Integrated Framework for Green and Sustainable Energy Resources within the South African Context

by

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Publication 1: Submitted to SAUPEC 2020 Conference. The authors of this study detailed the factors contributing to the development of an integrated framework for green and sustainable energy in the South African context.

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ABSTRACT

On the back of energy shortages, hiking electricity tariffs, mitigating climate change, and the initiative taken by households to generate electricity through renewable resources, it is important to study green technology, and in doing so, understand the perceptions of the utility with regards to green and sustainable energy resources, uncover the drivers that impact or influence these resources, and in tandem, study the impact that green and sustainable energy resource have on the utility, industries, the economy and society. Renewable Energy Independent Power Producer Programme (REIPPP) forecasts that renewable energy will contribute to almost 42% of the country's energy in the next 20 years.

However, improper integration of renewable energy resources could become a threat to the existing national power supplier. Since South Africa has plenty of green energy resources including solar, wind, hydro and biomass, this study investigates the impact of sustainable energy resources to the utility, small industries, the economy and society in order to develop an integrated framework for green and sustainable energy resources within the South African context.

Overall, the developed framework highlights the best possible way to integrate clean energy resources into existing power system network in a sustainable manner within the current energy landscape.

Keywords: integrated, sustainable green technology, renewable energy, energy landscape

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List of Abbreviations

CO_2	Carbon dioxide
CSP	Concentrated solar power
DG	Distributed generation
GDP	Gross domestic product
GHG	Greenhouse gases
IPP	Independent power producers
IRP	Integrated resources plan
KVD	Key value driver
LCOE	Levelised cost of electricity
NDP	National development plan
NERSA	National energy regulator of South Africa
NOx	Nitrogen oxide
PV	Photovoltaics
RE	Renewable energy
REIPPP	Renewable energy independent power producer programme
RET	Renewable energy technologies
SME	Small and medium enterprises
SO_2	Sulphur dioxide

Chapter 1: Introduction to the Research Problem

1.1 Background

Since late 2007, and of recent, in 2019, South Africa has been plagued with energy instability with the current national supplier failing to meet the growing demand. This has led to a sharp increase in electricity prices as the conventional power producer attempts to invest into infrastructure and add new capacities to meet the growing demand [1]. Traditional forms of power production, using fossil fuels, are seen to have an adverse impact on the economy as a result of increased greenhouse gas (GHG) emissions and reduced energy security. Integration of sustainable energy resources could prove to eliminate such concerns, however, over penetration or uncontrolled penetration could negatively impact the conventional utilities, which in turn will adversely impact the economy.

Secure energy supply is a necessity to ensure economic growth and quality of living. In fact, studies [3] indicate a two-way relationship between the usage of energy and economic growth, and consequently, the well-being of society. Figure 1 illustrates the relationship between economic growth and electricity consumption.

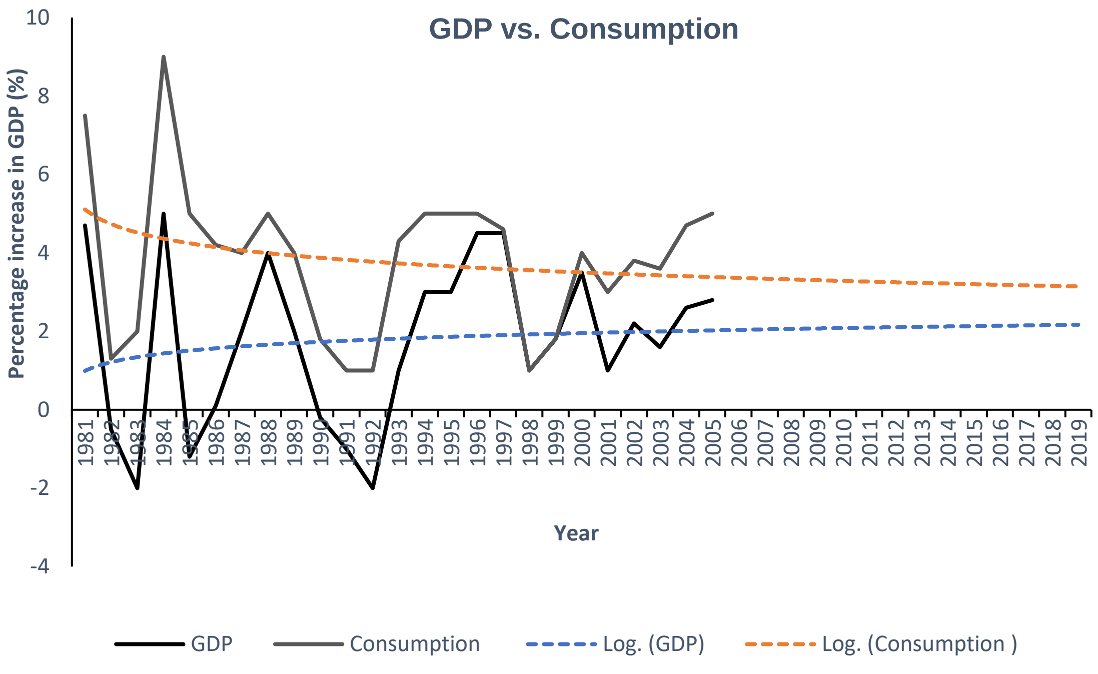

Figure 1-1: Adapted - Relationship between GDP (economic growth) and Electricity Consumption in South Africa

From the graph it is clear that the growth in the Gross Domestic Product (GDP) actually follows the trend in electricity consumption [2], that is, an increaase in electricity consumption is an indication of an increase, or growth, in the GDP of the country [2].

South Africa still generates up to 85% of electricity from coal-fired power stations [3] with other cleaner sources of energy such as nuclear, natural gas, diesel, solar, and wind contributing 5.2%, 3.2%, 1.7%, 0.9% and 0.9%, respectively [3]. In the earlier months of 2019, South Africa has been in the grips of an energy crisis [4] and energy resource usage has become an important and ongoing area of focus [5]. Since 2007, the national utility has faced a lack of capacity for generation, and this has hampered economic growth (first quarter of 2008) from 5.4% to 1.57% [2]. In addition, to crippling economic growth, current generation practices have resulted in the detriment of the environment to a great extent , ranking South Africa the highest in greenhouse gas emission per capita on the African continent [6]. Furthermore, it is evident from studies such as the one in [7] that increased adoption and use of green and sustainable energy within small industry, especially those operating in energy-intensive sectors, provides economic benefits. Additionally, small and medium enterprises (SMEs) also stand to benefit from reduced carbon taxes and penalties [7]. Over the recent years, and according to the Paris Accord (an agreement among more than 170 countries to reduce GHGs and decrease global temperatures worldwide) a new area of focus is the decarbonisation of the energy economy and the need to develop new technologies for the generation of environmentally clean power [8]. This increasing acknowledgement of the importance of clean and efficient energy change indicates the need for an integrated framework for green and sustainable energy resources in South Africa.

South Africa boasts a huge variety of clean energy sources. Emerging renewable energy sources include solar, wind, hydro and biomass [5], and the country has huge potential for solar and wind power generation, and a smaller scale potential for biomass, landfill gas and hydro power generation [6]. [9] identifies that renewable resources such as solar thermal harnessed extensively especially since South Africa has abundance of solar energy available; biomass currently contributes between 9 and 14% of the total energy requirement, but if used more efficiently could contribute more. [9] also suggest that in terms of hydropower, South Africa is abundantly endowed, so there is scope to develop micro-hydro potential. Wave power is also seen as a new technology from which the current energy landscape can benefit [9] as South Africa has an widespread coastline with high wave energy potential. Currently, the amount of energy generation through renewables is quite small, however the Renewable Energy Independent Power Producer Programme (REIPPP) forecasts that renewable energy will contribute to almost 42% of the country’s energy in the next 20 years [10]. Furthermore, the South African government and

National Energy Regulator of South Africa (NERSA) has established policies and projects for procuring and implementing renewable energy to supplement coal power generation to improve energy sustainability and diversification in energy sources [6]. South Africa has also adopted enabling strategies to surge the share of renewables in the energy mix. Although these adopted policies are useful to improve energy sustainability, developing an appropriate, customized, integrated framework for green and sustainable energy resources is necessary given the unique characteristics of the environment and economy in South Africa.

However, renewable energy technologies have also been surrounded by negativity. Inclusive in the negative connotations are the threat that conventional utilities face as a result of the rise of green energy technologies, as well as the public acceptance of renewable energy technologies. From a utility point of view, the integration of renewable energy technologies will eventually result in the utility death cycle, i.e., more consumers generate their own energy, as a result there are electricity tariff price hikes, further driving more people away from the conventional form of generation [11]. Also as suggested in [12] the increasing push for green energy technology has been seen as a growing threat and concern among the public because the public feel that increasing renewable technology infrastructure will undermine the beauty of the landscape , that is, land intrusion and noise intrusion.

With the movement towards mitigating climate change, and the initiative taken by households to generate electricity through renewable resources, it has become important to study green technology, and in doing so, understand the perceptions of the utility with regards to green and sustainable energy resources, uncover the drivers, impact or influence these resources, and in tandem, study the impact that green and sustainable energy resource will have on the utility, industries, the economy, and society in general.

The focus of this study is on the development of an integrated framework that can be used within the South African context, given the levels and potential of renewable energy within the country, to ensure the adequate uptake of green technology within the country.

1.2 Research motivation

Electricity is a factor influencing the economic development of a country [13] and is required to assist reduce problems of inequality and poverty [14]. There are significant studies that show the linkage between energy consumptioon and economic growth, i.e. economies with higher energy production and consumption have higher per capita incomes [15]. South Africa is an energy intensive economy, and the energy demand expected to grow significantly with economic development in the next 50 years. In fact, the total energy and electricity requirements are expected to triple by the year 2050 [15]. South Africa also ranks amongst the top twenty global emitters of greenhouse gases in the world, as it is highly dependent on coal as a primary source of power generation [14], and of recent has been experiencing energy shortages and electricity blackouts [16]. Additionally, the country also experienced shortages in other fuel sources such as petroleum in the years 2008 and 2011, and shortages in gas in the years 2011 and 2012 [15]. This overall instability in fuel sources and energy production has seen a decline in economic growth over the recent years [17]. This need for secure energy supply has seen an increase in new practices aimed at reducing energy consumption and reducing the carbon footprint [18].

In terms of integration of clean, green and sustainable energy sources, South Africa has a diverse wealth of green energy resources. There are three concentrated solar power plants (CSPs) all located in the Northern Cape, producing in total about 200MW of power. Generation of energy through wind energy sees potential for between 0.05 and 0.25 GJ/m^2 of production annually, aiming to reach a total wind energy supply of 8.4GW by the year 2030. There is further potential in the hydro-energy generation sphere and bioenergy sphere as well [16]. The Renewable Energy Independent Power Producers Procurement Programme (the REIPPP) hopes to install 17.8GW of electricty generation capacity over the priod of 2012 to 2030 from renewables (solar,wind,biomass,biogas, and hydropower). As a matter of fact, according to the Integrated Resource Plan (IRP), the country is focused on reducing the emissions of greenhouse gases by 34% by the year 2030 and diversifying its energy supply in order to reduce heavy dependence on coal-fired electricity [16]. Furthermore, the use of renewable energy sources has also been incentivised by various schems, such as the renewable energy feed-in tariff, which now has been replaced with a competitive bidding scheme [13].

The country has also commited to promoting economic growth, achieving energy security and imporving environmental protection both at an international and domestic level [14][19]. Also, with the cost of renewables decreasing rapidly over the last decade, and predicted to decline even further over the next coming years, it is becoming important to effectively integrate cleaner, greener and more sustainable sources of energy production into the existing power system networks. Evidently there is risk of instabilites and potential voltage fluctuations if there is an uncontrolled integration of renewables [20] hence, it becomes imperative to understand the key drivers influencing sustainability of green energy sources and understanding the impacts of this integration of cleaner energy sources on the utility, and its socio-economic effects.

1.3 Research aim

South Africa ranks among the top 20 highest carbon emitters globally [13]. The existing utility could use green and sustainable energy resources as an alternative to coal, which could potentially help stabilise electricity tariffs and reduce the carbon footprint. An integrated framework for clean, green and sustainable energy resources investigates how these resources can be used for the beneficiation of economy and society. In order to effectively manage energy demand and create an integrated framework, there are various factors that need to be taken into consideration such as the availability of energy and how present and future sources of energy will be managed. Hence, this study is aimed at understanding the perceptions of the utility with regards to green and sustainable energy resources in South Africa and investigating what the optimum green and sustainable energy resources in the country are. The study also seeks to understand the key drivers influencing the sustainability of energy sources within the country. Upon doing this, the research will also be used to uncover what impacts green and sustainable energy resources have on industries, the economy and society in order to establish the most conducive way to integrate green energy into the current power system.

1.4 Research management implications

This study investigates the impact of clean, green and sustainable energy resources on the utility, economy, and society. From a management perspective, addressing this study will help the utility, industry and society. Utilities will benefit from understanding how green energy technologies can be incorporated, and what their impacts will be. This will allow utilities to change their current business models to adapt to these changes and ensure the financial feasibility of their organisations. From an industry and societal point of view, this study will help understand what the optimum green and sustainable energy sources are, and will provide an integrated framework for green and sustainable energy sources, and in doing so, incentivise change within energy management systems and policies in order to accommodate increasing power generation through renewable resources. The study also aims to contribute towards a sustainable energy infrastructure within the context of a developing country.

1.5 Research problem statement

To demonstrate and develop through, qualitative analysis of existent literature, discussion, and feedback with experts within the field of energy, an integrated framework for green and sustainable energy in South Africa by looking into the perceptions of the utility on renewable energy resources in order to provide an overview of pragmatic considerations for industry on policies and management implications for utilities.

1.6 Research questions

The study aims to develop an integrated framework for green and sustainable energy within the South African context, hence the researcher developed three main research questions. The research questions used to provide clarity of the subject at hand is provided below.

1. What are the effects of green energy resources in South Africa?
2. What are the key drivers that impact sustainability of energy sources in South Africa?
3. Impact of green and sustainable energy resources to (a) utilities, (b) industry, and (c) society?

1.7 Structure of dissertation

The remainder of this dissertation is organised as follows:

Chapter two of this research discusses relevant literature to the energy landscape within the South Africa, and globally. The literature includes a review of the South African energy landscape, energy policies, technical challenges and various factors influencing the decision to invest into renewable energy technologies, placing directive for the need to develop an integrated framework.

Chapter three presents the methodology used for this research, approach and design used. The study makes use of qualitative analysis, and scenario analysis in order to gain imperative insight on the factors that need to be incorporated in developing the integrated framework for green and sustainable energy. Findings is established through interactive sessions with energy experts, which thereafter is analysed, through thematic analysis.

Chapter four is designed to provide meaning to the context of the research at hand. It describes the research objectives in relation to each of the three research questions developed and presented in section 1.6.

Chapters five presents the findings of the study and discusses it with relevance to the high impact factor literature and data from research studies in order to provide insights on what the study has brought forth.

Finally, chapter six summarises and concludes the research by providing conclusive insights of the study and outlining salient recommendations for future studies with regards to this topic.

