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Energy and security: The role of renewable energy in South Africa

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ABSTRACT

Conceptualising energy security is of the upmost importance when considering any definition of energy security applicable to a country or geographical context. This conceptualisation leads to the definition and allocation of applicable influencing elements, that ultimately underpin this definition, but more importantly lead to policy and the associated legislation formulation. A major contributing factor to energy security for any country is the understanding of the relationship between economic growth and energy consumption. There are various phases (Growth, Conservation, Neutral and Feedback hypothesis) of this relationship and each is represented by a different causal direction. This relationship forms a critical factor to consider when conceptualising energy security. A Second critical factor underpinning energy security is the selection of the appropriate electricity generation mix. Currently South Africa is dominated by coal as energy source, with nuclear, gas, diesel and recently renewable sources that contribute electricity to the national grid. Much of the worlds, including South Africa, generation fleet is reaching end of life and is standing at a pivotal point having to decide on the appropriate energy mix that allows transitioning to an environmentally friendly generation fleet.

This research set out to review the South African energy policies to ascertain whether the encapsulated elements are still valid and current, to review the historical 3:2 economic growth and energy consumption relationship utilised in the Integrated Resource Plan 2010 formulation to determine its validity and ultimately to explore the possibility of a 100% renewable energy generation profile for South Africa. A case study methodology was employed, where interviews with industry experts were analysed and validity of emerging themes plaid with the introduction of secondary data.

The research has found that i) the current definition of energy security, as stipulated in the South Africa Energy Master Plan (2007), is out of date and needs revision, ii) the historical 3:2 economic growth and energy consumption relationship is out of date and it is recommended that a bottom up sectoral analysis be done to determine the current relationship and iii) the a 100% renewable energy generation profile for South Africa is not currently feasible until such time as electricity storage becomes an economical viable option.

Keywords: Renewable Energy, Generation Profile, Economic Growth, Energy Consumption, Energy Security.

DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorization and consent to carry out this research.

______________ 9 November 2015

John R. Strydom Date

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"The National Development Plan aims to eliminate poverty and reduce inequality by 2030. South Africa can realise these goals by drawing on the energies of its people, growing an inclusive economy, building capabilities, enhancing the capacity of the state, and promoting leadership a partnerships throughout society" (NDP, 2011, p. 24).

CHAPTER ONE: INTRODUCTION TO RESEARCH PROBLEM

1.1 Introduction

The National Development Plan anticipates that the South African economy needs to increase a projected 2.7 times to reach an aspirational 5.4% p.a. GDP growth rate and electrification would increase, allowing 90% of people access to electricity by 2030. To reach this growth and electrification target, the electricity capacity in South Africa needs to grow by 40,000MW of new build capacity, taking in consideration 10,900MW of retiring capacity over the same period. It is expected that 20,000MW would be delivered by renewable energy sources with specific focus on shale gas exploration (liquid fuel imports and shale reserves), wind, solar, and imported hydro that would contribute to a lower carbon intense economy. It is expected that an economy wide carbon pricing mechanism would be in place by 2030 (NDP, 2011).

With a growing population of 1.58% (Statistics South Africa, 2014), the South African population has an increased need for additional services, and, with the high unemployment rate, there is a need for expansion in economic growth to allow new participants to enter the labour market (Koen & Holloway, 2014). Kebede, Kagochi, and Jolly (2010) stated that energy is a vital contributor to meet basic human needs and that business, industry, commerce, and public services, such as health care, education, and communication, are dependent on electricity services to service the population. South Africa is very industrialised and energy plays a large role in the large scale manufacturing and production processes (Ziramba, 2009). This is supported by Kebede et al. (2010) who state that all production activities involve energy as an essential input that ultimately contributes to the enhancement of capital, labour, and other production factors. Koen and Holloway (2014) stated that, from a national and local planning perspective, both private and public, future electricity requirements and the implications that energy supply security has on supporting the realisation of future development plans requires attention.

The term energy security originated during the early 20th century and was predominantly focussed on ensuring that the supplies of fuels (e.g., oil) to armies were uninterrupted and maintained. Energy security has subsequently evolved to include a broad range of other concepts that include technologies, environmental concerns, climate change, resources, and access to electricity (Jewell, Cherp, & Riahi, 2014), The connotational allocation of these concepts to energy security, in a particular case, will determine the main focus of policy makers and subsequent supporting energy policies. The South African Energy Security Master Plan (2007) defines energy security as "ensuring that diverse energy resources in sustainable quantities and at affordable prices, are available to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management and requirements and interactions among economic sectors" (p. 5). Trollip, Butler, Burton, Caetano, and Godinho (2014) argue that this places resources at the centre of energy security with the economy as recipient, and a policy heavily focussed on resource and energy supply is out of date. Due to the reliance of policy makers on the conceptual framing of energy security, it is essential that this take place as a preluding activity before any policy forming or subsequent measurement metrics be introduced.

As a standard input in the determination of energy supply security required by a particular country, the relationship between economic growth and energy consumption forms a vital concept that ultimately underpin policy forming and enable successful infrastructure planning. Ouedraogo (2013) stated that determining the causal relationship between economic growth and energy consumption is of prime importance when determining the appropriate energy policies. The Department of Energy (2010) stated that the historical economic growth and energy consumption relationship to be 3:2. This relationship translates to an increase of 3% in economic growth would necessitate an increase of 2% in energy supply. There are four types of growth phases (i.e., growth, conservation, neutral, feedback) a country can experience, and each of these phases represent a different causal relationship between economic growth and energy consumption (Apergis & Payne, 2010). It is essential to understand this causality relationship, within different growth scenarios, as this would ultimately influence policy makers in determining the type of supporting energy policies to be formed in promoting economic growth.

Energy mix is a topic for much discussion, as policy makers focus policy direction to enable energy security in a particular geographical context. Energy infrastructure models typically have sufficient energy generating capacity to cater for electricity demand, as it fluctuates between low, intermediate, and peak demand. Demand fluctuations are matched and aligned with supply via baseload, intermediate, and peak generating plants. Baseload power plants are normally associated with large nuclear and/or coal fired power plants that run permanently and cater for minimum demand, whilst the intermediate and peak power plants run to match increased demand as it fluctuated during peak periods. Due to quick start and stop functionality needed in the intermediate and peaking plants, to match sudden changes in demand patterns, these power plants are normally associated with gas, oil, and hydro that are very costly to run due to the high price of fuel (Matek & Gawell, 2015).

A key factor fuelling much support for policies to change focus towards energy from alternative or renewable sources are environmental concerns (Greenblatt, Succar, Denkenberger, Williams, & Socolow, 2007). According to Castelo Branco, Moura, Szklo, and Schaeffer (2013), 40% of greenhouse gas emissions originate from electricity, which results from the utility of large scale fossil fuels in the generation process. Global renewable energy penetration has increased tremendously over the period 1980 to 2009, with an increase of 55% in consumption of wind and solar generation and a further 30% over the period 1992 to 2001. China, alone, has increased their renewable profile in their generation mix to 37GW. Factors driving this growth are extreme capital cost reductions and government initiatives encouraging renewable energy investments (Greenblatt et al., 2007).

South African renewable energy penetration has increased tremendously with the introduction of the Independent Power Producer Procurement Program, which is a government initiative that allows private developers to develop, build, and run renewable energy plants, and, ultimately, sell electricity back to the state owned utility, Eskom. Launched in August 2011, the program has been hailed, worldwide, as a model for renewable energy procurement (Eberhard, Leigland, & Kolker, 2014), with 4,116MW being successfully procured across bidding windows one, two, three, and three point five. The fourth round bidding window attracted bids from independent developers that total 5,804MW, but only thirteen bidders have been accepted, totalling 1,121MW. This is a total of 6,921MW procured under the Independent Power Producer Procurement Program to date, with an expedited window in process to procure more bids (Department of Energy, 2015). This totals 6,921MW of the anticipated 20,000MW renewable energy procurement as stated in the National Development Plan.

Numerous studies have been done exploring the feasibility of a 100% renewable energy profile that brought back mixed results and these studies are further elaborated in chapter 2. The researcher has, however, found very little academic literature where this phenomenon have been explored within a South Africa context and forms a large basis of this study.

The aim of this study is to investigate the extent to which publicised definitions of energy security are representative of the views compiled from stakeholders, to determine the extent to which economic growth and energy consumption play in policy forming, and, ultimately, explore whether a 100% renewable energy profile is achievable for South Africa.

1.2 Rationale for the study

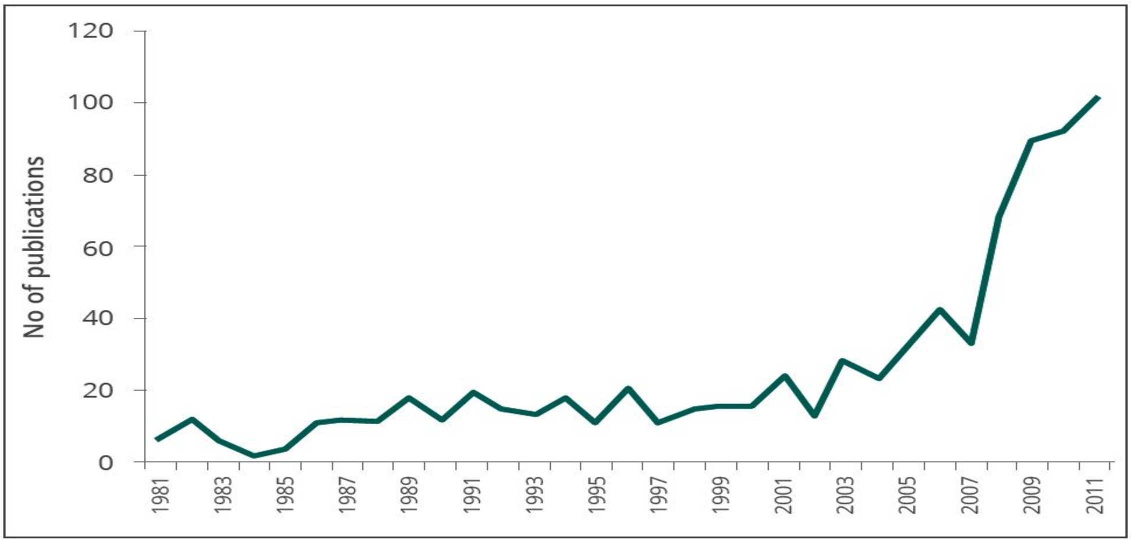
The current energy crisis has a debilitating social and economic effect on South Africa. Inglesi-Lotz and Pouris (2014) stated that the energy crisis in 2007/8 had significant consequences on the South African economy and the industry sector itself. Andersen and Dalgaard (2013), in their study on the effects of power outages on economic growth in Africa, concluded that a substantial growth drag is accompanied by weak power infrastructure in Sub-Saharan Africa. The current impact of rolling blackouts are headline news on a near daily basis, and the consequences are felt throughout businesses, which affect the quality, safety, and security of all individuals. Stern (2011) expressed that the scarce availability of energy imposes economic growth constraints, but has little effect if abundantly available. Adom (2011) stated that electricity consumption is a multifaceted energy currency supporting a wide range of product and services that contribute to improved quality of life, increased work productivity, and entrepreneurial activities. Bohi and Toman (1993) elaborated on this, stating that energy insecurity, underpinned by changing price or availability of energy, results in the loss of welfare.

According to definitions by any respective country, electricity is a key contributor to the promotion of energy security, and it is argued that energy consumption is a vital part of the production process alongside capital, labour, and material. Any business is reliant on energy to drive operations, and unplanned interruptions to this supply can have severe impacts on the operational efficiency that result in severe negative consequences, not only at business level, but ultimately on a national level as well. Business expansion could severely be hampered due to the associated risk of increasing capacity and work force with no available electricity to drive operations. Small and medium enterprises (SMEs) will play a key role in future economic and social strategies in South Africa. However, we find that SMEs are particularly vulnerable to shocks to their external environment due to a general lack of skills and resources. This is critical, as the future demand for electricity in South Africa is likely to outstrip supply and electricity will become increasingly unreliable and expensive (Ketelhodt, 2008). According to Brown, Wang, Sovacool, and D'Agostino, (2014), "our study finds that many industrialised countries have made limited progress towards the goal of achieving secure, reliable and affordable supplies of energy while also transitioning to a low-carbon energy system (p. 64)."

The corporate sector is the largest consumer of electricity with manufacturing comprising 27%, mining 10%, and commercial 10% of South Africa's energy utility (WWF international, 2014a). South Africa possesses some of the world's largest mineral reserves, with platinum, gold, coal, and iron ore contributing to the majority of the large scale exports from South Africa. South Africa is a large contributor to global production and supply of minerals and rank amongst the highest in the world, with Platinum 1st at 59%, Gold 5th at 6.5%, Coal 7th at 3.3%, and Iron ore 6th at 3.2%. This contributes to total employment generated in the mining industry, as per 2012 (446,668), with 197,847 in Platinum, 142,021 in Gold, 83,240 in Coal, and 23,380 in Iron ore mining. Electricity intensity in the mining industry is dominated by Gold at 47%, Platinum at 33%, and other industries at 20% (Global Green Growth Institute, 2014).

The researcher has selected this topic to better understand the impact of energy availability on the economy and economic growth, current capital infrastructure, and proposed plans to promote energy security in South Africa whilst driving a 5.4% GDP growth target under committed CO2 reductions initiatives. The study will make specific reference to South African policies (e.g., National Development Plan and Integrated Resource Plan).

Figure 1: The number of publications in the field of energy and fuels in South Africa from 1981 to 2011.



Source: Inglesi-Lotz and Pouris (2014, p. 1).

As depicted in Figure 1, the relevance of the topic is shared by scholarly interest in the field of energy and fuels, which is supported by the escalation in literature publications over the period from 1981 to 2011.

1.3 Research questions

The research questions that have been selected to address the research problem in this study are listed as follows:

- In conceptualising energy security, are South African energy policies out of date?
- What is the economic growth and energy consumption relationship that best reflect the South African economy?
- Can South Africa achieve a 100% energy generation profile?

1.4 Research objectives

The research questions and propositions that have been selected for this study are listed as follows:

- To determine whether the current definitions encapsulated in energy policies are current and reflective of stakeholders' views.
- To ascertain whether the historical relationship between economic growth and energy security of 3:2 is still valid.
- To determine if a 100% generation profile from renewable sources are achievable in South Africa.

1.5 Research propositions

The propositions are listed as follows:

- The South African energy policies are current and reflective of stakeholder assessments on energy security.
- The South African economic growth and energy consumption historic relationship of 3:2 is out of date.
- South Africa can achieve a 100% generation profile from renewable energy.

1.6 Document flow

This document will depart with an extract of the National Development Plan and the anticipated growth forecasts made to the South African public up to 2030. A literature review will follow, which explores the academic context of energy security, relationship between energy consumption and economic growth, and the optimal energy mix from a global and South African perspective.

The document will then move on to describe the proposed research methodology and design, taking into consideration the choice of methodology, population, unit of analysis, sampling method and size, measurement instrument, data gathering process, analysis approach, and limitations of the study. Due to the relatively recent formulation of the South African energy scenario, it is worthwhile noting that the study will use both primary and secondary data as part of the study.

The following chapters will elaborate on the results, a discussion of the results, and a concluding chapter that provide feedback on the hypothesis and stipulate whether the research objectives have been met.

CHAPTER TWO: LITERATURE REVIEW

2.1 Energy security

Energy security is a major contributing factor to achieving economic growth, stability, and is of particular interest to policy makers. Although the availability of academic literature on energy security is voluminous, a clear definition still remains unforthcoming. Löschel, Moslener, and Rübbelke (2010) stated that the concept of energy security is vague and blurred. This is endorsed by Winzer (2012), who emphasised the difficulty of measuring energy security and balancing policy objectives due to an unclear definition. Chester (2010) adds that the energy security concept, although ubiquitous with contemporary discussions, is slippery, blurred, elusive, and fundamentally difficult. Winzer et al. (2012) elaborate that the term energy security and its usage in many different policy goals has become an umbrella term.

Case after case, energy security is defined by researchers and academics. In the words of Creti andFabra (2007), ‘‘in the short-term, supply security requires the readiness of existing capacity to meet the actual load; supply adequacy, instead, refers to the ‘‘long-run performance attributes of the system in attracting investment in generation, transmission, distribution, metering, and control capacity so as to minimize the costs of power supplies (p. 260).’’ Jamasb and Pollitt (2008) also add that ‘‘security of supply is often discussed in terms of physical availability of energy sources and their commodity price risk (p. 4584).’’ Bohi and Toman (1993) elaborated to state that energy insecurity, underpinned by changing price or availability of energy, results in the loss of welfare, and Lieb-Doczy, Borner and MacKerron (2003) concludes that ‘‘security of supply is fundamentally about risk. More secure systems are those with lower risks of system interruption (p. 11).”

A definite trend is evident throughout the literate in that energy security has different situational connotations depending on the geography enveloped in the discussion and non-standardised inclusion of other energy issues that range from poverty to climate change and loose usage to drive political agendas (Cherp & Jewell, 2014). Joskow, (2009) argues that although the term energy security has no unique definition, people “stand up and salute” (p. 11), as it generally has something to do with global oil supplies, shortages, inflation, unemployment, slower productivity growth, and so forth. He further expands to state that “there is one thing that has not changed since the early 1970s. If you cannot think of a reasoned rationale for some policy based on standard economic reasoning then argue that the policy is necessary to promote ‘energy security’” (p. 11).

Cherp et al. (2014) identified energy security emerging from supplying oil to armies during the early 20th century. The longitudinal studies have seen the emergence of a classic and contemporary period. Classic period studies focussed predominantly on steady and uninterrupted supply of fuels, whilst contemporary period studies evolved to include various other issues. These other issues, although not exhaustive, include energy sectors, resources, markets, technologies, environmental degradation, climate change mitigation and access to electricity concerns. It is precisely this evolution that has, in part, eluded to the inconsistency in applying components to the energy security discussions, causing a non-comparable language or industry standard, worldwide. Researchers, either implicitly or explicitly, exclude components of the energy security mix due to the overwhelming effort needed to analyse the complexity of a multi-layered energy security concept. This has seen an enormous volume of studies done on fragmented components of energy security as a whole (Bohi & Toman, 1993; Brown et al., 2014; Chester, 2010; Creti & Fabra, 2007; Koyama, 2013; Trollip et al., 2014). Winzer et al. (2012) concluded that ineffective investment decisions result from partial analysis. Whilst conceptualising the notion of energy security, Baldwin (1997) opines that 'security' as principle concept is applicable to multiple areas. Baldwin argues that security is not fundamentally a different concept when considered in the context of economic, environmental, identity, social, and military security, but it is merely different forms. Cherp et al. (2014) reason that this principle is naturally applicable to energy security as well. A generally supported theme throughout the literature is that the term 'security' is inherently concerned with risks (Cherp et al., 2014; Chester et al., 2010; Winzer et al., 2012).

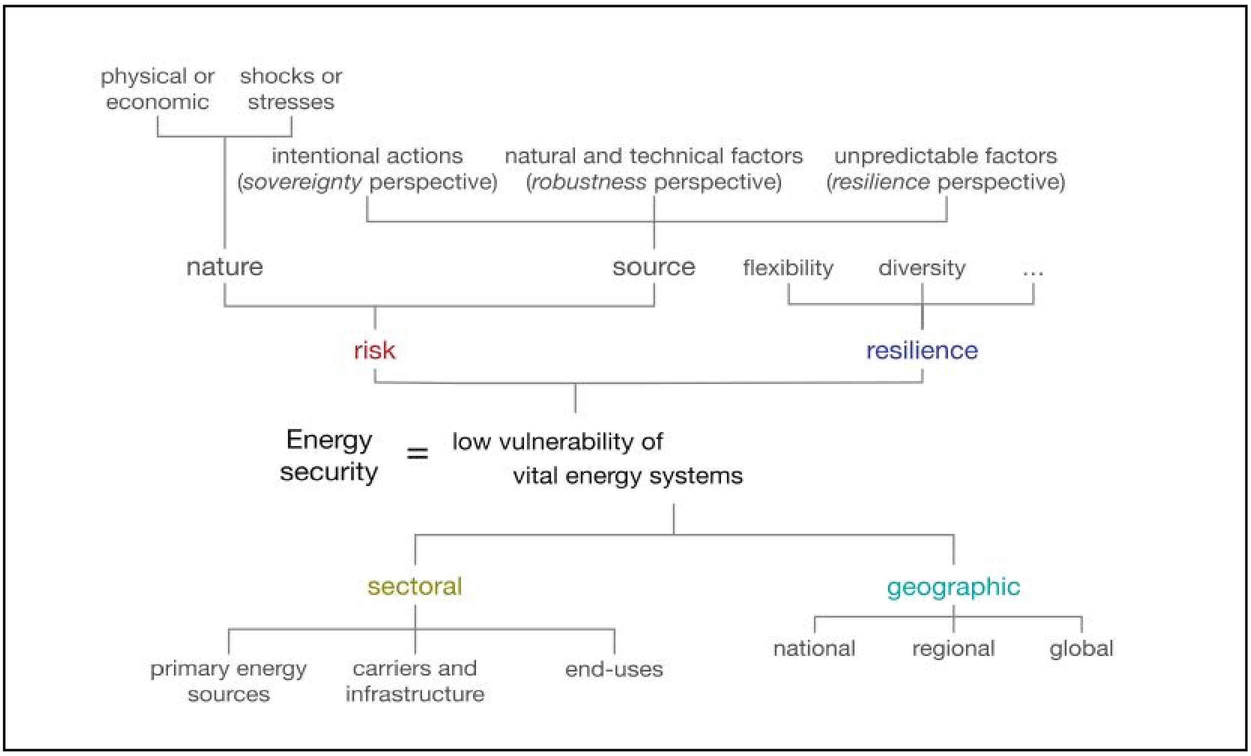
Baldwin et al., (1997) defines security as a "low probability of damage to acquired values" and concludes that this general description can be adopted by specific situations as long as it answers three basis questions of security for whom, security for which values and from what treats (p. 13)

Winzer et al. (2012) suggest narrowing down the concept of energy security to 'energy supply continuity,' thus enabling easier measurement and eliminating any possible double counting from overlapping energy security policy goals, sustainability, and economic efficiency. Cherp et al. (2014) defines energy security as "low vulnerability of vital energy systems". By adopting Baldwin et al., (1997) 'security' methodology Cherp et al. (2014) proposed an alternative approach to evaluating energy security against the backdrop of available literature.

The researcher has found remarkable similarities in the work done by Winzer et al. (2012) and later works by Cherp et al. (2014). Although not graphically depicted, the suggested framework from Winzer et al. (2012) is seen as the foundation work that would allow for the delivery of a suggested alternative approach as done by Cherp at al. (2014) and presented in Figure 2. Both of these works can be seen as complimentary and the researcher would attempt to combine the frameworks to contribute to the fullness of the research. It is seen that this comprehensive framework addresses the three questions posed by Baldwin et al., (1997) of for whom, for which values, and from what treats?

The proposed framework by Cherp et al., (2014), as depicted in Figure 2, breaks the energy security concept into components consisting of two main sections per the definition: "low vulnerability" of "vital energy systems" (p. 419).

Figure 2: Energy security defined as "low vulnerability of vital energy systems."



Source: Cherp et al. (2014, p. 419).

The "low vulnerability" section deals with Risks and Resiliencies and the combination of the two that is applicable to this study. The subcategory of Risk is further differentiated into the nature and the source of the risk or threat. The nature of the risk is typically associated with shocks and stresses (short-term or long-term disruptions) and physical or economic disruptions, where economic disruptions typically accompany price, elasticity, and the actors that are influenced. These actors include households/private customers, industry/businesses, nations and energy companies/investors. Sources of risk deal with three main perspectives of sovereignty, robustness, and resilience.

Sovereignty perspectives, referred to as human risk source by Winzer et al.(2012), include deliberate actions of foreign actors such as strategic withholding of supplies, terrorism, political instability, capacity underinvestment, sabotage, wars, and export embargos. It also considers demand fluctuations.

Robustness perspectives, referred to as technical risk source by Winzer et al. (2012), would natural and technological phenomena like resource scarcity, aging infrastructure, and natural events. Winzer et al. (2012) elaborate to include mechanical or thermal failure of infrastructure components (transmission lines, power plants, and transformers) caused by human error.

Resilience perspectives, referred to as natural risk source by Winzer et al. (2012), include unpredictable social, economic, and technological factors such as spare production capacities, stockpiling, emergency plans, diverse suppliers, and technological diversification. Winzer et al. (2012) elaborate to include irregularity of renewable supplies, fossil fuel stock depletion, and natural disasters.

Cherp et al. (2014) state that "vital energy systems" are linked systems that deal with energy flows supporting critical social functions. These energy systems can be defined by sectorial and geographical boundaries, such as the European gas market and the US electricity grid, and include primary energy sources, carriers/infrastructure, and end-uses.

