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# Innovative Financing Models for Rural Electrification in the Eastern Cape, South Africa


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**A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership**

**Johannesburg, 2022**

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# DECLARATION

I, THOBILE MAPHOSA, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: THOBILE MAPHOSA Signature: 

Signed at PRETORIA

On the 20th of June 2022

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# LIST OF ACRONYMS

| | |
|---|---|
| CDM | Clean Development Mechanism |
| CIF | Climate Investment Fund |
| CSIR | Council for Scientific Industrial Research |
| DER | Distributed Energy Resources |
| DG | Distributed Generation |
| DOE | Department of Energy |
| ESMAP | Energy Sector Management Assistance Program |
| FBE | Free Basic Electrification |
| FGD | Focused Group Discussions |
| GEF | Global Environment Facility |
| GPOBA | Global Partnership for Output Based Aid |
| IEA | International Energy Agency |
| INEP | Integrated National Electrification Programme |
| MFI | Micro-Finance Institution |
| NDP | National Development Plan |
| PPIAF | Public-Private Infrastructure Advisory Facility |
| PPP | Public-Private Partnership |
| PV | Photovoltaic |
| RDP | Reconstruction Development Programme |
| RE | Rural Electrification |

| | |
|---|---|
| REA | Rural Electrification Agency |
| RECS | Rural Electrification Collective Scheme |
| REIPPPP | Renewable Energy Independent Project Producer Procurement Programme |
| REP | Renewable Energy Project |
| RET | Renewable Energy Technology |
| ROI | Return On Investment |
| SADC | Southern African Development Community |
| SANEDI | South African National Energy Development Institute |
| SAPP | Southern African Power Pool |
| SHS | Solar Home Systems |
| SDG | Sustainable Development Goal |
| SSA | Sub-Saharan Africa |
| SSEG | Small Scale Embedded Generation |
| UN | United Nations |

# CHAPTER 1. INTRODUCTION

## 1.1 Purpose of the study

This research report is based on a case study that examines innovative financing models for rural electrification in the Eastern Cape, South Africa.

This qualitative study examines innovative financing models deployed to extend electricity in rural areas and promote renewable energy technology innovation in the Eastern Cape, South Africa.

## 1.2 Context of the study

One of the fundamental enigmas threatening the livelihoods of millions of impoverished people worldwide is energy insecurity (Chauhan & Saini, 2015). The overwhelming majority of the global population lives in developing countries, and more than one-third of developing countries are rural areas with no access to commercial forms of energy (Chauhan & Saini, 2015). Yet, rural electrification is moving at a painfully slow pace in most of the developing world. In many African and South Asian countries, it is even less than rural population growth (Barnes, 2010).

Electrification is critical for improving rural people's socioeconomic conditions, contributing to economic development, and promoting livelihood security by supplying electricity as a productive input in agriculture and rural industries, improving people's quality of life (Thapa et al., 2020). Furthermore, a large proportion of the global population lives in the countryside; therefore, focusing on sustainable rural electrification is another critical factor in protecting our environment, particularly when it comes to climate change and global warming (Barreto, 2018).

Various scholars like Ngoepe et al., (2016), Aswat et al., and Battacharyya (2016) have investigated concepts such as renewable energy technologies, the impact

of fossil fuels, drivers and barriers to rural electrification, funding methods, and environmental impact in the study of rural electrification.

Rural electrification in developing countries is moving at a snail's pace due to high costs, necessitating a significant capital investment and extensive program planning. The expenses include the purchasing and transportation of the equipment and system components and the acquisition or development of expertise for installing, operating, controlling, and maintaining the systems. Aside from the initial capital and planning costs, decentralized electrical systems, such as photovoltaic (PV), solar home systems (SHS) and renewable energy technologies, are typically expensive compared to the average individual income in developing countries. Therefore, securing financing is a critical step in expanding decentralised electricity in developing countries, whether via photovoltaic (PV) systems or other means.

Over the past two decades, rural electrification has gained prominence as a viable means of improving living conditions (Benavente et al., 2019). Most government policies have made rural electrification a priority to minimise the gap between those who have and those who do not yet have access to electricity (Mainali & Silveira, 2011). Several governments also attempt to deal with the persistent affordability gap that has made rural electrification subsidies dependant (Phillips et al., 2020).

Regarding access to electricity, South Africa is atypical of sub-Saharan Africa (SSA), having a unique array of threats and opportunities (CSIR, 2017). South Africa is an energy-intensive, medium-income economy with an annual per capita consumption of 4,326 kWh. Approximate 9 per cent of 45GW generation capacity in South Africa is renewable, while 86 per cent is coal-based (DOE, 2019b). Therefore, there is a tremendous potential for renewable energies to accelerate the transition towards a more efficient environment.

South Africa’s electrification is atypically high at 91 per cent, urban electrification at 92 per cent and rural electrification at 90 per cent. Compared to an average of 48% in the sub-Saharan area with a rural electrification rate of 32 per cent in 2018 (Worldbank, 2018). According to the South African National Energy Development Institute, despite South Africa’s success in its programmes for electrification of

rural areas compared to its counterparts in SSA, more than three million people residing in rural areas still lack access to electricity, according to the South African National Energy Development Institute (SANEDI, 2019). As a result, approximately four million rural households in South Africa rely on fuelwood for heating and cooking (Ningi et al., 2020).

The Eastern Cape is the second largest province in South Africa, and it has historically lagged behind the majority of the country's provinces (PMG, 2011). The unemployment rate is the highest at 37 per cent StatsSA (2019), and the region suffers abject poverty. An approximated 67 per cent of the Eastern Cape's population is multidimensionally poor and lives below the poverty datum line. Westaway (2012) argues that the legacies can be attributed to apartheid, where the provincial administration of Eastern Cape have inherited the largely poor Transkei and Ciskei., Ningi et al. (2020) further attest that almost 36% of people in the province relies solely on social support or grant. It is one of the regions with the highest rural population. Some communities still rely on alternative energy sources such as paraffin, wood and cow dung for different household activities, including lighting, cooking and food preservation, despite progress in other provinces, reducing reliance on energy sources associated with human and environmental illness.

The initial expense to connect new rural customers is a barrier that remains an expensive proposition. Public financing that addresses affordability issues will be required for countries to achieve universal access (Phillips et al., 2020). The challenges have led to the upsurge of alternatives to grid solutions (off-grid), primarily in the rural areas where despite the continuous expansion of the electricity grid, some areas are still inaccessible and disperse (Benavente et al., 2019).

The low and middle-income countries facing electricity challenges today are dealing with a new playbook of potential solutions. The solutions include drivers such as technological developments in distributed energy systems, monitoring and payment systems, and end-use equipment efficiency that will make off-grid electricity systems the lowest-cost and most desirable choice for the majority of unconnected rural communities (Phillips et al., 2020).

The fall of solar and battery prices, production of ultra-efficient equipment and appliances lead to a very different collection of potential paths for future electrification (Olówósejéjé et al., 2020). The International Energy Agency (IEA) estimates that over the coming decade, more than 70% of the rural population in the world gaining electricity will rely on the low-cost solutions of off-grid systems (IEA, 2017). The success of rural electrification will also be dependent on the transition from the conventional grid extension approach, and the rate of adaptation of innovative technology and finance approaches for off-grid solutions, especially in the SSA region (Vanadzina et al., 2019). The region needs to reconsider some of the enormous capital investment intended for expanding centralised generation. Simultaneously adopt Distributed Generation (DG) energy technologies that are modern, efficient, and based on sustainable resources, removing negative externalities associated with environmental pollution (Soumonni & Soumonni, 2011).

The South African government plans to electrify or achieve universal electrification by 2025 (97 per cent in the case of traditional households) (Scharfetter & Van Dijk, 2017). For this purpose, both grid-tied and high-quality and cost-effective off-grid technologies are being used (Jamal, 2015).

Financing models are critical in developing strategies for expanding electricity access about dealing with high connection costs and low affordability, mobilising financial resources, designing system ownership and management models, and supporting productive use of energy for development (Phillips et al., 2020).

A literature review on financial models for rural electrification has shown that various schools of thought exist around this study. Some scholars argue in favour of different models Estache (2006), while Kouassi and Pineau (2011) state that Sub-Saharan African countries rely on public finance for rural electrification (capital and maintenance expenditures). However, introducing new decentralised or off-grid energy technologies with the global objective of carbon reduction has increased participation or interest from the private sector. Scholars such as Eberhard et al. (2014) and Roy and Nightingale (2010) support private finance. There is also a group of writers who favour the combination of public and private funding in the form of a public-private partnership. Scholars such as Ajakaiye and

Ncube (2010) and Twesigye (2019) contend that rural electrification is structurally unprofitable and indispensable to social and economic development. Therefore, even in developed countries, it has never been the product of a purely commercial strategy and will never be done with private funding, but it requires substantial public financing.

In the context of the Eastern Cape, this is inconclusive, and it forms one of the primary motivations for this research. A critical insight from this study is that the literature suggests a correlation between financing models for rural electrification and the country's national context. The recent surge in renewable energy technology innovation has led to a growing interest in innovative financing models, especially for electrifying rural communities (Bhattacharyya, 2013).

South Africa is currently heavily reliant on fossil fuels. Approximately 90 per cent of its electricity is generated from low-cost coal (DOE, 2019b), and in 2019, coal contributed 200 210 GWh, which constituted about 92 per cent of the energy mix (Eskom, 2019). However, it remains the highest emitter of carbon dioxide in Africa (~45 per cent of the continental total) and seventh in the world (Joshua et al., 2020).

Lower access rates, as well as a scarcity of reliable and affordable electricity, pose a threat to Africa's rapid economic development (Olanrele, 2020). According to the World Bank's analysis of the SSA economy, technical innovations, particularly in solar energy, offer the potential for rapid progress in electricity provision by integrating grid expansion with mini-grids and home-scale systems (Chuhan-Pole et al., 2018). However, leapfrogging traditional phases of national grid-based electrification will necessitate a mix of different systems to meet various needs. Therefore, leveraging the private sector will be critical to scale-up electrification (Calderon et al., 2019).

Soumonni (2013) contends that African countries can and should strive to advance through the entire innovation cycle, particularly in renewable energy. Systems of innovation (SI) have the potential to increase access to electricity, and the concept of "learning" is considered a significant driver of innovation and production (Soumonni, 2013).

The concept of learning is central to SI thinking. It can be viewed as a mechanism of technological transformation accomplished through diffusion, adoption of innovations created elsewhere, and incremental or gradual innovation. (Viotti, 2002). According to (Lundvall, 2016), in the context of non-industrialised or late industrialising economies, much of the implicit and localised learning occurs through the DUI (Doing, Using and Interacting) mode.

As evidenced by key national planning strategies such as the National Development Plan (NDP), the National Systems of Innovation (NSI) is a critical concept in South African policy discourse. The country's potential for innovation is attributed to its future industrial development, which leads to social and economic growth (Manzini, 2015). Social and economic growth depends on both imported and local innovations. The innovations' effect depends on their extent of dissemination across society and industry (Cunningham, 2012). Therefore, innovation in financial models and technology are potential accelerants for unmet electricity sectors in the Eastern Cape, South Africa and other sub-Saharan African regions to leapfrog to clean energy to expedite electricity access in rural communities (Batinge et al., 2017).

