Access to energy and poverty alleviation in South Africa

By

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KR Letlhatlhe

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Abstract

Over 14 million South Africans live below the poverty line, and the country still has many people with no access to electricity. Despite the efforts by government, South Africa's electricity access is still unevenly distributed with disparities clear between urban and rural parts of the country. Providing energy access in rural areas without electricity has the potential to alleviate poverty in those areas. The main goal of this study has therefore been to investigate the impact of energy access in the form of electrification on poverty alleviation in South Africa. The study also focuses on the impact of a socioeconomic factor, namely unemployment. The study focuses particularly on South Africa (including all 9 provinces). The study adopts a quantitative approach, using secondary statistical data. Finally, Amartya Sen's Capability approach and other theories provide a deeper perspective in understanding the relationship between energy access and poverty alleviation. The key finding from the study is that access to energy can certainly alleviate poverty. The data showed an increase in productivity due to the use of energy, thus a decrease in the unemployment rate. The increase in investments and, intervention and policy implementation since 1994 led to a substantial increase in electricity access across South Africa.

Key words; Energy access, electrifications, poverty alleviation, provinces & South Africa

Glossary

Term	*Definition*
Energy	The capacity to produce electricity.
Poverty	A lack of sufficient income and/or resources to meet basic needs.
Sustainable Development Goals (SDGs)	United Nation's (UN) 17 global targets for 2030.
Electrification	The process of providing electricity.
ESKOM	South Africa's state-owned entity is responsible for producing electricity.
Integrated National Electrification Programmed (INEP)	A South African policy designed to expand electricity access, particularly in low-income areas.
Income	Earnings that determine economic wellbeing.
Unemployment	Work opportunities that determine economic wellbeing.
Department of Energy (DoE)	A South African government department that oversees energy regulation.
Non-grid Electrification	Electricity supplied through off-grid systems.
Municipalities	Local governments that are responsible for providing basic services within their jurisdictions.
Grid Electrification	Electrification via national power grid.
National Electrification Program (NEP)	A South African policy designed to provide and expand electricity access universally.

Department of Minerals Resources and Energy (DMRE)	South African department that manages energy policies.
State-owned enterprises (SOEs)	Entities operated by the government to deliver public goods or services.
Department of Energy (DoE)	South African department that formerly managed energy policies.
Food poverty line (FPL)	The minimum income needed to afford basic food needs.
National Energy Regulator of South Africa (NERSA)	South Africa’s authority that regulates electricity.
Lower Bound Poverty Line (LBPL)	Income threshold that covers basic food and inadequate non-food needs.
Connectivity	The state of being linked.
Pearson Correlation	A method used to measure the direction and strength of a linear relationship between two variables.
Linear Regression	A method used to determine a relationship between variables.
Upper-bound poverty line (UBPL)	Income threshold that covers adequate food and non-food needs.
R/R Studio	A programming environment used for statistics and data analysis

"Four decades ago, no one managed energy. No one sold energy or bought it. No one had heard of energy companies. No one made energy policy. Yet energy is now the world's largest business. […] Despite all the dramatic technological and economic advances, we have seen, some two billion people, one-third of humanity, are still without electric light. […] Something is seriously wrong with the way we manage energy. Can we not do better? And if so, how?".
(Patterson, 2008, pg. 2)

Shot by Haffejee (2015, cited by The Conversation, 2023)

Chapter 1 : Introduction

1.1 Background and Introduction

In 2024, South Africa held a population of 63 million people, ranking it 24 in the world and six in the African continent (WorldMeter, 2025). The country covers roughly over one million square meters, with 66.59% of the population categorized as urban (WorldMeter). Year-on-year population growth grew by approximately 1.33% from 2023 to 2024 (IRENA, 2024). In alignment with the Sustainable Development Goals (SDGs), an increasing population results to an energy demand (WorldBank, 2019), which automatically makes it the responsibility of government to ensure that every citizen has access to affordable and reliable energy (SDG 7) across the country. South Africa represents a good case: Energy is crucial for meeting the increasing human demand and represents a challenging global issue in achieving development goals (Asghar et al., 2022). South Africa is experiencing an energy deficiency characterized by electrification. According to Statistics South Africa (2019), about 10,2% of South Africa's population lives without electricity, whilst in Africa, one in three people do not have access to electricity World Bank (2019). Between 1990 and 2016, the percentage of people in sub-Saharan Africa lacking access to electricity has doubled (World Bank, 2019). IEA (2020) project that the demand for power, heat, and transport will increase as the world population rises. Thus, a projected increase in energy demand, potentially doubling by the year 2050. (IEA. 2020). Those without access to electricity in the population often rely on alternative energy sources such as firewood, leading to significant numbers living without electricity (IEA, 2020). Rural electrification in Africa remains deficient, primarily due to affordability issues hindering widespread connection to the grid (IEA, 2020).

The challenges to electrification in South Africa are partly a result of geographical obstacles that present a burden for distributing the electricity. In the same light, challenges relating to energy in South Africa are also primarily caused by the country's energy dependency on fossil fuels (Asghar et *al*., 2022). In this case, alternative energy systems are now present as a solution believed to solve these issues (Asghar et *al*., 2022). The transition from conventional energy systems, heavily reliant on coal and fossil fuels, to alternative energy solutions is a major challenge. In response to climate change and energy poverty, renewable energy sources like solar, wind, and hydroelectric power are emerging as promising alternatives. However, this shift is not without its own set of challenges. Most people can't afford renewable technologies, especially solar panels, because of their high initial costs (IRENA, 2020). Accordingly, without equitable solutions, in accordance with Amartya Sen's Capability Approach, the very population that suffers from energy poverty today will remain disenfranchised in tomorrow's energy landscape (Sen, 1999).

In addition, integrating these alternative systems into existing infrastructures poses technical and logistical challenges, exacerbated by outdated grid systems and regulation frameworks North (1990, cited in Faundez, 2016). The intermittent nature of renewable sources raises concerns about reliability and energy storage capabilities, complicating the transition process Chipper-Martinetti (2009). With this complexity, there are serious questions about employment opportunities; the renewable energy sector could create jobs, but it could also displace workers who are reliant on traditional energy industries, worsening unemployment (UNEP, 2021).

To successfully navigate the complex transition and align with the Sustainable Development Goals (SDGs), it is essential to learn from the limitations of South Africa’s current energy challenges. Understanding past experiences, such as unequal access, existing government programs, paradoxes and inefficiencies, will enable policymakers and researchers to design towards more inclusive and resilient energy systems. This study encourages future energy strategies to integrate considerations of both unemployment and capacity, promoting cooperative initiatives that empower communities and guarantee sustainable, fair access to electricity for everyone. The disparities in South Africa serve as a clear example, with some provinces exhibiting high electrification rates yet also experiencing significant poverty levels. This highlights the need for energy solutions that not only provide access but also address socio-economic inequalities.

1.1.1 Key Definitions

This section highlights the choice and significance of chosen variables in the study, namely the poverty income threshold, electricity access, and the unemployment rate. These are all critical in understanding the relationships between energy access and poverty reduction. Each variable data is obtained from credible datasets and supports the goals of the study.

Income Poverty Threshold

The income poverty threshold, measured in Rand per capita per month (Quantic, 2024), stands for the minimum income needed to meet basic needs in South Africa. Households falling below this threshold are classified as income-poor. In this study, the income poverty threshold is a precise measure of the Lower Bound Poverty Line (LBPL) as it describes the minimum cost of basic food needs, excluding non-food essentials, making it a stricter indicator of extreme deprivation (Stats SA, 2020). South Africa studies have shown energy poverty worsens financial strain, so the LBPL reflects households struggling to afford even essential services, aligning with the study's focus on energy access. (Bekun et *al*., 2021; Masuku, 2024). More so, the country has a high-income inequality gap, the variable will measure how many people cannot afford basic energy (Stats SA, 2020).

The variable is ideal for the study because it provides a measurable benchmark for evaluating how electricity access influences household economic stability (Masuku, 2024). For example, Gonzalez-Eguino (2015) found that energy access reduces income poverty by lowering energy expenditures and enabling income-generating activities, which we often classify as employment. By using the poverty threshold, the research practically evaluates whether electrification programs or efforts help raise households above this level.

Access to energy

This variable, sourced from the World Bank, shows the percentage of individuals with electricity access (WorldBank, 2022), highlighting the extent of electrification initiatives. Having access to electricity is fundamental for development, impacting areas such as education, healthcare, and economic efficiency (IEA, 2020). South Africa, with around 15% of the population still without access to the grid (Eskom, 2021), undermines the notable efforts. Thus, this variable is selected for its ability to directly reflect the study's emphasis on energy access and its value in alleviating poverty. Empirical research BY Dinkelman (2021) revealed that electrification can alleviate poverty by facilitating productivity in many sectors in South Africa. This variable aids in identifying infrastructure gaps too.

Unemployment

Unemployment measures the number of working-age individuals (15–64) actively seeking employment but unable to secure jobs (Quantec, 2024).

South Africa’s unemployment rate, exceeding 34% (Stats SA, 2023), is a critical socioeconomic challenge. The variable is included in the study because unemployment is seen as a factor that worsens poverty through limiting individual’s ability to afford energy (Bhorat et *al*., 2022). The study hypothesizes a linear relationship between electricity connectivity, and income poverty level and population of working age. These two factors have a positive impact on electricity connectivity.

Unemployment data provides a crucial lens for examining the impact of electrification on job creation, especially in informal sectors. Electrification often stimulates economic activities by providing reliable energy sources, which can lead to the establishment of new businesses and the expansion of existing ones (Pegels, 2019).

By incorporating unemployment data into the study’s analysis, researchers may better understand the relationship between energy policies and labor market dynamics. This integration allows for an exploration of how new energy infrastructures might influence job opportunities and economic growth in underdeveloped regions, potentially providing insights into effective poverty alleviation strategies. This holistic approach emphasizes the importance of considering multiple economic factors when designing and implementing development strategies.

The chosen variables collectively offer a robust framework for analyzing energy access and poverty alleviation in South Africa. Their relationship reveals policy-relevant insights, bridging gaps existing in literature as well as to inform SDG efforts.

1.2 Research Problem

South Africa's energy access challenge is just an isolated problem; it is a part of a bigger issue stretching across the African continent. The problem also has consequences for socioeconomic developments. Despite the efforts made towards energy access, a large percentage of individuals are still left without access (Bekker et *al*., 2008). It is overwhelming how one of the most energy-rich nations holds so many disparities, having provinces that are well-lit while others still linger in darkness. This is coupled with a high unemployment rate, translating to households that cannot afford electricity even when it may be available to them. This challenge essentially undermines any benefits that electrification might offer in alleviating poverty.

More so, policy promises under initiatives like the Integrated National Electrification Programme (INEP) have not materialized into equal access, largely due to issues like poor governance and mismanagement at Eskom (Bekker et *al*., 2008). These are compounded by inadequate planning for rural infrastructure (Asghar et *al*., 2022). It is as if the policies are there in theory but fail spectacularly in practice, running us off track from meeting crucial SDG 7 targets. While much focus has been on technicalities, like megawatts hours, it's important we consider the lens of human capabilities. This reveals that the current narrative overlooks the energy social impacts, like how energy challenges limit productivity or other economic activities. Without tackling these interconnected pieces, South Africa will not only be at risk for reaching its 2030 universal energy access goals (SDG 7), but the country will continue to deepen existing inequalities and miss out on the broader benefits of an equitable energy landscape. Thus, understanding and addressing energy access in South Africa should not just be about flipping a switch however to consider a much more considerable and meaningful approach, flipping the narrative from failure to practical success.

1.3 Research Objective

South Africa has played an important role in negotiating and developing the Sustainable Development Goals (SDGs). According to the United Nation (2015), access to energy plays a critical part in the SDGs, specifically goal 7, which aims to ensure that everyone has access to clean and affordable energy. Goal 7 recognizes that access to energy is essential towards achieving broader development goals, such as goal 1, which aims to alleviate poverty, this closely aligns with the basis of the study. In the same light, considering the abovementioned and the outlined problem, the core objective of this study is examining the relationship between energy access and poverty alleviation to not only contribute to the broader objective of SDG 7, but to also identify policy tools that could aid in improving access to energy and addressing poverty challenges at national level.

The focus of this study involves the nine provinces in the country which are later used as a case study, and the objectives are as follows:

- To understand the link between poverty alleviation and energy access.
- To examine the influence of these factors on poverty alleviation in South Africa.

- To analyse inequalities in energy access and poverty, finding provinces with the biggest gaps and analysing their underlying causes.
- To assess South Africa's progress toward SDG 7, highlighting policy successes and failures in achieving universal energy access.
- Investigate the potential of the site for alternative methods of energy.
- Evaluate and offer possible recommendations that align with South Africa's current context.

1.4 Research Questions

Three types of research questions emerge from this study, in line with its objectives. The first question is contextual, which describes the background of South African poverty trends. Two main research questions are then presented, aiming to better understand the nature of poverty for scholars and policymakers. As a final research question, we propose possible new or additional policy foci to assist policy makers in tackling poverty. These various types of research questions will be discussed in more detail below, as well as how they can be answered.

1.4.1. Contextual research question

The contextual research question is:

What are the trends in energy access, using electrification as a proxy in South Africa?

The contextual research question will aid in giving the researcher's understanding with regards to the trends in energy access over a period – enabling her to respond to the main research questions formulated.

1.4.2. Main research questions

The main research questions are:

- How does energy access influence poverty alleviation in South Africa?
- What are the disparities and challenges in energy access and poverty?

The results obtained from the above two questions could possibly assist scholars (and government) in further research, policy formulation and continuous fight against poverty. In view of that, the researcher has formulated an applied research question.

1.4.3. Applied research question.

The applied research questions are:

- In what ways has South Africa progressed towards the applicable SDGs?
- To what extent does unemployment influence the connection between energy access and poverty?

The suggestions from these questions emanate mainly from the results found in the response to the preceding questions. The results will thus guide the researcher in suggesting one of the possible directions that scholars and government should take, to reduce poverty in South Africa.

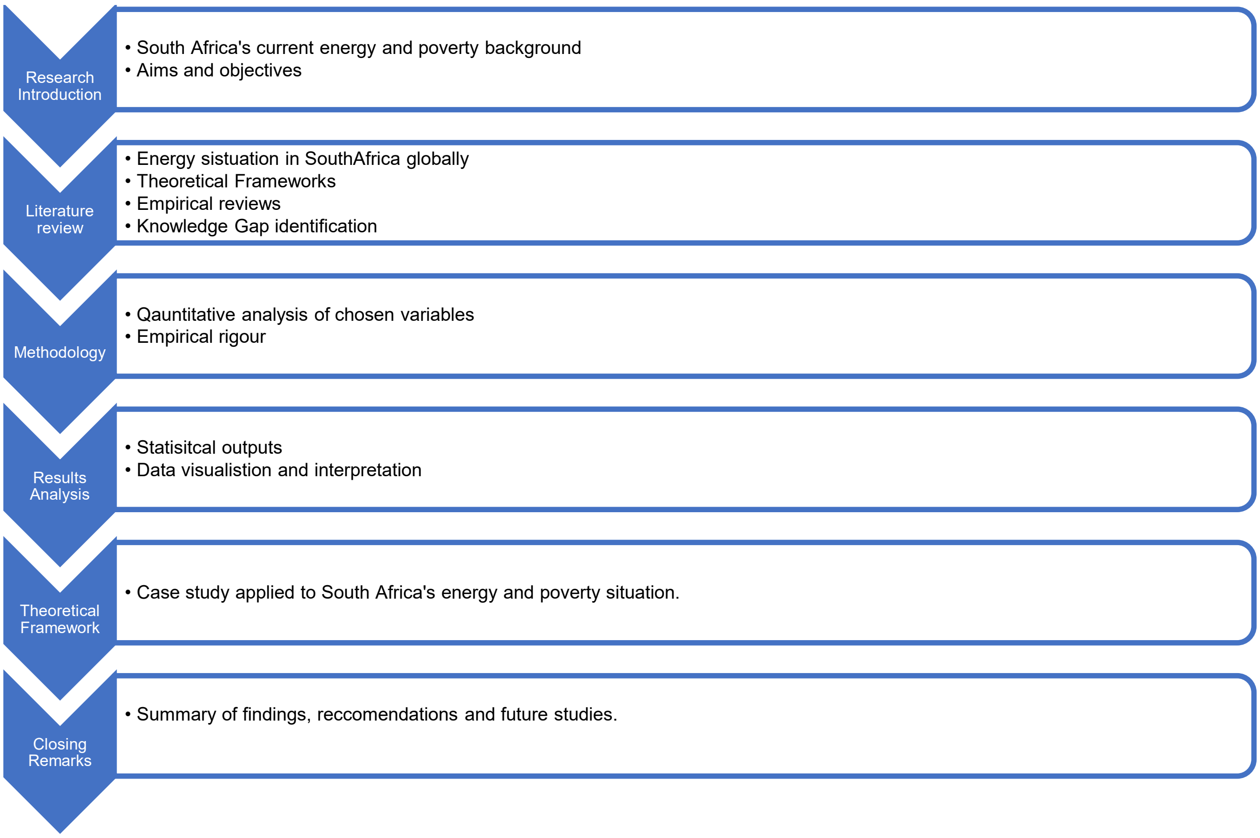
The following sub-section summarises the research methodology that will be employed in this research dissertation.

1.5 Research Purpose

The overarching aim of this research is to analyse the relationship between energy access and poverty alleviation in South Africa. This study seeks to identify and evaluate the barriers and enablers influencing energy access. Ultimately, this research aspires to contribute significantly to the existing body of knowledge on energy access and poverty alleviation in South Africa. By providing a detailed understanding of the complexities surrounding the topic, the findings will inform the development of more effective policies or strategies that align with socioeconomic realities, potentially serving as an example or framework for other regions facing similar challenges.

1.6 Research Methodology

Figure 1.1: *An overview of the study's methodology*



(Source: Author's own compilation)

To answer the research questions and fulfil the objectives of the study, a comprehensive methodology employed in this study. A quantitative approach will be adopted, which will include the collection of data, its analysis, and its demonstration as part of the research design (Johnson & Christensen, 2017). The strategy highlights the significance of a deductive method in understanding the connection between theory and research. It prioritizes the importance of testing theories. This study utilizes a correlational research design to assess the degree of association between multiple variables. Correlational research is crucial for identifying patterns and potential causal links, enabling researchers to ascertain if variables have a positive or negative association (Creswell, 2014). The primary aim of this study is to explore the relationship between poverty and energy access by employing statistical methods to analyze secondary data. The data has been sourced from reputable institutions such as Quantec and the World Bank, spanning from 1996 to

2022. This timeframe is intentionally selected because it corresponds with the post-1994 democratic era in South Africa, a significant period of socioeconomic change in South Africa. Data availability also influenced the selected period, as earlier data points for the variables of interest were inconsistent or unavailable. Although the study centers on this specific timeframe, references to earlier or later periods are included where necessary to provide context and enhance the analytical depth.

One key advantage of utilizing official secondary data sources like the World Bank and Quantec is the high reliability and validity they offer (Lim, 2024). These datasets are systematically collected, meticulously validated, and aim to provide comprehensive insights into useful trends and indicators. Moreover, using existing data sets optimizes research efficiency by avoiding the time and costs associated with primary data collection, while ensuring that the data has been gathered with standardized methods. A quantitative, particularly correlational, approach permits the application of advanced statistical techniques, including descriptive statistics, visualization, correlation coefficients, and regression analysis, to derive meaningful interpretations from the data (Hartwig & Dearling, 1979). These methods not only aid in identifying relationships between variables but also support analytical modeling and the formation of policy (Hartwig & Dearling, 1979).

A key part of this study is that it focuses on hypotheses, suggesting the presence of at least two interrelated variables. The aim is to assess if there is a positive or negative correlation between poverty alleviation and energy access. This evaluation is important for the study as previous studies (as discussed under the literature review) reveal that energy access is crucial to poverty reduction and/or development. Through correlation and regression analysis, the study will evaluate whether improving energy access leads to poverty alleviation or if certain socioeconomic barriers hinder the relationship. This analytical stage will ultimately identify statistical significance among the variables and how these relationships can influence policymaking.

Finally, Blackstone (2012) asserts that the deductive approach enhances scientific rigor by logically transitioning from theoretical frameworks to empirical testing. Thus, by attaching this study to well-established theories such as Sen's Capability Approach, the findings can contribute to existing literature while also producing practical yet inclusive recommendations. The results will not only confirm or challenge theoretical assumptions but also highlight policy-relevant insights that could inform strategies for South Africa and hopefully the rest of Africa.

1.7 Research Framework

Chapter one delivered an overview of the research topic. This included research problems, questions, objectives, rationale and a summary of the methodology.

The rest of the study is presented as follows:

Chapter 2:

Comprises of the literature review, which is shared into various parts, namely, an introduction of the variables selected and their dynamics. Four theoretical frameworks to aid in contextualizing the study, which is secondary to the study's analysis. An empirical study to test various theories. The study highlights unemployment, to reinforce energy and poverty dynamics as well as further align the study to SDGs. The political economy of energy is also explored in this chapter to dissect how different economies shape access, and to see how energy access is defined globally. Existing literature and examples of the political economy are integrated into developed, developing and underdeveloped economies. The final sub-section in the chapter summarizes the identified literature gaps.

Chapter 3:

Chapter 3 outlines the research methods and methodology in detail, beginning with the research philosophy and strategies. The chapter continues to discuss the research approach, clarifying the strategies the study used. An analysis of the research design, method, sampling techniques as well as the population in the study are also outlined in this chapter. The process of analysis is highlighted with emphasis development. Lastly, the chapter ends with an analysis of standards for social analysis where the limitations, feasibility, and positionality are addressed in effort to ensure the study's validity and reliability, while keeping in mind the ethical implications of the research process too.

presented.

Chapter 4:

This chapter presents a detailed analysis and interpretation of the research results. The findings are methodically analyzed in accordance with the study's chosen objectives. Section 4.1 provides descriptive statistics, offering an overview of key data trends related to energy access and poverty. Section 4.2 delivers a visual representation of the data, enhancing understanding through charts and graphs. Within this section, 4.2.1 explores the Pearson correlation, highlighting relationships between variables such as energy availability and socioeconomic indicators. Section 4.2.2 presents a linear regression analysis, quantifying the impact of energy access on poverty alleviation outcomes.

Throughout the chapter, findings are embedded in discussions, drawing connections to the research objectives and addressing overlaps due to the interpretivist approach. A summary of findings is provided to reinforce key insights for the reader. The chapter concludes by categorizing the discussions around the core themes of energy access and poverty alleviation, emphasizing their interconnectedness and the broader socio-economic implications for South Africa.

The chapter ends with the researcher's contribution to knowledge: interpretation of findings and implications thereof.

Chapter 5:

This chapter is key as it outlines the theoretical lens through which the research findings are interpreted. It begins by centering attention on South Africa's socioeconomic factors which directly influence both energy access and poverty alleviation. The beginning factors shaping shape energy distribution are examined in 5.1. This is followed by the paradoxical results of electrification explicitly emphasizing the dual impact. In alignment to institutionalism and understanding South Africa's far reaching socioeconomic landscape, the chapter delves into the effects of apartheid, highlighting existing effect to energy access currently. Government programs and initiatives are also analyzed to assess their effectiveness. Lastly, factors that hinder or drive energy access are categorized, focusing on both barriers and enablers of equitable energy distribution (addressing SDG 7).

Chapter 6:

This chapter concludes the study by summarizing findings and the implications of the chosen variables. Recommendations for policy and further research areas are also provided in this chapter.

Chapter 2 : Literature Review

2.1 Introduction

Diverse published literature on energy access indicates a positive relationship between access and economic development, particularly poverty alleviation. However, the case might be different in different regions due to unique structural factors of the residents. This literature review explores the currently published studies on this subject in different thematic areas. It also entails analysis of theoretical frameworks, methods, and approaches they have applied in responding to my thesis research question. Sen's capability approach serves as the primary theoretical framework in this thesis. Besides, other theories on energy access include the energy stacking theory and energy ladder theory. After the evaluation of the current literature, this thesis explores their contribution to the research question and the available research gaps, which this thesis aims at linking to add into the existing knowledge.

2.1.1 Electricity access dynamics.

Access to electricity is a crucial factor for socioeconomic development, influencing various aspects of daily life and overall economic growth. Theories examining this issue often highlight the relationship between energy access and poverty alleviation, economic development, and social equity. The Energy Ladder Theory, for example, posits that households transition to higher-quality energy sources as their income increases, improving their quality of life and economic productivity. However, this theory has limitations in explaining regional disparities and the impact of infrastructure and policy constraints. By examining the dynamics of electricity access in South Africa, this study aims to address these weaknesses and contribute to a broader understanding of energy access issues.

According to the UN Environment Programme (2017), South Africa had a population of 53.16 million in 2013. As of 2015, the country produced 25,399 ktoe of electricity, with 90% from fossil fuels, 4.8% from nuclear, and 4.3% from hydro sources. The final consumption was 20,877 ktoe. South Africa holds approximately 3.5% of the world's coal reserves and contributes 3.3% to annual coal production, exporting about 6% of the global total (DoE, 2016). The country's heavy reliance on coal for electricity generation presents both opportunities and challenges for energy access and environmental sustainability. This reliance has led to infrastructure limitations and stagnation in coal exports over the past decade (Ratshomo & Nembahe, n.d.).

The energy sector in South Africa is governed by the Department of Energy (DoE) and regulated by the National Energy Regulator of South Africa (NERSA) under the National Energy Act, 2008. Eskom, the state-owned enterprise, holds a monopoly in the power market but does not have exclusive generation rights (UN Environment Programme, 2017). This regulatory framework is critical in understanding the dynamics of electricity access and the challenges faced in achieving universal electrification.

The World Bank (2016) revealed that access to electricity in South Africa was 85.4% in 2012, with significant disparities between rural (66.9%) and urban (96.6%) areas. The government aims to achieve at least 97% electrification by 2025, focusing on a combination of grid technologies and solar systems (UN Environment Programme, 2017). Historical data indicates that access to electricity increased from 65% in 1990 to over 85% in 2012, reflecting substantial progress over 22 years (UN Environment Programme, 2017). Recent statistics show that access further increased to 89.8% in 2023, demonstrating the country's ongoing commitment to expanding energy access despite persistent challenges (Statistics South Africa, 2023).

When looking at the problem in the bigger picture of Africa, many countries have the same problems getting energy, which are made worse by a lack of infrastructure and rules that make it hard to get around. South Africa's experience offers valuable lessons for its neighbours, particularly those reliant on South Africa's electricity exports. The regional interconnectedness of energy supply underscores the importance of stable and efficient electricity production in South Africa for broader African development.

By examining the specific dynamics of electricity access in South Africa, this study contributes to the broader intellectual discourse on energy access and development. It draws from and adds to the body of knowledge on the socioeconomic impacts of electrification, the effectiveness of energy policies, and the implications for poverty alleviation. This study not only fills in the theoretical gaps in the existing literature, but it also gives policymakers real-world evidence to help them make changes that will make energy access fair and long-lasting.

2.1.2 Poverty dynamics

Francis and Webster (2019) define South Africa as a paradox: being one of the most unequal countries globally while boasting one of the most progressive constitutions, featuring a Bill of Rights that emphasises extensive social and economic rights. The South African government's aspiration for an equal and poverty-free nation post-apartheid has been articulated in the National

Development Plan (NDP) draughted since 2010 and the Sustainable Development Goals (SDGs) signed in 2015 (Statistics South Africa, 2019). The main objectives of the NDP and SDGs are to eliminate poverty and reduce inequality by 2030.Various theoretical lenses can help us understand the dynamics of poverty in South Africa. Structuralist theories highlight the historical and systemic roots of poverty and inequality, emphasising how apartheid-era policies have long-lasting impacts on socioeconomic disparities. Human capital theories emphasize the importance of education and skill development as essential elements in reducing poverty, whereas capability approaches, as outlined by Amartya Sen, consider a wider range of factors related to human well-being and freedoms. Both theories offer valuable perspectives but also have their shortcomings. For instance, structuralist theories may fail to fully recognize individual agency, while human capital theories might neglect the impact of structural obstacles. This research aligns with the capability approach by examining poverty as a multifaceted issue and supporting the Sustainable Development Goals (SDGs) aimed at creating a more comprehensive understanding of global challenges.

South Africa holds a well-founded tradition of studying poverty, although attention to inequality has only recently become significant in both academic and policy discourse (Francis and Webster, 2019). According to Mlaba (2020), the significant inequalities in South Africa exacerbate poverty. Addressing poverty without tackling inequality is impossible, as these issues are intrinsically linked (Francis and Webster, 2019). The World Bank (2018) ranked South Africa 114th out of 189 countries on the Human Development Index, focusing on indicators such as education, average life expectancy, and income inequality (Mlaba, 2020). South Africa’s wealthiest households are nearly ten times wealthier than the poorer households (World Bank, 2018).

