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# A Synopsis of Green Energy Technology Implementation in South Africa

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## Abstract

The implementation of green energy technologies in South Africa represents a pivotal strategy to address the nation's energy security challenges, mitigate climate change, and drive sustainable economic development. This study critically examines the adoption, diffusion, and scalability of green energy technologies, focusing on renewable energy sources such as solar, wind, and hydropower, as well as innovative energy storage and grid modernization initiatives. South Africa's energy landscape is notable for its reliance on coal, which contributes heavily to greenhouse gas emissions and environmental deterioration. However, regulatory initiatives like the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) have accelerated the integration of renewable energy into the national grid. This qualitative study employs a document review methodology to critically analyze the implementation of green energy technologies within the country's socio-economic and policy contexts. Drawing on a wide range of data sources, including government policies, energy sector reports, international agreements, and academic publications, the research explores the barriers, drivers, and impacts of transitioning to renewable energy systems. The study uses a thematic analytic methodology to find recurring trends and insights, with an emphasis on three key areas: policy formulation and execution, stakeholder collaboration, and the socioeconomic repercussions of green energy programs. The findings reveal a dual narrative of progress and constraint: while initiatives like the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) have successfully mobilized private investment and increased

renewable energy capacity, challenges such as policy inconsistency, insufficient grid infrastructure, and limited public participation remain. Furthermore, the study emphasizes the need for stronger alignment between green energy projects and the concepts of a just energy transition, particularly in terms of creating job opportunities, tackling energy poverty, and assisting communities that have historically relied on coal businesses. This research emphasizes the necessity of integrated, inclusive, and flexible policy frameworks for improving the scalability and sustainability of green energy technology. Through using document review as a primary data collection method, the study provides a nuanced understanding of South Africa's green energy transition, as well as recommendations to policymakers, industry stakeholders, and development practitioners to accelerate the country's transition to a low-carbon future. These findings add to the broader discussion of equitable energy transitions in the Global South, emphasizing the interplay of environmental, economic, and social concerns.

**Keywords; Green energy, policy, projects, South Africa, technologies, climate change**

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## 1. Introduction

According to Khan *et al.*, (2017), an estimated 520 quadrillion BTUs of energy were consumed worldwide in 2010, and by 2040, that number is expected to have increased by 56%. As things stand, energy consumption and demand exceed the amount of energy currently available, and by the end of the century, energy demand is likely to peak at more than six times the current capacity (Awasthi *et al*. Citation2019; Kothar, Tyagi, and Pathak 2010). The quest for renewable, clean, cheap, and sustainable energy resources has become inevitable. Moharir, Gautam, and Kumar (2019) add that the difficulty of disposing trash in a sustainable and environmentally sound manner faces developed as well as developing nations. Electricity generation, transmission, and use are major factors in a developing nation's socioeconomic and infrastructure development.

Thus, it should come as no surprise that South Africa, the continent's biggest energy consumer, is also one of the most developed countries (Ouedraogo, 458: 2017). South Africa is located on the southernmost tip of the African continent. The nation is endowed with an abundance of mineral resources, including gold, diamonds, platinum, and more (Erasmus *et al*, 2020), among these mineral resources, coal is found in South Africa, which ranks seventh globally in terms of coal production, according to the most recent edition of the International Energy Agency's (IEA) Energy Atlas (2022). According to Eskom (2002), more than 85% of South Africa's electricity is produced by coal, making it the nation's most abundant energy fuel. In addition to successfully contributing to the production of energy, coal has positioned South Africa among the top 10 global emitters of greenhouse gases.

In 2018, out of the three nations with the biggest economies—South Africa, Egypt, and Nigeria—it was determined that South Africa had the best plan for renewable energy (Aliyu *et al*, 2018). South Africa's need to diversify its energy mix, lower carbon emissions, and address issues with energy security has fueled the country's fast-growing green energy industry. According to Olusola *et al.*, (2021), there has been an attempt to diversify the nation's energy sources. Figure 1 illustrates the presence of solar PV, wind, biomass, and concentrated solar power (CSP) RE technologies in each of the country's provinces, according to the most recent data on renewable energy given by the South African Department of Energy (Olusola *et al*, 2021).