### 1.2.1 The State of Electrification in the SADC Region

The Southern African Development Community (SADC) region has a rural population that people characterise in the base segment of the economic pyramid. Due to their economic vulnerability and position at the periphery of the market economy, the financial disparity between rural electrification costs and affordability is enormous (C. G. Monyei et al., 2018). The funding mechanisms required to make rural electrification feasible generally include finance of electricity through Public, Private and Public-Private Partnerships (PPPs). The PPPs play a pivotal role in optimising and developing innovative funding solutions to ensure suitable production and distribution of electricity, especially in rural areas (Ngoepe et al., 2018). According to Mainali and Silveira (2011), identifying novel strategies of attracting capital and increasing funding is vital to rural electrification and, eventually, rural development. Experts suggest that focusing on end-user financing as offered by Micro-Finance Institutions (MFIs) could be

instrumental as it increases the viability of financing mechanisms to make Renewable Energy Technologies (RETs) more affordable, especially in the rural areas in most African countries (Soumonni, Oji & Ojah, 2016).

In SSA countries, rising rural marginalisation has resulted in profound economic development challenges and has sat alongside a surge in energy-poor households in rural communities due to lack of access to electricity (IEA, 2011) and (Ikejemba et al., 2017). This is evidenced in the significant variation in the rates of electricity access throughout rural and urban areas and between income groups (Prasad, 2011). Hence, in attempting to close the widening divide between urban and rural areas, several countries in SSA have adopted other interventions, notably the Solar Home Systems (SHS) (Moner-Girona et al., 2018). However, despite the widespread dissemination of the SHS, there has been no discernible or systematic decrease in rural "peripheralisation"[1] and poverty alleviation (C. G. Monyei et al., 2018). Conversely, South Africa is an appropriate example of how the SHS intervention unwittingly created instances of rural peripheralisation. Despite substantial government expenditure on SHS, an assessment of South African socioeconomic effects shows that households' energy needs are rarely satisfied because of the low power capabilities of the system, according to Azimoh et al. (2016).

Numerous elements are impediments liable for hindering high levels of rural electrification, amongst which are, lack of favourable or enabling policies; geographic locations and setup of rural communities and finally, poverty or low-income status of rural communities versus the high cost of grid connections (Yadav et al., 2019). Traditional financing methods, which are the main financing instruments, are debt and equity, including senior debt, venture capital and project finance (Justice, 2009) and (Olmos et al., 2012). These models are preferred for large-scale financing of projects, mainly through integration with regions, as validated by the goals of economies of scale and efficiency, the reliability and security of supply (Moner-Girona et al., 2018). However, the models

[1] The meaning of "peripheralisation" in this context has been extended to include discrimination in quality and quantity of electricity access to households of the same income bracket due to their proximity to the national grid.

have not moved the needle towards universal rural electrification significantly (Vanadzina et al., 2019).

The rural populace has continuously benefited from government funding. It is also said that no country in the world has achieved complete electrification without significantly subsidising connections for last-mile households (Guay, 2018). However, the high dependence on public funds makes energy projects multitudinously uncertain and difficult to manage. They have characteristics such as protracted durations, extensive budgets, multiple stakeholders, and uncertainty that are difficult to model, execute and manage effectively (Ikejemba et al., 2017).

Rural electrification funding is complex, and novel, innovative business models, must be built to realise higher private sector investments (Kyriakarakos et al., 2020). To address the challenge of funding Renewable Energy Technologies (RETs), various strategies and models have been built or developed to enhance adoption and stimulate economic development (Carley et al., 2012). These include (i) the public control model through a partner organisation; (ii) the bank and microfinance model (iii) the local business model (Roy, P., & Nightingale, K, 2010). The critical features identified from these models are a substantial financial sponsor and credit access; local control of financial resources; business approach; local involvement and approaches; technical expertise and low project complexities that public agencies can manage. Experts suggest that Renewable Energy Projects (REP) investments should focus on end-user financing, micro to medium-sized companies, small scale project funding for aggregate community development, and household finance (Soumonni, Oji, & Ojah, 2016).

Low population densities commonly typify rural areas with dispersed concentrations and, consequently, low-load factors (Ehnberg et al., 2020). The advent of cost-efficient off-grid power supply platforms was a transversal transition engine in the last decade (Phillips et al., 2020).

A thinly spread population over a large surface area relates to an increase in the costs of setting up energy infrastructure, prices that are non-cost reflective and unattractive returns on investment (ROI) C. Ketlogetswe et al. (2007). Due to this

geographical setup and population spread, other scholars believe that the SADC's objective to achieve equitable and universal electricity access targets will require innovative technologies, strategies, and financing of off-grid rural sectors. A space that is currently being tapped by the emerging energy entrepreneurs Ngoepe et al. (2018). Rural electrification in SADC can be accelerated by leveraging the off-grid area where the new entrants leverage the existing momentum in diffusing new technologies, notably Solar Home Systems (SHS), microgrids, pico-solar systems and leveraging on innovative financing (Ngoepe et al., 2018).

The SSA region lags behind the rest of the world, with most of its rural population dependent on traditional forms of bioenergy, which have substantial social and environmental costs (Chaurey et al., 2004). Energy poverty is a constant challenge as most countries still rely on centralised generation and distribution that has not always afforded equitable access (Yadav et al., 2019). According to REA (2011), the inability of grid extension efforts to catch up with the ever-increasing population in the rural areas has left the rural electrification levels in a dire state in SSA. However, the decentralised energy technologies are increasingly achieving financial parity and have certain environmental benefits over grid expansion, especially in remote rural areas (Yadav et al., 2019).

### 1.2.2 Post-Apartheid History of Electrification in South Africa

South Africa possesses a remarkable electricity programme compared to its counterparts in the SADC region. It presents a unique situation; rural electrification has succeeded predominantly through the expansion of the grid and high quality off-grid solar home systems under the Reconstruction Development Programme (RDP) and the Integrated National Electrification Program (INEP) (DOE, 2019a).

Despite the strong apartheid policies underpinning the electrification programme where only one-third of the populace had electricity access before 1990, it managed to double that proportion within a decade. According to Bernard Bekker et al. (2008), the voting of a new post-apartheid government post-1994 and the demise of apartheid contributed immensely to an overhaul of innovation and

financing, policy, planning, technology and institutional developments leading to access to electricity for over 5 million households between 1990 and 2007.

The 1996 census report showed that electricity access in South Africa was at 58%, which was a remarkable improvement from below 35% before 1990; it further revealed disparities in other essential services (StatsSA, 2000). The improvement was attributed to legacies left by the apartheid policies, which included a broadly racially defined contrast between rich and poor; and a history of racial discrimination in infrastructure provision (Bernard Bekker et al., 2008). Electricity distribution infrastructure development was highly unequal, and a substantial majority of the rural population was consequently migrated into autonomous territories. According to Davis (1997), rural communities were among the most marginalised in the country, with almost no infrastructure development due to low load profiles, mismanagement of funds, and a lack of industrial customers.

South Africa's success in its electrification programme depended on three critical phases: institutional/policy/planning, financing, and technological development. Financing is a crucial challenge that needed to be resolved, considering the cost of electrification, and determining the affordable tariff structures. Innovation and introducing new technologies brought down the overall costs until 2003 when the programme started to electrify remote areas; the expenses significantly increased (Bekker et al., 2008).

The Department of Energy recorded that more than 7,4 million households were electrified in South Africa between 1994 and 31 March 2018 through the RDP and INEP programmes DOE (2019a). In addition, the Free Basic Electrification Policy was an essential element in the INEP used to provide relief to poor un-electrified rural communities for social and economic benefit (Azimoh et al., 2015).

The private financing sector, especially banks, has taken advantage of the rapid growth in distributed energy generation by providing innovative energy finance. The recent evident success has been funding the South African Renewable

Energy Independent Power Producers Procurement Programme (REIPPPP) (Nedbank, 2019).

The public utility Eskom dominates the power sector of South Africa, and it is the primary electricity provider, generating more than 90 per cent of the electricity in South Africa and about 40 per cent of that in Africa (Eskom, 2019). The electricity supply industry includes the distribution, transmission, generation, and sale of electricity. Eskom operates most baseload and peaking capacity, but the role of Independent Power Producers (IPPs) is expanding. According to Eskom (2019), the coal-fired stations are the main primary energy source generating 200 000GWh. The value chains supply electricity to South Africa and the SADC region with an integrated network that connects the Southern Africa Power Pool (SAPP). The South African RE level is well established compared to other countries in the SADC region; despite having a line network that stretches over 387 000 km, there are still sections in the rural areas that remain with fragile power supply at the outskirts of the grid.

While studies have been conducted to examine barriers and drivers of electrification in other SADC or SSA countries (Ahlborg & Hammar, 2014), many experiences of successful RE are derived from Latin America and Asia (Khan, 2019). However, the drivers and barriers of the regions mentioned earlier cannot be directly transferable to the context of South Africa and are not necessarily generalisable due to differing economic, social and political contexts across countries.

## 1.3 Research problem

The South African government plans to electrify or achieve universal electrification by 2025 (97 per cent in the case of traditional households) (Scharfetter & Van Dijk, 2017). Additionally, the Department of Energy seeks to connect 90 per cent of the households to the grid, and seven per cent will use the off-grid options Bongwe (2013). For this purpose, both grid-tied and high-quality and cost-effective off-grid technologies are being used (Jamal, 2015). The two

electrification options considered are not without challenges or limitations in South Africa's rural communities.

South Africa is currently heavily dependent on fossil-based fuels. Approximately 90 per cent of its energy comes from low-cost coal, 60 per cent of the country's oil is imported, while the rest is produced from coal-to-liquid technology (DOE, 2019b). As a result, South Africa is Africa's highest emitter of carbon dioxide in Africa (~45 per cent of the continental total) and the 7$^{th}$ largest in the world in Carbon Dioxide (Joshua et al., 2020). Therefore, this study will explore the possibility of promoting wind and solar as renewable energy sources in electrifying public facilities, households, and enterprises in the study site.

According to Eskom's Integrated Results 2019, Eskom generated energy worth 218 939 GWh for the year; coal contributed 200 210 GWh, which constitutes about 92 per cent of the energy mix (Eskom, 2019). Renewables account for about 7 per cent of generated energy in South Africa. In the Integrated Resource Plan of 2010 (IRP), the Government's 2030 target is to secure 42 per cent of new electricity supply from renewable energy sources by 2030. The REIPPP, in terms of the national targets for renewable energy capacity goals, as outlined by the Integrated Resource Plan (IRP) and National Development Plan (NDP), had achieved 22 per cent and 57 per cent of the 2030 and 2020 targets by the end of June 2017 respectively (DOE, 2019b).