Poverty levels in South Africa have decreased over the years, as indicated by metrics such as the poverty headcount and the poverty gap. The poverty gap decreased from 25% in 1993 to 16.6% in 2014, and the poverty rate at the national poverty line dropped from 66.6% in 2005 to 55.5% in 2014 (World Bank, 2017). Despite this monetary decline in poverty, uncertainties persist regarding dimensions such as equality and access to energy. Approximately 18.9% of South Africa's population, roughly 11 million people, live below the international poverty line of R28 ($1.90) per day (Mlaba, 2020). The decline in the poverty gap and headcount reveals South Africa’s efforts to alleviate poverty; however, additional measures are necessary to sustain these lower levels as half of the country’s adult population lives in poverty (Bittar, 2020).

Regional disparities in poverty are also significant. According to Statistics South Africa (2016), poverty is most prevalent in the Eastern Cape (12.7%) and Limpopo (11.5%), while it is less common in the wealthiest provinces, Gauteng (4.6%) and the Western Cape (2.7%). This uneven distribution underscores the complexity of poverty dynamics within the country.

Understanding poverty dynamics in South Africa contributes to the broader intellectual area of development studies and poverty alleviation. By situating South Africa within the broader African context, this study aims to provide insights that can inform regional development strategies. South Africa's experience with electrification and poverty alleviation can serve as a model or cautionary tale for other African countries facing similar challenges. This study contributes to the discourse on how targeted interventions in electricity access can foster more equitable and inclusive socioeconomic development, supporting the goals of the NDP and SDGs.

2.2 Theoretical Framework

Several theories provide frameworks for examining the impact of energy access on poverty. These theories entail Sen’s capability approach, energy ladder theory, energy stacking theory, development theory, and human capital theory. Energy ladder theory says that access to energy is a linear process that is affected by a household's income. Households with low incomes use old, inefficient energy sources, while households with high incomes can use new, modern energy sources. People who use unclean energy sources face poverty and health risks. The energy stacking theory states that households rely on diverse energy sources. When switching, households primarily rely on off-grid energy sources, including traditional and environmentally polluting ones. Development theory emphasises the importance of infrastructure, including energy, as a foundation for economic growth. Human capital theory focuses on the enhancement of individual capabilities through access to resources such as electricity, which supports education and health. The capability approach, proposed by Amartya Sen, views poverty as a deprivation of basic capabilities rather than merely low income, highlighting the multifaceted benefits of energy access. This study situates itself within the capability approach, addressing its comprehensive view of poverty and its alignment with the holistic aims of the SDGs.

2.2.1 Sen’s Capability Approach

Sen’s approach emphasises the improvement of individual abilities as a core objective of development. Unlike most economic measures that emphasise GDP, Sen’s capability approach suggests that development should be assessed based on the opportunities presented to individuals to achieve the kinds of lives they value. In essence, Sen's capability approach revolves around two main concepts: capabilities and functionings (Nussbaum & Sen, 1993). Nussbaum & Sen (1993) define capabilities as the opportunities individuals must achieve various states of being and doing, while functionings are the actual realisations of these capabilities. This study assumes that access to energy (capability) enhances an individual's ability to live better (functioning). This emphasis on what individuals are able to be and do provides a more comprehensive measure of well-being compared to income-based approaches (Clark, 2005).

Sen categorised capabilities across various dimensions, including economic, political, and social freedoms. Key capabilities essential for poverty alleviation include access to education, healthcare, employment opportunities, and social inclusion (Nussbaum & Sen, 1993). For instance, access to electricity can facilitate high-quality healthcare through functioning medical technologies. Healthcare facilities require electricity to operate medical equipment, which directly impacts community health outcomes (Saied et al., 2022). The capability approach offers a contrast to traditional income- or consumption-based poverty measures. Jackson & Yu (2023) assert that income-based metrics can overlook non-monetary deprivations such as lack of access to healthcare. In comparison, the capability approach encompasses a broader spectrum of human development indicators, thus providing a more holistic view of poverty (The World Bank, 2015).

Theories that have traditionally examined poverty include the human capital theory, which focusses on the role of education and skills in improving economic outcomes, and the structuralist theory, which focuses on the systemic and historical causes of poverty. While these theories provide valuable insights, they also have limitations. The human capital theory may overlook structural barriers that prevent individuals from utilising their skills, and the structuralist theory might not fully account for individual agency and capability. The capability approach addresses these weaknesses by considering both individual and systemic factors, providing a more nuanced understanding of poverty.

Developing policies based on the capability approach requires comprehensive data on various aspects of individual well-being, which can be complex and resource-intensive to collect and analyse. Despite these limitations, the capability approach remains a powerful theoretical framework for understanding and addressing poverty in a multifaceted and human-centric manner

(Bourguignon, 2020). The application of the capability approach in developing countries like South Africa will yield valuable insights into its effectiveness. For instance, South Africa's energy policies aimed at increasing access and efficiency demonstrate the practical application of the capability approach in addressing both economic and social dimensions of poverty (GEA, 2012).

Amartya Sen's capability approach has led to the development of a nuanced and comprehensive framework for understanding poverty and formulating strategies for its alleviation. By focusing on enhancing individual freedoms and capacities, this approach offers valuable insights into the role of electrification access in promoting human development. Regarding the implementation and refinement of South Africa's energy policies, the capability approach will be instrumental in guiding efforts to improve the well-being and opportunities of its citizens (World Economic Forum, 2023).

Broadly, this study draws from and contributes to the intellectual area of development studies, specifically focusing on poverty alleviation and human development. It situates itself within a broader African context, recognising the regional implications of energy access. South Africa's experience serves as a case study for understanding how electrification impacts socioeconomic development, providing lessons for other African countries. The findings aim to inform regional development strategies and contribute to the global discourse on sustainable development.

The capability approach's emphasis on individual freedoms and capacities aligns with the core objectives of the Sustainable Development Goals (SDGs). According to Bologna (2013), energy access is essential for sustainable economic growth, leading to industrialisation, enhancing productivity, and fostering innovation. Ensuring energy access is also crucial for social inclusion, as it reduces inequalities by enabling marginalised communities to improve their living standards and participate more fully in economic activities (Casati et al., 2023). Thus, electricity access is not only a key driver of socioeconomic development but also a fundamental part of sustainable development, which is at the core of all the SDGs.

2.2.2 Energy Ladder Theory

The energy access process is presented as directly related to the financial capabilities of individuals, whereby those low on the poverty line depend on traditional sources of energy due to their low-income levels. The lack of financial capability and energy poverty contributes to their slow economic growth since traditional energy sources are inefficient in driving economic growth and development. In contrast, the case for those with high income levels has tech-advanced energy sources that enable them to achieve economic growth and development more efficiently.

According to van der Kroon et al. (2013), modern energy sources play a pivotal role in the economic and social development of diverse countries. However, there is a significant population of over 2 billion people still relying on traditional energy sources for their daily activities, according to the study conducted by van der Kroon et al. (2013). The population has since changed, but sub-Saharan African countries report the highest percentage of the global population without energy access. Fentie et al. (2023) report that the global population without electricity access is 770 million. Continued reliance on traditional energy sources negatively impacts the environment and health, making it ineffective in alleviating poverty. This study applies a meta-analysis of various existing choice models used in the investigation of energy switching and stacking behaviour in the urban and rural regions of developing countries. The application of this theory by van der Kroon et al. (2013) indicates slow socio-economic growth and development among those without access to clean and modern energy sources since it correlates with high income levels.

Fentie et al. (2023) also apply this theory to explore the energy choices among Ethiopian households. Due to a lack of adequate literature on energy choices among people in developing countries, this study utilises the World Bank's socioeconomic survey data. This study applies a panel multinomial logit model to investigate the various determinants of household lighting choices. The energy ladder theory demonstrates that the use of cleaner energy sources increases with an increase in income levels among households. In addition, education level is a critical aspect that promotes transitioning from traditional energy sources since it also creates more opportunities for people to earn more income, hence their ability to afford cleaner energy sources.

Kitole et al. (2023) explored the fuel options used by Tanzanian households, and they applied the energy ladder theory using a multinomial logit model to analyse data from the National Bureau of Statistics (NBS). The study indicates that a significant population of Tanzanians live in poverty, which correlates with their use of traditional and inefficient energy sources. This study has identified income and education levels as major determinants of cleaner energy access. Therefore, there is a correlation between income level and access to clean energy; those high on the energy ladder are characterised by high income, which indicates significant socio-economic development.

When applied to the case of South Africa, the energy ladder theory results in a complex scenario whereby other factors influence the energy use among households. Wernecke et al. (2024) state that energy use in South Africa is influenced by various factors that include location, source of energy, behaviour, time, and socio-economic aspects of the household. The cost of electricity is high for South Africans with frequent disruptions due to outages. This incidence is persistent in South Africa, despite the high level of access to electricity in most of its provinces. The load shedding results in energy switching and stacking, whereby people opt to use traditional energy sources among the low-income consumers who cannot afford other costly energy sources. While South Africa has made significant strides in energy access and distribution, the situation concerning clean energy access remains problematic. This reality diverges from the straightforward trajectory of energy use that the energy ladder theory proposes. Instead, the stacking theory of energy use is more relevant in the South African context, as residents often rely on a variety of energy sources simultaneously due to the high cost and unreliability of electricity. The energy ladder theory does not accurately reflect the current energy access landscape in South Africa, where interruptions in electricity supply frequently compel individuals to turn to alternative off-grid energy solutions, adversely affecting their economic growth and development. Therefore, the energy ladder theory does not effectively describe the dynamics of South African energy supply and distribution. Additionally, there is a noticeable lack of published research on this linear transition process in energy consumption.

2.2.3 Energy Stacking Theory

The significant expense associated with accessing clean energy often results in a dependence on conventional energy sources, which subsequently leads to energy stacking. As noted by Ateba et al. (2018), the inconsistent electricity supply in South Africa, along with various other factors, fuels this reliance on traditional energy sources. Access to clean energy is essential for driving economic growth and development (Tsagae, 2023). However, the frequent electricity outages in South Africa have hindered economic development among numerous households despite their electricity access. The change in their energy usage occurs frequently; hence, it aligns with energy stacking theory. It is mostly prevalent in rural areas and among the informal settlements in urban areas. This study, while focusing on Gauteng and North-West provinces, indicates that most of the households practice energy stacking. There is an observable inequality in energy access in South

Africa, indicating the challenging energy access among South Africans living under poverty. Lack of clean energy access also results in slow socio-economic development among low-income earners in the country.

In an enlightening study, Wernecke et al. (2024) delve into the energy stacking theory within the context of South Africa, shedding light on its significant impact on low-income households. The challenge of unreliable electricity supply continues to be a major roadblock in the journey toward embracing clean energy solutions. For many low-income households with access to electricity, a mix of energy sources becomes the norm, a fascinating phenomenon known as energy stacking and switching. Adding to this conversation, Masuku (2024) points out how the persistent issue of energy poverty has sparked a surge in the use of off-grid energy alternatives. As urban areas swell with population growth, city dwellers face mounting pressures that push them to explore a variety of energy options, even relying on traditional and less efficient methods. The landscape of energy consumption in South Africa is evolving, and it's a story worth paying attention to.

2.2.4 Human Capital Theory

The acquisition of advanced skills and knowledge enhances individuals' contribution to economic development and access to modern energy sources. Adepoju *et* al. (2022) explores the role of human capital in reducing the usage of non-renewable energy sources. The study applies a qualitative research approach in exploring the impact of human capital on renewable energy generation and access in Nigeria. Educated people are most likely to adopt renewable energy sources as they contribute to their development in their areas of residence (Shi *et* al., 2024). Besides, they have access to diverse economic opportunities that enable them to afford modern and renewable energy sources. Access to modern energy sources also enhances the attainment of higher education and skills. People in a region can efficiently access advanced technology, which enables them to acquire skills necessary to leverage renewable energy sources (Shi *et* al., 2024).

Sibanda et al. (2023) explore the relationship between human capital and sustainability in South African countries. The study found out that there is a positive relationship between the development of human capital and sustainability. Increased human capital translates into more environmentally sustainable practices such as the use of renewable energy sources and socio-economic development.

Dulvy et al. (2023) point out that human capital is a major contributing factor to economic growth and development. There have been notable advancements in human capital since South Africa gained independence and abolished apartheid. The focus of human capital development has enhanced the country's significant transitioning to renewable energy sources. Despite the advancement in human capital, South Africa reports significant inequality contributing to unemployment and extreme poverty.

According to Msweli (2015), apartheid's high inequality contributed to South Africa's lower human capital index than Botswana. This country inherited racial segregation, which impacted equality in the social-economic development process. Inequality remains a major challenge in the economic development of South Africa and hinders the realisation of growth, despite significant strides regarding human capital advancements. As this country strives to transition to renewable energy sources, the contribution of human capital is critical. Therefore, much is required to enhance this process, considering the current socio-economic state.

2.2.5 Institutional Theory

North (1990, cited in Faundez, 2016) asserts that the success of any economic system (in this case energy provision) depends on the quality of governance and the absence of corruption. Weak institutions lead to failures and exclusionary practices that undermine development efforts (Faundez, 2016). Such a theory relates to South Africa's energy crisis, where institutional failures have intensified energy access despite the 90% electrification rate. For years, South Africa's energy sector has shown how institutional failures have contradicted efforts by government. This is apparent through Eskom, a state-owned institution which has over the years been plagued by corruption which has led to unsustainable debt (Hanto et al., 2022), further undermining government's efforts, creating incompatible agendas between Eskom and Energy department, such as perpetuating reliance on coal instead of adopting renewable energy methods (Hanto et al., 2022). As a result, The National Energy Regulator (NERSA) has failed to implement tariff reforms which have since led to irregular pricing for electricity (SACEEP, 2022). Load-shedding disproportionately harms low-income households and informal businesses. Ndlovu et *al*. (2021), describes this as reason for the current poverty cycles in South Africa.

In contrast, Blimpo & Cosgrove-Davies (2019) found that Rwanda's government anti-corruption stance improved electricity access as well as attracted investment (IMF, 2021). Unlike South

Africa, where Eskom is state-owned, Rwanda's public-private partnerships in the energy sector also improved access and allowed for innovation (Blimpo & Cosgrove-Davies, 2019). A similar case is studied in Brazil, where Luz para Todos (Light for all) was launched in effort to achieve universal electrification through decentralizing implementation to state utilities (Barnes et al., 2018), another which is another example standing in contrast to South Africa's approach. According to the World Bank (2020), the program also holds strong anti-corruption measures and oversight leading to energy efficiency. The institutional theory clarifies why South Africa's energy access gains have not translated into poverty alleviation, where Rwanda and Brazil present great lessons for South Africa. Adopting these lessons and focusing on institutional weaknesses is therefore vital to solving challenges relating to both energy and poverty.

2.3 Political economy of energy access

In the context of South Africa, the institutional theory can help understand how historical policies shape access to energy currently. Whilst the study places emphasis on social structures, North (1990) asserts that institutions also play an important role in political and economic interactions. A study by Posel (1991) found that the policies and frameworks during apartheid, limited access to essential infrastructure such as electricity, for non-white individuals.

As Fine and Rustomjee (1996) explain, political economy focuses on power relations and economic structures. This historical power dynamic still shapes unequal energy access in South Africa, with marginalized communities getting poor service (Baker et al., 2014). It seems that apartheid-era institutions, along with current political and economic structures, perpetuate energy access challenges. Socioeconomic disparities in energy access can be understood by understanding this framework

The role of the state and institutional capacity significantly affects how energy access contributes (negatively or positively) to poverty at different levels of development. There's a lot of literature showing that energy poverty isn't just a technical problem, but also a political and economic one (Sovacool, 2012; Dubash et al., 2018).

2.3.1 Energy in Developed Countries

In developed economies, a shift has occurred from government-dominated electricity sectors to market-oriented systems (Hall, 2016; Bouzarovski & Simcock, 2017). This is seen in European Union (EU) and North America where electricity market liberalization has aimed to boost efficiency Bouzarovski & Simcock, 2017). However, findings indicate mixed results from these reforms, where some at-risk groups have grappled with energy insecurity owing to increasing costs and insufficient social protections. For example, Bridge (2018) studied the United Kindom's electricity sector, where in the late 1900s, privatization was intended to enhance efficiency but led to price instability, impacting low-income households negatively. Similarly, low-income households in the United Kingdom allocate a substantial portion of their income to energy, heavily threatening access to energy (Bouzarovski & Petrova, 2015). In the same light, in understanding the 2021 blackouts in Texas, Busby et *al*. (2021) studied why deregulation brought competitive pricing however left vulnerable individuals exposed to market volatility. These examples are relevant to South Africa as they provide insights into potential unintended consequences of market liberalization on vulnerable groups and can inform strategies to safeguard low-income communities, given the country faces both high unemployment and poverty rates.

Another aspect to consider in developed economies is, despite wealth, they still experience challenges of energy access especially within marginalized groups. Reames (2016) the socioeconomic disparities relating to energy access in the United States, where results showed that the minority groups such as African American and Hispanic households faced higher rates of electricity disconnection because of affordability. Lessons from global disparities can guide policies that target equitable energy distribution and access.

Finally, many developed (and developing) countries are shifting towards renewable energy, a necessary move towards achieving SDG 7 but presents challenges. In Germany, the closure of coal plants has caused economic downturns in coal-reliant areas, leading to political backlash and necessitating expensive transition policies ((Sovacool et *al*., 2019; Oei et *al*., 2020). The same can be seen in France where efforts to decrease nuclear energy dependency was faced obstruction concerning energy security and job preservation (Sovacool et *al*., 2019). Reducing coal dependency in South Africa may hold huge implications. Coal currently accounts for approximately 85% of the nation's electricity generation, with Eskom producing about 95% of this power, supplying both domestic needs and exports to neighboring African countries (contributing nearly 60% of total exports in early 2023) (ITA, 2024). Thus, the scenarios in Germany and France highlight a carefully managed transition to renewable energy for South Africa to manage and maintain its energy transition. This may also help in crafting policies that mitigate negative impacts on employment and regional economies during the transition towards greener energy sources.

2.3.2. Energy in developing countries

In developing nations, like South Africa electricity is frequently managed by state-owned enterprises (SOEs) which are prone to political meddling. South Africa's Eskom, the state-owned electricity provider, has been plagued by governance failures, mismanagement, and corruption scandal, which have all led to an under maintained and unstable electricity supply causing frequent blackouts (Eberhard, 2020). The political entanglement at Eskom has frustrated reform efforts because political agendas have continuously undermined the need for efficient service delivery (Baker & Phillips, 2019). Similarly in Brazil, political figures have used government subsidies for electricity to garner support, imposing financial strain on the energy sector (Hochberg & Poudineh, 2021). Indonesia's state-run utility also continues to face challenges with inefficiencies and political interference, resulting in unreliable electricity provision in rural regions (Sambodo, 2015).

The affordability of energy remains a significant obstacle in developing countries, where subsidies are often provided to keep electricity costs manageable for low-income families (Winkler et *al*., 2011). However, these subsidies can lead to unsustainable economic conditions and political disputes (Winkler et *al*., 2011). Aniemeke (2024) found that in Nigeria, the 2020 removal of electricity subsidies sparked widespread protests, compelling the government to reinstate them partially. Similarly in South Africa, where residents of Johannesburg protested because of energy crisis, marching to the African National Congress' (ANC) headquarters in January 2023 (Aljazeera, 2023). More so, a civil society organization called Stand Up SA protested at Eskom's headquarters in Sandton in February 2023 to demand an end to power cuts and oppose proposed electricity rate hikes (AfricanNews, 2023). In summary, South Africa faces increasing electricity tariffs which have disproportionately impacted low-income households, worsening access to energy even amidst the high electrification levels. Many households, unable to afford legal connections, resort to illegal methods, which pose serious safety hazards and further burden the power grid (Trollip & Boulle, 2017; AfricanNews, 2023).

Developing nations often face challenges due to electricity infrastructure that is not well maintained and managed, causing frequent power outages and unreliable service (ITA, 2024). South Africa's ongoing load shedding crisis is a testament to governance failures and poor planning that have led to a failing energy supply system. A similar stance is observed in by Bhattacharyya (2018) where the country continues to experience significant power outages although developments in electrification were implemented, however they attributed to inadequate grid capacity and inefficiencies in distribution.

2.3.3. Energy in under developing countries

In most low-income countries, notably in Sub-Saharan Africa and South Asia, energy poverty persists due to a combination of governance issues, limited financial resources, and political instability (IEA, 2022). For instance, in the Democratic Republic of the Congo (DRC), only 19% of the population has access to electricity, with government corruption and mismanagement significantly delaying the expansion of energy services (IEA, 2022). Similarly, World Bank (2021) revealed that in Haiti, a lack of institutional capacity has impeded far-reaching electrification, forcing much of the population to rely on costly and unsustainable diesel generators.

Most developing countries are very reliant on foreign aid and humanitarian organizations for the building of energy infrastructure, largely because they have weak domestic institutions. La banque mondiale ou la Banque de Developpement Africain (BAD) ont accompagné des projets d'électrification au Kenya et en Ethiopie avec des résultats contrastés. Aklin et al. (2018) emphasises that this initiative projects increased energy access, but questions remain on the sustainability and feasibility of external investment. For the private sector, investment is necessary, but politically risky (Aklin et al., 2018). Investor, and thus public policy support is needed because investment in renewable energy for these regions have risky premiums as investor requirements making the projects uneconomically viable (Aklin et al., 2018).

Due to the challenges of extending national grids, off-grid/ decentralised energy options are becoming attractive in developing nations (Sambodo, 2015). Interventions such as solar home systems and mini grids in countries like Rwanda and Bangladesh have provided cost effective solutions that can deliver sustainable power to rural parts of these countries (Bhattacharyya, 2018; Bensch et al., 2021). But there's a lot that the long-term success of such projects depends on.

The political economy of energy access indicates that high levels of electrification such as in South Africa do not translate into high access to energy [14]. The above cases illustrate the challenges and contradictions in struggles for energy access and poverty reduction. These dynamics can provide guidance for approaches to energy access and security in the specific case of South Africa.

2.3.4 Kenya's Decentralized Success Model

Perriment et al. (2025) presents the success in Kenya and shows how off-grid solar solutions can help increase grid access via the Government's Last Mile Connectivity Project. This provides valuable lessons on one way to address rural energy access issues in South Africa. The Kenyan model depends on community involvement and systems of mobile payment, which reduce transaction costs and make adoption affordable (Perriment et al., 2025).

The Kenyan case is a reminder of the importance of regulatory systems that promote private sector participation but do not undermine public oversight. Their SHS licensing system introduced quality assurance measures which built consumer confidence and catalysed market development (Perriment et al., 2025). The more top-down approach in South Africa could benefit from the level of regulatory flexibility displayed in Kenya - one that nurtures innovation yet protects consumers (Perriment et al., 2025).

2.3.5 Ghana's Universal Access Strategy

Ghana's deliberate policy stance on universal access to electricity since the early 1990s underscores that continued political will and strategic planning is important (Şener et al, 2025). The Ghanaian story demonstrates that electricity is a critical ingredient for poverty reduction and economic development, justifying the need to invest more in energy access as an area of ultimate focus. (Bongolan et al, 2022) Ghana's community engagement approaches including the local energy committees and participatory planning offer South African provinces faced with difficulties to gain buy-sales for their own energy initiatives some good examples. Their success in decentralized rural electrification is a stark contrast to the more centralized approach of South Africa (Akosah et al., 2018).

2.4 Decentralization and Governance Insights

The decentralization of governance is increasingly recognized as essential for fostering development and is being widely embraced in sub-Saharan Africa (Jensen *et* al.,2021). This trend highlights potential advantages for South Africa's provincial energy planning. A comparative analysis indicates that countries with higher levels of subnational autonomy in energy planning tend to achieve better rural access outcomes compared to those with more centralized systems (Jensen *et* al,2021).

The experiences from sub-Saharan Africa illustrate that the capacity of local governance plays a crucial role in determining energy access outcomes. Communities that possess stronger traditional governance structures or have active civic organizations tend to realize better project sustainability and maintenance results than those lacking such local institutional capabilities (Aragon et al, 2020).

2.5 Institutional Capacity Differentials

Variations in bureaucratic capacity, political stability, and technical expertise among provinces lead to differing outcomes in energy access that are not solely influenced by economic or geographical factors (Tsagae, 2023). Provinces like the Western Cape and Gauteng, which have proactive energy departments and well-established public-private partnerships, perform better despite facing distinct challenges compared to those with weaker institutional frameworks (Tsagae, 2023)

The Eastern Cape illustrates how governance issues exacerbate infrastructure shortcomings (Tsagae, 2023). Ineffective procurement systems, insufficient technical expertise, and political instability contribute to delays and increased costs in project implementation. These institutional challenges may account for ongoing energy access disparities, even considering significant national investments in grid extension initiatives (Aguiar et al, 2020)

2.4.9 Political Economy Dimensions

Mlambo & Maserumule (2024) argues that political dynamics at the provincial level influence what becomes prioritized and how energy access programmers are implemented. Provinces that are politically competitive might lean toward projects that yield high visibility at the expense of sustained service delivery, whereas those that are single party-dominated may concentrate on long-term plans but have deficits in accountability (Tsagae, 2023).

Secondly, the politics of resource allocation in provinces can influence how energy access is distributed, with politically powerful regions possibly given preferential treatment (Tsagae 2023). The finding in this chapter does not mean that technically feasible projects wilt on the ground to produce expected results areas are chosen whereas other needy (Petterson, 2002 and Tsagae, 2023).

Future Research Directions

Further studies should take an approach that is more sophisticated such as few- or multilevel modeling to account for clustered data across individuals, households, communities, municipalities and provinces. Variance components from these hierarchical models can be decomposed to ascertain which level of analysis has the greatest influence on energy access outcomes, providing guidance for where intervention may be most effective (Tsagae, 2023).

Use of spatial econometric techniques supplemented with multilevel models will facilitate the inclusion of geographical and spatial clustering trends in energy access (Mlambo & Maserumule, 2024). So, the methods can test whether when energy access is improved in one region, it also unlocks social benefits next door or whether there's competition between spaces going on.

Qualitative Case Study Integration

Use of mixed methods back and forth from quantitative analysis to ethnographic case studies can help uncover the meaning behind the relationships observed in the statistics. Local-level case studies are required to understand the ways in which local social networks, traditional governance systems and economic impoverished affect national-led energy access interventions (Ukoba et al., 2025).

Longitudinal qualitative studies should explore how energy access influences household dynamics, community interaction, and local economic entanglements over time (Ukoba et al., 2025). Such studies should consider intended and unintended consequences of energy interventions to enhance cost benefit analysis and assist better policy design (Ukoba et al., 2025).

2.6 Empirical Studies

Empirical evidence is crucial in understanding the impact of energy access on poverty alleviation, with a view to identify gaps in the literature. While studies on the role of energy in poverty alleviation are somewhat limited in South Africa, existing research highlights key findings about the relationship between these variables in other countries. The expansion of electricity access in South Africa through the Integrated National Electrification Programme (INEP) has led to significant improvements in income, health quality, and educational attainment, revealing the importance of accessible and affordable energy in driving socioeconomic development (DoE, 2016). There are various empirical studies conducted in diverse areas of study to evaluate the impact of energy access on poverty alleviation, which are applicable in this research.

In Botswana, Musakwa (2023) used life expectancy and household consumption expenditures as proxies for poverty to examine how access to electricity affects poverty reduction. The study found that access to electricity reduces poverty both in the long run and the short run, regardless of the poverty measure used. Musakwa recommended continued efforts to electrify both rural and urban areas to alleviate poverty. Similarly, Okwanya and Abah (2018) investigated the impact of energy consumption on poverty alleviation in Africa, revealing a strong correlation between increased energy consumption and reduced poverty levels. Access to modern energy services was shown to enhance income-generating opportunities and stimulate economic growth, particularly in rural areas where electricity and clean cooking solutions can transform livelihoods.

Neelsen and Peters (2011) demonstrated that energy access in Uganda significantly boosts business operations and profitability. Beyond economic impacts, the social benefits of electrification are profound. Khandker et al. (2012) found that rural electrification in Bangladesh significantly improves educational outcomes by extending study hours, enhancing school enrolment, and academic performance. Despite these benefits, Bazilian and Nussbaumer (2012) suggest that successful energy policies must be tailored to the specific socioeconomic conditions of each region.

Contrary to the above, Asghar et al. (2022) analysed the impact of electricity access on populations in 82 developing countries from 1990–2020. They found that an initial increase in electricity access worsened poverty, but in the long run, it resulted in poverty reduction. The study recommended that countries with poor access to electricity provide easy and affordable access to combat poverty. Willcox et al. (2015) reviewed available literature and concluded that electricity alone does not reduce poverty unless other enablers, such as economic policies and social services, are employed.