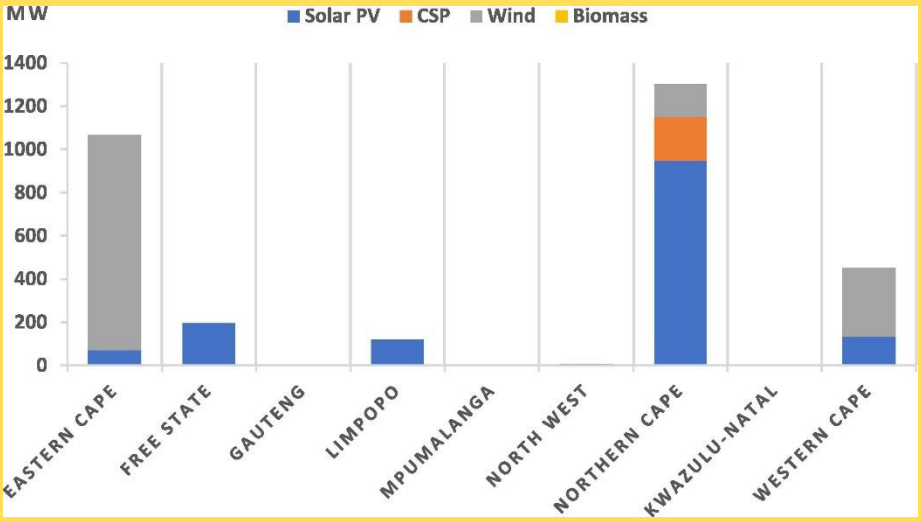


Figure1: South Africa’s electricity generation in TWh by different technologies.

Although South Africa was largely dependent on coal in the past, and it still generates about 80% of its electricity, however, a considerable push for renewable energy has been made because of environmental concerns, international climate commitments, and frequent power outages (load shedding). Olusola *et al.*, (2021) Indicates that like the majority of nations, South Africa recognizes the necessity of using renewable energy (RE) sources to supplement or replace its energy sector that is reliant on fossil fuels. Consequently, additional steps have been taken to diversify the nation's energy mix, such as the implementation of policy frameworks which shall be discussed in Section 3 of the paper.

A major factor in South Africa's energy shift is the efficient use of renewable technologies. In addition to hardware deployment, this entails addressing socioeconomic, infrastructure, and regulatory aspects to guarantee long-term acceptance. Additionally, the growth of the nation's renewable energy industry could lead to more employment openings and an improvement in the South African economy. South Africa also aims to increase the share of green energy technologies in total energy consumption by 15% by 2030 while adhering to national and international emission standards (IRENA,2020). However, only a brief overview of the difficulties and advancements in South Africa's adoption of green energy technology is provided. As a result, this paper expands upon earlier assessments to give readers a more thorough understanding of South Africa's advancements in green energy technologies.

## 2. Literature Review

### 2.1 Policy framework for green energy.

South Africa’s move towards a green energy economy is driven by a broad policy framework that backs the growth and use of renewable energy technologies. Over the past years, the country’s policy landscape has grown substantially with different legislation, regulations, and initiatives to reduce greenhouse gas emissions, increase energy security and stimulate economic growth.

This section gives an overview of the main policy frameworks that support South Africa’s green energy technology implementation. These frameworks have greatly contributed to the formation of the country’s renewable energy sector, as well as attracting investment and driving innovation.

### 2.2 South Africa's Nationally Determined Contribution (NDC) (2015)

According to United Nations Framework Convention on Climate Change (2022), the first Nationally Determined Contribution (NDC) for South Africa was submitted to the UNFCCC in October 2015. To this end it aimed to help the country address climate change through sustainable development, equity and science. The NDC details South Africa's commitments on greenhouse gas emissions reduction and a move to a low-carbon economy. Increasing the usage of renewable energy sources like solar and wind power is one way to meet the NDC's goal of a 42% decrease in greenhouse gas emissions by 2025 (South Africa, 2015). This target is in conformity with the Paris Agreement that the country has signed to reduce global warming to more than 2°C and as much as feasible to 1.5°C above the preindustrial levels (United Nations, 2015). Considering this, the NDC recommends, among other things, encouraging renewable energy projects, improving energy efficiency, and creating green jobs.