The conventional large-scale centralised power infrastructure has driven South Africa's electrification programmes, or utility (Eskom) concentrated historically on-grid power extension (Ngoepe et al., 2018). Similarly to other sub-Saharan African countries, public finance has been the dominant financing model for rural electrification (capital and maintenance expenditures) (Kouassi & Pineau, 2011). According to the CSIR (2017), on-grid projects under the Integrated National Electrification Plan (INEP) obtain almost 100% capital and operating cost subsidies. In contrast, off-grid initiatives do not receive equivalent financing, and this impacts rural electrification.

The energy transition is vital as part of efforts to increase and decentralise electricity access in rural communities. Adoption of green energy, in particular, is

gathering traction as a conduit to, or form of, equitable access for all (Batinge et al., 2017). This will play a pivotal role in combating the change in climate, degradation of the environment and energy security (Chauhan & Saini, 2015). Renewable energy may be used in the national grid as a source of power generation or stability of the network or in non-grid areas as an ideal means of generating electricity for rural electrification (Ngoepe et al., 2018). The main drivers or dependency on fossil fuels, especially coal, are cost factors and the abundant availability of coal. The main barriers facing the rapid deployment of renewables for electricity generation are cost, storage, intermittence, public acceptance and grid reliability (Ahlborg & Hammar, 2014).

Leapfrogging to renewable energy as an off-grid alternative is considered a viable route to attaining energy security (Batinge et al., 2017). The recent surge in renewable energy technology innovation has led to a growing interest in innovative financing models, especially electrification of rural sectors using off-grid options (Chuhan-Pole et al., 2018).

Despite South Africa's success in rural electrification programmes compared to its sub-Saharan region counterparts, more than three million people in rural areas still do not have access to electricity (SANEDI, 2019). This leaves a substantial populace component without adequate energy access or forming part of the unmet electricity market. As a result, these rural regions that remain particularly underserved in electricity use and access are impacted by poverty, lack of development and economic growth (Stern et al., 2019). According to Oji, Ojah, & Soumonni (2016), the growing shortage of access to reliable energy poses significant challenges for economic development in SSA countries, notwithstanding the proliferation of electricity initiatives in the rural areas over the past two decades (Schillebeeckx et al., 2012).

In light of the above, it is evident that energy is a capital-intensive investment dominated by fossil fuels. This persistent shortage of electricity supply is primarily due to the financial constraints and limited resources apportioned to the rural sector.

Rural electrification by renewable energy technologies needs innovative financing models that can aid in addressing a fundamental enigmas of energy access and security, which currently affect a significant rural populace globally (Mainali & Silveira, 2011). Alternative financing methods can pave the path for low-cost non-conventional energy technologies and hasten their development. Furthermore, their adoption is expected to eliminate the government's reliance on expensive grid solutions associated with lower electrification rates and other constraints identified in the literature review (Nayyar et al., 2014). Therefore, the study seeks to examine innovative financing models deployed to extend electricity in rural areas and promote renewable energy technology innovation.

## 1.4 Research Questions

This research aims to address the following questions:

1. What are the main drivers and barriers with respect to rural electrification in the Eastern Cape, South Africa?

2. What financing models, whether innovative or traditional, have been deployed for the extension of rural electrification in Eastern Cape, South Africa?

3. How can innovative financing further promote renewable energy technology innovation (that is beyond R&D) to support rural electrification at the study site?

## 1.5 Significance of the study

This study explores the existing financing models and identifies specific drivers and barriers to rural electrification. It will further investigate how innovative financing can promote renewable energy technology innovation to stimulate electrification in the rural Eastern Cape. The research will move beyond the objective of universal electrification in the underserved rural areas or unmet

electricity markets by leapfrogging to renewable energy. In South Africa, rural electrification is high compared to its counterparts in the SSA region. However, there is still a substantial portion of the populace that remains without access to electricity. Another objective is to transition from the current coal-based energy resource to renewable, sustainable, and clean energy-based resources. Therefore, the question of financing will remain a critical issue in the foreseeable future beyond striving to accelerate access to electricity by using the opportunity to leapfrog the fossil-based energy regime to embrace a clean or renewable energy regime.

Much research on rural electrification has been done from a global perspective and experience derived from other continents like Asia and Latin America. Therefore, these financing models in different sectors of the world cannot be generalisable, and neither can they be transferable to the context of the rural Eastern Cape, South Africa (Chaurey et al., 2004); (Ying et al., 2006); (Bhattacharyya & Ohiare, 2012); (Rathi & Vermaak, 2018); (Cherni & Preston, 2007); (Palit & Chaurey, 2011).

Although much of the Eastern Cape has been electrified, global trends and global agreements about climate change show increasingly concerted efforts to pursue new technologies that favour the production of clean energy instead of electricity generated from coal and other fossil energy sources. This is leading to renewed calls for new clean energy technologies. Innovative financing models will play a critical role in delivering electricity to all using renewable energy technologies. This study will assist the Government of South Africa and private players to consider essential issues in choosing suitable financing mechanisms for the electrification of rural areas in the Eastern Cape.

This research's objective is to contribute to the body of knowledge on innovative financing models for rural electrification in the Eastern Cape. It will provide relevant and vital insights that could spur or fast track rural electrification and provide potential solutions to the existing challenges. The study will benefit the government, donors, private sector, financiers, energy experts, civil society, and rural communities. It will further help the SADC community and South Africa on future electrification development in the energy industry and provide insights to

other countries experiencing dismal rural electrification. Lastly, this study will contribute to the scholarly community, literature and add to the body of knowledge about strategies used in the Eastern Cape, South Africa.

## 1.6 Delimitations of the study

The objective of this study was to examine innovative financing models and investigate how renewable energy technology innovation can be promoted to stimulate rural electrification in the Eastern Cape, South Africa, through the use of innovative financing models. Therefore, the delimitations were as follows:

1. The scope of this study was limited to the Eastern Cape, South Africa.
2. This study confined itself to interviewing the energy experts and respondents who know and experience rural electrification.
3. The calibre of the sampled population was taken from South Africa, the study area and stakeholder institutions affiliated with the study area from an electrification perspective.

## 1.7 Definition of terms

This part of the research report is intended to assist with understanding how terms are used, when reading, interpreting, and evaluating this research. In the context of the application of this analysis, general terms and phrases are also included.

**Energy Technology Innovation**

It is a series of processes whereby energy technology advancements are conceived, studied, built, exhibited, and optimised in environments from the laboratory to the commercial marketplace; and disseminated into widespread use. The technological improvements may be enhancements of existing technologies or their substitution by significantly different ones. Innovation, then, does not consist of research and development (R&D) alone; it is not complete until it incorporates the further phases through which new technologies or

improvements achieve widespread dissemination or application (Gallagher et al., 2006).

**Innovative Financing**

This is a financing strategy for businesses and projects that have a sustainable social and environmental effect. It seeks to use all the financial and philanthropic tools available to support their growth and promptly develop new ones if existing means are not practical (Ngoepe et al., 2018).

**Rural Area**

A rural area is a zone outside a town or city that is heavily populated. Rural areas are typically not metropolitan areas and, in contrast with urban areas with more significant populations, generally are large open areas with few dwellings and few inhabitants (Safeopidia, 2020). The Census Bureau defines rural as "any territory, housing or population not in an urban area" USDA (2019).

**Urban Area**

The built or highly populated areas include the town itself, suburbs and continuously inhabited places. It can be less or more extensive than the city itself, including the city and its outlying suburban area or a thickly populated surrounding countryside (Breckenkamp et al., 2015).

**Electrification**

It is the connection between a house, town, or area with a supply of electricity.

**Barriers**

These factors hinder the deployment of new technology; it may include economic, technical, political, social or environmental (Ahlborg & Hammar, 2014).

**Drivers**

These factors promote the deployments of new technology; it includes political, technical, social, economic or environmental (Ahlborg & Hammar, 2014).

### On-grid Electrification

A central power or power system consists of an integrated grid to transmit energy from generators to customers (IEA, 2011).

### Mini-grid Electrification

A 'microgrid,' also known as an independent grid, is a collection of electricity generators and possibly energy storage systems interconnected to a distribution network and provide electricity to a localised consumer population. They include small-scale power generation (10 kW to 10 MW) that serves a small number of customers through a distribution system that can operate independently of national electricity transmission networks (Bhattacharyya & Palit, 2016).

### Off-grid Electrification

A decentralised system that requires less land than a utility-scale renewable project may have fewer distance transmission losses but supplying electricity like a conventional grid link (as only a local customer or area is served). Furthermore, off-grid networks will offer electricity efficiency and flexibility and promote the introduction of localised renewable energy generation into the grid, marked by decreased power outages and their respective massive economic impacts on relevant economic activities (IRENA, 2015).

### User-Centricity?

The appropriateness of an intervention or technology in meeting the needs of users. Its fundamental core concepts are local embeddedness, reliability and affordability (Schillebeeckx et al., 2012).

### Electricity Technology

The generation, transmission, and distribution system of electricity. The three leading technologies are on-grid, mini-grid and off-grid (Granovetter & McGuire, 1998).

### Viability

The revenue structure of rural electrification considers the flow of funds from partners, customers and third parties (Schillebeeckx et al., 2012).

## 1.8 Assumptions

As a point of argument, Leedy and Ormrod (2010) stated that "Assumptions are so fundamental that the research problem would cease to exist if they were not present". This study has identified some assumptions that are generally expected to hold when conducting this scholarly research project.

- The respondents will answer truthfully, reflecting rational perspectives and experiences. The anonymity and confidentiality of each respondent will be preserved, and respondents are volunteers who have the right to terminate at any time. Failure to get accurate responses will impact the accuracy of data.
- The communication medium will be fully functional when using the research instruments to engage the respondents. The respondents will be notified and given a reasonable time to access and respond to the questions.
- There is available material about rural electrification in South Africa. Non-availability can impact the credibility of the conclusions as limited views may not be objective and reflect biases.
- Information and material will be accessible, but failure to gain access might significantly impact the purpose of the research.
- All respondents understand English. Suppose some respondents do not comprehend the primary languages used by the researcher. In that case, mitigating measures such as interpreting the question or seeking the services of a translator/interpreter will be used.

## 1.9 Chapter Outline

This research will consist of six chapters that will cover the following areas:

**Chapter 1: Introduction and Background**

This chapter will be a general introduction to the research, and it will provide a background and overview of the study. It will, by so doing, present the context and the electricity background of South Africa. An emphasis will be on the research problem and questions that the research seeks to answer. This section illustrates the significance of the study to explain the importance of this particular research.

**Chapter 2: The Literature Review**

This chapter will review the literature and engage in a critical discussion of innovative financing models to extend rural electrification and promote renewable energy technology innovation. Analysis and impact of each model will be discussed in detail.

**Chapter 3: Methodology**

It highlights the research approach and discusses the assumptions to qualify its appropriateness for this research. Evaluating and stating the benefits and drawbacks of the design further reinforces the suitability of the methodology and design for this study. The data collection methods are outlined concerning the defined population and sampling method. Furthermore, it describes the features of the research instrument and its ability to collect adequate data justified through the research questions.

**Chapter 4: Presentation of Results and Discussion**

The key results will be discussed in this chapter. This discussion will be based on the information in the tables and will describe the key findings that will be attained by administering the questionnaires and conducting semi-structured interviews. A description of the demographic information on the respondents will be available in this chapter.

