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A SWOT Analysis Approach for a Sustainable Transition to Renewable Energy in South Africa

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Abstract: South Africa is been faced with erratic power supply, resulting in persistent load shedding due to ageing in most of its coal-fired power plants. Associated with generating electricity from fossil fuel are environmental consequences such as greenhouse emissions and climate change. On the other hand, the country is endowed with abundant renewable energy resources that can potentially ameliorate its energy needs. This article explores the viability of renewable energy using the strengths, weaknesses, opportunities and threats (SWOT) analysis approach on the key renewable potential in the country. The result indicates that geographic position, political and economic stability and policy implementation are some of the strengths. However, Government bureaucratic processes, level of awareness and high investment cost are some of the weaknesses. Several opportunities favour switching to renewable energy, and these include regional integration, global awareness on climate change and the continuous electricity demand. Some threats hindering the renewable energy sector in the country include land ownership, corruption and erratic climatic conditions. Some policy implications are suggested based on the findings of the study.

Keywords: coal; energy systems; renewable energy; South Africa; sustainable development

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1. Introduction

The world needs energy to drive economic and human development as well as the sustenance of everyday lives. Worldwide, over 26 TWh of electricity was produced in 2019 [1]. This electricity was generated from different energy sources, mostly from fossil fuels but likewise nuclear and other renewable sources such as bioenergy, wind, hydro and solar. Globally, the principal source of greenhouse gas emissions is directly related to the system of production and consumption of energy. Greenhouse gases are conceived as the driving force responsible for climate change, and thus to ensure clean energy transition, most countries are working actively to diversify the means of energy production. This transition means a shift from producing energy from sources that releases a large amount of greenhouse gases to those with little or no emissions [2]. The global direction for transiting to clean energy was agreed by over 180 member countries of the United Nations Framework Convention on Climate Change in the Paris Agreement. One of the paramount objectives is to reduce greenhouse gas emissions by encouraging the use of low carbon energy sources in order to keep the average global temperatures increase well below 2 °C, relatively to the pre-industrial levels [1]. According to IEA, presently around the world, two-thirds of electricity generated is from fossil fuels, hence attaining the climate goals by 2050 will entail producing at least 80% of electricity from low carbon sources [1].

However, in South Africa, owing to the abundance of coal, the country largely depends on it as a major source of energy for its domestic and large-scale industrial purposes [3]. Coal-fired plants account for almost 90% of the electricity generated in the country [4]. The network of these coal-fired plants is fast ageing and to maintain the electricity supply levels, these coal plants require huge financial investment [3]. The recently built stations have been challenged by quality problems and are overwhelmed by overrun cost. As a result of coal consumption for energy, South Africa is one of the leading emitters of carbon dioxide on the continent, accounting for about 40% of the total emissions [5]. In addition, the country is ranked 7th in terms of per capita global emissions of carbon dioxide [6]. Currently, the country greenhouse gas emissions reduction for 2020 is at 30% with a progressive plan reduction to 42% by the year 2025 [3]. Despite the reliance on its large coal deposit for energy generation, South Africa's power system has been severely constrained in the last decade. This constrains has led to load shedding, whereby power is deliberately shutdown to all or parts of the country to relieve the grid from demand pressure [3]. On the other hand, there has been significant development in renewable energy sources as an alternative to fossil fuel. The Renewable Energy Independent Power Producer Procurement Programme has been lauded in inspiring investment from the private sector into the renewable energy market [7].

This has further paved the way for deeper consideration into renewable energy sources as alternatives for power generation in South Africa's energy mix. More so, the improvement of renewable energy and energy-efficient technologies is paramount in attaining sustainable development. To decarbonise the coal-intensive source of energy, there is a need for policies and measure support in achieving energy efficiency through the exploitation of renewable energy [3]. Decision-making regarding the extraction and conversion of electricity from renewable energy sources requires reliable and accurate information. This article, therefore, seeks to unravel the viability of renewable energy potential in South Africa, using the strengths, weaknesses, opportunities and threats (SWOT) analysis approach to promote a sustainable transition.

2. Energy Supply in South Africa

The Republic of South Africa is the southernmost country in Africa. The country is the 24th most populous nation in the world with about 59 million inhabitants. According to the general household survey of 2018, the percentage of households without electricity stands at 12.5% [3]. The administrative division is shared into nine provinces as indicated in Figure 1.