### 2.3 National Energy Act (2008)

According to Cliffe Dekker Hofmeyr (2023), the National Energy Act 34 of 2008 is a South African piece of legislation which aims at ensuring that there is a stable supply of energy through various sources at reasonable prices. The Energy Act of 2008 is a crucial piece of legislation that was passed to address South Africa's energy problem and guarantee a sufficient supply of energy (South Africa, 2008). With this comprehensive approach, the entire country will be able to develop a sustainable energy mix that considers its social, economic, and environmental concerns.

### 2.4 National Climate Change Response White Paper (2011)

In 2011, the South African government released a White Paper called "The National Climate Change Response White Paper," which essentially serves as their official national response to climate change. It lays out the country's strategy for a low-carbon, climate-resilient economy and society (Air Quality Lekgotla, 2012). According to AQL (2012) it further states that the Government adopted the National Climate Change Response Policy (NCCRP) in October 2011 and the policy was officially published as a White Paper in the Government Gazette (No. 34695, Notice No. 757). The policy highlights several strategic priorities, including the reduction of greenhouse gas emissions; promotion of renewable energy and energy efficiency; and the creation of climate-resilient infrastructure. Another goal of the NCCRP is to reduce greenhouse gas emissions in South Africa by 42% by 2025 (Department of Environmental Affairs, 2011).

### 2.5 Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)

According to Naude and Eberhard (2016) the literature states that The Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) was launched by the South African government in 2011 to promote the development of renewable energy sources This public-private collaboration aims to reduce greenhouse gas emissions, boost renewable energy production in South Africa, and achieve the nation's sustainable development objectives (National Treasury, 2012). Increasing the amount of power generated from renewable energy sources, such as solar and wind, is one of the primary objectives of the REIPPPP. Additionally, the initiative promotes the use of renewable energy sources, which help fight climate change because they don't create greenhouse gases change (IPCC, 2018).

## 2.6 Integrated Resource Plan (IRP) 2010

South Africa's energy policy for the forty-year period from 2010 to 2030 was largely established by the Integrated Resource Plan (IRP) 2010. The IRP 2010 relied on a number of fundamental assumptions, such as demand forecasts, the efficiency of current power plants, the cost of technology, and plans for new plant commissioning and decommissioning (Department of Energy, 2010). Based on these presumptions, the Base Case served as a benchmark for comparing various situations that were discussed in the IRP 2010 document. Technology overnight costs, which acknowledged the interest expenses these technologies accrued over time, were effectively incorporated into the IRP 2010. The IRP 2010 examined fuel costs, paying particular emphasis to liquefied natural gas. The IRP 2010 identified advancing technology as a vital matter within the energy sector especially for renewable energy systems which demonstrated substantial cost reductions throughout the recent years (IRENA, 2019).

## 2.7 Technological innovations and challenges.

The feed-in tariff is the second phase of a strategy that South Africa (NERSA) launched to support the renewable energy sector (NERSA, 2009). The policy's objective was to provide incentives to businesses and private investors who support the nation's quest for green power generation. In support of this, South Africa published a white paper in 2003 outlining its plans to transition to renewable energy sources, including biomass, wind, solar, and small-scale hydropower, in order to produce 10 TWh of electricity (Olusola *et al.*, (2021).

**2.8 Boimass energy.**

Renewable energy that comes from organic materials, either directly or indirectly, is known as biomass energy. It can be found in solid, liquid, or gaseous form (Sanderson *et al,* 2020). Technologies for biomass energy are essential to South Africa's shift to renewable energy since they provide environmentally friendly options for heating, power generation, and the manufacture of biofuel. According to Jahns (2023), Over 100 GWh of energy were produced using biomass power in 2016, according to the South African Renewable Energy Data and Information Service; no numbers have been recorded since. However, with various plant layouts, modern technology has made it possible to burn biomass on a big scale to generate energy. Adding biofuels to South Africa's energy mix will help diversify the fuel supply for power generation and offer a substitute for the country's ongoing reliance on importing crude oil for transportation.

**2.9 Wind energy.**

In South Africa, wind has long been a source of energy. As early settlers, who were mostly farmers, utilized windmills to pump water for farming, this practice was partly responsible for the farmers' high levels of production (Van der Linde,1996). The country's wind energy potential was divided into three categories based on the findings: good, moderate, and low. According to Olusola *et al.,* (2021), the Western and Eastern Cape regions' coastline areas were deemed to have good wind energy potential due to their average annual speed of more than 4 m/s at 10 m above ground level. The foothills of Drakensburg, Kwazulu-Natal, and Bushmanland are categorized as having modest potential for wind generation. And lastly, the Bushveld basin and Cape Middleveld were designated as low wind potential zones.