### Chapter 5: Discussion of the Results

The findings will be presented and clarified in the context of the literature review.

### Chapter 6: Conclusions and Recommendations

The last chapter will provide a deep reflection of the extent to which the goals and objectives of the study will be achieved. It will integrate the findings into the research questions. Furthermore, it will outline the conclusion and recommendations culminating from this research.

# CHAPTER 2. LITERATURE REVIEW

## 2.1 Introduction

This chapter reviews the literature that is relevant to the context of the study. The chapter shows the current state of knowledge regarding the progress made so far in rural electrification while simultaneously identifying gaps. The literature highlights the critical success factors that spur rural electrification. Further attributes the slow electrification rate to some impediments that cause ineffective provision, especially in rural areas. Amongst other identified factors, financing or financial models are vital in unlocking the widespread dissemination of rural electrification technologies, especially in developing countries. Furthermore, the type of technology used is dependent on such factors as finance, geographical set-up of communities, income levels of people and policies. The literature reviewed in this chapter shows the interrelatedness of financial models, drivers and barriers, energy technology innovation and the rate of electrification.

The chapter ends by focusing mainly on the type of financial models for rural electrification, which are traditional and emerging or innovative. According to other scholars, these are broadly categorised as public finance, private finance and public-private partnership.

## 2.2 The South African Outlook

The state of electrification in South Africa and its electrification programme is remarkable and is the best in the SADC region. The South African government intended to electrify the sector to the greatest extent possible (97% in informal households) by 2025 (Jamal, 2015). According to Bongwe (2013), 90 per cent of households will be linked to the national grid, while the remaining seven per cent will use efficient off-grid options. The grid limitations for remote rural areas include:

- Affordability – more than 95% of the non-electrified households are from a low-income group (Department of Energy, 2013).
- Transmission Network Costs – About 34% of the population lives in rural areas (Worldbank, 2017). More than 60% of the households have no access, and by deductive analysis, system costs will increase as transmission expands to the remainder of the households (Koopman & White, 2011).
- Consumption Levels – rural customers' consumption levels are so low that it is impossible to recoup capital and operational costs (Bernard, 2011).
- Forecasted Energy Costs – the Integrated Energy Plan perceives increased generational and operational costs, adding to the government's financial burden if the grid option is used (DOE, 2019a).

South Africa has a population of 57.8 million people and is a developing country, and 19.4 million reside in rural areas Worldbank (2017). According to Census (2011), around 24 per cent of the population did not have access to electricity, and the reliability of supply and affordability remain major issues (Rathi & Vermaak, 2018). The table below shows the World Bank (2019) data reflecting the growth in population versus the rate of electrification in South Africa between the period 1996 to 2018.

**Table 1: Population Growth and Rate of Electrification in South Africa (1996 - 2018)**

| | 1996 | 2018 |
|---|---|---|
| Urban Population | 7,9 million | 38,3 million |
| Rural Population | 9,1 million | 19,4 million |
| Total Population | 17 million | 57,8 million |

| | | |
|---|---|---|
| Urban Electrification | 84,3% | 92,1% |
| Rural Electrification | 25% | 89,6% |
| Overall Electrification | 57,6% | 91,2% |

Source: World Bank (2019)

The key aspects that contributed to the success include supportive policies, institutional environment, sustainable financing, technological developments and innovations (Bernard Bekker et al., 2008).

**Policy and Institutions**

South Africa was involved in small scale rural white farmhouse electrification since the 1940s. The electricity supply industry was counted amongst the best globally because of the state utility Eskom, which had above 55% reserve margins due to overbuilding (Bernard Bekker et al., 2008). Despite the usual barriers that affect electrification in general and electrification of rural areas in the developing countries specifically, the main barriers were political and institutional in the 1980s (Eberhard et al., 2014). According to Rathi and Vermaak (2018), these barriers were done away with at the dawn of democracy in 1994, which brought about a change in the political environment and created an institutional environment that enabled policymaking. The three-phased approach adopted by Bernard Bekker et al. (2008) in delineating the critical policy, institutional and planning events are summarised as:

I. Phase 1: Initial haphazard efforts and planning (the late 1980s – 1994)- Regarded as the transition phase where the past government policies or frameworks were dismantled, and a new constitution was enacted, as well as new government institutions.

II. Phase 2: Institutional Reform (1994 – 2000) – The objective was to increase connectivity in line with the Reconstruction and Development Programme (RDP). A more significant proportion of rural connections were established during this time, and Eskom played a dominant role.
III. Phase 3: Business as usual (2000 – present) – Slow connection rates characterise this phase as the focus was shifted to rural areas with increased costs for bulk infrastructure and transmission network extension
IV. Furthermore, there was formalisation and integration of the electrical policy and institutions with other policies.

**Financing**

Financing in the electrification programme had two objectives. Firstly, it had to address the cost of electrification with particular emphasis in rural areas to achieve the primary goal of rural electrification and secondly, to create affordable tariff structures (Bekker, Gaunt, Eberhard, & Marquad, 2008). Three phases were identified by Bekker et al., (2008) in the evolution of electrification financing as self-funding (the 1980s-1990s), funded by Eskom (1990s- 2000) and funded by the government (2000- present).

**Technological Developments**

According to Ahlborg and Hammar (2014), the necessity to reduce cost was a great driver and facilitator to technological development during the national electrification programme; this was achieved in the early 2000s where actual high costs per connection were realised. The technological development in South Africa underwent four phases: supply quality-driven optimisation, cost-drive optimisation, standardisation, and high impact innovation (Gaunt, 2003). The period between the 1980s to 1998 saw a rapid technological development which included the introduction of prepayment metering and single-phase lines; this had a significant impact on reducing costs and increasing the rate of electrification (Tewari & Shah, 2003). Whereas the period post-1998 has had minimal impact innovation in terms of on-grid connection costs, there has been significant off-grid innovation for technologies such as mini-grids, which distributes energy from

local generation sources like photovoltaics and wind to several households (B Bekker et al., 2008).

**Rural Electrification Micro-Grid Strategies**

Rural electrification necessitates a high initial capital investment per capita due to low energy demand and population density (Xu, Nthontho, & Chowdhury, 2016). It appears to be a loss-making venture due to a lack of consumer density demand. South Africa struggles to attract private investors due to insufficient incentives and government agencies (Xu, Nthontho, & Chowdhury, 2016).

The microgrid strategy seems to be well suited for rural electrification over traditional electrification methods as it aims to balance cost-effectiveness and robustness (Ngoepe et al., 2018). According to Xu et al. (2016), A cost-effective rural electrification strategy includes (1) potential site identification, (2) consumer profile understanding, (3) availability of local resources, (4) grid connection transmission costs, and (5) sites connection transmission costs. Strategy simulation scenarios are as follows:

I. Dedicated Generation – single consumers (home, hospital, or public infrastructure). There is no resource sharing because each system is self-contained.
II. Microgrid-based Support Generation – complete integration of all loads within the scope into a single microgrid network Provides additional load support to all grid-connected users.
III. Village-based Support Generation – consolidate consumer load demand as a single entity at the village level.

South Africa attributes its remarkable rural electrification programme success to sustainable policies, institutional environment, financing, and technology (Haanyika, 2006). The realisation that access and use of electricity are beneficial to people, including in rural areas where it has been considered a highly desired commodity and prerequisite to economic development, has contributed immensely to moving the needle in rural electrification rates (Cook, 2011).

However, it should be borne in mind that power distribution in rural areas is an infrastructure assignment that carries a considerable expense. This high cost is a significant drawback. Therefore, it is vital to examine the drivers and barriers to rural electrification in relation to how they strongly relate to the various actors in the planning and implementation (Amutha & Rajini, 2016).

## 2.3 Drivers and Barriers to Rural Electrification

### 2.3.1 Drivers of Rural Electrification

In most countries, the electricity supply industry or power sector, especially in the SADC region, has historically been very centralised (Goldemberg, 2000) and controlled by the governments and public officials (Azimoh et al., 2016). However, over the last few years, the structure and dynamics of the power sector have fundamentally changed, which has led to the rise in the participation of other actors (Morris, 2020). The disruption and reshaping of the electricity industry are multifaceted. Some critical narratives and interests that are significantly contributing to the direction of the transition are namely: the increasing competition between renewable energy and fossil fuels, the grid being upended by distributed energy due to its economics and lastly, climate change presenting critical issues such as environmental standards and sustainability (Phillips et al., 2020). These issues have led to compliance obligations to regulatory models and inevitably impacting the current electricity or power sector structures (Scharfetter & Van Dijk, 2017). These changes affect the rural electrification plan, and some actors play a critical role in driving or spurring electrification in rural areas. Rural electrification is a vital component in achieving social and economic development for rural populations in need (Palit & Chaurey, 2011).

There are approximately 1 billion people worldwide who do not have access to electricity, with 85 per cent of them living in rural areas IEA (2019) because of the marginalisation of the poor and long distance from the electric grid, amongst other

factors (Pauser et al., 2015). However, according to the IEA (2019), the Energy Access Outlook figures show that the number of people who lack electricity access decreased from 1.1 billion to 860 million; this indicates a significant movement towards achieving universal electrification globally.

Electricity is a highly sought-after commodity. There is little doubt that having access to and using it benefits people in the already-electric-dependent world and rural areas (Ahlborg & Hammar, 2014). Some of the prevailing drivers that enhance the deployment of new technologies and the increase in electrification rates in rural areas include policies, poverty mitigation, local initiatives, local demand, affordability, and environmental sustainability.

**Policy**

Governments worldwide have made it a top priority to ensure that their citizens have access to electricity (Morris, 2020). Political priorities are predominately the main driver for electrification in rural areas in many developing countries based on ambitions for development in the rural areas (Ahlborg & Hammar, 2014). The policy also plays an integral part in considering options for the provision of electricity to rural areas at a technical level as it was in the case of Bangladesh: (1) enlarging and reinforcing the central grid and (ii) deploying off-grid technologies (Rahman et al., 2013).

**Poverty Mitigation**

Poverty is a significant obstacle to sustainable development, not only for developing countries but also for the entire world (Nanka-Bruce, 2008). The role of electricity in rural areas has long been explicitly emphasised for poverty alleviation and addressing environmental, social and environmental issues (IEA, 2010). Its importance for better healthcare and education can no longer be overlooked and has become a critical point of consideration in ensuring that rural electrification programmes are prioritised (Rahman et al., 2013).

### Local Initiatives

According to Rahman et al. (2013), community involvement and participation are essential for the success of all rural electrification initiatives. Ownership in the projects can guarantee the protection of assets and significantly contribute to rural industries, farming cooperatives, commercial activities, and local skills development such as technicians. In the past, RE projects have been assessed purely on financial terms and therefore deemed not viable. However, a change in approach has occurred in recent years of evaluating the benefits of rural electrification to include its impact on social welfare, which makes RE projects more acceptable (Nanka-Bruce, 2008).