Winzer et al. (2012) introduced additional severity filters that are applicable to the respective elements as depicted in Figure 2. These severity filters include the speed of the threat, the size of the impact, the sustention of threat impacts, the spread of the threat, singularity of the threat impacts, and the sureness of the threat.

Chester et al. (2010) state that the changing nature of risks or threats to energy supply continuity over time may influence the meaning of energy security. Cherp et al. (2014) state that the differing meanings associated to energy security do not infer the existence of different concepts of energy security and that the same concept can find different meanings under different conditions. Winzer et al. (2012) conclude that the conceptual framing of energy security and selection of the correct measurement metrics are fundamental activities having to take place before attempting any measurement.

2.1.1 Energy security in South Africa

Critique and iterations of the energy security definition is evident throughout government publications. For instance, the Department Of Enviromental Affairs and Tourism South Africa (2005) cited that, prior to the publication of the White Paper on Energy (1998), security policies were heavily focussed on energy supply and self-reliance. With the publication of the White Paper on Energy (1998), focus was redirected to ensure adequate supply to previously ignored portions of the population. The White Paper on Energy (1998) expanded to included 5 main focus areas into the energy security definition that consisted of affordable energy services, greater integrated policy development and service delivery, encouraging fair competition in energy market enabling economic development, environmental impacts, and energy supply security.

The South African Energy Security Master Plan (2007) defines energy security as “ensuring that diverse energy resources in sustainable quantities and at affordable prices, are available to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management and requirements and interactions among economic sectors” (p. 5). It is evident throughout this publication that much focus is directed towards the assurance of uninterrupted energy supply carriers, at affordable prices, and balancing demand requirements that enable the macro economy whilst mitigating environmental impacts (Department of Minerals and Energy of the Republic of South Africa et al., 2007). Trollip, Butler, Burton, Caetano, and Godinho (2014) argue that this places resources at the centre of energy security with the economy as recipient and that a policy heavily focussed on resource and energy supply is out of date. Further to their argument, Trollip et al. (2014) concluded that this short-sighted view be expanded to include World Energy’ Council’s 3 A’s of Accessibility, Availability and Acceptability. Only by inclusion of this expanded view will economic growth, socio-economic development, and environmental challenges be addressed, which appear to be overlooked by the current definition.

The conceptual framing of energy security and selection of the correct measurement metrics are fundamental activities that need to take place before attempting any measurement (Winzer et al., 2012).

2.2 Energy consumption and economic growth

The academic literature is rich with studies done to determine the relationship between economic growth and energy consumption (e.g., BILDIRICI, 2013; Chouaibi & Abdessalem, 2011; Dogan, 2014; Menyah & Wolde-Rufael, 2010; Wolde-Rufael, 2005). According to the available literature, there are four (Growth, Conservation, Neutral, Feedback) hypothetic effects when evaluating the relationship between energy consumption and economic growth.

First, a Growth hypothesis suggests that a one-way causality exists between energy consumption and economic growth, which infers that energy consumption causes economic growth. This translates to an existence of an energy dependency, suggesting that an increase or decrease can either facilitate or restrain economic growth. An energy conservation initiative deployed by governmental bodies during a growth phase can have dire implications on GDP due the dependency of the economy on energy to grow. Second, a Conservation hypothesis suggests that a one-way causality exists between economic growth and energy consumption, suggesting that policies may have little or no impact on economic growth. This translates to economic growth causes energy consumption and policy focus could shift to energy consumption reduction initiatives, as the reduction in energy consumption has no impact on economic growth or causality runs from growth to energy. Third, a Neutral hypothesis suggests that no causality exists between energy consumption and economic growth. Within this phase, it is recommended that policy focus shift to energy consumption reduction initiatives. Fourth, a Feedback hypothesis suggests that a two-way causality exists between economic growth and energy consumption that points towards a complimentary association with energy polices and growth (Apergis & Payne, 2010; Dogan, 2014; Fatai, 2014, Menegaki, 2014).

Furthermore, according to Al-Mulali, Fereidouni, Lee, and Sab (2013), a positive bi-directional long run relationship (Feedback hypothesis) exists between GDP growth and renewable energy consumption for 79% of the 108 countries tested, whilst 19% showed no long run relationship (Neutrality hypothesis), and 2% of countries showed a one way long run relationship (Conservation hypothesis) from GDP growth to renewable energy consumption and renewable energy consumption to GDP growth (Growth hypothesis). This was supported by Al-mulali, Fereidouni, and Lee's (2014) findings for the period 1980 to 2010 involving 18 Latin American countries that a long run positive relationship exists between GDP growth and consumption from renewable energy sources and that renewable electricity consumption, in the promotion of GDP growth, is more significant than consumption from non-renewable sources. Marques and Fuinhas, (2012), however, argue that the opportunity cost of supporting renewable energy has still been too high due to the negative effect of creating income from exploiting natural resources outweighing the positive effect renewable energy usage in local markets and concludes that renewable energy is still not a positive driver for GDP growth.

Energy is utilised both from a demand side (consumer utility) and supply side (also embodied energy or total energy required to produce products/services; Stern, 2011) as a key factor in the production mix (Fatai et al., 2014). The inclusion of energy is necessary for economic production, but except for specialised resource economics, is not included in the mainstream theory of economic growth and excluded from standard models used to project economic growth (Fatai et al., 2014; Stern, 2011). This results in inaccurate economic growth forecasts and infers that energy consumption can essentially not be decoupled from economic growth and forms a vital part of the production mix alongside capital, labour and material. Hall and Klitgaard, (2012), with a focus on fossil fuel reliance, accentuated the role energy has on economic growth. Stern (2011) expressed that the availability of energy, when scarce, imposes economic growth constraints, but has little effect if abundantly available. Menegaki et al. (2014) emphasised that inefficient usage of energy would lead to global warming, which, in turn, adversely affects GDP.

Adom (2011) stated that electricity consumption is not just a multitalented energy currency supporting a wide range of product and services that contribute to improved quality of life, increased work productivity, and entrepreneurial activity, but is also highly correlated to GDP growth. Ouedraogo et al. (2013) further expanded that human, social, and economic development is primarily determined by the availability of affordable and reliable energy services in the promotion of productivity, health, education, water, and communication services. Menegaki et al. (2014) stressed the importance of understanding the relationship between energy consumption and economic growth that, in turn, enables the design and effectiveness of energy and environmental policies that promote economic development.

2.2.1 Energy consumption and economic growth in South Africa

Studies done on the relationship between energy consumption and economic growth for the period 1971-2001 support a neutral hypothesis for South Africa for the period (Wolde-Rufael, 2005). This contrasts a one way causality or unidirectional effect running from energy consumption to economic growth for the period of 1972-2006 (Odhiambo, 2009) and a substantial positive long run relationship between energy consumption and economic growth (Esso, 2010). Although no unilateral consensus amongst economists, researchers, analysts and policy makers on the causal relationship between GDP and energy consumption exists, it is generally agreed that energy consumption is related to economic development (Freed, 2005).

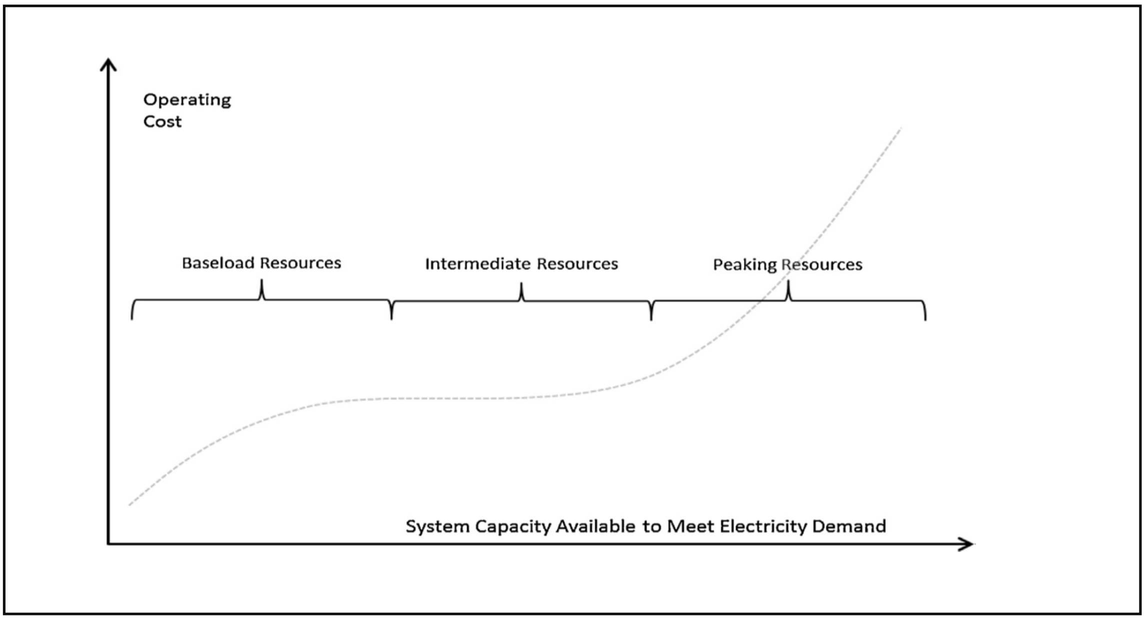
According to the Department of Energy et al. (2010), the historical 3.3% annual GDP growth rate achieved for the period 1994 to 2009 needs to be improved with a targeted GDP growth rate of 5.4%, as set out by the National Planning Commission et al. (2011) in the National Development Plan. This entails that the South African economy would double in size approximately every 12 years, which would require significant increases in the electricity required from the electricity supply industry to support such growth. It must be noted that electricity consumption accounts for 28% of final energy consumption in South Africa, and the Department of Energy stated that this historical GDP growth and electricity consumption relationship is 3:2, and, subsequently, has been utilised as direct input into the IRP2010 policy formulation (National Planning Commission et al., 2011; Trollip et al., 2014). This relationship translates to 3% GDP growth requiring 2% electricity growth. A further increase to 2:1 in this relationship is anticipated, as primary (mining and chemicals), secondary (retail), and tertiary (financial services) activities increase in line with the intent of the Government's industrial policy. As the economy shifts away from an energy-intensive phase of development, growth in GDP should de-link from growth in energy consumption (World Energy Outlook, 2014).

Ouedraogo (2013) stipulated that determining the causal direction of energy consumption and economic growth is of prime importance when determining the appropriate energy policies, but caution is expressed on the severity of policy decisions made based on inferences drawn from the consumption-growth model, their relationships or limitations, and the possible impact on economic growth (Apergis & Payne, 2010).

2.3 Energy mix

Historical infrastructure models on electricity supply networks consist of baseload, intermediate, and peaking power plants (Matek & Gawell, 2015). The US Department of Energy (2011) describes baseload power generating plants as coal and nuclear generating units, which are operational and despatched at constants levels, producing lowest-cost of energy when run at high capacity with minimal cycling. Intermediate generating plants, also load following power plants, are mostly utilised during high energy demand daytime periods, with flexibility in cycling and quick switch on/off ability to meet energy demand patterns. Gas, Oil, and Hydro plants are normally associated with intermediate generating plants. Peaking generating plants, normally gas/combustion turbines, are used to meet abnormal high levels of energy demand. Although peaking plants have low capital cost to construct, high fuel costs result in high operating costs. Peaking power stations provide energy during high system demand fluctuations normally associated with peak morning or evening rises and extreme temperatures.

Figure 3: Electricity market despatch curve.



Source: Matek et al. (2015, p. 103).

Matek and Gawell (2015) define baseload power as “the minimum amount of power that a utility or distribution company must generate for its customers, or the amount of power required to meet minimum demands based on reasonable expectations of customers’ requirements” (p. 103). As depicted in Figure 3, the fluctuating nature of demand patterns requires the immediate availability of the infrastructure an energy system has at its disposal in order to match customer demands, whilst balancing cost implications of running various energy producing unit to not negatively affect end usage pricing.

A key factor fuelling much support for policies to change focus towards energy from alternative/renewable sources are environmental concerns (Greenblatt et al., 2007). Global warming and CO2 emissions have been instrumental in driving focus to new technologies and energy solutions that has resulted in the choice of energy mixes becoming more complex. “As the global economy continues to grow and developing countries become more industrialised, policymakers and consumers around the world are increasingly confronting shortages in energy supply, rising prices and environmental degradation caused by excessive exploitation and use of fossil fuels" (Ren & Sovacool, 2014, p. 834). Turconi, Boldrin, and Astrup (2013) point out that 68% of worldwide energy originates from usage of fossil fuels that include coal, natural gas, and oil and that electricity generation is a key contributor to emissions of greenhouse gases responsible for approximately 40% of global CO2 emissions. Castelo Branco, Moura, Szklo, and Schaeffer (2013) stated that as much as 40% of the world's electricity demand is catered for by coal fired power stations. Amponsah, Troldborg, Kington, Aalders, and Hough (2014) elaborated to include heat, was well as electricity generation, as the key contributors to global CO2 emissions. Amponsah et al. (2014) further argued that for sustainable development, proper tools and methods are needed to determine the impact of human activities on the environment. Brown, Wang, Sovacool, and D'Agostino (2014) concluded that "our study finds that many industrialised countries have made limited progress towards the goal of achieving secure, reliable and affordable supplies of energy while also transitioning to a low-carbon energy system" (p. 64). Thoughtful planning about how to retire coal plants can help maximise economic returns, human health, and environmental benefits of a cleaner energy future, while maintaining reliable and affordable power (Fleischman et al., 2013).

Due to an estimated 37% increase in global electricity demand by 2040, the International Energy Agency (2013) estimates that new build capacity have to increase by 72GW, whilst taking into account that 40% of the global fleet is reaching end of life status. Much of this fleet consists of older coal fired generation plants that are becoming less and less economic. Many dirtier or underutilised coal plants cannot economically compete with natural gas or wind generation any longer (Fleischman et al., 2013). Rising coal prices also contributing favourably by narrowing the gap between conventional coal-fired power stations and alternative sources of energy (Africa Energy Outlook, 2014). The International Energy Association (2011) stated that, if measured according to their 450 parts per million scenario, 80% of the permissible energy related CO2 emissions are already locked-in by the existing energy infrastructure fleet.

The nuclear debate still remains controversial post the Fukushima and Chernobyl catastrophes, and, as the almost 200 of the 434 operational reactors approach end of life by 2040 (International Energy Agency, 2013), policymakers are faced with difficult decisions around the cost-to-benefit relationship of including nuclear energy into the generation mix. One main argument revolves around the inability to calculate the actual cost of dismantling and decontaminating reactors and associated site rehabilitation due to limited experience. This limited experience results in great uncertainties around what these costs could potentially be. The Massachussetts Institute of Technology (2003) stated that allocation of tax credits, legislative incentives, and inappropriate value recognition of fuel and capacity diversity make it difficult for nuclear power to compete in the energy market. An additional factor to consider is the view of the public and the associated safety concern around operating reactors, radioactive waste, and nuclear plants (International Energy Agency et al., 2013). Hong, Bradshaw, and Brook (2014) stated that nuclear power can reduce CO2 emissions and maintain a strong economy, whilst Joskow and Parsons (2012) argued that the future nuclear energy expansion trends, post the Fukushima catastrophe, would decline, albeit modestly, from a global perspective.

Increased public concerns around the environmental impacts of fracking is another topic of much discussion. “Hydraulic fracking“ is a process used by developers that sees large amounts of water, proppant (manmade sand based material, that includes ceramics, to keep a hydraulic fracture open), and other chemicals injected into the earth to fracture energy-bearing rock formations that allow for gas extraction (Evensen, Jacquet, Clarke, & Stedman, 2014). Sovacool (2014), in his seminal study on the advantages and disadvantages of hydraulic fracking, concluded that if it is done properly, it can promote energy security, secure availability of fuels, lower the price of natural gasses, provide a cleaner carbon solution, and, ultimately, promote economic development. On the opposing side, Sovacool et al. (2014) further stipulated that hydraulic fracking can have dire implications for the environment due to leakages and accidents that cause degradation, water contamination, induce earthquakes, have human health implications, and, ultimately, produce more economic losses that gains. Ashby and Meng (2014) elaborated to include that the distance from the fracking wells play an important factor in determining the risks associated with fracking wells on the environment and society. In conclusion, Ashby et al. (2014) stated that the risk for ground and drinking water contamination increase the closer it is situated to wells, and societies close to wells are at the highest risk of health problems associated with emissions. The highest/densest gas emissions are recorded closest to wells, seismic activities or earthquakes are recorded closest to wells, and, finally, fracking directly changes that local environments and the landscape characteristics in which it operates. Sovacool et al. (2014) concluded that policymakers, planners, and investors are left with difficult choices in having to decide on the correct trade-offs when pursuing shale gas exploration and generation.

Gabaldon, Spiegel, and Van Den Berg (2006) stated that the industry faces an overwhelming degree of uncertainty on the right choice for the next generation baseload. Matek and Gawell (2015) argued that variable energy resources are able to meet all power needs and that “baseload energy is dead” (p. 101). Elliston, Diesendorf, and MacGill (2012) concluded that the concept of an energy supply-demand system needs to change radically and that focus from replacing baseload coal with alternative baseload sources be diverted to large penetration of diverse renewable source technologies and geography with high peaking generation abilities and storage capabilities.

Several publications have documented the supply of baseload energy form renewable sources and have occupied scholarly interest over the last few decades. At the forefront of these literature debates are the optimal energy generation mix that would enable transitioning to a greener global energy future. A series of case studies have argued that regions, countries, and even the entire world can have 100% of energy requirements supplied from renewable sources. These three geographical scenarios are viewed from a national, regional, and global perspective.

From a national perspective, scenarios have seen Ireland include all three primary sectors (electricity, heat, and transportation) and various forms of renewable energy sources (wind, wave, solar, tidal, and biomass) to determine the possibility of a 100% renewable energy generation mix. Connolly, Lund, Mathiesen, and Leahy (2011) concluded that not only is this achievable, but there are various ways of realising it. New Zealand, with their high availability of hydro generation, concluded that a 100% renewable generation mix is achievable, comprising of 53-60% hydro, 22-25% wind, 12-14% geothermal, 0-12% peaking, 0.8-0.9% wood thermal, and 0.2-0.3% biogas (Mason, Page, & Williamson, 2010). Portugal concluded that a 100% renewable generation mix favours hydro and wind, with the possibility of hydrogen and battery storage once these technologies have been developed further (Krajačić, Duić, & Carvalho, 2011). Denmark have concluded that a 100% renewable generation mix consists of biomass and combinations of wind, wave, and solar (Lund & Mathiesen, 2009).

Furthermore, from a regional perspective, Australia demonstrates that a range of systems are available in a 100% renewable generation mix scenario, consisting of major contributions from concentrating solar thermal with storage and photovoltaic, existing of hydro and biofuel gas turbines for peaking (Elliston et al., 2012). A Northern Europe study investigated a 100% renewable generation mix scenario for countries based on geographic endowment of energy resources and hydrogen as storage. Sørensen (2008) concluded that considerable energy trading between countries can be established, introduction of reservoir-based hydro solutions and storage dependency based on fuel cell efficient technologies; Spain concluded that, although not a 100% renewable energy solution, large wind generation penetration and optimal spatial balancing, prime regional allocation, and interconnected wind farms can significantly contribute to baseload requirements (Santos-Alamillos, Pozo-Vázquez, Ruiz-Arias, Lara-Fanego, & Tovar-Pescador, 2014).

Ultimately, from a global perspective, Jacobson and Delucchi (2011) claim that global energy can be met through renewable source for all three primary sources (electricity, heat, and transportation) through an energy mix consisting of wind, solar CSP, solar PV, geothermal, hydro, waves, and tidal generation, and provides a detailed breakdown of each technology and output required. A global scenario is supported by the WWF International (2014), which stated that a 100% renewable option is reachable by 2050 by gradually phasing out fossil fuelled energy generation and replacing it of wind, solar, biomass, and hydropower as the main sources of electricity, with solar, geothermal, and heat pumps providing a significant contribution towards heat for buildings and industries.

Still, the high renewable energy penetration scenario remains controversial. Føyn, Karlsson, Balyk, and Grohnheit (2011) suggested that a 100% global renewable energy system is not cost effectively achievable in the scenarios that were studied. Although the results came close, Føyn et al. (2011) concluded that the transition to a 100% renewable energy generation scenario would be expensive. Another opposing publication from Trainer (2010) stated that all global scenarios assume available solutions for all technical issues that include the variability of renewable energy sources (i.e., intermittency and redundancy of renewable sources in winter), but does not account for high capital costs and limits on available biofuels. Elliston et al. (2012) drew attention to the limit of energy storage availability and that an energy system needs to have the ability to match supply with demand instantaneously. Sharman, Leyland, and Livermore (2011) stated that without technological breakthroughs in renewable energy or complimentary storage technologies, it is not technically feasible to have a 100% renewable generation mix. WWF International et al. (2014) supported the notation that radical investment is required in researching, developing, and commercialising technologies to support the shift to a 100% renewable energy supply and technologies that should be prioritised are carbon capture and storage. Some of the main critiques to the implementation of renewables into the generation mix is the variability and unpredictability of supply, with Holttinen et l. (2009) stating that by adding large wind penetration to the mix brings about variability and only part predictability to a power system that needs to balance demand with generation reliably. Diesendorf (2010) argued that electricity systems are already designed to cater for demand/supply side variability and wind/solar only add additional variability, ultimately stating that some renewable sources (solar thermal with storage, geothermal and bioenergy) have baseload characteristics that could potentially be integrated efficiently without any back-up.

Reichelstein and Sahoo (2013) highlighted that new renewable source installations, specifically wind and solar, have presented impressive growth over the past decade and that renewable energy consumption has increased by 55% during the 1980 to 2009 period (Al-Mulali et al., 2013). In 2009, China achieved total energy from renewable source of 226GW, with the added capacity of 37GW during that period. This is equivalent to four times Great Britain's required need for peak consumption and two times the total capacity of Africa. Renewable energy growth has increased nearly 30% between 1992 and 2001 (Greenblatt et al., 2007), with a 10% growth between 2011 and 2012. The 2011/12 growth, alone, has seen 56 billion Euro's invested that realised 45GW (US – 13.1GW & Europe – 11.9GW) of wind power capacity being installed, totalling 282.5GW (Reddy, Bijwe, & Abhyankar, 2015). Factors driving this growth are extreme capital cost reductions since 1992 to 2001 (Jungigner and Faaij, 2003, as cited in Greenblatt et al., 2007) and government initiatives encouraging wind energy investments (Greenblatt et al., 2007). Solar investment realised a total installed capacity of 22.9GW in 2009, which saw an increase of 46.9% from 2008 (Solangi, Islam, Saidur, Rahim, & Fayaz, 2011).

Levelised cost forms a critical factor when evaluating the different types of technologies for generation and their associated costs provide immediate comparability to other alternative that are available (Palacios et al., 2004). It is a widely used industry standard by which policymakers include levelised cost as a key input when deciding on future energy generation investment, and this affordability indicator has a direct impact on the price an end user ultimately pays (Kaggwa, Mutanga, & Simelane, 2011). The levelised cost ratio is determined by dividing the total generation output produced with the total generation production cost (Mulligan, Bilen, Zhou, Belcher, & Dastoor, 2015). Although levelised cost forms the basis of many policy decisions, Larsson, Fantazzini, Davidsson, Kullander, and Höök (2014) expressed caution utilising it for this purpose, as the inputs used for cost calculation are normally site or country specific and many calculations account differently for discount rates, fuel costs, and cost escalations. Larsson et al. (2014) concluded that policy makers should be aware of these differences in calculations and should only be used for rough ballpark estimates. Policymakers are standing at a pivotal point when having to decide on the right energy mix that meet accelerated energy demands reliably and at affordable prices and eradicate environmental challenges whilst positioning itself in a dynamic changing global energy market (Curran, 2012).

2.3.1 Energy mix in South Africa

The Integrated Resource Plan and Integrated Energy Plan are seen to be the primary tools for driving energy planning in South Africa (WWF International, 2014a) and utilises a lowest cost basis when deciding on energy supplies. A report commissioned by the National Planning Commission and issued by the Energy Research Centre tested the validity of assumptions made in the original IRP2010 against updated energy information. The categories reviewed included technology information, fuel availability, and demand growth expectations, with updated assumptions reflecting lower electricity demand, levelised costs (renewable and nuclear technologies), gas availability (natural gas, shale, imports), and CO2 trajectory implied by the South African Copenhagen pledges that stipulate mitigation actions for the reduction of CO2 emissions. The Energy Research Centre (2013) concluded that “the IRP2010 is out of date and no longer valid” (p. 2) and would result in a sub-optimal energy generation mix with increased energy prices should the current version of the IRP2010 be used to make future investment decisions. The Energy Research Centre, (2013) concluded that decreased electricity demand growth and the current committed investment plans (i.e., Medupi, Kusile, Ingula and IPPP program), is sufficient to cater for demand requirements up to 2025, with very little further investment needed. No nuclear generation is required up to 2040 and new build generation is dominated by gas, wind, and imported electricity.