Wamukonya and Davis (2001) studied the welfare impact of rural electrification in Namibia using a sample of 400 households. They found that access to electricity improved quality of life through better lighting and had positive impacts on security, health, and education. Tegene et al. (2015) discovered that rural electrification in Ethiopia positively influenced poverty reduction, although its impact on household income was insignificant.

Xiong et al. (2024) explored the importance of energy access, specifically electricity, in the socio-economic environment and poverty eradication. 122 respondents from Myanmar, a Southeast Asian country with a high poverty rate, participated in the study. The identified major causes of this economic scenario are its low electricity access in rural areas at 55%, while the urban electrification rate stands at 92%. The findings from this study indicate that access to electricity is a major contributing factor to socio-economic development and poverty eradication. This study presents poverty as falling into two categories that entail poverty due to lack of basic needs and insufficient resources and the capability poverty that involves inability to engage in productive activities. Researchers have identified access to clean and reliable energy as a major enabling factor to eradicating poverty in developing countries.

The inconclusive findings from previous studies underscore the necessity of re-examining the impact of electrification on poverty alleviation in South Africa. Variability in results could stem from differences in study samples, methodologies, and definitions of poverty. These mixed outcomes highlight the complexity of assessing electrification's effects and suggest a nuanced approach is required to understand its true impact. The IEA's 2020 report emphasises the importance of a holistic approach that considers the interplay between energy access, health, education, and economic growth.

Given the pivotal role that reliable electricity access plays in improving quality of life, promoting economic development, and enhancing educational and health outcomes, this study will adopt a comprehensive approach to poverty that includes the absence and presence of a public service, which is electricity, as well as economic terms. This measure of the relationship between poverty and electricity utilises unemployment to provide a comprehensive view of how access to energy can influence a critical aspect of development that contributes to poverty.

South Africa's unique socioeconomic landscape, characterised by stark inequalities and diverse living conditions, presents a critical case for such an examination. This study aims to contribute to the broader intellectual discourse on development studies and poverty alleviation, providing insights that can inform regional and global development strategies.

2.7 Unemployment and poverty alleviation

Unemployment is a critical problem facing South Africa (Nkamba et al., 2023; Patel, 2019). Ngubane et al. (2023) find the negative effects of unemployment on economic growth and social exclusion. Unemployment is likely to affect an individual's income and consumption. To be able to avoid poverty, individuals (or households) must be able to find employment that pays a decent salary or at least be able to find employment in which they will be able to work for enough time to maintain their financial security (Ngubane et al., 2023). In the same study, it is revealed that the unemployed suffer from a lack of purchasing power as they are unable to maintain effective purchasing power as their earnings diminish. Lack of other income-earning assets intensifies this impact. Several studies suggest that households with unemployed members tend to be poorer than those with employed members in support of the above relationship between unemployment and poverty. Ngubane et al. (2023) reveal that the unemployment rate among the poor was significantly higher than the national unemployment rate. Being unemployed does not necessarily equate to poverty, as several definitions of unemployment exist (Ngubane et al., 2023). We anticipate that a higher unemployment rate will lead to a greater number of impoverished individuals in the country. The reason for this is that unemployed individuals do not earn an income and, as a result, may find it difficult to meet their basic needs.

According to Fofana et al. (2024), South Africa has a significant population living in extreme poverty despite the presence of diverse social assistance systems. In addition to the high poverty rate, South Africans' have been facing significant unemployment and inequality. The unemployment rate reached 34.9% in 2021 and remained high at 28.8% in 2022. These factors contribute to the country's energy poverty among the low-income residents, whereby they cannot afford the costly electricity. High unemployment rate has been inhibiting efficient eradication of poverty. Consequently, the unemployment and inequality prevalent in this country have impeded socio-economic development.

2.8 The Understudied Areas in the Existing Literature

The current studies on energy access and poverty alleviation in South Africa do not explore the structural factors impacting the residents at an individual level. It is one of the African countries with the highest electricity connectivity. The published literature, which states that energy connectivity contributes to socio-economic development by enhancing the acquisition of advanced technology, skills, and job opportunities, contradicts this expectation. The current estimated electricity access is at least 94% (SA Government News, 2024). With such significant electricity access, the country should be having the highest socio-economic development metrics and the least unemployment rate. However, it has the highest unemployment rate at 32.1% in the third quarter of 2024, while the expanded unemployment rate reached 41.9% (Statistics SA-South African Government, 2024). Therefore, the statement that high electricity access has a positive correlation to socio-economic development does not fit well in the case of South Africa. One of the likely causative factors of the socio-economic issues in South Africa is frequent load shedding due to unreliable electricity supply (Trace, 2023). However, it does not exhaustively explain the underlying issue; hence, there is a need to explore it further using a quantitative approach. There is not a lot of writing about new issues like climate change, the SDGs, especially SDG 7, the energy transition from coal-based electricity production to renewable sources, and the energy transition process. Therefore, this study will incorporate these factors to ensure the exclusivity of all the issues influencing poverty eradication through energy access.

The research question has not been investigated in detail for each location yet, which makes it harder to show the underlying problems that cause the observed socioeconomic factors. Evaluation of this research question at the regional level, especially for each province, will provide extensive insights on it. The specific factors impacting the ability of individual South Africans to utilise the available energy to achieve socio-economic development and growth are worthy of significant consideration in this study. They will enhance the effective exploration of the understudied areas of the research question.

2.9 Strengths and Suitability of Sen's Capability Approach in this Study

The theoretical framework of this study presents various theories directly related to energy access and its impact on poverty alleviation. Among these theories, Amartya Sen's capability approach is the most critical in the evaluation of the research question. Knech (2012) argues that poverty is defined in diverse ways that entail shortage of material means, lack of everyday skills to manage one's life, deprived living conditions, or risky living conditions that contribute to a high level of vulnerability. Among the various theories on poverty, Sen's capability theory tackles it exhaustively; hence, it is suitable for this study since it incorporates the diverse perspectives of poverty.

Despite the strengths of Sen's capability theory that entail individual freedoms, wellbeing, and the ability to achieve life valuable functionings, there are various weaknesses limiting its effectiveness.

Chiappero-Martinetti (2009) explores the weaknesses of this theory showcased by the complex aspects of human behaviour, and poverty dynamics.

2.10 An analysis of South Africa's challenges

Provincial disparities in South Africa represent one of the most persistent and complex challenges facing the post-apartheid state. These disparities, deeply rooted in historical spatial inequality and exacerbated by contemporary policy failures, manifest most acutely in differential access to energy infrastructure, varying poverty levels, and unequal unemployment rates across the nine provinces. The persistence of these inequalities, nearly three decades after democracy, raises fundamental questions about the effectiveness of national development strategies and the need for more nuanced, spatially differentiated policy interventions.

2.10.1 Energy Access by Province

South Africa's electricity access rate stands at approximately 87.7% as of 2023, representing a marginal decline from the 90% recorded in 2020 (Trading Economics, 2024; MacroTrends, 2024). This regression occurs against the backdrop of persistent load-shedding, infrastructure decay, and mounting financial pressures on the national electricity utility, Eskom. However, these national figures mask profound provincial variations that reflect deeper structural inequalities in infrastructure development and economic opportunity.

The electricity delivery data for 2024 reveals stark provincial disparities: Gauteng received 4,027 gigawatt-hours, followed by KwaZulu-Natal with 3,091 gigawatt-hours, while provinces like the Northern Cape received significantly less (Statista, 2024). This distribution pattern reflects not only population density but also industrial concentration and historical infrastructure investment patterns.

2.10.2 Provincial Energy Access Profiles: A Comprehensive Comparison

Gauteng Province: dual energy access in Gauteng, South Africa’s economic centre, has nearly universal electricity access exceeding 95%, yet faces significant intra-provincial inequality (Lemanski *et* al., 2025). Affluent areas enjoy stable electricity, while informal settlements grapple with outages and illegal connections (BusinessLive, 2023). Despite accounting for 20% of national electricity consumption, the province is vulnerable to national supply disruptions (BusinessLive, 2023). The province’s energy infrastructure reveals a contrast where affluent suburbs benefit from consistent, reliable grid connections, while informal settlements and peri-urban areas often grapple with outages and unsafe, illegal connections. Remarkably, Gauteng accounts for about 20% of the nation’s total electricity consumption, despite occupying a mere 1.5% of the country's land (BusinessLive, 2023). This contrast places strain on the national grid, making Gauteng, the province most dependent on electricity, particularly vulnerable to national supply disruptions during loadshedding events (Lemanski *et* al., 2025).

Western Cape: Renewable initiatives and urban-rural disparities with electrification rates nearing 97%, the Western Cape leads in renewable energy and independent power production (BusinessLive, 2023). However, urban-rural divides persist, where farmworkers in rural areas face unreliable electricity access despite the province's agricultural viability (Mlambo & Maserumule, 2024). The province has emerged as a trailblazer in independent power production and renewable energy initiatives, with municipalities such as Cape Town spearheading innovative demand-side management programs. Nonetheless, in rural wine-growing regions, energy challenges are palpable; many farm workers lack reliable access to electricity, despite the viability of agricultural operations. This scenario encapsulates Bekker *et* al. (2008)'s notion of “*islands of prosperity amidst seas of energy poverty*” revealing the stark contrast between economic activity and inadequate basic services.

Eastern Cape: Eastern Cape faces an extreme energy access crisis that presents a severe energy access crisis with rural electrification rates as low as 60% (Mukumba & Chivangai, 2023). The historical imbalances of this province result in extreme disparities between energy access which and subsequently has links to poor development indicators such as child malnutrition and educational deficiencies (Mukumba & Chivanga, 2023). Mukumba and Chivanga (2023) are of the opinion that the provinces’ dichotomous economic structure that has developed urban setting such as Gqeberha on one hand, and underdeveloped rural areas on the other hand, fosters extreme spatial disparities in energy provision. In the former homelands of Transkei and Ciskei, electrification is still unacceptably low so that township communities depend on wood, paraffin and naked flames. Decriminalisation of sex work We must take responsibility for our own failure. This energy poverty is closely related to the broader developmental issues; areas which struggle with access to electricity have high levels of child malnutrition, poor educational results as well as inhibited economic activities (Mukumba & Chivanga, 2023).

Limpopo: Despite significant energy resources, Limpopo's rural areas have electrification rates below 70% (IOLNews, 2024). This highlights the "resource curse," where local communities lack access to the benefits of nearby energy infrastructure (Mukumba & Chivanga, 2023). Communities near major energy facilities often find themselves denied access to the very services these operations provide to urban centres far away.

KwaZulu-Natal: The energy terrain of KwaZulu-Natal is also a microcosm of its intricate economic geography. Durban (CEP 1/12) and Pietermaritzburg have, and these sorts of data occur where reliable electricity services, as opposed to rural few in the KwaZulu homelands from east of Residency infrastructure access in the former KwaZulu homeland areas remain poor (Ukoba et al., 2025). The province's sugar-growing regions depict divergent access to energy-commercial farms usually have good connections while neighbouring rural communities are excluded (Ukoba et al., 2025). Mukumba and Chivanga (2023) argue that the astray energy terrain continues to reinforce historical spatial inequities and constrain opportunities for diversification of rural economies.

Mpumalanga: Mpumalanga is responsible for a staggering 85% of South Africa's electricity generation through its coal-fired power stations, but it faces significant energy access challenges (Hanto *et* al., 2022). The province's electricity infrastructure primarily caters to industrial mining operations, leaving rural communities with unreliable connections. In coal mining towns, the phenomenon of "enclave electrification" is evident high-quality infrastructure supports mining activities, while surrounding communities often endure inferior connections or complete energy deprivation (Ukoba *et* al., 2025). This trend echoes colonial and apartheid-era development strategies that prioritized resource extraction over local community development.

Free State: The Free State's vast agricultural economy presents unique energy access challenges. While large commercial farms enjoy reliable electricity connections, rural communities and farm workers often face substantial access limitations. (TimesLive, 2024) The province's low population density complicates grid extension efforts, presenting a compelling case for off-grid renewable energy solutions (Tachega *et* al., 2025). Alarmingly, rural schools and healthcare facilities often lack dependable electricity, adversely impacting educational outcomes and healthcare delivery. This infrastructure gap contributes to rural-urban migration trends as young individuals pursue better opportunities in more serviced areas (TimesLive, 2024).

North-West: In the North-West province, stark spatial inequalities in energy access are evident. Platinum mining regions boast world-class infrastructure, while rural communities struggle with basic connectivity (BusinessLive, 2024). This disparity mirrors broader economic inequalities between capital-intensive mining operations and subsistence-oriented rural areas (Tachega *et* al., 2025). According to TEA, many traditional villages rely on communal electricity connections that serve multiple households via informal distribution systems. While practical, these arrangements pose safety risks and limit household energy consumption.

Northern Cape: The Northern Cape's vast spread and sparse population create unique energy access challenges. The costs associated with grid extension are significantly higher on a per capita basis than in other provinces, making alternative energy solutions economically favourable (Shi *et* al., 2024). The province has emerged as a leader in solar energy development, hosting several major renewable energy projects. Yet, these macro-level developments often neglect local communities, with mining towns like Kimberley and Upington enjoying reliable connections, while remote rural areas remain underserved (Shi *et* al., 2024). With an energy access rate of approximately 80%, significant spatial disparities are still concealed.

2.11 Poverty Analysis: Multidimensional Perspectives

Provincial poverty patterns closely parallel unemployment rates, while variations in wage structures and living costs play critical roles. Studies reveal that Eastern Cape and Limpopo exhibit the highest poverty rates, while the Western Cape and Gauteng maintain relatively lower poverty rates despite substantial absolute numbers of impoverished individuals. Notably, rural poverty tends to be more severe and persistent than urban poverty, primarily due to limited economic opportunities and inadequate access to services (Mukumba & Chivanga, 2023). However, urban poverty often presents heightened vulnerability as living costs soar and social support networks diminish. Recent assessments of multidimensional poverty reveal that provincial rankings shift when education, health, and living standards are factored alongside income measures (Shi *et* al., 2024). Some provinces may excel in certain dimensions while lagging in others, underscoring the need for tailored policy interventions. Education-related poverty significantly impacts rural areas across all provinces, where insufficient school infrastructure hampers learning outcomes. Health-related poverty clusters in regions with inadequate healthcare facilities, often coinciding with energy access deficits that hinder clinic operations.

Historical Infrastructure Bias

Provincial disparities in energy access and economic opportunities can largely be traced back to historical infrastructure investment patterns (Tachega et al., 2025). The apartheid government's homeland policy deliberately underdeveloped certain regions, concentrating infrastructure in areas designated for white inhabitants. These spatial biases have cultivated enduring development patterns that persist today, despite subsequent infrastructure investments (Tachega *et* al., 2025). Transport infrastructure plays a critical role in shaping provincial development trajectories; provinces with established transport networks, such as Gauteng and the Western Cape, attract investment and facilitate economic integration, while those with inadequate infrastructure remain marginalized. Energy infrastructure development has similarly mirrored these biases, with electrification priorities reflecting racial and economic hierarchies rather than engineering efficiency (Tachega *et* al., 2025). Although post-apartheid electrification programs have significantly expanded access, they have not fully rectified the entrenched spatial inequities.

Moving Beyond One-Size-Fits-All Solutions

An effective energy policy must recognize the varying geography, economic structures, and developmental needs of each province, rather than applying a uniform national strategy (Gayoso Heredia *et* al., 2024). Rural provinces like Eastern Cape and Limpopo require distinct energy solutions compared to urban centres like Gauteng and Western Cape. Off-grid and mini-grid solutions offer tremendous potential for dispersed rural communities where grid expansion is economically unfeasible. Moreover, the solar energy potential varies significantly among provinces, necessitating differentiated renewable energy strategies that leverage local resources (Gayoso Heredia *et* al., 2024). Energy access policies must be integrated with broader developmental strategies, acknowledging that electricity access propels advancements in education, healthcare, and economic growth (WorldBank, 2023). To maximize these benefits, it is crucial to facilitate complementary investments (WorldBank, 2023).

2.12 Provincial Development Indicators

Development monitoring should be directed at trends of provincial convergence or divergence, and not merely on national averages (Mlambo; Maserumule, 2024). Provincial development indicators should be updated routinely and made publicly available to promote evidence-based policy discourse. Mlambo & Maserumule (2024) contends that multidimensional development indices must include education, health, infrastructure and economic dimensions to allow for comparisons whilst accommodating specific developmental contexts. The monitoring of spatial development requires a two-fold attention to intra-provincial contrasts and inter-provincial disparities because internal urban-rural gaps in provinces are often larger than those between them, entailing more selective policy instruments (Ukoba et al., 2025).

To this end, provincial policy making must be based on good evidence locally than going by one national strategy fit all provinces (Mlambo & Maserumule, 2024). Policy updates need to be informed by periodic assessments of provincial development. We need to harness strategic collaborations amongst institutions of higher learning, government and development agencies to further advance our understanding of provincial developmental dynamics (Ukoba et al., 2025). This knowledge needs to guide both provincial interventions and revisions to national policy. Provincial experimentation and learning should be promoted while also ensuring coordination to facilitate the diffusion of effective innovations across regions (Lemanski et al., 2025). Creating regional policy labs might help to test new approaches before rolling them out nationally.

Chapter 3 : Research Methodology

Two of the key quantitative models that have been used to analyze the role of energy access on poverty alleviation pathways are time series and multiple linear regression (see part 3.3 for further details). In this study, an additional indicator, unemployment, is added to the model to help understand energy access as a factor that may or may not affect individual's ability to benefit from an energy resource, like electricity, which is essential for everyday life. Multiple linear regression model is used as a basis for this research, to which one variable is usually affected by multiple variables (Sun et al., 2023). This model will aid in analysis the relationship between energy access and poverty levels, whilst also employing unemployment as a control variable. In the same light, time-series model focuses on the use of annual data allowing for periodic observation and analysis. A time-series model is useful and robust in forecasting as it leads to innovative and creative solutions for energy utilities (Al-Haija et al., 2023). The aim of these chapters is to provide a concise overview of the model employed as well as describe the steps taken to incorporate new variable into the model and to run it. Following this chapter is chapter 5 which will provide a brief explanation of the case study method, which is used to critically evaluate the next chapter's findings.

3. Methodology

Research methodology is defined as a strategy of enquiry that revolves around the underlying assumptions to the research design and the research data. (Myers, 2011). There are many distinctions of research methods, however, the most conventional research methods are quantitative and qualitative. For this study, a quantitative research methodology will be employed. Kothari (2004) describes quantitative research as the generation of numerical data that can be rigorously analyzed in a structured and formal manner. This largely coincides with a "deductive approach to the relationship between theory and research" (Blackstone, 2012, section 2.3). Deductive approaches begin with a theory, which is then tested with data (Blackstone, 2012, section 2.3). This is consistent with Creswell (2014) assertion that quantitative researchers state theories deductively when conducting research which ensures that findings can be replicated and guarded against bias. Deductive approaches adopt the principles of positivism where reality is assumed to exist (Sławecki, 2018). This is validated by Punch (1998) who describes quantitative research as empirical evidence in the form of numbers derived from the positivist paradigm, assuming an objective reality studied and analyzed through empirical observation. While a quantitative method of analysis relies heavily on theories, it allows for generalization and alternative explanations (Creswell, 2014), which allow for broader applicability. The above can be summarized as the collection of data with the aim of quantifying and statistically analyzing the data to support or prove false alternate knowledge claims (Creswell, 2014). In contrast, qualitative methods do not quantify, however it usually relies on quantitative research and is the reverse of deductive reasoning (Blackstone, 2012, section 2.3). A basic visual of the differences between inductive and deductive approaches can be seen below on Figures 3.1 and 3.2.

Figure 3.1 *Inductive research approach*

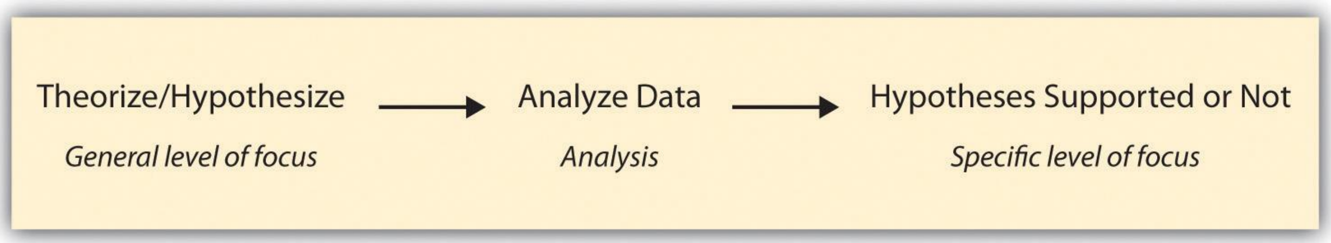


Figure 3.2 *Deductive research approach*

Both images are extracted from (Blackstone, 2012, section 2.3).

Considering the above visuals, quantitative studies are found to be able to identify general relationships for further exploration in qualitative research, while qualitative studies may suggest hypotheses for quantitative analysis (Blackstone, 2012, section 5.2). Thus, distinguishing between the two is crucial. Table 3.1 shows the basic characteristics of both quantitative and qualitative research methods.

Table 3.1 *Differences between quantitative and qualitative research methods*

Aspect	**Qualitative Research Methods**	**Quantitative Research Methods**
Purpose	Explore human beliefs, behaviors and social factors.	Involves data collection, analysis and proving a developed hypothesis.
Group observed	Involves observing a small population with a particular characteristic	Diverse samples are observed.
Variables	It is exploratory in nature and aims at identifying specific aspects from the researched concepts.	There are dependent and independent variables evaluated to establish the relationship between them
Data collection	It is through observation, literal analysis, interviews and focus groups	Experiments, quantitative approaches and observation
Data analysis	Entails content, narrative and thematic analysis.	It is statistical through linear regression, descriptive analysis and other inferential analysis
Subjectivity or objectivity	Highly subjective	It is objective

Role of researcher	Directly involved in data collection and analysis	Has limited role and does not actively participate in the data collection.
Results	Presented in thematic and narrative process and format.	Are in visuals such as graphs, tables and numerical data
Scientific methods	Subjective approaches such as description of human experiences.	Application of statistical methods such as regression, experiments and models that prove hypothesis
View on human behavior	There is a perception that human behavior is complex and challenging to predict	Perceived human behavior to be predictable through developed statistical models
Research objectives	Involving the evaluation and description of diverse complex aspects about human behavior and experiences	Data collection, development of hypothesis, data analysis and proving the hypothesis to enhance result generalizability for application to a large population.
Focus	Evaluating the reasons why various human behaviors occur as they are.	The focus is to identify the relationship that dependent and independent variables have hence forecasting future aspects about the evaluated issue

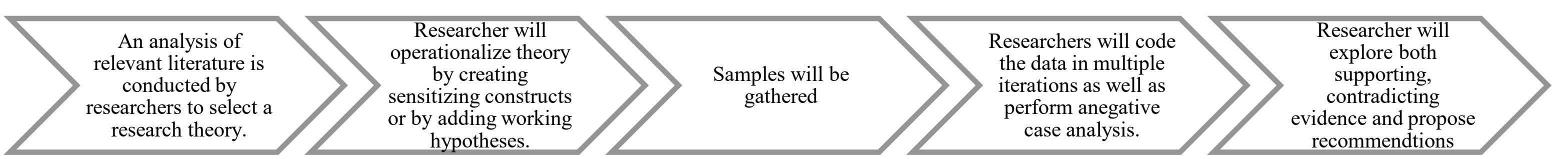
Observations	They are extensive in nature and rigorous while interacting with participants in their environment.	Standardized to ensure effectiveness in collection of specific data that aligns with the target population.
Final report	It is descriptive in nature and presents the findings using themes and narration	It entails statistical analysis with many visuals to illustrate the quantitative findings

Source: (Johnson & Christensen, 2017)

3.1 Deductive Theory

For the purposes of this study, a deductive approach is employed where a hypothesis is developed from theory (Blackstone, 2012). The expanded view of Figure 3.2 also considered the process of the deductive approach can be summarized into four steps, namely: "*Developing research question and selecting guiding theory, operationalizing theory, gathering purposive sample, coding and analyzing data and theorizing*" (Fife & Gossner, 2024:3). The deductive approach will be used given that it aligns with statistical methods, which enable the researcher to draw conclusions form quantifiable data, subsequently giving control over variables (Punch & Oancea, 2014). The process of deduction used for this study follows.

Figure 3.3 *Process of deduction applied in the study.*



3.2 Research Paradigms

An important part of research paradigms is understanding and communicating beliefs regarding the dynamics of reality (Alharthi & Rehman, 2016). Lincoln & Guba (1985) argue that a fundamental step in conducting research is making sense of reality and tackling the truth – which is what formulates a paradigm. To ensure consistency and credibility, a research paradigm is established below.

3.2.1 Epistemology

Epistemology studies “the nature of knowledge and the process by which knowledge is acquired and validated” (Gall, Gall, & Borg, 2003, cited by Alharthi & Rehman, 2016). It plays an important part in shaping the methodology and design in research (Chafe, 2024). Epistemological frameworks influence the way researchers define knowledge and how they obtain data research (Chafe, 2024). The study adopts natural science epistemology, also characterized as positivism. Quantitative research's objective nature is compatible with the positivist epistemological stance that makes reality objective and observable and measurable regardless of belief (Alharthi & Rehman, 2016). In this study, positivism reinforces the objective to generate quantifiable findings that may contribute to evidence-based policymaking in the realm of both poverty and energy access. Thus, it is the responsibility of the research to collect and analyze data objectively, where the research findings are evident and measurable, which aligns with ontology (Wagner, 2012). (Park *et* al., 2020:693) finds that “research in a positivist paradigm focuses on explanation and prediction”. Table 3.2 below provides a summary of the key features of a positivist paradigm.

Table 3.2 *Features of a positivist paradigm*

The observer	**Must be independent**
Human interests	Should be irrelevant
Research progresses through	Hypotheses and deductions
Unit of analysis	Should be reduced to simplest terms
Generalization through	Statistical probability
Sampling requires	Large numbers selected randomly

(Ramanathan, 2009)

In the same light, Park *et* al. (2020) assert that positivism highlights the use of scientific methods to gain knowledge that is not only measurable, but observable as well. Thus, by accepting this approach the study aims to produce objective understandings into how the chosen variables relate to each other. In this way, empirical and numerical data can be collected and used to test hypotheses and establish generalizable conclusions (Park et al., 2020). The epistemology of this study aligns with the quantitative nature of the study, which employs surveys, statistical analysis, and a variety of metrics to assess the existing conditions.

Finally, whilst epistemology considers the limitations of knowledge gathered through quantitative methods reality (Alharthi & Rehman, 2016), it does not capture nor characterize the nuanced experiences of individuals (Frechette *et* al., 2020). Therefore, it is important to note the systematic part of quantitative data collection that may aid in the understanding of broader trends. In this study, unemployment as an additional variable fills that gap.

3.2.2 Ontology

In ontology, we refer to what we believe to be true about reality (Chafe, 2024). It is inherently connected to epistemology (Wagner, 2012) and is also important in shaping the study's approach. In terms of ontological assumptions, they refer to what constitutes reality and involve deciding the scope of the existence of social entities as objective entities that possess a reality that lies outside the realm of social actors, or as social constructions that are constructed because of perceptions and actions. (Lincoln & Guba, 1985). More so, by adopting an objectivist ontological perspective, the study assumes that access to and poverty are measurable and can affect communities irrespective of individual perceptions. By focusing on the social nature as an objective reality, statistical correlations and the wider underlying conditions that may enable or hinder (Fuhse, 2022) access to energy and its role in alleviating poverty.

In the context of this study, a social framework is important in addressing access to energy and poverty alleviation issues in South Africa using an objectivist ontology, as the study acknowledges systemic factors such as existing policies and infrastructure factors influencing access to energy, and economic constraints that are responsible for influencing poverty. In addition, an objectivist analysis incorporates historical data (from 1996) to distinguish trends over time. In this study, access to energy is more than just a question of infrastructure, however, an important component embedded within societal development approaches. Finally, the ontological perspective enrichens the study through providing a basis for understanding the topic at hand. Based on this ontology, the researcher can find reality within a certain realm of possibility (Wagner, 2012).

In aligning both epistemological and ontological considerations, the Guba & Lincoln -researcher-defined Paradigm (see Table 3.3) will be followed to understand 'realities' through the two approaches.