### Local Demand

Although an average of the grid connects 35% of the rural population in developing countries, there is still a massive gap between supply and demand due to supply shortages (Rahman et al., 2013). According to the Worldbank (2010), the unreliability of power supply caused by vigorous load shedding has contributed immensely to problems such as (i) loss of public interest, (ii) increase in power theft, (iii) low collection rates, and (iv) diminished reputation for rural electrification programs. The drivers for rural electrification embedded in local demand include the increasing demand by rural industry and households, productive uses of electricity and the introduction of off-grid rural electrification technologies (Ahlborg & Hammar, 2014).

### Affordability

Affordability takes into account multidimensional issues such as pricing, energy poverty, and energy vulnerability; therefore, sustainable pricing and price stability are essential for alleviating energy poverty (C. G. Monyei et al., 2018). Subsidies and pro-poor policies are critical drivers for increasing rural electrification connection rates by both cushioning the high costs of grid connection and driving off-grid options (Åkesson & Nhate, 2006). Therefore, it is essential to design RE systems according to public needs, taking into consideration affordability and size. This will further ensure increased reliability and the number of users that can purchase and pay for the systems (Rahman et al., 2013).

**Environmental Sustainability**

The established constraints or barriers for RE prove that the rural energy transition process is not unproblematic; therefore, off-grid systems are not just a temporary solution but the most viable option for remote locations (Akella et al., 2009). According to Ahlborg and Hammar (2014), the aim of mitigating global climate change is an essential driver for RE with an environmental factor that enhances the deployment of new technologies. The World Bank has recognised renewable energy technology (RET)-based complement to traditional RE (IEG, 2008). The surge of RETs as viable alternatives to conventional energy solutions effectively decreases carbon emissions Kaufman et al. (2000).

Sub-Saharan Africa has excellent potential for RET-based electrification. It has declared to maximise the utilisation of most renewable energy sources like hydropower, solar photovoltaic (PV), wind power, geothermal energy and bio-energy (Akella et al., 2009). Prioritising such critical drivers has resulted in the success of most rural electrification programs worldwide (Nanka-Bruce, 2008). On the other hand, the barriers tend to be interrelated and difficult to isolate the impact of a single barrier. They are factors accounting for the decline in electrification rates and impeding the deployment of new technologies. Therefore, it is critical to understand these significant issues to provide appropriate innovative solutions (Byrne, 2011).

### 2.3.2 Barriers to Rural Electrification (RE)

The national grid extension efforts in rural areas have not achieved universal electrification (Kyriakarakos et al., 2020), especially in the most remote regions where electrification will not be reached in the foreseeable future (Ngoepe et al., 2018). Moreover, according to Vanadzina et al. (2019), the traditional approach to power supply, such as expanding the transmission grid, is not cost-effective due to high investment and connection costs.

The decentralised electricity grids are ideal for creating demand and increasing the consumer base as power sectors are undergoing transitions to accelerate rural electrification (Ahlborg & Hammar, 2014). However, despite rapid

transformation and innovation in the electricity sector, there are significant barriers to rural electrification (Rahman et al., 2013).

Some of the problems in most developing countries have stifled rural electrification: poor policies, weak institutional framework conditions, and limited funding (Haanyika, 2006). This view is also shared by C. Ketlogetswe et al. (2007), who highlight factors responsible for constraining rapid electrification in the rural sectors. The significant barriers often highlighted as leading contributors to poor rural electrification or energy provision include, among others, the following:

a) spatiality or geographical arrangements of communities.
b) ineffective energy policies or lack of policy certainty.
c) impoverished, poor, or low-income levels experienced by rural area-based citizens.

Haanyika (2006) cites limited financing, high transmission development costs, low electricity demand and consumption, and over-reliance on donors for RE resources as some barriers to rural electrification in Africa. In addition, financial institutions and executive agencies face challenges that necessitate resource management and technological development to overcome existing obstacles and issues (Javadi et al., 2013).

The Asian and Latin American experience of rural electrification has been widely explored and is dominant in literature (Van Ruijven et al., 2012). However, understanding the challenges or barriers requires an empirical investigation to determine the extent of transferability to the African context. Therefore, it is vital to examine factors that relate to the context of the study. Some significant barriers include weak institutions and organisations, economy and finance, social dimensions, technical systems and local management, technology diffusion and adaptation and rural infrastructure (Ahlborg & Hammar, 2014).

**Weak Institutions and Organisations**

Several scholars such as Mulder and Tembe (2008) and Jones and Thompson (1996) argue that institutional (high levels of corruption, weak policy and legal

frameworks) and organisational (lack of expertise or human capital) have a significant impact on the rate of rural electrification. The strong national influence due to political interference makes it difficult for private sector participation.

### Economy and Finance

A combination of lack of capital and rural poverty, which comprises a weak customer base of households and industry, has led to donor dependency on rural projects (Ahlborg & Hammar, 2014). Furthermore, the rural electrification long-term investment through grid extension is constrained by the low-income levels of the rural populace (Bugaje, 2006).

### Social Dimensions

Poverty and low household affordability harm the roll-out of electrification in the rural sectors from a financial sustainability perspective because subsides have a double effect of being drivers and barriers (Kankam & Boon, 2009). Lack of local engagement, participation and gender discrimination are critical factors that significantly contribute to the social dimension barrier in rural electrification.

### Technical System and Local Management

Off-grid or decentralised electricity grids have been identified as a complement to national grid extension uniquely suited for remote rural areas (Ahlborg & Hammar, 2014). Moreover, over time the projects collapsed due to poor management performance, lack of access to qualified personnel and a poor culture of performance and unproductive or non-profit generating use of electricity (I. M. Bugaje, 2006).

### Technology Diffusion and Adaptation

Funding is critical for the diffusion of energy innovations or technologies. However, most rural entrepreneurs lack access to financing due to a lack of financial institutions and lack of capabilities or know-how to initiate projects; this leads to a mismatch in the criteria for even qualifying for donor funding (Peters et al., 2009a). Addressing the funding constraints can lead to a widespread diffusion of off-grid technologies in rural areas, thereby accelerating rural electrification.

### Rural Infrastructure

Rural areas are distinguished by low population densities and dispersed settlements, a common geographical barrier that leads to high connection costs due to long-distance transmissions (C. Ketlogetswe et al., 2007). Another major constraint to rural electrification is the house infrastructure or building techniques. Most houses consist of mud and grass and are excluded or not considered for connection in most countries. However, according to Åkesson and Nhate (2006), these traditional houses are being connected in countries like Mozambique using protective material, which is more expensive.

Lastly, taking the barriers mentioned earlier into consideration coupled with a predominant rudimentary economy in the rural areas, the payback period for grid extension is very long due to the inability of households to pay connection costs. Furthermore, these sectors are also prone to seasonal droughts, and their incomes are seasonal, especially those dependent on farming. Therefore, Ahlborg and Hammar (2014) argue that the cash-flow problem can be solved by introducing suitable payment systems.

This section has addressed the main drivers and barriers concerning rural electrification in the Eastern Cape, South Africa. These offer a reflection on the first research question of the study, from the point of view of the peer reviewed literature.

## 2.4 Financing Models for Rural Electrification

Some of the contributing factors in Sub-Saharan Africa and the SADC region to poor rural electrification are poor financial models and limited funding (Malhotra et al., 2017). This view is supported by Kouassi and Pineau (2011), who points out that despite decades of international intervention through various financial models or approaches, the progress made has not been significant. According to Pauser et al. (2015), financial impediments to electrification in rural areas due to:

1) a lack of appropriate financing mechanisms for the end-user,
2) a lack of access to working capital and credit for local businesses,

3) a lack of processes and institutions to channel funds to the end-users,
4) uncertainty risk in investments due to the rural citizenry profile characterised as having the low willingness and ability to pay. Additionally, the initial costs for rural electrification are very high due to its remoteness from the grid and on the outskirts of cities in general

The financial impediments to rural electrification highlight the key factors affecting the rural populace's affordability, which ultimately determines the adoption rate of innovative energy technologies. In the SSA context, the key factors that affect affordability include risk shifting, periodic payments and capital access (Avila et al., 2017).

**Affordability**

Risk shifting, periodic payments, and capital access are essential factors in determining affordability. One of the common characteristics of rural areas is that the inhabitants have low income, few savings, lack technology experiences and cannot access credit due to lack of regular income. As a result, strict requirements for large down payments for renewable energy technologies have emerged, posing a significant barrier to the widespread adoption of RETs. In Bolivia, they doubled the number of customers for small grid connections by spreading the cost of payments over five years. In contrast, countries like Malawi still have abysmal rural electrification rates of under 10 per cent because companies demand full upfront payment of the 30-year cost of line extension (Barnes & Foley, 2004). Secondly, the timing, size, and duration of periodic payments (tariffs, operation and maintenance (O&M), spare parts, and interest are vital drivers for affordability. The payment period must be tailored to local requirements; for example, in Zimbabwe, payments were made yearly, following the annual cotton sale (Mapako & Afrane-Okese, 2002). Lastly, risk shifting is a problem that occurs after the transfer of ownership, and the new customer bears the O&M risk and associated costs. The Grameen Shakti case is unique because it carries the operational risk, while ownership is transferred to the customer immediately (Alamgir, 1999).

In analysing the South African situation, Thom (1994) argued that the main impediment to rural electrification is the high cost of grid connections (installation of remote area power supply (RAPS) systems), as well as the ongoing operation and maintenance of connections and systems when compared to costs in urban areas. The situation is exacerbated by the fact that poor rural households are generally not expected to consume enough units of electricity per month in the short term to allow the utility to recover the costs involved within a reasonable time frame. As a result, rural electrification is impractical without substantial funding from sources other than the rural consumer's actual 'rural revenue base'.

The literature on electrification financing has classified financial models or mechanisms based on the source of funds. According to Kouassi and Pineau (2011), current energy sector investment in SSA is primarily funded by three sources: (i) public financing resources (national and regional); (ii) international donors; and (iii) the private sector. Other financing schemes are classified under "Public-Private Partnerships", as Kouassi and Pineau (2011) pointed out.

### 2.4.1 Public Finance

In public financing for rural electrification, the government plays a critical role. According to IEA (2011), for most developing countries, their forms of finance include government subsidies, loans and grants from the national development banks, the balance sheet of state-owned energy utilities and other specialised institutions like the rural energy agencies (REA). They are usually used to finance grid expansion projects. The REA funding is provided mainly through national tax, concessional loans, donor funds, and grants and is funded by a 5% rural electrification transmission levy (Twesigye, 2019). The development banks were established primarily to assist in channelling government or donor finance to sectors that do not receive adequate private investment. Some of the public financing models are:

- **Guarantees:** These are arrangements by which the state assumes some or all of the downside risks to a venture. The use of public incentives to persuade private investors to finance new projects is attractive because this can enable the government to build the infrastructure without

immediate payments and benefit from private firms' expertise and enterprises (Irwin, 2007).