The National Planning Commission responded with an unofficial draft iteration of the IRP2010 that saw significant changes in methodologies used to make investment decisions. The proposed methodologies are geared towards a more flexible approach discarding a less rigid fixed capacity plan methodology. The revised plan would also take into consideration changing market conditions, including the poor performance of some state-owned enterprises, status of infrastructure maintenance programmes, increased cost of electricity contributing to lower demand, the energy consumption and economic growth relationship, impact of carbon tax rollout, changing technologies, availability of fuel and uncertainty/variability in costs, environmental impacts and civil society sensitivities (National Planning Commission, 2010). The new version allowed for 15% to 20% of the energy budget be allocated to renewable sources including wind, solar PV and CSP, but excludes biogas (WWF International et al., 2014a) and emphasises the statement by Matek et al. (2015) that “energy diversity helps maintain a sustainable supply of fuels for electricity generation that protects consumers from potential price spikes or shortages" (p. 101). Furthermore, it is envisaged that renewable energy technologies (wind and solar) would supply 42% of all new build capacity over the 2010 to 2030 period or 9% of total electrical energy (DoE, 2013). The second version of the IRP2010 was never adopted.

According to Montmasson-Clair, Moilwa, and Ryan (2014), South Africa is in a distinctive position to transition to a greener energy solutions due to the abundance of renewable resources (mainly wind and solar). Africa is well endowed with renewable resources and hydro power, from the Inga River alone of 40 GW, with supporting capacities from the Nile and Zambezi, which is sufficient to cater for the energy demands of the entire continent (Kaggwa et al., 2011). According to Kaggwa et al. (2011), there is sufficient wind in South Africa to keep the rotors turning and the Northern Cape is one of the best solar resources in the world, which falls within a total area of high radiation in South Africa of approx. 194, 000 square/km's producing a potential of 64GW of generation capacity. Wind and solar energy still remains an expensive option due to the need for additional energy supplements required to stabilise their intermittency, which influences the balancing of the national grid.

The introduction of the IPPP (Independent Power Producers Program) has seen South Africa's commitment towards a sustainable greener economy, especially in the field of renewable energy (Kaggwa et al., 2011). South Africa has surprised the international renewable energy community with the success, pace, and size of implementation of the program that has seen 4GW being procured in the first three windows (WWF International, 2014b), and is also seen as a direct response to three critical issues faced by South Africa. These issues are to address the shortfall in critical generation capacity to increase energy supply, international pressures to limit carbon emissions, and political will to deliver a cost effective energy solution that promotes socioeconomic development. Furthermore, the introduction of the IPPP bridged the gap in financial and technical capacity constraints experience by Eskom, the state owned vertically integrated utility, that could not meet South Africa's energy demands and deliver sufficient energy security (Montmasson-Clair et al., 2014). The Department of Minerals and Energy of the Republic of South Africa (2003), in The White Paper on Renewable Energy publication, stipulated 10GW of renewable energy by 2013, which is indicated to increase to 20GW beyond 2020.

During 2014, 1.6GW of renewable energy projects, mainly wind and solar PV, commissioned and feeds into the national grid (CSIR Energy Centre, 2015). Additional renewable energy generation of 1.6GW delivers a net impact on GDP of R1.1b annually, creating additional government revenue of R299m, generates additional income to low income households of R128m by creating 20,000 jobs, and contributes up to R26.6m in water savings (South African Department of Communications and Information Systems, 2013). The success of the IPP program has seen capacity increase from the originally anticipated R3.6GW over 5 bidding windows to 6.7GW between the 2017 to 2020 period (Montmasson-Clair et al., 2014).

According to the South African Department of Communications and Information Systems et al. (2013), nuclear is seen as an integral source of energy for the South African economy and will play a vital role in the IRP2010 implementation process. According to SAnews (2015), the Department of Energy has stated their readiness to begin the process of procuring an international vendor for South Africa's Nuclear Build Program, which was seen to be completed by the end of 2015. South Africa's Energy Minister was quoted stating to parliament that South Africa would have six nuclear reactors in operation by 2030 and would spend between R400b and R1tril in acquiring 9.6GW of generating capacity (Bayley, 2015). The Energy Research Centre et al. (2013) argued that no nuclear power is needed until 2040.

Shale gas, also referred to as fracking, has caused much controversy as it was established that South Africa likely has the eight largest shale gas reserves in the world (Hedden, Moyer, & Rettig, 2013). With South Africa being the only country in the world to reverse a moratorium on hydraulic fracking, it is deemed a step forward to exploring a potential of approx. 130,000GW/hrs of generation capacity per year (14.9GW Total). South African mineral reserve minister, Susan Shabangu, has expressed in a Financial Times blog that the South African government cannot be apprehensive that fracking is controversial. "We are confident, and we have taken the decision as government, that we are going to go the fracking route" (Whitehead, 2013). The NDP expressed the need for a gas target and that gas will supplement a growing share of power generation. The main concern around fracking is the process it utilises when extracting gas out of the allocated pockets underground. Water is utilised to fill these pockets, thus forcing the gas to immerse. With a dry Karoo region, environmentalists are concerned that this process will cause severe water pollution and further the depletion of an already limited resource (Whitehead et al., 2013). The NDP further states that this growing gas contribution, subject to acceptable environmental controls, be supplemented by fracking and imported liquefied gas imports (National Planning Commissionet al., 2011).

With the South African nuclear plant and coal fleet reaching end of life status (approximately 11GW), South Africa faces much of the same decision dilemmas as many other countries on deciding on the correct generation capacity mix. The literature on exploring a 100% renewable energy solution still remains controversial and policymakers are standing at a pivotal point when having to decide on the right energy mix that meet accelerated energy demands reliably and at affordable prices and in a manner that eradicates environmental challenges whilst positioning itself in a dynamic changing global energy market (Curran, 2012). Al-Mulali et al. (2013) concluded that investment in renewable energy does not only promote energy security through decreased reliance on fossil fuels, but promotes GDP growth. It is environmentally friendly and renewable energy projects, in the 108 countries investigated, created 3.5 million jobs in the industry. WWF International (2014a) stated that the most matured forms of renewable energy are wind, solar PV, and biomass, which are suitable for fixed generation and lower capital cost, access to funding, and a clear policy/regulatory environment will be the driving factors in renewable energy procurement going forward.

CHAPTER THREE: RESEARCH QUESTIONS AND PROPOSITIONS

This section outlines the research questions that need to be answered in order to better understand the relationship between the use of a unified framework to enable successful generation infrastructure planning within Governmental departments and other participating stakeholders, whilst exploring the possibility of a 100% renewable energy generation profile for South Africa

3.1 Research question and proposition 1

Winzer et al. (2012) argue that the conceptual framing of energy security and the selection of the correct measurement metrics are fundamental activities having to take place before attempting any measurement.

Research question 1

In conceptualising energy security, are South African energy policies out of date?
From the above question, the hypothesis have been developed.

Proposition 1

The South African energy policies are current and reflective of stakeholders' assessments on energy security.

3.2 Research question and proposition 2

Research question 2

What is the economic growth and energy consumption relationship that best reflect the South African economy?

From the above question, the hypothesis have been developed.

Proposition 2

The South African economic growth and energy consumption historic relationship of 3:2 is out of date.

What is the economic growth and energy consumption relationship that best reflects the South African economy?

From the above question, the hypothesis has been developed.

Proposition 2

The South African economic growth and energy consumption historic relationship of 3:2 is out of date.

3.3 Research questions and proposition 3

Policymakers are standing at a pivotal point when having to decide on the right energy mix that meets accelerated energy demands reliably and at affordable prices, as well as eradicates environmental challenges whilst positioning itself in a dynamic changing global energy market (Curran, 2012).

Research question 3

How has levelised technology costs changed in South Africa?

Research question 4

Can South Africa achieve a 100% energy generation profile?

From the above questions, the hypothesis has been developed.

Proposition 3

South Africa can achieve a 100% generation profile from renewable energy.

CHAPTER FOUR: RESEARCH METHODOLOGY

This chapter provides the description of the methodology choice, design, population, unit of analysis, sampling method and size, data gathering process and analysis, research instrument, and concludes with an elaboration on the limitations of the study.

Research is the systematic and logical manner in which new and useful information is searched for in relation to a specific topic (Rajasekar, Philominathan, & Chinnathambi, 2006). Yin (2013) stated that empirical research has an implicit research design and this design follows a logical sequence to connect the empirical data to the research questions identified that ultimately lead to the realisation of the conclusion. The underlying strategy of this study is to position itself in a logical manner to produce a rigorous case towards answering the research questions, meeting the research objectives, and addressing the research problems identified. This research project is classified as qualitative empirical research that is exploratory in nature and the principle strategy followed to designing the methodology was based on the classic case study.

The objectives of this study were to: 1) determine whether the South African energy policies are current and reflective of stakeholders' assessments on energy security, 2) determine whether the South African economic growth and energy consumption historic relationship of 3:2 is out of, and 3) determine whether South Africa can achieve a 100% generation profile from renewable energy. Due to the relatively recent formulation of the South African energy scenario, it is worthwhile noting that the study will use both primary and secondary data.

4.1 Methodology choice

The three categories of studies are exploratory, descriptive, and explanatory. Exploratory research aims to seek "new insights, ask questions and to assess topics in a new light" (Saunders & Lewis, 2012, p. 110), descriptive research is concerned with "an accurate representation of persons, events or situations" (p. 111), and explanatory research aims at "studying a situation or problem in order to explain the relationship between variable" (p. 113).

According to Rajasekar et al. (2006), quantitative research is an iterative process whereby numerical evidence is evaluated, is non-descriptive, applies statistics, is conclusive, and investigates the what, where, and when of decisions. Qualitative research, on the other hand, is concerned with meaning, feeling, a description of the situation, applies reasoning, is exploratory, and investigates the why and how of decision-making.

Several possibilities (e.g., experiments, surveys, histories, and archival analysis) exist for doing research. According to Yin et al. (2013), each strategy is associated with advantages and disadvantages, depending on three conditions. These conditions are: 1) the type of research questions, 2) the control of the researcher on the actual behavioural events, and 3) that the focus of the study is contemporary. Yin et al. (2013) elaborated that a case study is a preferred strategy for addressing “why” and “how” questions where the researcher has very little control of events and the research is focussed on contemporary occurrences in real life context. The rationale for choosing a cases study is the ability to study, in depth, the research topic in a real life context, and, according to Yin (1993), the case study method has reached routine status as a viable method for doing research.

4.2 Population

The population is “the complete set of group members” (Saunders et al., 2012, p. 132). The population in this consisted of all stakeholders utilising electricity from an economic context or from a social context, where stakeholders are exposed to the current electricity crisis. This population consisted of, but was not limited to, the South African government, Regulatory Bodies, Public Energy Enterprises (Eskom), Private Energy Producers (IPP’s), Environmental Agencies, Energy consultants, and the Public.

4.3 Unit of analysis

From a qualitative perspective, the unit of analysis were Government officials, Regulatory, Body officials, Public Enterprise officials, Private Entity officials, and members of the Public. These units were analysed to enable successful answering of the research questions.

4.4 Sampling method and size

There are two types of sampling techniques that can be utilised depending on the ability of obtaining a complete list of the population (Saunders et al., 2012). Probability sampling is used when the complete list of the population is available and non-probability sampling is used when the complete list of the population is not available.

Non-probability sampling was used from a qualitative base by utilising purposive and snowballing techniques. Due to the entire list of population not being available, the researcher used his judgement when the sample of members to be interviewed was selected, and this foundation will allowed for snowballing to take effect in obtaining more interviews. Snowballing was seen as the backup method to be used where the purposeful method did not obtain the interviews as planned.

4.5 Research instruments

According to Hancock and Algozzine (2006), doing case study research is deeply descriptive, as it is grounded in varied sources of information. These sources of information originate from key participants and are composed from interviews and other literature techniques utilised that brings to life the phenomenon being studied. Baxter and Jack (2008) stated that a hallmark of case study research is the ability to utilise multiple sources of information that ultimately enhance the data credibility, and these multiple sources of information may include documentation, archival records, interviews, physical artefacts, direct observations, and participant observations that allow for the convergence of data during the analysis process. This is seen to promote the strength of the research in that each source of data is seen as a piece of the puzzle that is ultimately weaved together to allow for greater understanding of the phenomenon of interest.

A single case with embedded sub units was seen to best suit this research instrument. According to Baxter et al. (2008), a holistic case with embedded sub units will allow the researcher to study the case whilst considering many influences under various other aspects. This is seen as a very powerful approach, as it allows for the review of data within the various sub-units and the ability to engage in such rich research only serves to illuminate the case (Baxter et al., 2008). There are, however, warnings of potential pitfalls in doing embedded design studies for novice researchers, as this could potentially lead to too much time being spent on the sub-unit level and failing to return to the larger unit of analysis (Yin et al., 2013).

A single case study design was seen to best suit the research at hand, as the researcher aims to study, in depth, the

- Characteristics of energy security with the accompanied influencing sub-elements to enrich the understanding of the concept of energy security from a South African context,
- Economic growth and energy consumption relationship that influences South African energy security, and

- Possibility of achieving a 100% renewable energy mix for South Africa.

The researcher selected an embedded case study design due to the width and breadth of all the stakeholders involved and influenced due to energy insecurity in South Africa. The sources of evidence were predominantly sourced from government legislation, policies, academic literature, media statements, archival records, reports, and semi-structured interviews.

4.6 Data gathering process and analysis

Yin et al. (2013) stated that three principles are crucial for doing high quality case study research. These principles are the usage of multiple sources of evidence, creating a cases study database, and maintaining a chain of evidence. Addressing these three principles would contribute to construct validity and quality of the case study.

The data gathering process was designed utilising the following techniques:

- Identify the key personnel within the various sun-units of analysis to conduct semi structured interviews.
- Develop a set questions to be used within the interviews.
- Develop a schedule for data gathering and completion.
- Develop a contingency plan for unobtained interviews or unavailability of information.
- Develop a database to manage and maintain a chain of evidence.

Yin et al. (1993) identified 6 types of sources (i.e., documents, archival records, interviews, direct observations, participant observation and physical artefacts) of evidence that can be utilised during data gathering, but the researcher only utilised documents, archival records, and semi-structured interviews. There are, however, drawbacks from this approach due to the overwhelming need of the study to introduce as many sources as possible during the study, which can cause the researcher to get lost in the data. This can easily be bridged with the introduction of a data base to organise and manage the large amount of data.

Documents were utilised to support or contest evidence within the various sub-units. Archival records were used to enhance the understanding of historical energy policies and their supporting frameworks. Semi-structured interviews incorporated a list of predefined questions that incorporated different techniques (i.e., probing, specifying, direct, and indirect), the interviews were recorded, transcribed, and interview transcripts were coded utilising manual and computer aided qualitative data software. A systematic thematic analysis approach was used to analyse the responses from the interviews that were conducted. A thorough list of categories was developed to comprehensively cover the responses from the participants and upon completion were reviewed to ensure that all responses are thoroughly classified. Due to the large and complex nature of the energy system, it was envisaged that responses would be relevant to more than one category. Categories were assessed and grouping of the similar categories were conducted to allow the observation of emergent themes throughout all interviews. The emerging themes were subsequently reviewed and re-assessed to ensure that the allocation of responses into emerging themes were conceptually relevant.

According to Yin et al. (1993) the usage of data triangulation contributes that the conclusions reached during a study are more convincing and accurate. Data triangulation encourages the researcher to collect information from multiple source, but aims at corroborating the phenomenon being studied. This allows for the researcher to address a broader range of historical, attitudinal, and behavioural issues. This is seen to address construct validity and quality concerns that may be inherent to research. Hancock and Algozzine (2006) stated that to establish information analysis credibility the adherence to the following principles are crucial: 1) implementing interrater reliability checks, 2) uncovering biases that could potentially be skew research findings, and 3) comparing obtained results to previously published research findings.

According to Yin et al. (1993), maintaining a separate database of all sources utilised is of utmost importance, and this will also enable additional research in the field for other researchers whilst contributing to the credibility of the research. A separate case study database was utilised to allow for independent inspection of the proposed research findings and includes all records used, interview transcripts, and other sources of evidence. Maintaining a good chain of evidence is crucial to substantiate any conclusions derived from the case. Strong focus was given to comprehensive citations throughout the case and cross-referencing in the report to interviews, documents, databases, and other sources of evidence to enable successful linking of research questions to objectives, results, and conclusions.

4.7 Limitations

Research validity refers to “the extent to which (a) data collection method or methods accurately measure what they intended to measure and (b) the research findings are really about what they profess to be about”(Saunders & Lewis, 2012, p. 127). Care has been taken to avoid any factors that threaten the internal validity of this study. It should be noted that the limitations of study can expose the study to criticism, but can provide opportunities for further detailed research in future:

- The snowballing sample used in this study resulted in bias towards stakeholders that were largely IPP developers or consultants from the IPP environment that share very similar ideologies. The researcher attempted to address this bias by introducing independent stakeholders outside of the IPP clusters.
- The coding of the research interviews could have been subjected to researcher bias as the process have primarily been done by the researcher and could have subjected the coding towards personal bias. The researcher attempted to address this bias with the utilisation of the case study method that incorporates secondary resources to corroborate or contradict identified themes and views.
- Levelised cost obtained in the public domain could potentially be biased to the region or country that it pertains to and could differ from the actual levelised costs within a South African context.
- This study does not take into account demand side management strategies or energy efficiency incentives.
- All secondary data from reports, publications, and online data systems were obtained from the public domain and the results are dependent on the accuracy of the data produced from these sources.
- Data may not always be value neutral as the original purpose for such data and data gathering techniques may not be well known.
- It is worth noting that the predominant theme of this study focusses on electricity and does not include the full spectrum of all energy components, including oil and heat, although these are mentioned in certain sections of the study.

CHAPTER FIVE: RESULTS

5.1 Data gathering process

The data gathering and analysis were executed as outlined in the research methodology chapter. Semi-structured interviews were conducted with energy industry experts ranging from economists, consultants to the IPP office, and IPP renewable energy developers. Interviews were structured around the three main propositions, as outlined in chapter 3, utilising open-ended questions. Notes were taken down during the interview process and the interviews were recorded to ensure quality representation of respondent comments and views. Subsequent to the conducted interviews, all notes were consolidated and recordings were analysed leading to the formation of transcriptions in preparation for the coding process.

Table 1 provides a list of the industry experts interviewed in order to obtain the primary data for this study, with a detailed description of industry designation and experience provided in Appendix A.

Table 1: Industry expert interviews conducted

Interviewee in order of interviews conducted	Reference in report	Designation
Interviewee 1	Respondent 1	IPP office - Independent Advisory Consultant
Interviewee 2	Respondent 2	Independent energy sector consultancy - Managing Director
Interviewee 3	Respondent 3	WWF - SA Senior Executive
Interviewee 4	Respondent 4	IPP - Managing Director
Interviewee 5	Respondent 5	Large scale construction, mining and property development - Managing Director
Interviewee 6	Respondent 6	IPP - Managing Director
Interviewee 7	Respondent 7	Consultancy firm specialising in energy, mining and electricity sectors - Managing Director and Senior Economist
Interviewee 8	Respondent 8	IPP office - Senior Economist

Secondary data was collected for use in data triangulation to facilitate conviction and accuracy of conclusions reached during the study. Multiple sources were utilised in gathering information aimed at corroborating the phenomenon being studied. Secondary data utilised for the triangulation phase is presented in Appendix C. Ultimately, this process was seen to facilitate construct validity, credibility, and the quality of the study being conducted.

5.2 Data gathered and stored

All original working documents, including interview transcripts and secondary sources, were stored in the research database for any future use. Appendix C contains listing of all the secondary sourced utilised during the data triangulation process.

5.3 Data gathering process

A systematic thematic analysis approach was used to analyse the responses to the interviews that were conducted. Following the generation of a thorough list of categories that appeared to comprehensively cover the responses of the participants, each participant's responses were subsequently re-examined to provide certainty that all participant' responses could be placed into at least one category. Categories were created for responses to ensure that comments accurately reflect the categories to which all comments and quotes were classified. Each of the participant's responses were re-examined relative to the previously identified and novel categories and were assigned a numerical value corresponding to the particular category that responses conceptually fit. More than one numerical value, corresponding to the categories, was assigned to responses that fit conceptually into more than one category. Once the accuracy of the numerical categorisation of each participant's responses for each item was assured, the categories were re-assessed to converge categories of similarity into themes that represented an encompassment of the categories most relevant to the theme. Following the generation of the themes, the participants' responses were then recoded, for each item, and the coded responses were then examined to provide certainty that the responses that were coded into particular themes were conceptually relevant. As a result, the key thematic areas that were identified represent the central features of the participants' responses to each area that was examined

In addition to the coding and identification of the central emerging themes, supplementary word count analysis was done to determine the weighting of key words used by the respondents during the interviews. This was seen as an indicative gauge of the level of importance, as expressed by the respective respondents, on the greater weighted word utilisation. The initial steps included a total extraction of all words utilised by all the respondents during the interviews. Subsequent filtering was applied to eliminate all words up the highest 23 weighted words used in total by all the respondents. Each respondent was analysed according to these top 23 identified words in order to obtain insight into the weighting of importance as expressed by each individual interviewee. This was also seen to facilitate the sound boarding of emerging themes. A graphical representation of this is detailed in Appendix E. Once all the themes were identified and listed, triangulation and secondary sources were introduced to corroborate the findings from the coded primary data.

5.4 Data analysis

5.4.1 Emergence of themes

Due to the broad nature of the energy industry, the researcher conducted interviews with a semi-structured framework to facilitate coding by grouping open-ended questions with the resulting information obtained from the interviewees in order of the propositions outlined chapter 4 in this study**.** During the coding process, emerging themes stemmed from the research interviews and are presented in the following general categories, as outlined in the literature review:

5.4.1.1 Energy and security

Table 2: Energy and security

Category	Theme	Emergent View
1. Energy and security	**Theme 1:** Generic characteristics of energy security	**1.a:** Electricity supply needs to match demand requirements / availability of supply **1.b:** Electricity supply needs to be reliable **1.c:** Financial implications of electricity supply security **1.d:** Supply security to promote economic growth **1.e**: Electricity security is dependent on a functioning grid **1.f:** Electricity security is dependent on the energy resources **1.g:** Electricity security is dependent on system policy and mechanism
	Theme 2: Drivers and threats on energy security in South Africa	**2.a.:** Electricity supply needs to match demand requirements / availability of supply **2.b.:** Electricity security is dependent on the energy resources **2.c.:** Electricity security is dependent on system policy and mechanism

5.4.1.2 Energy consumption and economic growth

Table 3: Energy consumption and economic growth

Category	Theme	Emergent View
2. Economic growth and energy consumption	**Theme 3:** Relationship exists, influenced by a range of factors	**3.a:** Relationship exists **3.b:** Influenced by a range of factors
	Theme 4: Economic growth and energy consumption	**4.a:** Energy consumption role **4.b:** Influenced by a range of factors
	Theme 5: South African growth	**5.a:** Sector dependent growth **5.b:** Impacts and influences

5.4.1.3 Energy mix

Table 4: Energy mix

Category	Theme	Emergent View
3. Availability of renewable energy resources and levelised technologies	**Theme 6:** Levelised technology costs	**6.a:** Reduction in renewable technology costs **6.b:** Other technology cost changes
	Theme 7: Technologies of focus	**7.a:** Renewable energy as choice **7.b:** Non-Renewable energy of focus
3. A 100% renewable energy	**Theme 8:** 100% Renewable energy generation profile achievable	**8.a:** Feasibility / Necessity questionable **8.b:** Storage **8.c:** Areas of exploration **8.d:** Budget allocation and R&D focus

5.4.2 Theme 1 – Generic characteristics of energy security

According to the Department of Energy and Climate Change (2012), in Great Britain "there is no perfect definition of energy security" (p. 5) and that some of the more important characteristics promoting energy security is the accessibility and reliability of supply to all customers (consumers and business) at a price that is least volatile. According to an analysis done by Cherp (2012) on energy security and its variety of meanings, notions of availability, sufficiency, affordability, welfare supplies, and interruptions were seen to be some of the most prominent.

From the aforementioned themes originating from the respondent interviews, there was a tendency for the participants to emphasise the importance of supply and demand factors, such as the stability in electricity supply, as the cornerstone of energy security. Another factor that was outlined was the necessity for the electricity to be reliable and affordable in order to achieve energy security. This seems to be coherence with the views stipulated by the Department of Energy and Climate Change (2012) in Great Britain, Cherp et al. (2012), and the interviewees around the central dominant characteristics promoting energy security.