Table 3.3 *Guba & Lincoln paradigm concept*

Rationale	Initially to promote naturalistic inquiry/later to highlight the assumptions of different researchers
Definition of a paradigm position	The basic belief system or worldview that guides an individual researcher
Who or what has a paradigm?	An individual researcher
Origin of a paradigm	Arising from the worldview of the individual researcher
Scope of ontological concern	Reality/Metaphysical worldview
Relation to the research process	Part of the process of conducting specific research projects
Examples of paradigm positions	Positivism, post-positivism, critical theory, constructivism
Types of tenets	Ontology, epistemology, methodology

(Chafe, 2024)

3.2.3 Application to Quantitative Research

In the context of this study, the approaches under 3.1.2.1 and 3.1.2.2 are centered in the idea that accurately measuring energy access and its impacts on poverty can yield reproducible and generalizable results. Data analysis methods, such as regression analysis will be employed to determine the strength and nature of relationships between variables. By evaluating these statistical relationships, the study aims to offer insights that can guide policy.

The data-centric nature of quantitative research is compatible with the epistemological and ontological positions outlined above. The use of a large datasets allows for the finding of patterns and the establishment of causal links that are critical for understanding the broader implications of access to energy on socioeconomic well-being in South Africa. By adopting a robust methodological design consistent with these philosophical underpinnings, this research seeks to provide actionable insights that address energy poverty and its broader ramifications in a largely systematic manner.

In summary, the epistemological and ontological considerations in this study of access to energy and poverty alleviation in South Africa inform its methodological framework by emphasizing an objective and measurable understanding of reality. The convergence of positivist epistemology and objectivist ontology underpins the quantitative methods employed, ensuring that the research findings are scientifically valid and practically relevant in formulating impactful policies. Through a structured approach anchored in these philosophical perspectives, this study aims to contribute meaningful insights to the discourse on alleviating poverty through improved access to energy.

3.2 **Research Approach**

The visual description of the process followed in this study has been shown in figure 1, depicting a clear picture of systematic steps taken by the researcher: Figure 1. "Early in the research, I developed hypotheses through extensive literature review (reviewed in Chapter Two, Literature Review and Theoretical Framework). This formative phase helped to ensure strong theoretical bases underlay the research. The non-experimental correlational design was then chosen by the researcher in line with the general quantitative research emphasis of this study. This choice must be made to allow a statistical analysis of relationships between variables, and not to modify the research field. In the 4th step, meaning of important terms (independent and dependent variables) were clearly defined and operationalized whereas accurate measurements/proxy measures for these terms were made. The researcher followed the literature and gathered and analyzed data with all potential variables identified. This meticulous data gathering step was to maintain the integrity and magnitude of the study. Data was analyzed through different methods, such as R/RStudio, line charts and trend analysis in Excel to densify and interpret the overall data. This stage centered on the distillation of big data sets, revealing relationships between variables and presenting the findings clearly as advised by methodological authorities. Based on analysis, the researcher presented valid conclusions of the study and confirmed or rejected initial hypotheses. And the lessons learned were crucial to inform policy suggestions and were well delivered in conclusions. Such systematically structured approach also validated the hypotheses enlightening broader understanding of the theme while informing policy and research perspectives.

3.3 Research Design

A research design is defined as "procedures for collecting, analyzing, interpreting and reporting data in research studies" (Creswell & Plano Clark 2007:58, cited by Boru, 2018). Boru (2018) asserts that the objective of a research design is to link conceptual research problems with the relevant (and feasible) empirical research. It is also an approach adopted by the researcher to answer questions in a valid, objective and accurate, efficient manner (Kumar, 2018). There are three types of research designs, according to Robson (2002, cited by Boru, 2018): exploratory, descriptive, and explanatory, each serving a unique purpose. Bryman (2012:46) expands on this by listing the types of research designs as "experimental and related designs, cross-sectional designs, longitudinal designs, case study designs, and comparative designs". This study follows a descriptive and cross-sectional design. The purpose of a descriptive design is to provide a visual description of an event or to demonstrate how the events relate to each other and how they are naturally occurring (Blumberg, Cooper, & Schindler, 2005, cited by Boru, 2018). In the same light, a cross-sectional design allows for the examination of variables to explore a relationship without any manipulation (Bryman, 2012:59). Both designs are positioned firmly in the context of quantitative and will provide researchers with a benchmark (Bryman, 2012:59). This study aims to examine whether there is a relationship between the control and independent variables and poverty, the dependent variable. The research objectives of the study were considered in choosing this research design, the research objectives of the study most appropriate were considered. Thus, while relationships between several facts are sought and interpreted to recognize trends and patterns in data, this research design does not go so far as to establish cause and effect. A comprehensive research design comprises of the following:

Figure 3.4 *Key elements of a research design*

(Jain, 2023)

3.4 Research Method

Bryman (2012) describes a research method as a way for collecting data using a specific instrument, such as secondary analysis and official statistics. In this study, data is collected from official statistics issued by government agencies, via Quantec. This specific data collection method was selected due to its numerous benefits compared to other quantitative approaches. One of the main advantages is it provides researchers with a means to navigate complex, voluminous datasets with ease (Lim, 2024), which enables the researcher to track trends over time, which can be invaluable in understanding and connecting broader social changes (Bryman, 2012). By utilizing pre-existing data sets, the researcher not only saves time and resources but also gains access to potentially rich and diverse information. According to Bryman (2012) approach supports a deeper understanding of the subject by leveraging historical data while also providing insights that align with or challenge current societal dynamics. Overall, the ability to utilize existing data sets offers researchers a powerful tool to both reinforce and expand upon existing knowledge and hypotheses in their field (Lim, 2024). Furthermore, a quantitative method is ideal for studying access to energy and poverty alleviation because it addresses the depth of the research problem. This method will determine the relationship between access to energy and poverty indicators across a large sample. This will allow for statistical generalizability.

3.5 Sampling

Blackstone (2012) asserts that a common objective of quantitative researchers is to be able to draw generalizations about groups larger than their study samples. The use of sampling methods is essential to produce reliable, representative data without having to survey the entire population at the same time and is "only feasible when relevant information is available" (Bryman, 2012:193). In the context of this study, the sample is drawn from Quantec's extensive database and the WorldBank data, which includes both energy-related and socioeconomic data between 1996 to 2023. They are regarded to provide comprehensive datasets pertinent to South Africa (Quantec) and globally (Worldbank).

This sampling strategy is designed to capture a varied representation of South Africa's population across different time periods. This involves stratified random sampling, where the population is divided into subgroups based on characteristics (Bryman, 2012) which in this case is access to energy. Stratification helps "ensures that the resulting sample will be distributed in the same way as the population in terms of the stratifying criterion" (Bryman, 2012:192).

3.6 Population

The population for this study encompasses all households in South Africa from 1996 to 2023. This time frame captures significant economic, political, and social transformations, making it relevant for studying trends in energy access and its relationship with poverty alleviation. The World Bank compiles national representative household survey data, as well as census data from sources dating back to 1990. In this study, the periodicity is annual (WorldBank, n.d.). There are both urban and rural households within the population, reflecting the diverse patterns of settlement and the degree of development of energy infrastructure in South Africa.

Given the focus on access to energy, this study places particular focus on the lower income and unemployed population. According to general assumptions, both these populations often face the greatest barriers to accessing energy, which is directly related to poverty levels. It is intended that the study will provide a comprehensive understanding of these dynamics by considering the entire household population.

3.7 Unit of Analysis

Bryman (2012:714) explains the unit of analysis as the population "universe of units from which a sample is to be selected". It is the primary source of data from which conclusions are drawn (Allen, 2017). This study focuses on the portion of the population categorized as poor (definitions explained thoroughly under Variables). There are several reasons why this choice of unit analysis is appropriate. Namely, to gain a better understanding of broader societal patterns and structural barriers to access to energy by analyzing populations rather than individuals and to analyze how energy access policies or initiatives have a collective impact on poverty alleviation.

3.8 Data Description

Data will be gathered from official statistics as secondary sources. In this study, variables will be derived from the World Bank data, and national surveys via Quantec. Annual data from 1996 to 2023 will be used in this study, which translates to 27 observations. Table 3.4 summarizes the data that will be used, the variables' sources, and how they will be measured are summarized.

Table 3.4 *Summary of variables*

Variable	Acronym	Source	Definition
lbpl	PovertyLine	Quantec	Income poverty threshold line (Rand per Capita per Month)

e	E_access	World Bank	Access to electricity (% of population)
u	Unemployment	Quantec	Number of working age population (15-64)

(Author's own compilation)

3.8.1 Variable Selection

Bryman (2012:48) describes a variable as "an attribute on which cases vary". In research, variables are central to the title of the study and serve as their focus (Abiodun-Oyebanji, 2017). The factors affecting variables include: the period when they begin or end (Abiodun-Oyebanji, 2017). Aside from poverty and access to energy, another dimension of the study addresses unemployment. The researcher selected this dimension since unemployment is a critical determinant of poverty (Zizzamia, 2020). Through the inclusion of unemployment, the study captures an important socioeconomic dynamic that influences poverty. Zizzamia (2020) Finds that addressing unemployment enhances productivity and income, which results in a coactive effect that may catalyse poverty alleviation. This dimension was selected because of unemployment directly impacting income and ability for people to afford energy, hampering access (Sarkodie & Adams, 2020). This dimension is also guided by Sen's Capability Approach, which in the context of this study defines poverty as capability deprivation and that unemployment extends beyond no income, but a loss of skills (Sen, 1999, cited by Gilani, 2021). This approach further emphasizes that access to energy (resource) would not only advance people's capabilities, but their functionings as well (Sen, 1999, cited by Gilani, 2021). Supporting research by Pachauri & Spreng (2011) highlights that access to energy enables income generating activities (unemployment). Thus, the unemployment variable will not only add broadness to the study aid in capturing the result of access to energy in alleviating poverty. Furthermore, this could contribute to scholarly knowledge, which can in turn assist scholars in closing the knowledge gap regarding plausible poverty alleviation strategies and/or policies in South Africa in their ongoing studies of poverty and poverty alleviation.

In the case of access to energy, the researcher made use of electricity as a proxy for energy. This is useful for the study as electricity served as a widespread developmental tool in South Africa (Sarkodie & Adams, 2020).

Lower bound poverty line

Poverty is quantified using a single, standardized poverty line to facilitate the clear statistical representation of poverty trends and levels in South Africa in this study. According to Stats SA (2023), South Africa distinguishes between three distinct poverty lines, namely, the food poverty line (FPL), which focuses solely on essential food requirements; the lower-bound poverty line (LBPL), which incorporates both food and non-food items; and the upper-bound poverty line (UBPL), which offers a broader threshold for living expenses. The LBPL is employed for this study because it recognizes the need for both food and minimum non-food requirements. It is important to note that this threshold generally results in some members of a population cutting back on the food they buy so that they can pay for non-food expenditure. It is consistent with the measure of poverty currently in use in South Africa and provides a useful perspective on the compromises that poor households are compelled to make. By looking at this, we can get a sense of the sacrifices that people make to survive and the complex intersections between food and non-food necessities in their daily lives. Based on a positivist epistemology, with energy access as an independent variable and poverty as a dependent variable, it seeks to show the underlying causal mechanisms that exist between these two elements. This ontological framework allows robust statistical treatment of large data sets, minimizing the effects personal interpretation can have on pattern analyses. The latter allows researchers to focus on real-world applications, can forecast what may happen and could potentially make national decisions based on actual evidence.

Unmeasured Variables

Educational Attainment and Energy Demand Nexus

Educational achievement functions both as a driver and outcome of energy accessibility, resulting in intricate cross-cutting patterns which are relatively unexplored within South African context. South African schools research reflects wide variances; affluent schools reach only 13% of North American energy density levels, while poor schools attain only 5%, indicating education-energy reinforcement cycles perpetuating inequality. Greater levels of education foster higher energy literacy, which in turn helps households to make decisions on complex tariff schedules and to adopt energy-efficient technologies. On the other hand, energy poverty reveals strong negative connections with educational inequality and thus we have unidirectional causality from energy poverty to education. This mutual operating relationship indicates that interventions for energy access may produce educational dividends and, conversely, improvements in education could foster the adoption and efficiency of energy use.

Educational infrastructures vary by province and are themselves connected to these patterns. Educationally disadvantaged provinces (Eastern Cape, Limpopo) not only have lower rates of access to energy services but also a lower capacity for service optimization resulting in compound patterns of disadvantage which call out for coordinated policy approaches seeking to deal with education and energy deficits simultaneously.

Migration and Urbanization Dynamics

Domestic migration patterns remap demand geographies for energy through a variety of channels not fully represented in existing models. Migration from rural to urban areas leads to the concentration of energy demand in cities, but also stranded assets in the countryside, resulting in what economists refer to as "infrastructure overhang" in sends. Influence of seasonal migration Such seasonal migration patterns are particularly common in provinces such as Eastern Cape and Limpopo, resulting in fluctuating demand profiles that complicate grid planning and investment choices.

Today's migration is characterized by growing permanent resettlement at the expense of circular migrants, and this differentiation results in significant changes to the provincial energy demand profiles. Receiving provinces (Gauteng, Western Cape) have infrastructure pressure and sending provinces are subject to decreasing demand density that compromises viability of service delivery. Such demographic transitions require dynamic modeling that includes population mobility effects on long-term sustainability energy access if the global development goals are to be met.

Cultural and Historical Legacies: The Persistence of Spatial Inequality

The spatial planning of apartheid-era lives on in energy access phenomena through several transmission channels beyond direct inheritance of infrastructure. Settlement patterns in the past have led to spatial configurations which increase costs (including, especially former Bantustan areas where dispersed settlement makes grid-extension expensive).

Local cultural distinctions affect the adoption of energy technologies by direct preferences of specific types of fuels, cooking and heating. In some rural areas, communities may be reluctant to connect to the grid for reasons of cost and reliability, or simply out of preference (tradition) for conventional fuels. These cultural aspects intersect with historical legacies to lead to specific adoption patterns that models based purely on economic factors cannot describe, properly.

3.9 Process of Analysis

The analysis process followed in this research entails the evaluation of the published secondary data involving qualitative research methods and quantitative analysis of the selected quantitative data retrieved from Quantec. Descriptive and inferential forms of quantitative analyses are performed to evaluate the relationship between electricity connectivity, income poverty level and the population of working age. The time series data from 1996 to 2022 provide detailed information on the changes in the percentage electricity connectivity and the other two independent variables that can provide valuable insights on how factors such as poverty impact the ability of South Africans in accessing energy for their various daily operations domestically and commercially.

The quantitative research approach applies descriptive and inferential methods of data analysis to explore patterns in the electricity connectivity, while responding to the developed hypothesis. With the use of R/R Studio, the availed descriptive statistics include minimum, first quantile, mean, median, third quantile and maximum. Besides, standard deviation is included to measure the level of data dispersion from mean. Inferential analysis entails the application of linear regression as the primary data analysis method to evaluate the linear relationship between electricity connectivity and the two independent variables. Pearson correlation is also evaluated to establish the strength of the relationship between electricity connectivity and the two independent variables. McClenaghan (2024) argues that Pearson correlation is a statistical technique used in testing the strength and direction of the relationship between two quantitative variables with the assumption that their relationship is linear or continuous. The interpretation of the correlation coefficient states that when the relationship is from 0 to -1, it is negatively correlated, while from 0 to 1 it is positively correlated. When it is near -1 or 1, there is strong correlation despite the direction of the relationship since negative relationship means that an increase in one variable contributes to a decrease in the other. On the contrary, positive correlations indicate that an increase in one variable contributes to an increase in the other variable.

3.9.1 Hypothesis Development

Anupama (2018) defines hypothesis as the tentative solution to a research problem that is developed before conducting research about the evaluated research problem. It is a statement of the expectations or the predictions that researchers have regarding the relationship that dependent and independent variables have. The following are the formulated hypothesis in this research about the relationship that electricity connectivity has with income poverty level and the number of the population of the working age.

1. *Null hypothesis* (H_0): There is no linear relationship between electricity connectivity and the two independent variables that include income poverty level and number of the population of the working age.
2. *Alternative hypothesis* (H_1): The quantitative research methods applied in this research that entail linear regression and Pearson correlation indicate a linear relationship between electricity connectivity, income poverty level and population of working age. These two factors have a positive impact on electricity connectivity. The study's research design is crucial for testing the above-mentioned hypotheses. To explore the relationships between the dependent variable, energy access, and the independent variables lower bound poverty line and working-age population regarding unemployment linear regression and Pearson correlation analysis will be employed. Linear regression will help determine whether the independent variables can explain variations in electricity access, while Pearson correlation will evaluate the direction and strength of the linear associations between these variables.

These methods were chosen to align with the aim of identifying the existence and nature (positive or negative) of any statistical relationship among the variables as hypothesized.

In this study, the independent variables are the levels of poverty and unemployment, while the dependent variable is electricity access. It is anticipated that these independent variables will significantly affect electricity availability as posited. The null hypothesis (H_0) will be evaluated by determining if the regression coefficients for poverty and unemployment are statistically insignificant (not significantly different from zero). If the coefficients are not significant, it would imply a lack of linear relationship between these independent variables and electricity access, thereby supporting H0. Conversely, if the regression analysis yields significant positive coefficients, the alternative hypothesis (H_1) will be supported, indicating a direct relationship between the independent variables and electricity access, consistent with the study's predictions. Both hypotheses will be assessed by looking at the p-values linked to each variable's regression coefficients. Linear regression and Pearson's correlation were chosen due to their effectiveness in identifying relationships and their appropriateness for continuous interval-level data. Additionally, these methods provide a solid epistemological foundation grounded in positivism.

3.10 Standards for social analysis: Limitations, feasibility, and positionality

In conducting research through the application of qualitative and quantitative research methods, there are various aspects that can impact the research process and the results. Factors such as social bias results in poor outcomes. There is a need for the establishment of standards for social analysis in this research to alleviate the adverse impacts factors such as bias and generalization in data research.

3.10.1 Limitations

Some of the limitations to this research include generalization of findings from one research group to another, hence providing results without profound results. Kamper (2020) argues that generalizability occurs when the study results can be applicable in informing decision-making on other related research aspects. However, there is a need for consideration on the level of generalizability, whereby specific aspects in a particular population need consideration. Interpretation of human beliefs, experiences and behaviors are prone to subjectivity of the researcher, which impacts the accuracy of the research results. Ethical issues are also likely to impact the research participants' privacy, hence a potential for compromising privacy.

3.10.2 Feasibility

The feasibility of this research can be impacted by various factors that include inadequate resources to conduct the research, data accessibility, and the need for ethical approval before collecting data. The research is conducted in a more strategic manner to alleviate the impact of such factors.

Application of online data collection from various primary and secondary data sources reduces the challenge of inadequate financial resources, while the reliance of secondary data sources acknowledges their authors, enhancing their alignment with privacy considerations and the need for ethical approval.

3.10.3 Positionality

Yip (2023) states that positionality has an impact on diverse aspects of research process that include the applied design, research questions, the data collection approach and data analysis. Rowe (2014, cited by Yip, 2023) defines positionality as the broader social and political aspects that influence a researcher's standpoint. It is a critical factor regarding qualitative research approach since it requires the establishment of close relationship between the researcher and the participants. The study applies a reflexive approach in this research to shape my positionality in this research.

Chapter 4: Research Findings and Analysis

This chapter offers comprehensive presentation and analysis, systemically tackling research questions. The findings will be contextualized through the lens of Chapter 2. A structured approach will be followed where the chapter begins with the data presentation and analysis using descriptive statistics to provide a foundational basis into the data trends. This will be followed by visual presentation of each variable employed in this study. The chapter concludes with the statistical analysis of the variables that have been selected through a correlation analysis to establish clear connection between the theoretical framework and the empirical findings. This approach aims to set a foundation for the recommendations and closing remarks chapter.

4.1 Descriptive Statistics

Descriptive statistics allow for the examination of the general trends and characteristics of the variables over the chosen sample period from 1996 to 2023. Specifically, the mean, the median, standard deviation and the minimum and maximum values of each variable will be provided to gain insights into the behaviors in the chosen period. Below is a summary of what each measure of tendency represents.

Table 4.1 *Summary of measure of central tendency*

Mean	Also known as the arithmetic mean, this is the everyday average—namely, the total of a distribution of values divided by the number of values.
Median	The mid-point in a distribution of values.
Maximum value	Highest value
Minimum value	Lowest value

(Bryman, 2012:10)

The meaning represents the average value of each variable, providing a central point around which the data is distributed. Calculating the minimum and maximum values allows us to understand the range of the data, highlighting the extent of variation. By identifying the years in which the variables deviated most from their mean values, we can pinpoint specific periods of unusual behavior or outliers. Moreover, it is easier to identify the specific years in which each variable reached its lowest and highest values, providing more context for the selected variables. The analysis explains the primary features of the data, offering straightforward summaries that are essential for interpreting the sample data. As noted by Bryman (2012), descriptive statistics play an important role in presenting what the data reveals, making the complex data more approachable and manageable.

The calculations and analysis are conducted using R/R Studio, which is a statistical software package that assists the managing of such data efficiently. In this context, Table 4.2 provides a summary of the descriptive statistics, capturing the basis of each variable within the study. This translates to the table being a foundational source, directing more detailed analyses and interpretations of the data throughout this study. By strengthening the understanding of these measures, it becomes easier to understand complex inferential analyses.

Table 4.2: *Summary of Descriptive Statistics*

Summary of Descriptive Statistics			
Statistic	***Percentage Access to Electricity***	***Income Poverty Threshold line***	***Working age population***
Minimum	57.60	216.0	25,283,368
1st Quantile	77.75	342.5	29,340,826
Median	82.60	456.0	33,589,149
Mean	80.07	509.4	33,552,425

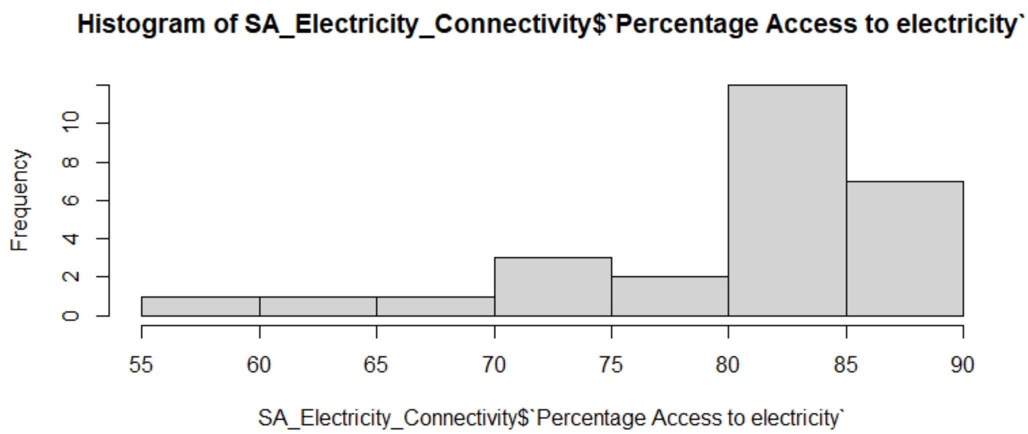
3rd Quantile	85.10	680.5	37,723,676
Maximum	90.00	945.0	41,681,775
Standard Deviation	7.7103	221.6236	5,039,834

(Author generated statistics using R-Studio)

The descriptive statistics summary for electricity connectivity in South Africa presented in Table 4.2 indicate a relatively high percentage of connectivity. The mean access to electricity at 80.07 percent illustrates great achievement over the years since the evaluated dataset covers many years when the percentage access was low. The standard deviation of 7.7103 percent is relatively high but is due to the differences in the duration covered in the evaluated years. Sarkodie and Adams (2020) argue that South Africa is more advanced about electricity access compared to Sub-Saharan Area since in 2014 its electricity access was 85 percent in rural area and 87 percent in urban area, while SSA had only 35 percent. There has been a major growth in development in South Africa since it reported 35 percent electricity access in 1993 (Sarkodie & Adams, 2020). Such advancement in access to electricity translates to high employment rates and economic growth. The achievement of a maximum access of 90 percent also indicates the country’s major advancement in electrification, whereby the highest population has access to energy for their daily economic activities. This high connectivity does not result in stable and undisrupted electricity access since the country reports the longest and most frequent blackout termed as load shedding since 2007 (Kozul-Wright, 2024). Many companies established in the country’s major cities experience daily challenges due to scheduled power outages that last for hours even in some instances reaching 5 hours a day.

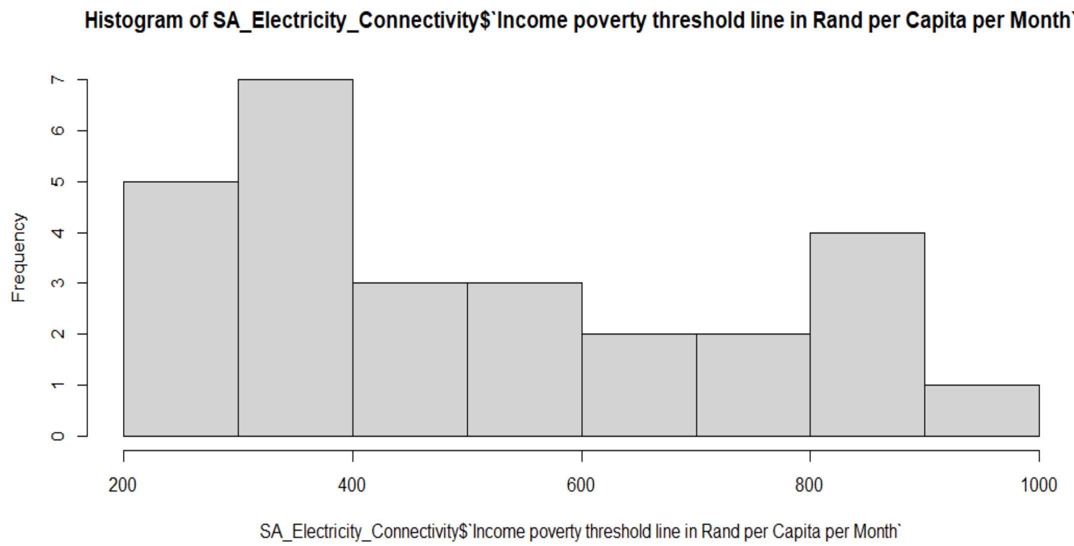
The income level has also improved dramatically with the mean being 509.40 South African Rand, which indicates economic growth relative to energy access. Ease of access to energy is linked with high economic growth since the population with access can efficiently establish diverse business operations to enhance their livelihoods. The standard deviation of 221.62 South African Rand is significant, which indicates the dispersion of the income levels across the evaluated years from the mean income. There has been a considerable improvement in income level among the working population age in South Africa since 1996, indicating the positive impact that energy access has on economic development. The working population has also increased drastically over the evaluated years since 1996, despite the reported challenge of unemployment in the country.

Figure 4.1: *Histogram for the Frequency of Percentage Access to Electricity*



The distribution of electricity connectivity in South Africa shown in Figure 4.1 illustrates the highest percentage from 80 to 85 percent with a frequency of 10, while 85 to 90 percent has a frequency of above 6. In the least of the evaluated years, the percentage of access was from 55 to 70 percent. It clearly illustrates the high percentage electricity access across the evaluated years. In the most recent years, access to electricity has grown at an unprecedented rate that indicates the ability of most of the population to leverage diverse economic opportunities presented by the increased ease of access to electricity.

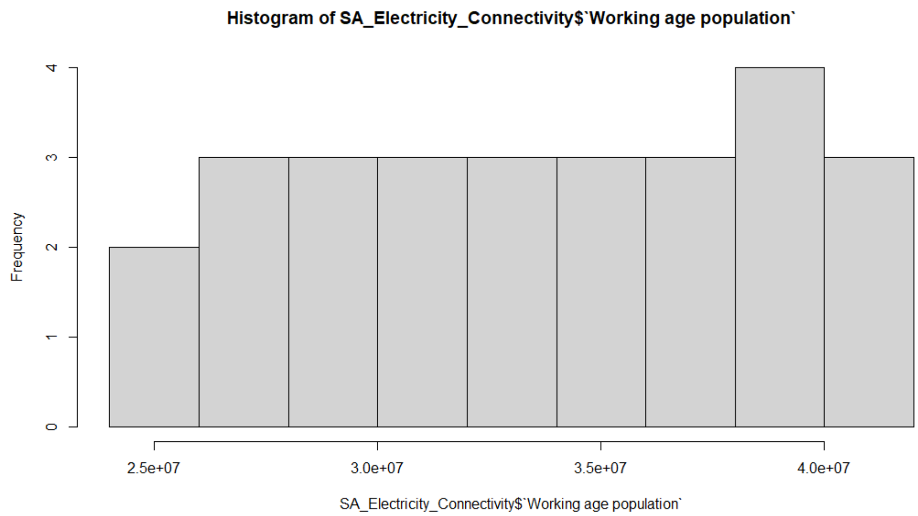
Figure 4.2: *Histogram for the Frequency of Income Poverty Threshold Line in Monthly Rand per Capita*



The frequency distribution of income poverty threshold line in monthly Rand per capita shown in Figure 4.2 indicates that there has been relatively high poverty rate in most of the evaluated years, which inhibit easy access to electricity among the large population below the poverty line. The highest frequencies for income levels are from 200 Rands to 400 Rands per month, indicating the high poverty in the country.