- **Grants:** Grants are substantially advanced funds without any repayment requirements (Kamara, 2016). According to the literature, grant competition can result in the lowest capital subsidy per new connection and create incentives to reduce operating costs for rural electrification (Tomkins, 2001).
- **Concessional Loans:** These are loans that are significantly more generous than market loans. The concession can be achieved through, or through a combination of, interest rates below those on the market. Concessional loans typically have long periods of grace. The China EXIM Bank is the Chinese government's primary financial arm in Africa. It primarily operates in the energy sector and offers concessional loans and loans to foreign investment projects. These loans are given to Chinese contractors, typically state-owned enterprises (China EXIM Bank, 2011).
- **Donor Funding:** The Organisation for Economic Co-operation and Development (OECD) and International Development Banks form a group representing bilateral and multilateral agencies providing funding to African governments (Kouassi & Pineau, 2011). Botswana's first rural electrification programme in 1975 was funded by International Organisations, including the Swedish International Development Agency (SIDA) (C. Ketlogetswe et al., 2007).
- **National Fiscus:** In South Africa, the Integrated National Electrification Programme (INEP) aims to provide universal access to essential electricity services. The fiscus makes funding available as a line budget item on a budget of the Department of Minerals and Energy (Wentzel, 2005).

Infrastructure projects in SSA continue to rely heavily on public funds for capital and operating and maintenance costs (Estache, 2006). This viewpoint is shared by Kouassi and Pineau (2011), who argue that due to a lack of private sector participation, many SSA states rely on public resources and donors for investment.

### 2.4.2 Private Finance

In the context of rural electrification, it is not always easy to justify a competitive rate of return that motivates a business case for private sector participation since investors respond to trade-offs between risk and reward.

The primary sources of the private sector for energy access investments, according to IEA (2011), include local banks, microfinance institutions and international banks, and developers, concessionaires and contractors. It also encompasses risk capital providers like venture capital funds, pension funds and private equity. However, equity, debt and mezzanine finance are the primary forms of instruments.

Foreign players supported by DFIs (e.g., AfDB, World Bank) or coalitions such as the PIDG are unsurprisingly the leading private players in the SSA energy sector. They finance through loans, guarantees, or equity Kingombe (2011). According to Mainali and Silveira (2011), innovations in financial mechanisms, combined with local private sector involvement, appear to play an essential role in increasing rural electrification penetration in developing countries. Some types of private finance are:

- **Project Finance:** The fund is established to finance an economically separable capital investment project. The funding providers see the project's cash flows as a source of loan servicing and provide a return on equity capital invested in the project. The main feature of project financing is that lenders offer project development funds solely based on risk and future cash flows (Scannella, 2012). In rounds 1, 2, and 3 of the South African Renewable Energy Independent Power Producer Procurement Program (REIPPPP), 56 of the 64 projects received were funded through project finance (Eberhard et al., 2014).
- **Debt:** Debt financing is distinguished by (fixed) interest rates and repayment terms. Senior debt can take the form of a project loan or a credit line, and it will take precedence over all other liabilities. This type of debt lowers the project's overall cost because it is generally less expensive than additional available funding (Kamara, 2016). Like China, India has

financed infrastructure in Africa through the line of credit (LOC) of the EXIM Bank of India (Kouassi & Pineau, 2011).

- **Mezzanine Finance:** It is a hybrid of debt financing and direct investment; a method of financing the realisation of a venture project in which the investor does not contribute to the company's capital but rather contributes resources for its development through debt obligations while simultaneously acquiring the option to purchase the borrower's stocks in the future at a pre-determined price. As a result, the financier acts as both a lender and an investor (shareholder) in mezzanine financing. Mezzanine financing instruments include subordinated debt obligations, preferred stocks, warrants, and special zero-coupon bonds (Sazonov et al., 2016).
- **Equity:** Equity investors invest in a project in exchange for a share of the project's equity. This type of investment is frequently riskier, necessitating high returns. Therefore, investors require risk compensation, and the level of risk for capital is commonly reflected in the expected Internal Rate of Return (IRR) (Kamara, 2016).

Kouassi and Pineau (2011) indicate that another finding of the researchers is the private sector's lack of involvement in financing electricity infrastructure in Sub-Saharan Africa. However, Roy and Nightingale (2010) argue that specific issues in rural areas (such as the lack of power grids and historical failures), global carbon reduction goals, and technological advancements gradually create new investment incentives and alternatives for developing countries energy projects. They are frequently led or implemented by private companies and non-governmental organisations with government oversight. Concerning the private sector's role in the REIPPPP, Eberhard et al. (2014) contend that the country's banking industry has been critical to the program's success. This is Africa's most prominent, most in-depth and most advanced sector. It has high liquidity, long-term debt (15-17 years in REIPPP) programs, understanding of project finance and PPP and public infrastructure financing. The industry also comprises a small but working secondary bond market and syndicated paper. While the industry is perceived to be conservative and expensive, it has been essential in helping REIPPPP achieve numerous closed transactions in a relatively short period.

## Public-Private Partnerships

Many private sector participants consider the PPP model to be one of the most appealing. Mainly when the business case for private sector investment is marginal, but there are clear public benefits, the government's role is to guarantee investment returns (IEA (2011). In the energy sector, predominantly in power generation, this financing model is gaining popularity in most emerging markets. Similarly, commercial banking financing terms can be less onerous than the government covers risks through guarantees. As a result, the private sector is attracted to industries where the public or government plays a critical role.

Kouassi and Pineau (2011) point out that the financial schemes classified under the "Public-Private Partnership" were due to the need to attract private actors and minimise the financing gaps for infrastructures through appropriate governance reforms and strong economic figures. According to Estache (2006), since Chile's experience in the 1970s, PPIs have generated clear welfare gains following the failure of financing schemes with quasi-exclusive public control on infrastructure projects in developing countries. According to some authors, such as Ajakaiye and Ncube (2010), private players' lack of interest could be explained by the fact that the private sector is readier to invest where a strong commitment and dominance of the public sector are demonstrated.

Microfinance has been identified as an appropriate model to tackle end-user financing for electricity access, mainly in rural areas. However, the main obstacle leading to energy deprivation is the inability of users to pay, and this issue can be addressed through some form of public financial support.

Uganda depicts a successful case in which the bulk of domestic connections have been executed under the Output-Based Aid (OBA) Global Partnership Programme, mainly funded by the Ugandan government, the World Bank, the European Union, and the KfW Development Bank through the REA. This is the first of its kind; cooperation between a private entity (Umeme Ltd) and a public entity (REA) has revealed the potential for institutional collaboration in the access levels to investors if the right incentives are provided Twesigye (2019).

The traditional financing models or mechanisms consist of public finance, private finance and public-private partnerships (Bhattacharyya, 2013). However, the rapid demand for electricity as a highly desired commodity in the new markets, and the already electricity-dependent world with global commitments to address environmental impacts has led to a vast deployment of innovative technologies. These low carbon innovative technologies are unique and require customised or innovative financing solutions to exploit entrepreneurial opportunities. It is, therefore, essential to explore the financing of energy innovation (Wohlgemuth, 2000).

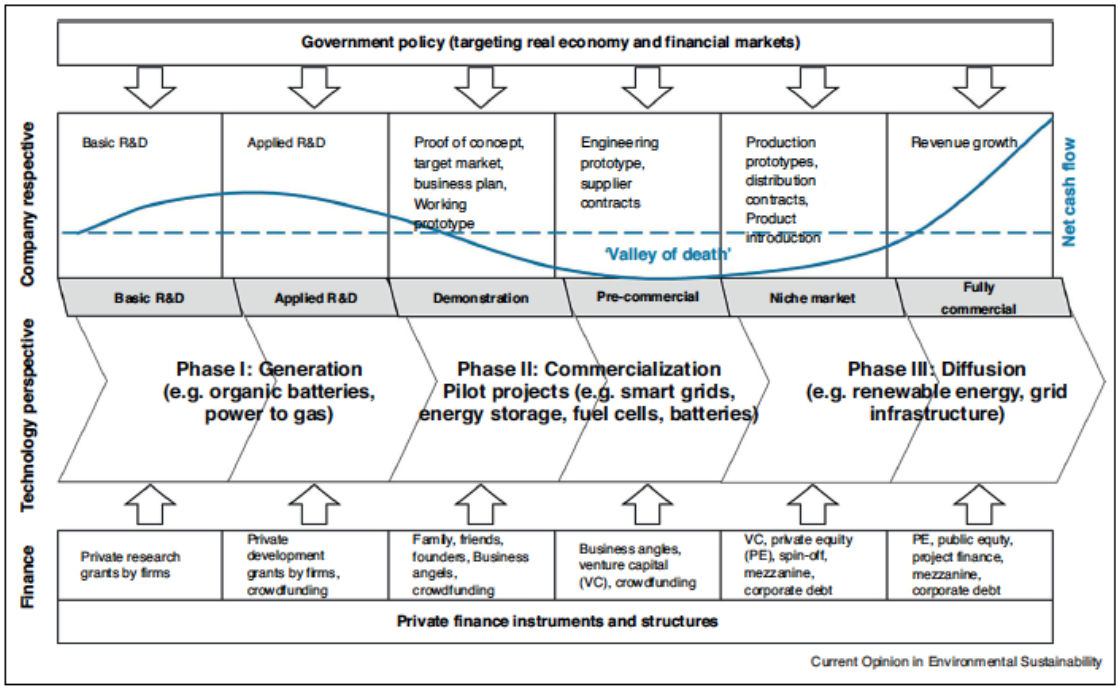
## 2.5 Financing of Energy Innovation

Management of the energy transition is a great challenge for humanity in the 21st century to a more decentralised and renewable system that can address the abysmal electrification rates in the impoverished rural areas (Hall et al., 2017). The energy system transformation will require a vast deployment of innovations, and accordingly, huge investments estimated to be USD 700 million, which amounts to a mere 1% of the global GDP (Iyer et al., 2015). Scholars and experts have identified financing as one of the most salient barriers to low-carbon innovation (Polzin, 2017).

In his theory of innovation, Joseph Schumpeter placed finance at the centre, as it is critical for exploiting entrepreneurial opportunity (Mazzucato & Semieniuk, 2018). There is no doubt that the financial sector could play a crucial role in funding transition or innovative renewable energy technologies (Polzin, 2017). According to Polzin et al. (2017), if financial systems are more diverse, the flow of funds to innovative, small-scale, or experimental firms that drive sustainability transitions can increase (more equity, less debt, more non-bank intermediation and more specialised niche banks giving more relationship-based credit). Vanadzina et al. (2019) back this up, stating that investments in equity or equity-like interest-bearing assets are most urgently needed and best suited for innovative energy firms.

The concept of learning is fundamental to systems of innovation (SI), where adoption of innovations produced elsewhere, incremental innovation of acquired techniques and diffusion all contribute to technological change (Viotti, 2015). According to the literature, learning occurs primarily through DUI in the context of non-industrialised or late-industrialising economies (Doing, Using and Interacting) (Lundvall, 2016). Soumonni (2013), on the other hand, contends that African countries can and should aspire to the full range of innovation stages, particularly in renewable technology, to increase their rates of access to electricity.