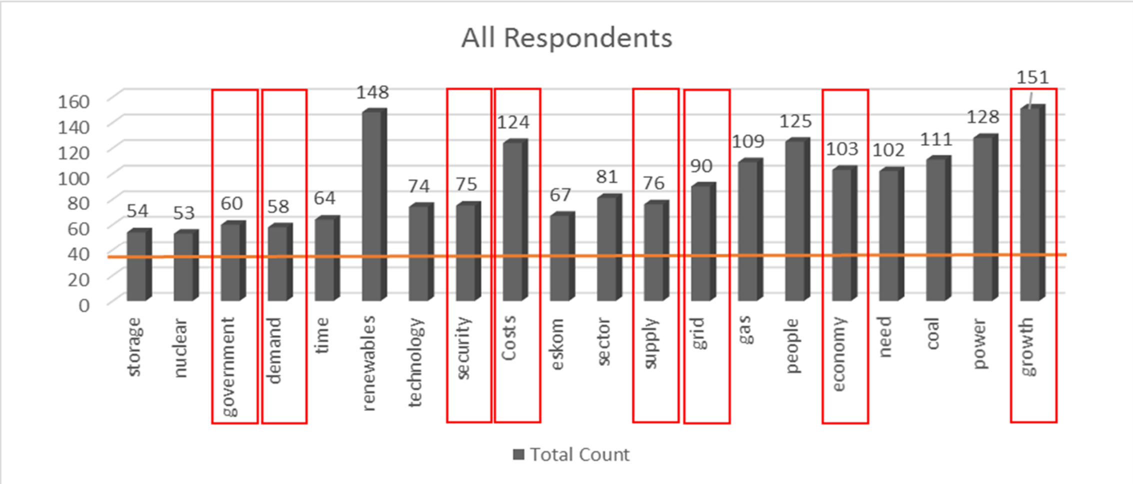
Economic growth was also highlighted as an integral component, seemingly because energy security can create the basis for sustainable economic growth. Policies and plans were also emphasised as vital to attaining and maintaining energy security.

Table 5: Frequency table: Emerging themes on energy security characteristics (generic)

Emerging views	Frequency	%	Theme classification
1.a. Electricity supply needs to match demand requirements / availability of supply	**9**	**25%**	Generic characteristics of energy security
1. Supply vs. Demand Matching	6	67%	
1.1 Demand Fluctuations	1	11%	
1.2 Requires Supply Adjustments	1	11%	
1.3 Influence Demand	1	11%	
1.b. Electricity supply needs to be reliable	**3**	**8%**	
3 Reliability	3	100%	
1.c. Financial implications of electricity supply security	**6**	**17%**	
2. Financial Implications	5	83%	
2.1 Interplay Among Factors Impacting Supply	1	17%	
1.d. Supply security to promote economic growth	**4**	**11%**	
4. Economic Growth	3	75%	
4.1 Equitable	1	33%	
1.e. Electricity security is dependent on a functioning grid	**2**	**6%**	
5. Functioning Grid	1	50%	
5.1 Transmission	1	50%	
1.f. Electricity security is dependent on the energy resources	**7**	**19%**	
6. Energy Resource	1	14%	
6.1 Location	2	29%	
6.2 Importation Costs	1	14%	
6.3 Availability of Resources	3	43%	
1.g. Electricity security is dependent on system policy and mechanism	**5**	**14%**	
7. System Policy and Mechanism	1	20%	
7.1 Inadequate / Absent	2	40%	
7.2 Environmental Impact Considerations	1	20%	
7.3 Revise Integrated Resource Plan	1	20%	

Word count analysis revealed another interesting dynamic on the weighting that respondents allocated to the various categories under discussion. As mentioned previously, this measure is only utilised to obtain an indicative gauge on the level of importance as view by the respective industry experts. As see in Table 5 the largest weighting is associated with economy and growth. Although the emerging views in energy security ultimately promote economic growth, this could potentially be a distorted (inflated) view on the level of importance when compared to the other remaining top ranked words, as a large section of this study is focussed on the relationship between economic growth and energy consumption. What does seem to coincide with the aforementioned emerging views are supply, demand, grid, government, and the associated costs. Costs are ranked one of the highest in terms of weighting, and this is supportive of the notion that electricity needs to be available at an affordable price. An inference can be made on the level of importance of the words utilised and does support the emerging themes as stated in the aforementioned section. While this is not an exhaustive list of the components contributing to electricity security, the emergent views point towards fundamental characteristics needed in the promotion towards it.

Figure 4: Word count analysis resulting in the top 8 words utilised underpinning the generic theme of energy security



The open-ended questions posed to interviewees were aimed at obtaining a generic view of what energy security, in view of the interviewee's interpretations, were. The industry experts were asked their opinions on the typical characteristics of energy security, which would contribute to the formation of a generic baseline to benchmark South Africa against. The following emerging views contribute to this generic view applicable to the broader characteristics of electricity security, which then lead to the exploration of energy security within a South African context. The views and emerging trends from the industry experts and secondary data sources are consolidated in the following section.

Emergent View 1.a: Electricity supply needs to match demand requirements / availability of supply.

There was a general consistency amongst the respondents around the concept of energy security in that it is essentially around matching supply with demand, with no limitations to customer requirements. This concept infers that electricity supply needs to be available.

Respondent 1 stated that energy security is ultimately "the probability that supply meets demand." Respondent 2 stated that energy security is "security of supply." Respondent 2 opined that in order to achieve energy security "you need sufficient electricity to operate a stable grid." Respondent 3 was in coherence with the aforementioned statement by stipulating that "a straightforward simplistic view of energy security is about having enough supply of electrons." Respondent 8 added that "energy security cannot only be seen from the face of meeting your current demand but also planning to be able to meet your future demand and this is done by extrapolating energy consumption." Respondent 8 further stipulated that "electrical energy security could be seen as a situation in which there is sufficient and reliable domestic generation capacity and supply capabilities to meet national demand that allows for an expansion of economic activities."

It is evident from the aforementioned views that electricity security is securing sufficient available dispatchable capacity to meet the requirements of the customer in order to promote expansion of economic activities. There is a strong emphasis on the supply side ability of the sector or industry.

Emergent View 1.b: Electricity supply needs to be reliable.

Reliability is another key characteristic needed to achieve energy security and "it needs to be associated with reliability of supply, so reliability of supply is the key issue," according to Respondent 7. Respondent 8 added that "the notion of energy security should go beyond physical electrical power activities required to meet current demand, but also involve undertakings to ensure sufficient future electricity availability." Respondent 2 stated that "an important point, not to forget, is that energy security is not just about electrons, but it is the link between energy security and other economic factors and drivers that need to be taken into account." This interplay is a key factor to be considered for any planning in ensuring that electricity supply remains reliable.

Emergent View 1.c: Financial implications of electricity supply security.

Within the financial category, a similar consistent view from the respective respondents are that electricity needs to be affordable. Respondent 3 stipulated that electricity "must be affordable," Respondent 6 added that electricity security is essentially "security of supply at affordable prices" and respondent 7 added that the key to electricity security is the "affordability of electricity. There is no use in having electricity that is disproportionately expensive relative to similar emerging markets or neighbouring countries." Respondent 4 strengthens this view by stating that it "it doesn't help that you have enough energy in the mix but it is not affordable for the public or business."

Emergent View 1.d: Supply security to promote economic growth.

The availability, reliability, and financial aspects of electricity security is of the utmost importance for the promotion of economic growth. Respondent 6 expressed that South Africa "have to raise economic growth for economic and political prosperity and security. Central to that is raising the electricity and energy growth. You cannot have economic growth without electricity growth and energy growth as productivity is dependent on improving electricity supply." Respondent 4 added that South Africa "needs enough energy to grow the economy and create jobs and that could be a balance of different types of energy, but energy security is where there is enough energy to grow the economy." Responded 3 emphasised the aforementioned views with South Africa needs "enough electricity for growth in the economy." Respondent 7 elaborated that "energy security is actually talking about equitable growth, spread across the spectrum of the population and not confined, as it has been in Africa to the greater extent, to a group of the elite."

Emergent View 1.e: Electricity security is dependent on a functioning grid.

Distribution infrastructure is the key mechanism to enable the successful transportation of generated electricity to the end user to engage in economic activities. Respondent 3 stated that electricity security will seriously be undermined "if you do not have a functioning grid." Respondent 3 further elaborated that a stable grid "must be stable electricity supplies, sufficient capacity for growth and must be affordable. All three elements must be present, at the same time, and if any one of these elements are not present, you don't have a functioning grid." Respondent 2 agreed with this view by stating that "energy security is not just about the ability to generate electrons but also to be able to send them somewhere."

Emergent View 1.f: Electricity security is dependent on the energy resources.

Determining the energy locality and availability of energy resources is a vital component that affects any electricity systems' security. Some of the key aspects to consider when considering the utilisation of resources for electricity generation is the location of the resource. Respondent 2 stated that "if the resource is outside of the country you have to consider political risk, risk of supply constraints in the future due to influences resulting from political conflict, logistics or other issues." Respondent 2 elaborated that "importing something in a foreign currency has balance of payment issues, which affects the macro economic conditions of a country."

A great emphasis is placed on the availability and efficient usage of local resources to supply the electricity generation profile of a country. Respondent 2 stated that in order to protect a country against the affects (political risk, currency fluctuations, and balance of payments issues) resulting from the importation of electricity from foreign countries, one has to determine "how much can be secured using your national domestic resources." Respondent 7 emphasised the "sustainability of that supply" and that, depending on the technology utilised, if the resource is "available and secured for the life of the project." Respondent 8 stated that the availability of the resource should not be considered in isolation, but "rather to use the available energy resources effectively and efficiently so as to have adequate electrical energy security."

Emergent View 1.g: Electricity security is dependent on system policy and mechanism.

Respondent 5 stated the importance of clear policies to guide the energy industry. He elaborated that energy security relies on Government institutions having "reached a view on what your reserve margin should be; what your acceptable level of cross border imports should be; have all the correct institutional arrangements in place to achieve those indicators over time. So it is not only just having policy on what your reserve margin should be but it is actually having the mechanism in place to achieve that." Respondent 8 added to this topic by stating that "a country has to have a regulatory environment that allows for competition, because without competition, as any business, a monopoly will just exploit consumers, not focus on delivering services, resulting in the product or service delivery deteriorating." Respondent 5 stated that if a country is dependent on private sector investment "addressing the policy environment is of the utmost importance." Respondent 8 emphasised the importance of policies that promote competition in order "to have a vibrant and innovating industry, an industry that does research, that can actually take advantage of their own technologies" which will allow "for businesses to find niches in the electricity industry."

5.4.3 Theme 2 – Drivers and threats on energy security in South Africa

According to Cherp et al. (2012), national and human security is closely entangled with a countries' energy systems, and the associated concerns over the reliability of these vital systems have led to the shaping of public opinions and political agendas that eventually affect broader security issues ranging from risks of conflicts, viability of national economies, and the integrity or stability of political systems. Cherp et al. (2012) elaborated that policies have been historically, and will likely remain, a key driver towards the transformation of energy systems.

The responses largely centred on the role of government and related entities in ensuring energy security through proper planning and policy measures. It is evident from the frequency tables, as depicted in Tables 6 and 7, that the role of government is viewed as the largest contributing element driving or threatening energy security for South Africa.

Demand and supply issues and the variables that influence such were also among the common drivers that were cited, which is not surprising considering these were suggested as the markers of energy security. These are dynamic elements that serve as contributing components when assessing the requirement for electricity needs. Along these lines, the range of factors that were reported indicate that there are several factors involved, perhaps denoting the dynamic interplay among these factors towards achieving optimal levels of energy security.

Table 6: Frequency table: Emerging themes on drivers of energy security in South Africa

Emerging views	Frequency	%	Theme classification
2.a. Electricity supply needs to match demand requirements / availability of supply	**7**	**19%**	Drivers of South African energy security
1. Demand Severity	3	43%	
2. Supply	2	29%	
2.1 Private Sector Risk	2	29%	
Not utilised. Financial implications of electricity supply security	**2**	**6%**	
3 Finance	1	50%	
3.1 Capital Costs	1	50%	
Not utilised. Supply security to promote economic growth	**2**	**6%**	
4. Economic Growth	2	100%	
2.b. Electricity security is dependent on the energy resources	**5**	**14%**	
5. Fuel Sources	4	80%	
5.1 Long-term Reliance on Coal	1	20%	
2.c. Electricity security is dependent on system policy and mechanism	**20**	**56%**	
6. Governmental Influences	3	15%	
6.1 Questionable Decision-making	2	10%	
6.2 Security Begins with Policy / Planning	5	25%	
6.3 Performance of State Owned Institutions, e.g. Eskom	6	30%	
6.4 Environmental Considerations and incentives	2	10%	
6.5 Technology	1	5%	
6.6 Contestation over Renewables in Future	1	5%	

Along with being core drivers of security, government aspects were outlined as the largest threat to energy security, with poor administration and a lack of government involvement in electricity issues and legislation developments key areas the participants highlighted. Notably, the participants reported issues relating to Eskom, its functioning, and related micro factors (grid system strain) as the primary threats to energy security. It would appear that, as depicted in Tables 6 and 7, institutional aspects are seen as critical in driving energy security. This is essential for maintaining energy security and can be a major challenge to manage.

Broader macro factors were also identified as important, such as the necessity to diversify energy sources and develop skills and capacity in South Africa, which would not just stimulate growth in the energy industry but also on a broader macro level as well. According to the The Institute of Risk Management South Africa at al. (2015), skills shortages are seen as on the key contributing factors preventing the achievement of targeted growth rates, with prescriptive regulation and the lack of a skilled workforce as the most significant business growth inhibitors. Not only is this a problematic concern that negatively impacts Eskom, but it is a national level problem for South Africa as well.

Table 7: Frequency table: Emerging themes on threats on energy security in South Africa

Emerging views	Frequency	%	Theme classification
2.b. Electricity security is dependent on the energy resources	**7**	**14%**	Threats to South African energy security
1. Supply Risk	2	29%	
1.1 Single Source Reliance	1	14%	
1.2 Resource Cost Variance	1	14%	
1.3 Diversification Strategy	3	43%	
2.c. Electricity security is dependent on system policy and mechanism	**43**	**86%**	
2. Broader Political Implications	2	5%	
2.2 Private Sector Involvement Decisions	1	2%	
2.3 Regulations, Legislature, and Involvement	3	7%	
2.3.2 Urgent Redress Required	2	5%	
2.4 Strategic Public-Private Partnerships	2	5%	
2.5 Maladministration	4	9%	
2.6 Continued Poor Political Discourse and Decisions	1	2%	
2.7 Governmental Role and Assistance	1	2%	
2.8 Attention on Nuclear Power	1	2%	
2.8.2 Hidden Expenses	1	2%	
3. Perfromance of State Owned Institutions			
3.3 Finances	3	7%	
3.3.1 Impact on Government Financing Ability and Decisions	1	2%	
3.4 Future Financial Decisions	1	2%	
3.5 Inadequate Performance	3	7%	
3.6 Project Completion Risk	1	2%	
3.7 Human Resource Issues	5	12%	
3.7.3 Skills and Capacity	2	5%	
3.8 Infrastructure Maintenance	2	5%	
3.8.3 Recent Improvements	1	2%	
3.8.3 Transmission Capacity	1	2%	
3.9 Scheduled Outages (e.g., mid-life)	1	2%	
3.10 System Strain	1	2%	
3.10.3 Absence of Grid Back-up	1	2%	
3.11 Utility Decline	1	2%	
3.12 Inadequate Understanding of Electricity Sector	1	2%	

The industry experts were asked their opinions on the drivers and threats to energy security to allow for a thorough analysis of the underpinning elements influencing energy security in South Africa. The views and emerging trends from the industry experts and secondary data sources are consolidated in the following section.

Emergent View 2.a: Electricity supply needs to match demand requirements / availability of supply.

With a generic supply matching demand characteristic, as previously stated, respondent 1, with a strong focus on demand side management, stated that an additional dimension driving energy security is “the time of use” and a difference in supply requirement from low to peak demand. There is a vast difference in the supply requirement during peak time and that of late evenings. Respondent 1 elaborated that this difference can be as much as “36MW during evening peak and 22MW at night.” Demand side strategies and government incentives should be implemented to change electricity consumption behaviour that would allow for “load shifting” to alleviate some pressures on the electricity supply system during peak times.

As stipulated in emerging theme 1.a., it is imperative that supply meet demand at the moment in which the request is posed by the customer to the supplier (i.e., uninterrupted supply). Respondent 1 supported supply and matching criteria, but expressed that the responsibility of energy security is a unidirectional one. Thus, a large focus on influencing demand patterns is emphasised that would result in demand shifting from high peak usage to alternate time outside of the high peak periods.

Emergent View 2.b: Electricity security is dependent on the energy resources. When factoring in the fuel source in developing an energy mix, respondent 5 stated that the first step is to determine what the “primary fuel sources available are,” with respondent 8 elaborating that an additional quality is the “fuel substitution abilities” available to the country. Respondent 2 stated that “optimal coal sites have reached a peak” and coal availability is “on the decline.” “This means although we have still a vast amount of coal in the Waterberg, the ability to mine and extract is coming at a higher cost, requires other infrastructures” and “the supply security issue, with regard to a single resource, which in this case is coal, we need to find ways to reduce our dependence on it.”

Respondent 2 stated that “complete reliance on a single resource, in which the future supply and price cannot be easily determined” is one of the biggest threats to energy security and if this resource “is outside of South Africa then you have to ask questions about political risk, and risk of supply constraints in the future due to political conflict, logistics or other issues.” Respondent 6 emphasised this with “what we need to do is diversify our energy sources. Unfortunately, what is happening is we are diversifying them in a manner which is not economically sensible. The fact of the matter is that all countries provide their energy and electricity through utilising those resources of which they have a comparable advantage.” Respondent 1 elaborated that “even though you may say gas and renewables are expensive today, they help you offset costs that you predict or other risks associated with other technologies, like coal, to find ways to offset that, so that the system as a whole is not at risk due to dependence on a single energy source. It is a way of diversifying and hedging against future risk.” Respondent 8 stated that “we are diversifying our electricity sector” and that a “lack of diversification or dependence on a primary fuel source is not a risk” due to South Africa exploring the ability to source “fuels that are not domestically” available.

It is evident from the interview responses that diversification of the resources and resulting technology mix is imperative to ensure that no single resource or technology reliance can influence energy security in South Africa. Diversification leads to risk mitigation that ultimately lead to energy security.

Emergent View 2.c: Electricity security is dependent on system policy and mechanism.

The largest weighted emerging themes revolved around the role of government and the associated policy support and the current state of Eskom, South Africa’s state owned electricity supplier.

The current operational deficiencies and financial dire position of Eskom is largely, as inferred by emerging themes, due to questionable decisions made by our local government. The “aging electricity generation and supply (transmission and distribution) infrastructure” (Respondent 8) and the “non-performance by Eskom,” resulting in a “lack of maintenance” and the associated “project risk of getting Medupi” (Respondent 1), and other newly completed builds, are seen as highest regarded factors influencing energy security. Respondent 1 stated that one of the biggest drivers in South African energy security “is the well-known political indecision around the new build” and that it is well documented that President Thabo Mbeki “apologised that it was government’s error.” Responded 6 supported that it is due to “government not having provided for, and gone ahead, in the electricity and energy growth that was required at the time.” Respondent 8 placed a high emphasis on the performance of the state owned entity, Eskom, by stating that “very significant mismanagement of their maintenance programme on existing coal fleet, resulted in energy availability factors deteriorating to really ridiculously low levels.” Respondent 5 agreed that “it is Eskom’s institutional performance in managing its capital programme or mismanaging its capital programme with the associated significant delays and cost overruns on Medupi and Kusile.” Respondent 3 stated that his view on the biggest threat on energy security is the “inability of Eskom to commission new capacity.” Respondent 1 stated that the “the magnitude of deferred maintenance is horrific.” Respondent 8 stipulated that “insufficient national electricity grid expansion in order to accommodate for new build generation capacity” as one of the biggest threats to South African energy security. Respondent 1 elaborated that, although there are a vast amount of deferred maintenance, existing plants are approaching “mid-life outages” within the next five years, which are “bigger, more expensive and longer outages than normal.” Respondent 5 added that the current electricity supply system is under immense pressure, which “increase the risk factors, stress resources, stress plant equipment,” resulting in ”higher rate of accidents, failures and outages.” Respondent 4 elaborated that “if South Africa can’t maintain something as simple as a coal silo at Majuba power station to the level of integrity that it should, how can South Africa go into a program where we build nuclear power stations?” Respondent 3 added that although Eskom was largely a “successful utility and an excellent performer,” the state owned entity is “now failing.”

According to Respondent 4, a large contributing factor to Eskom not performing is due to not having the “requisite or suitably qualified skilled and experienced individuals to actually manage the current fleet of power generators.” Respondent 7 added that Eskom does not have the “technical skills to operate and maintain our infrastructure” and a “lack of understanding the electricity business and the political interference in it.” Respondent 4 contributed with “there are too many incompetent people in Eskom that can’t make the right decisions, can’t manage the company and can’t solve the problem” as root causes for Eskom’s poor performance and non-delivery of infrastructure and maintenance. Respondent 6 added that it is due to the “shortage of skills that negatively influence energy security.” Respondent 4 concluded that “people that can’t make management decisions and can’t execute projects” should be drastically changed to incorporate “people that can do the job or has the industry experience in all aspects, not only in energy, to allow for energy security.” Respondent 7 elaborated that some of the larger root causes are “gradual eroding of the status of craftsmen or artisans in society” that “really keep our infrastructure growing. The demise of the trade schools and the apprenticeship programs result in a huge risk, not only in South Africa but globally as a whole.”

The interviewees placed emphasis on the highly regulated electricity industry and the role of government in creating an enabling environment for electricity generation and supply that contributes towards achieving greater electricity security for the country. Respondent 1 stipulated that “the right policy would determine the flow of actions, and the actions will then result in having sufficient capacity to operate a stable grid, having sufficient capacity to enable growth whilst keeping prices affordable.” Respondent 4 added that “good enough planning will drive energy security” resulting in “having a comprehensive energy plan, which firstly starts with an integrated energy plan and then over into an integrated resource plan." Respondent 5 added that the "the integrated resource plan was a very good first step towards that" but is now out of date and was due to being finalised "five years ago." Considerations should be given that "a lot has changed in the world since then" and that "it should be redone." Respondent 1 stated that "people forget what happens between policy and regulation," as "regulations are written to give effect and detail to legislation" and suggests that the "energy policy white paper" needs to have the appropriate "legislation to transform the energy sector." Respondent 8 stipulated the importance of "an adequate legal framework governing the electricity industry." Respondent 6 stated that there are "are tremendous conflicts of interest in government policies which reigns through many of the policies."

Respondent 7 stipulated that "the biggest threat to security of supply at the moment is lack of political will to resolve this issue," whilst respondent 4 added that "government created a new policy but didn't actually follow through by executing it". Respondent 1 stated that "load shedding is politically unappealing" and the load shedding factor would contribute to be the "biggest political influence to the upcoming municipal elections." This has resulted in government's appetite to restrict load shedding to increase significantly. Respondent 1 elaborated that "there is more political appetite for load shedding in a way that doesn't defer maintenance anymore" and that "government is doing a lot of work now and they have really realised it." Respondent 5 added that there is a lot of "focus on the short term" and emphasised that it is not "a particularly useful approach to policy. What is needed is long term policy and long term vision." Respondent 1 finalised with "the energy policy in the country has nothing wrong with it, government just didn't use it. So the white paper says all the right things, so the policy is right. What is missing is the legislation and the acts of parliament."

What is evident is the role of public and private partnerships in the realisation of energy security in South Africa. Respondent 1 stated that what is needed is to get "private capital involved to build infrastructure," as there are an abundance of private enterprises having "strong conviction to partner with the public sector." Respondent 7 added that "the private sector has demonstrated, since the introduction of the REIPP programme, the capability to delivering generation capacity, on time, on budget and at no risk to the fiscus or South Africa." Respondent 7 elaborated that the "risk is completely ring fenced within the private sector and Eskom, and South Africa, should be looking at procuring its electricity requirements primarily from the private sector. This would allow Eskom to focus on the delivery (transmission) of reliable cost effective quality electricity to the consumer."

Respondent 8 added that what is needed is "a regulatory environment that allows for competition and private sector investment in the electrical energy industry."

Not surprising was the enormous weighting placed on the role of government and the resulting supporting policies needed to promote a healthy, vibrant, and competitive energy market. From the respondent views it is evident that the South African government needs to have a dynamic robust model in place to facilitate electricity planning. This model will assist in determining demand patterns and allow planning towards the diversification of resources and technologies when deciding on the optimal energy generation mix.

5.4.4 Theme 3 – Economic growth and energy consumption

Emerging from the coding process is the dynamic interplay of elements that influence both economic growth and energy consumption. What is evident from the comments coded from the interview responses is that a relationship exists between economic growth and energy consumption, although a direct correlation between economic growth and energy consumption could not be determined. This is partly due to the comments received from the interviews were opinions and were not supported by the associated quantitative studies that would allow for the determination of the causal relationship between the two relevant elements. There is a central tendency from participants to suggest that, currently, the economic growth and energy consumption relationship is negative, with some reasons related to the premature movement into the service industry while not completely moving through the industrialisation cycle. According to Statistics South Africa (2015), the economy has contracted by 1.3% within the second quarter alone, represented by 5 of the 10 main industry groups. These industry groups include the mining industry (6.8%) due to lower outputs, agriculture (17.4%), manufacturing (6.3%), electricity (2.9%), and the trade (0.4%) industry. The Institute of Risk Management South Africa (2015) stated that insufficient electricity supplies continue to undermine economic growth where banks are becoming more averse to lending to investors in energy intensive industries. This, in turn, will lead to further growth contraction that negatively affects economic growth.

