic development. It is important to apply findings practically to obtain meaningful contributions from the field of study. The study focused on identifying an applicable framework to electricity adequacy in South Africa. It is important to sample the structural framework to the electricity legislature in general to create awareness over unique outcomes in the empirical research and to sample their opinion with regard the developed framework. The developed framework is a three-phased structured systems. It is necessary to further explore on each of the systems in the framework.

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Appendix 1: Further paper associated with the study

The impact of energy fuel choice determinants on sustainable energy consumption in the South African household sector

Belobo Benedict Ateba, Johannes Jurgens Prinsloo and Erika Fourie

ABSTRACT

The Low electricity supply capacity, combine with other factors continuous to be a pestilence to households electricity demand, leading to increasing reliance on alternative energy fuels. The reliance on alternative fuels is characterised with the usage of traditional fuels by mostly low-income households contributing significantly to environmental emission. The empirical research was aimed at assessing primary determinants to energy fuel choice in the South African household sector, in order to inform policy makers on important energy consumption behavioural tendencies that can assist policy towards sustainable energy growth and biomass reduction usage in households. Parameters for the conducted empirical investigation was primarily based on the energy consumption models. The empirical research employed a quantitative research design. The Gauteng and North West provinces were target population considered for data collection. A purposive-convenience sampling was employed to select participants for the empirical research. Data collection utilised a closed-ended questionnaire. Results from the empirical finding reflect that determinants to household fuel choice decision for its activities contribute significantly to a household usage of sustainable or traditional energy for a certain household need. South Africa households tend to practice energy stacking tendency. Important recommendations has been point out for policy to prioritize on towards sustainable energy usage in the household sector

Keywords: *Energy fuels, fuel choice tendency's, households energy sustainable*

1. INTRODUCTION

Kenny (2015:1) asserts that the most important need in life is the availability of energy to vehicle social development and industrial competitiveness. Elias and Victor (2005:4) asserts that historically, human behaviour towards the usage of energy has been in a constant change due to the influence of technological developments. However, despite the need for effective access to sustainable energy in the globe, Ellingsen (2010:3) asserts that is still a constant

growth in energy inequality as most rural households in the world still struggles to access modern energy, leading to increasing reliance on traditional biofuels. Pachuari and Rao (2014:1) highlight that energy inequality is commonly analysed on the following bases;

- (1) Income or some related monetary measure as prevailing inequalities in income will closely mirror inequalities in energy accessed and consumed.
- (2) Disparities in energy quantities consumed and types of energy sources predominantly use across the population.

Pachuari and Rao (2014:1-2) state that the distribution of modern energy sources remains highly unequal, with a much higher dependence on environmental unfriendly energy fuels by most citizens, especially in developing countries. According to IEA (International Energy Agency) (2006:40) studies on households usage of biofuels, the following findings are reflected;

- (1) Over 2.5 billion of the world's population still primarily rely on traditional energy sources such as fuelwood, charcoal, agricultural and animal waste to meet their daily energy demand for cooking and heating yearly. A total of 1.6 billion people of the above statistics are still without complete electricity access.
- (2) In developing countries over 90% of most household daily energy consumption comes from biofuels.
- (3) One-third of the world's population calculating to 2.7 billion will still be primarily depending on biofuels by 2030.

Musango (2014) point out that biomass fuels can be used directly or indirectly. The empirical research in this paper is solely focused on direct use of biomass energy fuels as biomass study, in general, is a wide scope. According to Oparinde (2010:3), biomass fuels can be regarded as combustible renewables such as vegetable materials that can be converted into vegetable oil, landfill gas and bio-additives. Biomass can also be traditional energy fuels such as fuel, wood and animal waste and intermediate biomass such charcoal and coal. Gallachóir (2007) recommend that researching on energy is primary for developing reliable policies and initiating a change towards increased energy sustainability. This empirical research will significantly contribute to addressing the aspect of energy poverty in South Africa.

1.1 Introduction to the problem

According to IEA (2002:376), only 23% of the Sub-Saharan population is electrified with modern energy, and calculating to about 500 million people are still un-electrified making it

the lowest electrified world's region. Winkler (2006:34) state that recent estimates suggest that by 2025 a large proportion of South African households will still be un-electrified. Treiber *et al.* (2015) note that improvement towards the consumption of cleaner fuels will reduce energy poverty. The linear model predicts a positive relationship between socio-economic development and energy fuels transition. There have been a growing research among environmental and energy researchers to determine the actuality of combustible biomass on the environment. Howells *et al.* (2005) note that a primary hindrance to facilitating energy transition in South Africa is the lack of knowledge by policymakers on factors that govern energy choices by households.

The paper identifies that economic and non-economic factors are significantly growing usage choice of biomass as an energy source in the South African households. The growing usage of biomass energy by households account for environmental emission and increasing levels of indoor air pollution.

2. LITERATURE REVIEW

The following section outlines theoretical literature content on consumers' motives to the usage of alternative energy fuels and energy inequality in the South African household sector.

2.1 Energy access and biomass use

High dependence on traditional biomass fuels by a large number of households in sub-Saharan Africa significantly contributes to deforestation, forest degradation and land degradation in the region (Mekonnen & Köhlin, 2008:1). Muller and Yan (2016:2) continues that since pollutants from bio fuels primarily constitute of Carbon-dioxide (CO₂), it contributes to respiratory diseases, cardiovascular mortality and climate changes that are significantly destroying the world's vegetation. Pauchauri *et al.* (2013) say the growing concern on the impact of traditional biofuels, and the growing reliance by a significant world's population on biomass energy has mobilised the international community to launch a campaign for universal modern energy access by 2030. Figure 1 reflects a schematics of energy pollution in domestic environments. Due to emission from energy fuels, most rural and poor households have an indoor environmental pollution 20 times higher than the limits set by the World Health Organization (WHO) (Sanga & Jannuzzi, 2005:4).

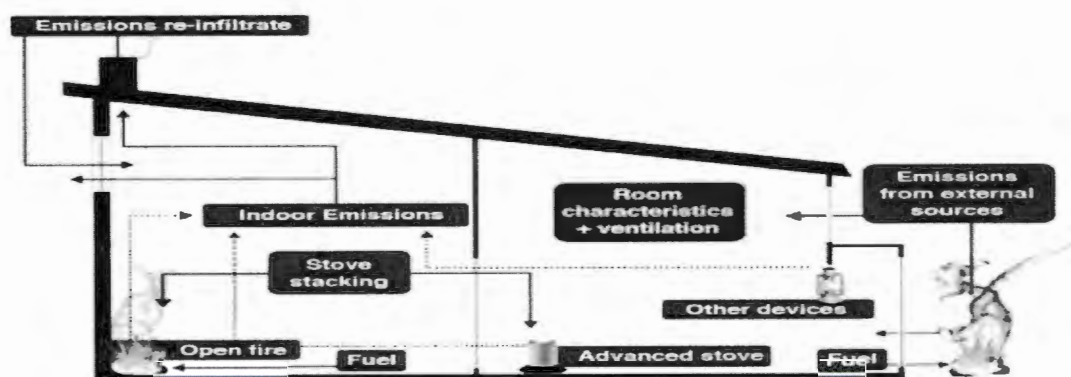


Figure 1 Schematics of energy pollution on indoor air quality

Johnson *et al.* (2013:6)

Johnson *et al.* (2013:6) argue that both energy fuels and appliance categories contribute to the actual emissions in domestic surroundings. However, energy sources such as open fires from traditional biomass and appliances such as traditional lamps powered by intermediate biomass fuels will tend to emit more. The affordability of energy-using equipment is just as important as the affordability of fuels. The initial cost of acquiring kerosene and Liquid Petroleum Gas (LPG) stoves and LPG bottles may discourage some people from switching away from biomass (IEA, 2002:369). A serious issue in South Africa is the growing electricity consumer price. Howells *et al.* (2005) report that most low-income households in South Africa utilised biomass fuels such as wood and coal exposing household dwellers to indoor emission as a result of carbon monoxide and particulates. Davis (1998) mention that over half of the South African rural household use fuelwood more than ones per month. Madubansi and Shackleton (2006) also states that fuelwood is also utilised by some urban and electrified households frequently and trends reflect that households usage of fuelwood in South Africa will increase in the future. Howells *et al.* (2006) argue it is preferable for South African households to utilised alternative energy sources as compared to electricity due to cost. According to Louw *et al.* (2008) in South Africa, low-income households are price sensitive, and their consumption behaviour reflects the preference of fuel choice based on price. Louw *et al.* allude low-income households tend to display attitude whereby energy fuels reflect perfect substitutes for each other. Alternatively, high-income households at times reflect behaviours that show over-burdened from electricity cost leading to alteration in the quantity of electricity demand and thus, cross utilisation of different energy fuels. For instance, Howel *et al.* (2006) point out that it is 252 a year cheaper to utilise Liquid Petroleum Gas (LPG) for cooking compared to electric hotplates and a 1.3 KW LPG stove provides approximately the equivalent cooking capacity as a 1.5 kW electric stove.

Alternatively, Howells *et al.* (2005) argue most low-income and rural households have a low and irregular income which affects their ability to afford costly fuels and modern energy appliances. Low-income households prefer energy fuels that are available in small, discrete quantities. Thus, is habitual for fuel like paraffin to be easily consumed as compares to LPG's that are only economical when procured in full tank. IEA (2002:369) concur that households will tend to use biomass energy as long as it remains cheaper to modern fuels. In most rural settings, biomass is perceived to be readily available within the reach of every household.

Gaunt (2005) highlight that the government approach of withholding energy service resulting from non-payment has made electricity access further unviable for most households in South Africa. Gaunt (2005) asserts that households connected to electricity in South Africa does not conclude on households ability to use electrical energy. Households in South Africa still tend to rely on biomass sources such as wood candles and paraffin even when electricity is available. As a result, improving health and reducing environmental pollution by discouraging biomass energy fuel may not be easily accomplished. Howells (2005) reports that the South African government has alleged that it is not cost effective for the national utility to electrify some rural communities.