**2.10 Solar energy.**

South Africa has a vast amount of solar energy potential, according to the World Bank Group's Global Solar Atlas in collaboration with Solargis, even though regional variations in irradiance exist. Findings indicate that scholars such as Bischof-Niemz & Trollip, (2019); Baker, (2015); and Roux-Rosier *et al.,* (2018) support that despite ongoing issues like policy uncertainty and grid integration, South Africa's enormous solar energy potential—fueled by the country's high solar radiation and bolstered by programs like the REIPPPP—has drawn substantial investment, encouraged technological advancements, and produced socioeconomic benefits. According to Edkins, Marquard, & Winkler, (2010), South Africa receives an average of 2,500 hours of sunshine each year, making it one of the countries with the highest levels of solar radiation worldwide.

This high solar insolation makes both photovoltaic (PV) and concentrated solar power (CSP) technologies highly viable. Mokwena *et al.,* (2018) examined the latest developments in PV efficiency and energy storage technologies in South Africa's solar industry and according to their research, hybrid systems that include solar and battery storage are essential for improving grid stability in isolated locations. Furthermore, Szewczuk (2017) wrote about how combining solar and microgrids has increased rural areas' access to electricity.

**2.11 Challenges.**

Lack of access to contemporary electricity results in less options for social services including water supply, healthcare, and educational facilities, all of which depend on contemporary energy sources. The development and utilization of green energy sources in South Africa are hindered by a number of obstacles. The following are some of the main challenges found when conducting this research:

- Human and technical capability limitations
- Governing the cost of power
- Political barriers
- Inadequate rural energy markets and infrastructure
- Lack of skilled manpower
- Lack of coherent and clear policies

In South Africa, the electrical sector is responsible for about half of greenhouse gas emissions (Smarte Anekwe *et al*, 2024). Eskom (2022) adds that over the course of the next three decades, the nation's 39 gigawatts (GW) of coal-fired power facilities will be decommissioned, with 22 GW expected to shut down by 2035. For the energy transition to succeed, these challenges need to be addressed. The stagnant green energy policy framework of the nation exacerbates these issues. Akinbami, Oke and Bodunrin (2021), revealed that the nation's strategy for integrating renewable energy into the energy mix is disjointed and devoid of the resources required to encourage the expansion of the usage of renewable energy in the nation.

**2.12 Investments and financial mechanisms.**

South Africa has many opportunities for investment in green energy technology due to government incentives and private sector as well as financial mechanisms' investments. This paper will discuss two (2) main investments which are Private Sectors Investments and Government Incentives.

**2.13 Private Sector Investments**

The development of the green energy sector in South Africa relies heavily on private sector financing. This paper presents information about several private sector companies that have made significant investments in renewable energy, particularly in solar and wind energy.

**2.14 European Investment Bank (EIB) and Development Bank of South Africa (DBSA) Partnership.**

For the purpose of assisting South Africa's renewable energy project development, the EIB and DBSA have reinforced their collaboration. A €100 million loan from the EIB was matched by the DBSA in order to increase the generation of clean energy and generate new jobs (EIB, 2023). This funding is part of the Global Gateway, a European external strategy for clean and sustainable infrastructure and is consistent with the Just Energy Transition Partnership (JETP) aims of supporting South Africa's decarbonization efforts (European Commission, 2022). *"We have just reached an exciting milestone in our exciting journey with the EIB as we increase our financial backing of renewable energy,*" added Boitumelo Mosako, CEO of DBSA and the partnership demonstrates the two groups' dedication to the environment and their mutually exclusive goals (DBSA, 2023).

**2.15 Other Private Sector Investments.**

In South Africa, various private sector businesses have also made investments in renewable energy projects. For example, the 96MW solar photovoltaic facility in the Northern Cape called the Jasper Power Project has received funding from Google (Google, 2013). The Jeffreys Bay Wind Farm, a 138MW wind farm in the Eastern Cape, is another investment made by Mainstream Renewable Power (Mainstream Renewable Power, 2014).