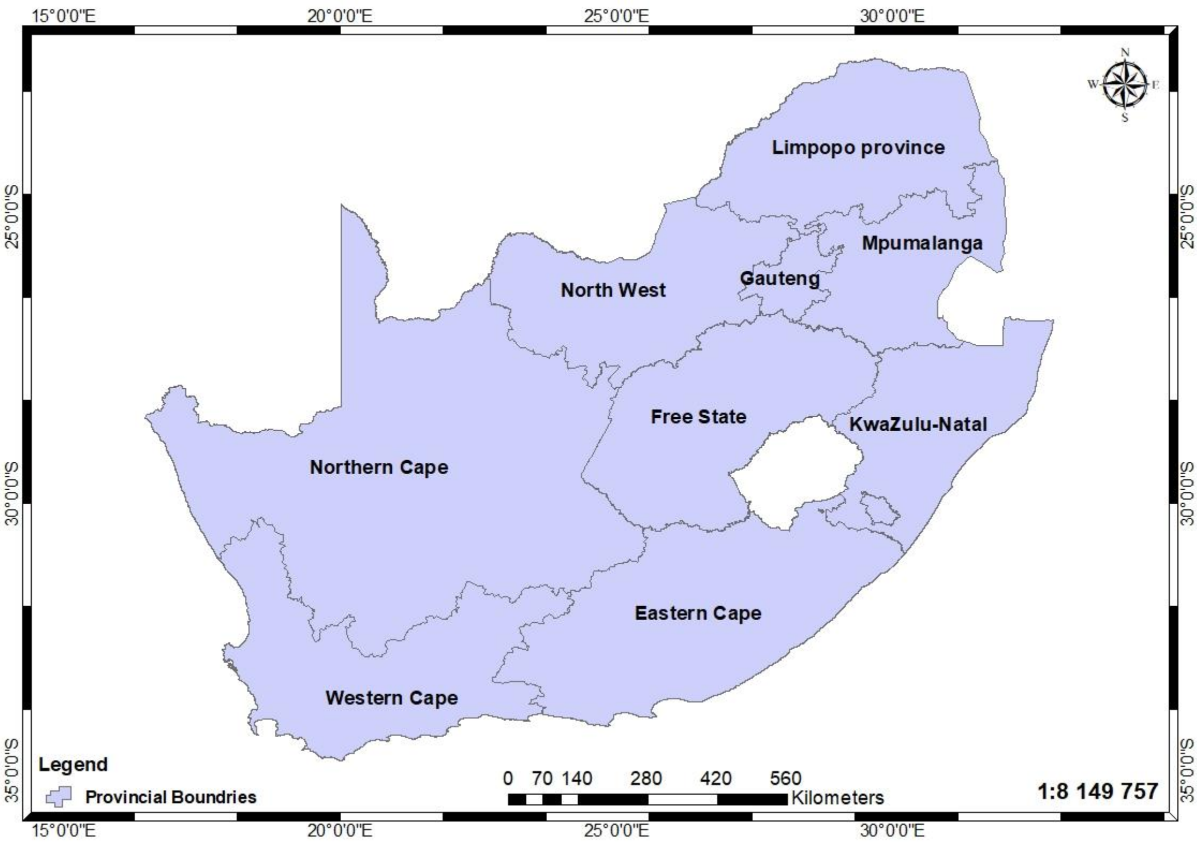

Figure 1. Provincial map of South Africa.

In the post-apartheid era, the government has tried to deliver equal access to electricity to all its citizens. However, the electricity demand is increasing by 4% yearly according to Eskom, which oversees electricity generation, transmission and distribution in the country [8]. According to the Department of Energy, South Africa is witnessing tremendous industrial and economic growth that requires mass and a stable electrification programme because of the energy demand [3]. Coal has been the dominant source of energy in the country. This is because of its abundance and cheapness, which is regarded in the world as one of the lowest in terms of energy cost. From the abundant deposit, low-quality stocks are consumed locally, and part of the high-quality stocks are exported as part of the Gross Domestic Product (GDP) [9]. In 2016, apart from coal, which was the principal contributor to the total primary energy supply, other sources include nuclear, crude oil, gas, renewables and waste energy as indicated in Figure 2.

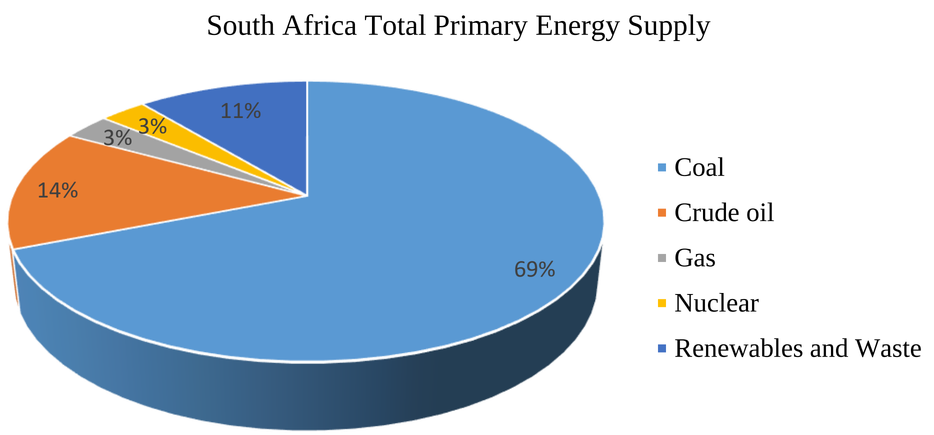

Figure 2. Total primary energy supply in South Africa [10].

3. Renewable Energy Potential in South Africa

The renewable energy industry in South Africa is relatively infant but growing [3]. To meet its energy demand requirements, South Africa plan to build additional 400 GW of new electricity generating capacity by the year 2030 from the current domestic generation of about 58,095 megawatts (MW) from all sources [3]. According to the National Development Plan, as part of the energy mix, 18.2 GW (Table 1) of the electricity is expected to be generated from renewable energy sources mostly from solar PV and wind energy, each at 8.4 GW respectively [11]. Table 1 indicates the renewable energy set target and the sources.

Table 1. Set renewable energy target for South Africa [11].

Sector/Technology	Targets
(Electricity)	18.2 GW
Solar PV	8.4 GW
Wind	8.4 GW
CSP	1 GW
Others	0.4 GW

3.1. Solar Energy

Sunshine is abundant throughout the year in the Southern Africa region, and indeed, in the whole of the African continent. South Africa receives about 4.5 to 6.6 kWh/m^2 of radiation, on average 8 to 10 h daily and a national yearly average of about 2500 h [12]. The mean annual solar horizontal irradiation of the country is indicated in Figure 3. The solar radiation indicates an average value of 3200 kWh/m^2 per annum for the Northern Cape Province, which makes it the most suitable part for solar power generation and consequently regarded as one of the best regions for solar energy resources in the world. The results of a prefeasibility study for Concentrated Solar Power were positive with

Northern Cape, in particular Upington being the most preferred area based on the solar irradiation data. The first Solar Park initiative in Upington, Northern Cape is aimed at producing 5000 MW in a period of ten years [13]. In KwaZulu-Natal Province, the radiation is low, compared to the other provinces but is still greater than the annual average of 2000 kWh/m^2 that is required as the minimum reference value for generating electricity. This is because the yearly average ranges from 1500 to 2400 kWh/m^2 [14]. The conversion of solar energy to electricity is regarded as solar power. Primarily, this is done by concentrating photovoltaic (CPV) systems or through conventional photovoltaic (PV), which directly converts irradiation into electricity and/or solar heating. The photovoltaic system is regarded as one of the cleanest and most eco-friendly forms of generating power. This is because during operation, it has no direct impact on the environment but may influence the environment on some other phases of its life cycle [14]. The roadmap for complete solar energy in South Africa consists of three components sector; namely, Concentrated Solar Power (CSP), Solar Thermal Technologies (STT) and Solar PV, with insights into solar fuels and hybrid technologies. Currently, the roadmap estimates the potential of harnessing 30 GW of CSP, 40 GW of solar PV and 4 GW of solar thermal can be developed by the year 2050 [3,12].