Chapter 2: Literature Review

2.1 Introduction

With resources such as coal and natural gas being used up faster than it can be replaced, the focus on green and sustainable energy resources becomes of utmost importance. The development of Renewable Energy (RE) in South Africa has been somewhat limited prior to 2011, and the current national utility, driven by electricity energy through coal, holds about 85% of the country's electricity generation [2]. The South African government has begun to recognise the need for RE [2]. This, along with the constantly increasing electricity tariffs, prompts the need to find a framework for the integration of clean, green and sustainable energy resources into the current energy landscape.

Various aspect of green and sustainable energy will be covered in this literature review: (1) the perceptions of the utility with regards to green and sustainable energy resources in South Africa; (2) the optimum green and sustainable energy resources in South Africa; (3) the key drivers that impact sustainability of energy sources in South Africa; and (4) the impact of green and sustainable energy resources to utilities, large industries, small industries, as well as commerce and society. In order to fully understand the need for integrated framework, current policies and frameworks that influence the integration of clean and sustainable energy within the South African context will also be investigated.

2.2 Current energy landscape in South Africa

South Africa is considered the 'powerhouse' of Africa [21]. In terms of energy production, coal powered generation meets 43% of industrial demand, 32 % of commercial and agricultural demand and 28% of residential demand, making South Africa one of the most coal dependent countries in the world [21]. Dependence of coal has only decreased ever so slightly from 75% in 1994 to 72% in 2014. Energy shortages and bottlenecks cost the African economy about 2 to 4% of the GDP annually.

South Africa has become the largest avenue for renewable energy projects in the world. With over 3900 MW of renewable energy projects under construction, South Africa is considered the 12th most promising investment destination for renewable energy projects [21].

Of recent, however, the country has been facing unplanned/planned power outages, energy shortages, and an escalation in energy tariffs. In terms of economic growth, the country is challenged by (i) energy challenges, (ii) aged infrastructure, (iii) inefficient regulatory processes, (iv) lack of adequate planning and vision. Energy is a significant driver of economic growth [21]. South Africans with access to energy increased by 8.2% between 2002 and 2012. However, the South African General Household Survey of 2012 indicated that about 11% of residents have no access to electricity. Annual energy demand is forecasted to increase from 345 TWh to 416 TWh by the year 2030. The country is looking to invest about US$ 50 billion on clean energy in over the coming years to reduce dependence on conventional forms of generation (coal-based), which currently provides about 85% of the total energy produced. The government has also promised to reduce emissions by 34% by the year 2020 [21]. Hence, there is a need to develop a framework for effective integration of green, clean, and sustainable energy resources.

2.3 Green and sustainable energy resources in South Africa

Economic development, achieving energy security, and ensuring environmental security will require investment into renewable energy [19]. The national development plan (NDP) requires the establishment of an extra 10 000 MW of electricity by the year 2025, compared to the baseline of 44 000 MW established in the year 2013. The Integrated Resource Plan (IRP) has taken this into account and developed an energy mix to meet these needs by the year 2030. Of this energy mix, 17 800 MW of electricity is to be produced from renewable energy sources such as concentrated solar power, solar PV, onshore wind, biomass/biogas, and a small amount of hydro power [19]. Energy from wind, solar PV and concentrated solar power was measured to be 431-618 GWh, 220-334 GWh, and 55-139 GWh, respectively [5]. This was average monthly energy measured during the period of January 2018 to December 2018 [5]. Wave power may also be a technology that can be looked upon as South Africa is surrounded by coastlines. Renewable energy sources should be considered not only to curb a growth in demand.

2.3.1 Solar Energy

Solar resources are of abundance in South Africa as the country is exposed to a high number of sunny hours, regardless of the time of the year [9]. This energy can be harnessed with the help of solar PV to make electricity. Concentrated solar photovoltaics (CSP) are considered emerging renewable technologies that can replace fossil fuel product. This technology is popular in hot and dry climates, as the one in South Africa [9]. CSPs use mirrors and lenses to direct the solar rays from the sun to the receiver. The receiver has a thermal carrier, such as oil, water or molten salts that absorbs heat. This heat can be used directly or send to a secondary circuit to generate power [14]. CSPs can still generate heat, even when the sun goes down as a result of storage systems that embed/store heat [14]. Interestingly, all CSPs have a backup system to generate power, in order to ensure stable production, and to maintain the expected capacity [14].

However, there are setbacks in the advancement of renewable energy as a sole medium for energy production [22]. Major challenges include high initial capital costs needed for the execution of renewable energy projects such as solar, and underdeveloped storage technologies and technologies for harnessing renewable energy [22]. With the onset of new technologies such as super capacitors, fuels cells and improvements in chemical batteries, storage costs are also expected to decrease dramatically over the upcoming years [4]. In fact, the price of solar modules has been decreasing steadily, and it is envisaged that solar power will contribute up to 14% of the total energy supplied by the year 2050 [22].

2.3.2 Wind Energy

A myriad of studies has established that South Africa has an abundance of wind resources, which could position the country as a leader in wind power generation on a continental scale [23]. The country is said to have a wind power generation potential of about 80 TWh (installed capacity of 30.6 GW) [23]. Wind farms consist of a group of wind turbines in a fixed location which are used to produce electricity. The first ever wind farm in South Africa began operation in 2002 under Eskom. This became larger scale in 2014. The largest windfarm producing approximately 136 MW of energy is in the Eastern Cape namely, Cookhouse Wind Farm. South Africa could potentially become Africa's leading wind power producer, as it has a wind power generation potential of about 80.54 TWh [23]. However, wind energy, like solar energy, is very much weather-dependent. Wind energy may be used to produce electricity through wind farms. As proposed in the most recent IRP, South Africa is looking to install 8.4 GW of wind capacity by the year 2030, with the significant portion of it being produced by large-scale wind turbines [23]. However, the performance of a wind turbine is very much dependent on factors such as wind speed and wind distribution at the site. Hence the power, P, generated by wind can be expressed as a function of wind speed:

$$P = C\rho vA \qquad (1)$$

where ρ is the air density, v refers to wind speed, r is the radius of turbine rotor, A = πr 2 (swept area of the rotor), Cp is the power coefficient of the rotor or the aerodynamic efficiency, and the wind density ρ is assumed to be 1.225 kg/m3.

Currently, off-grid, small-scale wind technology is still at start, and very little research has been done on the subject. As with any other renewable energy source, the main factors influencing development of wind energy projects includes substandard technology and maintenance capacities. Technological factors to be considered include poor productivity, lack of choices in wind turbines, siting, and interconnection rules [23]. Further, there is a level of public support that is required to grow the technology and promote changes in consumer behaviour [23].

2.3.3 Hydropower

Hydropower or hydroelectricity is a sustainable energy resource as a result of water flow. This can either be from water stored in a dam or energy produced with the aid of hydraulic turbine in rivers. Eskom has three types of hydroelectric power stations [8]:

- Reservoirs
- Run off river
- Pumped storage schemes

In South Africa, the current hydroelectric infrastructure generates peaking power for Eskom, the national utility, and are also part of systems transporting water to industrial areas and city centres [8]. Most often, the scarcity of water is the main reason why hydropower is not considered in South Africa [9].

2.3.4 Wave power

Wave power is electricity that is produced by means using forces that are exerted by the waves along the coastline. In 2015, a software company Blackbird International announced the development of a power plant in South Africa [10]. Eskom itself are looking to harness this form of energy as well [8]. In South Africa, infrastructure for Wind Energy, and Hydropower are currently available. This, along with solar energy which is available year-round, can be perceived as the optimum green and sustainable energy resource in South Africa. Wave power is a future alternative energy source [8].

2.3.5 Biomass

Use of bioenergy has been a technique that has been utilised for a while, obtained from i.e. waste, wood, and fuels [24], [25]. Bioenergy is considered to have its primary energy source coming from living organisms and plant [24]. The most common use of biomass is for energy generation.

Presently in certain parts of the world's biomass is the primary form of energy supply [24], [26]. However, in comparison with oil reserves, biomass contains limited energy densities for optimum exploitation [27]. Bulk mass must be used in comparison with oil products with higher calorific values. South Africa is one of the country's leading in biomass conversion technologies with Sasol leading the break through [28]. Though leading in gasification techniques, more needs to be done from a talent management point of view [28].

From an electricity generation point of view, existing studies suggests that bioenergy remains conceptual and non-economically viable to pursue. In the work of [26], the cost of producing electricity using biomass techniques cost double compared to when coal is used. This shows that the viability for biomass is low. These projects however are still carried on under the umbrella of a government incentives [26].

2.4 Evaluating renewable energy technology

There are three main factors, among others, that influence the movement onto more sustainable forms of energy generation, namely, technical factors, economic factors, and social factors [31]. There are many studies that indicate that energy transition is dependent on technological innovation, while others contend that social factors play a major role in this transition.

Over the recent years, investment in renewable energy has increased, globally, from USD 39.5 billion in 2004 to USD 270 billion in 2014, most of which have been delivered under a private-public partnership, as governments often find it difficult to fund such high-capital investments [32]. Within developing countries, renewable energy technologies are still considered to be emerging technologies, hence there is a level of uncertainty associated with it [33]. In fact, studies have noted that mature technologies are more likely to be financed by investors looking to fund and promote the use of renewables [33]. Over the year of 2016, the levelised costs for wind powered generation dropped by 18%, while large-scale solar PV generation prices fell by 17% [34], [35]. Importantly, it should be recognised that most of South Africa's R193billion in green energy projects were funded by banks and private investors, of which R53billion was funded internationally [36]. Additionally, renewable projects on a smaller scale, such as powering a home or village by solar, can be operational within weeks. Investors are also sensitive to changes in electricity price, and this uncertainty and volatility in fossil fuel prices have caused noticeable hesitation in investment in the recent years [37]. Ultimately, factors such as economic performance, social performance and technical performance contribute hugely to investment and transitioning into sustainable forms of energy generation.

Hence, it is imperative that these factors be considered when developing an integrated framework for green and sustainable energy resources.

2.4.1 Technical factors

Energy technology innovation refers to the research and development of alternative energy technologies and includes improvements in current energy technologies[38]. South Africa is still very heavily dependent on coal-powered plants for electricity generation [38], hence renewable energies will have to be incorporated into the power system effectively. An area of concern is that introducing distributed energy generators will cause bi-directional flow of power through the grid, which could lead to voltage fluctuations and harmonic distortion [39]. At the same time, this integration will allow the grid to have back-up supply, where any excess energy that is generated can be absorbed by the utility. In order to achieve optimal integration, the optimal size, design, and location of Distributed Generation (DG) need to be understood in order to minimise any instabilities to the power system network.

Reliability of renewable energy is a regular critique, that is, wind and solar are variable [40]. However, computer software and modelling tools such as PLEXOS, which is used to develop South Africa's IRP, can provide a least cost, ideal generation mix that can meet the required supply and ensure energy security for each hour of the day, yearly. The latest energy models represented in IRP 2017 indicates that there is enough "dispatchable power" to cater for peak demand. The IRP also considered the use of concentrated solar plants- this source is still considered expensive within the South African context, however, globally, developments indicate that the price is becoming increasingly competitive [40].

However, even if storage is not available, renewable energy sources such as wind and PV variability can be accurately forecasted and managed with several proven methods [41]. This is not merely a theoretical proposition – it has been proven in practice. Wind and solar work optimally at different times, and together, such combinations of optimal performance make contributions towards catering for the morning and evening peak loads [36].

Cogeneration is also another dispatchable source offered by South Africa's heavy industry. This is far more efficient, economical and could also make advantageous use of emerging supplies of natural gas as well. Mines can also add to demand response by adjusting their major loads such as milling and beneficiation to the grid needs, and by the same logic, metallurgical industries could potentially see more profit by selling demand response rather than metal. Investing in low cost power generation sources makes sense, and it is evident that renewable energy resources such as solar and wind can be integrated without affecting system reliability if sufficient flexible and demand-side resources are also used. Such a combination is indicative of the lowest system costs in the IRP models [41].

A recent study "confirms that the South African power system will be sufficiently flexible to handle very large amounts of wind and PV generation to cope with increased flexibility requirements resulting from the installation of 4.2 GW of wind generation and up to 12.8 GW of PV by 2020, and 11 GW of wind and 27.5 GW of PV by 2030; flexibility requirements can be handled by existing and planned power plants at moderate additional costs" [42].

2.4.2 Economic factors

Economic factors also come into play when looking into the production of energy by using renewable energy technologies. [43] states that capital costs of renewable energy technologies, annualised costs, such as operational costs, and levelized costs are key decision makers influencing the sustainability of green energy technologies. There is a lack of local manufacturers and suppliers of renewable energy technology and components. This implies that, often, technologies must be imported to South Africa [44], consequently adding to the increase in the capital costs of green energy technologies. The sustainability of these technologies are also mitigated by the fact that many of these technologies are relatively new, hence uncompetitive [43].

2.4.3 Socio-economic factors

Socio-economic factors include carbon emissions, electricity price, the GDP, and energy demand. There are several studies that indicate that a reduction in CO_2 levels is driver for achieving sustainability as a result of increased emissions that there is an expected growth in RE. Additionally, energy consumption is an indicator of development [40] i.e., the larger the consumption needs, the higher the level of energy use. Furthermore, as population increases there is further increase in energy demand, which could potentially be supplied by a mix of conventional power generation and renewable energy technologies[40].

2.4.3.1 Public acceptance

Acceptance and non-acceptance is categorised into four levels; (1) passive acceptance (approval), (2) active acceptance (support), (3) passive non-acceptance (rejection) and (4) active non-acceptance (resistance) [45]. Public acceptance of renewable sources of energy is vital in seeing the growth of the technologies [46]. Market penetration is pushed by public consumption and government laid out legislations. Public support becomes an enabler or a barrier in the adaptation of using technologies. Public awareness and understanding prolongs the time spent to innovate and implement renewable energy programs. Efforts are required from all stakeholders involved in ensuring awareness reaches consumers. These include the government and the corporate businesses. Some of the factors that affect public acceptance are public awareness, costs involved, risks involved, benefits involved and the environment of operation [45].

2.4.3.2 Public awareness

Awareness of current climate changes plays key role in making people aware of the existence of renewable energy. Continuously increasing fuel prices and limited natural gas supply have opened opportunities for renewable strategies to be adopted [20]. In a study of the Malaysian environment in [3] there is a disconnection between the public being aware of existence of renewable energy and the perceived ease of using renewable energy.

Governments in both developing and developed countries have rolled out awareness programs that support sustainable initiatives. However, little emphasis is placed on identifying the perceptions public has on renewable energies [45]. In the South African context, [47] identifies the country to put limited emphasis of protecting the environment, especially from a power generation point of view. Despite the technologies being there in the country, they remain being used by only those that are proactive in environmental conservation.

Countries like South Africa which have no large generating plants for renewable energy has most of the generated energy being used for residential purposes and not linked to supply grid [13]. The cost and burden of installation remains on the end user, which suggests strong collaboration between government and the private sector being needed for the successful large-scale implementation of sustainable initiatives. One of the barriers that limit corporate support is the availability of funds [40].