Goldemberg (1996:30) estimated a household's direct basic primary energy requirement per unit of time to satisfy basic needs and the findings reflected about 500W per person monthly. Inglesi (2010) states that in South Africa the government has implemented an electricity poverty programme to access typical poor households with 50 kWh of electricity per month. Critics like Adam (2010:15) argues that the research circumstances which led the government to such a conclusion failed to investigate if poverty was the result to low electricity consumption by poor households. According to Howell *et al.* (2006), the government misapprehend that a typical poor household in South Africa requires electricity for just lighting, radio, television, ironing and boiling of water. Thus, 50 kWh of electricity will be adequate for such basic households energy needs. According to Prasad (2008), energy sector reforms are aimed at improving the quality of life of the poor communities in a country. Numerous African states have initiated some sectoral energy reforms which have not necessarily benefit disadvantaged communities to energy access. Despite the sectoral reforms, none has managed to restructure its energy industry completely. Schlag and Zuzarte (2008:12) argues that an irony to energy reforms in sub-Saharan Africa is that it tends to be more beneficiary to the wealthy and middle-class households and not the targeted poor households as such policy aimed.

Balmer (2007) maintains that in South Africa the electricity-free electricity programmes initiated to uplift energy poverty is flawed in a number of ways:

- (1) Households located in rural areas are not benefiting from the programmes.
- (2) The implementation of the free basic electricity is very ambiguous in non-grid rural locations.
- (3) Increasing access to electricity is failing to alleviate energy transition as poor households are still unable to benefit from electricity subsidies.

Bekker *et al.* (2008) view that from a South African perspective, the exclusion of almost all of the poor population from accessing electricity during pre-94 restricted energy poverty from being a prioritised policy agenda. The concern for energy poverty only emerged by the 1980s. However, it was still side-lined in strategic decision-making structures. Howells *et al.* (2006) mention energy strategies that contribute to elevating the poor should be a core political discourse in South Africa.

2.2 Energy consumption models

Ado (2016) point out that energy is primary for daily household activities such as heating, cooking, preservation and movement. In the post-Neolithic revolution, energy sources with biomass were the dominated household energy source. It was later replaced by coal based on its energy density. According to Kowsari and Zerriffi (2011) assessing and analysing household energy behaviour has been difficult due to its unique characteristics. For instance, there is diversity in energy systems for households at both energy demand and energy supply. Ado (2016) maintains that the first-ever effort to produce an empirical evidence on what influences households energy preference was reflected in the energy ladder model. Muller and Yan (2016:3) states that the energy ladder pioneered energy researchers' interest in exploring possible hypotheses considerations for household energy consumption behaviours.

Taylor (2011) highlight that interest in the idea of the energy ladder emerged with the occurrence of the world oil crisis in the 1970s and 1980s. The notion was adopted by energy researchers. However, Baldwin (1986) and Hosier and Dowd's (1987) study of household fuel choices in Zimbabwe has been significantly credited to have pioneered research under this agenda. An appropriate energy ladder framework with the contextual applicability of this paper is reflected in figure 2.

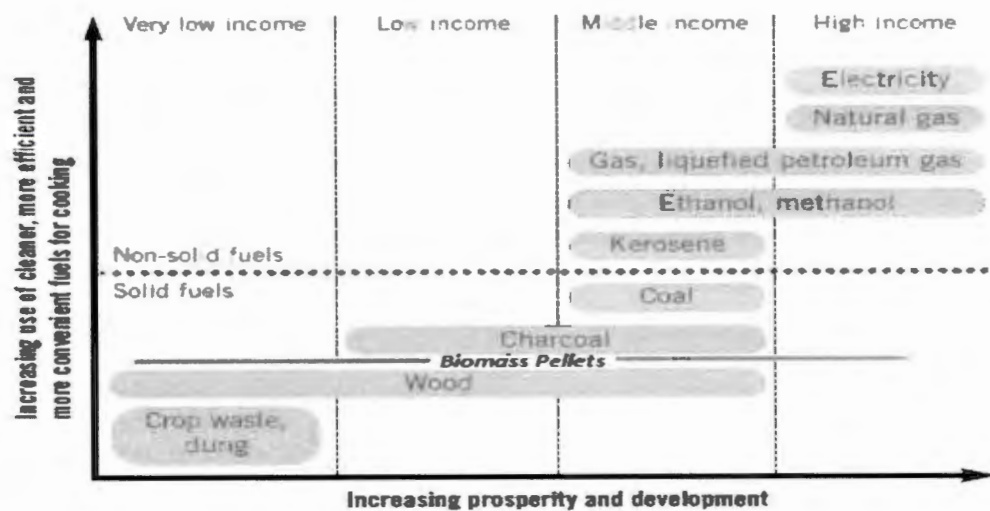


Figure 2 Energy ladder

Rehfuess (2006:8)

Risseuw (2012:14) notes that the energy ladder places energy fuels in a sort of hierarchy. The framework maintains that some fuels are considered superior to others, and different fuel categories have a competitive edge than others. It assumes that there is a high probability that households as a household socio-economic status improve, it will tend to switch towards a more sustainable energy sources as it climbs up the energy ladder. Gordon and Hyman (2012) mention that the energy ladder model presents an empirical evidence with the view that households in urban areas and the wealthier households in rural areas will tend to prefer modern fuels such as electricity as compared to low-income households.

Like any other model, the energy ladder was not without its limitations. Pachauri and Spreng, (2004) state that significant criticism to the energy ladder is the complication and the volatile relationship between income and fuel choice. Heltberg (2004) states that critics to the energy ladder have an opposing view that household energy consumption behaviour does not reflect unidirectional as even households with high-income status switch back to traditional biofuels even after primarily adopting modern energy carriers.

After continuous criticisms, there was a call for the modification of the energy ladder to the currently acclaimed “energy stacking approach“. A proposed way forward was introduced by Masera *et al.* (2000) opinion that households utilise a mixture fuels simultaneously. The model demonstrated that multi-factors such as fluctuating budgets, accessibility of an energy fuel, fuel subsidies, tradition, household size and education often lead to multiple-fuel use patterns

regardless of a household's income status and location. Stacking considers two main assumptions;

- (1) Households do not immediately ascend to improved fuels and simultaneously abandon inferior ones.
- (2) Households rely on multiple fuel types by consuming a higher proportion of superior fuels with rising income.

It can concur with Elias and David (2005:4) that energy stacking can be viewed to have limited development to the gaps of the energy ladder as the hypothesis of stacking still follows similar directives to the hierarchical relationship of the energy ladder. The energy stacking framework is reflected in figure 3.

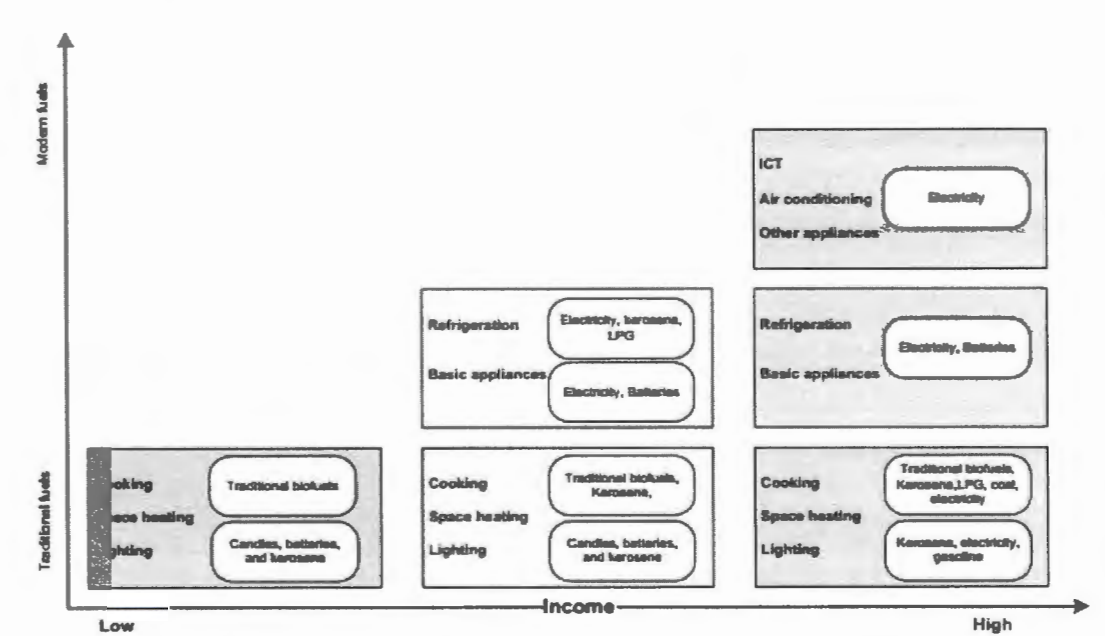


Figure 3 Energy stacking framework

IEA (2002:370)

Kowsari and Zerriffi (2011) conducted a subsequent research concurring to the energy stacking model but exposed shades on both the energy ladder and the stacking. Kowsari and Zerriffi initiated another viewpoint by arguing that household energy behaviour systems have been oversimplified with different aspects examined in isolation of each other to simplify the models and analysis. Kowsari and Zerriffi allude that household energy demand is a combination of three factors: energy carriers, energy conversion technologies, and energy service demands. A significant number of existing research on the agenda of household energy systems has been mostly based on the energy carrier, fuel choice and appliance mix. The energy profile transition

framework is focused on the energy services instead of energy quantity. According to Elias and Victor (2005:12-13), cooking appliance that will be used by households within the same socio-economic status will depend on the cooking service requirements. The energy profile transition framework is reflected in figure 4.