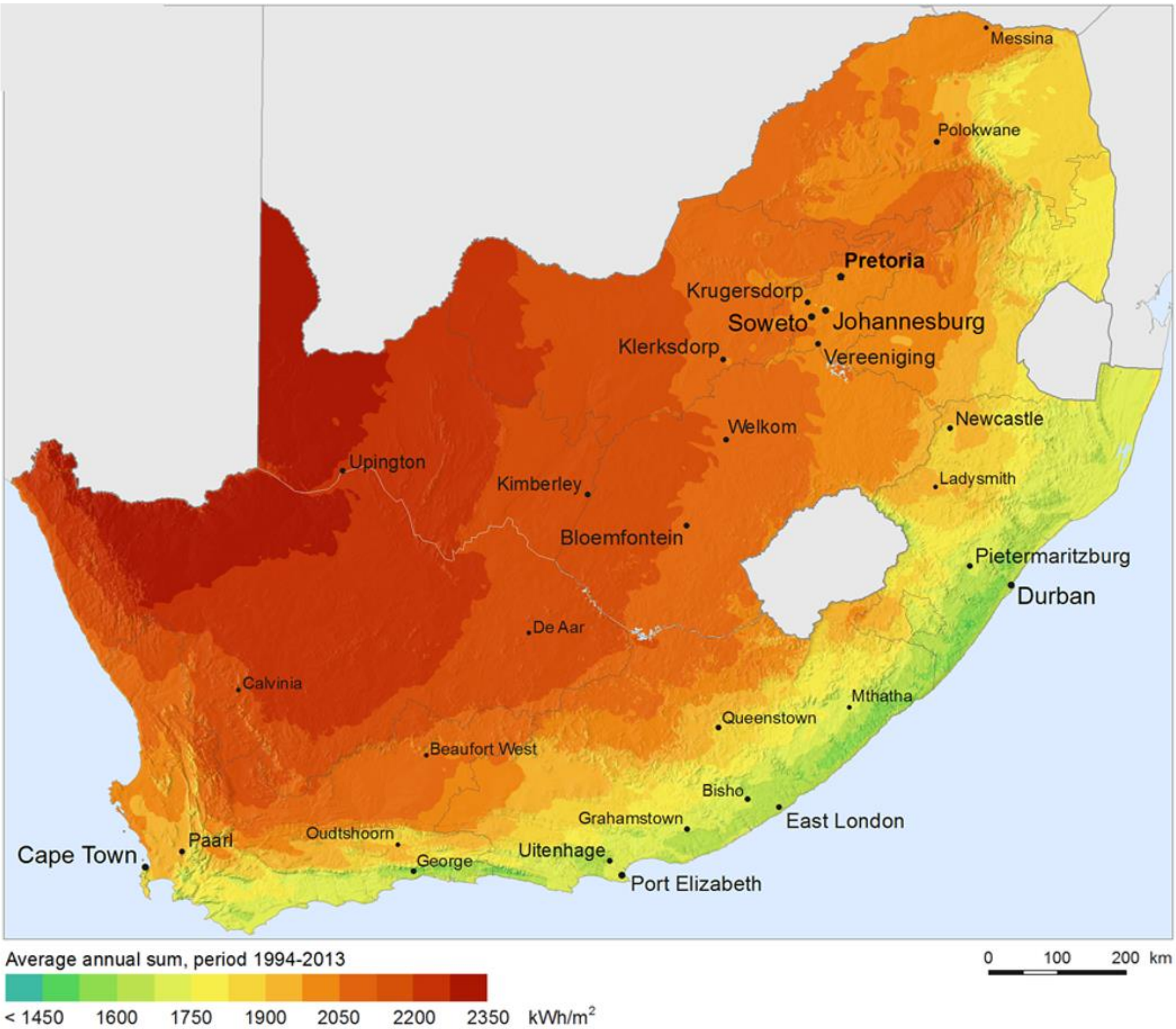

Figure 3. Mean annual solar horizontal irradiation of South Africa [13].

3.2. Wind

Wind energy is indirectly related to solar energy. This is because energy from the sun drives the cyclical movement of air, water vapour as well as climatic pattern [15]. The conversion of air kinetic energy from the flowing air into electrical energy generates wind power. An electrical generator enables wind turbines to convert air kinetic energy into mechanical energy [14]. Wind energy is advantageous because it produces energy which is considered free from greenhouse gas emissions in the course of operation, but emissions could be significant during turbine production and maintenance. Wind energy can be widely distributed and requires a small surface area for installation. Thus, the energy produced is considered to be environmentally friendly [14]. The rate at which power is produced depends on the wind turbine's size and wind speed. Recently, onshore wind energy capacity has been widely developed as an alternative source of energy to fossil fuel [16]. In South Africa, many parts lie near the equatorial zone. However, there are overlaps in the northern and southern regions, with the wind regime in the temperate westerlies [15]. Wind energy is also considered as one of the greatest prospects for energy generation in the country. Theoretically, wind energy potential in the country is estimated at 6700 GW [12]. The average wind speed in the country ranges from 7.29–9.70 m/s which was recorded in the Cape Agulhas. Generally, the potential of wind energy is good along the entire coast lines of the country, with some areas like the coastal promontories displaying a strong potential. Moderately, the inland areas are potentially noted such as the Eastern Highveld Plateau, the Drakensberg foothills in KwaZulu-Natal and Eastern Cape. So far, the implementation of about 3.366 GW of wind power is underway, with an envisioned addition of 5.034 GW capacity to be included by 2030 [3,17,18]. Eskom has two experimental stations which are expected to produce 4.5 MW of electricity annually [19].

3.3. Hydropower

South Africa is a semi-arid nation and thus regarded as a water-stressed, water-scarce country [20]. South Africa was importing electricity from Mozambique's Cahora Bassa hydropower station and is likely to continue to do so after the transmission lines are repaired. Also, there is the potential of importing more hydropower from countries like Zaire, Zambia and Zimbabwe. If this could happen, the country will depend less on its coal-fired power plants [3]. However, serious attention has not been paid to the extensive deployment of hydropower for electricity generation. This is because no recent studies have been conducted in the country. However, a baseline study by the Department of Mineral and Energy indicated proven potential for hydropower in the short and medium terms in specific areas of the country [3]. There is the existence of mix small-scale hydropower stations which have played a significant role in providing energy to urban and rural areas of the country [21]. Of note, in 1892, two 6 kW turbines were used for powering the gold mine at Pilgrims' Rest. In 1894, the two turbines were augmented to 45 kW, to power the first electrical railway [22]. New small-scale 247 MW hydropower installations potential with surrounded water transfer and gravity-fed systems are believed to be in existence in the rural areas of Mpumalanga, Eastern Cape, KwaZulu-Natal and the Free State Provinces. Technically, the total feasible hydropower potential is estimated at 11,000 GWh/year, with an economical feasible potential of 4700 GWh/year [23]. Despite the potential of the country's hydropower, only 38 MW capacity has been installed [20].