**2.16 Government incentives.**

The South African government has implemented several incentives, such as tax incentives, the Renewable Energy Master plan, and tax incentives for electric vehicles, to encourage investment in green energy technology. Different incentives have been implemented by the South African government to encourage the transition from conventional automobiles to electric and hydrogen-fueled vehicles. This follows the February announcement of the R500 million investment allowance for 2026–2027(National Treasury, 2023).

This incentive's enabling elements were incorporated into the draft Taxation Laws Amendment Bill (TLAB), which permits automakers to deduct 150% of their investments in new electric and hydrogen-powered fleets (TLAB, 2023).

The government has also provided tax incentives to individuals and companies who buy electric or hydrogen fuel vehicles. The Taxation Laws Amendment Act, for example, permits buyers of electric or hydrogen-fueled vehicles to get a tax refund of up to R100,000 (Taxation Laws Amendment Act, 2022). In conclusion, the government's incentives are developed to enhance the development of the electric and hydrogen vehicle industry in South Africa, and to persuade companies to invest in the production of these vehicles.

**2.17 Socioeconomic impacts of green energy.**

Green energy sources like wind and solar power typically have positive socioeconomic effects, such as stimulating the economy and creating jobs, improving energy accessibility in developing regions, improving public health by reducing pollution, increasing energy access for everyone, and promoting social equity through distribution (IRENA, 2017). Although the specific effects can vary depending on the region and the method of implementation, there are certain obstacles, such as the high initial investment costs and job displacement in the fossil fuel industry. This section will address the following three (3) socioeconomic factors:

**2.18 Employment Generation**

Across the solar and wind energy value chains, South Africa stands out as the market leader for employment impact across Africa (Shortlist, 2023). The Forecasting Green Jobs in Africa report projects that the region will see the generation of between 2 and 3.3 million green jobs, with the greatest coming from renewable energy sources such as solar power (Shortlist, 2023). According to Shortlist (2023), between 85,000 and 275,000 green employments are expected to be created in South Africa by 2030, with the main contributors coming from the energy and power production sector, as well as the agriculture and nature sectors.

Through proper training, apprenticeships, and job/skill matching programs, this goal can be accomplished (Breloff, 2023). The initiative outlined here has the potential to reveal the socio-political benefits of the renewable energy sector for South Africa's workforce and create new jobs for its residents.

**2.19 Economic Growth**

According to Shortlist (2023), with lowering energy costs, attracting foreign investors, developing domestic capabilities, and creating job possibilities, a green energy project can help South Africa achieve economic growth. This is especially crucial in South Africa because the country experiences both very high unemployment and slow economic growth (Stats SA, 2022). Therefore, the creation of new employment opportunities in the green energy sector may contribute to the improvement of the socioeconomic status of South Africa.

The International Renewable Energy Agency (IRENA) indicates that the renewable energy sector may create up to 24 million new jobs worldwide by 2030, with most of the jobs being created in Africa (IRENA, 2020). SAWEA (2022), further added as of this writing, South Africa's renewable energy industry has already generated thousands of jobs, with thousands more anticipated to be added in the upcoming years. Therefore, as the renewable energy sector is expected to grow further, it is crucial for South Africa to develop this sector in order to create more employment and boost economic growth.

**2.20 Energy Access**

For East and Southern Africa to achieve universal access to electricity by 2030, the rate of electrification must grow threefold (IEA, 2022). If the current rate of electrification does not increase substantially, more than 300 million people will continue to lack access to electricity in this region up to 2030. To bridge the energy access gap, both grid expansion and densification as well as distributed renewable energy (DRE) systems deployment must be scaled up.

Moreover, Geospatial modelling by EASE (2022) indicates that the quickest and most efficient approach to providing clean electricity to almost half of the unelectrified people in the region is through distributed energy generating. Expanding access to electricity will lead to an overall improvement in the lives of South Africa's citizens, especially in rural and poor areas. For universal energy access, South Africa can focus on several strategies.

**2.21 Environmental sustainability and climate mitigation.**

Climate change mitigation seems to be the most extraordinary and crucial issue facing economies in the upcoming decades, given the significant climate hazards posed by global warming to life on Earth (Abul and Satrovic 2021; Ahmad *et al.* 2021c). According to several research, man-made emissions are to blame for these disastrous climatic shifts (Adedoyin *et al.* 2021; Ahmad et al. 2022). Unmatched risks to human life, the environment, and development have been brought on by climate change brought on by greenhouse gases (GHGs).