Another barrier that deters efforts being made in this industry is the existence of a monopolistic company in the power generation sector. Though government does support renewable energy, policies seem to clash as coal fired plants get more incentives. The costs for electricity generated from coal fired plants has been heavily amortized, thus economically nullifying any potential competition making any changes difficult. These huge start-up costs according to have a huge impact on the perceived ease of use and perceived usefulness of renewable energies [40].

2.4.4 Political factors

Politics is a huge determinant in the growth of RE technologies. According to a myriad of studies, political factors such as policy developments and energy security are factors that influence the development of renewable technologies [40]. Since renewable technologies are more expensive to deploy, there must be policies that support the deployment and growth of these technologies, in fact, several studies indicate that public policies are one way to grow RE i.e. establishing reliable frameworks and policy objectives that are technology specific and influenced by domestic and international factors [40]. Furthermore, policies that enable localisation of renewable technologies will reduce costs and the higher reliance of a country on energy imports, proving beneficial to RE growth.

2.5 Key drivers impacting energy and sustainability in South Africa

The use of sustainable energy resources could be driven by the increase of prices of energy in South Africa while non-renewable resources continue to become scarce. Climate changes as well as the need to reduce the carbon footprint of the country are also factors motivating the move to more sustainable and cleaner sources of energy generation [20].

According to [3] Eskom, South Africa’s main utility produces about 90% of the electricity generated in the country. According to [2], South Africa is relatively new to the concept of green energy, deployment only really starting after 2011. Although the government has recognised the need for clean, and sustainable energy, particularly from Independent Power Producers (IPPs), the implementation of green and sustainable resources infrastructure poses a threat to attaining private capital as finance companies and investors may not be too keen to lend or provide finance to companies willing to generate using renewables. This lack of infrastructure and finances has made it difficult to harness the full potential of the green energy [2]. Furthermore, the integration of clean, green, sustainable energy resources could pose some problems for power system networks. The major impacts of RE penetration include voltage variation and unbalance, current and voltage harmonics, grid islanding protection among others [48]. However, at the same time, studies such as the one in [49] indicate that penetration of sustainable energy sources, such as solar, could see a decrease in the excessive aging of distribution transformers in situations of overload, which could eventually result in wear-reduction.

Interestingly, according to studies such as [40], the main factors determining the sustainability of renewable energy resources boils down to economic factors. Developing countries, such as South

Africa, which are part of Kyoto Protocol, although aware of the environmental ramifications of conventional energy production, still investigate the deployment and sustainability of Renewable Energy Technology (RET) in terms of economic growth and development in order to prove that renewables are cheaper than conventional forms of electricity generation [40].

2.6 Impact of green and sustainable energy resources to utilities, large industries, small industries, and society.

South Africa is ranked in the top 20 of highest carbon emissions globally [13]. In South Africa, most of the electricity is provided through coal generation, and consequently, the utility is sensitive to the utility death spiral because the current utility provides electricity through this form. The utility market in South Africa is very fragmented with around 120 municipalities serving less than 1000 customers and around 90 municipalities receiving less that R1 million in revenue. Hence utilities are depending heavily on tariff customers, not only to subsidize the provision of free basic electricity but also to cover the cost of maintaining and expanding the national energy grid. Utilities are sensitive to utility death spiral, because they provide cheap or free electricity to consumers that otherwise cannot afford to pay for it. However, as more customers move to alternative forms of generation, the utility is forced to hike prices, further reinforcing the utility death spiral [48], [50]. However, utilities may be able to use the green and sustainable energy resource as an alternative to using coal. This will help preserve coal reserves for future use. The use of the sustainable energy resources may also help stabilise the electricity tariffs as sustainable energy will always be available, if there is measures in place for effective capture and storage.

Industries will be able to reduce their carbon footprint using sustainable energy resources. This is indeed beneficial to the industries as there are fines in place for emitting too much volumes of greenhouse gas. As a result, this will help reduces global warming. Green and sustainable energy resources emit very little to no greenhouse gases. The increase usage of green and sustainable energy resources will help reduce the use of energy sources emitting too much greenhouse gases. Figure 2-1 illustrates the emissions from different type of energy resources. It is observed that wind power, solar power and other green energy resources emit far less greenhouse gas when compared to energy sources such as oil and coal [51].

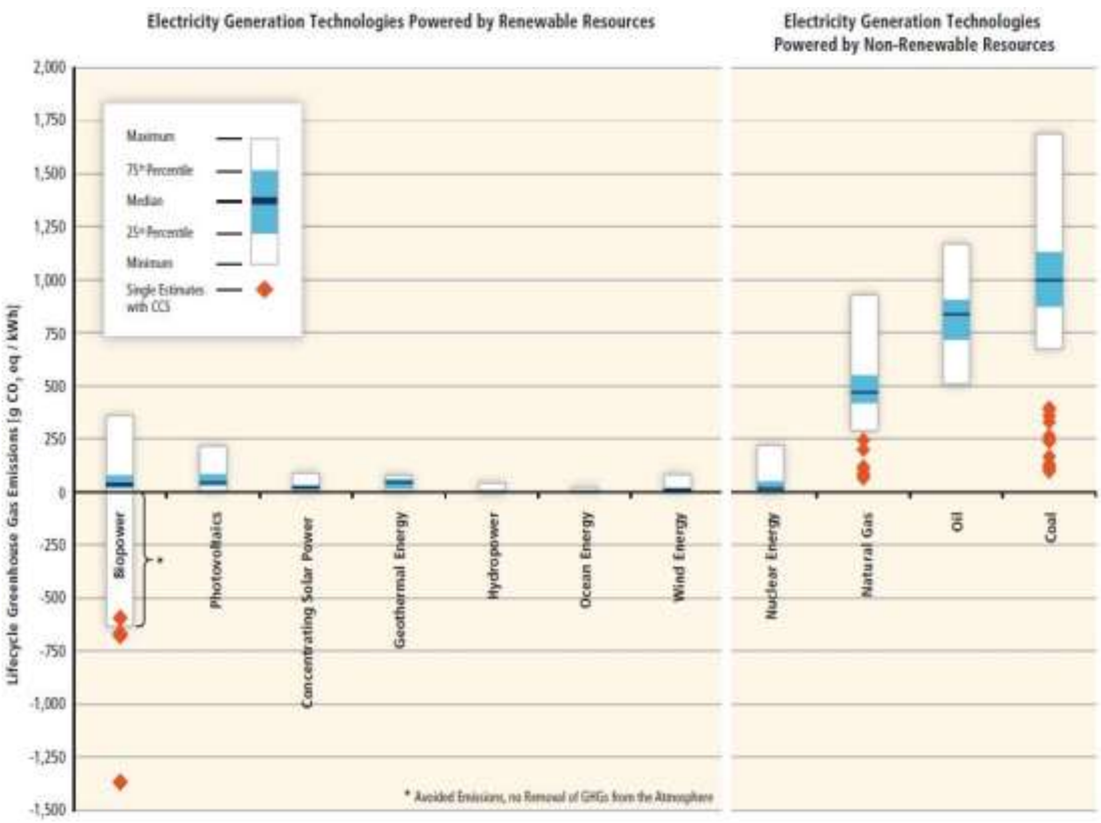

Figure 2-1: Emissions from Different Energy Sources.

The reduction in the emissions lead to a general betterment in the public health of the society. Energy sources such as wind and solar energy need no water to operate, and a result, water resources remain intact. This means that there is higher availability of water for agricultural use and essential water use [51].

From a social point of view, the use of green and sustainable energy resources increases job opportunities. Solar panel and wind power need technicians for maintenance purposes [51]. This will help to contribute to the development of South Africa economically whilst reducing poverty [51]. The IPP projects implemented to date in South Africa have contributed to a total of 32,532 job years for its citizens, with employment in the construction phase being higher than estimated. Those projects that have been successfully constructed and moved into the operation phase is expected to deliver a further 20,689 job years (about US$ 1.9 billion in salaries) [49], [52].

Interestingly, both [27] and [53] speak of financial implications of pursuing RETs in South Africa. There is a negative connotation on the use of bioenergy for electricity generation as there are costs incurred in transporting raw materials to site [27] as generation uses bulk material due to low calorific values [28]. [26] would argue in support of the supplier saying the supplier incurred lower costs as government incentivises the project. However, costs still would be incurred on the part of the government. For the full benefits of RE to be realised, the stratigraphic information of the area needs to be assess. [24] suggests areas with vast non-renewable resources would highly likely not recognise the benefits of RE from an availability and resource point of view. South Africa is dominantly a coal producing nation, though suggestions are to shift to renewable energies, the country would rather keep and optimise the existing techniques.

[53] implied the costs of electricity production from biomass to be more than two-fold that of coal production suggesting this to be a deterrent of acquiring investors.

2.7 Economic impact of clean, green, sustainable energy

A study identified that improving energy efficiency can reduce the total energy consumption, and the emissions of greenhouse gases, thereby ensuring economic growth [54] . In fact, according to [21], energy is seen to be an “important catalyst for growth”. Energy consumption and economic growth is shown to share a bi-directional relationship [55]. This implies an increase in economic growth has a positive impact on energy consumption, i.e., increased energy use is a sign of a growing economy. However, this being said, increased energy consumption, especially based on the fact that about 95% of energy is generated from coal in South Africa [2] shows that there will be an increase in CO_2 emissions. In fact, [56] illustrates that a 1% growth in GDP per capita results in a 0.40% increase in CO_2 emissions.

2.8 Environmental impact of clean, green, sustainable energy

It is anticipated that primary energy sources such as oil, coal and gas, will be exhausted within the next 50 years [57]. Furthermore, at the current economic growth rate, it is predicted that there will be insufficient capacity to meet the world’s energy needs[58]. The costs of renewable energy sources are decreasing dramatically, allowing them to compete with non-renewable energy sources [48].

Transitioning to more sustainable and cleaner forms of energy generation, especially with an increase in the price of fossil fuels, increasing CO_2 emissions could be seen as a major contributor to decreasing global warming and boosting growth of the economy by cutting down carbon emissions and consequently carbon tax [56].

Sustainable development goals are also looking to mitigate adverse environmental impacts such as air pollution, which is considered the fourth greatest risk factor for human health, globally.

This issue cannot be looked at in isolation as it is linked to the energy policies in place, among other issues. Mitigating environmental concerns through increased energy efficiency and the deployment of renewables is in line with the commitments adopeted within the Paris Agreement [46].

On another note, from an environmental perspective, it became evident that developments, such as utility scale solar could affect bird communities through habitat loss, and mortality as a result of collisions onto the infrastrucutre . The effect of such developments on nature and ecosystems are also a discerning factor that should be considered when developing a sustainable framework.

2.9 Levelised cost of electricity (LCOE)

Levelised cost of electricity refers to the breakeven price, which is a key metric considered in feasibility studies as it allows comparisons of fuels [48]. From a financial point of view, the smallest LCOE is desirable, because it implies that electricity is being produced at a low cost [49]. The LCOE is calculated by taking the sum of all the costs incurred in the project lifetime divided by the total amount of energy produced within this lifetime [49]. The LCOE is a factor considered by governments when evaluating policy decisions regarding conventional generation and renewable electricity generation [50]. Hence, LCOE needs to be considered when developing an integrated framework as it provides an indication as to how much of an economic impact integration of renewables will have. However, it should be noted that LCOE does not fully consider the rate of return, the impact of inflation or commodity price fluctuations [50].

2.10 Energy security

[59], [60] identify that energy is the support of economies and necessary for poverty reduction and economic growth. [51] states that renewable energy sources increase energy security and brings about socio-economic benefits, while mitigating climate change, hence there is a need to ensure that there is secure supply of energy within a country.

The International Energy Agency (IEA) defines energy security as the availability of energy sources at affordable prices [52]. There are two main aspects to energy security: (1) long-term energy security looks at energy supply in line with economic developments and the needs of the environment, whereas (2) short term energy security looks into the capability of energy supply systems to react quickly to changes in supply and demand. Some studies identify features of energy security to be the four A’s [52]:

- Availability
- Affordability
- Accessibility
- Acceptability

[59], [60] define availability to be the physical availability of the energy resource; affordability indicates that the energy sources are competitive and affordable. Acceptability focuses on the environmental impacts of the energy technology and the way it is produced, while accessibility focuses on how energy will be supplied and transmitted, i.e. infrastructure network, and geopolitical aspects [59], [60]

A plethora of studies have indicated the positive relationship between energy security and economic growth and [59], [60] suggest that introducing a diversified mix of green energy technologies will likely result in economic vulnerability to changes in commodity prices and improving the security of energy supply. The lack of consistency in electricity availability in South Africa made the country prioritise energy security as a vital factor to restore economic growth [61]. Furthermore, [11] states that diversification will impact developed countries and save them as a result of decreased emissions and taxes paid on them. However, it should be noted that increased integration could see global energy geopolitics become more complex.

With South Africa having a monopolistic energy sector, it is a challenge acquiring energy security and penetration of renewable energy producing companies is low [62]. Successful energy security is achieved via making knowledgeable decision i.e. regulatory impacts, target industries and implementation approaches [63]. [63] compares non-renewable energies and renewable energies suggesting the niche idea of RE as an energy security measure is the notion of it being based on flow, acceptance and usage rather than exhaustibility. Furthermore, with this perspective in mind, RE energy security plans are proactive plans. Emphasis is rarely given on renewable energies running out, however the consistent availability is questionable [63].

Active participation of countries in establishing RE is not only to achieve energy security, but also to achieve reduction of global warming gases [64], [65]. Active participation is put on emerging technologies like wind power and solar power [65].

2.11 Barriers to renewable energy

According to [66], the main barriers to renewable energy, from a South African context is the current innovation system in South Africa, and the economics surrounding green energy technologies. [66] identified that South Africa has a ‘path dependency’ since most of the energy is generated by two main energy providers, using coal, which is abundant, creating a pattern that has an innovative bias towards fossil fuel-based energy production.

From an economic perspective, barriers to the deployment of renewable technologies include their potential capital costs, and lack of competitiveness of newer technologies [67]. [66] suggests that economic factors can be grouped into (1) risk and (2) cost factors. Figure 2-2 indicates the lending cycle, which relates the risks and costs factors that are considered when deciding whether to invest in a renewable energy project or not. This cycle is also indicative of the barriers that may prevent the deployment of renewable energy projects.