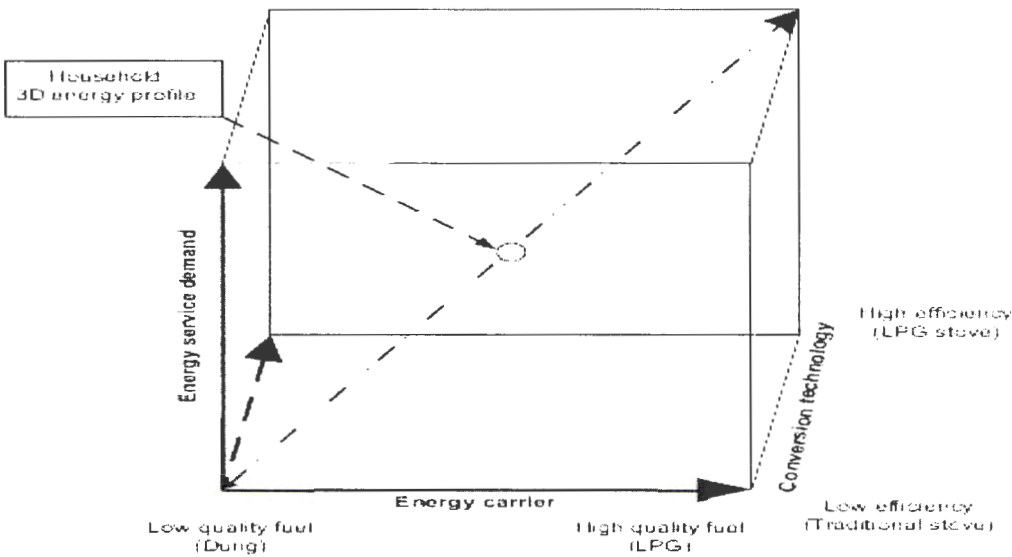


Figure 4 Energy Profile transition through a three-dimensional path

Kowsari and Zerriffi (2011)

Muller and Yan (2016:2) acknowledges that different empirical finding has drawn dissimilar conclusions with regards to the influence of social-economic factors on household energy fuel consumption. The current research environment on households and energy fuel choice is now in uncertainty on what policy direction is reliable and comprehensive for policy recommendation due to divergences between authors.

Muller and Yan (2016:2) says despite a numerous research about the determinants of household fuel use, intensive knowledge on the agenda remains limited. Despite the continuous criticisms on each every hypothesis, Ado (2016) note that most empirical researchers conducted in different regions across the globe Such as Pachauri and Spreng (2004) in India, Hiemstra-van der Horst and Hovorka (2008) in Botswana and Masera and Navia, (1997) in Mexico primarily concurred with the energy stacking making it a dominant tool for determining households energy choice behaviours by most energy researchers.

3. CONCEPTUAL FRAMEWORK DEVELOPMENT

After the above literature, a critical question that follows is which of the discussed model appropriately explain households fuel choice? To attain a reliable contribution, this paper has

taken into consideration both the energy ladder and the energy stacking hypotheses. Howells *et al.* (2005) point out that the concerns on biomass fuels usage and environmental implications have not been adequately analysed in the South African context. There is diminutive empirical research exploring the appropriateness of energy choice models in the South Africa household sector. However, it is noteworthy that authors such as Alberts *et al.* (1997), Davis (1998), Howells *et al.* (2006) and Louw *et al.* (2008) have conducted empirical research in South Africa, applying relating features to the energy ladder. Despite research from authors such as Madubansi and Shackleton (2006) and Musango (2014) with objectives related to the energy stacking hypothesis, there is a limited trace of empirical research that has comprehensively advanced the applicability of the energy stacking hypothesis in the South Africa household sector. If any exist, this paper might possibly be the first publication to have comprehensively explore both the energy ladder and the energy stacking simultaneously in the South African context.

The developed conceptual framework of this paper considered both the energy ladder and the energy stacking hypotheses. The Kowsari and Zerriffi (2011), household's fuel choice classification criteria of endogenous factors (household characteristics) and exogenous factors (external conditions) guided the development of the conceptual framework for the empirical research.

Table 1 Household fuel choice factors

Categories	Factors	Measuring aspect
Endogenous factors		Endogenous factors characteristics reflect the capabilities of households, behavioral attitudes, preferences and experiences of households
Economic characteristics	Income, Expenditure and Landholding	
Non-economic characteristics	Household size, gender, age, household composition, education, labor and information	
Behavioral and cultural characteristics	Preferences(e.g food taste), practices, lifestyle, social status and ethnicity	
Exogenous factors		Exogenous factors influence household decisions regarding their energy system by affecting the choices available to households and the incentives to choose one energy technology or fuel over another.
Physical environment	Geographic location and climatic condition	
Policies	Energy policy, subsidies and market and trade policies.	
Energy supply element	Affordability, availability, accessibility and reliability of energy supplies	
Energy device characteristics	Conversion efficiency, cost and payment method and complexity of operation	

Kowsari and Zerriffi (2011)

This paper only considered the endogenous category. Two factors were considered from the economic characteristics, four factors from the non-economic characteristics. The next section elaborate more on factors that were sampled in the empirical research.

3.1 Economic characteristics

The economic category has generally been considered to be a primary influence on households' energy choice. In this category, the income and expenditure factor were sampled in the empirical research. Overemphasizing income or expenditure as a measurement of wealth in determining a household fuel choice is unclear as in some countries a large proportion of households depend on free sources of energy and home production from the government such as the case of South Africa. In spite that a researcher has the freedom to decide on which of the economic factors to use as a measurement for wealth, Elias *et al.*, (2005) argues that a researchers decide to use whether income or expenditure should be precise to the research context.

3.1.1 Income and setting

Income was the first ever factor studied by energy researchers as a major determinant of energy fuel choice through the energy ladder model. Findings from early empirical researches conducted by authors such as (Barnes *et al.*, 1994, 1996; Pachauri & Spreng, 2004; Wuyuan *et al.*, 2008) concurred that there is a significant association between income and households energy choice. Even though new findings continuously emerged exploring more comprehensive approaches to factors influencing household fuel choice pattern, Whitfield (2006:143) points out that energy researchers have failed to advance the understanding of household fuel choice pattern significantly beyond the influence of incomes. According to Van der Kroon *et al.* (2013), the placement of a household in the environment will normally determine the level of opportunity and possible income level.

3.1.2 Expenditure

Even though rare, some researchers such as Davis (1998) and Heltberg (2005) extensively used expenditure instead of income in measuring the economic influence of households energy fuel choice. Low-income and high-income households differ in energy spending as; (1) the price of modern fuels, as well as their transaction cost, is usually high; (2) a large portion of income from low-income households is typically too low to accommodate payments associated with modern energy systems; (3) low-income households have an uncertain income source to accommodate regular spending required by modern energy sources (Kowsari & Zerriffi, 2011). A household's expenditure of an energy fuel will depend on the unit price of the fuel demanded (Schlag & Zuzarte, 2008:10). As a rise in a household income will enable its capacity to switch to more sustainable energy fuels, primary and useful energy consumption will also increase as

well (Mestl & Eskeland, 2009). Link *et al.* (2012) highlight that minimal wages will influence the possibility to rely on biomass energy fuels. Rao and Reddy (2013) maintain that household incomes derived from wages or salaries have a positive impact on the probability of using cleaner fuels. According to Van der Kroon (2013), a household capital will determine the possibility of which fuel type to rely on.

3.2 Non-economic characteristics

In early household energy fuel choice studies, economic factor was the only element used to determine household fuel switching through the aid of the energy ladder. However, non-economic elements later gain momentum based on the energy transition philosophy. Campbell *et al.* (2003) argue that income continuous to be a major determinant of energy fuels choice and the world is gradually heading to a situation of a possible dichotomy were norms such as wealthier households who can adopt modern fuels and poorer households who are increasingly forced to choose biomass will be irrelevant. In this category household size, education and gender were considered for empirical research.

3.2.1 Household size

Kowsari and Zerriffi (2011) point out that household size will determine the amount of energy consumed by a household. Household size usually indirectly influence households to practise both energy switching and stacking behaviours. Ado (2016) says household size will significantly influence the usage of energy fuel type. Household size influence fuel transition with regards to the fact that large families may tend to practise energy stacking as opposed to smaller families.

3.2.3 Education

Link *et al.* (2012) asserts that education will influence energy fuel transition from two perspectives; (1) schooling will limit the labour force for fuel acquisition activities such as wood collection. Thus, a family that put efforts to reject children collection of wood might tend to adopt fuels that require no accusation efforts like paraffin and gas instead (*ceteris paribus*); (2) education can initiate change by providing knowledge about the dangers of consuming biomass energy fuels to health quality and the environment. According to Schlag and Zuzarte (2008:14), a large proportion of individuals have not received any significant education on energy systems to have been inform on the consumers fuel choice frameworks. Thus, public education on fuel choice theories will greatly impact on households energy fuels preferences. Many consumers do not possess a clear understanding of what are fuel alternatives. Prasad

(2008) highlight that it is necessary for people to be well informed, and empowered individually and at household level on the advantages of cleaner energy opportunities and the limitations of biomass fuels. In the theory of cognitive dissonance, individuals strive for consistency between their knowledge and behavioural attitudes (Kowsari & Zerriffi, 2011). Whitfield (2006:143) mention that information education and social learning can be a note to influence households energy fuels adoption significantly. The educational level will influence households to adopt modern fuel types the same as higher income and expenditure (Musango, 2014).