According to South Africa's 2011 National Development Plan (NDP), the government has a duty to lower emissions by accelerating the use of renewable energy technology and in particular, South Africa's National Development Plan 2030 includes the transition to a green and climate-resilient economy (South Africa Government, 2012). It is commonly known that innovations in technology can reduce carbon emissions. However, some research has found that innovation raises CO2 emissions (Villanthenkodath and Mahalik 2022; Demir *et al.* 2020). Environmental harm results from South Africa's heavy reliance on fossil fuels, primarily coal and oil, for energy.

The implementation of green energy technologies in South Africa is essential for promoting environmental sustainability and combating the growing threats of climate change. As the country faces significant risks from climate-related hazards, there is an urgent need to reduce greenhouse gas emissions, which are largely driven by human activities and the heavy reliance on fossil fuels like coal and oil.

South Africa's commitment to transitioning towards a green, climate-resilient economy, as outlined in its National Development Plan, highlights the role of renewable energy in reducing emissions and supporting sustainable development. However, while technological advancements have the potential to lower carbon emissions, they can also inadvertently contribute to environmental challenges if not managed effectively. Therefore, a balanced and strategic approach is crucial to ensure that green energy technologies truly support environmental goals while driving economic growth.

**2.22 Barriers and opportunities.**

Most literature has previously focused a lot of emphasis on barriers to energy efficiency, and strategies to overcome them have been examined in numerous studies and categorized in a variety of ways for decades s (Aboltins and Blumberga, 2019; Buettner *et al.* 2018; Sorrell *et al.* 2011; Thollander *et al.* 2010; Reddy, 1991, Schleich, 2009; Singh and Lalk 2016; UNIDO, 2006). Verbrugger *et al.*, (2010:852) defined barriers as the *"man-made factors or attributes that operate in between the actual and potential development or use*." Nonetheless, some academics offer a thorough analysis of the obstacles to South Africa's adoption of green energy and also suggest calculated remedies that combine legislative changes, financial incentives, technological advancements, and social concerns in order to promote a sustainable energy future. This section highlights the key barriers hindering the successful implementation of green energy technologies in South Africa as well as potential strategies and opportunities to overcome these barriers and accelerate green energy adoption

**2.22.1 Technical Barriers.**

The absence of infrastructure required to support the technologies and insufficient technology are technical factors that contribute to energy efficiency obstacles (Reddy, 2007:6; Shen *et al.* 2012:21). According to the literature, one of the main obstacles to people's willingness to invest in energy efficiency is technology (Sorrell et al. 2004:30; Singh and Lalk, 2016:290; Reddy, 1991:18).

In South Africa, the lack of sufficient infrastructure to support green energy technologies and a lack of technological advancements present major technical obstacles to their adoption. These factors limit the country's transition to sustainable energy solutions by impeding energy efficiency and eroding investor confidence in renewable energy projects.

### 2.22.2 Financial Constraints and High Initial Costs.

Pegels (2010) notes that the high capital costs of renewable energy technologies are a major obstacle in South Africa, and she also highlights that both large investors and small-scale energy entrepreneurs have difficulties due to the limited government subsidies and the absence of cheap financing options. Furthermore, Sovacool and Ryan (2016), provided an analysis that the high costs of technology such as energy storage devices and wind turbines are among the global obstacles to renewable energy. They contend that the adoption of renewable energy is constrained, particularly in developing nations, by a lack of financial incentives and risk-averse banking institutions.

### 2.22.3 Governance barriers

Fragments in the institutional structures, financial mechanisms, and legislative framework that should cooperate to promote the execution of energy efficiency policies, programs, and strategies are known as governance hurdles (Sorrell *et al.* 2011; Thollander *et al.* 2010: 46). The institutional theory behind governance barriers to energy efficiency states that a major obstacle to escalating electricity problems in any nation is a lack of sound governance inside an economy. Several research have interpreted governance constraints in energy efficiency using institutionalism (Blumstein *et al.* (1980), Hirst and Brown (1990); Stede (2017)).

### 2.23 Opportunities and potential strategies

#### 2.23.1 Strengthening Policy and Regulatory Frameworks.

Stable, transparent green energy policies expedited approval procedures, and targeted policy incentives—like tax breaks, feed-in tariffs, and renewable energy credits—can all help to strengthen South Africa's regulatory and policy frameworks. This will boost investor confidence, cut down on red tape, and hasten the successful adoption of green energy technologies throughout the nation.