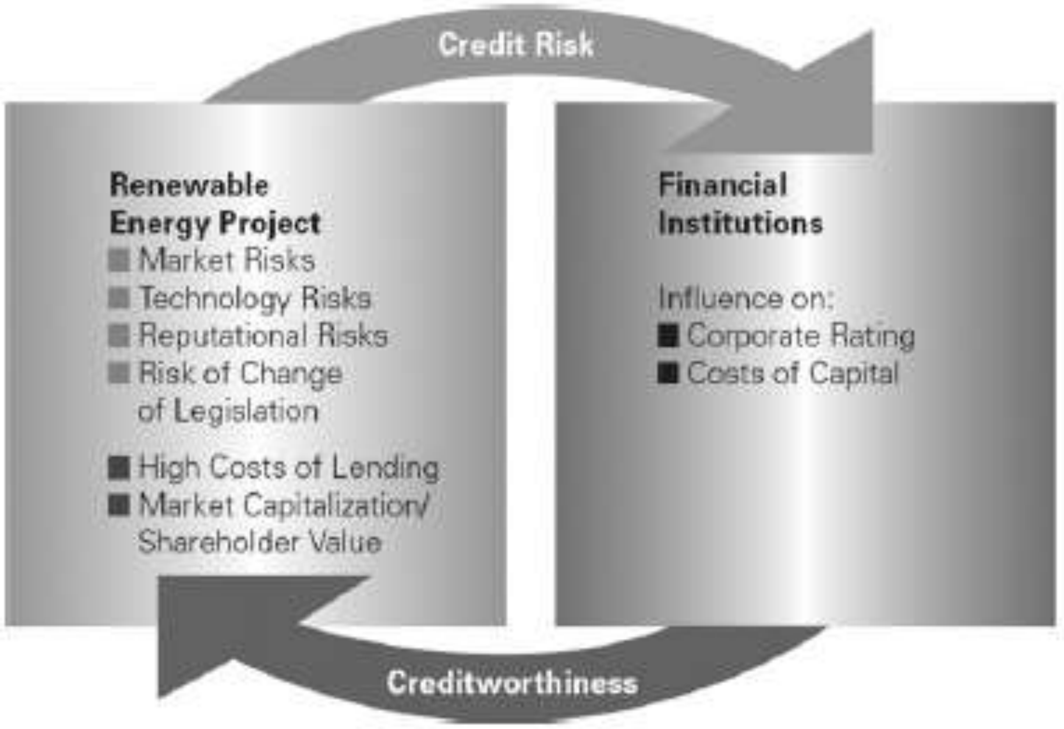

Figure 2-2: Renewable Energy Projects Lending Cycle

2.11.1 Risk factors

From a risks perspective, risks to the uptake of renewable energy technology could be in the form of market risks, technology risks, reputational risks and even risks as a result of a change in legislation. South Africa is relatively new when it comes to renewable energy technology. [66] indicates the market for renewable technologies is relatively young; also there is a lack of local manufacturers and suppliers [67]. [66] suggests that young markets are often susceptible to higher volatility and consequently greater risk. Also, since the technologies are relatively new, there is an additional technology risk associated with green energy generation [66], which poses a barrier to the uptake of renewable technologies. [66] also indicate that there is a lack of experience with renewable energy projects and this coupled with a lack of general awareness and skills from the general public on green energy technologies poses as a barrier for the sustainability of RETs [67]. This often makes it difficult for project developers to find funding or investors for RET projects.

2.11.2 Cost factors

The cost of green energy technologies is seen to be a barrier to renewable technology uptake in South Africa [66]. [66] identifies that in Europe wind generation could provide electricity at EUR 0.03 per kWh. However, this is deemed unfeasible within the South African context as wind speeds do not average those in Europe. Solar energy has huge potential, such as concentrated solar plants (CSP), but, in order to transmit the energy generated from areas of high solar irradiation would require heavy investments in transmission infrastructure [66]. Moreover, since South Africa has an abundance of coal reserves, electricity price, through the coal-fired generation is relatively low, a further barrier to the uptake of renewables. This is evident from studies such as the one in [26] who indicated that energy produced through the use of biomass is not yet economically viable and almost double that of coal generation costs.

One additional factor that could influence the uptake of renewable energy technologies is public acceptance [45].

2.12 Perceptions of utility on green and sustainable energy resources in South Africa

The national utility is trying sequel the energy crisis that has plagued the country since late 2007. The energy crisis led to nationwide blackouts, load shedding and economic losses [50].

Deployment of renewable technologies could alleviate peak load periods, voltage support, and delay further investment for grid expansion [49]. Furthermore, developing countries are looking to ensure energy security, and systems with lower system interruptions are more secure. However, increasing DG will see utilities increasing their energy prices in order to recover lost revenues. Further, increasing penetration of RETs could result in the utility becoming obsolete as a result of competition, and in countries, such as South Africa, where there is only one major supplier, this poses negatively on economic growth [68]. Another area of concern from a technical point of view is that introducing distributed energy generators will cause bi-directional flow of power through the grid, which could lead to voltage fluctuations and harmonic distortion [38]. At the same time, this integration will allow the grid to have back-up supply, where any excess energy that is generated can be absorbed by the utility [38].

Hence, in order to achieve optimal integration, the optimal size, design, and location of DG needs to be understood in order to minimise any instabilities to the power system network.

2.13 Need for sustainability

Energy price instabilities, supply insecurity, climate change, and environmental pollution are all factors that are motivating the move towards cleaner sources of energy generation [23] . The recent climate change agreement sets out the need to decarbonise and develop and integrate new technologies for the generation of clean electrical energy [69] . There are number of socio-economic issues related to poor energy access, such as, impacts on health and education, poverty, social disorder, and impact of human wellbeing, as well as undesirable migration. Poor quality of illumination among electricity deprived South Africans limits the hours for study for school children and consequently impacts their academic performance [70]. Furthermore, lack of electricity affects small and micro-scale businesses, usually set up within households such as tailoring, venturing, and hence compromises the livelihood of such people. Non-availability of electricity deprives such consumers from extending their businesses and income. Poverty and crime are also issues that arise as a result of non-electrification /energy insecurity. Various studies have concluded that streetlights reduce crime relates, and that informal settlements without electrification experience a higher crime rate than those with electrification [55]. There is a higher affinity for people from rural areas to migrate to urban or industrial areas caused mainly by the unavailability of basic needs such as electricity. The number of people who do not have access to electricity, worldwide, has decreased from 1.7 billion in 2000 to 1.1 billion in 2016.

According to [69] the sustainability of energy systems is influenced by three sustainability dimensions, namely, environmental factors, social factors and economic factors. Economic indicators include capital costs of RETs, levelized costs of electricity (LCOE) and total maintenance and operational costs associated with RETs [69]. Social factors consider energy supply security, the mix (diversity) of supply, acceptance of the public, health and safety and integrational issues, while environmental considerations include the depletion of fossil fuel reserves, increasing emissions and environmental degradation [69].

Energy generation, or the way energy is generated, has a huge impact on climate change [23], hence it is relevant to understand and develop a sustainable and clean approach to produce electrical power.

2.14 Conclusion

South Africa's obligations towards the Kyoto Protocol and United Nations Framework Convention on Climate Change signifies that the country is looking to move into cleaner forms of energy generation. The current policy landscape is conducive for the implementation of green energy technology projects. This being the case, development of a suitable framework will potentially fast track the penetration of renewables while remaining cohesive with the current energy landscape in the country.

This chapter examined the key literature relevant to provide context for the development of an integrated framework for green and sustainable energy resources. Studies reveal that there are three main drivers pivotal for the development of a framework for sustainable energy, namely, energy efficiency, renewable energy integration and smart energy management. Also, renewable energy technology needs to be studied in order to identify trade-offs when selecting appropriate renewable energy technology. Further, criteria for the framework should encompass factors – technical, economic, social and political. From a developing country perspective, there are also barriers to technology adoption, investment decisions need to be motivated in order to work towards sustainable energy infrastructure.

Overall, there is a need to for sustainable energy generation, especially given the fact that South Africa is plagued with an energy crisis, developing an integrated framework will prove beneficial.

Chapter 3: Methodology

3.1 Introduction

This chapter discusses the methodology and approach this research will follow in order to come to conclusive ideologies for the creation of an integrated framework for clean, green and sustainable energy. The methodology will also characterise the data gathering process and analysis of results, and the limitations of the study. Chapter 1 provided the need for the study while chapter 2 discussed the relevant literature in relation to the key constructs and objectives. The choice of methodology will be stipulated in relation to the "Research Onion" as described in [71]. This study makes use of a qualitative research approach in order to gain relevant insight on new concepts that may affect the development of a tangible framework.

3.2 Research design and philosophy

Figure 3-1 illustrates the research onion which provides a holistic view of the phases that need to be covered when developing research methodology for a study [71].

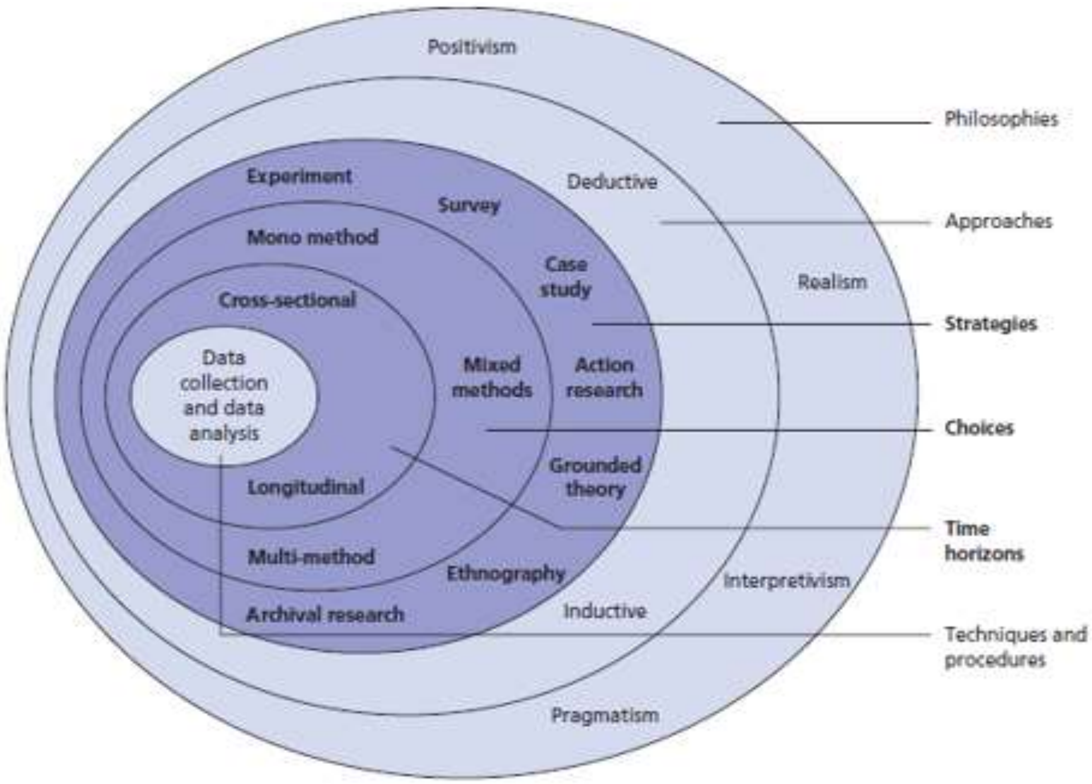

Figure 3-1: Research Onion

According to [72] there are three types of research, exploratory, explanatory and descriptive.

- **Exploratory**: investigates problems in order to lay the foundation for future studies [48], after which descriptive research will be needed to substantiate the findings.
- **Descriptive:** Explores and explains the research problem.
- **Explanatory:** Defines the relationship between given variables in order to assess the relationship and interaction between the variables.

Furthermore, it is imperative that the research design flows with the methodology chosen [73]. Qualitative, quantitative and mixed research methods have been defined in [73], and it is vital that the chosen methodology is coherent with the research design.

[73] defines four main facets of research philosophy, namely positivism, realism, pragmatism and interpretivism. Since the reality of this research exists, hence the research philosophy used for this study is positivism. Furthermore, [71] mentions two different approaches to research, (1) deduction and (2) induction. The deductive approach involves testing a research strategy that is designed specifically for testing this proposition. On the other hand, the inductive approach looks at analysing data that is already collected. Since this study aims to develop a thorough review of existent literature in order to understand the variables being investigated in order to develop an integrated framework for green and sustainable energy.

3.3 Research method and rationale

The purpose of research is to create new knowledge through an orderly investigative process [71]. Quantitative research tests theories by looking into the relationship among variables, and the data is usually analysed through statistical procedures [74]. Qualitative research makes use of open-ended question in order to gain insight into new concepts and develop new ideas [74]. Mixed methods combine both quantitative and qualitative research methods. This study aims to discover new insights in order to gain a broad understanding of green and sustainable resources in South Africa in order to develop an integrated framework for these resources. Due to the nature of this topic, this study was chosen to be qualitative and exploratory in nature because:

- Project initiatives are still in the development phase and more lessons still need to be learnt;
- Concepts need to be clarified;
- Research sought to find new insights into the concept of an integrated framework for green and sustainable energy resources.

Quantitative analysis was not considered to be feasible for this study as the research predominantly investigates the perception of energy stakeholders in order to develop an integrated framework.

3.4 Population

According to studies such as [71], [74] population refers to a group of individuals to which the research is applicable. The population is also a group of individuals that possess one characteristic that distinguishes them from other groups [74]. In this study, the population was identified to be individuals within the energy space. Within this context, as defined in [74] , the target population, which refers to the actual list of sampling units from which a sample is selected was identified to be individuals who have in depth understanding and knowledge of the current energy landscape and how it is impacted. This target population was deemed suitable because of their experience within the energy industry, which led to meaningful insights delivered through informal discussions with them.

3.5 Unit of analysis

The unit of analysis refers to the subject matter experts that the researcher held discussions with to gather insights on the topic at hand, or as [74] defines it, the unit that is used to gather data. The unit of analysis was decided upon by identifying individuals who can provide answers and insights to the study. In this research, the unit of analysis referred to personalities from various regions in South Africa, such as decision makers, policy makers, energy modellers, CEOs and energy planners.

3.6 Sampling method and size

A sample is defined as the relevant subset of the population [71], and selection of a good sample is necessary in order to ensure the credibility of the results achieved [71]. This is because, as mentioned in [74], the findings achieved from the sample is generalised to the entire population. According to [71] there are two main sampling techniques namely, probability sampling and non-probability sampling.

Element selection technique	Representation basis: Probability sampling	Representation basis: Non-probability sampling
Unrestricted sampling	Simple random sampling	Haphazard sampling or convenience sampling
Restricted sampling	Complex random sampling (such as cluster sampling, systematic sampling, stratified sampling etc.)	Purposive sampling (such as quota sampling, judgement sampling)

Figure 3-2: Sampling Methods

These sampling types [75] are differentiated by the availability of the complete list of the population, i.e., if the entire population list is available, then probability sampling should be used, however, if the complete list is not available, then non-probability sampling is employed. In this research non-probability sampling was used as the researcher was not able to obtain the entire list of the population. Within the sphere of non-probability sampling, techniques such as purposive sampling was employed when selecting the sample and snowballing when asked to identify potential subsequent subject matter experts that can be engaged in discussions.

3.7 Data collection and measurement instrument

[76] notes that the main difference between quantitative and qualitative methods of data collection, is the actual method used to gather findings. Quantitative research makes use of standardised questions that will be asked to participants in a predetermined order. On the other hand, [76] indicates that qualitative research data are not collected through a set of pre-determined questions, rather data is gathered by raising issues around the topic of enquiry. Examples of qualitative methods for data collection include in-depth interviews, narratives and orals histories. [76] also suggests that secondary sources can also be used as a method of data collection, from historical and current sources.