The participants also reported that there are a number of factors, as depicted in Table 8, which are important to consider, including which sector one is interested in, and that there are additional factors to consider when looking at the relationship between these two variables. Some participants suggested that without economic policies and efforts to enable or facilitate growth, the maximal relationship between the two is unlikely to be attained.

Table 8: Frequency table: Emerging themes on economic growth and energy consumption relationship

Emerging views	Frequency	%	Theme classification
3.a. Relationship exists between economic growth and energy consumption	**14**	**37%**	Relationship exists, influenced by Range of Factors
1. Uncertain of Precise Estimate	2	14%	
1.1 Below Designated Criterion	1	7%	
2. Historically Positive	1	7%	
2.2 Currently Negative	2	14%	
2.3 De-industrialisation Process	2	14%	
3. Positive Relationship	3	21%	
3.1 Current Decline	1	7%	
3.1.1 Energy Consumption Shift	2	14%	
3.1.2 Influence of Suppression Unknown	1	7%	
3.b. Influenced by Range of Factors	**24**	**63%**	
4. Sectoral Designation Required	2	8%	
4.1 Dependent on Sector	1	4%	
4.2 Planning Based on Scenarios	2	8%	
4.2.1 Accurate in Past	1	4%	
5. Varied Perspectives	2	8%	
5.1 Indecision and Inaction	2	8%	
6. Energy a Prerequisite / Factor	5	21%	
6.1 Growth Enabling Factors Required	5	21%	
7. Economic Influences on Energy Demand	1	4%	
8. Importance of Energy Use Efficiency	2	8%	
8.1 Influence of Consumer Behaviour	1	4%	

It is worth noting that the negative impact of not having sufficient energy availability to the economy is suggestive of the existence of this relationship, and, once again, the emergence on the role of government to create an enabling business environment to stimulate economic growth. According to MWEB (2015), the impact of load shedding (10 hours x 20 days per month) can be as much R20bil per month for stage 1, R40bil for stage 2, and R80bil for stage 3 on the economy. Electricity production has decreased by 1.4%, and the impact of load shedding on the economy can be as much 0.5% - 1.0% (Financial Times, 2015). According to Mail and Guradian, (2015), the current impact of load shedding in 2015 so far has had severe impacts on the manufacturing and mining outputs. Although the finance and business services industry remain the strongest sectors, the mining industry reflects severe stresses that would eventually lead to conflict with government, and, ultimately, job losses (Mail & Guradian, 2015).

Semi-structured interview questions were posed as a mechanism for extracting the views of the respondents on the relationship between economic growth and energy consumption. The semi-structured interview questions would also facilitate the extraction of the type of growth South Africa is currently experiencing that would ultimately facilitate the in-depth understanding of this relationship and dynamic interplay of elements that shape and influence each other. The views and emerging trends from the industry experts and secondary data sources are consolidated in the following section.

Emergent View 3.a: Relationship exists.

Stemming from the coding process and emerging views, the majority of the respondents agree that a relationship between economic growth and energy consumption exists. Although in agreement on the relationship, the researcher was unable to determine a clear relationship from the interview responses.

Respondent 3 stated that the relationship is “positively correlated historically” and where the “economy grew the gigawatt hours sold increased.” Respondent 4 stated that “GDP growth does not drive energy consumption, energy availability drives GDP growth.” Respondent 8 stipulated that “some might say it is not always clear cut” but “all the evidence points towards the relationship in South Africa currently being one way, and that electricity capacity will boost economic growth.” According to respondent 5, “a very clear relationship exist between economic growth and energy or power consumption.” Respondent 5 stated that the relationship has a “clear curve that has peaked and is currently declining.” Respondent 4 stated that “energy availability will drive GDP growth,” but limited growth is experienced in South Africa due to not having “access to enough energy.” Respondent 8 supported this with “it is definitely one of the primary factors that is constraining economic growth.”

Respondent 5 emphasised that the “nature of the economy is shifting more and more towards the services sector (a less energy intense form of economic activity),” but does not suggest a “decoupling of this relationship” but merely a “decline in energy intensity of the economy.” This is supported by Respondent 1 that added “heavy intensive users, (chrome, ferrochrome, manganese smelters)” are “declining.” Respondent 4 added that South Africa is “de-industrializing,” which would result in “energy intensity declining”. Respondent 3 inferred that the South African economy has “contracted due to a decrease in gigawatt hours sold.” Respondent 6 cautioned that South Africa has “not yet reached peak industrialisation” and that we “cannot move from the latter stage of industrialising” towards a “more service sector orientated growth” prematurely. What is quite alarming is the “degree of supressed demand within the economy for large energy intensive projects that would have gone ahead if Eskom had been able to provide supply in the last five or so years since," as suggested by Respondent 5. Respondent 1 added that "mines and energy intensive industries" create "secondary industries," which, in turn, drive "job creation," and, ultimately, "GDP growth." Respondent 6 added in order to growth the economy, South Africa has to continue "developing its major sources and downstream industry, which are more energy and electricity intensive."

Emergent View 3.b: Influenced by a range of factors.

Respondent 1 suggested that in order to accurately determine the influence of the constituent parts on the overall energy demand factor, a consolidation from the bottom is needed. One has to consider the "heavy engineering, heavy manufacturing, and light commercial" as well as "household consumption." Respondent 2 added additional consideration should be given to factors, such as "where investment is directed, i.e. high intensity energy intense sectors" where "demand for energy is probably going to be high" and the impact of "electricity prices" on consumer behaviour. If this approach is not followed "you actually don't get agreement on what is needed" which ultimately "lead to inaction."

Respondent 2 expressed concern that South Africa lacks the ability to accurately "link energy supply with coordinating growth in the economy" and expressed concerns around building large scale capacity and "do nothing else to help the economy grow." Respondent 7 stated that other African countries, with similar electricity problems, are experiencing "5%-7% growth" and that there is a "far deeper and broader impact on the South African economy in terms of leadership in government, unfriendly business working or legislative bureaucratic environment in South Africa," which does not promote economic activities and "in order for our economy to grow we have to produce." Respondent 7 supported that our "economy is stagnating" primarily due to the "lack of electricity," but expressed that this is "not the only contributing factor" and our economy is "not growing like other countries in the SADEC or Southern African region."

Respondent 8 stated that in order for the economy to grow, electricity has to be "available" in order to stimulate "investment" to enable a business environment where "people can build and manufacture, thus enabling the businesses" to "expand" due to generation ability to "meet their power" demands. Respondent 1 opined that what is needed is the "removal of barriers to growth" and by removing "red tape bureaucracy, creating an enabling environment for foreign direct investment, for entrepreneurs to flourish" would allow for economic growth by addressing the "structural issues in the economy." Respondent 7 expressed that if South Africa is going to be an "efficient economy and compete globally," what is needed is "reliable electricity" in order to "beneficiate the mineral resources that we are extracting from the reserves that we have in this country," which would allow for South Africa to be a "producer economy as an opposed to a consumer economy." Respondent 6 added that "without proper energy, South Africa is not going to achieve economic growth and is not going to achieve economic prosperity."

5.4.5 Theme 4 – Economic growth and energy consumption forecasting

In terms of growth forecasting, many of the participants indicated that energy consumption plays an important role, though some suggested this depends on the sector or the role may be more indirect through employment generation. It would appear that there is general consensus that greater energy consumption is associated with superior growth forecasts, with many of the participants reporting concern around the current growth of South Africa. As with many of the areas examined during the course of the interview, there are a number of factors, as depicted in Table 9, that influence the relationship between these two aspects, including electricity demand levels.

Table 9: Frequency table: Emerging themes on economic growth and energy consumption forecasting

Emerging views	Frequency	%	Theme classification
4.a. Energy Consumption Role	**15**	**79%**	Energy Consumption and Growth Forecasting
1. Critical Role in Selected Sectors / Areas of Economy	3	20%	
1.1 Manufacturing and Commercial	1	7%	
1.2 Not Mining and High Energy Consumption	1	7%	
1.3 Employment	1	7%	
1.4 Small Businesses	1	7%	
2. Determine Target Sectors	3	20%	
3. Positive Relationship	2	13%	
4. Economy Energy Dependent	3	20%	
4.b. Influenced by a range of factors	**4**	**21%**	
5. Growth Dependent on Several Factors	1	25%	
5.1 Currently Impairing Growth	1	25%	
6. Demand	1	25%	
7. Warrants Greater individual Sector Attention	1	25%	

Semi-structured interview questions were posed as a mechanism to extract the opinions of interviewees on the level of importance and potential process followed in order to forecast economic growth with the associated energy demand forecasting to enable infrastructure planning. The views and emerging trends from the industry experts and secondary data sources are consolidated in the following section.

Emergent View 4.a: Energy consumption role.

According to Respondent 1, comprehensive planning around economic growth and energy consumption "plays an absolutely crucial role in the areas" to enable an outcome that would promote growth, not just in in big industry, but also "family businesses" or small businesses where "you employ 20/30 people in a factory." Respondent 8 elaborated that sectoral analysis should be done to determine "weighting" that needs to be factored in to the forecasting model that is used. Further emphasis was placed on the importance of getting this role right, as "without electricity there is just no growth." As stipulated in **Emergent View 3.b.**, understanding the constituent parts is vital to effective planning. It has already been extensively quoted that the economic growth and energy consumption relationship is "positively correlated" (Respondent 3) and "huge" (Respondent 6). Respondent 3 has elaborated that this relationship is seen as a "truth indicator" that cannot be manipulated.

As stipulated in **Emergent View 3.b.**, one has to consider the "heavy engineering, heavy manufacturing, and light commercial" as well as "household consumption." Respondent 2 added additional consideration should be given to factors, such as "where investment is directed, i.e. high intensity energy intense sectors," where "demand for energy is probably going to be high," and the impact of "electricity prices" on consumer behaviour. If this approach is not followed "you actually don't get agreement on what is needed" which ultimately "lead to inaction."

Respondent 8 added that analysis should be incorporated around the "general trend and what is happening in the world" and then "extrapolate that against the future economic growth trajectory through normal macro-economic analysis, what is given as a status quo, what we know, what can possibly be a growth trajectory, how to increase or delay maintenance and ultimately build new plant generation capacity to fill this gap in the short and long term." Respondent 8 emphasised the frequency of policy reviews and recommended that this be done on a "bi-annual or three year interval."

These are a mere fraction of the interplaying elements, but are nonetheless important to take into consideration when planning for economic growth and energy consumption.

Emergent View 4.b: Influenced by a range of factors.

Respondent 5 emphasised again the importance of understanding the relevant elements that support or threaten economic growth and energy consumption and specified that "economic growth forecast is based on many factors like how trade is going to go and elements like where the currency is going." Respondent 5 stated that South Africa "has a problem with availability of electricity which has had a negative impact on growth forecasts" and potentially is negatively affecting at least "1% off what the country is naturally capable of and what it is actually achieved." Respondent 4 added that what is needed in South Africa is a detailed study "incorporated sectoral analysis (agriculture, industrial, mining, smelting, manufacturing, tourism and the service industry) to determine how the forecast growth patterns will influence energy requirements."

5.4.6 Theme 5 – South African growth

Although some of the participants were more optimistic in their perspectives and reported growth in some sectors and not others, many reported that growth was stagnant or declining in South Africa and a cause for major concern for energy supply and security. A host of factors, as depicted in Table 10, that both impact and are impacted by the current economic growth status of the country were also highlighted, which, if resolved or addressed, could assist in improving the current economic growth rate.

Table 10: Frequency table: Emerging themes on South African growth

Emerging views	Frequency	%	Theme classification
5.a. Sector Dependent Growth	**38**	**60%**	South African growth
1. Mixed Growth	3	8%	
1.1 Developed and Developing Economies	1	3%	
2. Comparable to Emerging/Developing Countries	2	5%	
3. Behind Industrialised Countries	1	3%	
5.b. Impacts and Influences	**20**	**32%**	
Employment Implications	2	10%	
Lack of Key Stakeholder Coherence	1	5%	
Indirect Effect of Commodity and Global Economic Decline	2	10%	
Infrastructure and Skill Deficits	2	10%	
Foreign Direct Investment	2	10%	
Policy Effects	1	5%	
Role of Other Sectors	1	5%	
Access to Energy	3	15%	
5.c. Unchanged / Negative Growth	**5**	**8%**	
Negative GDP	1	20%	
Low Growth	2	40%	
Contraction	2	40%	

Semi-structured interview questions were posed as a mechanism to extract the opinions of interviewees on the type of growth South Africa is currently experiencing. The views and emerging trends from the industry experts and secondary data sourced are consolidated in the following section.

Emergent View 5.a: Sector dependent growth.

There was a strong conviction resulting from the interviews that South Africa is currently experiencing a mixed growth in the economy. Respondent 1 stated that the South African economy is "mixed" due to "high end banking and IT that constitute a whole sector of the industry that is already decoupled from energy provision." Respondent 4 added that South African "financial services sector is world class," "manufacturing is in early childhood development," and "mining is quite well developed," resulting in "different growth phases" in the respective sectors. Respondent 6 elaborated that South African growth has been "fairly disappointing" due to isolated growth in the "resource sector," with very limited "filtering to downstream industry" resulting in "limited growth of downstream industries and industrialisation processes which broaden the spread of growth." Although comparable to economies like India and China (Respondent 6), South Africa still has a lot to accomplish before being comparable to industrialised countries like Japan and Europe, which is largely due to the fact that South Africa "is still industrialising." Respondent 2 sated that South Africa "is in a low growth phase," whilst Respondent 7 added that South Africa is in a "stagnant recessionary type phase of economic growth" and that South Africa is "not growing economically." Respondent 3 expressed his concern that if "government spending" is excluded then South Africa's real GDP is "negative."

Emergent View 5.b: Impacts and influences.

As stipulated in **Emergent View 3.a**, the nature of the economy is changing to a largely service sector, although is still strongly influenced by the heavy industry electricity users. It was also expressed that there is currently a negative impact on the economy due to electricity availability and this has a widespread impact on the economy. As expressed by Respondent 3, the amount of "gigawatt hours sold since 2007 until now" compared to the amount of "job losses" experienced in the economy reflects that "no jobs being created in the economy" and until "the power supply system becomes stable, reliable and sufficient" South Africa "will continue to experience contraction in growth." Respondent 8 expressed his concern that the expanded definition of unemployment is reaching "35% to 40%," which is made up of a large portion of the population that "has given up looking for work" and "do not contribute to sectoral development," resulting in not just "informal activities but also "criminal activities that destabilise a country and the resulting decline in investment due to higher country risk."

Respondent 2 emphasised the "structural issues" present where the shift to a "services and consumption orientated economy is mismatched with the skills (matric or higher) that is needed within these sectors." Respondent 4 added that sufficient "access to skills, suitably qualified and experience people, directly inhibit growth in South Africa." Respondent 6 stated that South Africa needs foreign direct investment and foreign skills that can transfer intellectual capital but mining companies are uncertain of the possibility of owning assets." Respondent 2 stated that "outbound foreign direct investment is higher that inbound," which has a negative impact on economic growth.

From a global perspective, the indirect impact of commodity price decreases can have a devastating impact on the South African economy, where countries like "China's economy is approaching 0% growth and as China is seen as the world driver of economic growth" will not only have dire results for the South African economy, but could "spark off a global recession" (Respondent 3). Respondent 2 elaborated that "China's growth is declining, India's growth might go a little bit more than originally and if you look at Brazil's growth it used to be around 7% and it is now down to 2%." South Africa, which is largely dependent on their "mineral resources as main exports," which is affected by "commodities trade" from "China, India and Japan," could result in South Africa experiencing another "recessionary period" and from an electricity point of view "with sufficient supplies" due to "the global demand for commodities decreasing."

5.4.7 Theme 6 – Levelised technology costs

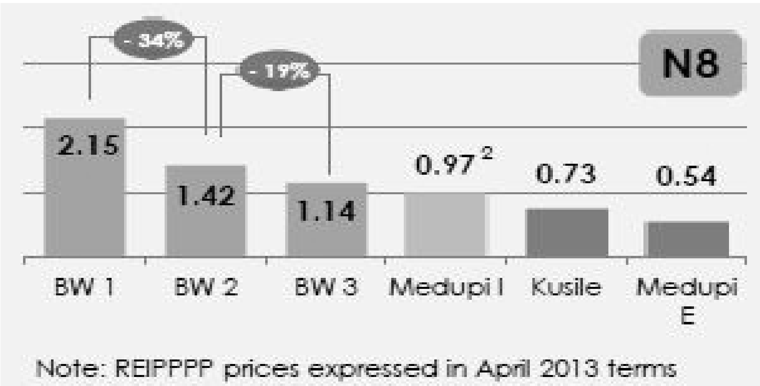
Across most of the interviewees, levelised technology costs reportedly declined (see Table 11) for renewables such as wind and solar as well as gas. The non-renewables of coal and nuclear have reportedly increased, perhaps indicating that renewables may become a more appropriate energy source option over time. One participant cautioned that renewables are still more costly, suggesting that although the costs have decreased, they are still not as cost-effective as traditional non-renewable methods. There were some considerations that the participants posited in terms of levelised technology cost comparisons, including affordability and the likely future costing of different types of energy sources.

Table 11: Frequency table: Emerging themes on levelised cost changes

Emerging views	Frequency	%	Theme classification
6.a. Reduction in Renewable Technology Costs	**30**	**77%**	Levelised Technology Cost
1. Insufficient Expertise	2	7%	
2. Drastic Change	1	3%	
2.1 Technological Advancement	1	3%	
3. Decline in Renewables	7	23%	
3.1 Future Projections Unclear	1	3%	
3.2 Competition Reducing Costs	3	10%	
3.3 Supply and Investment in Renewables	1	3%	
4. Gas Reduced	1	3%	
5. Lower Storage Costs	1	3%	
6.b. Other Technology Costs Changes	**6**	**15%**	
6. Nuclear Increased	1	33%	
7. Coal Increased	2	67%	
8. Thermal Unchanged	1	33%	
9. Renewables More Costly	1	33%	
9.1 Inadequate Assessment of Costs	1	33%	
6.c. Cost Considerations	**3**	**8%**	
10. Future Cost Orientation Required	1	33%	
11. Dependent on Energy Source	1	33%	
12. Based on Affordability	1	33%	

According to the latest report published by the IPP Office et al. (2015), renewable energy prices are increasingly competitive with conventional power sources. This downward trend, as depicted in Figure 5, is encapsulated in the prices decreasing within every bidding window. With the additional delays and cost overruns with the construction of Medupi and Kusile, renewable energy tariffs are increasingly becoming even more competitive.

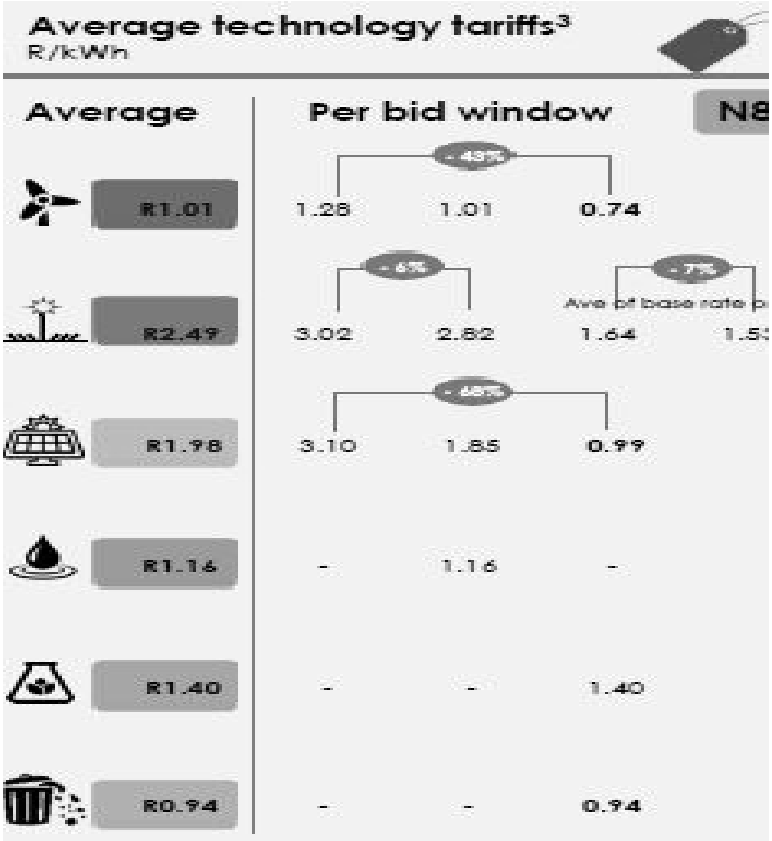
Figure 5: DoE levelised cost changes between bidding windows



Source: IPP Office et al. (2015).

Levelised cost change in specific technologies, as depicted in Figure 6, show the incremental decreases between bidding windows. This is ultimately supportive of the notion that technology cost changes due to technological advances, but, more importantly, due to competition in the market.

Figure 6: DoE levelised cost changes between bidding windows



Source: IPP Office et al. (2015).

Semi structured interview questions were utilised to obtain a view on the direction of levelised technology cost changes to facilitate the exploration of a 100% renewable energy mix for South Africa. The views and emerging trends from the industry experts and secondary data sources are consolidated in the following section.

Emergent View 6.a: Reduction in renewable technology costs.

With strong reference to the South African REIPP programme, most of the respondents have expressed their views on the reduction of renewable technology costs from the 1st bidding window to that of the last. Respondent 7 stated that "certain technology costs have come down remarkably" whereas Respondent 3 emphasised that levelised costs actually changed "dramatically." Respondent 2 expressed his surprise that certain technology costs like "wind and solar" have decreased "so much." Respondent 4 expressed the reduction of "wind and solar" in the REIPP domain, with Respondent 5 adding that "gas has also reduced." Respondent stated that "technology developments in shale gas" has "brought prices of gas down." Respondent 7 stated that "it's well known that solar costs have reduced" and "it's remarkable just how much wind energy costs have reduced." Respondent 8 added that "wind" could potentially "reduce more than current prices" and certainly has much more "potential for higher cost reductions in solar PV and in solar CSP." Respondent 7 stated that a "total myth" exists that "wind is now as cheap as normal fossil fuel coal-fired power" and could potentially be as much as "40%-50% more expensive" and solar almost "100% more expensive." This is due to the availability factor only reaching "25% to 30%" with the need to have "100% backup ready" to support.

Respondent 3 directed towards the actors that drive these changed with "advancements in technologies." Respondent 4 agreed that "technology plays a vital role" where certain wind turbine supplier costs, between bidding windows, being reduced by as much as 10% to 15%." Respondent 8 elaborated that "innovation, government support and market interest in a new technologies have really contributed in a massive incline in renewable energy technologies" where costs are driven down by introducing "more competition to this already competitive bidding ground." Respondent 2 agreed that "competition in the sector is very tough" and "where competition is strong, prices will come down." Respondent 4 agreed that "tariffs come down due to competition." Respondent 5 elaborated on the global competition in the solar market "between China and the US," with "state support to both industries" having "led to massive drops in the cost of solar panels." Respondent 2 added that some of the main drivers of technology cost reductions is the "scaling up of renewables" due to the "investment rate in renewables outpacing conventional power investments." Respondent 7 added that "what is particularly exciting is the price trends we are starting to see in energy storage and how that has reduced."

According to the Department of Energy's IPP office, "prices contracted under the REIPPPP for all technologies are well below the published REFIT prices. The REIPPPP has effectively translated policy and planning to deliver clean energy at very competitive prices. As such it is contributing to the national aspirations of secure, affordable energy, lower carbon intensity and a transformed 'green' economy." (IPP Office, 2015)

Emergent View 6.b: Other technology cost changes.

Respondent 5 stated that the levelised costs for "nuclear has increased" whereas Respondent 2 elaborated that the costs for coal "have increased" due to "capital and fuel costs." Respondent 6 stated that levelised costs for coal have "increased substantially" due to environmental obligations not being included in the levelised cost calculation previously." Respondent 2 expressed his concern in using a "least cost" method for making technology choices for energy generation, as this could potentially "limit the way you can make very strong and proper decisions" and what is recommended that your model incorporate a "more dynamic view, where you took the present and future into account and the other risks associated with different technologies" would result in "a more robust sense of which technology choices would be best."