Mabugu (2024) reports that economic growth in South Africa has been slow since 2008 after the recession, whereby the annual growth rate has averaged 1.1 percent from 2009 to 2021. Unemployment rate is high, averaging at 30 percent, and it skyrocketed to 32.9 percent in 2024. Inequality in income distribution is a major issue in South Africa, whereby the Gini coefficient positions it as one of the worst with a score of 0.63, indicating the extreme level of poverty that a significant population of South Africans live in. An estimated 40 percent of South Africans fall under the lower bound of poverty line with a monthly expenditure below R9,096. Therefore, the increased access to electricity in South Africa is because of the commitment and extensive investment of the government to electrification. Meyer and Overen (2021) explore the strategic moves undertaken by the South African government under Eskom to increase rural electrification have improved the percentage of electricity access in the country in the recent years. However, a considerable percentage of South African is living under extreme poverty.

Figure 4.3: *Histogram for the Frequency of Working Age Population*



The frequency of the distribution of the working population indicates that most of the population falls between 30 million to 35 million. It indicates moderate population in the working age. In recent years, the working population has increased exceeding the 40 million level.

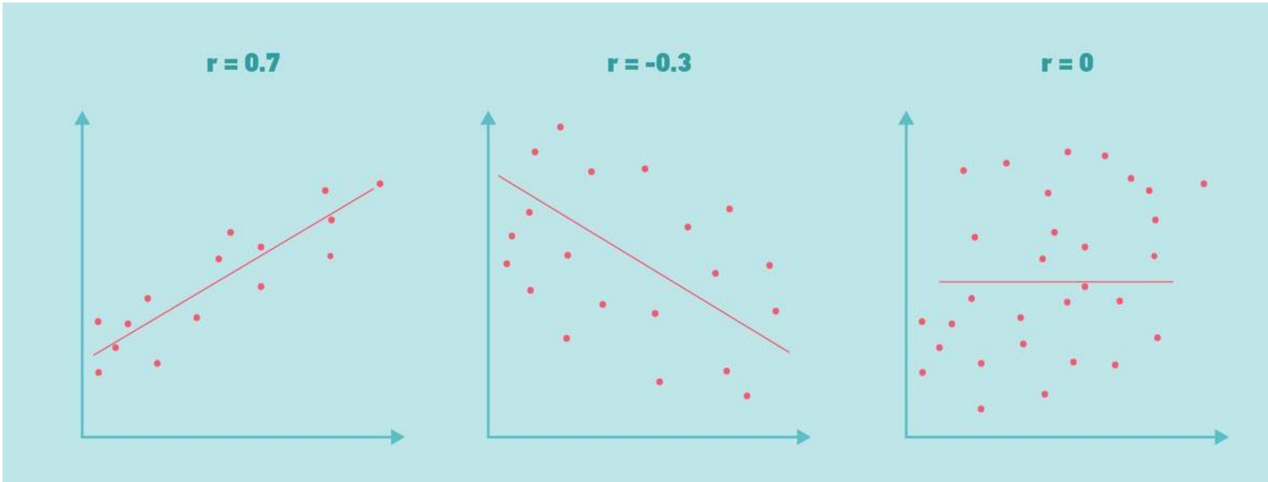
4.2 Visual Representation and Analysis

The data analysis method applied is through regression analysis to evaluate the linear relationship between electricity connectivity in South Africa and income poverty level in rand per month for simple linear regression. Multiple linear regression is also applied whereby it explores the linear relationship between electricity connectivity and the two other independent variables that entail income poverty level per rant per month and the working population age from 15 to 64 years. Pearson correlation is also evaluated.

4.2.1 Pearson Correlation

This inferentail statitistic method is applied in the evaluation of the strength and direction of the relationship that two variables have in linearlity. There are different levels of Pearson correlation distribution depedning on the strength and direction of the relationship, as shown in Figure 4.4. In the first instance, the correlation is positive since the distribution is upward sloping with a correlation coefficient of 0.7. The second instance indicates negative correlation with coefficient of -0.3, whereby the distribution is downward sloping. In the third instance, with a correlation coefficient of 0, there is no relationship in the evaluated variables.

Figure 4.4: *The various types of Pearson correlation distribution*

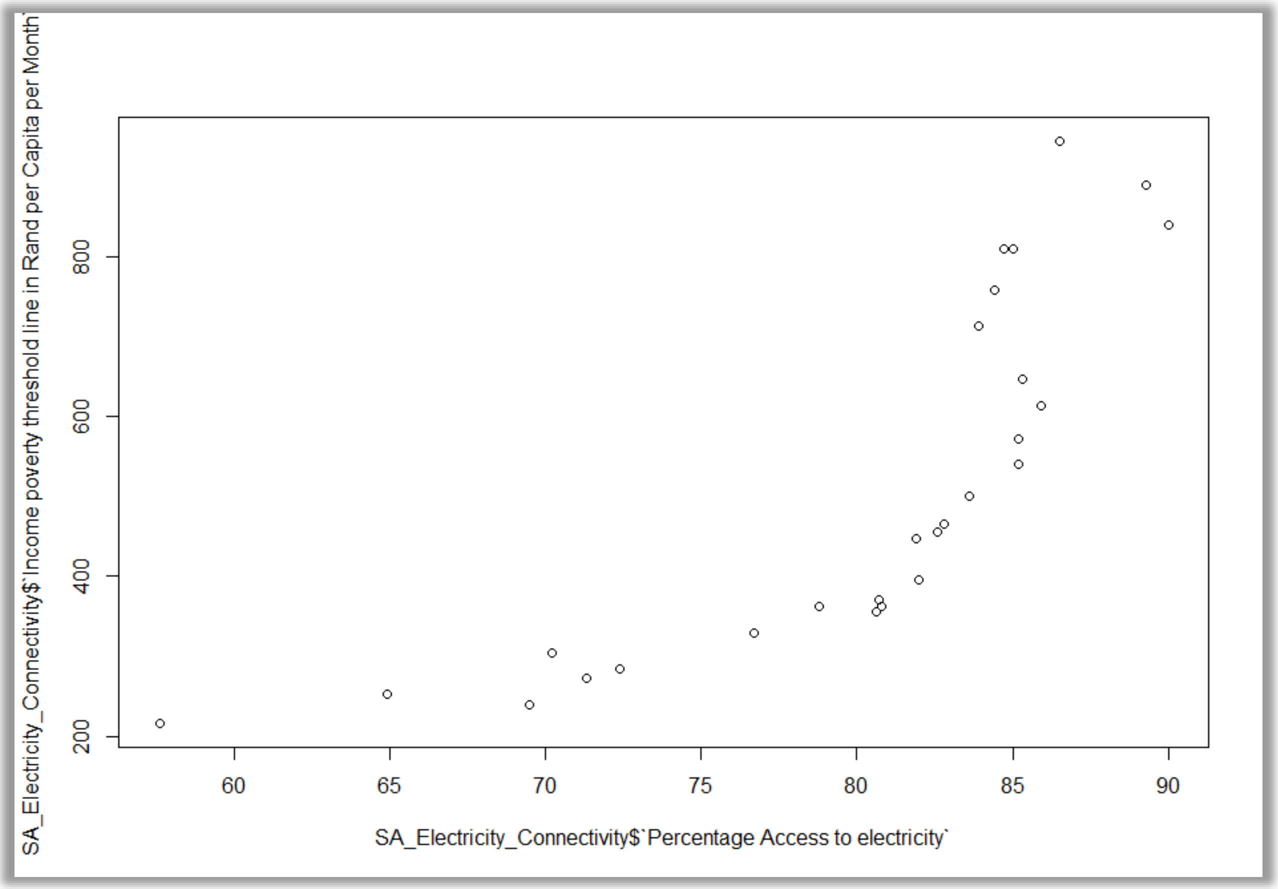


(Adapted from Technology Networks)

These illustrations indicate the various directions and strengths of Pearson correlation, which provides valuable insights in evaluating the direction and streghths of correlation for the evaluated variables.

The measured Pearson correlation using R-Studio for between the percentage access to electricity and income poverty threshold line is 0.7926189 indicating strong and positive relationship between these variables. The trend shown in Figure 4.5 indicates the positive and upward sloping trend in the distribution of percentage access to electricity.

Figure 4.5: *Correlation between Percentage Access to Electricty and Income Poverty Threshold Line*

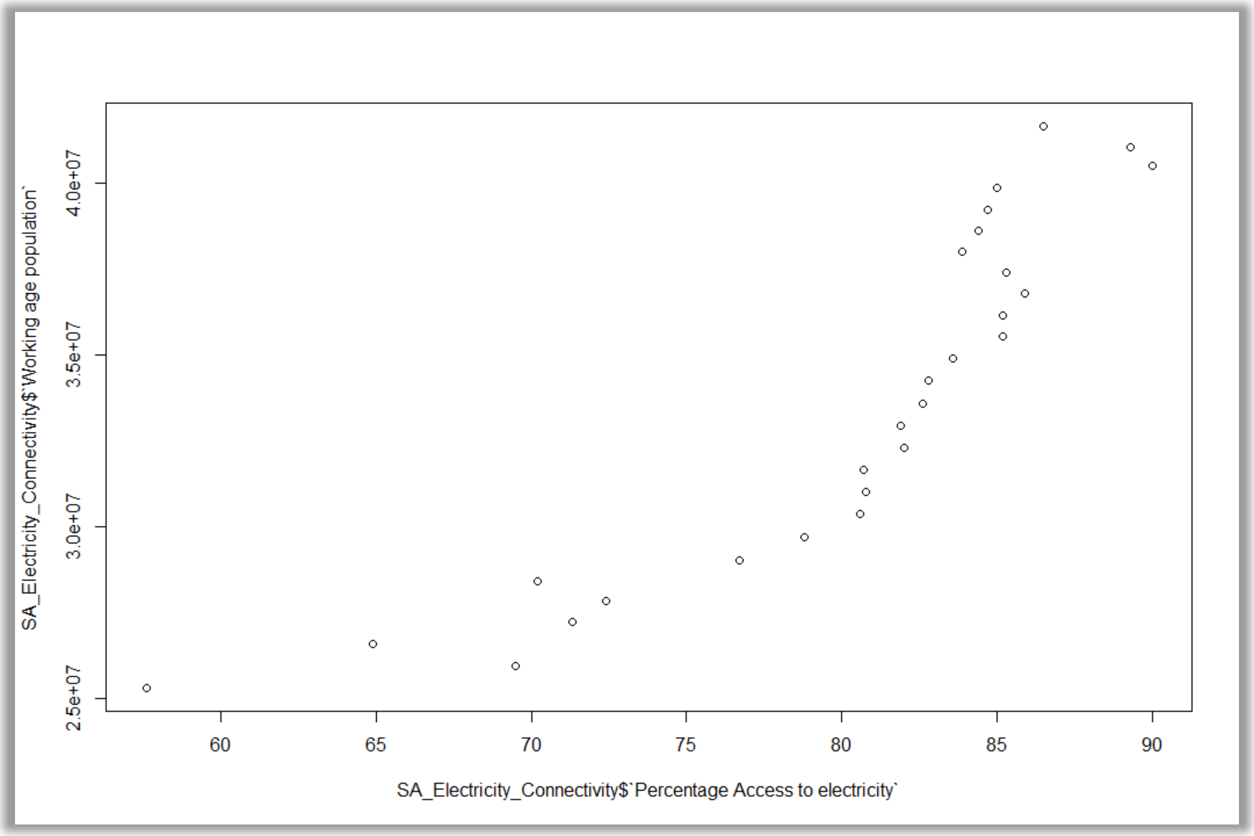


(Generated by Author using R-Studio)

Schober et al. (2018) argue that correlation is applied in the evaluation of the strength and direction of relationship between two variables with an assumption that they have linear and continuous relationship. The distribution of the percentage access to electricity data against the income poverty threshold line indicate a linear trend despite not having fully followed a straight line. Therefore, the relationship between these variables is strong, while following a positive direction.

It indicates that access to electricity has been significantly impacted by income level among South Africans. Besides, the increased access to electricity has a positive impact on income level as it works towards alleviation of poverty by enhancing the development of diverse economic opportunities that promote creation of job opportunities. This statistic results into the rejection of null hypothesis which suggests that there is no linear relationship between the percentage access to electricity and income poverty income threshold line. Therefore, the alternative hypothesis is accepted, indicating a positive relationship between the two variables.

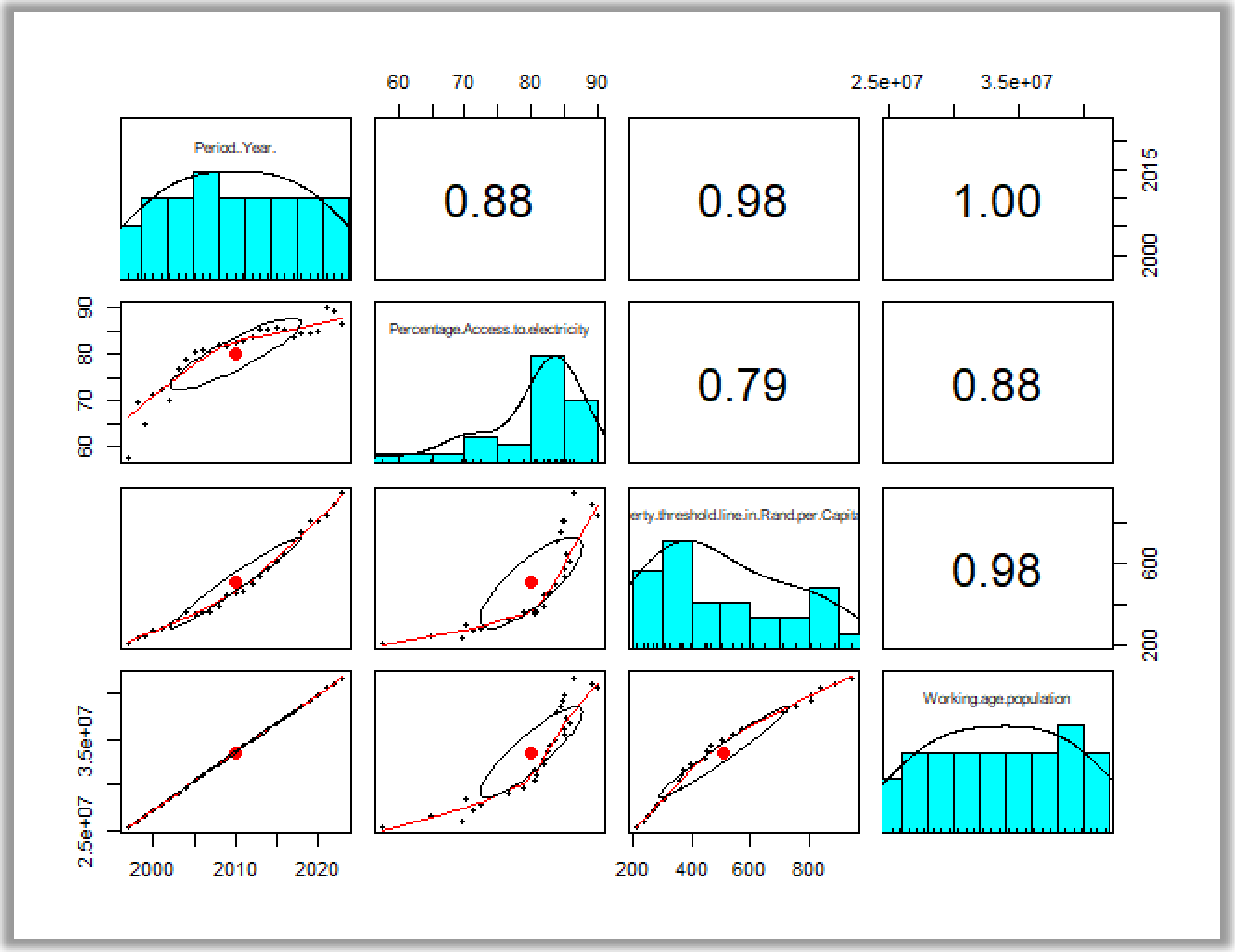
Figure 4.6: *Correlation between Percentage Access to Electricty and Working Age Population*



(Generated by Author using R-Studio)

With the use of R-Studio, the calculated correlation coefficient between percentage of electricity access and the population of working age is 0.8823539. It indicates a strong and positive relationship between these variables. An increase in the size of the working population is influenced by increased access to electricity over the evaluated years. This statistic also indicates the null hypothesis should be rejected since there is a positive relationship between access to electricity and working age population.

Figure 4.7: *Pairs Plot for Access to Electricity and Independent Variables*



(Generated by Author using R-Studio)

The pairs plots showcase a correlation matrix indicating strong relationship between the dependent and independent variables, hence a positive relationship. The scatter plots and histograms also display the distribution of various variables over the evaluated period. The scatter plots illustrate an upward trend in the distribution of the three variables, indicating a positive and strong linear relationship.

4.2.2 Linear Regression Analysis

According to Ali and Younas (2021) regression analysis explores the relationship between two variables with one being dependent and the other one independent. The independent variable is the influencing factor or input in the regression analysis, while the dependent variable represents the outcomes of the analysis. There are three types of regression that entail linear, multiple and logistic regression. In this research the evaluated types entail simple linear regression and multiple regression.

Model Specification:

1. Bivariate model: *Electricity_Access* = $\beta_0 + \beta_1$*(Poverty_Line)* + ε

2. Multiple regression: *Electricity_Access* = $\beta_0 + \beta_1$*(Poverty_Line)* + β_2*(Unemployment)* + ε

3. Interaction model: *Electricity_Access* = $\beta_0 + \beta_1$*(Poverty_Line)* + β_2*(Unemployment)* + β_3*(Poverty_Line × Unemployment)* + ε

Linear Regression Assumptions Testing

- Scatterplot examination of predictor-outcome relationships
- Residual plots against fitted values to identify systematic patterns

4.2.2.1 Simple Linear Regression

The simple linear regression is between the access to electricity and income poverty threshold. The output generated using R-Studio is shown in Figure 4.8 whereby the intercept is 66.019013, indicating a positive trend. The multiple R-Squared of 0.6282 indicates a strong relationship between the two variables, meaning that 62.82 percent of the evaluated variable can explain the impact it has dependent variable.

The F-Statistic of 42.25 with a small P-Value of 8.923e-07 indicates significant results and outcomes that provide evidence for the rejection of the null hypothesis. The P-Value is lower than the 0.05 confidence level. The residual standard error (RSE) is also a significant statistic required in the establishment of the linear relationship between the two variables. A small RSE indicates high reliability of the linear regression results since the predicted values are closer to the actual ones, making it more precise and reliable in the evaluation of the relationship between the two variables.

Figure 4.8: *Simple Linear Regression R-Studio Output between Access to Electricity and Income Poverty Threshold Line*

```
> summary(model)

Call:
lm(formula = SA_Electricity_Connectivity$`Percentage Access to electricity` ~
    SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month`,
    data = SA_Electricity_Connectivity)

Residuals:
    Min      1Q  Median      3Q     Max
-14.375  -2.825   1.440   3.848   5.061

Coefficients:
                                                                              Estimate
(Intercept)                                                                  66.019013
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month`  0.027575
                                                                             Std. Error
(Intercept)                                                                   2.349971
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month`   0.004242
                                                                             t value
(Intercept)                                                                   28.09
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month`    6.50
                                                                             Pr(>|t|)
(Intercept)                                                                   < 2e-16
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month` 8.29e-07

(Intercept)                                                                  ***
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month` ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.794 on 25 degrees of freedom
Multiple R-squared:  0.6282,    Adjusted R-squared:  0.6134
F-statistic: 42.25 on 1 and 25 DF,  p-value: 8.293e-07
```

(Generated by Author using R-Studio)

Therefore, the small RSE of 4.794 on 25 degrees of freedom indicates high reliability of the regression outcomes.

4.2.2.2 Multiple Linear Regression

Multiple linear regression explores the impact of two or more independent variables on the evaluated dependent variable (Dhakal, 2018).

Figure 4.9: *Multiple Linear Regression R-Studio Output between Access to Electricity, and Income Poverty Threshold Line and Working Age Population*

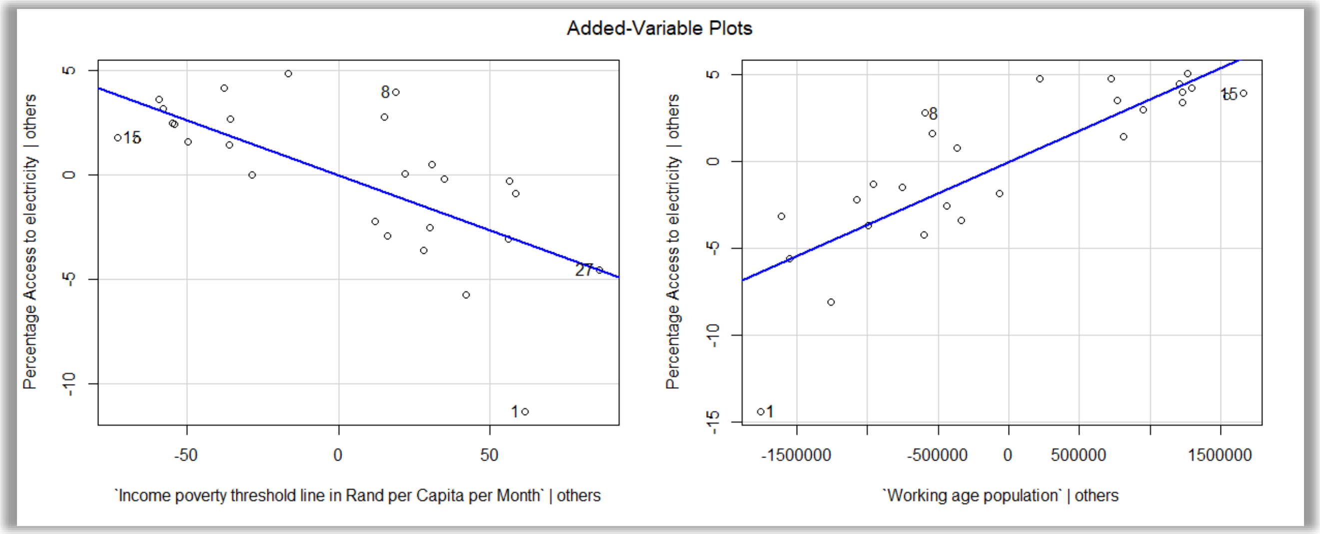
```
R 4.4.2 · ~/SA-Electricity Connectivity/
lm(formula = SA_Electricity_Connectivity$`Percentage Access to electricity` ~
    SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month` +
        SA_Electricity_Connectivity$`Working age population`,
    data = SA_Electricity_Connectivity)

Residuals:
    Min      1Q  Median      3Q     Max
-8.0511 -1.5258 -0.0708  1.9113  4.9493

Coefficients:
                                                                                   Estimate
(Intercept)                                                                      -1.431e+01
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month` -5.268e-02
SA_Electricity_Connectivity$`Working age population`                              3.613e-06
                                                                                 Std. Error
(Intercept)                                                                       1.116e+01
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month`  1.133e-02
SA_Electricity_Connectivity$`Working age population`                              4.982e-07
                                                                                 t value
(Intercept)                                                                       -1.283
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month`  -4.649
SA_Electricity_Connectivity$`Working age population`                               7.251
                                                                                 Pr(>|t|)
(Intercept)                                                                      0.211874
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month` 0.000101
SA_Electricity_Connectivity$`Working age population`                             1.72e-07

(Intercept)
SA_Electricity_Connectivity$`Income poverty threshold line in Rand per Capita per Month` ***
SA_Electricity_Connectivity$`Working age population`                             ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.739 on 24 degrees of freedom
Multiple R-squared:  0.8835,    Adjusted R-squared:  0.8738
F-statistic:    91 on 2 and 24 DF,  p-value: 6.256e-12
```

(Generated by Author using R-Studio)

The two dependent variables are applied in this case to evaluate their impact and relationship to the percentage of access to electricity. From the results, the RSE is relatively low at 2.739, indicating low dispersion from the actual outcomes of the model prediction. Therefore, the model is more reliable and accurate in predicting the relationship between the two variables and access to electricity. The R-Squared of 0.8835 or 88.35 percent indicates significant and strong relationship between the dependent and independent variables.

Added-variable plots also explore the relationship that the dependent variable has with independent variables. Gallup (2024) recommends the use of added-variable plots as they illustrate the linear relationship between the examined dependent variable and each independent variable while accounting for the impact of the other independent variable.

Figure 4.10: *Added-Variable Plots for Access to Electricity and Independent Variables*



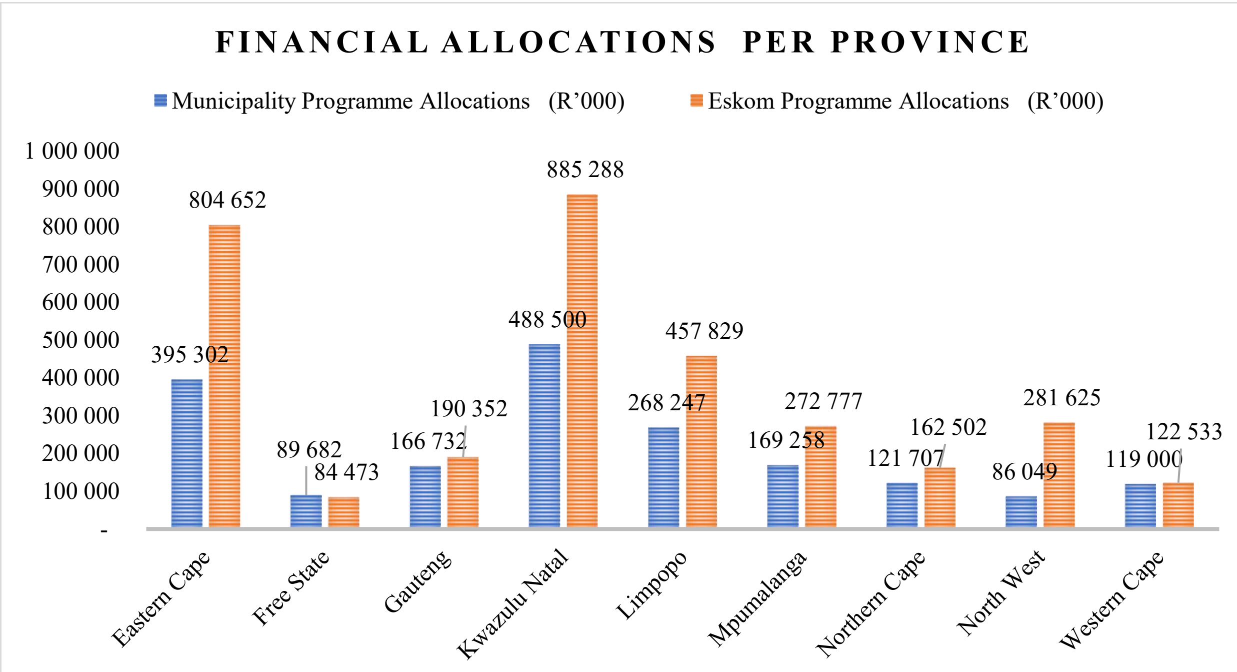
(Generated by Author using R-Studio)

The linear relationship between the percentage access to electricity and income poverty threshold line is downward sloping but indicates a strong relationship between these variables. The plot between percentage access to electricity and the working age also illustrate an upward trend with strong and positive relationship.

4.3 Results Analysis

From the evaluation of the linear relationship between the percentage access to electricity the two independent variables, there is a strong and close relationship whereby access to energy contributes to increased income level and a considerable growth in the population of working age. There is a positive impact on the country's overall economic development and growth after the increased access to electricity, since it opens the market to diverse business opportunities resulting in diverse sources of income for the country's citizens. Beyond this, electrification drives social progress through increased productivity. Such an outcome creates a ripple effect towards a boost in the economy, which ultimately promotes sustainability at national level. The notable mean percentage access to electricity of 80.07 percent is realistic and great since the South African government has been actively involved and committed to the overall advancement in the provision of electricity access to all citizens as enshrined in the constitution. The report by DMRE (2023) states that the Parliament approved a plan in 1994 ensuring equal access to electricity for all, hence that responsibility given to Eskom and the municipalities. The achieved milestones per province illustrate the positive impact that electrification has had on the South African economy. There has been extensive financial investment by the government in the move to achieve equal access to electricity in the country.