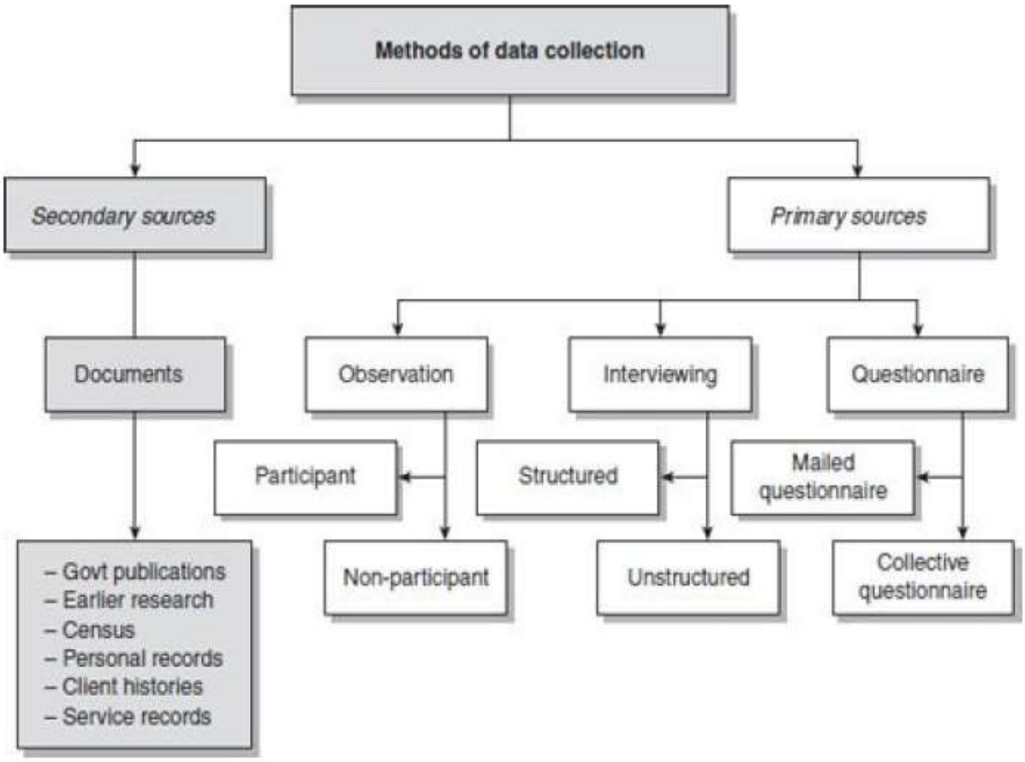

Figure 3-3: Data Collection Methods

According to [74] secondary data is defined as "data used for a research project that was originally collected for some other purpose", and may include [76]:

- Government or semi government publications from organisations that collect data on various subjects regularly
- Earlier research conducted on similar topics
- Personal records such as written historical and personal records such as diaries
- Mass media which includes data from newspapers, magazines, on the internet etc.

For the purposes of this study, findings were established by making use of (1) narrative and (2) secondary data sources, i.e., previous research and literature. Narratives rely on people narrating their experiences; hence insights were provided through informal discussions with subject matter experts within the energy sector [74]. [74] indicates that narratives need to be consistent with the criteria of a good qualitative study, and for this reason, it was ensured that:

- Focus was kept on one individual through informal discussions
- The experiences of individuals were noted on the subject

- The researcher collaborated closely with the participant to ensure that the experiences narrated accurately portrays conclusions that are of value.

In addition to discussion with subject matter experts, data obtained from relevant studies done previously on the same subject which was thought of as appropriate in order to gain new insights was also used and allow the researcher to arrive at qualitative conclusions on the topic. In determining the type of measurement used, the researcher made sure that the approach used ensured findings achieved were credible [74].

3.8 Limitations of the study

The key limitation of this study is identified below:

- In order to prove tentative answers, exploratory studies need to be followed up with more detailed research, i.e. quantitative analysis, in order to provide more dependable results [74].
- The research investigates the effects of green energy technology within the South African landscape hence could be subjective and may differ for different countries.
- The population was selected through non-probability sampling, hence may not be an accurate statistical representation of the population [59].

- Interpretation was dependent on the researcher’s judgement.
- Since data from relevant literature was used, the definition and criteria might not have been well aligned to the current research.
- Since secondary data in the form of previous literature were used, limitations such as the availability, format and quality of the data could present issues in the validity and reliability of the data [76].
- Informal discussions with subject matter experts could have been subjected to respondent bias unknowingly because of either comments made by the researcher or body language displayed during the discussions [74].

Chapter 4: Research Questions and Objectives

4.1 Introduction

This chapter serves to present the findings from relevant and informal discussions held with subject matter experts within the field of energy, as well as data and findings gathered from high impact literature and research studies. The main insights gathered, and findings of this study are presented and discussed in greater detail in the chapter that follows. This chapter is presented in line with the three main research questions.

4.2 Findings of research question 1

The aim of research question 1 was to understand the current energy landscape, and how the uptake of renewables was impacting it. Through this, the objective was to understand whether the effects were being perceived as adverse or positive. The experience of the subject matter experts with whom discussions were held ensured that this objective was met. This, together with findings from relevant literature concreted the impact that green energy resources have on the energy landscape.

4.2.1 Objective of research question 1

Research Question 1: What are the effects of green energy resources in South Africa?

Research Objective 1: To determine the effects or impacts that renewable energy resources and the integration thereof have on the current energy landscape in South Africa.

4.2.2 Impact of green energy on the South African energy landscape

From discussions with subject matter experts and findings from literature, it is was evident that there are both positive and negative impacts of renewable energy on the current energy landscape.

South Africa is heavily fossil-fuel dependent for energy production and has a huge carbon emissions impact [11]. The South African government has taken initiatives to reduce greenhouse gas emissions by promoting renewable energy, especially given the fact that developing countries, such as South Africa contribute towards 55% of the yearly global greenhouse gas emissions [11]. In fact, there is a vast movement towards green energy; there is a proposal for around 600 green energy projects, which range from grid to off-grid solutions and from large scale to house-hold level systems [68]. The energy landscape has been impacted by the adoption and integration of green energy technologies and the drivers for renewable energy technologies and negative factors which could hamper uptake of renewables were identified. It was evidenced that the positive impact of renewable energy technologies on the energy landscape included the fact that renewables can be used to produce cheaper electricity (lower LCOE) and ensure security of supply. At the same time, however, integration of renewables beyond certain percentages was found to create imbalances in the power system, such as voltage fluctuations, increasing frequency, oscillations and system instabilities. From the perspective of the utility, increasing penetration of renewables could potentially see the traditional power producers become obsolete as a result of the utility death cycle.

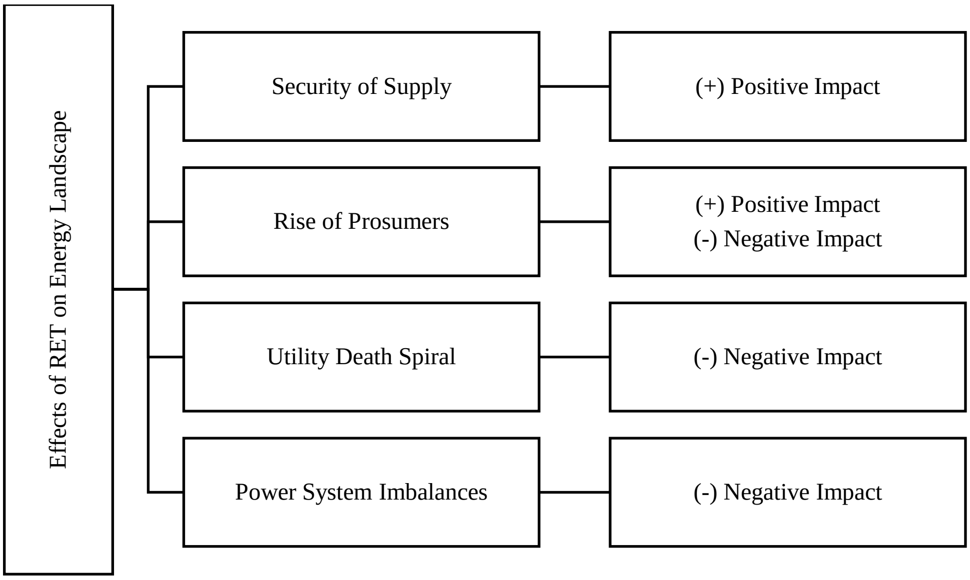

Figure 4-1: RET Impact on Energy Landscape

Figure 4-1 summarises the main impacts that green technology has had on the energy landscape in South Africa. The positive effects include security of supply and the rise of prosumers. Energy security has been identified as pivotal for economic growth and general well-being of the citizens of a country [44], [77]. Moving onto green technology, ensures that South Africa will be able to meet the demands of a growing economy in line with objectives to reduce carbon emissions and mitigate climate change [12], [78]–[80]. The rise of prosumers also impacts the energy landscape positively because it alleviates the current utility from stress of growing demand. Prosumerism further attributes to the decline in climate change and improvement in energy awareness and public acceptability, which is an indicator of sustainability [12]. However, from the perspective of utility and current power systems, the integration of renewables will likely see adverse effects, which include utility death spiral, and power system imbalances, which could result in more costs for utilities. Furthermore, the rise of prosumers could see a further detriment to the utility, especially through the death spiral effect. The factors illustrated in Figure 4-1 are elaborated in more detail in sections 5.2.1 and 5.2.2.

4.3 Findings of research question 2

Research question 2 aimed to identify the key drivers impacting sustainability of green energy technology. This was done in order to concrete the factors that would have to be considered in the development of a framework. Conclusions provided by subject matter experts were in line with many relevant research studies, which helped determine the factors that would be used in the framework.

4.3.1 Objective of research question 2

Research Question 2: What are the key drivers that impact sustainability of energy sources in South Africa?

Research Objective 2: To determine the key drivers that influence sustainability of specifically renewable energy resource technology in South Africa.

4.3.2 Drivers influencing sustainability

The need for sustainability has been reinforced by economic concerns, environmental impacts and growing demand. Outcomes from personal meetings indicated that moving towards a more sustainable form of renewable energy generation would be a key measure to fight climate change and resource depletion. Sustainability was looked at from the perspective of (1) sustainability of the green energy technology itself, (2) the policies and regulatory frameworks in place that ensure sustainability as well as understanding (3) the factors that impact sustainability (positive and negative).

Several factors were identified to have some form of influence on sustainability, such as financial factors; market pull; geographical factors, political factors and behavioural factors which were grouped into the following main factors: economic; social and environmental. A study conducted in [7] also talked to the same factors, i.e., environmental, economic and social aspects of energy as influencers of sustainability. [81] further evidence that the concept of sustainability is not only focused on improving green energy technology and their efficiency but also dependent on ensuring the environmental, social costs, risks and benefits are also well managed and balanced.

The summary of insights and literature observations on sustainability indicators is illustrated in Figure 4-2.

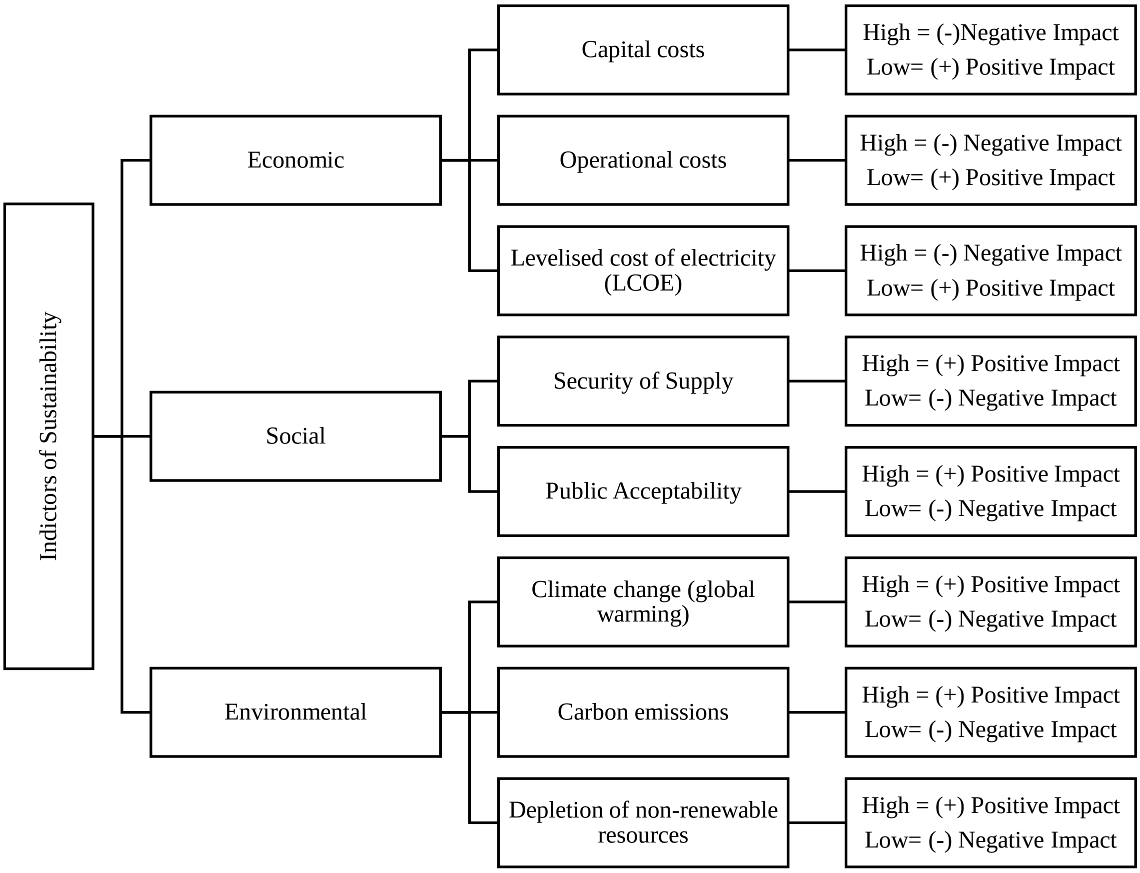

Figure 4-2: Sustainability Indicators

The key sustainability indicators that were identified were factors of economy pertaining to the costs and operational costs of renewable technology itself. The more costly a technology, the less competitive it is compared to conventional forms of energy generation. Hence a lower cost will ensure sustainability of the technology. From a social aspect, security of supply is a stand for sustainability while it was identified that a lack of public acceptance, that is, the unwillingness of society to acknowledge and welcome green technology, could hinder sustainability of green technology. From an environmental point of view, the mitigation of carbon emissions and the rampant depletion of non-renewable resources were drivers for sustainability.

Sub-sections 5.2.1, 5.2.2 and 5.2.3, elaborate on the key literature used to identify indicators of sustainability (economic, social and environmental) as well as confirm the insights obtained from personal meetings with various subject matter experts.