3.2.4 Gender

Gender can immensely influence fuel choice. For instance, women are generally responsible for cooking and do have particular preferences on what cooking method is perfect for certain delicacies especially in traditional kitchens. Since women are commonly associated with cooking, a household where a male is the primary income earner and the main decision-maker might neglect the importance of the costs and benefit of clean cooking fuels (Schlag & Zuzarte, 2008:13-15). Treiber (2015) concur that culture and tradition can influence women ignoring modern energy technologies. In his study of energy transition in Kenya, it was found that women prefer preparing “Chapati” with the use of charcoal and fuelwood as it will be less time consuming due to constant and controllable heat, the cooking process involves traditional pots and biomass fuel positively influence the taste of the delicacy. According to Van der Kroon *et al.* (2013), just as children, women are a primary labour force for wood fetching as is the case with most South East Asian countries. Balmer (2007) maintains that gender roles refer to the different tasks individuals are to perform in the society. In the case of households, it entails some form of division of labour in which certain obligations are assigned to men and women in the household. Women are normally linked to reproductive activities which involves all aspect of domestic labour.

3.3 Household activities and energy fuel usage in the South African context

The empirical research considered that certain fuels are mostly utilised for a particular household activity in the South African context. Electricity is the only energy type that households universally can use for various activities such as cooking, lighting and heating. LPG usage is mainly limited to cooking. However, Paraffin can also be used for lighting. In South Africa, solar energy is usually used for water heating mainly for bathing and washing. Direct utilisation of biomass fuel types (coal, wood and charcoal) by households include

heating and cooking (Musango, 2014). In general, world trend reflects that most households basic energy demand is for heating, cooking and lighting. Household fuel choice is mostly restricted to the aforementioned daily household energy needs (IEA, 369). Addressing these three activities together is necessary for a realistic approach to household energy analysis (Kowsari & Zerriffi, 2011). Thus the survey only focused on the three household energy needs.

4. METHODOLOGY

The empirical research was focused on households from the North West and Gauteng provinces of South Africa. Gauteng province was considered for empirical research because of its level of urban growth and is also the nucleus of social development in South Africa. The North West province was selected as it was necessary to also target a developing geographical location to represent the spatial geography of South Africa. In the Gauteng province, Pretoria and Johannesburg were the target sample cities while Mafikeng and Potchefstroom were target sampled cities from the North West. A purposive-convenience sampling technique was used in this paper. Purposive targeting was employed to obtain mostly income earners considered to be the financial nucleus in providing households day to day needs. Convenience sampling involved targeting households based on availability and willingness to participant in the study. The data collection employed closed-ended questionnaires with defined categories to examining the effect of electricity supply and consumption on the South African domestic sector and related electricity consumer behaviours. Questions were strictly dichotomous, and participants just had to tick “yes” or “no” on the options that relate to their practised fuel choice behaviours. In total 400 households were given questions to respond but just 323 questionnaires were obtained from the fieldwork.

5. DATA ANALYSIS AND DISCUSSION

This section will present a detailed analysis and discussion of acquired data from the empirical research. The IBM Statistical Package for Social Science statistics version 23.0.0 as prescribe by SPSS Inc (2016) was used in analysing data. A test for reliability was conducted on the data. The Cronbach Alpha obtain was 0.74, implying that there is a sufficient internal consistency from acquired data. Cramer’s values >0.1 , >0.3 , >0.5 indicates small, medium and large associations respectively. Note p -values are only reported for completeness purpose. *The p values are reported for completeness sake, but won’t be interpreted since a non-probability sample was used and not a probability sampling.*

5.1 Influence of Income on energy fuel choice

The criteria that were used in this factor determinant involved sampling participants based on quotas within the target sampled demographics. As already mentioned the Pretoria and Johannesburg were target cities from the Gauteng province and Mafikeng and Potchefstroom from the North West province. Based on South Africa background, the demographics are mostly in clusters where an urban city has an outskate rural settlement which is normally refer to as townships. These townships reflect rural characteristics as compared to the central city settlements with strictly urban tendencies. A description of quotas is presented in table 2.

Table 2 A description of sampled quotas

Cities	Quotas	Income rank status
Mafikeng quota (A)	Riviera park	High-income
Mafikeng quota (B)	Extension 36	Low-income
Potchefstroom quota (A)	Potchefstroom town	High-income
Potchefstroom quota (B)	Ikakeng	Low-income
Pretoria quota (A)	Pretoria North	High income
Pretoria quota (B)	Soshaguve	Low-income
Johannesburg quota (A)	Auckland park	High income
Johannesburg quota (B)	Soweto	Low-income

Analysis considered grouping all settlements with similar income status to perform general analysis base on each of the identified income ranks (High and low-income groups).

Table 3 Usage of electricity by income groups

Electricity usage for Lighting						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P value	Effect size
Frequency	158	7	149	9	0.05	0.03
Percentage	95.80%	4.20%	94.30%	5.70%		
Electricity usage for cooking						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P value	Effect size
Frequency	139	19	128	37	0.01	0.13
Percentage	95.80%	5.70%	77.60%	22.40%		
Electricity usage for heating						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P value	Effect size
Frequency	125	33	118	47	0.05	0.21
Percentage	79.10%	20.90%	72%	29%		

Table 3 reflects results for income groups' usage of electricity for lighting, cooking and heating. Results reflect that most households from the high-income group (95.8%) and low-

income group (94.3%) uses electricity for lighting. Alternatively, results reflect that income influences household’s usage of electricity for cooking and heating. High-incomers uses electricity more for cooking (95.8%) and heating (79.1%). Low-incomers use electricity less for cooking (77.6%) and heating (71.5%). Both cooking and heating have an effect size tending towards small (0.13 and 0.12) respectively.

Table 4 Usage of liquid petroleum gas by income groups

Gas usage for cooking						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P value	Effect size
Frequency	58	107	26	132	<0.001	0.21
Percentage	35.20%	64.80%	16.50%	83.50%		
Paraffin usage for cooking						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P value	Effect size
Frequency	5	160	24	134	<0.001	0.21
Percentage	3%	97%	15.20%	84.40%		

Table 4 reflects results for income groups’ usage on LPG’s. Results reflect that High-income households tend to utilise gas as an alternative for cooking (35.2) as compare to low-income groups (16.5%). Alternatively, low-income groups tend to use paraffin most for cooking (15.2%) as compared to high-income households (3%). The use of gas and paraffin for cooking has a small effective size, (0.21) and (0.21) respectively.

Table 5 Usage of renewable energy by income groups

Usage of solar for heating						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect size
Frequency	40	125	16	142	0.001	0.26
Percentage	24.20%	75.80%	10.10%	89.90%		

Table 5 reflects results for income groups’ of renewable energy for heating. Results reflect that High-income households tend to utilise solar energy as an alternative energy source for heating (24.2%) as compared to low-income groups (10.1%). The usage of solar within the income groups has an effect size tending towards medium (0.26)

Table 6 Usage of traditional fuels (biomass) by income groups

Usage of wood for cooking						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect size
Frequency	9	156	38	120	<0.001	0.34
Percentage	5.50%	94.50%	24.10%	75.90%		
Usage of wood for heating						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect size
Frequency	20	145	28	130	0.05	0.07
Percentage	12.10%	87.90%	17.70%	82.30%		
Usage of coal for cooking						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect size
Frequency	125	33	118	47	0.05	0.13
Percentage	79.10%	20.90%	72%	29%		
Usage of coal for heating						
Description	High-income		Low-income		Cramer's V	
	Yes	No	Yes	No	P values	Effect size
Frequency	12	146	15	150	0.05	0.02
Percentage	7.60%	92.40%	9.10%	90.90%		

Table 6 present results on households income groups (high-income and low-income) usage of energy fuels with biomass (wood and coal). The results reflect that low-income households tend to use wood more for cooking (21.1%), compare to high-income households (5.5). The usage of wood as fuel for cooking on income groups has an effect size tending towards large (0.34). Low-income groups also use wood more for heating (17.7%). Low-income groups also tend to use coal for heating (72%), compared to high-income households (79.1%) with an effect size tending towards small (0.13). High-income households also use coal lesser for heating (7.6%), compared to low-income households (9.1%).

5.2 Expenditure

Expenditure on energy was also tested to determine the influence of wealth on households' energy choice. Participating households from the two sampled income groups had to indicate their monthly spending on electricity on a scale ranging from below R200 to above R300. The aimed was to determine the disparity on spending's on electricity within the sampled household groups.

Table 7 Expenditure per income groups

Electricity spending margins for high-income groups				
Description	<R200	<R300	>300	Total
Frequency	11	20	133	164
Percentage	6.70%	12.20%	81.10%	100%
Electricity spending margins for low-income groups				
Description	<R200	<R300	>300	Total
Frequency	83	31	44	158
Percentage	52.50%	19.60%	27.80%	100%

The table presents results for households' spending's on electricity. Results reflect that high-income households spent most on electrical energy. A larger proportion of high-income households (81.1%), spend above R300 for electricity monthly. Alternatively, low-income households (27.8%), spent less than R300, while (52.5%) spent less than R200.

5.3 Household size

Household size has been noted to be a significant influence on households' energy choice. The aimed of this factor was to determine if households with fewer members tend to use advanced energy fuels as compared to households with more members.