3.4. Biomass

Biomass is formed when plants convert sunlight to plant material through the process of photosynthesis. The stored energy from this process can be broken down into chemical energy through decomposition, digestion or combustion [24]. Biomass status will continue to rise as much as national energy strategies and policies follow the route of renewable energy options [25]. Recently, specific interest has been gained in biomass energy generation because of its progressive results in reducing conventional fossil fuel, which has led to the intensification and usage as a renewable energy option [25]. The term biomass refers to all organic resources that stem from plants. Currently and globally, research have shown that bioenergy is one of the leading renewable energy options [26–30]. In Africa, the total primary energy output from biomass resources in 2016 was 56.5 EJ, which constitutes about 70% of the total share from all the renewable energy options [31]. Significantly, the power generation level from biomass in South Africa is high. To produce steam, some paper packaging companies, and sugar mills factories burn bagasse to generate about 210 GWh of electricity yearly [15,17]. There is about 4300 km^2 of sugarcane plantations and an extent of about 13,000 km^2 forest farm expanse in South Africa [17]. Limpopo, KwaZulu-Natal and Mpumalanga Provinces are the main hubs for biomass production in South Africa.

In summary, the resource mapping in the provinces by the Department of Energy indicates the type of the renewable energy potentially endowed in each province as presented in Table 2. Renewable energy sources not indicated are not necessarily absent in the province, but rather, are comparatively small, compared to the emphasised potentiality as determined by the Department of Energy. For instance, there is the existence of cogeneration and landfill opportunities in all the large cities of the province, but they are not specifically indicated in the resource mapping [3].

Table 2. Potential sources of renewable energy in provinces of South Africa [3].

Province	Energy Sources (Potential)
Eastern Cape	Hydro, Solar (limited), Wind
Free State	Hydro, Solar
Gauteng	Solar
KwaZulu-Natal	Biomass, Small-Scale Hydro
Limpopo	Biomass, Solar
Mpumalanga	Biomass
North West	Solar
Northern Cape	Hydro, Solar (including Concentrated Solar Power), Wind
Western Cape	Solar, Wind

4. Methodology

SWOT is an acronym for strengths, weaknesses, opportunities and threats. It is a well-structured comprehensive comparative analytical tool that is applied in strategic planning in a business environment [32]. The evaluation is based on internal and external criteria as explained by the educational description approach in Figure 4. In business organisation planning, the internal factors are examined to highlight and interpret the strengths and weaknesses. Similarly, the external factors are explored which are related to the opportunities and threats. Strengths represent all resources that are available and can improve business performance. The weaknesses are shortcomings which may reduce the profitability, efficiency and competitive gains of the business resources.

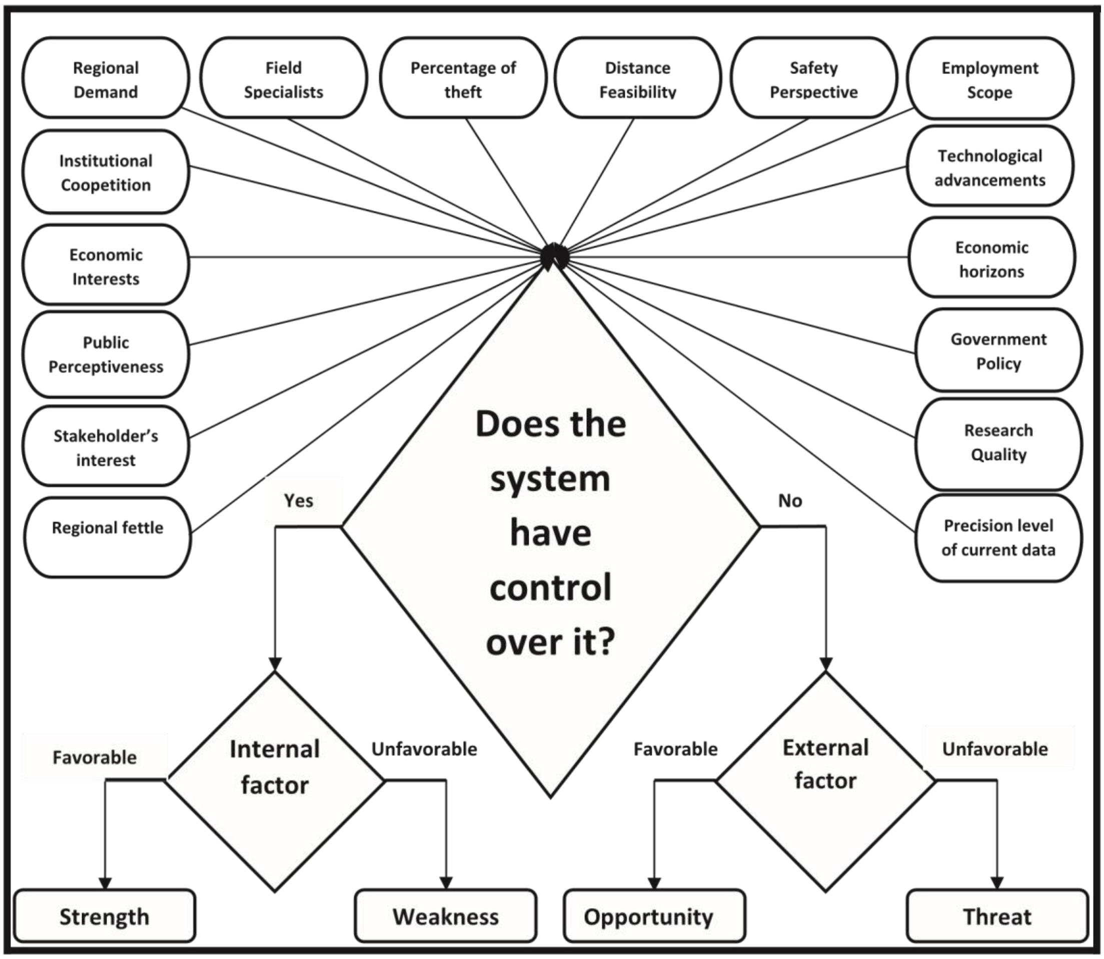

Figure 4. Strengths, weaknesses, opportunities and threats (SWOT) analysis description approach [32].