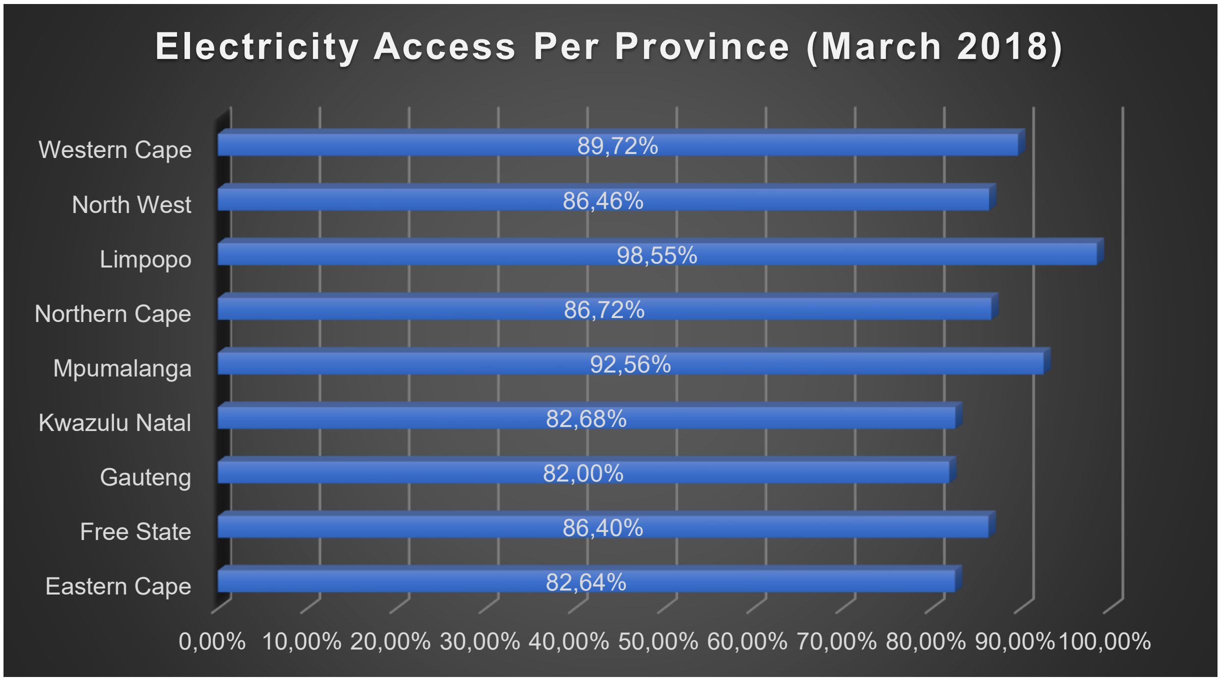
Figure 4.11: *The 2018/19 Financial Allocations Per Province*



(Data retrieved from DMRE)

The Government has allocated significant funds towards advancement of electricity access in the provinces of South Africa under the two major programmes aimed at enhancing electricity connectivity. The two leading provinces with the highest investment in electrification are Eastern Cape and KwaZulu Natal. In most of the provinces, Eskom takes the lead in the provision of services aimed increasing access to electricity in South Africa. The percentage access to electricity in March 2019 was high as shown in Figure 4.11, whereby Limpopo has the highest percentage access. The lease connected to the province is Gauteng with 82 percent, which was a significant level of electricity connectivity.

Figure 4.11: *The 2018 Electricity Access Per Province*

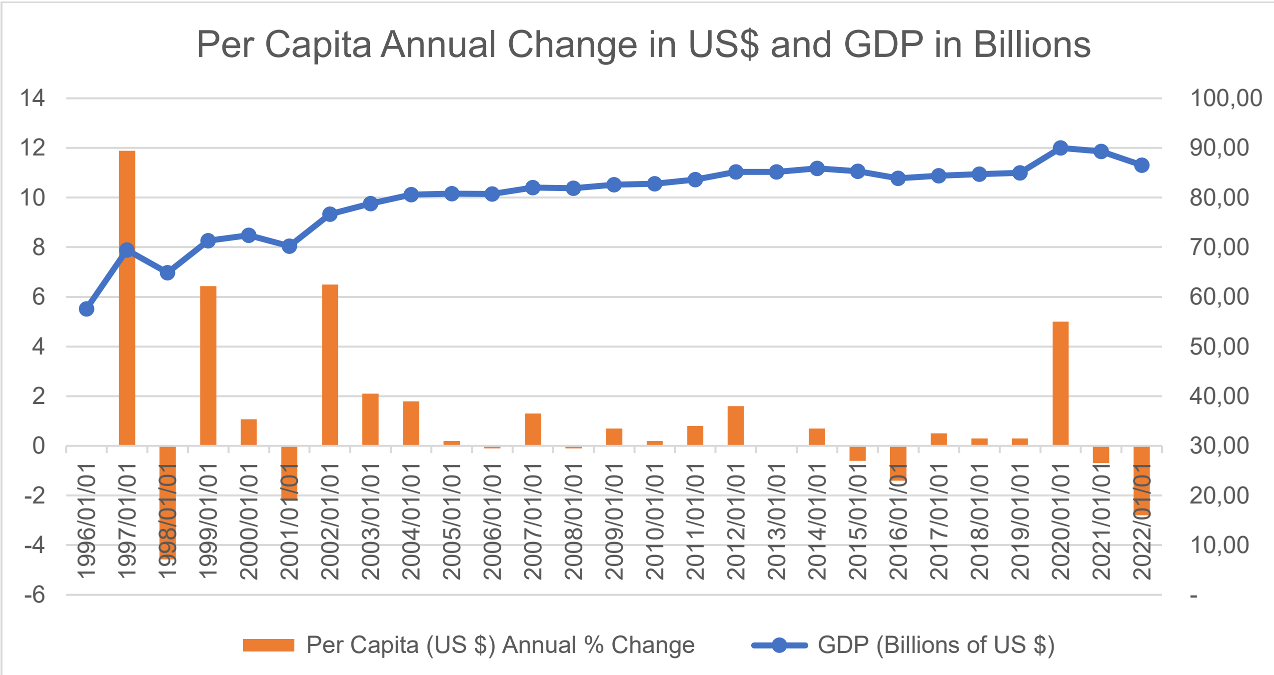


(Data retrieved from DMRE)

The electricity access data provided from diverse online platforms illustrate the increased accessibility to energy in South Africa. It aligns with the statistical results from the linear regression analysis and the descriptive analysis. Despite the low connectivity in Gauteng in 2018, it reported the highest level of electricity delivery between January 2023 and January 2024 (Cowling, 2024). Together with KwaZulu-Natal, Gauteng had the highest level of electricity delivery in this period.

There has also been an increase in the annual investment in funding for electrification since 1996 as shown in Figure 4.12. However, the rate of annual change has been fluctuating over the evaluated years. The investment in electrification has been increasing steadily since 1996 as shown in Figure 4.12, whereby the highest positive change was reported in 1997. In most of the year, the annual change has been low with others having negative changes. The investment in 2020 was significant, which can be linked to the economic challenges experienced during the pandemic.

Figure 4.12: *Per Capita Annual US$ Change and GDP in Billions from 1996 to 2022*



(Data retrieved from Macrotrends)

The trend in electricity generation and distribution indicates that in 2020 the rate of electricity distribution was the lowest from January 2020, whereby it declined by over 20 percent (Stats SA, 2024). Besides, electricity generation in gigawatts per hour was the lowest in January 2020. The trend in electricity generation has also been declining in the post-pandemic period due to diverse factors that include the high decline in coal in South Africa, which has been a major material for the generation of electricity in the country. Mirzania et al. (2023) state that the transition from coal-based energy to just and renewable energy has been disrupted by technological, economic, and political factors, including high corruption. The issue is a major challenge in the move to the achievement of renewable energy, which is likely to impact the stability of electricity distribution in the country.

4.3.1 Infrastructure Quality and Service Reliability

South Africa's ongoing energy crisis, characterized by persistent load-shedding and power cuts experienced daily in major cities, demonstrates that infrastructure presence differs substantially from service reliability. Grid stability variations, maintenance regimes, and service interruption patterns create accessibility gaps that connectivity statistics cannot measure, contributing significantly to unexplained variance in actual energy access experiences.

4.3.2 Policy Implementation Heterogeneity

Provincial disparities in policy implementation, funding allocation, and bureaucratic efficiency create systematic variations in energy access outcomes that transcend income-based predictors. Spatial settings where geography matters for environmental and energy goods require analysis of spatial heterogeneity in policy effectiveness, suggesting that administrative capacity differences contribute substantially to model residuals.

4.3.3 Methodological Implications for Future Research

The substantial unexplained variance necessitates mixed-methods approaches incorporating qualitative insights from community-level stakeholders to explore lived experiences and informal energy practices. Nuanced perspectives examining energy poverty at intersections of gender and disability reveal additional complexity layers requiring ethnographic investigation to complement quantitative analysis.

Econometric models incorporating spatial patterns in energy systems demonstrate how spatial dependencies affect energy access outcomes, while spatial regression models reveal that geographic clustering of residuals indicates spatially correlated omitted variables. Spatiotemporal modeling approaches supporting energy system planning with distributed energy resources offer methodological frameworks for capturing geographic clustering of unexplained variance through spatial lag and error specifications.

Lack of energy capacities based on household needed energy consumption show temporal variations in access that cross-sectional analysis cannot detect. Evidence showing significant reductions in lack of energy levels propose that longitudinal designs can capture variation adjustment processes contributing to current model residuals.

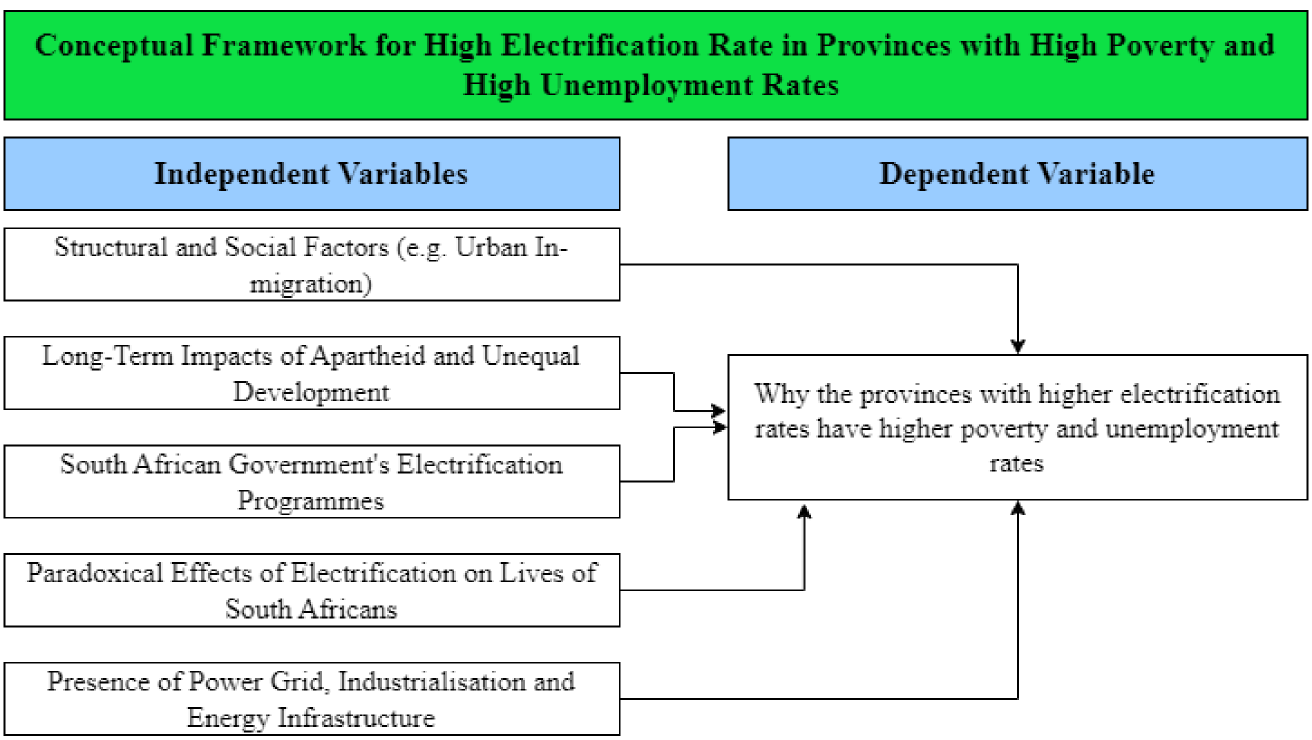
Future investigations should incorporate environmental considerations into infrastructure inequality evaluation while developing national-scale energy systems optimization models with enhanced sub-national data availability. The unexplained variance suggests theoretical model extensions incorporating institutional quality measures, social capital indicators, and climate vulnerability assessments that current poverty-unemployment frameworks cannot capture.

This residual variance, rather than representing analytical limitation, illuminates the multidimensional complexity of energy access requiring interdisciplinary approaches that bridge quantitative modeling with qualitative understanding of energy poverty's lived realities.

Chapter 5: Conceptual Framework

Chapter 4 carried out a quantitative analysis. This chapter presents several concerns that require thorough evaluation through case studies and a conceptual framework. According to the findings, there is a linear relationship between energy access, which in this case is through electrification, and overall economic development. The trend over the years from 1996 to 2022 indicates a positive impact on the income poverty threshold per rand per month and the population of working age, which aligns with the reported growth in electricity access. Besides, provinces that rank lowest in the employment rate and have high poverty rates report high electrification rates. There are diverse factors likely to result in this phenomenon; hence, there is a need for extensive evaluation. We identify the factors contributing to this scenario by applying a conceptual framework, as illustrated in Figure 5.1. Based on what was found in Chapter 4, the conceptual framework also includes case studies that go into detail about the main reasons for what was seen.

Figure 5.1: *Conceptual Framework*



(Author Generated Conceptual Framework)

5.1 Structural and Socio-Economic Factors

The presence of diverse structural and social aspects in South Africa has impacted energy access. The country's major cities are experiencing immigration, which is one of the major influencing factors. According to Mthiyane et al. (2022), the surge in rural-urban migration has resulted in strained government resources in the provision of critical social services that include electricity, water, education, adequate housing, and medical services. Limited investment in rural areas is a major contributing factor to the increased rural-urban migration, as many rural residents face numerous economic challenges. As a result, people migrate to urban regions in search of better living conditions and employment, whereby they move there and establish informal settlements that meet their financial positions. Mthiyane et al. (2022) explore the case study of the KwaDukuza municipality in KwaZulu-Natal, which has led to many challenges for its residents due to the high influx of rural residents.

The energy access issue in Gauteng is significantly influenced by the influx of migrants to the province, which is home to major cities in South Africa. Thobejane (2020) highlights that the pursuit of improved economic opportunities has driven many rural individuals to migrate to this urban area. Migration from other provinces to Gauteng has reached unprecedented levels, with some provinces experiencing double-digit percentage increases. The main motivation behind this rural-to-urban migration continues to be the search for employment opportunities in urban centers. The growth in the population of Gauteng has been on an upward trend over the years, which indicates its increasing challenges in the provision of socio-economic factors. There has been a significant increase in the number of immigrants in the country, which is a major driver of population change after death and birth (Statistics South Africa, 2018). The estimated population contribution due to immigration between 2016 and 2021 is 1.02 million. Gauteng is a major recipient of migrants in the country, considering its economic position as a significant economic hub in the country. People perceive it as a promising region that will eventually enhance their lives because of its diverse opportunities.

International migrants also impact the living conditions in Gauteng. Richter et al. (2006) argue that there has been a notable surge in the number of people migrating from neighboring countries. This is in addition to the reported rise in the number of migrants from rural areas who are seeking better opportunities. The various experienced instances of xenophobic attacks indicate the impacts of immigration in South African cities. Immigrants originate from neighboring countries and even as far as Western Africa, with most of them from Nigeria. The pressure for socio-economic opportunities due to the increasing population has led to animosity between natives and immigrants. Segatti and Landau (2011) argue that the economic development for urban people has been slow due to the surge in immigrants from diverse countries across the region, hence the pressure for sustainable services and opportunities for most urban residents. The presence of gold mines and other minerals is a major contributing factor to the surge in immigrants in the country. With the decline in minerals, many immigrants reside in major cities as they search for job opportunities. Moreover, there has been a noticeable discrepancy in job opportunities in major mining sites, which jeopardizes the living conditions of immigrants who enter the country with low skills and are limited to labor-intensive industries like mining and construction. All these factors increase the number of urban residents living in informal settlements. Therefore, the pressure to provide adequate social services by the government impacts its ability to provide the required services.

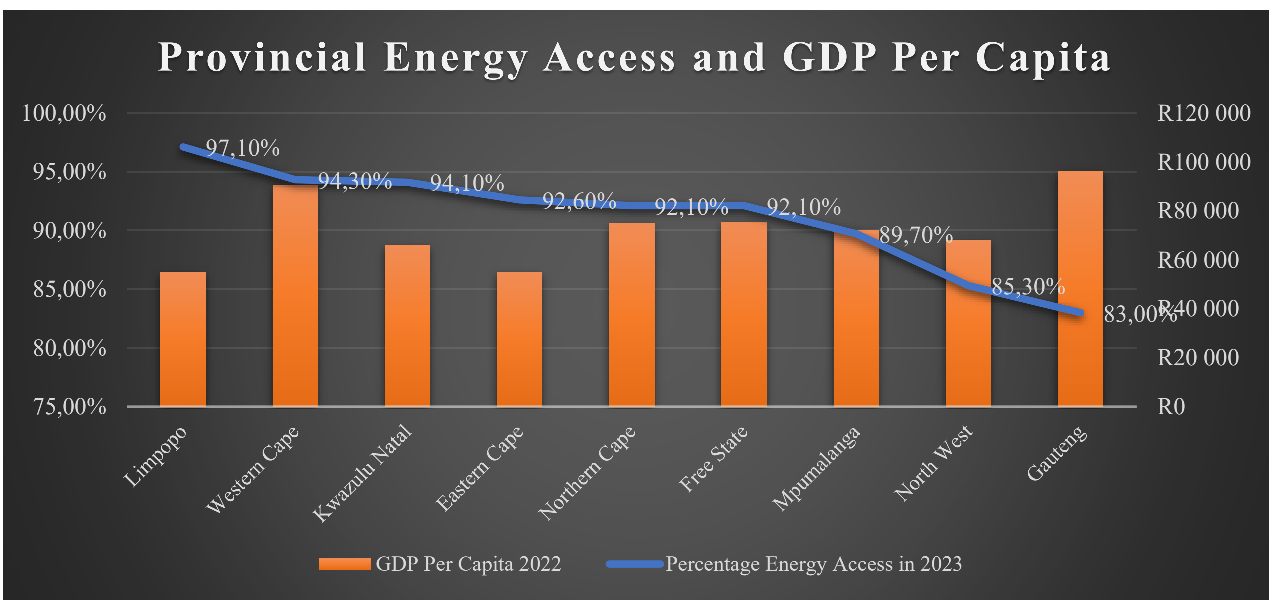
The structural establishment of the informal settlements also limits the ability of city administration to offer quality and adequate services, including the distribution of electricity. The economic situation of the urban poor living in informal settlements also limits their ability to afford the cost of energy access. Masuku (2024) opines that the increased urban population has been a major driving factor contributing to the costs of living for rural-urban migrants. The deteriorating infrastructure of energy generation and distribution companies, especially Eskom, which accounts for 95 percent of the country’s electricity, also contributes to energy generation challenges that lead to high energy costs. Those living in informal settlements only rely on alternative energy sources that are unsustainable and less reliable. Their challenging economic situation also limits their ability to invest in solar power sources. Masuku (2024) states that the cost of electricity is high in South Africa due to infrastructural challenges facing Eskom and other issues related to energy generation, such as the continuous decline of coal.

The geographical location characteristics of Limpopo also contribute to its poor economic conditions despite the significant electricity access in the country. Myeni et al. (2024) explore the economic activities and factors likely to impact the efficient growth and development of this province, suggesting that it is majorly arid and semi-arid. It hinders performance of agricultural sector, which makes most of its residents impoverished and has limited economic opportunities. Extreme temperatures also do not favor agriculture, hence limiting the region's development capabilities. However, the argument about the unfavorable conditions present in Limpopo does not equate Gauteng as a province with a conducive economic environment for all. There is notable lack of equity in Gauteng considering the prevalence of informal settlements in major cities in the province. It means that the highest percentage of wealth is held by a small percentage of residents in the province, majorly those with investments in real estate and industrials.

5.2 Paradoxical Effects of Electrification on Lives of South Africans

There has been a common belief that a high rate of energy access translates to high economic growth in the impacted region. However, the contrary occurs whereby high energy access may not result in poor living conditions. Figure 5.2 illustrates the state of economic and living status of South Africans in each of the nine provinces while accounting for percentage energy access. With a focus on two provinces at extreme levels of GDP per capita, Limpopo has the second lowest GDP per capita of R54,935 despite its highest percentage of energy access of 97.10. On the contrary, Gauteng has the least percentage of energy access at 83 while it leads in GDP per capita at R96,252. It indicates the paradox between high energy access and a high poverty rate.

Figure 5.2: *Provincial Energy Access in 2023 and GDP Per Capita in 2022*



(Electricity Access Retrieved from Africa Check and GDP Per Capita Data from unece.org)

Matinga and Annegarn (2013) suggest that high energy access does not usually contribute to high economic growth and performance; they argue that the linkage between energy access and economic development has complex aspects that are not deterministic. The differences in the social contexts of people living in a particular area influence the impact that energy access has on economic development. However, diverse published literature suggests that there is a positive impact on the economic development of a particular region after increasing access to energy, such as electricity. They fail to account for the individual aspects of the region's residents, group agency, and social settings, which significantly impact the outcomes of the results (Matinga & Annegarn, 2013).

Andersen and Pedersen (2023) state that most African countries experience electricity overproduction but fail to meet the market demand. This leads to a paradox between the controversial outcomes of increased access to electricity and development. Inadequate funding and poor planning are some of the leading factors contributing to this paradox. Most of the time, the available funds prioritize energy generation over transmission and distribution. Nkomo (2005) also says that the connection between energy access and economic growth is complicated because investing a lot of money in electrification might not solve the social and structural problems that are needed to make the environment favorable for economic growth and development. Because Limpopo is predominantly rural, it has limited opportunities for economic development, which could lead to improved living conditions for its residents. The required structural aspects for economic development and growth after increased energy access are missing, resulting in a high poverty rate. Critical factors that enhance economic growth, such as security, are also lacking in the rural area, which limits the residents' ability to establish diverse investments. high GDP per capita in Gauteng with a low percentage of energy access is also contrary to the expectations whereby there should be high energy access to contribute to high economic growth and development.

Hlongwane and Daw (2022) link high electricity consumption to high population growth, which significantly impacts urban centers. Gauteng has the highest electricity consumption rate and a high population, which results in energy poverty among its residents. Therefore, the high population in various provinces results in a low percentage of energy access while having a high GDP per capita. It is also contradictory for a province to have a high GDP per capita with low electrification, which brings about the issue of inequality in South Africa. Gauteng has a significant number of informal settlements, which indicates that the low energy access is due to extreme poverty among its residents in these informal settlements (Metelerkamp, 2024). GDP per capita does not account for welfare and equality; hence the high GDP per capita in Gauteng is due to its urban economic activities, which are under a small number of residents.

5.3 Presence of Power Grid, Industrialisation and Energy Infrastructure

The provincial ranking regarding energy access rate in Chapter 4 indicates that Limpopo had the highest rate at 98.55 percent in 2018 and still holds the lead, as shown in Figure 5.2, with energy access of 97.10 percent. The primary reason for this high percentage of energy access is the availability of coal in this province, which enhanced the establishment of the largest coal-powered energy-generating plant in the Medupi Power Station, which is located near Lephalale in both the country and Africa. This power source is a major contributor to enhanced energy access in most parts of Limpopo. This region also boasts other energy generation sources, including the 2022 launch of the Lephalale Solar Project (LSP). This solar project is making significant milestones and its anticipated contributions to energy generation in Limpopo province, hence the enhancement of energy access. Therefore, the availability of power grid resources that entail coal required for energy generation and other renewable energy sources positions Limpopo at the top regarding energy access in South Africa.

Energy infrastructure has also been well-developed in this province compared to others due to the availability of energy sources. Despite the economic challenges in various rural villages in Limpopo, energy infrastructure is well-developed and efficient, which facilitates the ease of electricity distribution. However, the high connectivity of energy sources in this province does not result in high economic performance considering its climatic conditions that hinder the exploration of diverse economic opportunities for its residents. As a result, it ranks low in terms of GDP per capita.

In contrast, Gauteng has a high GDP per capita but the least energy access in the country's provinces. Factors such as its high rate of industrialization and extensive real estate in its urban centers position it as the country's economic hub. South Africans from other provinces flock to this province in search of better opportunities. There are diverse industries present in this province that include agriculture, manufacturing, processing, mining, and real estate. These industries make a significant contribution to Gauteng's economic performance, hence its high GDP per capita. However, the wealth gap is significant in this province, which means it experiences low energy access among the South African provinces. The cost of energy is high in urban centers, which has a significant impact on energy poverty. In research on energy access in diverse provinces of South Africa Ismail (2014) argued that Gauteng was among the leading provinces with a positive relationship with energy poverty. The current statistics indicate that its lowest ranking about energy access is a clear indication of energy poverty. The high entry of immigrants from various neighboring countries, including Zimbabwe and Mozambique, and rural-urban migration, majorly in Gauteng, contribute to its high energy poverty rate, since many of these low-income earners cannot afford energy. The disparity in energy access between Gauteng and Limpopo emerges because of the differences in population and structural factors regarding energy infrastructure and growth. Ye and Koch (2021) also report significant energy poverty in South Africa among the low-income earners. Low-income groups in society contribute to high poverty rates in an economy.

5.4 Long-Term Impacts of Apartheid and Unequal Development

Equality in economic development and access to critical resources, such as electricity, in South Africa has become a major issue due to the long-term impacts of apartheid. Koomson et al. (2022) state that ethnicity in South Africa has a direct contribution to the disparities in energy access. High energy prices, low-income levels, and energy inefficiency have also been prevalent among Africans in this country compared to the Whites. They also reported significant levels of investment and access to critical resources that enhanced their economic growth and development compared to native South Africans. Racial segregation resulting from apartheid has contributed to the high rate of energy access among the Whites, who have a 47 percent higher energy consumption rate compared to the natives. Despite the low population rate of Whites, which is 10 percent of the entire South African population, it has the highest rate of energy access. The long-term effects of apartheid significantly contribute to the energy access challenges faced by low-income earners, primarily Natives. Mirzania et al. (2023) argue that the history of social and environmental difficulties in South Africa has impacted energy access.

Anwar (2017) states that there has been persistence in the dominance of whites regarding capital access in South Africa, despite the country's realization of independence. Apartheid's historical influence has exerted extensive control over the South African economy. Other political factors, such as corruption, the government's incompetence, the faltering economy, and the high unemployment rate caused by the poor policies implemented by the governing African National Congress (ANC), also significantly contribute to this situation. Whites enjoy various privileges over the Black communities that experience rampant unemployment rates. Patterns in land ownership, expertise in the workforce, and investment in the Johannesburg Stock Exchange are skewed towards the Whites, which indicates the country's high level of inequality.