Table 8 Household size influence on the usage of electricity for domestic activities

Household size influence on electricity usage						
Usage of electricity for lighting						
Houshold size	Description					
	Measurements	Yes	No	Total	P value	Effect size
1 to 3 house hold members	Frequency	128	2	130	0.05	0.18
	Percentage	98.50%	1.50%	100%		
4 to 6 household members	Frequency	148	8	156		
	Percentage	94.90%	5.10%	100%		
7 and above	Frequency	29	5	34		
	Percentage	85.30%	14.70%	100%		
Usage of electricity for cook						
Houshold size	Description					
	Measurements	Yes	No	Total	P value	Effect size
1 to 3 house hold members	Frequency	47	78	125	0.021	0.15
	Percentage	37.60%	62.40%	100%		
4 to 6 household members	Frequency	61	94	155		
	Percentage	39.40%	60.60%	100%		
7 and above	Frequency	19	12	31		
	Percentage	61.30%	38.70%	100%		
Usage of electricity for heating						
Houshold size	Description					
	Measurements	Yes	No	Total	P value	Effect size
1 to 3 house hold members	Frequency	102	21.5	130	0.03	0.08
	Percentage	78.50%	21.50%	100%		
4 to 6 household members	Frequency	116	40	156		
	Percentage	74.40%	25.60%	100%		
7 and above	Frequency	23	11	34		
	Percentage	67.60%	32.40%	100%		

Table 8 presents results for household size usage on electricity for lighting, cooking and heating. Results hold that households' size will influence the usage of electricity with effect sizes tending towards small for lighting (0.18) and cooking (0.15). Even though with an insignificant effect size, results also reflect that household sizes show minor differences in electricity usage for heating for 1 to 3 members (78.5%), 4 to 6 members (74.4%) and 7 and above members (67.6%).

Table 9 Household size influence on the usage of LPG's

Usage of LPG's for cooking						
Usage of paraffin for cooking						
Household size	Description					
	Measurements	Yes	No	Total	P value	Effect size
1 to 3 house hold members	Frequency	7	149	130	0.03	0.14
	Percentage	4.50%	95.50%	100%		
4 to 6 household members	Frequency	17	113	156		
	Percentage	13.10%	86.90%	100%		
7 and above	Frequency	4	30	34		
	Percentage	11.80%	88.20%	100%		

Usage of gas for cook						
Household size	Description					
	Measurements	Yes	No	Total	P value	Effect size
1 to 3 house hold members	Frequency	29	101	130	0.06	0.13
	Percentage	22.30%	77.70%	100%		
4 to 6 household members	Frequency	41	115	156		
	Percentage	26.30%	73.70%	100%		
7 and above	Frequency	14	20	34		
	Percentage	41.20%	58.80%	100%		

Table 9 reflects results for household size influence on the usage of LPG's for domestic activities. Results reflect that households with more members tend to utilise LPG's for cooking. Households with 1 to 3 members use paraffin less for cooking (4.5%), compared to households with 4 to 6 members (13.1%), and 7 and above members (11.8%). Households with 1 to 3 members also use gas less for cooking (22.3%), compared to households with 4 to 6 members (26.3%), and 7 and above members (41.8%). Effect sizes tending towards small are reflected for paraffin (0.14) and gas (0.13).

Table 10 Household size influence on the usage of biomass

Usage of Biomass						
Usage of wood for cooking						
Household size	Description				P value	Effect size
	Measurements	Yes	No	Total		
1 to 3 house hold members	Frequency	22	134	156	0.05	0.09
	Percentage	14.10%	85.90%	100%		
4 to 6 household members	Frequency	17	113	130		
	Percentage	13.10%	86.90%	100%		
7 and above	Frequency	8	26	34		
	Percentage	23.50%	76.50%	100%		
Usage of coal for cooking						
Household size	Description				P value	Effect size
	Measurements	Yes	No	Total		
1 to 3 house hold members	Frequency	6	150	156	0.29	0.09
	Percentage	3.80%	96.20%	100%		
4 to 6 household members	Frequency	8	122	130		
	Percentage	6.20%	93.80%	100%		
7 and above	Frequency	2	32	34		
	Percentage	5.90%	94.10%	100%		
Usage of wood for heating						
Household size	Description				P value	Effect size
	Measurements	Yes	No	Total		
1 to 3 house hold members	Frequency	22	134	156	0.13	0.11
	Percentage	14.10%	85.90%	100%		
4 to 6 household members	Frequency	17	113	130		
	Percentage	13.10%	86.90%	100%		
7 and above	Frequency	9	25	34		
	Percentage	26.50%	73.50%	100%		
Usage of coal for heating						
Household size	Description				P value	Effect size
	Measurements	Yes	No	Total		
1 to 3 house hold members	Frequency	10	146	156	0.26	0.09
	Percentage	6.4	93.6	100%		
4 to 6 household members	Frequency	12	118	130		
	Percentage	9.2	90.8	100%		
7 and above	Frequency	5	29	43		
	Percentage	14.7	85.3	100%		

Table 10 reflects results for household size influence on the usage of biomass for domestic activities. Results reflect that household size will not significantly influence the use of biomass

for domestic activities. For instance, the usage of wood for heating when the frequency of participants and percentages scored are compared reflect that household size with 1 to 3 members (14.1%) and 4 to 6 (13.1%) reflect a similar capacity of wood usage for heating.

Table 11 Household size influence on the usage of renewable energy

Usage of renewable energy						
Usage of solar for heating						
Household size	Description					
	Measurements	Yes	No	Total	P value	Effect size
1 to 3 house hold members	Frequency	12	118	130	0.26	0.09
	Percentage	9.20%	90.80%	100%		
4 to 6 household members	Frequency	10	146	156		
	Percentage	6.40%	93.60%	100%		
7 and above	Frequency	5	29	34		
	Percentage	14.70%	85.30%	320		

Table 11 reflects results for households’ size of renewable energy for heating. Results reflect that households’ size has a limited influence on domestic solar energy usage. There is no consequential effect on household sizes and usage of solar energy for heating for households with 1-3 members (9.2%), 4 to 6 member (6.4%) and 7 members and above (14.7%).

5.4 Education

Education is a primary exogenous factor that has significantly been agreed upon in existing literature as a primary determinant of households’ energy choice. This factor assessed the opinions of participants by evaluating the influence of primary income earners educational levels on household’s fuel choice.

Table 12 Education's influence on usage of electricity for domestic activities

Usage of electricity for lighting						
Qualification levels	Description					
	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	52	2	54	0.5	0.07
	Percentage	96.30%	3.70%	100%		
Diploma	Frequency	57	1	58		
	Percentage	98.30%	1.70%	100%		
Degree	Frequency	86	5	91		
	Percentage	95.50%	5.50%	100%		
Post-graduate	Frequency	106	7	113		
	Percentage	93.80%	6.20%	100%		
Usage of electricity for cooking						
Qualification levels	Description					
	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	37	17	34	0.18	0.12
	Percentage	68.50%	31.50%	100%		
Diploma	Frequency	48	10	58		
	Percentage	82.80%	17.20%	100%		
Degree	Frequency	81	10	91		
	Percentage	89%	11%	100%		
Post-graduate	Frequency	96	17	113		
	Percentage	85%	15%	100%		
Usage of electricity for heating						
Qualification levels	Description					
	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	37	17	54	0.03	0.15
	Percentage	68.50%	31.50%	100%		
Diploma	Frequency	48	10	58		
	Percentage	82.80%	17.20%	100%		
Degree	Frequency	86	5	91		
	Percentage	95.50%	5.50%	100%		
Post-graduate	Frequency	96	17	113		
	Percentage	85%	15%	100%		

Table 12 present results on the influence educational level on household's electricity usage for lighting, cooking and heating. Effect sizes tending towards small are reflected for cooking (0.12) and heating (0.15), while lighting reflects equal capacity usage within across educational levels (0.07). Results reflect that participants with higher qualifications such as postgraduates (85%) and degrees (89%) use electricity most for cooking, compared to participants with diploma (82.8%) and grade and below (68.5%). For heating, participants with higher

qualifications; post-graduates (85%) and degrees (95%) use electricity most for heating compared to participants with a diploma (82.8%) and grade and below (68.5%).

Table 13 Education’s influence on usage of LPG’s for domestic activities

Usage of LPG's						
Usage of paraffin for cooking						
Educational levels	Description					
	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	18	95	113	0.01	0.19
	Percentage	15.90%	84.10%	100%		
Diploma	Frequency	6	48	54		
	Percentage	11.10%	88.80%	100%		
Degree	Frequency	3	88	91		
	Percentage	3.30%	96.70%	100%		
Post-graduate	Frequency	2	56	58		
	Percentage	3.40%	96.60%	100		
Usage of Gas for cooking						
Educational levels	Description					
	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	19	94	113	0.02	0.18
	Percentage	16.80%	83.20%	100%		
Diploma	Frequency	15	43	58		
	Percentage	25.90%	74.10%	100%		
Degree	Frequency	25	66	91		
	Percentage	27.50%	72.50%	100%		
Post-graduate	Frequency	21	33	54		
	Percentage	38.90%	61.10%	100%		

Table 13 reflects results on the influence of educational level on the usage of LPG’s for domestic activities. Results reflect that educational level will significantly influence the usage of LPG’s with. Results reflect effect sizes are tending towards small for the usage of paraffin (0.19) and gas (0.18) for cooking. Participants with lower educational levels such as grade 12 and below (15.9%), diploma (11.1%) tend to use paraffin most for cooking compared to participants with higher educational levels; degree (3.3%) and postgraduate (3.4%). Alternatively, participants with higher qualifications; postgraduate (38.9%) and degree (27.5%) tend to use gas most compared to participants with lower qualifications; diploma (25.9%) and grade 12 and below (16.8%).