4.4 Findings of research question 3

The final research question aimed to ascertain the findings of research questions 1 and 2. Through this research question, the two factors presented in RQ 1 and RQ 2 were collaborated, i.e., success of green energy technology and the uptake and integration thereof can only be ensured through both positive impacts presented by renewable energy and the sustainability thereof. In presenting this it was important to understand the impact RETs, that are sustainable would have given the current energy landscape

4.4.1 Objective of research question 3

Research Question 3: Impact of green and sustainable energy resources to (a) utilities, (b) industry, and (c) society?

Research Objective 3: To determine the impact that green and sustainable energy resources have on three main stakeholders, namely, the utility, industry and society.

4.4.2 Impact of green and sustainable energy resources on utilities, industry and society

The main impact factors that were mentioned in the discussions were in line with findings from literature. These factors are also interconnected to the first two investigations wherein the researcher confirmed the impact of green energy on the current energy landscape and the indicators/drivers of sustainability.

From Figure 4-3 energy security and reduction of carbon emissions are few of the positive impacts that the industry can see from green and sustainable energy. It has been also been evidenced that economic growth is linked to energy security, hence security of supply will prove beneficial for industry. These same factors also prove to have a positive impact on society, that together with the fact that green and sustainable resources will enhance job creation is a further advantage to society. However, there is also concerns of land and noise intrusion associated with renewable energy technologies were also noted – these could affect society adversely. The utility seemingly will see the main negative impacts of green energy, such as the utility death spiral, technical complexities in power system infrastructure and obsoletion, especially if they fail to adapt their current business models to reflect and adapt to these changes in energy technology.

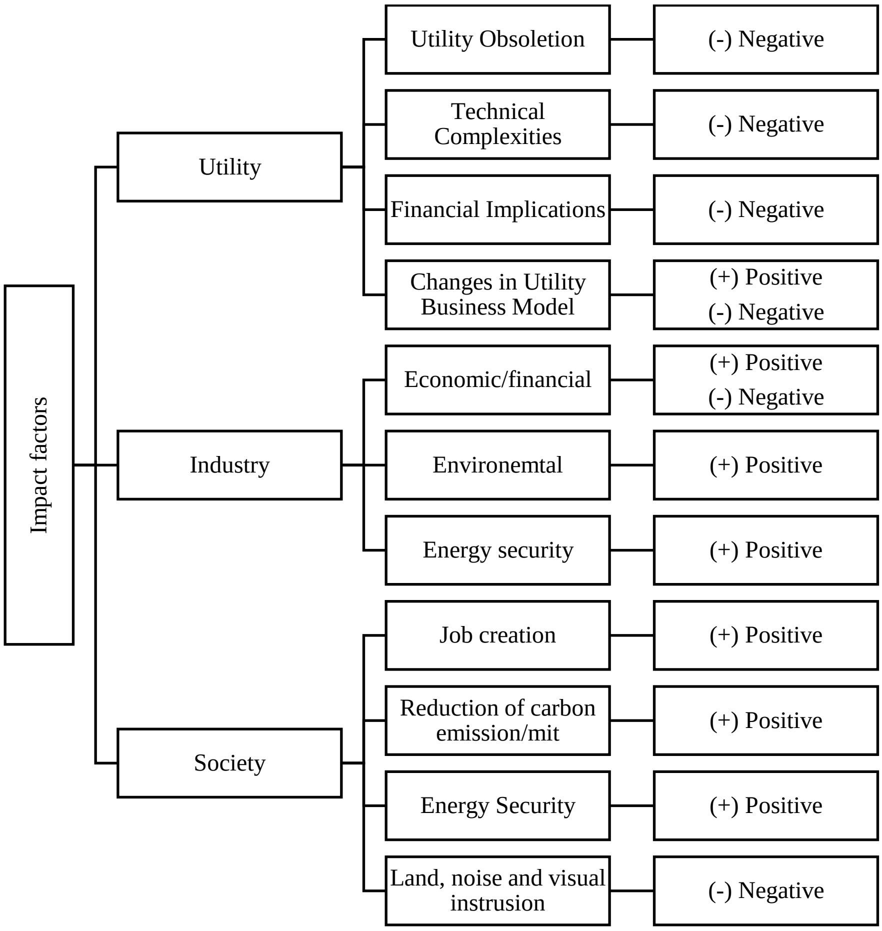

Figure 4-3: Impact of Green and Sustainable Energy

4.5 Conclusion

This chapter highlighted the main findings established through data gathered from relevant and high impact literature and research studies conducted, as well as informal discussions held with subject matter experts. All three research objectives were met, and the findings prove beneficial to the development of an integrated framework.

Chapter 5: Results and Discussion

5.1 Introduction

The purpose of this research is to provide a better understanding of how South Africa's energy landscape has been influenced by renewable energy; the key drivers that influence the sustainability of renewable energy technologies, and the impact of green and sustainable energy on the utility, large and small industries and society. In this chapter, findings are discussed and described by relating it to high-impact literature and through personal meetings from personalities from various regions in South Africa, such as decision and policy makers, energy modellers, chief executive officers and energy planners, were used to establish an integrated framework for green and sustainable energy. This chapter is divided into three subsections that relate to three main areas of investigation to identify the Key Value Drivers (KVDs) to be used in the framework which is to be developed in the conclusions chapter.

5.2 Impact of green energy on the South African energy landscape

5.2.1 Positive effects of green energy technologies

The main findings indicate that the use of RETs improve energy security, which in turn enhances economic stability and development. Furthermore, there is more movement of individuals to cleaner generation – rise of prosumers. The subsections below elaborate on the main positive effects of renewable energy technologies.

5.2.1.1 Energy security

Studies [79],[82],[83] indicate that several definitions for energy security exist; according to [83] energy security refers to accessibility to various forms of energy at affordable prices and in sufficient quantities, which is similar to the definition of energy security provided by the International Energy Agency (IEA), i.e., the uninterrupted availability of energy sources at affordable prices. Other research suggests that energy security implies assuring citizens that there will be protection from energy shortages and blackouts [82]. But regardless of the definitions provided, as stated in [83], energy security is key parameter needed for the stable development of countries.

From a long-term perspective, energy security considers the supply of energy in line with economic development and environmental needs, whereas in the short term, secure supply means the ability to meet sudden changes in demand [11]. With forecasts suggesting that there will be an increase in energy consumption by 53% globally by the year 2030, and 23% of the current world's electricity is produced through green technologies, and close to 59% of new capacities have been set up worldwide, it is indicative that renewables will play a pivotal role in ensuring security of supply, especially in the long run [11].

Interestingly, [83] suggests that concept of energy security is adaptive and could be dependent on a concept that justifies government policy and actions. Countries are developing strategies to be energy secure, of which internal strategies focus on maximising energy efficiency and using renewable energy sources [12]. This further emphasises the positive impact that green technology has on ensuring security of supply [43].

5.2.1.2 Rise of prosumers

Evidently the rise of renewable energy production has motivated opportunities for self-sufficiency in terms of energy production [84]. The rise of prosumers has become popular, especially given the current challenges facing the energy landscape in South Africa. Most are motivated to move onto self-generation because of increasing electricity prices, as well as to reduce the environmental impact of fossil-fuel generated electricity [43]. Furthermore, with improved efforts to increase energy awareness, and promoting behavioural changes, i.e. better and more efficient energy use, consumers are beginning to make informed decisions about energy consumption and practices[43].

As highlighted from the outcome of personal meetings, the rise of prosumers provides numerous advantages. In terms of energy demand and supply, as identified in [43], the rise of prosumers will greatly reduce the need for energy, and in doing so relief stress of the current utility. "Prosumerism" has also become an attractive option for SMEs, as these small players will see themselves in control of their supply and energy demand requirements [84].

Furthermore, studies [43], [84] have highlighted the importance of social acceptability and community acceptance. By creating more energy conscious individuals, who are willing to adopt green energy technologies, sustainability will also be ensured.

The observations from literature have made it clear that green technology has a major play in the rise of prosumers within the country.

5.2.2 Negative effects of green energy technology on the energy landscape

The main adverse impacts brought on by the penetration of renewables into the current energy landscape include the obsoletion of the traditional utility through the utility death spiral and the adverse impacts it may have on power systems, i.e. voltage fluctuations, system imbalances, increased oscillations.

5.2.2.1 Utility death spiral

The transformation of the electric power sector towards more sustainable forms of energy production through green energy, also sees the traditional utility face challenges in terms of the current structure of the utility, and the way in which electricity is produced, transmitted and sold [84]. This, especially at a time where the costs of traditional electricity are increasing in South Africa [43]. Observations from literature and insights from personal meetings indicated that the main effect of renewable energies on the landscape is the fact that conventional generation methods could become obsolete. [84] indicated that until some years ago, energy generation was niche to utilities, however, in many countries, as in the case of Germany, about 23% of generation now occurs using renewable sources which has eroded the market share for conventional utilities. [44] concedes this finding by stating that in countries such as Hawaii, where the penetration of renewable technologies such as solar PV is one of the highest, the sales of electricity from traditional utilities have declined by about 21%. This notion is also carried through in studies such as the one in [77] that indicate that, the displacement of conventional means of generation technology by renewable energy technologies could have traditional utilities see a decline in their revenues and profits– which could ultimately lead to utility death spiral. The utility death spiral which is brought on by the fact that transmission and distribution costs are “largely fixed”, and these expenses are covered through the charges allocated to the consumers [77], are forced to hike electricity prices in order to compensate for the reduced demand and help recover costs with more adoption of green technologies [77]. This results in a *cache-22* situation as increasing prices further drive the rise in IPPs and prosumers, which consequently run the utility out of business.

However, there are some contradictions to this view [43][84]. These studies suggest that the reasons conventional power generation utilities are finding themselves in a death spiral are beyond the fact that there is an increased penetration of renewables. [84] explains that traditional utilities do not see renewables as a threat to their current business, even though they have lost significant market share to green energy producers and prosumers. [44] even suggests that the write-off of substantial assets by conventional energy generators, as seen in the case of Germany, was rather a reflection of the actions of generators themselves, rather than the penetration of renewables, such as solar PV. This, although opposing many observations and beliefs, indicates that the utility death spiral could be a result, not merely because of the increase and adoption of green technology, but rather, the incapability of traditional utilities to adapt and innovate their business models to benefit from energy transitions [84].

The findings from research have bolstered the insights provided by subject matter experts – more than the renewable energy impact playing a part in the utility death spiral, the obsoletion of the current utility could be a result of the failure to adapt and transform current business models within conventional utilities to incorporate green energy technologies, especially provided the fact that most of the IPPs work to complement the conventional utility [44]. Currently, however, the 'death' of conventional utilities is still seen to be the adverse effects of renewable energy technologies [68].

5.2.2.2 Power system instabilities

One prominent adverse effect of renewable energy penetration is the impact that it has on power systems. Unlike conventional methods of generation, in which fuel can be stocked and processed, green energy presents many uncertainties in terms of forecasting energy production and grid management. Such uncertainties may lead to voltage fluctuations and system instabilities, as identified through observation from literature and insights provided by key subject matter experts.

From observations, it has been revealed the penetration of renewables could strongly reflect on the operating conditions of power systems because of the variable nature of green energy resources such as wind and solar [85]. [86] confirms that changes in load affect the frequency of the power network, hence an increase of renewables such as solar PV and wind power could see the inertia of the power system being reduced, an increase in the frequency deviation, and more oscillations, i.e. increased system instabilities. [68] adds to these findings by indicating that green energy sources such as wind and solar PV require more flexibility from the power system than conventional thermal generation. Hence, the "limited predictability" and variability could result in a number of "power system impacts", which becomes more prominent at higher penetration levels. This tune is harped in [87] who also state that the variability of green energy sources, namely wind and solar, creates problems in grid stability and a mismatch between power demand and supply. To further reinforce the issues with overpenetration of green energy, [88] show that if the share of renewables become relatively high, and there is no curtailment of the power, then conventional resources may be required to decrease or increase their output to compensate for this additional variability introduced. Furthermore, since renewable energy generators are located at points where there is high availability of resources, it could result in a weak interconnection between the central grid and the generator, which lead to voltage fluctuations, which could lead to equipment damage or even cascading blackouts [88].

These findings are in line with the numerous grid integration studies [87], [88] conducted; however, it should be noted that if penetration does not exceed certain levels, there is no cause for concern. Studies [86] show that the penetration of renewables (on the power system in Egypt) up to 20% is still considered within safe limits. Furthermore, interconnection between isolated power systems could reduce the variability of renewables, consequently minimizing the problems associated with their intermittency [87].

Overall, due to the variable nature of the most popular forms of renewable energy, wind and solar, especially from a South African context, uncontrolled or over penetration could result in huge negative implications such as equipment damage or even black outs. Effects of green energy on power systems within the current energy landscape are still considered negatively.

5.2.3 Conclusion

The outcomes of the study were indicative of the positive and negative effects of green energy within South Africa. Given the current energy landscape of the country, adoption and integration of renewable energy technologies will ensure that there is energy security and motivate the rise of prosumers. At the same time however, South Africa is still heavily dependent on coal for its generation, hence, overpenetration could result in imbalances to the current power infrastructure and see decline in sales to the utility resulting in the onset of the utility death spiral.

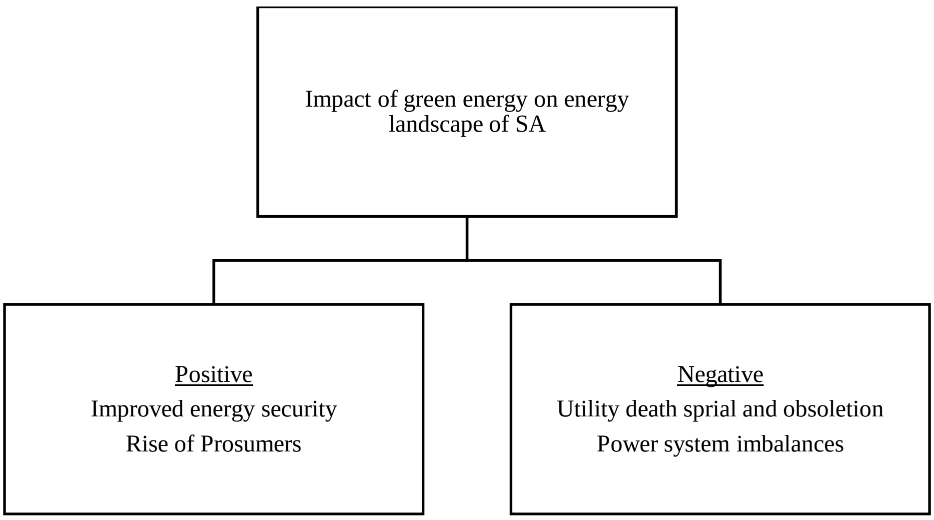

Figure 5-1: Conclusion of Findings for Impact of Green Energy on the Energy Landscape

5.3 Key drivers influencing sustainability of renewable energy technology

Key drivers ensuring the sustainability of renewable energy technology include economic factors, social factors and environmental factors. These findings are discussed in relation to high impact studies.

5.3.1 Economic Factors

The economic factors, considered in section 2.7, linked to the costs of renewable energy technology. From an economic point of view, capital costs, annualised costs and levelized costs are decision makers in the sustainability of green technologies [31]. Hence there is clear relationship between the costs of construction and installation of power plants, operational costs and their sustainability [31].