5.4.8 Theme 7 – Technologies of focus

Many of the responses trended around focusing on various aspects of renewable energy, though some suggested that, due to the access and availability of coal resources, South Africa continue utilising the resource. It was suggestive that coal should be phased out over time to allow for the transition to renewables, with gas as supplement for the variability. Of those that mentioned nuclear power, most indicated concerns over this approach, particularly in terms of safety and the ability to manage such plants. According to News24 (2015), nuclear is not needed and the only government motivation for going forward with this deal is power. Slivyak, as cited by News24, (2015), which leaked the Russian Intergovernmental Framework agreement to South Africa, stated that the drive for nuclear power has less to do with energy as opposed to political/geopolitical power and that the evidence proves that nuclear power is far more costly than renewable. The commission of these nuclear reactors can be as much as 30 years in some cases, whereas renewables are a fraction of the time. Slivyak et al., as cited by News24, (2015), elaborated that no country in the world has successfully been able to deal with nuclear waste and associated environmental concerns and nuclear power ultimately creates a dependency on the supplier for decades. Hallowes, as cited by News24, (2015), stated that nuclear will bankrupt the country.

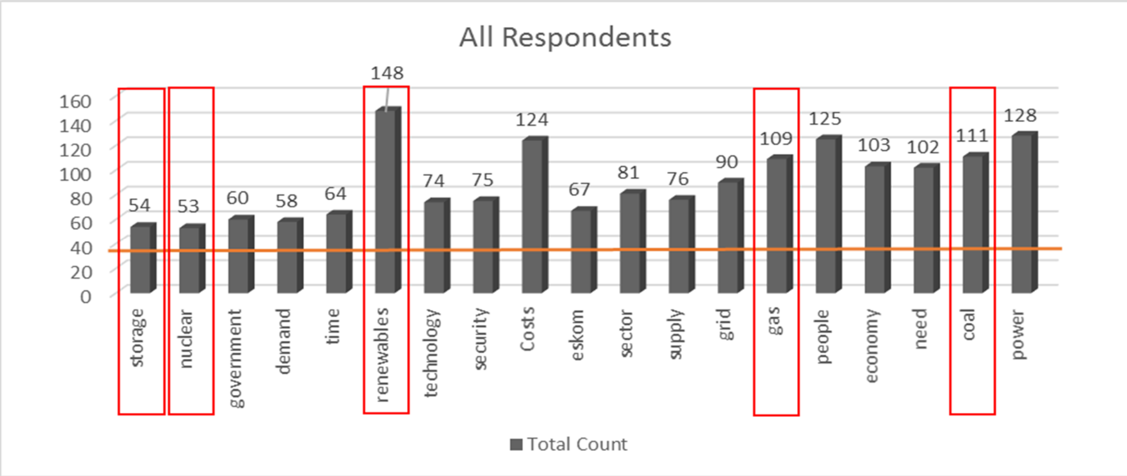
Generally, it appeared as though the participants would like to see greater penetration of renewables, but that this transition will be gradual over time. The respondents suggested a combination of energy sources in the short to medium term to ensure sufficient supply as the transition unfolds. Table 12 directs focus towards the emerging themes and the underpinning sub-elements supporting the associated weightings.

Table 12: Frequency table: Emerging themes on technologies of choice for South Africa

Emerging views	Frequency	%	Theme classification
7.a. Renewable energy as choice	**10**	**20%**	Technologies of Focus
1. Renewable Energy	7	70%	
1.1 Grid Integration Limitations	1	10%	
1.2 Localised Generation and Storage	1	10%	
1.3 Limited Use	1	10%	
7.b. Non-Renewable energy of focus	**27**	**54%**	
2. Nuclear Energy	1	4%	
2.1 Safety Concerns	3	11%	
2.2 Construction Time	2	7%	
2.3 Costing	1	4%	
2.4 Nuclear Inappropriate	3	11%	
2.5 Skill Deficit	1	4%	
2.6 Political Influence	1	4%	
3. Superior Life Span	1	4%	
4. Limited Nuclear	1	4%	
5. Coal	3	11%	
5.1 Accessibility	2	7%	
5.2 Stability of Supply	1	4%	
5.3 Procurement Policies	1	4%	
5.4 Transition Away from Coal	4	15%	
5.4.1 Total Renewables Currently Inappropriate	1	10%	
5.4.2 Expense of Customers	1	4%	
7.c. Combination of Sources	**13**	**26%**	
6. Natural Gas	6	46%	
7. Underexploited	1	8%	
8. Diverse Supply	1	8%	
8.1 Reliance on One Institution for Supply	1	8%	
9. Mixture of Renewables and Gas	4	31%	

Word count analysis revealed the weighting that respondents allocated to the various categories under discussion. As mentioned previously, this measure is merely utilised to obtain an indicative gauge of the level of importance as viewed by the respective industry experts. As see in Figure 7, the largest weighting is associated with nuclear, renewables, gas, and coal.

Figure 7: Word count analysis resulting in the top 5 technology of focus when considering a generation profile



Although strong conviction from the interviewees around the future on-going role that renewables, gas, and coal will play, it is indicated that nuclear is not the best technology of choice for South Africa due to the health and safety concerns, skills needed in this technology, and the historically bad track record of South Africa.

Semi-structured interview questions were utilised to obtain a view of the technology choices that would best suit an electricity generation profile for South Africa. The views and emerging trends from the industry experts and secondary data sourced are consolidated in the following section.

Emergent View 7.a: Renewable energy as choice.

There was a generic theme emerging from the interviews that greater focus should be placed on considering renewable energy as generation technology choices. Respondent 5 stated the renewables are “the lowest cost of energy” and that renewable should play a much larger role “in the future” due to it being “the cheapest option for the country” and “given the energy situation in the country at the moment, the only thing that can really be scaled up rapidly, of which we have got good experience, is renewables” (Respondent 2). Respondent 4 added that larger focus should be placed on “wind and solar,” and Respondent 3 added that “renewable energy” is the technology of choice. Respondent 8 stated the technologies to focus on include “wind, solar PV and solar CSP.” Respondent 2 stated that his “preferred technology choice is “renewables” due to short lead times when considering other technologies like “gas and nuclear plants.” Respondent 1 directed focus towards the revised Integrated Resource Plan that “was never approved by cabinet” that incorporated scenarios like “big gas.” This big gas scenario incorporates “massive renewables” that is augmented by enough Open Cycle

Gas Turbines to the supplemented the “variability of renewables.” Respondent 2 warned that “after a 15% to 20% renewable energy threshold” that “grid balancing and back up becomes a big issue, whereas Respondent 6 contested that there isn’t space for more than “1,000MW of wind and solar” and the renewable energy should be kept at a ”lower end.” Respondent 7 directed focus towards “rooftop solar” with the “introduction and incorporation of storage” at “household and local utility” level to generate electricity “right where it is needed.”

Emergent View 7.b: Non-Renewable energy of focus.

Respondent 1 stated that for baseload requirements, strong focus should be directed towards “nuclear,” whereas Respondent 4 expressed concerns around the “health and safety risks in nuclear” due to the “quality of suitably skilled and experienced people that can manage risk around the technology.” Respondent 1 expressed disinterest in “nuclear,” not due to “distrust in the technology,” but rather in the “safety impact on people from nuclear and nuclear accidents.” Respondent 6 added that due to the cost, “excessive nuclear is not an option,” but in order to promote energy security South Africa potentially needs “two nuclear power stations delivering up to 3,000MW.” Although “generation capability between 40 to 60 years, once completed,” Respondent 1 expressed his concern around nuclear “costs” and the associated “risk on price due to non-delivery of plants on time,” as the “average time for construction has shifted from 5 to 7.5 years.” Respondent 8 stated South Africa does not deliver large scale generation projects “on time and on budget,” “Medupi and Kusile” case and point, and is quite concerned that government is looking at “9,600MW” of “nuclear generation build.” Respondent 5 stated that “nuclear is not a sensible bet” and Respondent 4 confirmed that South Africa “should not drive nuclear.” Respondent 2 stated that nuclear has the potential of “high cost over runs” and Respondent 7 supported that “the long bill times and poor track record that government run projects, around the world, have with regards to bringing projects in on time and on budget” does “not make nuclear a sensible technology choice.” Respondent 4 finalised that “political greed” is a main driver for nuclear and that South Africa should be “wary” of this technology choice.

Respondent 1 expressed that coal still remains the technology of choice, as “the coal is under our feet, we do not import” from other countries and is not influenced by “currency volatility.” Respondent 6 expressed that countries utilise resources of which they have “a comparative advantage” and in the case of South Africa, it is “coal.” Respondent 1 stated that the South African economy “needs large amounts of power supply” that is “stable, constant, available” and that “coal can provide the required baseload.”

Respondent 4 added that South Africa is “rich in coal and should be a focus point” when deciding on the optimal energy generation mix. Respondent 8 stated that South Africa has “competitive advantage” with coal, it is “minable” and that it has “always been used and most likely always will be.” Respondent 7 added that South Africa “probably has another 50 years of coal fire generation ahead” and suggested that “building any additional coal fire generation capacity” be stopped. Respondent 2 stated that South Africa needs to “diversify away from coal and look at options like renewables, nuclear, and gas as other alternatives.” Respondent 8 suggested that “gas is a transitionary energy source, together with coal, as South Africa moves towards a more renewable path.” Respondent 5 strongly suggested that South Africa “transition to gas, beyond gas, and away from coal.”

Strong focus was directed from the interviewees towards gas and a larger role that gas should play in the future electricity generation profile of South Africa. Respondent 1 stated that “gas” is the “next big” technology of focus. Respondent 5 added that South Africa needs “large amounts of gas that would stimulate the development of a gas industry and the associated exploration of gas production.” Respondent 4 stated that South Africa needs to focus on “gas and fracking” in addition to “expanding infrastructure for importing gas in the medium term.” Respondent 7 stated that South Arica should “be building two or three gas-powered stations as a matter of urgency” by using “imported gas initially,” which is later substituted with “offshore gas or the potential of shale gas in the Karoo.” What remains a “mystery is to why South Africa has not procured gas or booked a block of gas?” where countries like “Japan, India, Korea and China has already procured or booked supply” (Respondent 1).

Although the focus on gas is strongly supported by the interviewees, Respondent 7 warned that South Africa “needs to use their resources in a logic and sensible way.” Respondent 5 suggested that “the classic answer is to have diversity of supply” as “having too much reliance or exposure on any one technology for supply is dangerous.” Respondent 2 suggested “focus on integrating renewables and gas as a hybrid mix,” as this will provide a very good “interim and even medium term solution” allowing for “higher supply from renewables.” Respondent 7 supported this notion in that South Africa should use “gas fired generation capacity to supplement the renewable energy resources” over a “20 or 30 year period.”

5.4.9 Theme 8 – 100% Renewable energy generation profile

The participants' perceptions largely suggested that a 100% renewable energy mix is not currently feasible, though likely attainable in the long term. Some questioned whether it is entirely necessary to achieve this, citing the availability of resources, such as coal, that are cheaper and accessible to the country. Others reported that a number of factors would have to fall into place in order to achieve a 100% generation profile, which included adequate supply to meet demand and the advancements in technology (e.g., storage ability and costs). Although a number and variety of different constraints were identified, it would appear that the most substantial constraint relates to whether the issue of energy storage can be resolved, which seems to be an area of concern when considering renewable energy. Some indicated that although there are constraints, the 100% mix is attainable, though there was one report that it is simply unattainable.

Table 13: Frequency table: Emerging themes on achieving a 100% generation profile and technologies other technologies of focus

Emerging views	Frequency	%	Theme classification
8.a Feasibility / Necessity Questionable / Factor Dependent	**25**	**63%**	100% Renewable energy generation profile
1. Unconvinced of Attainability	6	24%	
2. Economic Structure	2	8%	
2.1 Necessity Questionable	1	4%	
3. Dependent on Supply and Demand	2	8%	
4. Dependent on Role of Renewable Energy	2	8%	
5. Renewable Energy Supply Dependent	1	4%	
6. Reduction in Environmental Impact	1	4%	
7. Technology Dependent	1	4%	
8. Suggestions of Possibility	1	4%	
9. Long-term Feasibility	4	16%	
10. Potential Attainment	3	12%	
11. Cost Dependent	1	4%	
8.b. Storage	**7**	**18%**	
12. Cost of Storage	1	14%	
13. Distribution of Generation and Storage	2	29%	
14. Storage Ability / Effects	3	43%	
15. Batteries	1	14%	
8.c. Areas of Exploration	**8**	**20%**	
16. Infrared / Thermal / Heat / Technologies	2	25%	
17. Exploration of "Mini" / Grids / Decentralised Grids	3	38%	
18. Pump Storage	1	13%	
19. Expense of Remote Lines	1	13%	
20. Proportional Mix of Gas, Nuclear, Coal, and Renewables	1	13%	

A number of interesting types of technologies that may be focused on were reported with a host of potential options to explore for not only achieving greater levels of renewable energy but also energy security as a whole. Table 13 provides a detailed breakdown of the emerging themes and supporting sub elements driving the emergence of these themes.

Table 14: Frequency table: Emerging themes on budget allocation and R&D focus

Emerging views	Frequency	%	Theme classification
8.d. Policy and Public-Private Partnerships	**3**	**14%**	Budget focus
1. Policy and Legislature	1	4%	
2. Stimulate Private Involvement	1	4%	
2.1 Engage Private Sector for Energy	1	4%	
8.d. Policy and Public-Private Partnerships	**2**	**10%**	
3. Skills and Capacity	1	4%	
4. Reshaping Electricity Perceptions	1	4%	
8.d. Avoid R & D Focus	**9**	**43%**	
5. None	1	14%	
6. Requires a Functional Grid	1	14%	
7. Resolutions Required	1	14%	
8. Country to Focus on Strengths	1	14%	
9. Outside of Renewable Energy	2	29%	
10. Global Effort Required for Resolutions	1	14%	
11. Attract and Develop Global Partnerships	2	29%	
8.d. Financial Considerations	**4**	**19%**	
12. Limited Funding Capacity	1	13%	
13. Security and Affordability	2	25%	
14. Unnecessary Expenditure Currently	1	13%	
8.d. Renewables	**3**	**14%**	
15. Maintenance and Integration of Renewables	1	13%	
16. R & D Investment Important	1	13%	
17. Localised and Personalised Storage	1	13%	

Interestingly, many of the participants indicated that the focus of the national budget be outside of renewable energy research and development and should rather be directed towards the strengths and particular interests pertinent to South Africa. This focus should be directed towards policy and legislature aspects involving private entities, education in the public sector, and the development of skills. Some, however, reported the necessity to invest in renewables and research and development, with others noting the inherent financial limitations or constraints currently, with the need to spend money more effectively and make more appropriate budget choices. Table 14 provides a detailed breakdown of frequency tables pertinent to the relevant emergent themes.

Interview questions asked to the respective respondents were aimed at gathering an opinion and/or view on the possibility of a 100% renewable energy generation profile for South Africa. The views and emerging trends from the industry experts and secondary data sources are consolidated in the following section.

Emergent View 8.a: Feasibility / Necessity Questionable.

There was a collective view that a 100% energy generation profile is currently not yet achievable for South Africa. Respondent 1 stated doubt with "I am yet to be convinced that it is realistic," where others added that "it is unrealistic" (Respondent 3), "it is not realistic" (Respondent 6), "in the short term, definitely not" (Respondent 8), and "theoretically it is possible but practically most likely not" (Respondent 4). Respondent 2 added that "theoretically it looks very feasible" but due to "technical, policy regulatory, and financial hurdles" it is not "feasible in the immediate future." Respondent 7 stated that "if it is going to happen not for at least another 20 - 50 years." Respondent 4 directed focus towards the structure of the economy in that South Africa has an "industrial economy" and Respondent 3 elaborated that "if you still want to talk about beneficiation and industrialization you will never get to it a 100%." Respondent 7 questioned the necessity of having a 100% renewable generation profile, with "would it necessarily benefit our economy and South Africa as a nation?" Respondent 5 stated that "there are many parties going around stating that" a 100% renewable generation profile is "achievable" and that "South Africa does have fantastic sun." Respondent 4 added that if one should model "all the wind and the solar in the country, combine the technologies and determine the total percentage of total potential generation in megawatt hours that can be produced," one would be "surprised by results of how much it really is." Respondent 5 added that South Africa has "surprisingly good wind resource and that the potential to achieve a very high level of renewables penetration and ultimately transition to 100% renewable world is much higher than we might think at the moment."

Most of the respondents stated that, in the short term, a 100% generation profile is most likely not achievable, whereas Respondent 5 elaborated that "one has to look at this in the context of the timeframes involved" and that "nobody sensible is saying it can be done tomorrow." Respondent 2 added that "in the long term with a good match of demand, supply and a more sophisticated or smarter grid, theoretically it looks like it is a feasible idea." Respondent 2 added that in the "long term South Africa will have a better sense of new technologies, from grid storage and also improvement in the performance of renewable technologies."

Emergent View 8.b: Storage.

The largest contributing factor leading to not achieving a 100% renewable generation profile is due to the variability of renewable energy sources, as Respondent 1 stated that "until storage is cheaper it is not realistic" and Respondent 7 strengthened this view with "it is not feasible until we develop low-cost storage. As storage gets solved you enter a very different world." Respondent 5 added that "battery storages are more likely to crack the cost curves for the simple reason that batteries are used more widely and battery technology is developing faster than heat storage." Respondent 4 added that "whatever the storage type is will lead to a completely different demand profile that South Africa had not experienced previously and that will have an impact on baseload capacity." Respondent 1 stated that "some of the renewable technologies do have storage that is not too bad" where heat is stored in "molten cells" that can be accessed when the renewable source are not available. Respondent 5 elaborated that "storage technologies are not mature enough right now. If one looks at the movement in storage, it really is moving along and there are very big, very serious players investing very large amounts of money in storage" and that the "curve will shift in a kind of the same way that the renewables curve has shifted."

Emergent View 8.c: Areas of exploration.

Although there was no consensus on the approach for focussing on other areas of energy development, there was a general consensus on the availability of options that could potentially be explored. Respondent 4 emphasises that the only feasible solution to achieving a 100% renewable generation is "off grid solutions" with "micro little grids, not attached to the main grid and with storage." Respondent 5 added that there are "smart grid" solutions that allow for "much better management of the power sector if entrepreneurs were allowed the space to get more involved." Respondent 3 stated that one option "that has not been explored, with huge potential in South Africa, are mini off grids. Many small communities can be fed from mini off grids." Respondent 2 directed focus towards a decentralised model that allows for "diverse generation outside of utility" where "multiple generators (households or commercial buildings or industrial users), on much smaller scale, usually below 100MW, are able to integrate surplus supply into the grid if they are allowed access." Respondent 2 suggested options that would "improve on bringing the costs down of solar thermal baseload potential that would realise even higher levels of penetration of renewables." Respondent 4 stated that more work can be done on "investment in pump storage," Respondent 7 added that "working on the ultra violet spectrum of the radiation spectrum, work more on the infrared which would allow them to generate technology at night as well, because of most bodies emit infrared energy," "waste heat recovery" and "thermal technology." Respondent 7 concluded that what needs to be focussed on is "bringing in barges for gas electricity."

Emergent View 8.d: Budget allocation and R&D focus.

Questions where directed to extract a view from the respective respondents on the allocation of national budget towards renewable energy research and development. Although there were numerous areas identified that required national budget allocation, a central theme from the respective interviewees was not identified.

Respondent 1 stated that government should direct larger focus and budget allocation toward the "policy and legislative environment" that would allow for "greater participation from the private sector" as opposed to directing any budget towards renewable energy research and development. Respondent 4 added that government should "redirect money into buying electricity from the private sector and let the private sector do the necessary R&D." Respondent 3 stated that "zero" budget be allocated towards renewable energy research and development and rather focus on allocation towards "strengthening the grid, as not having a functioning grid will not allow for any renewable energy to be accept onto it." Respondent 7 stated that "government should not be pushing on the R&D side as there are already a lot of work going on out there (world)." Respondent 5 stated that South Africa should "be concentrating on its strengths as a country, in the science and technology space, and direct R&D spend towards those strengths" due to South Africa's strengths "not being in the renewable energy space." Respondent 2 elaborated that South Africa has to "accept that the ability of government to be able to spend a lot on R&D and renewables, is limited." Respondent 8 added that South Africa has "to invest in R&D" but actually "be looking very closely a producing cleaner coal" for baseload. Respondent 1 stated that "a lot that can be done in terms of energy security and getting affordable energy to more of our people" and that "energy security that allows energy access to the rest of the 15% of South Africans, is more important in the next 10 years, that going a 100%." Respondent 7 added that "R&D should be focused on improving the operations and maintenance of renewable energy technologies, integrating renewables and electricity storage into the grid and optimizing that concept" and where South Africa "is losing a lot of money is having to sign operations and maintenance contracts with foreign companies, as oppose to doing it ourselves."

Respondent 5 stated that "these are global problems and there is a very big global push to crack them. This is the kind of technology that moves around fairly easily across borders so we don't need to solve these problems." Respondent 2 strengthens this view with what South Africa needs to do is be "in collaboration with countries looking to scale up these technologies, where we are in a partnership with them, where we are learning to understand the performance improvements that can be obtained. We are never going to be in a situation where, without partnerships, South Africa is going to be able to lift again on just our own R&D spend." "The only way we can attract or improve on the situation is to work with big original equipment manufacturers, attract them into the country, get them to do some of the R&D spread in the country" where the "partnerships with these other emerging economies, like China, have flexibility to use larger budget" to drive renewable research and development (Respondent 2).

CHAPTER SIX: DISCUSSION OF RESULTS

6.1 Introduction

This chapter discusses the data gathered and the findings that emerged from the interview and coding process, as presented in Chapter 4. These findings are compared to the Chapter 2 literature review and discussed in accordance to the three main research propositions in the study. The purpose of the study was to: 1) determine whether the South African energy policies are current and reflective of stakeholders' assessments on energy security, 2) determine whether the South African economic growth and energy consumption historic relationship of 3:2 is out of, and 3) determine whether South Africa can achieve a 100% generation profile from renewable energy. This chapter concludes with a discussion of the overall results.

6.2 Research proposition 1

The South African energy policies are current and reflective of Stakeholder assessments on energy security.

The purpose of this section was to evaluate the South African policy definitions of energy security and to determine if those definition are still valid. The validity of these definition were benchmarked against the views as expressed by the pertinent respondents' opinions.

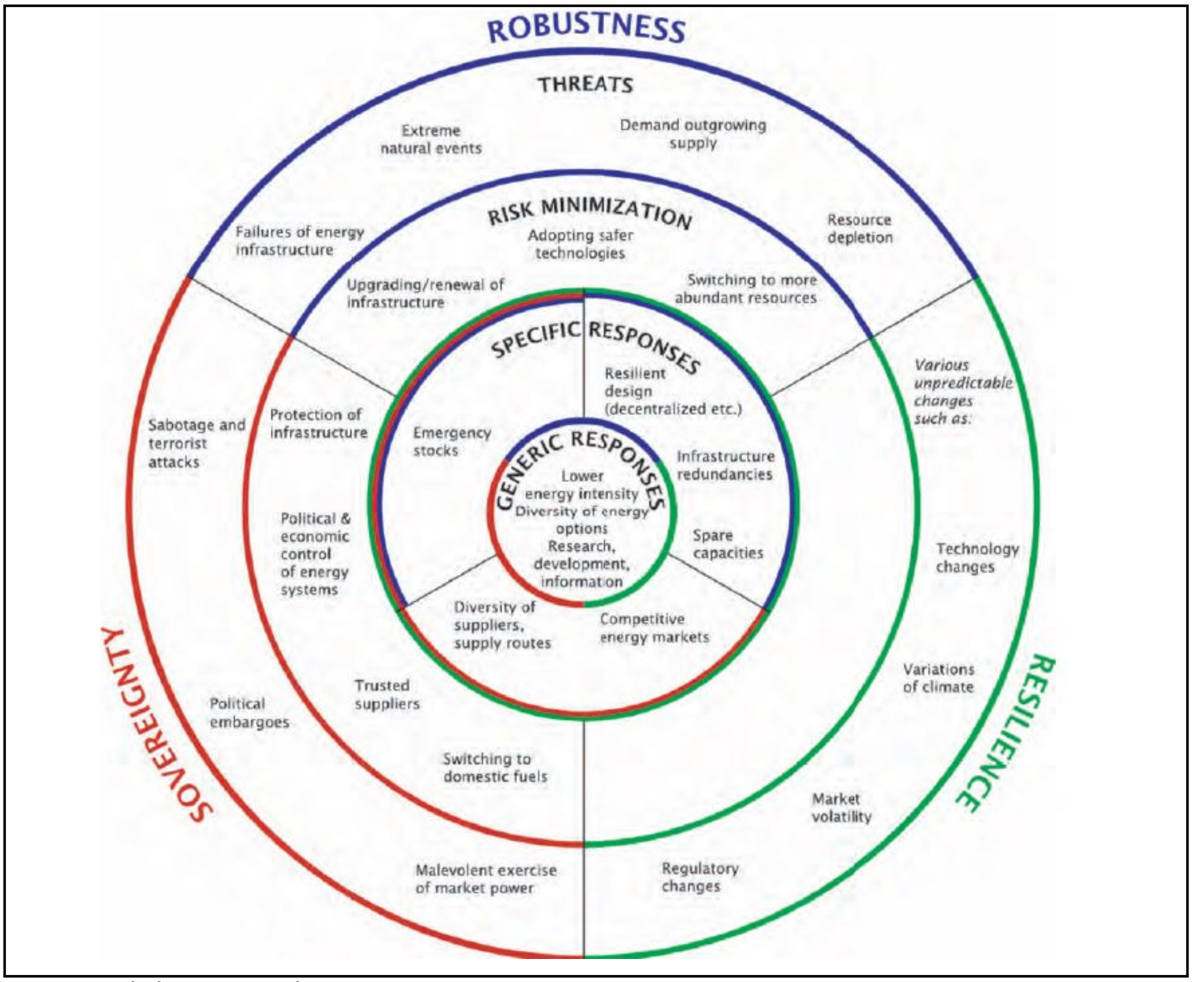
Energy security

According to Cherp et al. (2014), energy security is defined as "low vulnerability of vital energy systems" and has historically been viewed as protection against disruptions of essential energy systems and services. Cherp et al. (2012) stated that energy security is linked to risks and protection from these risks are mitigated with independence, reliability, resilience, availability, accessibility, affordability or sustainability of energy systems. Types of risks include natural *(resource scarcity, extreme natural events)*, technical *(aging infrastructure, technological accidents)*, political *(intentional supply or technology restrictions, sabotage or terrorism)* and economic *(high or volatile prices)* factors. As depcited in Figure 8, three perspectives of energy security exist that directly link to distinct policy strategies. These persepctives are robustness, sovereignity and resilience:

- Robustness is focussed on the protection from disruptions originating from predictable natural, technical, and economical factors such as resource scarcity, rapid rise of demand, aging infrastructure, or rising energy prices.