Initially, the SWOT analysis was developed primarily for business and marketing purposes. Lately, it has been applied in other research fields, including the field of energy [33]. Opportunities are external possibilities that could lead to progress, while threats are external elements that may create problems [34]. In much renewable energy research, the SWOT analysis has been applied as a tool. Jordan, [35] applied the tool to investigate the current status of renewable energy. Nigeria also [36] used the tool to access the country's nuclear exploration. Kamran et al., [37] used the SWOT approach to evaluate the sustainable evolution of Pakistan renewable energy. In Ghana, [38] it was used to access the country's agenda on nuclear energy development. Furthermore, a study by [39] applied the SWOT analysis technique as a tool to promote renewable energy in Japan, South Korea and Taiwan. In Myanmar, del Barrio Alvarez & Sugiyama [40] used the analysis in evaluating the utility-scale solar system. The SWOT analysis tool was used in examining large-scale energy project barriers through environmental impact assessment streamlining efforts in Japan and the EU [41]. Also, the tool was applied in the approval procedure for large-scale renewable energy installations by the national legal frameworks in Japan, New Zealand, the EU and the US [42].

The data for this study were elicited from relevant literature and working documents relating to renewable energy development in South Africa. These academic and grey literature were extensively reviewed to identify list of factors to be considered in the SWOT matrix and these factors were subsequently categorised into the four classes of the SWOT analysis. Furthermore, to obtain a balanced and diverse perspective to the extensiveness of the study, a semi-structured interview was conducted with energy stakeholders from private, civil and government organisations based on their educational and professional qualifications. Eleven out of the fifteen contacted interviewees that responded had post-graduate degrees in energy related field. Five were at managerial positions with the Department of Energy, while six were from the private and civil sector serving as directors and coordinators. They were presented with a template list of the factors and were asked to offer their assessment and importance, which were to (i), evaluate the wholeness of the list and (ii), offer a detailed discussion of each factor. Some of the questions contained in the semi-structured interview include: what is the accuracy level of the available renewable energy data? Does the current polices support the renewable energy promotion? Which conventional situations in the country favours the growth of renewable energy alternatives? What is the interest of promoters, developers and investors in renewable energy projects? What is the level of awareness regarding renewable energy sources? Will the introduction of renewable energy lead to jobs creation? What are the developmental opportunities of renewable energy at small, micro and medium scales? What are the experts' levels in renewable energy technologies? What are the developmental and economic opportunities for renewable energy? What are the available grants and profits in renewable energy projects? Does renewable energy and fossil fuels impact the environment? What is the electricity demand of the country? Has renewable energy achieved grid sameness or is it inexpensive than generating electricity from fossil fuel? What is the coordination level between climate guidelines and energy? The SWOT analysis guidelines developed for this study was to firstly identify factors relative to renewable energy by specifying if the factors fall within the strengths, weaknesses, opportunities or threats. Secondly, in each category, the factors were listed which were limited from either making the list too short or too long. Thirdly, each factor was clearly defined as specific as possible. Fourthly, the factors were facts and not opinion as the information provided by the interviewees were unbiased opinion as it was cross-checked with external information from literature and working documents. Lastly, the factors were action oriented.

A key advantage of SWOT analysis is to yield useful information about the future viability of the system under consideration. This robust and extremely effective technique is found to be very helpful to clearly point out the current flaws. Each point is allocated a weightiness factor of 0 and 1. 0 depicts the factor as least important and 1 as most important. For probability calculation, the allotted value ranged from 1 to 3, where 1 represents least occurrence chance and 3 depicts high chances of occurrence.

5. Results and Discussion

Based on the conducted SWOT analysis, the following are some of the factors considered very significant in the study.

5.1. Strength

5.1.1. Geographic Position

The Republic of South Africa is the most southern country in the Africa continent. It is located between latitude 22° to 35° S and longitude 17° to 33° E, covering a total surface area of 1,221,037 square kilometres, of which 1,216,417 square kilometres of land area and about 4620 water areas. The country's climate is subtropical, with a patchwork of hot deserts, snow-topped mountains, warm coastal subtropics and an enclave of Mediterranean weather in the southwest. The country is famous for enormous sunshine which puts it at an advantageous position for large-scale development of solar plants. The country is transverse by the Tropic of Capricorn and this intersection allows the country to receive a high degree of solar radiation. The position also puts the country in an appropriate spot for commercial development of wind energy due to the high wind speed. Additionally, there is vast natural vegetation which covers most parts of the country, which is associated with the average annual rainfall of 465 mm. The vegetation zones are the Kalahari savannah, Karoo scrubland, Mixed woodland, Bushveld, Fynbos and forests [43]. The vegetation is rich in abundant flora and fauna and places the country in a favourable position for the production of biomass energy.

5.1.2. Political and Economic Stability

In Sub-Saharan Africa and the world at large, South Africa is viewed as one of the most stable countries, without military interference since its transition to democracy in 1994 [44]. This has been recorded as a significant step in amalgamating the democratic achievements of the country. This consolidation provides a conducive working environment for prospective investors. In 2012, South Africa was the fourth leading investor in renewable energy in the world [12]. More so, the country serves as a key entry point into the Southern African Development Community (SADC) region, which is made up of 16 member states [45].

5.1.3. Policy Environment Supporting Renewable Energy Implementation

The policy environment for renewable energy development in South Africa is robust and provides an enabling environment in all tiers of government to effectively implement and deploy these policies. To provide a platform for an enhanced effective energy sector to the citizens, government commitment in promoting renewable energy technologies dates back to the post-apartheid constitution. Since then, several policy documents have emerged, such as the 1998 White Paper on Energy Policy, 2003 White Paper on Renewable Energy, 2005 National Energy Regulator of South Africa, 2011 White Paper on National Climate Change Response Policy, 2011 National Development Plan and the Renewable Energy Power Producers Procurement Programme. In summary, the overall objectives of these policies are, but not limited to, the following:

- Increase access to inexpensive energy facilities;
- Improvement of energy governance;
- Management environmental impacts from energy-related crisis;
- Diversification of energy supply;
- Economic growth stimulation from the application of feasible technologies and implementation;
- Equitable investment of national resources in renewable energy; and
- Solution to constraints in the development of renewable energy.