#### 2.23.2 Enhancing Financial Support Mechanisms

The high initial costs of green energy technologies can be addressed by strengthening financial support mechanisms in South Africa through increased access to green financing, public-private partnerships, subsidies, and risk mitigation tools. This will make renewable energy more affordable for small businesses, rural communities, and companies while promoting sustainable growth in the industry.

#### 2.23.3 Reducing Fossil Fuel Dependence and Promoting a Just Energy Transition

Diversifying the energy mix by increasing the share of renewable energy, investing in workforce skill development, and increasing public awareness to garner support for the green transition are all important steps in reducing South Africa's reliance on fossil fuels and fostering a just energy transition. This will ensure that communities that depend on fossil fuel industries can prosper in new, sustainable sectors while minimizing opposition from special interests.

## 3. Methodology.

This qualitative study utilizes a document review methodology to critically examine the implementation of green energy technologies, focusing on their integration within South Africa's socio-economic and policy frameworks. Bowen (2009) asserts that document review makes it easier to spot trends and themes, which makes it possible to comprehend complicated occurrences in their entirety. Using this method, policy documents, energy reports, and legislative frameworks pertaining to green energy in South Africa are critically examined. Merriam and Tisdell (2016) emphasized how documents aid in establishing contextual depth, which is essential for evaluating the ways in which past energy regulations impact present green energy projects.

Thematic analytic methodology is also deployed in this research paper. In their most recent work, Braun and Clarke (2019) highlight theme analysis as a versatile technique for gathering rich, detailed data that enables researchers to examine texts' explicit content as well as their underlying meanings.

## 4.0 Results and Discussion

### 4.1 Future directions

Thus, the research's novelty lies in providing an analysis of how green energy technologies and policies are being implemented in South Africa. While previous studies such as those of Atsu *et al.*, (2021); Udeagha & Muchapondwa, (2023a) and Udeagha *et al.*, (2024) have been more curious about the environmental effects of the technological advancements. Prior studies have improved our knowledge of how energy use and technological development affect environmental quality, but they have also failed to address several important issues such as addressing policy failures and technological failures. These components are included in the current study to significantly add to the expanding body of knowledge.

Even though this study has yielded solid empirical findings in the South African setting, it is important to recognize its limits so that future research initiatives can be guided. Two notable limitations are those of the research within the financial constraints as well as strengthening policy implementations. Future investigations could delve into these components and how South Africa can utilize the two to improve their green energy technology implementations.

### 4.2 Policy recommendations.

To accelerate the successful implementation of green energy technologies in South Africa, the following future policy recommendations are proposed:

- Just Energy Transition Policy
- Stakeholder Engagement and Public Awareness Policy
- Renewable Energy Research and Innovation Policy
- Green Financing and Climate Fund Policy
- 13th Five-Year Plan for Energy Development (2016–2020)

## 5. Conclusion.

In conclusion, a dynamic policy framework, changing technological advancements, and urgent environmental and socioeconomic imperatives have all influenced the complex process of implementing green energy technology in South Africa. Although the country's progressive policies, such the Integrated Resource Plan (IRP), have set the stage for a shift to sustainable energy sources, there are still issues with policy coherence and regulatory enforcement. Solar, wind, and bioenergy technologies show great promise, but large-scale adoption is still hampered by issues with funding, infrastructure, and technical capability.

Green energy has a significant socioeconomic influence in South Africa, providing chances for increased energy security, job creation, and economic diversification. Disparities in access to green technologies, however, as well as the transitional risks that communities reliant on traditional energy sectors confront, underscore the necessity of inclusive initiatives that advance social fairness. Furthermore, green energy is essential for environmental sustainability since it promotes cleaner industrial methods and lowers greenhouse gas emissions, which helps to mitigate climate change.

In the future, overcoming obstacles including institutional slowness, low public awareness, and budgetary limitations will be essential to hastening the adoption of green energy. Fostering public-private partnerships, improving research and development, and establishing an environment that encourages investment, and innovation should be the main goals of future policy approaches. In the face of a changing climate, South Africa can establish itself as a pioneer in green energy technology and promote socioeconomic growth and environmental resilience by coordinating national priorities with international sustainability goals.

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