- Resilience is focussed on the protection from disruptions originating from less predicatable factors such as political instability, game changing innovations, extreme weather events, flexibility of demand, and institutions capable of adequatly adjusting to disruptions.
- Sovereignity is focussed on the protection from disruptions originating from intentional actions of political powers and strong market agents. Sovereignity suggests energy independence (reliance on domestic resources and technologies) and the ability to control the behaviour of energy systems (control over infrastructure, stable prices, and trusted institutions).

Figure 8: Three perspectives on energy security. Threats and risk minimising strategies



Source: (Cherp, 2012).

As stated within the literature section of this study, some of the prominent characteristics associated with energy security, in the short term, is the readiness of the current infrastructure to meet load requirements *(Robustness)*, whilst the supply adequacy, in the long term, is associated with the ability of the system to attract investment in generation, transmission, distribution, metering, and capacity control that affect supply costs and price *(Robustness, Resilience, and Sovereignty*; Creti et al., 2007). Jamasb et al. (2008) expressed that availability and price risk affect energy security *(Robustness)*, whilst Lieb-Doczy et al. (2003) stated energy security is a result of systems with reduced risk of interruptions *(Robustness, Resilience, and Sovereignty)*. According to the interpretations of the interview respondents' comments, which is discussed in Theme 1 in Chapter 4, generic characteristics energy security need to demonstrate is the availability to meet demand requirements, must be reliable, be affordable, should promote economic growth, is dependent on a functioning grid, dependent on available resources and is ultimately supported by driving policies and enabling mechanisms *(Robustness, Resilience, and Sovereignty)*. There is a general consensus emerging from the literature and the respondents' annotations that energy security is directly influenced by characteristics like availability, reliability, and affordability and is also found at the core of energy security. The literature additionally suggests that the energy system needs to be able to attract investment in generation, transmission, distribution, metering, and capacity control to regulate cost and price, which, ultimately, is supported by the views of the respondents in that an energy system is dependent on a functioning grid. The respondents elaborated that an energy system is dependent on driving policies and enabling mechanisms that would promote energy security, and, ultimately, economic growth. Strong focus is directed towards all three perspectives *(Robustness, Resilience and Sovereignty*) of an energy system.

According to Cherp et al. (2014), the evolution from the classic to contemporary period in energy security has seen the introduction of more dynamics forces (energy sectors, resources, markets, technologies, environmental degradation, climate change mitigation, and access to electricity) that contribute to the non-comparability of the concept or a worldwide industry standard design. This is partially due to the situational connotations allocated to energy security depending on the geography, region, or country specific circumstances impacting energy security.

Engaging in energy security discussions or the conceptualisation of energy security within a particular geographical context will allow for the emergence of the dynamic idiosyncrasies or factors that drive or threaten energy security within that specific context. Emerging from the respondent interviews, which is discussed in Theme 2 in Chapter 4, strong emphasis was placed on the importance of the South African energy system to:

- Match demand (availability) requirements *(Robustness),*
- Eradicate energy resource (diversification) dependence *(Robustness)*, and

- Adequate system policy (government role) and mechanism *(Sovereignty).*

These elements are seen to be the current pressing matters affecting energy security in South Africa and address the Robustness and Sovereignty perspectives, as depicted in Figure 8. South Africa energy security definitions are extracted from the following policies:

- The publication of the White Paper on Energy's (1998) focus was redirected to ensure *adequate supply* to previously ignored portions of the population. The White Paper on Energy (1998) expanded to included five main focus areas into the energy security definition that consisted of *affordable* energy services, greater *integrated policy development and service delivery*, encouraging *fair competition* in energy market enabling *economic development*, *environmental* impacts and energy *supply security*. Within this context, all three perspectives (Robustness, Resilience, and Sovereignty) are addressed with the additional expansion of environmental and social welfare not covered by the model designed by Cherp et al. (2014).
- The South African Energy Security Master Plan (2007) defines energy security as "ensuring that *diverse energy resources* in *sustainable quantities* and at *affordable* prices, are available to the South African economy in support of *economic growth* and *poverty* alleviation, taking into account *environmental* management and requirements and interactions among *economic sectors*." (p. 5). Within this context, two of the three perspectives (Robustness and Resilience) are addressed with no mention of policy development that addresses the Sovereignty perspective. Environmental and social welfare are also addressed that is not explicitly covered by the model designed by Cherp et al. (2014).

Trollip et al. (2014) stated that the South African Energy Security Master Plan (2007) energy security definition, although supportive of poverty, environment, and affordability, is out of date, as it is primarily concerned with energy resources and energy supply, with the economy as the recipient of energy resource outputs. From a consolidated view, and as stipulated in Table 15, resources, at 19%, and supply, at 25%, remain the two most prominent elements when considering generic characteristics of energy security. From a South African perspective, resources, at 14%, and supply, at 19%, were included as the two biggest drivers of energy security following systems policy and mechanism, at 56%. Resources, at 14%, were reported as the second largest threat to South African energy security following systems policy and mechanism, at 86%. Based exclusively on resources and supply, the argument that the current energy definition being out of date cannot be supported as this still remains at the core of energy security as expressed by the emerging views form the respondents.

Table 15: Emerging energy security characteristics as per interview

		South African characteristics %	
Emerging views	**Generic characteristics %**	**Drivers South Africa %**	**Threats South Africa %**
Electricity supply needs to match demand requirements / availability of supply	**25%**	**19%**	**0%**
Financial implications of electricity supply security	**17%**	**6%**	**0%**
Electricity supply needs to be reliable	**8%**	**0%**	**0%**
Supply security to promote economic growth	**11%**	**6%**	**0%**
Electricity security is dependent on a functioning grid	**6%**	**0%**	**0%**
Electricity security is dependent on the energy resources	**19%**	**14%**	**14%**
Electricity security is dependent on system policy and mechanism	**14%**	**56%**	**86%**

Both the White Paper on Energy (1998) and the South African Energy Security Master Plan (2007) cover a large majority of the required characteristics reported by the responses in the interviews and the coding process.

Table 16: Analysis of policy definitions of energy security

Policy	Generic characteristics %	Drivers South Africa %	Threats South Africa %
White Paper on Energy, (1998)	**67%**	**86%**	**86%**
affordable energy services	17%	6%	0%
integrated policy development and service delivery	14%	56%	86%
encouraging fair competition	0%	0%	0%
economic development	11%	6%	0%
environmental impacts	0%	0%	0%
supply security	25%	19%	0%
South African Energy Security Master Plan, (2007)	**72%**	**44%**	**14%**
diverse energy resources	19%	14%	14%
affordable prices	17%	6%	0%
available to the South African economy	25%	19%	0%
economic growth and poverty alleviation	11%	6%	0%
environmental management	0%	0%	0%
interactions among economic sectors	0%	0%	0%

The White Paper on Energy (1998) covered 67% of the generic required characteristics, as reported by the literature and the respondent interviews. Interestingly the drivers and threats of South African energy security covered 86% of the required reported characteristics encapsulating the largest element of system policy and mechanism. The South African Energy Security Master Plan (2007) covered a larger, 72%, component of the generic required characteristics, but does not encapsulate the role of system policy and mechanism. One of the key divers and threats towards achieving energy security, from a South African perspective, is the role of government in ensuring adequate systems policy and mechanisms. Trollip et al. (2014) stated that the energy system will not be able to attract the necessary investment to resuscitate itself if government does not manage to generate consensus between key members and other stakeholders and if an agreed vision and necessary regulatory power to command support is not established. Respondent 1 stated that “the energy policy in the country has nothing wrong with it, government just didn’t use it. So the white paper says all the right things, so the policy is right. What is missing is the legislation and the acts of parliament.”

Conclusion

The views expressed by the respondents on energy security and the underpinning elements that shape, influence, drive, and threaten energy security in South Africa are effectively represented in the definitions stated in the White Paper on Energy (1998) and South African Energy Security Master Plan (2007) from a generic perspective. The White Paper on Energy (1998) encapsulated the largest elements of South Africa’s country specific energy security characteristics. The South African Energy Security Master Plan, (2007) did not cater for the role of government in ensuring the design and effective implementation of system policy and mechanism. Based on these results and the date of publication of policy definitions, the South African Energy Security Master Plan (2007), which is the most current, is out of date and not current nor reflective of stakeholder assessments on energy security.

6.3 Research proposition 2

The South African economic growth and energy consumption historic relationship of 3:2 is out of date.

The purpose of this section is to evaluate the current economic growth and energy consumption relationship to establish whether the historic 3:2 relationship, as stipulated by the DoE and utilised as direct input into the Integrated Resource Plan of 2010, is still valid. The validity of this ratio was benchmarked against the views, as expressed by the pertinent respondents’ opinions, of the underpinning factors that influence, drive, and threaten the economic growth and energy consumption relationship.

Economic growth and energy consumption

When considering the relationship between economic growth and energy consumption, four types of hypothetic effects have been identified in the literature. As stipulated in section 2.2 of the literature review, these four hypothetic effects are:

- Growth hypothesis – A one way causality exists between energy consumption and economic growth.
- Conservation hypothesis – A one way causality exists between economic growth and energy consumption.
- Neutral hypothesis – No causality exists between economic growth and energy consumption.
- Feedback hypothesis – A two way causality exists between economic growth and energy consumption (Apergis at al., 2010; Dogan et al., 2014; Fatai et al., 2014, Menegaki et al., 2014).

According to Wolde-Rufael et al. (2005), no causality existed between economic growth and energy consumption in South Africa for the period 1971 – 2001, whereas Odhiambo et al. (2009) argued that a unidirectional relationship existed for South Africa during 1972 – 2006, and Esso et al, (2010) stated that a substantial long run relationship existed between economic growth and energy consumption. According to the annotations decoded following the interview process, and discussed in Theme 3, Emergent View 3.a. in Chapter 4, there was no conclusive outcome of the causal relationship between economic growth and energy consumption.

"The relationship is positively correlated and where the economy grew, the gigawatt hours grew" Respondent 1.

"GDP growth does not drive energy consumption, energy availability drives GDP growth" Respondent 4.

"A very clear relationship exist between economic growth and energy or power consumption" Respondent 5.

"Some might say that the relationship is not always clear cut but all the evidence points towards the relationship in South Africa currently being one way, and that electricity capacity will boost economic growth" and "it is definitely one of the primary factors that is constraining economic growth" Respondent 8.

The respondents did, however, agree that the relationship between these two elements exists, that they are most likely correlated and supported the notion that there is no unilateral consensus amongst economists, researchers, analysts, and policymakers on the causal relationship between economic growth and energy consumption, although it is generally agreed that they are related (Freed et al., 2005). As stated previously, determining the causal relationship between energy consumption and economic growth is of pivotal importance when deciding on the relevant energy policies (Ouedraogo et al., 2013).

The National Development Plan suggests that the economy needs to be improved from the historic 3.3% growth rate to that of 5.4%. The Department of Energy stated that the historical GDP growth and electricity consumption relationship is 3:2 (National Planning Commission, 2011), which translates to 3% GDP growth requiring 2% electricity growth. This historic relationship has been utilised as a direct input in the Integrated Resource Plant, 2010, which would suggest that any market related changes on demand, supply and resource requirements would influence this ratio.

According to the World Energy Outlook, (2014), growth in GDP should de-link from growth in energy consumption as the economy shifts away from an energy-intensive phase of development. It was generally agreed that the South African economy is shifting from a heavy industrialised phase to that of a service economy.

"The nature of the economy is shifting more and more towards a service sector (a less intense form of economic activity) but does not suggest a decoupling of this relationship but merely a decline in energy intensity" Respondent 5

"Heavy intensive users (chrome, ferrochrome, manganese smelters) are declining" Respondent 1

"South Africa is de-industrialising which would result in energy intensity declining" Respondent 4

Some participants expressed optimism in their views and reported growth in certain areas of the economy with others reporting growth as stagnant or declining. According to Statistics South Africa et al. (2015), South Africa is experiencing contraction in the economy (mining, agriculture, manufacturing, electricity, and trade) and insufficient electricity supply further contribute to banks becoming more adverse in lending to investors in heavy industries (Risk Management South Africa, 2015). This, in turn, will have additional negative impacts on the economy, leading to more contraction.

The respondents further expressed that South Africa is experiencing a mixed growth economy during the transition from an industrialised phase to more services orientated economy.

"The South African economy is mixed die to high end banking and IT that constitute a whole sector of the industry that is already decoupled from the energy provision" Respondent 1

"The financial services sector is world class, manufacturing is in early childhood, whilst mining is quite well developed, resulting in different growth phases in respective sectors" Respondent 4

"Growth has been fairly disappointing due to isolated growth in the resource sector with very limited filtering to downstream industry resulting in limited growth in these downstream industries and industrialisation processes which broaden the spread of growth" Respondent 6

Reported factors that influence the economic growth and energy consumption relationship included unreliable electricity supply, structural issues, skills shortages, and the commodity market.

"Until the power system becomes stable, reliable and sufficient South Africa will continue to experience contraction in growth" Respondent 3

"The structural issues present where the shift to a services and consumption orientated economy is mismatched with the skills (matric or higher) that is needed within these sectors" Respondent 2

"Access to skills, suitably qualified and experienced people, directly inhibit growth in South Africa" Respondent 4

"South Africa is largely dependent on their mineral resources as main exports which is affected by commodities trade from China, India and Japan could result in South Africa experiencing another recessionary period, and from an electricity point of view, with sufficient supplies due to the global demand for commodities decreasing" Respondent 2
It was suggested that a sectoral analysis, from the bottom up, be adopted that incorporates the understanding of the constituent parts in forecasting their respective

needs. Strong emphasis was placed on the importance of this approach that would facilitate proper planning and energy policy formulation.

"Comprehensive planning around the economic growth and the energy consumption relationship plays and absolute crucial role in the area to enable an outcome that would promote economic growth, not just in big industry, but also family businesses or small businesses where 20/30 people are employed in a factory" Respondent 1

"Sectoral analysis should be done to determine the weightings that need to be factored into the forecasting model as without electricity there is no growth" Respondent 8

"A detailed study should be done on South Africa incorporating sectoral analysis (agriculture, industrial, mining, smelting, manufacturing, tourism and services) to determine how the forecast growth patterns will influence energy requirements" Respondent 4

"Currently South Africa has a problem with availability of electricity which has a negative impact on growth forecasts and potentially negatively affecting at least 1% of what the country is naturally capable of achieving" Respondent 5

Conclusion

There are were no agreement between respondents on the type of relationship that exists between economic growth and energy consumption, although most agreed that a relationship exists. It is evident from the respondent interpretations that South Africa is in a mixed growth phase, though undergoing the transition from an industrialised phase to a service economy. The current unreliable electricity supply negatively affects the economy and this evident from the reports published by Statistics South Africa, (2015). This restriction of energy availability supports the notion that, at minimum, a one way relationship exists in which electricity consumption will increase economic growth in South Africa (Growth hypothesis). This supports the claim of a substantial long run relationship that exists between economic growth and energy consumption for South Africa (Esso et al., 2010). It was not statistically proven that a growth hypothesis exists, as Stern et al. (2011) argued that the availability of energy consumption imposes economic growth constraints, when scarce, or has little effect if abundantly available.

As the global markets are changing and growth is slowing down, the impact on commodity prices can have a dismal effect on South African exports and associated economic activities. The associated upstream affects increases adversity from banks to lend to heavy industry users and further contributes to the contraction of economic activities. The skills needed to enable the transition to a service industry are mismatched and slowing down this process. It is suggested that a bottom up sectoral analysis be done for South Africa to determine the constituent parts' energy requirements, taking into consideration all influencing elements, as discussed. Based on these results, the South African economic growth and energy consumption historic relationship of 3:2 is out of date and needs to be revised.

6.4 Research proposition 3

South Africa can achieve a 100% generation profile from renewable energy

The purpose of this section was to uncover the best energy generation profile for South Africa and to ascertain whether a 100% renewable energy generation profile is achievable based on levelised technology cost changes. The researcher also explored the potential limitations that would obstruct this 100% renewable energy generation profile.

Levelised technology costs

When considering the best energy generation profile levelised technology cost provides immediate comparability of the associated costs relevant to the available technologies under consideration (Palacios et al., 2004). As stated in the literature section 2.3 in this study, the utilisation of levelised technology cost has reached industry standard status and is used as a key input when deciding on future generation investment. This affordability indicator ultimately effects the price of supplied electricity to the end user (Kaggwa et al., 2011). Levelised technology costs are normally very site or country specific and many calculations incorporate different methodologies to discount rates, fuel costs, and cost escalations. Larsson et al. (2014) expressed concern in utilising transferred levelised costs from site to site or country to country without being aware of the underlying methodologies used in the calculation. For the purpose of this study, the levelised technology costs were examined within a South African context and did not form part of greater worldwide comparability exercise. It is, therefore, assumed that the methodologies utilised by the DoE in calculating levelised technology costs, adopted the same principle methodology across all technologies.

As stated in Theme 6 Chapter 4, the respondents, with strong reference to the South African Renewable Energy Independent Power Producer programme (REIPPP), expressed (Theme 6, Emergent View 6.a., Chapter 4) that levelised technology cost, for renewables, has reduced remarkably between bidding windows, which is largely contributed by competition in the market. The respondents elaborated (Theme 6, Emergent View 6.b., Chapter 4) that both coal and nuclear energy levelised costs have increased due to capital, fuel costs, and costs associated with environmental obligations.

"It's well known how the solar costs have come down, particularly in the renewable space and it is remarkable how the wind energy costs have come down" Respondent 7

"It is solar that ranks the highest. The production of electricity from solar PV between bidding round 1 and round 4 saw a dramatic decrease and even wind is comparing favourably with coal. Solar and wind rank the highest" Respondent 3

"It surprised everyone that certainly for wind and solar renewable, costs have come down so much" Respondent 2

"In terms of wind and solar PV, we have seen prices coming down" Respondent 4

"Renewable overnight costs and levelised costs reduced "Respondent 5

"Prices contracted under the REIPPPP for all technologies are well below the published REFIT prices. The REIPPPP has effectively translated policy and planning to deliver clean energy at very competitive prices" (IPP Office et al., 2015)

Based on the published results from the Department of Energy technology, cost reductions in the renewable energy field has decreased dramatically between bidding windows. According to the IPP Office, (2015), the REIPPP is producing energy at increasingly cost competitive rates where the levelised cost, at portfolio level, reduced by 34% from bidding round 1 to round 2, 19% from bidding round 2 to round 3, with a further reduction of 39% from bidding round 3 to round 4. At a technology level, wind energy has seen a price reduction of 43% from bidding round 1 to 3, solar PV reduced by 75%, and solar CSP reduced by 6% between round 1 and round 2, with a further reduction of 7% between round 2 and round 3. Levelised technology costs for renewable energy are now becoming more competitive with conventional coal fired power plants, such as Medupi and Kusile, when compared to the current costs associated with lengthy delays and other cost overruns.

Technologies of focus

As stated in the literature section of this study, one of the core characteristics needed by an energy system is baseload. The energy system needs to be immediately available to cater for demand, as and when requested. Baseload power is the minimum amount of dispatchable electricity needed by an electrical system to cater for the minimum demand requirements and is normally associated with coal or nuclear plants (Matek et al., 2015). Load following (gas, oil, and hydro) and peaking (gas and combustion turbines) plants are generation plants that follow baseload and supplement supply during high demand periods. High demand periods are normally associated with extreme hot and cold temperatures or normally early morning and evenings.

The environmental aspect of electricity generation is driving focus to change to new technologies and energy solutions that ultimately alleviate our global CO2 footprint. As stated by Turconi et al. (2013), 68% of worldwide energy usage originates from fossil fuel (coal, oil, and gas), with electricity contributing 40% of global CO2 emissions. Brown et al. (2014) stated that limited progress in many industrialised have been made in securing reliable and affordable supplies whilst transitioning to a low carbon energy system.

- Coal

Approximately 40% of the global electricity generation fleet is approaching end of life and with a projected 37% increase in global electricity demand new build capacity needs to increase by a projected 37GW (International Energy Agency et al., 2013). This generation fleet is largely occupied by older coal fired power plants that are no longer economical resulting in gas or renewables technologies becoming more attractive and environmentally friendly. Thoughtful planning about how to retire coal plants can help maximise economic returns, human health and environmental benefits of a cleaner energy future, while maintaining reliable and affordable power (Fleischman et al., 2013).

According to the views interpreted from respondents (Theme 7, Emergent View 7.b., Chapter 4), coal has been and will certainly play an integral role in the generation fleet for South Africa for the immediate future. The argument suggested that coal is a natural resource available to South Africa that provides independence from having to import this fuel source and enhances South Africa’s competitive advantage. Although the respondents agreed on the on-going role coal is to play in future generation supply, the recommendation is that coal be slowly transitioned out of the mix towards a more diversified portfolio.

"Coal still remains the technology of choice as the coal is under our feet, we do not import from other countries and is not influenced by currency volatility. The South African economy needs large amounts of power supply that is stable, constant, and available. Coal can provide the required baseload" Respondent 1

"Countries utilise resources of which they have a comparable advantage and in the case of South Africa, is coal" Respondent 6

"South Africa probably has another 50 years of coal fire generation ahead but building any additional coal fire generation capacity should be stopped" Respondent 7

- Nuclear

Similar to the global coal fleet, almost 200 of the 434 operational reactors approach end of life by 2040 (International Energy Agency, 2013). Nuclear still remains controversial post the Fukushima and Chernobyl events. Policy makers attempt to identify the cost to benefit relationship, public opinion and safety concerns around operating reactors, radioactive waste and nuclear plants, whilst balancing the benefits (reduced CO_2 emissions and strong economic support) of including nuclear in the new generation fleet. Uncertainty around the cost of dismantling, decontaminating, and site rehabilitation make it difficult to determine the competitiveness of this technology and the associated high costs could impact the price to the end user.

According to the views interpreted from respondents (Theme 7, Emergent View 7.b., Chapter 4), no collective agreement was established for the inclusion of nuclear in the generation profile. The argument revolved around the concept of baseload and that nuclear would be able to supply steady and reliable baseload to support the South African economy. The majority of the respondents did, however, state that nuclear is not the appropriate option for South Africa, as the skills experience needed to maintain the health and safety aspect of nuclear plants are not available.