In 2011, the National Energy Regulator of South Africa revised the feed-in-tariffs for renewable energy [3]. Table 3 presents the feed-in-tariffs of South Africa compared to that of other countries in relation to incentives accrued per kWh from generating energy from renewable alternatives.

Table 3. South Africa feed-in-tariffs compared to other countries [46].

Country	FIT (USD/kWh)		Guaranteed Period (Years)	Priority Grid Access
	Wind	Solar		
Canada	0.14–0.16	0.45–0.48	20	Partial
China	0.08–0.1	0.14–0.16	-	-
Germany	0.06–0.13	0.28	15–20	Yes
Ghana	0.13–0.14	0.15–0.17	10	No
India	0.09	0.15	20	-
Kenya	0.11	0.12–0.20	20	Yes
* South Africa	0.05	0.13	-	-
Spain	0.1	0.38	25–30	Yes
UK	0.07–0.35	0.11–0.25	20–25	-

* Included by authors. $1 equals R16.8.

5.1.4. Research Institutions and Institutional Supports

In the year 2020, South Africa had 8 of the 10 top-rated 200 universities in Africa [47]. These universities are mainly comprehensive and are actively involved in different areas of research, including the development of renewable energy technologies. Most of the universities have established centres for renewable energy which facilitate research and innovation as well as develop manpower. A critical aspect relating to the deployment of renewable energy is the availability of proficient skilled manpower. It is vital to train people in this scientific field at the level of workers, researchers and technicians/specialist [48]. The growth and attention of renewable energy in the country has attracted the development of several research bodies, including the Southern African Biogas Industry, Water Research Commission, Council for Scientific and Industrial Research, Agricultural Research Council, South African Renewable Energy Council, Sustainable Energy Society of South Africa and the South Africa National Energy Development Institute to mention a few. These instituted bodies provide funding, collaborations and scholarships to deserving students and staff in tertiary institutions, to support research and innovation in renewable energy programmes.

5.1.5. Open Market Investment

The South African government, through the Department of Energy, has unlocked the energy sector for public and private investment [3]. This investment partnership is a strategic plan by the government to achieve its objective of providing accessible, clean and affordable energy to all its citizens. The government also aim at recapitalising and financing the energy sector through private investment partnership. The vision of this investment has led to the use of most renewable energy systems in off-grid situations such as solar for water heating and cooking as well as photovoltaics which is mostly used as a separate electricity source in areas that are too far away from the grid system. In line with the open market investment, in 2000, over 1852 schools and an unspecified number of clinics were connected to the off-grid systems through these finance projects [49].

5.2. Weaknesses

5.2.1. Government Bureaucratic Processes

Indications by different studies and stakeholders have revealed that the processes leading to licence approval for the development of renewable energy are very challenging. They are also complex, lengthy and cumbersome. The processes involve several institutions that require different permits. Also, the time it takes for acquiring these permits is unnecessarily long [50,51]. In South Africa, there are lengthy Environmental Impact Assessment (EIA) processes. This is costly and requires extensive monitoring of procurement, stakeholders' engagement and community education relating to the project to be carried out [51].

5.2.2. Level of Awareness

The factors promoting renewable energy technology are influenced by environmental as well as technical and socioeconomic factors, which are momentous for the benefits, knowledge and awareness of the technology. There is also a lack of information and education regarding the huge sustainability and viability potential of renewable energy in most countries, including South Africa [18]. This limits investment in the sector [51]. For instance, in South Africa, the ministerial declaration, under the National Legislation 102, Independent Power Producers not connected to the national electricity grid do not have to obtain a licence but are required to register with the National Electricity Regulator of South Africa [3], but this is unknown to most small-scale independent power producers like the household biogas users.

5.2.3. High Initial Investment Cost

Renewable energy technology is always associated with high investment costs, particularly during the elementary stages of development. Unlike conventional fossil fuel, renewable energy goes with upfront costs regarding maintenance and operation as well as costs of local raw materials. The associated high investment costs have created difficulties for most investors in financing renewable energy alternatives [52]. In South Africa, these associated costs stifle the initiation of most renewable energy options, even at smaller scales.

5.2.4. Little Attention to Off-Grid Systems

Although off-grid systems are considered as unquestionable ways for providing power to remote and non-remote communities that are distant from the national electricity grid system, little attention has been paid to this sector. This is because of the lackadaisical commitment to its developmental programmes [12]. Furthermore, the off-grid programmes in South Africa have not been extensively endorsed by the government in a way that is consistent and clear. For the off-grid sectors to make a meaningful and expected contribution in improving access to energy in the country, it follows that it should be open to the energy service industries in private and public markets. Off-grid contribution cannot be achieved without a clear obligation to the programmes [48]. The concession of off-grid programmes in the Eastern Cape and KwaZulu-Natal Provinces are among the few examples of installed off-grid technologies in the country. The achievement of these programmes has been undermined by the players involved because it lacks coordination [53]. Thus, opportunity steadiness is indispensable in attracting investors and this entails consistency and unwavering government support.

5.2.5. Low Electricity Tariffs

Despite the continuous increase in the price of electricity in South Africa, the cost is still one of the lowest in the world because of its abundant coal deposit, which is used for generating electricity [3]. This has made the financial viability of renewable energy tougher, coupled with the revised low feed-in-tariff for renewable energy alternatives when compared to coal.

5.2.6. Dearth of Commercialisation of Scientific Research

South Africa is faced with challenges of commercialising and implementing proven scientific research [53]. Several extensive studies have been done to prove the efficiency of renewable energy options as the solution to the associated energy problems in the country. However, much of the research that has been undertaken is not implemented or even considered.

5.3. Opportunities

5.3.1. Regional Integration

Several tertiary institutions from the member states of the Southern African Development Community (SADC) are collaborating on various aspects of improving and decentralising renewable energy alternatives [54]. One such programme is in resource mapping and new solar data study. The primary objective of this programme is to stimulate the use of solar energy and also to advance the quality of available satellite-derived data from all areas in the member states. High-resolution and ground-based solar radiometric data from different stations across the member states are being collected by the various collaborating institutions [54]. The resource mapping and solar data study are piloted by the Southern African Universities Radiometric Network (SAURAN). It is expected that outputs from this collaboration will mutually benefit all member states in SADC. In addition, the study is expected to pave the way for improved energy security, job opportunities, as well as a broader market for the finished products [54].