From a South African perspective, it is evident that local manufacturers and suppliers of renewable energy technologies are limited, which adds onto the costs of the technologies [50], because importing technology is more expensive than if the technology was to be manufactured locally. Furthermore, some of the renewable technologies available, such as biomass, geothermal, ocean and solar are not yet “fully competitive” [31], hence the initial high investment costs are predicted to be owing to their learning curves [31]. There are also a “lack of financial incentives” in place, as with many developing countries [50]. This according to [50] could affect the sustainability of renewables, especially for SMEs who lack the finances for adopting cleaner technologies [50].

Further observations from high impact literature sources and insights gathered from personal meetings with key energy modellers and energy planners indicated that losses experienced through transmission and generation could hike up investment costs. This concedes with findings from [50], [89] that state that losses exceeding as much as 30% have been observed in the distribution and transmission of generated electricity. This coupled with the initial investment cost for green technologies could hamper the sustainability of the green energy. Additionally, due to the nature of renewables (variability of supply) [87], [89], there has to be provisions for storage, i.e., storage devices, in order to ensure continuous and uninterrupted power supply, which could further push up costs of green technologies [7]. At the same time, however, studies such as [90] confirm that effective grid integration and flexibility improves efficiency and can create a “striking economic value”.

Sustainability could be affected adversely by the initial high investment costs associated with green technologies. Insights gathered from personal meetings have been concreted through observations from literature. Economic factors are key drivers determining the sustainability of green technologies. If the costs of green technology, that is, its operational costs and LCOE are too high, it could mitigate the adoption of green technologies, and consequently disprove sustainability of green energy resources.

5.3.2 Social factors

The sustainability of green technology is dependent on the impact that it has on society. This is proven in [69] who defined the social indicators of sustainability to be (1) energy security, (2) public acceptance, (3) health and safety, and (4) intergenerational issues [69].

5.3.2.1 Energy security

Energy security, as explained in section 4.1.1, is seen to be a huge driver of sustainability. It is evident that in order to secure energy supply for the future, there has to be a diversification of the energy sector based on low carbon technologies [31], which is possible through the use of green energy technologies. The availability of renewables is also an important indicator of supply; from a South African context, there is an abundance of renewable resources.

However, there is an ongoing myth that renewables can be scaled up to meet electricity demands, even on those days where there is low sunshine or wind levels, by enforcing bulk storage. Storage costs are still thought of to be heavily expensive, suggesting that scaling up of renewables could prove impractical – a negative for energy security. But, findings wherein 1600 stakeholders over 71 countries were surveyed, indicated that the systematic integration of renewables, by up to 70% is feasible [91]. [91] further reiterates that over 80% of 600 North American utility professionals expect moderate to significant increase in renewable energy in their systems and looking only at storage, in order to confirm the value of green energy is simplistic [41].

5.3.2.2 Public acceptance

Observations from literature has evidenced that one key social indicator that could hamper the sustainability of any energy technology is public acceptability. There is generally a resistance to change, which is magnified as a result of a lack of understanding to adopt and adapt the technologies for greater benefit [92]. Using renewable resources such as wind to generate electricity require the use of vast amounts of land, and it is coupled with visual intrusion and noise

[31]; concerns for biomass are related to competition for agricultural land, water and food production [31]. This factor may hinder public acceptance and if not accepted by the public, energy transition is unlikely to take place. [31] identified that the main barriers to sustainability is still the lack of awareness from the general public on green technologies, hence sustainability of the green technology can only be ensured if there is an increase in awareness about the positive potential for the technologies, i.e. green energy is seen as a potential for job creation and economic development in order for it to be accepted among the public. In fact, [93] states that prospects for employment in the renewable energy sector is significant, about 16.7 million jobs to be created by the year 2030. This is conceded by the UNEP report which specifies how energy transition to a low carbon economy will result in additional jobs being created, i.e., green energy is considered to produce 25% more jobs than conventional forms of generation (coal-based) and 90% more jobs than nuclear energy, per unit of energy produced [52].

From the findings it can be concluded that public acceptance is a key indicator for sustainability, in that, if public acceptance is not achieved, energy transformation is highly unlikely.

5.3.2.3 Health and safety

Emissions from conventional power plants have risen; studies [94] have indicated that generation through conventional sources, such as coal powered plants, will account for more than a third of the total emissions of CO_2 globally. Hence the need for clean environment and the mitigation of air pollution are drivers for renewable energy technologies and their sustainability are becoming more prevalent.

Numerous studies have concluded the health and safety benefits of integrating renewables into the current generation systems. In fact, [95] indicates that adoption of renewables could reduce emissions of climate change substantially – between 0.4 to 0.9 billion tonnes of CO2 between the years 2010 and 2020. Another study [96] provides the findings of an experiment conducted in the USA. The experiment focused on the effects of generating through conventional means versus wind and solar generation. The findings of this experiment indicated that over a period of nine years (2007-2015), total power sector emissions of GHGs, such asCO_2, sulphur dioxide (SO_2), nitrous oxides (NO_X) declined by 20%, 72% and 50% respectively due to the inclusion of renewable technologies into their current operating systems. In order to make these figures tangible, the study indicated that emissions avoided by using wind generation between the years 2009 and 2015 amounted to between 28.4billion USD and 107.9billionUSD in air quality and public health benefits, in addition to 29billionUSD in climate benefits. Since renewable technologies have zero emissions, its health benefit can be compared to health impact of coal generated power that it replaces [94]. Consequently, proving health benefits, and reduction of premature mortality is a factor that impacts society positively, thereby reinforcing the sustainability of green energy technology.

5.3.2.4 Intergenerational aspects

These aspects refer to issues that could affect current and future generations [31]. These include the mitigation of climate change and fossil fuel depletion [31]. These indicators have also been used by other authors [97].

5.3.3 Environmental factors

From the environmental point of view, the main drivers for the sustainability of green energy technology is the increasing concerns around climate change and the increasing depletion of non-renewable energy resources. This is supported in [31] who indicates that CO_2 emissions are likely to double from 129Megatons/ year to 259 Megatons by the year 2050. This notion is also supported in [92] that states that consumption of fossil fuels to generate energy through conventional methods have contributed to the increase in greenhouse gas emissions and climate change. Rampant depletion of fossil fuel and non-renewable resources would also see prices of coal and gas go up compared to renewable energy sources. According to [31], coal would cost $16/GJ, gas ($27/GJ), oil (S25/GJ) and biomass ($5/GJ). Furthermore, a study conducted at the CSIR indicates that solar and wind power are 40% cheaper than new coal currently [48]. The findings from literature have strengthened the points of view provided in personal meetings with subject matter experts. From an environmental perspective, the mitigation of climate change and the depletion of conventional energy resources (non-renewable) will enhance movement onto green energy technologies and consequently their sustainability.

5.3.4 Conclusion

From the outcomes, it is evident there are three main factors influencing the sustainability of renewable energy technology. These include economic factors, social factors and environmental factors.

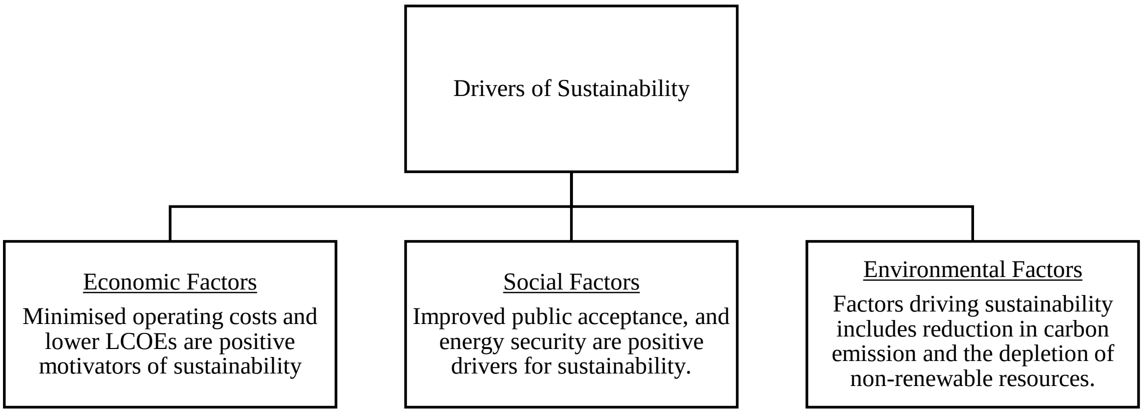

Figure 5-2: Conclusion of Findings for Drivers of Sustainability

5.4 Impact of green and sustainable energy resources on the utility, industry and society.

In order to establish and develop a holistic framework, it was necessary to understand the impact of integration of renewables on three main stakeholders – utility, industry and society. The findings established in chapter 4 are discussed in detail below, in relation to relevant studies.

5.4.1 Impact on utility

According to the theory of organisational ambidexterity, "successful organisations are those that can exploit their existing capabilities while developing new competencies at the same time" [70]. This implies by changing and adapting their current business model, in order to build up asset and knowledge in the field of green energy, traditional utilities can avoid becoming obsolete. However, the integration of green and sustainable energy resources seemingly have higher adverse impacts on the utility, which could prove detrimental for the economy because South Africa is heavily dependent on the conventional generator for its energy [66].

5.4.1.1 Utility death spiral and power system imbalances

As indicated in section 1.2 of this chapter, the movement onto green and sustainable energy could result in the obsoletion of conventional energy generator [43], [44], [84]. Furthermore, penetration over certain safe limits could cause oscillations within the power system's voltage and frequency, placing more stress on voltage regulation devices, which may even cause the malfunction of these equipment [85]–[87], [89], resulting in more operational and maintenance costs to the utility.

It was also identified from discussions with SMEs and data from literature that the more movement onto renewable sources could lead to the eventual obsoletion of the utility. Utilities generate most of their revenue through electricity tariffs, hence is dependent on a consistent demand for electricity. However, the decreasing costs of renewable energy technology has led many customers to generate their own energy. In order to maintain their budget, utilities increase their tariff prices. Hence further incentive is created for customers still connected to the grid to transition to renewable sources [98] which leads to the utility death spiral. If utilities fail to adapt their current business models, it will likely face negative impacts through the integration of green and sustainable energy into the current energy landscape.

5.4.1.2 Economic and financial implications

As indicated in [51], energy is vital for the growth of the economy. South Africa's utility still accounts for 85% of the total energy produced [54], and offers jobs to a substantial number of people, almost 50 000 people. Hence, the obsoletion of the utility could result in huge economic implications for the country. Furthermore, increased generation by prosumers and private individuals will decrease demand from utilities, eroding utility revenues. This is backed up by a study conducted in [81] which indicated that with increasing penetration of renewables such as solar, revenue loss by utilities increase exponentially. Hence, it can be concluded that movement onto green and sustainable energy forms will have a negative implication on the utility's finances, and consequently the economy if the utility does not modify their business models to account for these energy transitions.

5.4.1.3 Implication for business models

It is evident that the current business models conventional power producers have in place do not cater for changes in the energy landscape. In fact, [84] suggests that utilities do not find the integration of renewables a threat, hence have not revised their models to reflect value propositions for any such energy integration. If not revised, and adapted, utilities could see themselves run out of business within the coming years [84].

5.4.2 Impact on industry

Globally, SMEs account for 35% of economic development in developing countries and up to 50% in first world countries [93]. Closer to home, these statistics are even higher, with SMEs making up 90% of the private sector and accounting for about 50% of jobs in Africa [93]. In fact, [93] refers to SMEs as "the engine of economic growth, employment, and poverty eradication in a positive manner". From these observations it has become apparent that any adverse impacts on SMEs, especially from an energy reliability point of view, would contribute to the decline in a country's GDP. This study attempted to uncover the impact of green and sustainable energy on small industry within South Africa.

5.4.2.1 Economic benefits

It was evident that increased adoption and use of green and sustainable energy within small industry, especially those operating in energy-intensive sectors, provides economic benefits [78]. According to [77,79], SMEs will benefit financially by mitigating rising energy prices as a result of lowered cost of energy production (LCOE) of renewables (wind and solar) which reportedly is about 40% cheaper than coal in South Africa [77]. Furthermore, observations indicate that industry also stands to benefit from the reduction of GHG emissions and consequent carbon tax penalties [79]. Additionally, SMEs are associated with sustainable reporting and green and sustainable energy use, reduce the stakeholder risk and establish a global identity in the market as leaders of sustainability and eco-innovation, which boosts marketability and turnover [79].

Remarks offered by literature have confirmed the positive impact of green and sustainable energy on small industry, especially from an economic point of view. However, it should be noted that most SMEs still lack the financial grounds to adopt cleaner technologies, which could hinder the movement to green energy technology, despite the benefits mentioned [80].

5.4.2.2 Environmental implications

Surprisingly, the SME sector contributes to about 13% of total energy consumption globally [79]. In countries such as India, industrial SMEs proved to be responsible for about 45% of the total GHG emissions annually [79]. With the onset of carbon tax penalties, provision for cleaner technologies could see positive financial implications for SMEs.

5.4.3 Impact on society

From a social point of view, green and sustainable forms of energy seemingly have a positive impact in that it creates jobs, mitigates climate change, reduces emission of toxins into the atmosphere and ensures energy security [31][99]. However, movement onto green and sustainable energy would also result in the loss of land to set up wind farms and solar PV sites, and the possibility of noise and visual intrusions [31]. The main impacts identified in this study, from a societal point of view, include job creation, energy security and landscape intrusion. These are discussed in the subsections that follow.

5.4.3.1 Job creation

The findings of the study are in line with findings from literature review [100] indicates that the potential for 'green jobs', that is, jobs created as a result of renewable energy, especially within construction and operation is vast. The study also shows that opportunities for jobs in research and development (R & D) of renewable energy technologies may be also added as a category of employment [100]. Units of measurement to indicate job creation potential include jobs/MW; man-years/MW; Jobs/year/$Millions [101]. Various studies indicate the potential of renewable energy as a potential for job creation [72,73]. [52] conducted a study in Colorado, USA, which illustrated that the installation of a 2750 MW rooftop solar would result in about 32500 jobs. Further to this, job opportunities can be created in the value chain, especially if incentives are in place to localise manufacturing and supply. For example, job opportunities created in the PV value chain would see increase in manufacturing jobs, racking equipment, installers etc. [101]. These findings are supported in [52] stating that direct jobs (globally) associated with the electricity sector is predicted to increase from about 21 million in 2015 to 35 million by the year 2050 as a result of renewable technologies such as solar PV, batteries, and wind power.

From a South African point of view, the IPP projects implemented thus far in South Africa, have created employment for several people from local communities, especially during the construction phase. The number of South African citizens hired during the construction phase surpassed the forecasted numbers by about 83%, however, most jobs created were unskilled. Furthermore, there had also been an increase in the number of jobs created through local manufacturing opportunities, wherein renewable energy projects have exceeded the estimated value provided to local manufacturers. In fact, the expenditure of projects that are underway and those that have completed construction is now sitting at 50% of total project value [36].