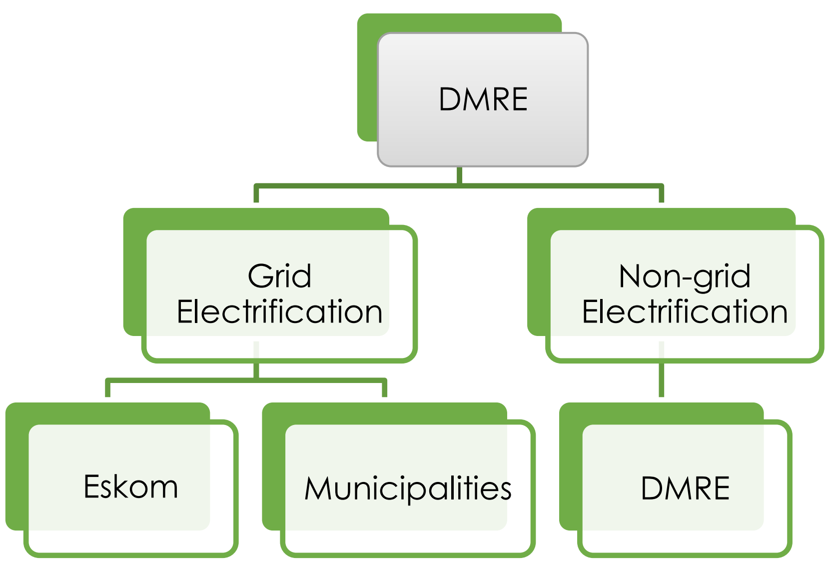
Francis and Webster (2019) state that South Africa is one of the most unequal countries globally, whereby half of South Africans live in poverty, and there are high rates of stagnation, unemployment, and inflation. There have been significant improvements in poverty reduction in South Africa without considerate improvement in inequality, which indicates the long-term impacts of apartheid. The unequal development and growth in South Africa have also become a leading contributor to the lack of energy access. Wilson (2011) explores various factors that have contributed to experienced inequalities due to occupational mobility barriers, the South African industrial revolution, and the accumulation of capital investments. The historical perspective of South Africa indicates that these factors have a significant contribution to the energy poverty currently experienced. In the context of the selected South African provinces with energy access differences, Gauteng has the highest GDP per capita, which does not account for the significant economic inequality in this province. The low-income earners living in informal settlements have the highest contribution to low energy access, despite it failing to translate into low GDP per capita. The contrast is in Limpopo, which has the highest percentage in a rural region. High energy access does not necessarily lead to significant economic development and growth. In this scenario, the long-term impacts of apartheid and unequal development have contributed to the differences in energy access in diverse provinces.

5.5 South African Government's Electrification Programmes

With the notable impacts of unequal development and energy access in most of the rural provinces, the South African government has been at the forefront in the promotion of electrification. Different programs, such as the National Electrification Program (NEP), the Integrated National Electrification Program (INEP), and others undertaken by the World Bank, have significantly contributed to energy access and efficient distribution in the country since 1994. Government-supported strategic investments by ESKOM and the Department of Minerals Resources and Energy (DMRE) have enabled rapid electrification.

The first programme for electrification was NEP, starting from 1994. Bekker et al. (2008) states that in the 1980s and before 1990, electricity access was less than one-third of the entire population. However, with the adoption of rapid electrification programmes the electricity access doubled in a decade's time. There was a notable disparity in access to critical resources, services, and infrastructure, which includes electricity. In 1996, only 58 percent of the entire population had access to electricity, with the least access by non-urban Blacks, while non-urban whites had energy access of 97 percent of their total population. ESKOM has been the leading energy distributor in the country. The INEP electrification initiative aims to provide municipalities with capital subsidies to address residential dwelling electrification issues. ESKOM established the initiative in 1991 and is responsible for managing and planning electrification.

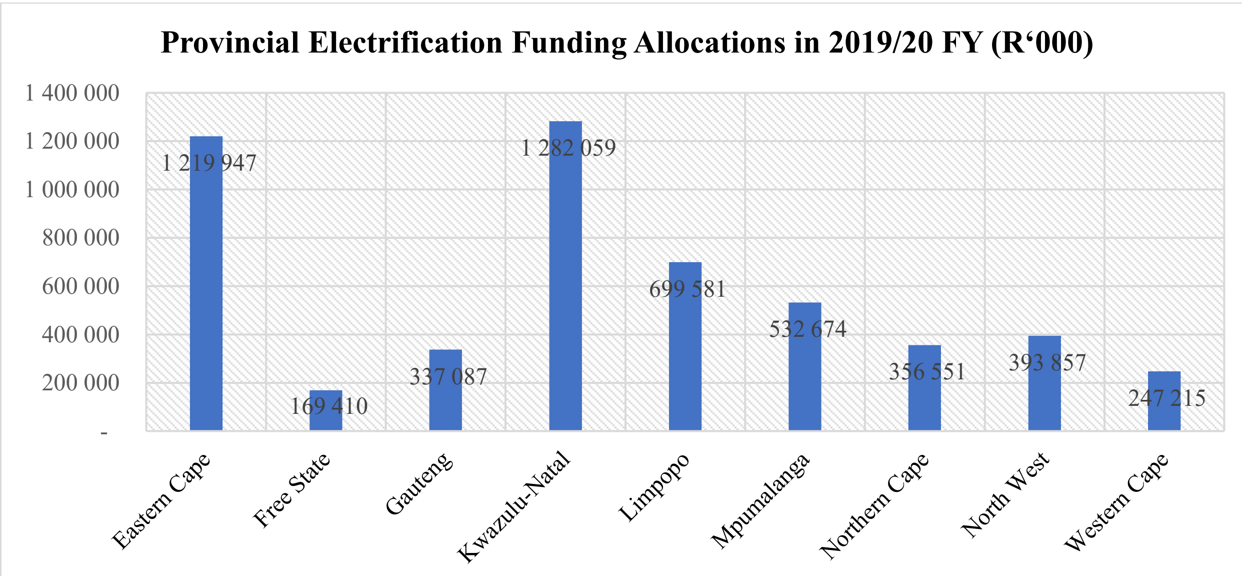
Figure 5.3: *The Funding and Electrification Model*



(Retrieved from DMRE Briefing Presentation)

The government has assumed management and running this program since 2001. As shown in Figure 5.3, DMRE is also responsible for this electrification program. INEP serves the purpose of managing the electrification funding, planning, and the implementation process, primarily to solve the electrification backlog. Tinto and Banda (2005) state that INEP has been a success in the provision of electricity in the country, serving as a post-apartheid energy paradigm shift. The extensive investment by the government in electrification has also become a bargaining tool for political systems, as observed in past elections. Since the programmes have majorly been focusing on increased energy access in rural areas, there has been a surge in the access rate in rural areas as compared to urban areas.

Figure 5.4: *The FY 2019/20 Provincial Electrification Funding Allocations*



(Data Retrieved from DMRE Briefing Presentation)

Figure 5.4 illustrates that the funding allocation model primarily aims to promote electrification in rural areas. KwaZulu-Natal has the highest allocation, followed by Eastern Cape and Limpopo, which have the highest populations in rural areas. Therefore, this funding model has contributed to high energy access in rural provinces, which do not have adequate opportunities and developed infrastructure to facilitate economic growth and development. Gauteng is among the least funded provinces despite having the least energy access in the country. The adopted electrification programs have been more focused on the enhancement of energy access in rural areas in anticipation of promoting economic development in these regions. However, it is contrary to the government's expectations that provinces with the highest energy access report low GDP per capita. This phenomenon is due to the increased rural-urban migration of an energetic population that could enhance development in rural areas.

5.6 Factors that Hinder or Drive Energy Access and their Influence on Poverty Alleviation

There are diverse factors that hinder or promote access to electricity; hence, they have been a major influence on the government's commitment to poverty alleviation. Some of the factors promoting simple access to energy include the electrification programs undertaken by the government led by Eskom, funding and the provision of subsidies, transitioning to renewable energy sources, external trade with its regional partners, and increased participation of the private sector in energy generation. Factors that impede energy access include the aging coal energy-generation infrastructure, the fast-depleting coal required for energy generation, economic inequality and poverty, and the financial challenges Eskom faces.

5.6.1 Factors Hindering Energy Access

There are various factors that hinder energy access, primarily in urban regions. The reported low energy access in Gauteng is majorly due to energy poverty among most of the informal settlement dwellers. The cost of energy is extremely high, with regular price hikes over the past few years, and it is anticipated that these hikes will continue in 2025, 2026, and beyond. Mathetsa (2024) reports that ESKOM requested approval for a 35.1 percent hike in 2025, an 11.8 percent hike in 2026, and a 9.1 percent hike in 2027. With such exorbitant prices, energy affordability for informal settlement urban residents is challenging, hence the low energy access. Therefore, it has become a challenge to have straightforward access to energy in such regions. Another issue affecting energy access is the declining infrastructure for energy distribution at ESKOM. It has resulted in regular electricity outages, which impact its reliability. The poor economic situation experienced in the country due to the high unemployment rate also hinders energy access since those without access to grid electrification cannot afford non-grid electrification resources, such as solar panels.

5.6.2 Factors Promoting Energy Access and their Impact on Poverty Alleviation

The government's investment in various electrification initiatives, including the NEP and INEP under the DMRE and ESKOM, has significantly improved energy access. These efforts have provided subsidies and financial support specifically designed to enhance energy availability in rural areas and urban regions, with a focus on informal settlements. Masuku (2024) suggests that the promotion of off-grid electrification has further increased energy access across various regions, making it an essential factor in poverty alleviation. According to Avordeh et al. (2024), energy access is a vital element in reducing poverty, as it fosters the growth and development of small and medium-sized enterprises (SMEs), which in turn drives economic growth. The implementation of various strategies to promote energy access has thus played a crucial role in the country's efforts to alleviate poverty. However, due to a lack of the required enabling factors for economic development, electrification has not been effective in poverty alleviation since unemployment remains a major challenge in the country. The frequent and extended power outages also impact on the efficient performance of SMEs in the country as they interrupt their normal operations.

5.7 Sen's Capability Approach

Aspects such as people's wealth and mental reactions are important in their lives. However, they may not adequately provide information on what the actual progress and processes of life are (Wells, 2011). Amartya Sen developed this approach in the 1980s with concerns about the differences in human capabilities. There is a distinguished difference in human capability to transform various resources into meaningful and valuable functioning. With adaptive preferences, a person's objectivity might not get in the way of them pursuing different goals, if they are driven by a strong belief and declaration of achieving certain goals and objectives. The availability of options is critical to achieving people's goals and objectives, as they impact actual achievements. There is also complexity since assumptions result in arriving at conclusions that do not showcase the various underlying factors that may influence people in a particular manner.

Robeyns (2020) says this way of thinking is based on two normative claims: the freedom to achieve well-being is very important from a moral point of view, and well-being should be understood in terms of a person's abilities and how they act or behave. If two people have equal access to the same resources that will help them reach their goals and objectives, the fact that one of them has a physical disability will affect how well they reach their goals. On the contrary, the abled person will effectively utilise all their resources to achieve the desired results in a more efficient manner. This capability approach is at the heart of the literature review for this thesis, so it is important to look at the effects of energy access and the economy of South Africans through this lens. High energy access for various people in rural areas or other provinces does not guarantee equal economic development. Those in areas with low energy access have reported high GDP per capita primarily due to the availability of various factors that enhance their capabilities.

5.8 South African Energy Policies and the SDGs

There are various policies implemented by the South African government, aiming to provide clean energy to the largest market possible. Bridle *et* al. (2022) examine various energy fiscal policies aimed at enhancing energy access. These policies include subsidies for energy production and distribution, as well as financial assistance for struggling companies such as ESKOM, which heavily rely on carbon-intensive practices. In South Africa, fossil fuels, particularly coal and petroleum products, currently dominate the energy mix (Bridle *et* al., 2022). This reliance results in significant social costs associated with energy generation and distribution due to environmental externalities. Given the prevalence of coal and fossil fuels, transitioning to renewable and clean energy is essential for South Africa. The government is committed to promoting energy affordability, decarbonizing the energy sector, strengthening energy security, and encouraging economic growth and development. Various initiatives aimed at improving revenue collection, increasing subsidies, and exploring other government spending options have contributed to greater energy access in the country. Besides, the increased government spending to support ESKOM has facilitated its energy generation and distribution; hence, a notable increase in energy access since 1994.

South Africa aligns with the United Nations SDGs and strives to achieve these goals for a better country. SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all (United Nations, 2024). There are three major targets established under SDG 7, which entail access to energy, increasing the percentage of renewable energy in the energy mix, and enhancing energy efficiency substantially (SEforAll, n.d.). The government is increasingly investing in the transition process from fossil fuels to renewable energy sources. The notable strategies include investment in hydroelectricity, solar energy, and wind energy. Lephalale Solar Energy Project is one of the major investments that promotes the production of renewable energy for the country. Despite the extensive investment in various renewable energy sources with the aim of enhancing sustainability, issues such as frequent outages and the dominance of coal in energy generation are evident. ESKOM's management of the ageing energy generation and distribution infrastructure also hinders the attainment of reliable energy. Therefore, the realization of this SDG calls for the adoption of strategic measures that will facilitate a quick transition from fossil fuels to clean energy while enhancing reliability in energy distribution.

5.8.1 SDG 7 – Affordable and Clean Energy

The study's positive association between income levels and electricity connectivity directly supports SDG 7.1's target for universal access to affordable, reliable, and modern energy services by 2030. Recent research demonstrates that multidimensional energy access assessments reveal declining global energy affordability from 2001-2016, indicating that income-energy access relationships require nuanced policy approaches. South African evidence specifically shows the importance of combining energy affordability and accessibility into multidimensional poverty measures that differentiate between rural and urban contexts.

The study's findings align with global trends show that clean and affordable energy access is key to developing agriculture, business, communications, education, healthcare and transportation sectors. However, despite increased electricity access in sub-Saharan Africa from 33% in 2010 to 46% in 2019, affordability issues prevent many households from connecting to available grid infrastructure. This research contributes to understanding these affordability barriers through its income-energy access correlation analysis.

5.8.2 Provincial Energy Access Disparities and SDG 7 Targets

The study's provincial analysis reveals how historical and geographical factors create differential SDG 7 progress rates. Energy poverty assessment using fuzzy set approaches demonstrates that access to clean energy has become a foremost SDG priority, requiring objective evaluation methods. The research findings showing provincial variations in energy access directly inform SDG 7.2 (increasing renewable energy share) and SDG 7.3 (improving energy efficiency) by identifying areas where decentralized renewable solutions could address access gaps most effectively.

South African research confirms that energy poverty disproportionately affects Non-White populations, with approximately 11.5% higher prevalence rates than White counterparts due to historical discrimination patterns. These findings support targeted interventions that align with SDG 7's universal access mandate while addressing historical inequities.

5.8.3 SDG 1 – No Poverty: Energy as a Poverty Alleviation Mechanism

The study's demonstration of improved electricity connectivity contributing to poverty alleviation aligns directly with SDG 1.4's emphasis on equal access to basic services. Research on household energy poverty demonstrates that access to affordable, reliable and modern energy services presents a clear pathway to social and economic development, supporting this study's income-energy access correlation findings.

Energy access enables poverty reduction through multiple mechanisms that extend beyond direct income effects. Recent evidence from sub-Saharan Africa shows significant negative associations between energy poverty and health outcomes, with multifaceted energy poverty index scores exceeding 0.5 across the region. This health dimension connects energy access to SDG 1's broader poverty alleviation objectives beyond income measures.

5.8.4 Household-Level Poverty Dynamics

The study's household-level analysis contributes to SDG 1.2 (reducing poverty in all dimensions) by demonstrating how energy access affects multiple poverty dimensions simultaneously. South African research incorporating household energy needs into Foster-Greer-Thorbecke poverty measures reveals complex energy poverty patterns that require comprehensive measurement approaches. These methodological advances support more effective targeting of poverty alleviation interventions that incorporate energy access components.

5.8.5 Education and Skills Development (SDG 4)

Energy access enables educational advancement through multiple pathways including extended study hours, digital technology access, and improved school infrastructure. The study's findings support SDG 4.1 (quality primary and secondary education) and SDG 4.3 (affordable technical and higher education) by demonstrating how energy access correlates with household economic capacity for education investment.

5.8.6 Gender Equality (SDG 5)

Energy access particularly benefits women through reduced domestic work burdens, improved safety, and enhanced economic opportunities. The study's income-energy correlation analysis implicitly supports SDG 5.1 (ending discrimination) and SDG 5.4 (recognizing unpaid care work) by revealing how energy access can transform household economic dynamics.

5.8.7 Health and Well-being (SDG 3)

Energy access improvements directly support SDG 3 through enhanced healthcare facility operations, reduced indoor air pollution from traditional fuels, and improved food storage capacity.

The study's poverty alleviation findings connect to SDG 3.8 (universal health coverage) by demonstrating how energy access enables household economic capacity for healthcare expenditure.

5.8.8 National Progress Assessment and Policy Alignment

South Africa's SDG Country Report 2023 indicates positive trends in 33% of targets, though data challenges hamper assessment of poverty, food security, health and inequality issues. This study contributes crucial evidence for addressing these data gaps while demonstrating concrete energy-poverty linkages that support multiple SDG targets simultaneously.

To accelerate progress toward SDG 7 and SDG 1 simultaneously, policy frameworks must recognize energy access as both a development outcome and an enabling factor for broader poverty reduction. The study's provincial analysis supports spatially differentiated approaches that align with SDG 17.14 (policy coherence for sustainable development) by demonstrating how local contexts affect energy-poverty relationships.

Decentralized energy solutions, particularly solar microgrids, offer pathways for addressing both rural energy access gaps and poverty reduction objectives. These approaches support SDG 7.2 (renewable energy targets) while enabling SDG 1.4 (basic service access) in areas where grid extension remains economically challenging.

Streamlined regulatory frameworks that enable private sector participation while maintaining affordability protections support both SDG 7.1 (universal access) and SDG 1.3 (social protection systems). The study's income-energy correlation findings suggest that targeted subsidies for low-income households could accelerate progress on both goals simultaneously.

Financial inclusion strategies that enable energy access financing support SDG 1.4 (financial service access) while advancing SDG 7.1 (affordable energy access). These integrated approaches maximize development impact through coordinated interventions that address multiple SDG targets.

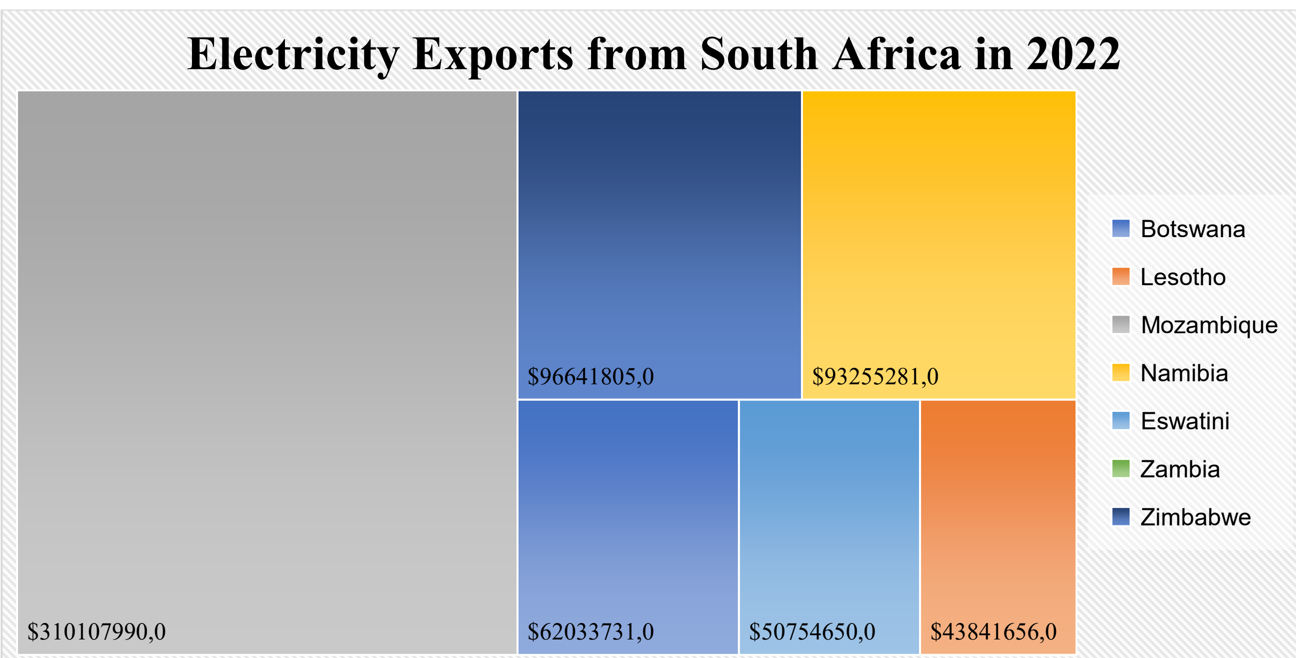
This study advances SDG monitoring frameworks by demonstrating empirical methods for measuring energy-poverty correlations that inform policy targeting. The provincial analysis methodology provides replicable approaches for tracking subnational SDG progress, supporting SDG 17.18 (capacity building for data monitoring) objectives.

The research contributes to global knowledge on energy-poverty linkages that supports international development cooperation aligned with SDG 17.6 (knowledge sharing) and SDG 17.9 (capacity building support) through its methodological innovations and empirical findings applicable to similar developing country contexts.

5.9 Electricity Generation for Other African Countries

South Africa is a major economic hub for its neighboring countries, which is evidenced by the large number of immigrants entering the country from Zimbabwe and Mozambique and, to an extent, Nigerians from West Africa. In terms of energy generation, South Africa exports to a variety of countries, a practice that negatively impacts its energy distribution and adequacy. As shown in the figure below, the highest exports were made to Mozambique, amounting to $310 million, while Zambia has the least at $1,305, making it a negligible export recipient for this commodity.

Figure 5.3: Energy Exports Data from South Africa to Its Neighboring Countries in 2022

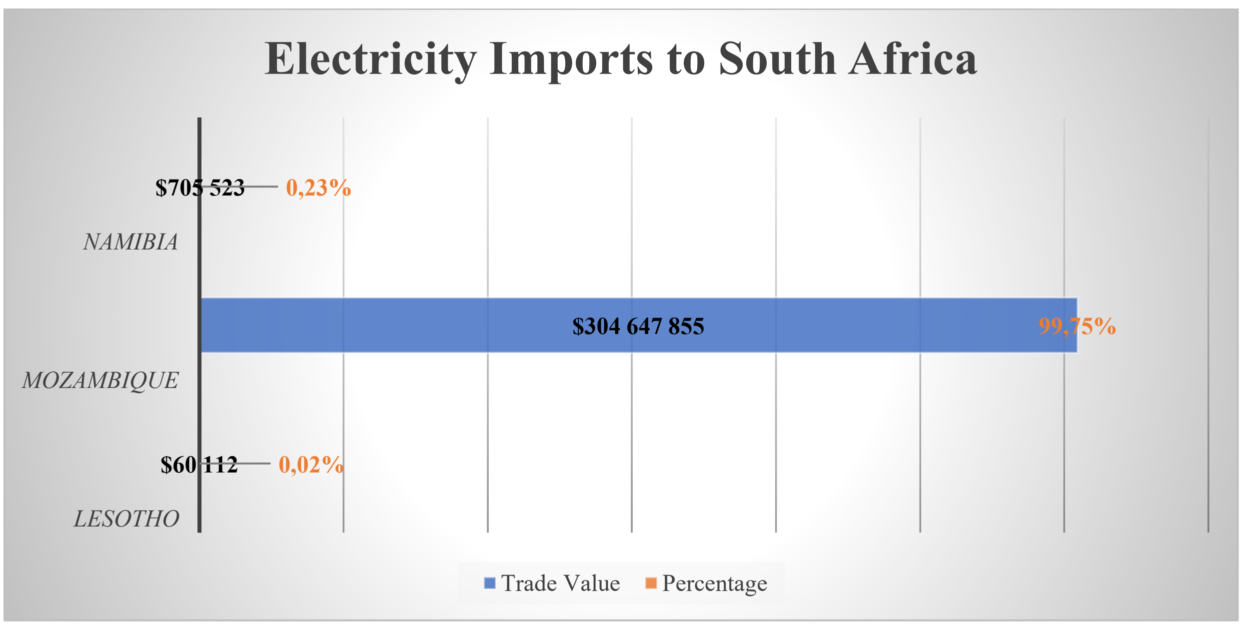


(Energy Exports Data Retrieved from The Observatory of Economic Complexity)

The high quantity of electricity exports to these countries, amounting to $657 million in 2022, indicates their high level of energy generation, which paradoxically leads to the ongoing persistence of energy poverty and inequality in the country. The existence of electricity load shedding in a planned manner indicates the country's poor management of its resources since it also exports a significant quantity of electricity to its neighboring countries (Wiese & van der Westhuizen, 2024). However, this energy access issue cannot be effectively solved through blame on various authorities or the government. The experienced recurrent disruptions are planned, which showcase the presence of illegality in the involved energy supply bodies in the country when ensuring the distribution and even access to energy.

In contrast to the large electricity exports made to its neighboring countries, South Africa's imports in 2022 amounted to $305 million, which is relatively lower than exports in the same financial year. Mozambique is the leading source of electricity imports for South Africa, indicating its significant contribution to energy generation for its neighboring countries.

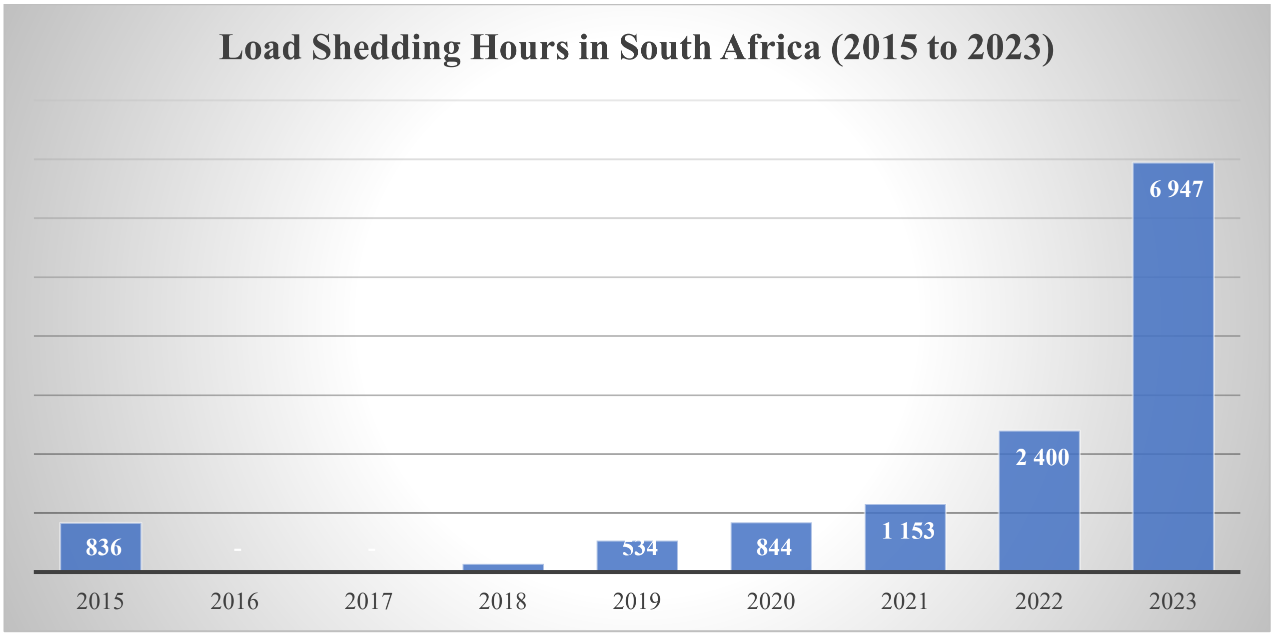
Figure 5.4: Electricity Imports to South Africa in 2022



(Energy Exports Data Retrieved from The Observatory of Economic Complexity)

Mozambique is also the largest recipient of South Africa's electricity. However, South Africa leads in energy generation due to the net energy exchange between the two countries. The fact that it exports more than it imports can be linked to its high energy access in diverse provinces without a corresponding economic development. For instance, the Western Cape experiences load shedding due to the country's high focus on exporting electricity, despite its poor infrastructure.

Figure 5.5: *Load Shedding Trend in South Africa from 2015 to 2023*



(Load Shedding Data Retrieved from Statista)

The trend in electricity load shedding from 2015 to 2023 indicates an upward trajectory, with 2023 indicating the highest number of hours of electricity outages. The large number of hours in 2022 also indicates a lack of proper planning regarding the exportation of electricity. Sound decision-making and profound planning should guide the generation and export of electricity to other countries. With such an effective approach, most of the provinces would have high energy access. Wiese and van der Westhuizen (2024) suggest that these planned electricity outages have a negative impact on economic development, majorly impacting the low-income earners who do not have access to off-grid sources of energy. The improvement of energy infrastructure would result in increased energy access and distribution in the country.

Chapter 6: Recommendations and closing remarks.

6.1. Introduction

Our study findings clearly indicate that electricity is a fundamental element in the pursuit of economic development and social advancement in the country. Despite South Africa's pledge to ensure equitable electricity access through policies established in 1994, significant disparities persist between urban and rural areas, revealing an urgent need to address infrastructural gaps. The analysis identifies a dual trend; there is a strong connection between electricity access and poverty reduction, but this is frequently obstructed by structural and logistical hurdles. In urban settings, despite the historical commitment to equal access, informal settlements and unplanned urban growth hinder the administration's capacity to provide comprehensive energy services. The increase in informal housing and high levels of migration has created situations that there is not enough electricity available to amenities, impediment to economic development in these lands as they have attractive economic potential. There is an even greater crisis in rural provinces of poor investment and energy inaccessibility, which is hampering economic development. Harsh environmental further complicates agricultural production, one of the key drivers of economy that depend on these conditions. These challenges in the environment, and weak infrastructure also explain why they are still arching the developing stage. Furthermore, the unequal wealth distribution complicates the pursuit of equitable electricity access.