Table 14 Education's influence on Biomass usage for domestic activities

Usage of Biomass						
Usage of wood for cooking						
Qualification levels	Description				P value	Effect size
	Measurements	Yes	No	Total		
Grade 12 and below	Frequency	31	82	113	<0.001	0.29
	Percentage	27.40%	72.60%	100%		
Diploma	Frequency	4	50	54		
	Percentage	7.40%	92.60%	100%		
Degree	Frequency	7	84	91		
	Percentage	7.70%	92.30%	100%		
Post-graduate	Frequency	2	56	58		
	Percentage	3.40%	96.60%	100%		
Usage of coal for cooking						
Qualification levels	Description				P value	Effect size
	Measurements	Yes	No	Total		
Grade 12 and below	Frequency	6	107	113	0.52	0.08
	Percentage	5.30%	94.7	100%		
Diploma	Frequency	4	50	54		
	Percentage	7.40%	92.60%	100%		
Degree	Frequency	3	55	58		
	Percentage	5.20%	94.80%	100%		
Post-graduate	Frequency	2	89	91		
	Percentage	2.20%	97.80%	100%		
Usage of wood for heating						
Qualification levels	Description				P value	Effect size
	Measurements	Yes	No	Total		
Grade 12 and below	Frequency	27	86	113	<0.001	0.20
	Percentage	23.90%	76.10%	100%		
Diploma	Frequency	8	46	54		
	Percentage	14.80%	85.20%	100%		
Degree	Frequency	8	83	92		
	Percentage	8.80%	91.20%	100%		
Post-graduate	Frequency	4	54	58		
	Percentage	6.90%	93.10%	100%		
Usage of coal for heating						
Qualification levels	Description				P value	Effect size
	Measurements	Yes	No	Total		
Grade 12 and below	Frequency	6	102	108	0.31	0.09
	Percentage	5.30%	90.10%	100%		
Diploma	Frequency	9	82	101		
	Percentage	9.90%	90.10%	100%		
Degree	Frequency	6	48	50		
	Percentage	11.10%	88.90%	100%		
Post-graduate	Frequency	3	55	58		
	Percentage	5.20%	94.80%	100		

Table 14 presents results on the influence on educational qualification on the household use of biomass fuels (wood and coal). Results reflect that educational qualification has a significant influence on the usage of wood for cooking and heating. The usage of wood reflect effect sizes are tending towards medium and small for cooking (0.29) and heating (0.20) respectively. The results reflect that participants with lower qualifications; grade 12 and below (27.4%) and diploma (7.4%) uses wood most for cooking compared to participants with higher qualifications; degree (7.7%) and post-graduate (3.4%). Results also reflect that participants with lower qualifications; grade 12 and below (23.9%) and diploma (14.8%) utilise wood most for heating compared to participants with higher qualifications; degree (8.8%) and postgraduates (6.9%).

Table 15 Education's influence on renewable energy for domestic activities

Usage of renewable energy						
Usage of solar for heating						
Qualification levels	Description					
	Measurements	Yes	No	Total	P value	Effect size
Grade 12 and below	Frequency	2	111	113	0.05	0.16
	Percentage	1.80%	98.20%	100%		
Diploma	Frequency	1	90	100		
	Percentage	1.10%	98.90%	100%		
Degree	Frequency	3	51	54%		
	Percentage	5.60%	94.40%	100%		
Post-graduate	Frequency	5	53	58		
	Percentage	8.60%	91.40%	100%		

Table 15 reflects results for educational qualification on the usage of renewable energy for heating. Results reflect an effect size, tending towards small (0.16). Participants with higher qualification's; postgraduate (8.6%) and degree (5.6%) uses solar energy most compared to participants with lower qualifications; diploma (1.1%) and grade 12 and below (1.8%).

5.5 Gender

Gender is primary determinant to the usage of energy types. The will influence energy choice usage across all energy sources for domestic activities. In this factor, an assessment was done the on the males and females participant with regard to the different energy sources for domestic activities.

Table 16 The influence of gender on electricity usage for domestic activities

Gender influence on electricity usage						
Usage of electricity for lighting						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	153	3	156	0.01	0.14
	Percentage	98.10%	1.90%	100%		
Female	Frequency	154	13	167		
	Percentage	92.20%	7.80%	100%		
Usage of electricity for cooking						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	65	91	156	0.01	0.16
	Percentage	41.60%	58.40%	100%		
Female	Frequency	63	104	167		
	Percentage	37.70%	62.30%	100		
Usage of electricity for heating						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	121	35	156	0.34	0.05
	Percentage	77.60%	22.40%	100%		
Female	Frequency	122	45	167		
	Percentage	73.10%	26.90%	100%		

Table 16 presents results on the influence of gender on electricity usage for lighting, cooking and heating. Effect sizes tending towards small are reflected for lighting (0.14) and cooking (0.13), while heating reflects a lesser effect size (0.05). Results reflect that male participants' use electricity most for lighting (98.1%), compared to females (92.2). Results also reflect that male participants' use electricity most for cooking (41.6%), compared to females (37.7%).

Table 17 The influence of gender on LPG's usage for domestic activities

Gender influence on LPG'S usage						
Usage of paraffin for cooking						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	39	117	156	0.27	0.1
	Percentage	25%	75%	100%		
Female	Frequency	47	120	167		
	Percentage	28.1	71.90%	100%		
Usage of Gas for cooking						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	45	111	156	0.26	0.11
	Percentage	28.80%	71.20%	100%		
Female	Frequency	39	128	167		
	Percentage	23.40%	76.60%	100		

Table 17 reflects results on the influence of gender on the usage on LPG's. Results tend to reflect relative usage of LPG's among males and females participants. Alternatively, results also reflect that paraffin is used for cooking most by females (28.1%) compared to males (25%). Results also reflect that gas is used for cooking most by males (28.8%) compared to females (23.4%). However, inconsequential effect sizes are reflected for gender influence on LPG's usage.

Table 18 The influence of gender on Biomass usage for domestic activities

Gender influence on Biomass usage						
Usage of wood for cooking						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	19	137	156	0.06	0.14
	Percentage	12.20%	87.80%	100%		
Female	Frequency	51	116	167		
	Percentage	30.50%	69.50%	100%		
Usage of coal for cooking						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	6	161	167	0.26	0.06
	Percentage	3.60%	96.40%	100%		
Female	Frequency	10	146	156		
	Percentage	6.40%	93.60%	100%		
Usage of wood for heating						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	23	144	167	0.05	0.03
	Percentage	13.80%	86.20%	100%		
Female	Frequency	25	131	156		
	Percentage	16%	84%	100%		
Usage of coal for heating						
Gender	Description					
	Measurements	Yes	No	Total	P value	Effect size
Male	Frequency	9	147	156	0.10	0.09
	Percentage	5.80%	94.20%	100%		
Female	Frequency	18	149	167		
	Percentage	10.80%	89.20%	100%		

Table 18 reflects results on the influence of gender on the usage on biomass for cooking and heating. The usage of wood for cooking reflect an effect size, tending towards small (0.14). Results reflect that wood is used mostly for cooking by females (30.5%), compared to males (12.2%). Results also reflect a noteworthy difference ion the usage of coal for heating for female (10.8%) and male (5.8%).

Table 19 The influence of gender on renewable energy usage for domestic activities

Gender influence on renewable energy usage						
Usage of Solar energy for heating						
Gender	Description					
	Measurements	Yes	No	Total	P values	Effect size
Male	Frequency	19	137	156	0.42	0.07
	Percentage	12.10%	87.90%	100%		
Female	Frequency	4	120	167		
	Percentage	2.60%	97.40%	100%		

Table 19 reflects results on the influence of gender on renewable energy usage for heating. Results reflect solar energy is most used for heating by male participants (12.1%), compared to female participants (2.6). However, the effect size is insignificant.

6. CONCLUSIONS

The empirical research was aimed at assessing determinants of energy fuel choice in the South African household context by capitalising on the energy ladder and stacking hypotheses in the Gauteng and North West province of South Africa. Results maintained similar ideology to some existing studies in the theoretical findings. However, there are some findings that reflect unique to the South African context.

Findings reflect that high-income household tends to use more advanced energy sources of energy fuels as compared to low-income households who utilises advanced energy fuels lowest. Electricity is reflected to be used on comparable capacity by income groups for lighting. Electricity is mostly used by high-income groups for cooking and heating compared to low-income groups. LPG's reflect to be significantly used by income groups for cooking. The low-income households tend to use paraffin most for cooking as compared to high-income households that tend to use more of gas. Solar energy is mostly used by high-income households for heating. Low-income households tend to use wood fuel significantly for cooking and heating. Coal tends to be used equally by income groups for cooking. This might be possibly explained by the fact that, coal is usually indispensable for barbeques "braai" in South Africa by households regardless of income status. Findings also reflect that monthly electricity expending above R300 is highest with high-income households (81.1%) compared to low-income households (27.8%)

Results reflect that household size will influence the usage for lighting, cooking and heating. Households with more members tend to use LPG's for cooking most compared to households with fewer family members. Household size reflects a limited influence on biomass usage

except for wood for heating. Implying that household size will influence usage of LPG's as an alternative cooking fuel more as compared to biomass. Findings also note that household size has no influence on the usage of solar energy for water heating. Results reflect that education is a primary factor in determining household energy fuel choice. Household participants with higher educational qualification levels (Post-graduates and degree) tend to use electricity most for lighting, cooking and heating. Usage of LPG's reflects that household participants with lower academic qualifications (Diploma and grade 12 and below) use paraffin most for cooking while participants with higher qualification tend to use gas most. For biomass, education reflects to immensely influence the usage of wood fuel for both heating and cooking. Findings also reflect that education has a small impact on the usage of solar energy for water heating.

The influence of gender on energy choice reflects that male participant maintain to use electricity most for lighting, cooking and heating compared to female participants. The usage of LPG'S also reflected that males uses gas more as an alternative fuel for cooking while females used paraffin most. Biomass reflect insignificant differences usage capacity except for the usage of wood for cooking with an effect size tending towards small. Findings also reflect that male participants note to utilise solar energy most for heating compared to female participants.

7. FINAL STATEMENT

This paper will extensive contribute to policy as it has create awareness to important determinants that drive household fuel choice. The empirical research will assist policy makers on how to capitalise on important human tendencies to influence growth in clean fuel usage and reduction in biomass usage. Behavioural studies on household energy usage have the capacity to enrich government policy on green economic development and empowerment and poverty alleviation. The findings of the paper has identified important factors to designed programs that will improve sustainable energy consumption and growth in the South African house hold sector. Such programs can improve reduction in the usage of primitive energy fuel sources to reduce environmental pollution and to improve households' indoor air quality. There is, an urgent need for the government to concentrate resources and efforts on programmes and measures that will address energy requirements of low-income households if not, health and safety issues relating to energy usage and household energy security will never be adequately addressed.