Low access to electrification, particularly in rural areas, is an enigma that has led to increased demand for renewable energy in Africa (Chuhan-Pole et al., 2018). The region is endowed with natural resources, and there has been a proliferation of the adoption of renewable energy (Ahlborg & Hammar, 2014). However, hardly any local industries produce either component of renewable energy systems or complete packages (Soumonni, 2013). Therefore, most off-grid renewable energy technology systems are imported at a high cost, impacting affordability to an already impoverished rural sector. This paper seeks to examine innovative financing models to spur electrification in these sectors and further explore how finance can enhance renewable energy technology innovation. Figure 1 below shows the types of financial instruments and structures used in all innovation process stages, from research and development (R&D) to full commercialisation. It is critical to recognize that the process of technological innovation is non-linear and can be influenced by institutional factors (Bolton & Foxon, 2015); the mobilisation of resources (including financial) is a critical process (Jacobsson & Karltorp, 2013).




Source: (Polzin et al., 2017)

**Figure 1: Financial instruments and structures in clean energy innovation**

a. **Private Research Grants:** They are mechanisms that allow for more applied research trajectories for those who can combine publicly and industry-sponsored research (Hottenrott & Lawson, 2017).
b. **Private Development Grants:** Private foundations, for example, are increasingly important in funding development in non-profit, governmental organisations and the private sector (Herzer & Nunnenkamp, 2013).
c. **Crowdfunding:** Instead of soliciting a small group of sophisticated investors, funds are raised externally from a large audience (the "crowd") in which each individual contributes a small amount (Belleflamme et al., 2014).
d. **Family, Friends and Founders (FFF):** Individuals who have social (family, friendship, or professional) relationships with the entrepreneur are typically organised to provide resources for the new venture (Khayesi & George, 2011) before capital mobilisation from professional investors (Kotha & George, 2012).
e. **Business Angels:** Investor angels are individuals who invest their money in the early stages of start-ups in exchange for a stake in the company.

They frequently serve as mentors and offer entrepreneurs their support and expertise (Parhankangas & Ehrlich, 2014).

f. **Venture Capital:** This type of funding is offered in return for equity interest to start-ups or companies that exhibit high growth potential (Apergis, 2019). Venture capital financing aids in resolving the asymmetric information problem in the "Valley of Death," as depicted in Figure 1, which necessitates the transition of technologies from proof of concept to commercial scale (Mazzucato & Semieniuk, 2018).
g. **Private Equity:** this is an alternative class of investment that consists of capital made into companies that are not publicly traded (Ragosa & Warren, 2019).
h. **Spin-offs:** they are considered a significant source of entrepreneurial activity (Rasmussen & Borch, 2010). A spin-off happens when a parent company splits part of its operations into a second entity publicly traded and distributes shares of the new entity to its established shareholders (Elpida et al., 2010).
i. **Mezzanine:** this is a complex and non-traditional form of financing that combines debt with equity. In the event of a default, it gives the lender the right to convert to an equity stake in the company (Holstenkamp, 2019)
j. **Corporate Debt:** this is a debt issued by a company to raise capital. Renewable energy technology's leverage in Germany increased by reaching 80 per cent of debt financing in 2017 (Egli et al., 2018).
k. **Public Equity:** These are the proceeds from the sale of a company to the general public. When public equity financing is readily available, agreements are more likely to grant the R&D firm fundamental control rights (Lerner et al., 2003).
l. **Project Finance:** This is a customised form of long-term financing for infrastructure and industrial projects that are solely based on the project's projected cash flows and does not include the company's balance sheet (Barroco & Herrera, 2019) argues that project finance has emerged as a powerful tool for mobilising capital for renewable energy.

These non-conventional and innovative financing models have a great potential to act as significant accelerants for the diffusion of innovative renewable energy

technologies (Ottinger & Bowie, 2016). They have a tremendous potential to solve the global climate crisis and energy security; therefore, it is vital to explore the technology innovation process in relation to renewable energy sources that can be accelerated through innovative financing mechanisms (Zhang, 2016).

## 2.6 Renewable Energy: Innovative Technologies and Financing

### 2.6.1 Innovative Renewable Energy Technologies

Joseph Schumpeter declared in 1943 that "industrial mutation... continually revolutionises the economic framework inside, incessantly destroys it, and unceasingly creates it" when he described the concept of creative destruction (Schumpeter, 2013). The idea of creative destruction implies a fundamental mechanism that allows the commercialisation of emerging technologies, resulting in the extinction of incumbent technology (Valentine, 2013). To overcome the critical enigma of energy deficiency affecting the livelihoods of millions of impoverished people worldwide, a transition from fossil-based energy sources into innovative renewable energy solutions is imperative (Mazzucato & Semieniuk, 2018). This alternative technology may evolve only in a seamless network of technical, social, political and economic factors supporting a particular technological system (Chai & Zhang, 2010).

Energy access in rural areas is a complex task with numerous energy barriers (Ahlborg & Hammar, 2014). Natural resources, such as animal dung, agricultural waste, forest leafy, water flows, solar intensity, and wind, are abundant in these areas (Barnes, 2010). The most appropriate solution for rural energy access will be to use these resources for off-grid electrification (Chauhan & Saini, 2015).

Renewable energy sources meet 14% of total global demand; they are primary, domestic, and clean, as well as inexhaustible energy resources (Panwar et al., 2011). Therefore, they have a tremendous opportunity to reduce greenhouse gas emissions and slow global warming. Primary renewable energy sources and their usage forms are given the Table 2 below:

**Table 2: Main renewable energy sources and usage forms**

| Energy Source | Energy Conversion and Usage Options |
|---|---|
| Hydropower | Power generation |
| Morden biomass | Heat and power generation, pyrolysis, gasification, and digestion |
| Geothermal | Urban heating, power generation, hydrothermal, hot, and dry rock |
| Solar | The solar home system, solar dryers, solar cookers |
| Direct solar | Photovoltaic, thermal power generation, water heaters |
| Wind | Power generation, wind generators, windmills, water pumps |
| Wave | Numerous designs |
| Tidal | Barrage, tidal stream |

Source: (Panwar et al., 2011)

With the world's largest recoverable reserves at 66.7 billion tonnes, the coal-dominated South African energy market is ranked 6th in coal production in the world (Ratshomo & Nembahe, 2018). A significant contribution of coal-powered fire stations makes more than 80% of the maximum electricity generating capacity

mix (Joshua et al., 2020). It is the largest carbon dioxide emitter in Africa (~45% of the continental total) and 7th globally (Joshua et al., 2020).

Despite South Africa's endowment with non-renewable energy resources (Saedpanah et al., 2020), It is considered the leading candidate for increasing utilisation of renewable energy, with its abundance of wind and sun natural resources (Azimoh et al., 2017). South Africa is ranked 12th in terms of attractiveness for renewable energy investment, and the REIPPP has attracted R209.7 billion in investment (debt and equity), of which R41.8 billion (20%) is the foreign investment (Energy, 2016). The Renewable Energy White Paper of 2003 set a ten-year target of achieving 30% power generation through the REIPPP (DOE, 2019a). In compliance with the national pledge to a low-carbon economy transition, the IRP (2010) set ambitious targets of achieving 17 800 MW (42%) of renewable energy by 2030 (DOE, 2019b).

According to the Renewable Energy Policy, this electricity will be generated from biomass, wind, solar and small-scale hydropower sources (Edkins et al., 2010).

## 2.7 Off-Grid Electrification

Many developing countries are suffering from insufficient and unreliable electricity supply (Urpelainen, 2014). The ultimate challenge for rural electrification is providing electricity to areas with low population densities (Scharfetter & Van Dijk, 2017). The national electricity grid, which state-owned power utilities with natural monopolies have traditionally operated, fails to provide a reliable electricity supply to rural communities.

According to Shukla and Bairiganjan (2011), traditional rural electrification programs' shortcomings have created a demand for alternative solutions. Off-grid electrification is one such solution in which electricity is generated without connecting to the national power grid (Kumar et al., 2009). The off-grid system consists of several approaches that lead to competitive and effective rural electrification (mini-grid, micro-grid and autonomous systems) (Gebrehiwot et al., 2019).

### Mini grids

The mini-grid is a non-grid system that caters for small-scale electricity generation (10 kW to 10 MW) which can be distributed in isolation from national transmission networks to a limited number of customers (Ngowi et al., 2019). Rural communities in emerging economies such as Africa have found success with mini-grids that can operate autonomously or connected to a local distribution network (Peters et al., 2019). These mini-grids function exactly like macro-grids, only on a smaller scale, by utilising distributed energy resources (DER) such as solar or wind, or more likely diesel generators (Azimoh et al., 2017). Mini grids can provide electricity to densely populated areas, including residential, commercial, and institutional customers, at or above grid quality levels.

### Micro-grids

A micro-grid connects the central grid and its users interactively and functionally. The interactive relationship enables a microgrid to connect to and use the services of the primary grid and support the services of the central grid when it is advantageous to do so (Gebrehiwot et al., 2019; Nasir et al., 2017). A micro-grid can also be disconnected from the grid and operated similarly as a mini grid, maximising the benefits to both the central grid and end-users. It can be used in various sizes and locations, ranging from a single building to an entire municipality (Williams et al., 2015).

### Stand-alone Systems

Individual appliances, homes, or other commercial uses, such as small businesses, are powered by stand-alone systems, small electrical networks that are not connected to the central electricity distribution grid (CSIR, 2017). They meet the needs of individual consumers by utilising readily available renewable resources in the local area. Pico, home, and production systems are the three types of stand-alone systems (Gebrehiwot et al., 2019).

## Success Factors for Off-grid Electrification

Electrification is almost synonymous with modernisation in the rural energy sector, yet it accounts for only about 10-15% of the total energy supply on average. When compared to other forms of energy, electricity is more convenient and versatile in meeting the diverse needs of the rural population (Kumar et al., 2009). According to Williams et al. (2015), improved economics, technical performance, environmental sustainability, and regional equity are inherent drivers for off-grid systems in the context of rural electrification.

Off-grid electrification project design is far from an exact science. Combining high service costs, unsatisfied customers, and newer, less familiar technology options makes it a more difficult task than planning a traditional energy project (Mondiale, 2008). Nonetheless, the evidence is clear; remote communities with any decentralised electricity supply have seen significant improvements in welfare (Barnes, 2010). The factors that drive successful off-grid electrification are:

**Technology:** The choice of a decentralised[2] solution or a mix of technologies should be made when it is established that connecting the community is not justified via grid extension (Mondiale, 2008). The upfront collection of baseline data on energy consumption, income, willingness to pay, and information on the availability of local resources is implicit in the overall process (Ahlborg & Hammar, 2014). Regardless of technology, care must be taken to ensure that the products provided to consumers are dependable and meet the service levels promised. Quality compromise can have serious negative consequences in customer satisfaction, resulting in non-payments and reputational risk, discrediting the technologies and projects (Bandara et al., 2012).

**Social Safeguards and Environmental Consideration:** The quest for reliable, economic and environmentally sustainable energy sources to meet the rising energy demand has become important worldwide due to rising concerns such as

[2] In this context, “decentralised” refers to not being connected to the central electricity network. Some decentralised options for concentrated customers are centrally located (i.e. within a village) generation systems located to isolated mini-grids.

energy scarcity and environmental issues (Saedpanah et al., 2020). Any solution strategy for increasing energy access must consider several factors, including technological, economic, governance, socio-political, environmental, and financial considerations. The ecological dimension includes environmental desirability of solutions, including benefit and unfavourable effects, the sustainability of resources and social impacts on the environment (Bhattacharyya, 2012).