Unequal wealth distribution leads to uneven energy access and leaves millions of lower-income households with insufficient access to energy services. This vicious cycle of restricted accessibility and poverty inspires discourse on the implications of such disparities to national growth, as well as possible solutions.

An analysis of electricity access within the framework of economic development in South Africa: It’s a complicated story. Home electric surplus does not equal economic success because of inefficient means to meet markets. This paradox raises concerns regarding the structural efficiency of energy distribution grids and their ability to match electricity supply with economic needs. Government programmes, such as the National Electrification Programme (NEP), have effectively increased access by offering subsidies and financing intended to improve under-electrified regions. But an endless lack of infrastructure is preventing more radical change. These results show that we must do a strategic reorientation and reallocation of resources to see to it that policies are not just great, but also applicable and efficient.

Conceptual frameworks such as Amartya Sen's capability approach, along with energy ladder and stacking theories (Perkins et al., 1998), and human capital theory are instrumental in disentangling these issues. Sen's methodology advocates enlarging individuals' freedoms. He implies that including energy access in a holistic development approach, which places the value of human capital as an imperative, has potential to improve lives. The energy ladder and the theory of stacking explain how households prioritize their uses of different fuels in the context of their lived experience, indicating an inclination toward cleaner and more efficient forms of energy, as well as barriers to moving up the hierarchy. Moreover, human capital theory also argues that better access to energy facilitates education and employment opportunities, thereby increasing livelihoods. The quantitative data from the nine provinces graphically depict South Africa as a mosaic and energy access is pivotal in relation to socioeconomic outcomes. The variation of development challenges and opportunities across provinces signals a demand for more tailored, not one-fits-all, policy orientation in the future.

This inquiry into South Africa's energy framework reveals important insights and underscores the multifaceted role of electricity access in poverty alleviation and economic advancement. However, the path to achieving equitable access remains incomplete. Stakeholders must engage in coordinated efforts, incorporating government bodies, private sectors, and local communities, to establish inclusive action frameworks. Forward-looking strategies should focus not only on expanding access but also on enhancing infrastructural resilience, addressing socioeconomic inequalities, and tackling environmental challenges that hinder potential pathways to prosperity. While strides in electricity access have been made, there is a pressing need to focus on the quality and consistency of the energy services provided. Strengthening governance structures, increasing investments in smart grid technologies, and adopting sustainable energy practices are crucial steps toward overcoming existing barriers.

In conclusion, the transformative potential of electricity is unmistakable; however, it must be harnessed through a holistic and inclusive approach. South Africa's overarching aim of poverty alleviation through energy access relies on adaptive policies, actionable commitments, and robust infrastructural systems. The narrative of development, while promising, depends on the ability to synchronize production with actual demand, theoretical frameworks with real-world implementation, and overarching policies with local needs. Addressing these concerns will help ensure that the aspirations established in the post-Apartheid era for equal energy access are fulfilled for every community, urban or rural, transcending all backgrounds and unlocking South Africa's full potential in the global economic arena.

6.2. Policy recommendations

It is now clear that trying to provide energy isn't just about lighting homes; it's also pivotal for lifting people out of poverty. By really addressing energy access and poverty, a comprehensive approach is needed. That's not simply about spreading power more equitably but also stimulating economic growth in the provinces. There is a clear connection between accessing electricity and improved living standards. All provinces have unique needs, particularly in rural areas where we haven't seen investments in energy. "There is need to build a coalition between the government and the private sector, partnering with international bodies to improve infrastructure in neglected areas. These partnerships can be part of the solution to the lack of funding that hinders progress.

It is necessary to incorporate the informal settlements into the city designs to be able to provide the essential services to the inhabitants of these areas. Services such as electricity would be guaranteed for every citizen. What this implies is an upgrade in the land tenure systems and ensuring that the cities extend in a sagacious and coordinated way. The local governments, which oversee these different zones, can get a lot of advantages if they decide to make use of smart grid technologies. The areas with high migration and therefore high demand for electricity are the places where the use of the smart grid will be more beneficial. In addition to this, getting the communities involved in the discussions about their special electricity requirements is going to be the perfect way to come up with the right answers for their needs.

Another piece of the puzzle is effectively addressing wealth concentration in a meaningful way. The government needs to create policies that promote economic participation through energy-driven enterprises. Ideally, entrepreneurs should be getting the chance to thrive because they have access to affordable and reliable energy resources. Offering incentives to businesses that focus on sustainable practices could help distribute wealth more evenly. Not to forget about vocational training programs which may provide locals with the skills needed to thrive in the energy sector.

The future will survive in a world where a solid energy policy aligns with the goals of sustainability and equality. It's essential to revisit the commitment made in 1994 about equal electricity access, ensuring we have a robust oversight system in place. Keeping Eskom and local municipalities accountable is crucial for improving how electricity is provided. Plus, revamping regulatory frameworks can make it easier for private investors to step in, especially in areas that have been seen as risky.

With climate challenges limiting agricultural development in some regions, renewable energy like solar and wind could offer alternative economic opportunities. By developing hybrid energy systems that mix renewables with existing grids, we can provide a steady power supply and improve resilience to climate fluctuations. Offering bonds or other incentives could attract investment in renewable projects and open new economic avenues beyond traditional farming.

Bridging the gap between supply and demand is a bit of a conundrum as South Africa holds electricity overproduction in some areas, but market demand is not being met. To tackle this, it is necessary to have coherence between electricity infrastructure and development priorities. It is vitally important for government to develop electricity infrastructure standards and regulations that will help our grids and improved demand forecasting so there is a connection between electricity generation and a place-specific need. Development priorities must be flexible to consider operational market and policy changes and shifts, and we should have real data to bolster developmental interventions.

Ultimately, addressing energy access in South Africa is as much about planning and financing, as it is about policy changes and partnership with communities. It should be understood clearly; energy is far more than simply turning on a switch. It is about the socio-economic context, the investments to support building and keeping reliable jobs and infrastructure, and the environment and other aspects connected to better work and living conditions. Providing provinces more autonomy to plan and implement energy processes (e.g., generation, distribution) will lead to a more local response than a blanket and encapsulated response. It is also crucial to enable, or even require, regulatory changes to promote innovation in social change initiatives to allow for not only competition, but controlled interprovincial competition and cooperation, but simultaneously effective national solutions. Developing for jobs and skills training in the energy industry will need to base programs on areas of district or local needs and not simply develop generic skills. For example, rural provinces will need to support agricultural processing, tourism and renewable energy initiatives, while urban districts may spend more energy on advanced manufacturing and knowledge services. If we need to manage rural movement, we may have to discuss also growing small towns and job creation in those towns that will also eventually tie provincial economies to urban centres. Overall, the extent of success of a political cross-section will depend on speed and convenience of political alignment of decision making, on the floor of provincial and national councils, with understanding from a political perspective on political commitments to an allocation. National government will make standards and policies for guidelines and local government will make services available in areas where services are to be provided. There will be a need to check performance of regions or provinces regularly and provide adjustments if needed either policy or allocation. Finally, to progress developmental action to developmental planning, policy action may require more partnership relationship into provincial digging technical and operational ability relations, and relationships unlocking wealth access through public, private and development finance entities.

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Appendices

Appendix A: Raw data

Total: South Africa — LBPL: South African Lower Bound Poverty Line — Income poverty threshold line (Rand per Capita per Month) *(lbpl)*

1996/12/31	216
1997/12/31	239
1998/12/31	252
1999/12/31	272
2000/12/31	285
2001/12/31	305
2002/12/31	329
2003/12/31	362
2004/12/31	356
2005/12/31	363
2006/12/31	370
2007/12/31	396
2008/12/31	447
2009/12/31	456
2010/12/31	466
2011/12/31	501
2012/12/31	541
2013/12/31	572
2014/12/31	613
2015/12/31	647
2016/12/31	714
2017/12/31	758
2018/12/31	810
2019/12/31	810
2020/12/31	840
2021/12/31	890
2022/12/31	945

Source :
Quantec

Total: South Africa — Working age population (Number of persons) — Working age (15-64) *(u)*

1996/12/31	25283368
1997/12/31	25936879
1998/12/31	26577185
1999/12/31	27205503
2000/12/31	27815487
2001/12/31	28415321
2002/12/31	28999815
2003/12/31	29681838
2004/12/31	30365879
2005/12/31	31024164
2006/12/31	31656583
2007/12/31	32296110
2008/12/31	32933234
2009/12/31	33589148
2010/12/31	34242103
2011/12/31	34904477
2012/12/31	35548647
2013/12/31	36166522
2014/12/31	36801812
2015/12/31	37417691

2016/12/31	38029659
2017/12/31	38633362
2018/12/31	39236898
2019/12/31	39891609
2020/12/31	40529986
2021/12/31	41050400
2022/12/31	41681774

Source : Quantec

Access to electricity (% of population in South Africa)

1996/12/31	57,6
1997/12/31	69,5
1998/12/31	64,9
1999/12/31	71,3
2000/12/31	72,4
2001/12/31	70,2
2002/12/31	76,7
2003/12/31	78,8
2004/12/31	80,6
2005/12/31	80,8
2006/12/31	80,7
2007/12/31	82,0
2008/12/31	81,9
2009/12/31	82,6
2010/12/31	82,8
2011/12/31	83,6
2012/12/31	85,2
2013/12/31	85,2

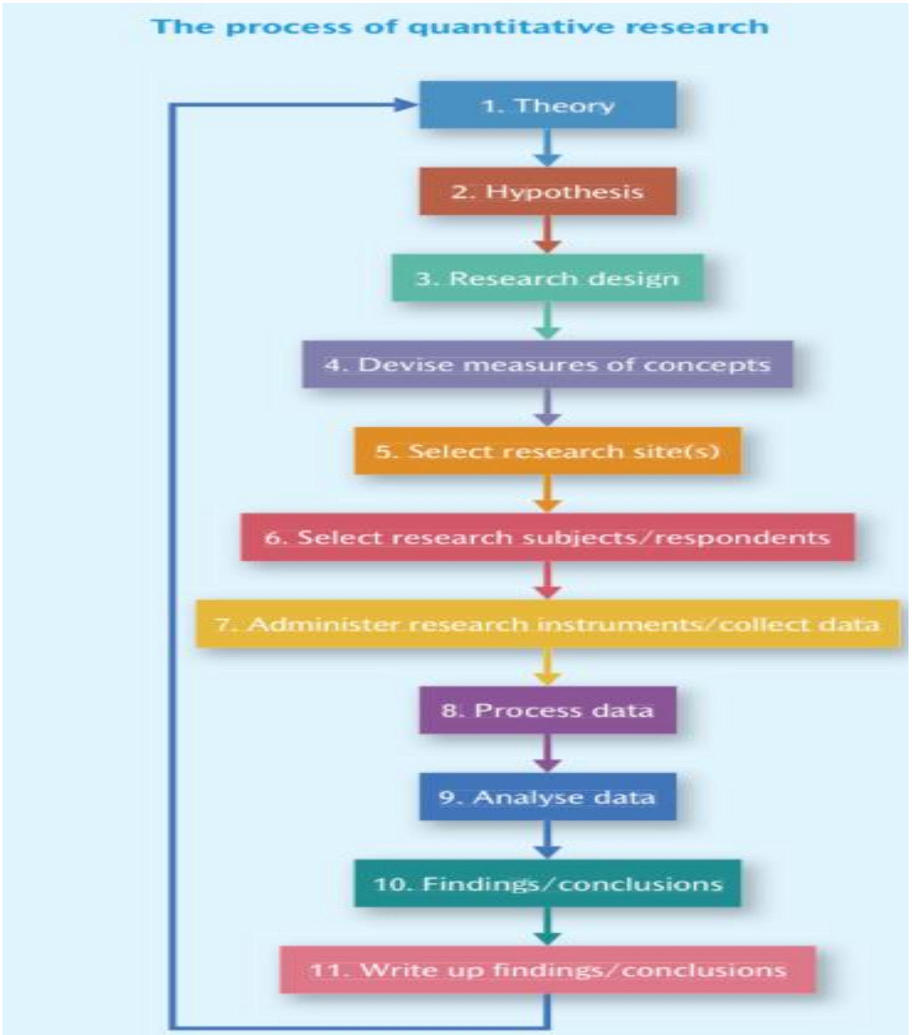
2014/12/31	85,9
2015/12/31	85,3
2016/12/31	83,9
2017/12/31	84,4
2018/12/31	84,7
2019/12/31	85,0
2020/12/31	90,0
2021/12/31	89,3
2022/12/31	86,5

Source: WorldBank data

Appendix B: Duplication procedure

This section sketches out the process of quantitative research and the steps which this study adopted. As is shown below, the process begins with theory and ends at the write up of the findings and conclusion.

Figure 1: Process of quantitative research



Source: Bryman, 2012, pg. 161

1. Theory

This refers to the stage in which the researcher seeks to understand empirical and theoretical frameworks as well as comprehend the key principles related to the chosen topic.

2. Hypothesis

This refers to the stage where the research is trying to test the relationship between the chosen variables. The researcher predicted the hypothesis based off the theoretical and empirical observed in the literature review.

3. Research Design

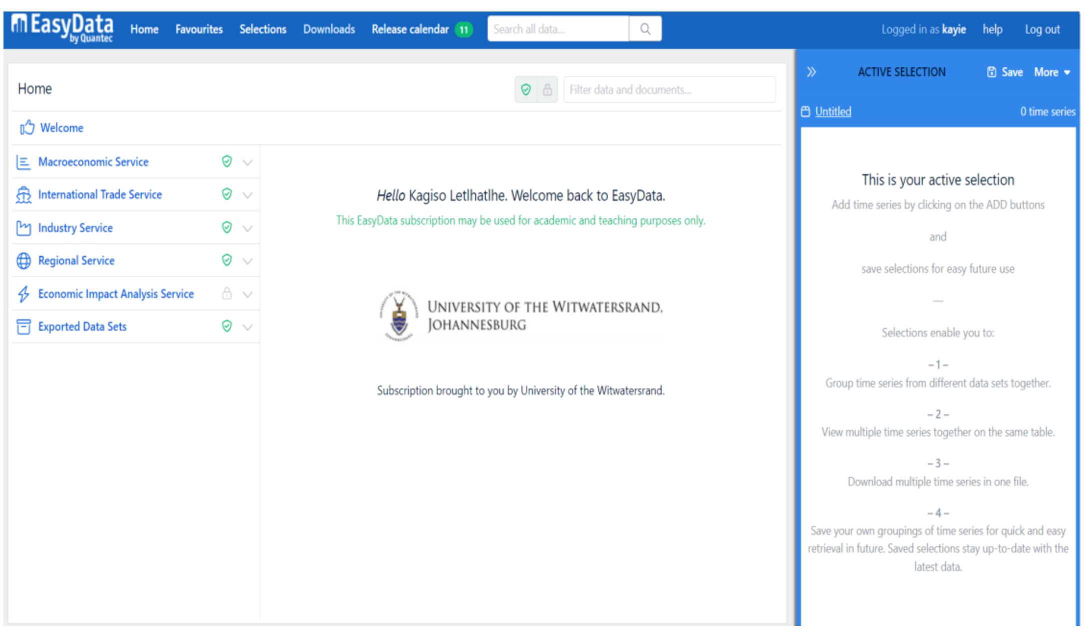
This refers to the stage where the researcher developed a structured framework in effort to address the research problem, fulfil the research objectives and answer the research questions using the empirical and theoretical frameworks selected.

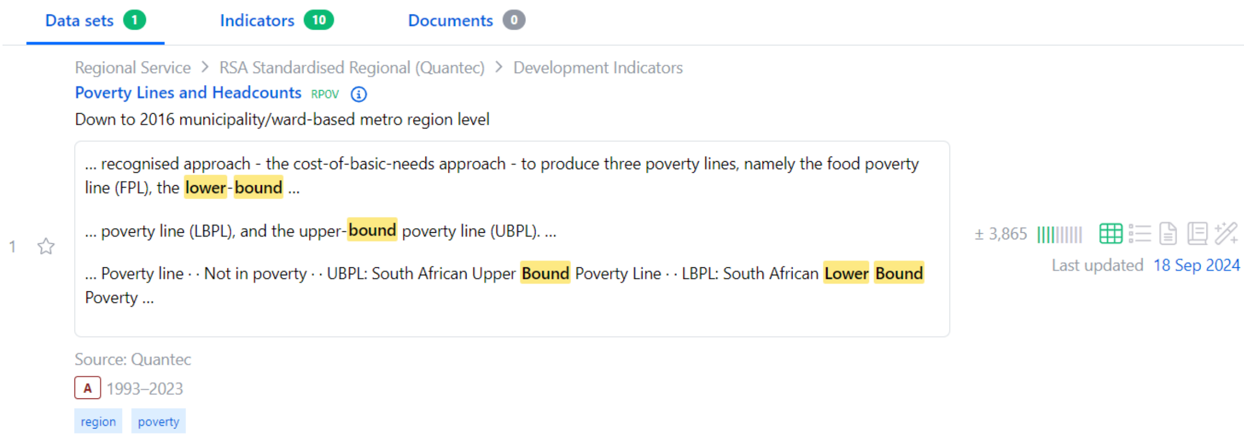
4. Devise measures of concepts

This stage outlines and gives definition to the chosen variables employed in the study and how they will be measured (e.g. electrification is used as a proxy for energy access). Guided by Sen's Capability Approach and the Human Capital Theory, the researcher made use of an additional variable named unemployment (as a proxy for productivity).

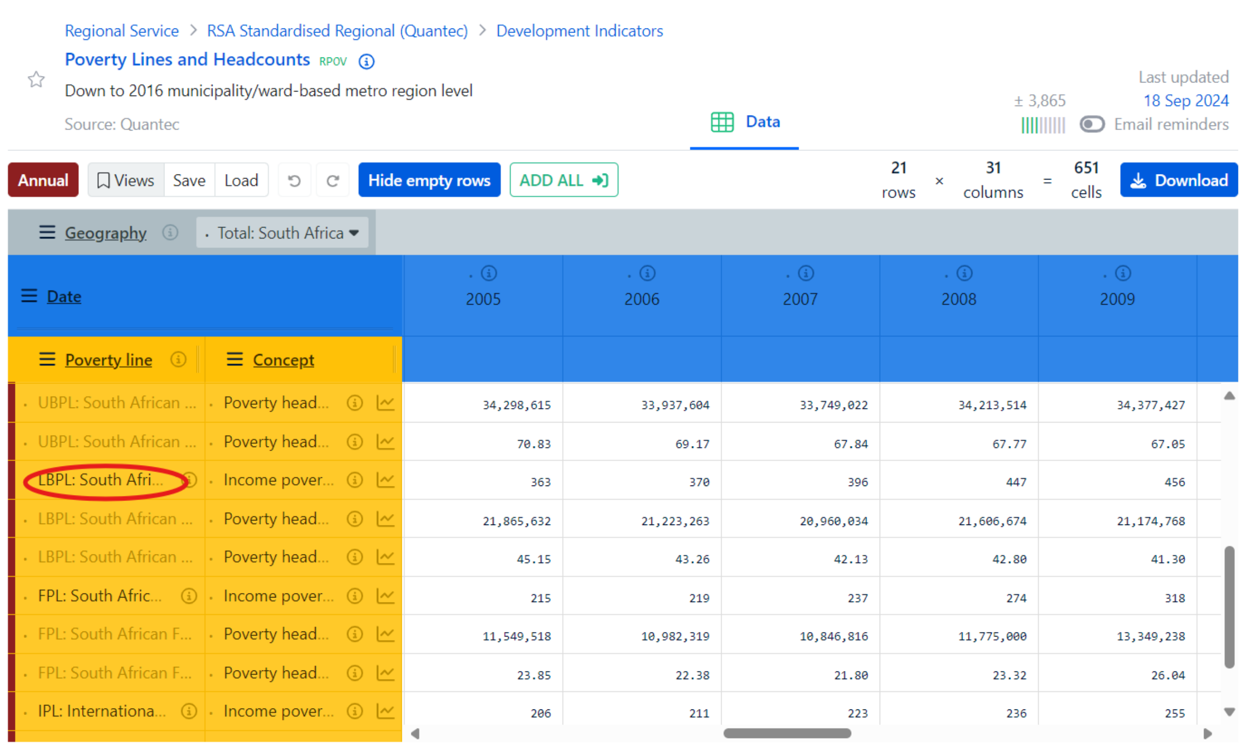
5. Selecting data (research sites)

The researcher collected data of all the variables chosen for the study. The lower-bound poverty line and unemployment variable data were collected from the Quantec website: https://www.quantec.co.za/

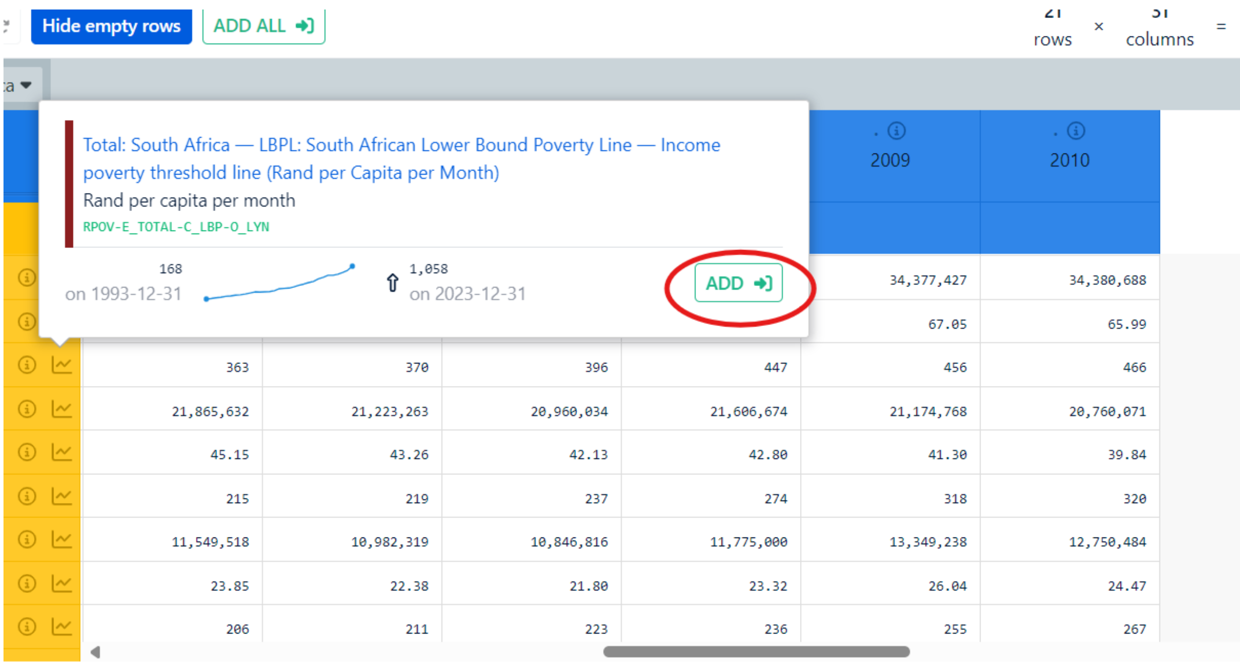
1. 

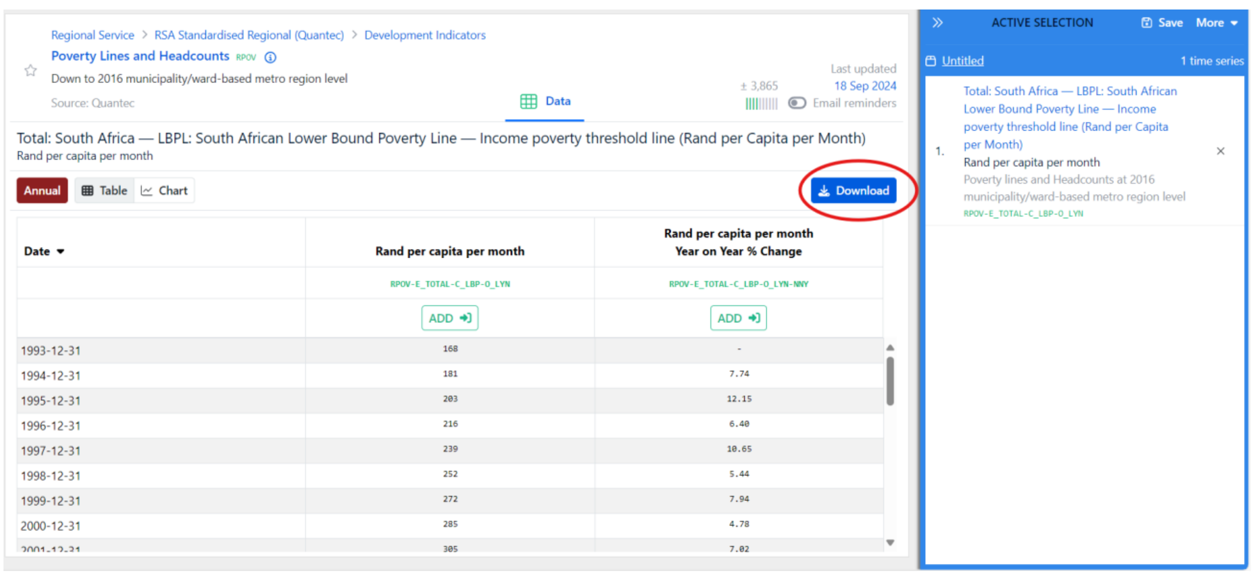

Data sets 1
Indicators 10
Documents 0
Regional Service > RSA Standardised Regional (Quantec) > Development Indicators
Poverty Lines and Headcounts RPOV
Down to 2016 municipality/ward-based metro region level
... recognised approach - the cost-of-basic-needs approach - to produce three poverty lines, namely the food poverty line (FPL), the lower-bound ...
... poverty line (LBPL), and the upper-bound poverty line (UBPL). ...
... Poverty line · · Not in poverty · · UBPL: South African Upper Bound Poverty Line · · LBPL: South African Lower Bound Poverty ...
1
± 3,865
Last updated 18 Sep 2024
Source: Quantec
A 1993–2023
region
poverty

2.


Regional Service > RSA Standardised Regional (Quantec) > Development Indicators
Poverty Lines and Headcounts RPOV
Down to 2016 municipality/ward-based metro region level
Source: Quantec
Data
Last updated
± 3,865 18 Sep 2024
Email reminders
Annual
Views
Save
Load
Hide empty rows
ADD ALL
21 rows × 31 columns = 651 cells
Download
Geography
Total: South Africa
Date
2005
2006
2007
2008
2009
Poverty line
Concept
UBPL: South African ... Poverty head... 34,298,615 33,937,604 33,749,022 34,213,514 34,377,427
UBPL: South African ... Poverty head... 70.83 69.17 67.84 67.77 67.05
LBPL: South Afri... Income pover... 363 370 396 447 456
LBPL: South African ... Poverty head... 21,865,632 21,223,263 20,960,034 21,606,674 21,174,768
LBPL: South African ... Poverty head... 45.15 43.26 42.13 42.80 41.30
FPL: South Afric... Income pover... 215 219 237 274 318
FPL: South African F... Poverty head... 11,549,518 10,982,319 10,846,816 11,775,000 13,349,238
FPL: South African F... Poverty head... 23.85 22.38 21.80 23.32 26.04
IPL: Internationa... Income pover... 206 211 223 236 255

3.

4. 

5. 

All five images extracted from Quantec, 2024.

The access to electricity variable data was collected from the World Bank Open Data website: data.worldbank.org

3. Process data

Firstly, the raw data (as presented in Appendix A) was loaded into R as a csv. Excel file. Once the data was imported, the research first performed descriptive statistics to analyse data in this study as shown under 4.1. The researcher then used R to generate graphs (plot function) from the raw data which allowed for the identification of patterns and trends.

4. Analyse data

A Pearson Correlation analysis was then conducted. During this process, the data that was inserted into R to obtain descriptive statistics was also analyzed concurrently. This was achieved through using the cor () and cor.test functions. The aim of this step was to measure the relationship between access to energy and poverty alleviation. Similarly for the following analysis in 4.2.2, linear regression analysis, which required basic modelling to establish the R squared, coefficients and p values.

4. Findings and conclusions

The researcher gathered results from 4.1 and 4.2 and made relevant analyses in 4.3, where findings were interpreted in context and linked to research objectives and knowledge.

5. Write up findings with closing remarks

This refers to the stage where the key findings were briefly highlighted, and their significance reaffirmed and proposing recommendation and further areas of future research.