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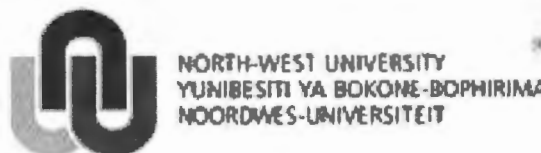
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Appendix 2: Domestic sector empirical research data collection instrument



For office use only; Respondent code...

Voluntary Questionnaire for PhD studies

Researcher: Ben Ateba (PhD)

Student Number: 21994358

Contacts: 0736902154

Supervisor: J.J Prinsloo (Promoter)

Contacts: 0829040977

Email: hein.prinsloo@nwu.ac.za

Dear Participants (Households)

Thank you very much for your willingness to complete this questionnaire regarding the **Impacts of the low electricity supply on the South African domestic sector and resulting consumption behaviour.**

The purpose of the questionnaire is to collect data that can be used to:

- a) Determine the consequences of poor electricity supply to households.
- b) Assessing resulting consumption tendencies.

This study is focus on the electricity grid in South Africa only. The grid electricity consists of electrical power supply to consumers with Eskom Limited as the main administrator. This is an anonymous survey that will take respondent a maximum of 10 minutes to complete. You cannot be identified and the answers will be used for academic research purposes. Only members of the research team will have access to the information. As respondent, you are not obliged to complete the questionnaire. Completion of the questionnaire also indicates your consent that the data may be used for the purposes of this study and any subsequent study. Accompanied is also a signed and stamped letter authorised from the research office.

Please answer all the questions. There is no right or wrong answers.

Thank you so much for your participation

Please provide the required information by marking with an (X) in the appropriate space provided.

Section A: Biography

1. In which city do you live?

1	Pretoria North	
2	Soshanguve	
3	Auckland	
4	Soweto	
5	Riviera park	
6	Extension 39	
7	Potch Town	
8	Ikakeng	

2. Biographical information (Please mark the (ONE) most applicable option at all questions):

	Gender	Type of Household member	Marital Status	Qualification	Income contribution
1	Male	Father	Married	Grade 12 and below	Primary income earner
2	Female	Mother	Single	Diploma	Not the primary income earner
3		Child	In a relationship	Degree	
4		Tenant	Divorced	Post Graduate	
5		Grand parents			

3. Please indicate the number of household members per category:

		4.1: Household members 18 years and younger	4.2: Household member 19 years of age and older	4.3: Total number of household members
1	1 – 3 members			
2	4 – 6 members			
3	7 – 9 members			
4	10 and more members			

4. Indicate the type of electricity meter on the property you are staying at:

1	Prepaid meters	
2	Conventional meters	

5. Total monthly electricity expenditure of the household:

1	R10 – R50	
2	R51 – R100	
3	R101 – R150	
4	R151 – R200	
5	R201 – R250	
6	R251 – R300	
7	Above R301	

6. Total Gross (pre-tax) monthly income of the household:

1	Less than R15, 000	
2	R15,001 – R25, 000	
3	R25,001 – R34,000	
4	R34,001 – R46,000	
5	Above R46 000	

Section B: Operational reliability

Supply sufficiency	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
1. The supply of electricity in South Africa is:					
a) Sufficient					
b) Consistent(low voltage)					
c) Without interruptions (blackouts)					
d) Allows to perform basic household activities.					
2. Future electricity supply will be without interruptions.					
3. Electricity supply strength allows for effective functioning of household.					

Statements	Yes	No	Don't know
1. Are you aware of the government scheduled free monthly electricity (50 kwts per household)?			
2. Do your household make use of the government scheduled free monthly 50kwts electricity?			
3. Is the 50kwts electricity enough to meet your household demand?			
4. Has your residential area experienced electricity interruptions (black-outs) in the last 6 months?			

Section C: Supply adequacy

Service quality	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
1. Electricity supply volumes meet the households in South Africa's demand.					
2. Multiple electric appliances (e.g. stove, geyser & kettle) can be used simultaneously in your house.					
3. Load shedding has an effect on household functioning (e.g. study time for school children).					
4. Unannounced load shedding destroys home appliances.					
5. Domestic family comfort (watching Tv, heating water, security lights, and pool pumps) has been influenced negatively by inconsistent electricity supply.					
Health Risk					
1. Alternative sources for heating and cooking (e.g. paraffin and wood) cause health problems.					
2. Alternative sources for heating and cooking could contribute to hazardous consequences (e.g. accidental arson).					
3. Continues coal usage by electricity producers causes air and environmental pollution.					
Cost reliability					
1. Electricity price increases is relatively higher than increases to your household's disposable income.					
2. Increased electricity fees impact on domestic electricity purchasing ability.					

3. The current cost of electricity is acceptable.					
4. Future electricity price increases is a threat to domestic electricity purchase ability.					
5. Due to the increasing high cost of electricity, you tend to rely on alternative energy sources (wood, paraffin or candles).					

Section D: Consumption behaviour

Energy saving activities	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
1. In your household you switch off lights when leaving a room.					
2. In your household you switch off geyser at certain times.					
3. In your household you use warm clothing or blankets instead of a electric heater.					
4. In your household you switch appliances (e.g. routers and modems) on standby mode when not in use.					
5. You report members of society that gain electricity illegally.					
6. Itemised billing could contribute to more effective electricity usage.					

Indicate which of the following appliances....	1	2	3	4	5	6	7	8	9	10
	<i>Fridge</i>	<i>Geyser</i>	<i>Cooking stove</i>	<i>Air-conditioner</i>	<i>Pool pump</i>	<i>Space heater</i>	<i>Iron (clothing)</i>	<i>Kettle</i>	<i>Washing machine</i>	<i>Micro wave oven</i>
1. are being used in your household?										
2. usage has been reduced due to electricity cost and supply?										
3. do you demand all day?										

4.used in your household are older than 5 years?										
6. can you function without?										
7. are being used during warmer summer months?										
8. Are being used during colder winter months?										

Section E: Usage of other sources of energy

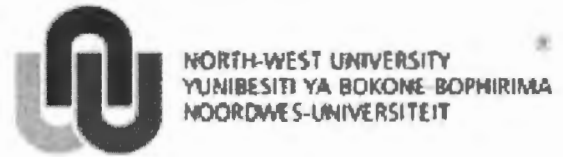
Indicate the main source of energy for the following activities in your household:

Activities	1	2	3	4	5	6	7
	<i>Electricity</i>	<i>Paraffin</i>	<i>Gas</i>	<i>Solar</i>	<i>Generator</i>	<i>Wood</i>	<i>Coal</i>
1. Lighting							
2. Cooking							
3. Heating							

Thank you so much for accepting our invitation, to be a participant in this empirical research

*Ben Ateba
PhD Candidate*

Appendix 3: Industrial sector empirical research data collection instrument



For office use only; Respondent code...

Voluntary Questionnaire for PhD studies

Researcher: Ben Ateba (PhD)

Student Number: 21994358

Contacts: 0736902154

Supervisor: J.J Prinsloo (Promoter)

Contacts: 0829040977

Email:hein.prinsloo@nwu.ac.za

Dear Participants (Business Industries)

Thank you very much for your willingness to complete this questionnaire regarding **South Africa industrial electrical power supply and industrial growth.**

The purpose of the questionnaire is to collect data that can be used to:

- c) Determine the consequences of poor electricity supply on industrial activities.
- d) Assess electricity mitigation activities for grid short falls
- e) Evaluate electricity consumption control programs towards efficiency

This study is focus on the electricity grid in South Africa only. The grid electricity consists of electrical power supply to consumers with Eskom Limited as the main administrator.

This is an anonymous survey that will take respondent a maximum of 10 minutes to complete. You cannot be identified and the answers will be used for academic research purposes. Only members of the research team will have access to the information.

As a respondent, you are not obliged to complete the questionnaire. Completion of the questionnaire also indicates your consent that the data may be used for the purposes of this study and any subsequent study.

Accompanied is a signed and stamped letter authorised from the research office.

Please answer all the questions. There is no right or wrong answers.

Thank you so much for your participation.

Please provide the required information by marking with an (X) in the appropriate space provided.

Section A: Biography

1. In which province does your company operate

1	Gauteng	
2	North West	

2. In which industry does your company operate (choose most applicable option)

	Services	Tick <i>x</i>	Manufacturing	Tick <i>x</i>	Mining	Tick <i>x</i>
1	Supermarkets (Cold-chain)		Construction materials		Minerals (Coal & Diamond)	
2	Financials		Chemicals		Mining purification	

3. Profile (Please mark the most applicable option at all questions)

	Capacity in the company	Tick <i>x</i>	Gender	Tick <i>x</i>	Highest qualification	Tick <i>x</i>	How many years have you been working for the company	Tick <i>x</i>	Business category	Tick <i>x</i>
1	Owner		Male		Grade 12 & below		0-5		Small	
2	Manager		Female		Diploma		6-10		Micro	
3	Director				Degree		11-15		Medium	
4	CEO				Post Graduate		16-20		Large	
5	Sole proprietor						More than 20			

4. Total monthly expenditure on electricity

1	R5,001 - R10000	
2	R10,001 - R15,000	

3	R15,001 - R20,000	
4	R20,001 - R25,000	
5	R25,001 - R30,000	
6	More than R30,000	

5. Cost per unit of electricity (optional)

1	0.8cent - 0.16 cent	
2	0.17 cent - R1.50cent	
3	R1.51cent to R2	
4	R2.1cent to R3	
5	R3.1cent to R4	
6	More than R4	