"I am not a great fan of nuclear personally, not because I distrust the technology or the safety issues and what not – because if you actually take a hard, pragmatic look at the safety impact on people of nuclear and nuclear accidents. The average time for construction is supposed to be 5 years and has now shifted to over 7.5 years. The positive thing with nuclear is that once it is built it lasts for 40-60 years, rather than 30 years or less in many of the other technologies" Respondent 1

"I am not convinced that we need nuclear as it has the ability of high cost to overruns. We haven't been able to demonstrate with Medupi that we are able to manage cost overruns very well. If you look at all the infrastructure from rail to other things, the more complicated and complex the technology is, the more likely you are going to find cost over runs" Respondent 2

"I do worry that the health and safety risks in nuclear are big. I don't think we have got the right quality of suitably skilled and experienced people that can manage the risk around nuclear" Respondent 4

"I would say that the drive behind nuclear is very big risky for the sector and probably not so much that nuclear will happen because I think it is very unlikely that it will happen. The drive for nuclear displaces decision making and creativity and action on other options that we are then effectively foregoing" Respondent 5

"Nuclear is an option. Excessive nuclear is not an option as it is too expensive. What we need is to relook at our future needs and aim possibly for, give us security of supply by 2030, is potentially two nuclear power stations of about 2.5-3.0GW" Respondent 6

"Nuclear, I disagree a 100%, the long bill times, the very poor track record that government run projects around the world have with regards to bringing projects in on time and on budget" Respondent 7

- Hydraulic Fracking

The environmental impact of hydraulic fracking causes the plausibility of this technology and is a topic of much debate. The process in which proppant (manmade sand based material, which includes ceramics, to keep a hydraulic fracture open) and other chemicals are utilised to extract gas from rock formations have environmentalists concerned that drinking water can be contaminated as societies close to wells may be at the highest risk of health problems associated with gas emissions. Furthermore, seismic activities, water contamination, and induced earthquakes, have human health implications and the local environments or landscape characteristic changes are also associated with fracking. Sovacool et al. (2014) did, however, argue that if hydraulic fracking is done properly, it can promote energy security, secure availability of fuels, lower the price of natural gasses, provide a cleaner carbon solution, and, ultimately, promote economic development.

According to the views interpreted from respondents (Theme 7, Emergent View 7.b., Chapter 4), the transition away from coal towards a more diversified portfolio is recommended. Gas is seen as transitionary technology that will facilitate this diversification to enable less dependence on a single resource that would ultimately contribute toward energy security.

"You want lots of gas because that will promote the development of gas industry in the country and the exploration of production of gas. We need to transition onto gas and then obviously beyond gas and away from coal" Respondent 5

"In terms of gas we should look at fracking, at shale gas in the Karoo, but I also think we should look at expanding infrastructure for importing gas in the medium term" Respondent 4

"We have gas and I think we should be building two or three gas-powered stations at the coast as a matter of urgency. Using initially imported gas, but later our own, offshore gas and also our potential of shale gas in the Karoo" Respondent 6

"Gas as a transitionary energy source together with coal, as we move to a more renewable path" Respondent 8

"Moving into a gas with a combination of combined and open cycle, to supplement the renewable energy resources that we have over a 20 or 30 year period" Respondent 2

"Gas and renewables as a hybrid mix is probably a very good interim and even medium term solution because it allows for a higher input of renewables but it also allows gas to play a little bit of a peak role, a peak load role but also some level of base load – a balancing role" Respondent 7

"The National Development Plan further states that this growing gas contribution, subject to acceptable environmental controls, be supplemented by fracking and imported liquefied gas imports" (National Planning Commission et al., 2011)

100% Renewable generation profile

The literature debate in achieving a 100% electricity generation from renewable sources remains unresolved, as discussions around baseload requirements and the intermittency of renewables are being studied. Balancing environmental obligations with alternative renewable technologies, bearing in mind reliability, stability, availability, and the cost implications to the end user, results in a highly complex task when deciding on the appropriate energy mix. Elliston at al. (2012) stated that the concept of replacing baseload supply with other baseload supply be changed to replace baseload with large diverse renewable energy technologies over large geographic areas. Various studies suggest that a 100% generation profile from renewable sources is already a feasible option, although some arguments suggest that without economically viable energy storage solutions, achieving a 100% is not yet realistic. These studies covered national, regional, and global geographical areas that resulted in positive feedback towards achieving a 100% solution.

Table 17: Geographical studies exploring the potential for a 100% energy generation profile

		Technology						
Geogrpahy	**Achievable**	**Wind**	**Wave**	**Hydro**	**Solar**	**Tidal**	**Biomass**	**Storage**
National								
Ireland	Yes	✓	✓		✓	✓	✓	
New Zealand	Yes			✓			✓	
Portugal	Yes	✓		✓				✓
Denmark	Yes	✓			✓	✓	✓	
Regional								
Australia	Yes			✓	✓		✓	✓
Northern Europe	Yes			✓				✓
Spain	Yes	✓						
Global								
Study 1	Yes	✓		✓	✓	✓		
Study 2	Yes	✓		✓	✓		✓	

These 100% renewable generation profiles derived from the various studies are achievable based on the utilisation of the various technologies as depicted in Table 17 and detailed in the literature section 2.3.

National – Ireland (Connolly et al., 2011), New Zealand (Mason et al., 2010), Portugal (Krajačić et al., 2011) and Denmark (Lund et al., 2009).

Regional – Australia (Elliston et al., 2012), Northern Europe (Sørensen et al., 2008) and Spain (Santos-Alamillos et al., 2014).

Global – Study 1 (Jacobson et al., 2011) and Study 2 WWF international et al., 2014).
The argument around variability remains at the forefront of this topic, where researchers stated that the variability of renewable energy sources does not contribute to the availability factor of supply when the demand arises. Many argue that the 100%

scenarios assume solutions for all technical issues, and, until storage is economically feasible, that a 100% renewable generation profile is not achievable (Elliston et al., 2012; Sharman et al., 2011; Trainer et al., 2010).

Emerging from the coding process following the interviews and as described in Theme 8, Emergent View 8.a., Chapter 4, there was consistent agreement amongst respondents that a 100% generation profile for South Africa is not yet feasible. South Africa is well endowed with natural resources and has some of the best wind and solar irradiation.

"Theoretically it looks very feasible but I think in reality there are lots of technical, policy regulatory, and financial hurdles that I don't think in the immediate future you will see that feasible. "Respondent 2

"However I do think if you model all the wind and the solar in the country and you combine those and you say what percentage or what amount of megawatt hours can I get, we will be surprised at how much it is" Respondent 4

The ability to dispatch electricity when required is a core characteristic needed within a generation system, and, until energy storage becomes an economically feasible solution, the attainability of a 100% generation profile is unlikely.

"The biggest barrier at the moment for integration of solar thermal for instance, which can act as a base load, is the cost issue and performance issue. That limits the level of integration of higher levels of renewables, because you can't simply do them on variable technologies because then you need other technologies to be able to deal with intermittency and variability" Respondent 2

"The constraint is it's not affordable due to the current lack of electricity storage and the fact that you would end up with a whole lot of stranded fossil or thermal fossil essence. The key issue is the economic constraints or the affordability constraints" Respondent 7
"I think that battery storages are more likely to crack the cost curves for the simple reason that batteries are used more and more widely and battery technology is developing faster than the sort of heat storage. There is just far more investment in batteries. We are at the mature end of battery technology and I don't think there is a view out there that we are going to have some step change in battery technology. I think the view is that to achieve sort of step change and pricing you need to focus on the production side of

things and go for high levels and maintenance mechanised very low cost production" Respondent 5

Conclusion

South Africa stands at a pivotal point in having to decide on the best generation mix that would best fit all the requirements for a fully functioning energy system. Much of the decisions to be taken would have to take into consideration the environmental impacts and committed obligations that would ultimately enable an energy system that is reliable, available, and cost effective for consumers.

The respondents suggested that coal dominates as baseload supplier for the immediate future and renewable energy slowly progress whilst incrementally delivering larger contributions to the national grid. There is an overall agreement amongst respondents that a 100% renewable energy profile is not yet achievable until a time when energy storage provides an economical alternative. It is recommended that gas be utilised as a transitory technology that would allow for storage technologies to develop further. Nuclear has predominantly been rejected by the respondents due the requisite skills shortages in South Africa to manage the health and safety aspect of nuclear technologies. Thus, the mix, as proposed by the respondents, constitutes wind, solar, gas, and coal.

Although renewable energy levelised costs and available natural resources contribute favourably towards achieving a 100% generation profile, the variability remains the biggest constraints for such large uses of the technologies. Therefore, the proposition cannot be accepted that until such time as storage becomes an economically feasible choice.

CHAPTER SEVEN: CONCLUSION

7.1 Introduction

The purpose of this study was to investigate whether the South African energy policies are current and reflective of stakeholder assessments on energy security, to determine whether the historical economic growth and energy consumption relationship of 3:2 is still valid, and, ultimately, to ascertain if a 100% renewable energy generation profile is achievable for South Africa. This chapter summarises the key findings from this study in regards to the research objectives, as set out in section 1.3 in Chapter 1. This section will further elaborate on implications for management, the limitations of the study, and suggest areas for further research.

7.2 Principle findings

7.2.1 Energy and security

According to Winzer et al. (2012), the conceptual framing of energy security and the selection of the correct measurement metrics are fundamental activities having to take place before attempting any measurement. During the review of the energy security concept, the researcher found that there are no universal definitions available that can be utilised as a blanket definition applicable to most situations. The geography enveloped and the situational connotation attached to an energy systems' security ultimately leads to a specific definition in support of policy and legislation formation. From the different timelines associated with measuring energy security, the classic period was largely centred on the assurance of uninterrupted oil supply to army fleets. The contemporary period redirected focus to attach a fast amount of other factors (energy sectors, resources, markets, technologies, environmental degradation, climate change mitigation, and access to electricity concerns) that ultimately influences the security of energy in a specific country or geography (Cherp et al., 2014). The attachment of these various elements to different situations leads to the difficulty in determining a universal definition of energy security.

There are, however, general characteristics of energy security that are applicable to all situations. These general characteristics of reliability, affordability, availability, and area specific inclusion directly influence the security of any situation. As argued by Baldwin et al. (1997), energy security is principally concerned with security and that it is not fundamentally a different concept when considered in the context of economic, environmental, identity, social, and military security, but it is merely different forms. This study found that there is a general consensus that the term 'security' is predominantly concerned with risks. (Cherp et al., 2014; Chester et al., 2010; Winzer et al., 2012). Cherp et al. (2014) defines energy security as "low vulnerability of vital energy systems" and is concerned with disruptions of essential energy systems and services. The types of risks associated with this vulnerability are natural *(resource scarcity, extreme natural events)*, technical *(aging infrastructure, technological accidents)*, political *(intentional supply or technology restrictions, sabotage, or terrorism),* and economic *(high or volatile prices)* factors. It is against this framework that the researcher benched the evaluation of the South African energy security policies' definitions to determine their present day validity. Definitions of South African energy security are stipulated as follows:

- The publication of the White Paper on Energy's (1998) focus was redirected to ensure *adequate supply* to previously ignored portions of the population. The White Paper on Energy (1998) expanded to include five main focus areas into the energy security definition that consisted of *affordable* energy services, greater *integrated policy development and service delivery*, encouraging *fair competition* in energy market enabling *economic development*, *environmental* impacts and energy *supply security*. Within this context, all three perspectives (Robustness, Resilience, and Sovereignty) are addressed with the additional expansion of environmental and social welfare not covered by the model designed by Cherp et al. (2014).
- The South African Energy Security Master Plan (2007) defines energy security as "ensuring that *diverse energy resources* in *sustainable quantities* and at *affordable* prices, are available to the South African economy in support of *economic growth* and *poverty* alleviation, taking into account *environmental* management and requirements and interactions among *economic sectors*." (p. 5). Within this context, two of the three perspectives (Robustness and Resilience) are addressed with no mention of policy development that addresses the Sovereignty perspective. Environmental and social welfare are also addressed, but is not explicitly covered by the model designed by Cherp et al. (2014).

The White Paper on Energy (1998) and South African Energy Security Master Plan (2007) were utilised, the captured definitions were evaluated, and it was found that:

- The White Paper on Energy (1998) encapsulated the majority of the broad general characteristics as stipulated by the respondent interviews. In addition to the general characteristics, the drivers and threats to South African energy security were better captured within this definition when compared to the Energy Security Master Plan.

- The South African Energy Security Master Plan (2007) encapsulated a larger section of the general characteristics of energy security, but did not manage to capture large enough portion of the specific drivers and threats within a South African context. The role of government in policy formation and support was not included within this section, which was seen as central to the assurance of energy security within a South African context.

The key finding from this section was that the current definition of energy security is out of date. The current need for an all-encompassing policy definition of energy security is seen as one of the key contributing factors when addressing energy security in South Africa. The role of government in developing enabling policies and legislative mechanisms is central to South Africa and cannot be excluded within this concept. It is, therefore, recommended that the current energy security definition be revised to include governmental roles, as the exclusion of this role will not allow for the correct measurement metrics to be introduced for effective performance tracking.

7.2.2 Economic growth and energy consumption

From a South African context, the historic relationship between economic growth and energy consumption of 3:2 (3% GDP growth requires 2% electricity growth) has been utilised as a direct input in the formulation of the IRP2010 policy. The National Development Plan stated that the South African economy needs to grow by 5.4% annually and this would require that appropriate energy availability and accompanied utilisation to support this growth.

There are four types of hypothetic effects when evaluating the relationship between economic growth and energy consumption. These are Growth hypothesis (one-way causality between energy consumption and economic growth), Conservation hypothesis (one-way causality exists between economic growth and energy consumption), Neutral hypothesis (no causality), and Feedback hypothesis (two-way causality exists between economic growth and energy consumption), and each distinguishes between a different type causal relationships growth (Apergis et al., 2010; Dogan et al., 2014; Fatai et al., 2014, Menegaki et al., 2014). As stated within the literature review, Section 2, determining the causal direction of energy consumption and economic growth is of prime importance when determining the appropriate energy policies (Ouedraogo at al., 2013). Studies on the economic growth and energy consumption relationship supported:

- A neutral hypothesis: 1971 – 2001 (Wolde-Rufael et al., 2005),
- A unidirectional effect running from energy consumption to economic growth: 1972 – 2006 (Odhiambo et al., 2009), and
- A substantial positive long-run relationship between energy consumption and economic growth (Esso et al., 2010).

The key findings from this study did not contribute to determining the causal relationship between economic growth and energy consumption, but there was a general consensus that the relationship exists. This is in accordance with the literature that there is a generally supported view that a relationship exists, but there is still no consensus on the actual causality. The South African historical relationship between economic growth and energy consumption of 3:2 has been found to be out of date due to various economic and energy availability factors. It has been suggested that a bottom up approach be adopted to evaluate all the constituent parties' energy requirements, taking into consideration all the relevant elements that influence this relationship. This will allow for effective energy planning when considering polices that drive energy security.

7.2.3 Energy mix

Baseload energy supply is the key contributing factor when considering the appropriate energy mix. Baseload energy is normally associated with coal or nuclear plants that are dispatchable at any given time to meet the minimum load requirements of customers. There are loads following and peaking plants that cater for high demand periods substituting where baseload supply falls short. For renewable energy the dependence and variability of renewable energy sources do not contribute favourably to baseload power, as this is in contrast to the always available or dispatchable characteristics associated with this technology. Renewable energy has achieved remarkable penetration into the general generation mix over the last decade, and various studies have returned favourable results in achieving a 100% generation capacity from renewable technologies. Still the debate remains controversial, as the variability component drives much debate around such large renewable energy penetration. Researcher argues that until storage abilities become a more economically viable solution, achieving a 100% generation mix from renewables is not yet achievable.

Much of the world, including South Africa, is reaching a point where coal and nuclear plants are reaching end of life status. This is adding to the complexity of choosing the appropriate energy mix that will still achieve the general and specific energy security characteristics, as defined by the applicable energy polices.

The key findings from this section is that South Africa will be dominated by coal for the immediate future, whilst the penetration of renewable technologies will gradually increase in order to avoid negatively affecting the stability of the national grid. It is recommended that gas be explored in an environmentally responsible manner that will allow for the utilisation of this technology as a transitory method until such time as storage development becomes an economically feasible choice. It was found that a 100% renewable generation, although supported from a levelised cost basis, will not be achievable for the immediate future. This is largely dependent on storage. The generation mix was found to largely consist of wind, solar, gas, and coal. There was a strong conviction that no further nuclear be added to the generation mix, as South Africa currently does not have the requisite skills to adopt and maintain this technology.

7.3 Limitations of the study

As stipulated in research section 3.7 in Chapter 3, and for ease of the reader, the limitations of the study are reiterated as follows:

- The snowballing sample used in this study resulted in bias towards stakeholders that were largely IPP developers or consultants from the IPP environment that share very similar ideologies. The researcher attempted to address this bias by introducing independent stakeholders outside of the IPP clusters.
- The coding of the research interviews could have been subjected to researcher bias, as the process has primarily been done by the researcher and could have subjected the coding towards personal bias. The researcher attempted to address this bias with the utilisation of the case study method that incorporates secondary resources to corroborate or contradict identified themes and views.
- Levelised cost obtained in the public domain could potentially be biased to the region or country that it pertains to and could differ from the actual levelised costs within a South African context.
- This study does not take into account demand side management strategies or energy efficiency incentives.
- All secondary data from reports, publications and online data systems are obtained from the public domain and results are dependent on the accuracy of the data produced.

- Data may not always be value neutral, as the original purpose for such data and data gathering techniques may not be well known.
- It is worth noting that the predominant theme of this study focusses on electricity and does not include the full spectrum of all energy components, including oil and heat, although they are mentioned in certain sections of the research.

7.4 Future suggested research

The purpose of this study was to investigate whether the South African energy policies are current and reflective of stakeholder assessments on energy security, to determine whether the historical economic growth and energy consumption relationship of 3:2 is still valid, and, ultimately, to ascertain if a 100% renewable energy generation profile is achievable for South Africa. The principle findings in this study relate to other areas of future research areas that may be examined, including

- Research on the price elasticity in the various energy user sectors,
- Research on the frequency of policy review with an ever changing economic growth and energy consumption relationship within a certain geographical context,
- Research on the role of government in the promotion of energy security,
- Research on the impact of private sector involvement in promoting energy security, and
- Research on the status of energy storage development to determine potential economic viable deployment for larger renewable energy profiles

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APPENDICES

APPENDIX A: Summary of Respondent Profiles

Respondent 1: Independent energy consultant to the Independent Power Producers office with numerous years' experience in the technology, mining and energy sector.

Respondent 2: Managing Director of a power sector consultancy firm with extensive experience in providing energy solutions to private companies, private developers and energy intensive mining industries in the African and Sub-Saharan African regions.

Respondent 3: Senior Executive for the WWF-SA (World Wide fund for Nature) with responsibilities for long-term policies in the areas of transition economies, investment and environmental sustainability. Currently the main goal of the unit is to evaluate long-term economic, finance and investment options in the food, energy, and water nexus from the point of view of environmental sustainability and economic development. The primary focus is on renewables but the unit also evaluates other energy carriers and sectors like shale-gas, coal, nuclear, fuel cells, biofuels, grid capacity, the food value chain, mining, hydro-power, LNG, sustainable use of water, climate change and others elements.

Respondent 4: Managing Director of an Independent Power Producers company with three successfully commissioned renewable projects delivering 238MW to the National Grid. Respondent also has extensive experience in energy and economics with jobs held within the stated owned entity Eskom, minerals and energy policy centre and other consultancy services and specialities in power project development, energy sector policy development, power sector reforms and business strategy.

Respondent 5: Managing Director of a large scale construction, mining and property development company. Respondent has extensive experience in the energy industry with a specific focus on Clean Energy and Energy Storage Technologies. He is directly involved in the development of numerous energy projects in Southern Africa. Respondent's experience as an energy business developer, engineer and entrepreneur enables him to deliver practical and sound input into energy projects and to other developers from a commercial perspective, backed by an in-depth knowledge of the technical, legal and commercial challenges associated with the implementation of such technologies in the real world.

Respondent 6: Managing Director of an Independent Power Producers company with two projects in construction that will deliver 233MW the National Grid. Respondent has extensive experience the mining and energy industry with a strong entrepreneurial background with a strong drive to social upliftment creating infrastructure and skills that will enable people to uplift themselves.

Respondent 7: Managing Director and Senior Economist of a consultancy firm specialising in energy, mining and electricity sectors. Respondent has wide experience ranging from negotiations with domestic and international companies and public authorities, to direct line responsibility for investment decisions, mergers and acquisitions, capital projects, company rationalisation and restructuring, and the development and profitable growth of private and listed companies. Respondent specialises in project consulting covering a range of industrial and policy issues in the public and private sectors including a focus on the energy, mining and electricity sectors. He also gives presentations on international and domestic economic developments and growth strategies, including advising on investment and development strategies for corporations. Respondent has advised on the economic impact of major industrial projects for multinational companies and is involved in the energy requirements of the South African economy and the economic impact of alternative electricity generating sources

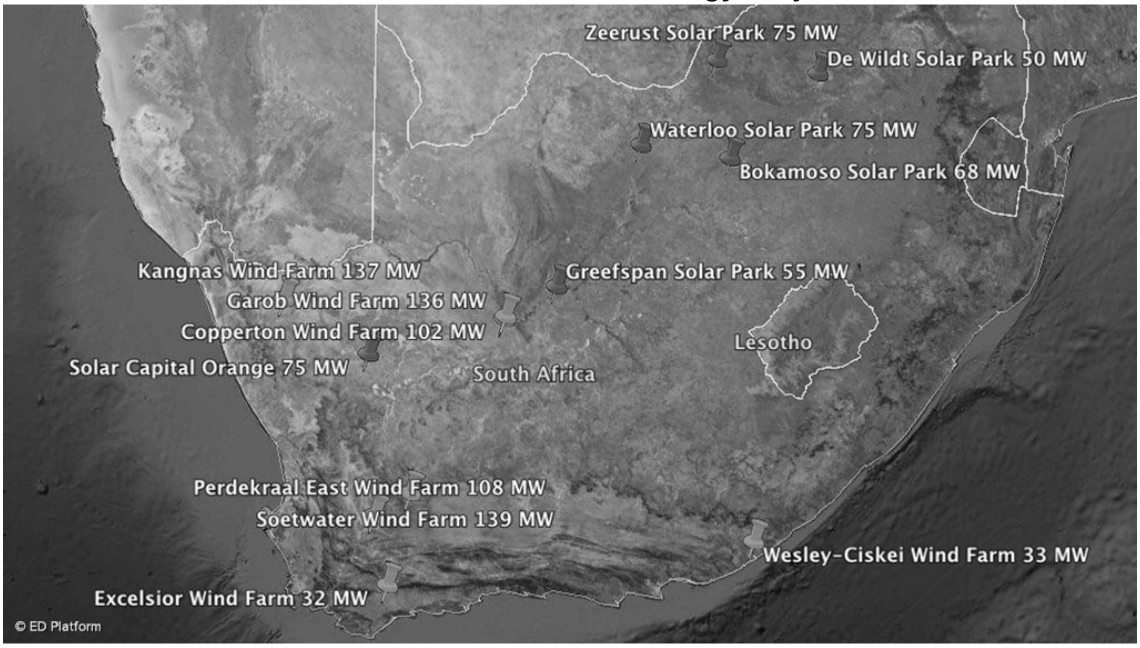
Respondent 8: Economist for the Department of Energy with special experience in sustainable economic development, macroeconomics, energy markets and international business. Experience in macroeconomic overviews focussing on Gross Domestic Product (GDP), Gross Domestic Expenditure (GDE), Personal Disposable Income (PDI), Personal Consumption Expenditure (PCE), Consumer Price Inflation (CPI), Interest Rates and Exchange Rates with sector focus reports analysing the electricity, mining and agriculture sectors.

APPENDIX B: Secondary Data Sources

Data triangulation phase secondary sources used

1. **Government report –** Independent Power Producers Procurement Programme (IPPPP): An overview – March 2015
2. **Annual report -** http://www.statssa.gov.za/?p=5323 - South Africa's economy contracts in the second quarter of 2015
3. **Report -** Energy Security Strategy, Department of Energy & Climate Change - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65643/7101-energy-security-strategy.pdf
4. **Report –** Global Energy Assessment: Toward a Sustainable Future - http://dx.doi.org/10.1017/CBO9780511793677.011
5. **Media report -** Economic effects of load-shedding hit home - http://mg.co.za/article/2015-08-26-economic-effects-of-load-shedding-hit-home
6. **Media report -** Load shedding effects on South Africa - http://www.mweb.co.za/Features/ViewArticle/tabid/2910/Article/19183/Load-shedding-effects-on-South-Africa.aspx
7. **Media report -** Economy hamstrung by load shedding - http://www.fin24.com/Economy/Economy-hamstrung-by-load-shedding-20150111
8. **Media report -** Nuclear not needed and perfect for graft - http://www.news24.com/SouthAfrica/News/Nuclear-not-needed-and-perfect-for-graft-20150824
9. **Report -** South Africa Risks 2015: The Institute of Risk Management South Africa, (2015) **-** http://www.irmsa.org.za/?page=IRMSARiskReport
10. **Archival record -** Skills for Infrastructure Delivery in South Africa; the Challenge of Restoring the Skills Pipeline, Discussion Document, (2007) - http://unpan1.un.org/intradoc/groups/public/documents/cpsi/unpan030466.pdf
11. **Archival record -** South Africa's Electricity Crisis - Centre for Development and Enterprise, (2008) - http://www.cde.org.za/wp-content/uploads/2013/02/South%20Africas%20Electricity%20Crisis%20Full%20Report.pdf

APPENDIX D: Renewable Energy Projects



APPENDIX E: Respondent Word Count Frequency