These findings are in line with the outcomes of discussions with subject matter experts relevant in the energy field, who identified job creation to be a positive impact of the integration of green and sustainable energy on society.

5.4.3.2 Energy security

As indicated in section 4.2.1, one major positive impact of the integration of green and sustainable energy is energy security. Outcomes of the study were in line with findings from studies such as the ones in [102], who opine that reliable energy supply (energy security) is crucial for the sustainability of modern societies, and renewables can ensure that energy security issues are addressed effectively. Moreover, as stated in [103], the provision of secure energy supply, at affordable prices is also a critical component in stability, peace and prosperity through various levels of society. Energy security is a major driving factor for RETs, especially because a secure supply of energy is required for stable development of a country's economy [83]. Findings indicate that poor energy security or lack thereof will impact society negatively, i.e. the lifestyles of individuals will deteriorate; in fact, [59] state that energy security is a necessary driver of economic growth and poverty eradication – both necessary to ensure well-endowed lifestyle for society. Furthermore, fluctuations in global energy markets and prices could lead to macroeconomic and financial instabilities, especially for those countries that depend on energy imports [59]. Overall, the integration of renewables will have a positive impact on society as it ensures secure supply of the commodity at affordable prices – both necessary in order to ensure a quality of life for all individuals.

5.4.3.3 Intrusion

One important negative impact or concern of renewable energy that was highlighted through the discussions and extensive literature review covered was the land and noise intrusion associated with the technology. Studies [45] indicate that there is an increasing drive towards renewable energy technologies; in fact, Europe has seen an increase in renewable energy technology from 15% to 30% over the past few years. Hence, renewable energy technologies are vastly impacting on the geographic landscape [45]. [104] indicates that this increasing push towards RETs has resulted in a growing threat and concern among the public that the increasing number of green energy infrastructure will undermine the beauty of the rural landscape. The intrusion of wind energy generation infrastructure, for example, has created visual intrusion on the rural landscape, and have contributed to a condition known as "place attachment", which impact rural property prices, and potentially even sleep patterns and health [104]. Seemingly, there is a weariness among the public to accept largescale RE projects due to the geographic intrusion the technology poses, and this lack of public acceptance have led to protests, against the technology – a factor impacting the sustainability and uptake of green energy. However, it is important to note that other forms of generation have also impacted the landscape negatively, i.e., open cast coal operations, intrusion of oil and gas structures etc [104].

5.4.4 Conclusion

Outcomes of discussions with subject matter experts, and findings from relevant literature have indicated that overall, the integration of green and sustainable energy within the current energy landscape has a positive impact, despite a few adverse factors that were identified. From a utility perspective, the adoption and adaptation of current energy frameworks to include renewable energy technologies could see economic and financial benefits to the utility. Furthermore, the utility death spiral can be avoided by integrating and investing into green technologies. However, if the utility decides to stick to current frameworks and business models, it could see major adverse impacts from the integration of renewables, from both an obsoletion point of view and power system instabilities point of view. Industry serves to benefit positively because improved energy supply and more affordable tariffs ensures the growth of the firm. From a societal point of view, individuals will benefit from more jobs, secure supply of energy and a cleaner environment to live in. However, landscape and noise intrusion need to be tackled, and public support gained for renewable energy infrastructure to ensure overall societal wellbeing.

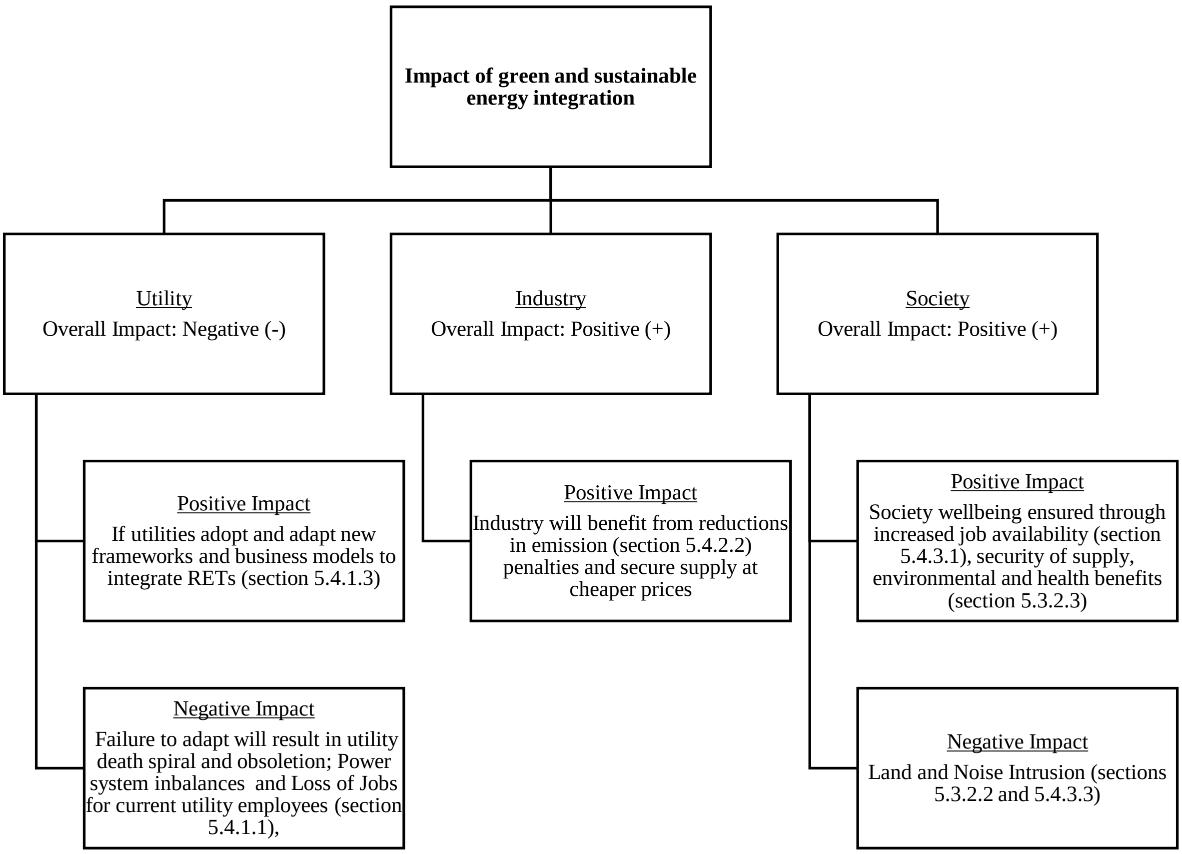

Figure 5-3: Conclusion of findings of the Impact of Green and Sustainable Energy

Chapter 6: Conclusions and Recommendations

The primary objective of this study was to develop an integrated framework for green and sustainable energy within the South African context. This chapter provides a summary of the main findings of this study, research implications for management, the limitations of this research and suggests recommendations for future study.

6.1 The green and sustainable energy framework

From the outcomes of the study and careful integration of the main objectives of the study, a conceptual framework was developed. The framework draws from understanding (1) the impact of green energy on the current energy landscape in South Africa, (2) indicators of sustainability of green energy, and (3) identifying the impacts of green and sustainable energy on three main stakeholders – utility, industry and society. The constructs identified have been assigned impact factors based on their reoccurrence and likelihood to impact the adoption and sustainability of green energy technologies.

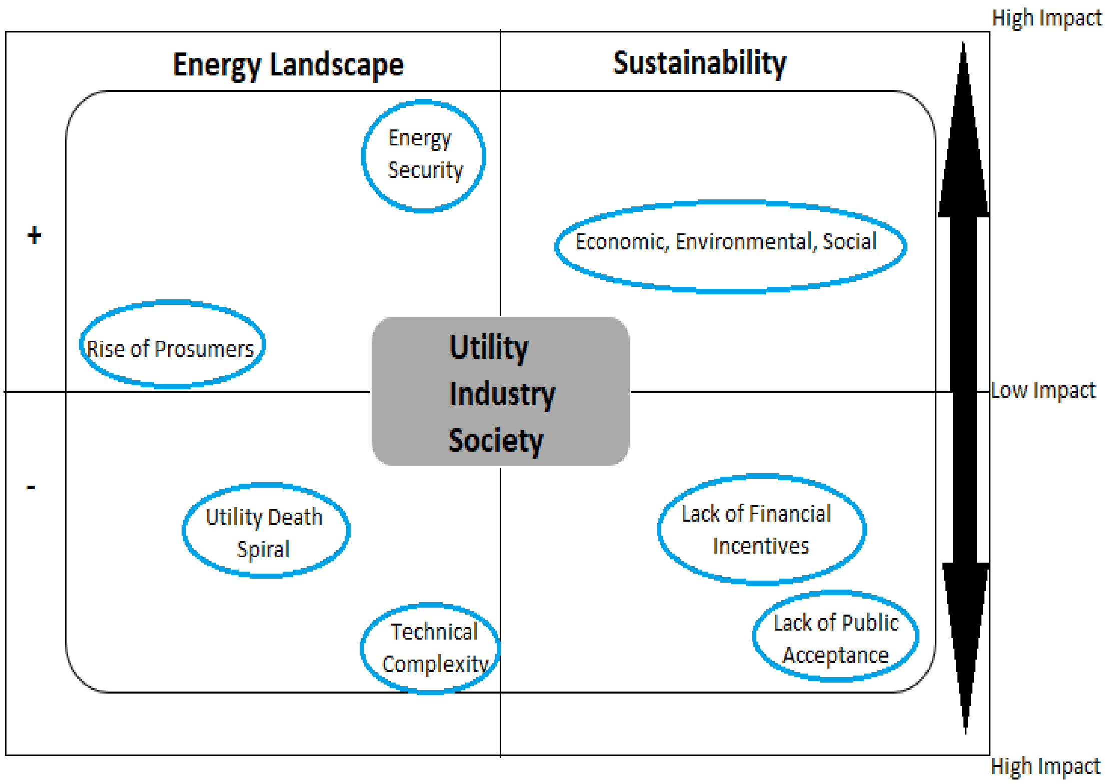

Figure 6-1: Integrated Green and Sustainable Energy Framework

6.1.1 Explanation of the model

The framework looks at two main aspects – the energy landscape and sustainability indicators. These were studied in relation to their positive and negative influences or impacts in order to establish the overall impact of integrating green and sustainable energy on the three stakeholders, as indicated in the centre block in Figure 6-1. The model is divided into four quadrants:

- Top two quadrants investigate the positive motivators for renewable energy technology and the drivers for sustainability
- The bottom two quadrants provide insight into the negative impact of green energy technology in the current landscape and the factors that may hinder the sustainability of RETs.

The top left quadrant indicates that energy security and the rise of prosumers were the positive effects of green energy technology within the current energy landscape. The negative impacts of the adoption of RETs within the current energy landscape is inclusive of the utility death spiral and the technical complexities associated with the overpenetration of green energy on the current power infrastructure, as indicated in the bottom left quadrant of the model. The right-hand side of the framework focuses on the drivers for sustainability. Environmental, economic and social factors are positive drivers for sustainability and have a medium impact factor. Factors that may be detrimental to the sustainability of renewable energy includes lack of public acceptance for the technology, the lack of financial incentives and landscape intrusion that may be caused by RET infrastructure. The centre block is influenced by all four quadrants (either positively or negatively) – that is, the impact on utility, industry and society is driven by the factors provided in the framework.

From the outcomes of the study, it came across that energy security, and the rise of prosumers are the positive effects of the integration of green energy technology given the current landscape. These findings are in line with what is suggested in literature [7], [81], [89]. Energy security is seen to have a high impact factor because, as indicated in numerous studies [31], [52], [92], the supply of energy, when needed and at affordable rates, is important for economic development and wellbeing of society. Rise of prosumers is considered a by-product of the lack of energy security and is deemed feasible to those who can afford to investigate self-generation, hence reflected as a low impact factor in the framework. There was consensus from the observations and data studied in literature that threat to the utility and possibilities of imbalances caused by the overpenetration of renewables are main negative effects brought about by the adoption of RETs within the current energy landscape. These factors are seen to have medium to high impact factors, that is, if green technologies become a threat to the utility and the operation thereof, particularly given the fact that South Africa is dependent on the utility for its energy needs [80][95], [105], [106], this could potentially lead to policies and regulations crippling the uptake of renewable energy technologies.

From a positive impact point of view, it is evident that effects of green technology includes energy security, rise of prosumers, and the decrease in GHG emissions as well, However, the researcher considered this a key value driver for sustainability (falls under the right-hand quadrant) hence was not considered a direct key value driver to the positive effects of green energy in the current energy landscape in South Africa (left hand quadrant).

The right-hand side quadrants represent the key value drivers that could either reinforce or hamper the sustainability of RETs. The observations and data studied indicated that factors that promote the sustainability of RETs include economic factors such as LCOE, environmental factors such as GHG emissions and decreasing non-renewable resources. As suggested in [95], [105], [106] increasing GHG emissions have motivated movement onto green energy technologies; decreasing LCOE is also a motivator for the sustainability of green energy technologies [16], [81], [107]. At the same time, factors such as the lack of public acceptance, intrusion and lack of financial incentives [31] hinder sustainability. Economic factors such as LCOE and operational costs of RETs are classified as high impact factors because an increase or decrease in economic factors could substantially influence the sustainability of green technologies.

The researcher placed the three main stakeholders to which the findings of this study applies in the centre block because they are impacted the integration of renewable technologies and the drivers of sustainability. A common theme that was brought up during the discussions was that of energy security – a positive impact of green energy technology and a driver for sustainability.

6.1.2 Implications for management

- It is evident that the integration of renewables will lead to the eventual obsoletion of the utility, hence the utility should reconsider their current business models.
- Over penetration of renewables could potentially lead to a loss of utility revenues, and imbalance in the power system.
- Industry players can stand to benefit from the use of renewable technologies, hence should look to effective ways of integrating green energy technologies within their current infrastructure and operations.

6.1.3 Recommendations for future research

The aim of this study was to develop an integrated framework for green and sustainable energy within the South African landscape. The principle findings of this study relate to other areas for future research, which includes:

- Quantitative research should be conducted into the variables that affect factors affect the sustainability of renewable energy technologies, possibly leading to the development of a mathematical modelled integrated framework.
- Research should be conducted on political factors and how the development of policies and frameworks impact the current energy landscape and influence the sustainability of renewable energy technologies.
- The choice of technology (renewable technology) contributes to economic factors for sustainability. Further research should be conducted to understand which technologies, and what factors would make certain RETs more viable and improve sustainability.

6.1.4 Limitations of the study

The limitations of this study are listed below:

- The study involved using observations from relevant literature, and outcomes and findings from discussions with subject matter experts within the energy sector and involved the discretion of the researcher in determining the main findings, hence subject to researcher bias.
- This study is qualitative in nature, hence need to be followed up with detailed research, such as quantitative research, in order to provide more dependable results.
- The population was selected through non-probability sampling, hence may not be an accurate statistical representation of the population [71].

- Secondary data in the form of findings from previous literature were used, hence limitations such as the availability, format and quality of the data could present issues in the validity and reliability of the data [76].

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