5.3.2. Global Awareness of Climate Change

Globally, most governments, including the South African government, are becoming more concerned by the impact of fossil-driven fuels for energy, and are therefore looking for substitute energy sources [2]. These alternatives energy sources will be clean and devoid of environmental consequences. Globally, this notion has unlocked the integration of renewable energy options, to play an essential role in the energy mix of different countries [2]. Several countries, especially those generating energy from carbon-intensive sources have pledged their support of the abatement of carbon. South Africa, as one of these countries, hosted the 2011 United Nations Climate Change Conference, tagged

Conference of Parties (COP 17) where new treaties were established to limit the emissions of carbon.

5.3.3. International Support Funding

Several funding bodies have partnered with the South African government in funding and providing financial instruments in the deployment of low-carbon technologies in the country [55]. Some of these include but are not limited to the following:

- World Bank through the Prototype Carbon Fund
- French Development Bank under the Carbon Emission Reductions Programme
- United Nations Framework Convention on Climate Change through the Clean Development Mechanism
- The Danish International Development Assistance Programme of the Danish Government
- Norwegian Development Fund
- The Finish Government through the Energy and Environmental Partnership Programme
- United Nations Development Programme
- Global Environment Facility
- German Technical Co-operation Organisation (GTZ)
- United States Agency for International Development
- United Nations Industrial Development Organisation

5.3.4. Price Decline in Renewable Energy Technologies and Rebates

Throughout the world, because of technology advancement, the associated costs of generating energy are getting much cheaper than exploiting same from coal-fired plants. According to a study conducted by the Council for Scientific and Industrial Research (CSIR), the same is true in South Africa [56]. The International Renewable Energy Agency (IRENA) has also indicated that since 2010, the associated cost of generating electricity from solar PV has decreased by almost 73%, in the same period, while the associated costs of generating power from wind technology have also decreased by a further 23% [57]. Additionally, implementing carbon inducement in using green technology, such as the Eskom discount schemes has further reduced the repayment periods for most renewable energy technologies as well as aiding their promotion [3].

5.3.5. Electricity Demands

South Africa has continued to witness an exponential growth in all sectors of the economy as well as in population growth. Although, the 2017 general household survey by Statistics South Africa indicates that 15.6% of households still do not have access to electricity from the national grid [58]. These growths continue to pile pressure on the already constrained power sector to meet the increasing demand. Therefore, an integration of renewable energy into the power sector should be considered as a viable investment because the energy generated will lessen the burden of electricity demand.

5.4. Threats

5.4.1. Land Ownership

The South Africa White Paper on land reform, lists three components of a comprehensive programme, as outlined in the policy. These are imperatively addressed in the constitution. They are restitution, redistribution and tenure reform [43]. Nevertheless, the government and privately-owned land are constantly invaded and illegally occupied. These actions pose a threat in the actualisation of renewable energy technology projects in the country as these technologies are often situated on land and in some cases, vast portions of land are required.

5.4.2. Corruption

There has been damning evidence of corruption in most state-owned entities in South Africa, including the Department of Energy and the like of Eskom, which is the statutory body mandated with generating, transmitting and distributing electricity in South Africa [59]. These allegations are not unconnected with over-inflating tenders, kickbacks and the provision and expansion of renewable energy technologies. These allegations have prompted the government to set up a "Commission of Inquiry into State Capture", to adequately and thoroughly investigate the alleged corruption in all government parastatals. Such corrupt activities do not provide an enabling environment for the investment and implementation of renewable energy alternatives in the country

5.4.3. Fossil Fuel Dominance

Currently and in the near future, it is unlikely that the South African government will completely eradicate its dependence on coal as a major source of energy supply [3]. This is because besides the abundance of coal, it supports the energy-intensive, large-scale mining industries that support and account for most of the country's gross domestic product. Continued reliance and dominance of coal for generating power, does not create a conducive avenue for renewable energy options to penetrate South Africa's energy sector.

5.4.4. Wheeling Arrangements, Supply and Feed-in-Tariffs

These aforementioned factors are limiting the advancement of renewable energy technology in the country. Wheeling bargain between the power generator and the grid owner (Eskom) is very problematic. For instance, the impressive 4.4 MW capacity Bio2Watt large-scale biogas digester located in Bronkhorstspruit, north of Pretoria which supplies electricity to the BMW motor plant. The gas from the digester has to be wheeled from the site to the Eskom grid, through the Tshwane grid, then to the Tshwane municipality before arriving at BMW plant [60]. The challenges of the feed-in-tariffs offered for renewable energy options are low and not close to uniformity. For instance, biogas is offered R0.94 c/kWh, solar R2.76 c/kWh, wind R1.25 c/kWh and small-scale hydro R0.94 c/kWh ($1 equals R16.8) [9]. These tariffs are likely to skew the investment direction in the country's renewable energy agenda.

5.4.5. Erratic Climatic Conditions

Renewable energy sources are determined by the cyclical movement of air and water vapour. These are driven by climatic patterns [61]. Climatic conditions in South Africa are influenced erratically by its long coastline. The coastline stretches about 3 000 km, from the Namibia border on the Atlantic Ocean to the north. It borders subtropical Mozambique to the south and east of the Indian Ocean [43]. Renewable technologies are dependent on weather conditions and can be disrupted by climatic variability. More so, along the value chain, weather conditions can also impact on energy transmission and equipment.

5.4.6. Environmental Impacts and Food Security

Environmental issues of biomass include the impact on water resources as well as food security [62]. The advocacy for renewable energy also poses a problem in terms of food security [63]. In most sub-Saharan African countries, food security remains high. The insecurity is further worsening and acute by the increasing degradation and scarcity of natural resources. The varied local settings that serve as the base of agriculture are therefore assumed to be overridden by technology [63]. A systematic method that focuses on sustainability of the local ecosystem can be as, or more productive than industrial agriculture and have a much better opportunity to increase food security in developing countries [63]. This is because there is a tendency to focus on producing crops to support the renewable energy industry, as against producing food for human sustainability and livelihood, particularly if the crops are in demand for energy production and are driven by the available financial incentives. According to the Food and Agriculture Organisation, the global production of biofuels accounts for a significant part of global use of a number of crops. During the period 2007 to 2009, 20% of all sugar cane, 4% of sugar beet, 9% of oilseed and 9% of coarse grains was used for biofuels [64]. Argued and demonstrated by several studies regarding increase in food prices over the years is that biofuels were in part responsible and will continue to cause more surges in prices even in the near future [65]. The magnitude of their role has been calculated with the aid of sophisticated economic models and conclusion drawn from these studies indicated that agricultural demand shock from biofuels in a market leads to a spike increase in food prices [65].