6. Indicate your electricity meter type

1	Prepaid meters	
2	Conventional meters	

Section B: Levels of supply adequacy complimenting business growth

Importance of electrical energy	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
1. Electrical energy is mainly used as energy source					
2. Electricity disruptions has a negative effect on your company's production levels					
3. Consistency in electricity supply is necessary for your business growth					
Supply sufficiency					
1. Electricity supply volumes is sufficient to meet business demand					
2. Your organisation is optimistic about future consistency in electricity supply					

3. Currently in South Africa, businesses are operating in an energy crisis environment.					
Operational vulnerabilities					
1. Your organization's production reliability is affected negatively by inadequate electricity supply					
2. Your organization have experienced industrial equipment damages due to inconsistent electricity supply					
3. Electricity supply inconsistency contributed towards a reduced workforce (labour) in your organisation					
4. Production deadlines have been influenced negatively by electricity supply inadequacy					
5. Electricity inconsistency has a negative effect on employee motivation levels in your organisation					
6. Productive working hours are being reduced due to electricity supply:					
a. Inadequacy					
b. disruptions					
7. Electricity supply inadequacy caused a decline in your product range (product lines closure etc.)					
8. Electricity supply inadequacy:					
a. had a negative influence on communication technology infrastructure in your organisation					
b. resulted in a loss of data in your organisation					
9. Electricity supply inadequacy has a negative effect on investments possibilities in your industry					
10. Electricity supply inadequacy has negatively effect financial market behavior in your industry in the:					
a. Short term					

b. Long term					
11. Your company have lost direct investment possibilities due to electricity uncertainties					
12. Electricity cost has a significant effect on profit margins in your organisation					
13. Electricity price increases are being spiraled down to the final consumer (business's)					
Business performance					
1. Your business growth (linked to performance) has declined since 2007 due to instability of electricity supply					
2. Your business growth (linked to performance) has declined since 2007 due to the general economic downturn					

C. Control programs

Mitigation control	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
1. Your organisation have an adequate understanding of electricity crisis management programs (e.g alternative power sources)					
2. Electricity crisis management programs have been successfully implemented in your organisation					
3. Alternative electricity generating systems (for example solar power and generators) have been adopted successfully					
4. The organization's alternative power systems is capable of solving any form of grid short-fall					
5. Your organisation have been able to acquire investors to sponsor your energy mitigation programs					

6. Trade unions are involved with the stabilizing of electricity supply (strategic discussions with suppliers)					
7. Commercial business forums are involved with the stabilising of electricity supply (strategic discussions with suppliers)					
Intensity control					
1. Electricity efficiency within your industry is important to the public sector (NERSA / DME).					
2. Electricity distribution control programs have been introduced successfully to stabilize intensity in:					
a. High demand industries					
b. Low demand industries					
3. Conservation of available power has become a major focus in your business strategy					
4. Your organisation take part in efficiency programmes such as:					
a. Reducing electricity consumption					
b. Guidelines toward a cleaner emission control					
c. Facing-off energy intensive operational activities					
5. Administrators (Eskom, NERSA):					
a. levy penalties in cases of non-compliance to efficiency control policies					
b. ensure administration in cases of levy to non-compliance to efficiency control policies					
6. There is a general corporate awareness towards efficient use of electricity					
7. The general organisation attitude towards energy control is					
a. positive					
b. negative					

8. Do you think that controlling industrial energy consumption is important					
9. Administrators have established guidelines towards cleaner emission control					
Please mark the most applicable option	Yes	No	Partially		
Would you be interested in participating in energy saving activities					

Thank you so much for accepting our invitation to be a participant in this empirical research

Ben Ateba
PhD Candidate

Appendix 4: Data used for article 4 analyses

Years	LOG_EP	LOG_EC	LOG_CV	LOG_CP	LOG_EPR
1998Q1	9.726272933	10.72715848	5.559527119	3.33220451	No data
1998Q2	9.766292313	10.76774788	5.571012697	3.347680564	No data
1998Q3	9.779680157	10.79591583	5.575949103	3.311516991	No data
1998Q4	9.717338681	10.72891221	5.582744146	3.313942339	No data
1999Q1	9.706681602	10.72117268	5.552184091	3.29497353	No data
1999Q2	9.728955578	10.77444613	5.565286397	3.262574956	No data
1999Q3	9.78227991	10.81369985	5.581614841	3.183870216	No data
1999Q4	9.725197857	10.76506863	5.565669173	3.172203417	No data
2000Q1	9.720585827	10.75709404	5.530222424	3.202746443	No data
2000Q2	9.796292021	10.80531418	5.56681662	3.295714636	No data
2000Q3	9.81345343	10.84259597	5.624017506	3.33220451	No data
2000Q4	9.759905824	10.78448266	5.577463108	3.423718533	No data
2001Q1	9.729550745	10.76333491	5.569488887	3.581664442	No data
2001Q2	9.765833387	10.80431941	5.589493328	3.583796678	No data
2001Q3	9.836332277	10.85125757	5.586874056	3.551147824	No data
2001Q4	9.746833742	10.77851869	5.517854422	3.486151088	No data
2002Q1	9.739261284	10.77808091	5.503296947	3.401197382	3.392482413
2002Q2	9.833065088	10.86343147	5.549465114	3.28291297	3.396675016
2002Q3	9.869465304	10.89943938	5.612763076	3.150738302	3.434931222
2002Q4	9.830217691	10.85300027	5.577841251	3.333514366	3.4369674
2003Q1	9.808462332	10.83799141	5.534574557	3.302481409	3.447921132
2003Q2	9.875190953	10.88549112	5.622572419	3.244933359	3.450175895
2003Q3	9.930324206	10.92274995	5.681536866	3.474292937	3.499841694
2003Q4	9.898826708	10.89165233	5.660178837	3.668357818	3.501796523
2004Q1	9.877605483	10.88941628	5.637998734	3.761200116	3.512802278
2004Q2	9.930664881	10.92899137	5.6563414	4.00952714	3.516291358
2004Q3	9.967353973	10.9644672	5.698099692	4.180139922	3.547068201
2004Q4	9.912496847	10.91113521	5.658785109	4.081625686	3.556709486
2005Q1	9.888424675	10.89314026	5.572534188	3.887336793	3.563333547
2005Q2	9.93265793	10.93916004	5.677096209	3.872934923	3.574204984
2005Q3	9.948986593	10.95486846	5.712081277	3.914934762	3.601340603
2005Q4	9.924319062	10.93097971	5.66711849	3.732365098	3.582303147
2006Q1	9.913833845	10.91476114	5.582367853	3.922385133	3.581616489
2006Q2	9.967447781	10.97850704	5.655642099	3.980615797	3.588120781
2006Q3	9.993785191	11.00088243	5.69642212	3.957745612	3.65341805
2006Q4	9.961048663	10.96503813	5.692047218	3.919330242	3.647687896
2007Q1	9.953229644	10.96859476	5.668500661	3.965563772	3.648210178
2007Q2	10.0047798	11.01705413	5.66296048	3.985212127	3.652378643
2007Q3	10.03753756	11.04876076	5.690359454	4.116595171	3.732183589
2007Q4	9.990078008	10.99172959	5.655991811	4.462531159	3.72134147
2008Q1	9.958449111	10.96002706	5.622572419	4.699325153	3.723280881
2008Q2	9.989435865	11.00223317	5.7212949	4.827857633	3.728100167
2008Q3	10.01966931	11.03605028	5.740114404	5.06554637	3.958270257
2008Q4	9.938468521	10.93880499	5.667809814	4.53378159	3.982170765
2009Q1	9.864850669	10.88502281	5.592478405	4.234203601	3.982170765
2009Q2	9.941650014	10.95609081	5.676411278	4.116921116	3.979058407
2009Q3	10.00703643	11.01751377	5.773930235	4.145671189	4.186113124
2009Q4	9.951706125	10.96816381	5.673666851	4.236953174	4.193687006
2010Q1	9.948078436	10.96412102	5.671603576	4.447589631	4.194189897
2010Q2	9.990032154	11.00771737	5.630135934	4.519794198	4.194692536
2010Q3	10.00432787	11.02033261	5.787817204	4.489871562	4.354141431
2010Q4	9.984929281	10.98647846	5.732369932	4.645764955	4.359269648
2011Q1	9.963406043	10.97831931	5.647917342	4.799527357	4.361823927
2011Q2	10.01270064	11.02503481	5.671603576	4.805388961	4.366489896
2011Q3	10.0145816	11.02514883	5.713402718	4.768308923	4.515245478
2011Q4	9.981559088	10.98784878	5.692721527	4.680713556	4.517795106
2012Q1	9.956080003	10.9696283	5.677438499	4.663410792	4.519249124
2012Q2	9.966650127	10.97866061	5.723258251	4.548282324	4.521788577
2012Q3	10.01413407	11.00524489	5.741399338	4.482098188	4.608165695
2012Q4	9.964300392	10.95598609	5.713402718	4.46352943	4.613468989
2013Q1	9.935422171	10.9251468	5.655292265	4.45058091	4.615450495
2013Q2	9.982437356	10.98569942	5.753524567	4.39896364	4.616110126
2013Q3	10.0081178	11.01993976	5.744924418	4.302500356	4.683981366
2013Q4	9.946786477	10.95976629	5.661570626	4.431135796	4.683981366
2014Q1	9.937067386	10.94711553	5.655642099	4.374078885	4.684905154
2014Q2	9.968713337	10.98009279	5.75669113	4.330426714	4.684905154
2014Q3	9.997478681	11.00780023	5.768633447	4.264977236	4.752152376
2014Q4	9.947073723	10.96315109	5.710095837	4.202401938	4.75272775
2015Q1	9.937067386	10.9587225	5.705780477	4.144632018	4.751864565
2015Q2	9.944917362	10.96900831	5.68963355	4.122760317	4.751864565
2015Q3	9.959395184	10.97150317	5.702781974	4.012447358	4.857484115
2015Q4	9.93022685	10.94082709	5.649326289	3.952377691	4.857484115