5.5. Analysis

In comprehending the likely effect of the points summarised in Table 4, a weighted score count was conducted. This creates a focal point for the stakeholders regarding the most crucial factors that requires immediate consideration. Prioritisation of Factors Matrix was used to categorise the factors into importance, rating (impact and probability), and score [66]. This goes a step further in eliminating in drawbacks that may be found in the SWOT analysis as some factors may be given too much or much emphasis and the most relevant factors may be overlooked. The aim of the Prioritisation of Factor Matrix is to identify the most significant factors of the analysis from all the identified factors [66]. The various points were assigned with weights and probabilities as follows: Weights and probabilities were assigned to the various points as follows: Each point was assigned a weightiness factor between 0 and 1. 0 depicting the least important and 1 representing the most important point. For probability, the assigned value ranged from 1 to 3 where 1 signifies the least chance of occurrence and 3 designates high probability chances. Identified by weight analysis results as the main strengths were geographical position, research institutions and institutional supports, and policy environment supporting renewable energy implementation. Key weaknesses were dearth of commercialisation of scientific research, high investment cost and little attention to off-grid systems. The opportunities include increasing electricity demands, regional integration and support funding from international bodies while the threat is corruption, fossil fuel dominance and land ownership system. Presented in Table 5 is the weighted score analysis.

Table 4. Summary of SWOT analysis of renewable energy potential in South Africa.

Internal Factors	
Strengths (++)	Weaknesses (–)
S1: Geographic position	W1: Government bureaucratic processes
S2: Political and economic stability	W2: Level of awareness
S3: Policy environment supporting RE implementation	W3: High initial investment cost
S4: Research institutions and institutional support	W4: Little attention to off-grid systems
S5: Open market	W5: Low electricity tariff
	W6: Dearth of commercialisation of scientific research
External Factors	
Opportunities (++)	Threats (–)
O1: Regional integration	T1: Land ownership
O2: Global awareness on climate change	T2: Corruption
O3: International support funding	T3: Fossil fuel dominance
O4: Price decline in RE and rebates	T4: Wheeling arrangements, supply and feed-in-tariffs
O5: Electricity demands	T5: Erratic climatic conditions
	T6: Environmental impact and food security

Table 5. SWOT Analysis weighted score.

Strengths				**Weaknesses**			
	Impact	**Probability**	**Total**		**Impact**	**Probability**	**Total**
S1	0.1	3	0.3	W1	0.05	2	0.1
S2	0.05	2	0.1	W2	0.05	1	0.05
S3	0.1	3	0.3	W3	0.1	3	0.3
S4	0.1	3	0.3	W4	0.1	3	0.3
S5	0.05	2	0.1	W5	0.05	2	0.05
				W6	0.1	3	0.3
Opportunities				**Threats**			
	Impact	**Probability**	**Total**		**Impact**	**Probability**	**Total**
O1	0.05	3	0.15	T1	0.05	3	0.15
O2	0.05	2	0.1	T2	0.1	3	0.3
O3	0.1	3	0.3	T3	0.1	3	0.3
O4	0.1	3	0.3	T4	0.05	2	0.1
O5	0.1	3	0.3	T5	0.05	2	0.1
				T6	0.05	1	0.05

6. Conclusions and Policy Implications

South Africa is endowed with different renewable energy sources which are abundant and potentially viable. Renewable energy can meet the high energy demand in South Africa and particularly households without electricity through off-grid connection and create a sustainable and feasible transition to the decarbonisation of the present energy system which is coal-dependent. An exploration of renewable energy options has been beclouded by the abundance and high dependence on coal, which have dominated the energy market in South Africa for decades.

This study evaluated the different renewable energy sources and its potential using the SWOT analysis. This study has revealed several significant policy implications based on the applied methodology. Some appropriate policies drawn from the study for policymakers highlight the need for promoting programmes for renewable energy sources to build a pathway into a sustainable transition of the South Africa energy system. These include the fact that South Africa has robust policies to tackle the energy challenges afflicting the country. There is potential in all the identified renewable energy options but harnessing energy from solar and wind is more advantageous as the country is well-positioned geographically. As witnessed with many developing countries, especially in sub-Saharan Africa, there is a tendency of political volatility, and South Africa is no exclusion. It is hoped that governments will strengthen the political gains by doing what is right for the economy and the citizens to avoid instability. This will help in opening the country for local and international investments. The importance of a stable government cannot be overemphasised, as this ensures the continuity of foreign direct investment, especially those that were contextualised by the existing policies. South Africa can further reinforce its foreign cooperation with its allies and members of the SADC through a collaboration of the current and new projects in respect of renewable energy alternatives, thereby expanding the existing market.

The direction taken by the country regarding renewable energy will also be influenced by the world outlook, politics and global obligation to renewable energy. There is also a need for improved integration in the grid systems, by augmenting it with the renewable energy mix, thereby increasing the number of entities that can be supplied with energy. Eskom has been faced with enormous criticism vis-à-vis its ability to adequately meet the demand for energy in the country. This can be complemented through off-grid systems by paying attention to either small-scale or large-scale applications which are key to combating the energy crisis, ensuring sustainable development and mitigating climate change. The continued expansion of renewable energy alternatives in South Africa can be sustained through various international institutional agencies that have provided funding and financial instruments for subsidising the deployment of these technologies owing to the associated high investment cost. However, the viability of renewable energy options may be limited if the dominance of fossil fuels is not reversed by the government. The reliance and dominance of fossil fuel against other options will also continue to pose a threat to the revitalisation of renewable energy.

One way to attract renewable energy investment and promote its use is by increasing the feed-in-tariffs. Furthermore, eradicating the wheeling arrangements and supply process or making it less cumbersome can be employed. There is a need for government intervention in the issue of land due to its sensitivity. Large portions of land are sometimes required in the development of renewable energy projects for the entire societal benefits, and where unavailable or invaded, there is a high possibility of the technology failing. Above all, corruption is a cankerworm in any society and poses a risk. The government should thus arrest this menace at all tiers, as the consequences are very devastating. The outcomes of this study and policy implications can be applied in other countries, especially the developing nations as they exhibit similar characteristics, yet endures energy scarcity and deficiency.

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