**Productive and Institutional Applications:** Mondiale (2008) argues that programs for rural electricity should aim to generate new income and influence livelihoods directly. Effective and institutional measures were classified respectively as systemic and pragmatic (De Gouvello & Kumar, 2007). The systematic approach analyses the technologies used in the rural production of goods and services. The report identifies bottlenecks and determines if electricity use can help to reduce or eliminate limiting factors (Ngowi et al., 2019). The pragmatic approach takes an opportunistic approach, exploiting the current opportunities derived from a continuing or planned project implementation (Bhattacharyya & Ohiare, 2013).

**Enhancing Affordability:** Subventions, consumer financing, cheap technology options and policies and business practices to increase affordability must be considered for off-grid projects (Mondiale, 2008).

a. **Subsidies:** Off-grid technologies have high upfront or investment costs exceeding the customer's ability or willingness to pay (Trotter et al., 2019). Subsidies are based on a socio-economic basis for off-grid populations. That is the need for remote and poor residents in concentrated areas that benefit from the additional infrastructure expenses of grid extension and lifeline tariffs to achieve parity with households. As a result, off-grid interventions have more significant welfare gains than long-term costs. (Barnes & Halpern, 2000).
b. **Financing:** Subsidies could be supplemented or replaced by consumer financing. According to Winiecki et al. (2008), a strong partnership between microfinance institutions and energy companies involves successful lending programs.

c. **Technology:** One technological option to improve affordability is to provide more minor, less effective services without compromising the quality of service (Ciller et al., 2019).
d. **Policies and Business Practices:** Capital cost reductions are another way of making capital-intensive off-grid technology more affordable (Mondiale, 2008). Governmental exemptions for off-grid products that have achieved prescription quality standards are an option for governments to consider (Palit & Bandyopadhyay, 2015).

**Private Sector:** Off-grid players other than the government will mobilise additional financial and human resources and reduce the pressures exerted on already over-extended electricity companies (Rafique et al., 2019). Private sector companies, individuals, NGOs, or community organisations could be other players (Gunaratne, 2002).

**Regulating Off-grid Electrification:** Rural off-grid service standards should be lower than those for the central grid to cut costs, lower tariffs and make electricity services more affordable in rural areas (Palit & Bandyopadhyay, 2015).

**International Co-Financing Assistance:** Off-grid projects designers should be aware of international grant financing facilities (Bhattacharyya, 2013). These include Global Environment Facility (GEF), Global Partnership for Output-Based Aid (GPOBA), Energy Sector Management Assistance Program (ESMAP), Public-Private Infrastructure Advisory Facility (PPIAF), Clean Development Mechanism (CDM) and the Climate Investment Funds (CIF) (Mondiale, 2008).

The literature reveals the importance of innovative financing models in promoting renewable energy technologies. The traditional financing mechanisms, which include private financing, public financing and public-private financing, are predominantly used in electrification projects but cannot easily play a significant role in renewable energy diffusion in off-grid settings due to their limitations and barriers to entry like high capital requirements (Bhattacharyya, 2013).

The advent of innovative financing can address the shortcomings of the traditional methods by eliminating constraints such as high capital requirements, affordability, and risk in investments due to the rural citizenry characterised as

having a low willingness and ability to pay. Moreover, these non-conventional financing models are adaptable and applicable in all innovation stages, from research and development to full commercialisation. This includes renewable energy technologies and off-grid options (Zhang, 2016).

## 2.8 Adaptive Financing Theoretical Model

The IEA estimates that up to US$53 trillion of investment will be required by 2035 within a credible emissions framework to meet the projected energy demand (IEA, 2019). In recognising this investment challenge, scholars focus on identifying financing models that can support low-carbon technologies through the innovation value chain to commercialisation and finally drive widespread deployment (Polzin, 2017). As a result, the critical theoretical perspective used in this study will be in light of emerging understandings of financial markets as behavioural and structurally constrained, a departure from neoclassical assumptions of markets as efficient resource allocators (Polzin et al., 2017). In the context of rural electrification, this is important as Grubb et al. (2014) contend that aligning financial systems with real physical needs for long-term and sustainable investment necessitates the development of new types of financial instruments. Fig 2 below shows the analysis of the economic responses to challenges of energy demand and transition, considering climate change as being constituted by “three domains” (Grubb et al., 2014).

| **THIRD DOMAIN** | |
|---|---|
| Field of Theory | Evolutionary and Institutional |
| Compatible Theory of Capital and Finance | **Adaptive Markets Hypothesis** |

**Figure 2: The Adaptive Markets Hypothesis - compatible theory of finance and capital.**

Source: (Polzin et al., 2017)

### 2.8.1 Adaptive Markets Hypothesis

It is an evolutionary and institutional approach to addressing the changing structural and institutional effects on system change (Polzin et al., 2017). This domain is concerned with the challenges of strategic investment in innovation and infrastructure that can transform energy systems (Grubb et al., 2014). According to (Foxon, 2011) this co-evolutionary approach to socio-technical systems gives an overview of how innovations such as technology for renewable energy proliferate through complex physical and social systems such as rural areas. This approach is used in energy systems as it exhibits high levels of interdependency between physical assets, social practices, economic cycles and technological changes (Arapostathis et al., 2013). In addition, (Grubb et al., 2014) argues that price actions aimed mainly at stimulating investment in renewable energy in rural electrification are part of tackling the challenge of under-investment in innovation in the market. Finally, this field analyses how energy innovations penetrate large systems and face barriers beyond simple problems of grid parity (Jacobsson & Bergek, 2011).

A compatible energy finance theory is based on the Adaptive Market Hypothesis (AMH) rooted in the principles of variation, retention and choice to explain the changes and stability of economic systems (Lo, 2012). It also suggests that the investment environment, in conjunction with investor behaviour, may change over time; investors adapt to new realities during turmoil and change (Soufian et al., 2014). Financial crises, new financial regulations, high energy demand, new governments, policy, societal preferences, financial vehicles, market regulation, and technological innovation are structural changes that can force investors or associated institutions to evolve or face extinction (Polzin et al., 2017). The AMH is ideal for energy technology finance because it is characterised by significant lump-sum investments that are amortised over several political and even economic cycles (Grubb et al., 2014).

According to Polzin et al. (2017), the capital market conditions for energy finance (AMH) are:

a. Energy investors are boundedly irrationally.
b. A changing energy investment environment consisting of policy, regulation, incentives, and technology innovation calls for the new conditions adapted by existing companies and investors.
c. The structures of financial vehicles and broader capital markets impact the submarkets of energy finance.
d. These behavioural, environmental, and institutional characteristics develop in conjunction with individuals, entities and organisations involved in energy investment, which characterise a turbulent energy finance market over time.

The Adaptive Markets Theory is the third field of finance that has evolved after two related theories, namely Behavioural Finance and Efficient Market Hypothesis, as seen in Fig.1. It meets some of the inadequacies described in the below theories concerning rural electrification financing.

**First Domain – Behavioural Finance**

It focuses on individual behaviours/cognition and organisations. This is a branch of behavioural economics in which individuals and organisations have "bounded rationality" (the ability to gather and process relevant information is limited) (Pollitt & Shaorshadze, 2013). In contrast to profit maximisation, economic actors seek satisfactory rather than optimal solutions (Marechal & Lazaric, 2010). This is demonstrated by the fact that nominal decisions on energy and resource efficiency are implemented unevenly, even when cost-effective measures are available (Pollitt & Shaorshadze, 2013). Additionally, this field is focused on non-financial investors, who find cognitive aspects of technological convictions, entrepreneurial appetite, and network learning as crucial drivers for innovation in renewable energy technology (Bergek et al., 2013). In the context of rural electrification and enhancing renewable energy technology innovation, this theory has limitations in that it does not consider more comprehensive systematic changes in the energy industry (Polzin et al., 2017).

### Second Domain – Efficient Markets Hypothesis

It is a neoclassical and welfare approach that assumes market efficiency and rational players making optimal decisions based on economic factors (Bowman et al., 2014). According to (Foxon, 2011), this theory is derived from the hypothesis of “efficient” financial markets. In the “efficient markets hypothesis” (EMH), investors are driven by profit opportunities; and when they recognise attractive investments, they are quick to allocate capital to exploit them (Soufian et al., 2014). Masini and Menichetti (2012) argue that most energy policies implicitly assume an efficient market exists, as it relies on prices and markets for specific energy transition and electrification in general. Therefore, investments in innovative renewable technologies will depend on exploitable investment opportunities. However, in rural areas, the investment and electrification rates will remain abysmal since they are not considered attractive by rational investors (Polzin et al., 2017).

Energy infrastructure investments have distinguishing characteristics that set them apart from other investment types (Ehlers, 2014). The illiquidity of energy infrastructure, which is not divisible and cannot be quickly sold due to the lack of a secondary market for such infrastructure, is arguably one of its most distinguishing characteristics. Furthermore, due to the social implications of electricity provision, energy projects, according to Beeferman and Wain (2016), are highly scrutinised by the government and the general public. As a result, these projects are vulnerable to undue political interference (Beeferman & Wain, 2016). These distinctive features, including high start-up costs, lead to unique economic, political and financial arrangements, not for any other investment (Hall et al., 2017). Therefore, to overcome these energy infrastructure characteristics and barriers, innovation in financing models to enhance sustainable, innovative energy technologies are imperative. In light of the fact that traditional financing models do not easily lend themselves to rural electrification, this study primarily uses the Adaptive Markets theory to examine the financial models for rural electrification. It is especially relevant for the study because it combines efficiency and behavioural considerations in identifying an appropriate mix of financing

models, not only with respect to the diffusion of energy technologies for access, but for higher up in the innovation value chain as well.

## 2.9 Propositions

1. The drivers of rural electrification are policies, poverty mitigation; local initiative; local demand; affordability and environmental sustainability (Ahlborg & Hammar, 2014; C. Monyei et al., 2018; Morris, 2020). Conversely, the barriers to rural electrification are rural infrastructure, weak organisations and institutions; economy and finance; technical system and local management; technology diffusion and adaptation (C Ketlogetswe et al., 2007; Mulder & Tembe, 2008; Peters et al., 2009b).
2. The traditional or innovative financing models that have been deployed in the extension of rural electrification in South Africa are classified as Public Finance, Private Finance and “Public-Private Partnerships” (Estache, 2006; Kouassi & Pineau, 2011; Mainali & Silveira, 2011).

3. Innovative financing models can promote renewable energy technology innovation when used appropriately in the right socio-economic, environmental, and policy frameworks (Mazzucato & Semieniuk, 2018; Polzin et al., 2017; Vanadzina et al., 2019).

## 2.10 Conclusion

The literature review presented various findings of the drivers and barriers to rural electrification, innovative financing models and innovative renewable energy technologies incorporating the perspectives of different regions (World, Sub-Saharan Africa, SADC, and South Africa). It provides the general outlook, firstly in terms of how the world has progressed in rural electrification over the years and the global objectives set by the United Nations Sustainable Development Goals. It further shows how the Sub-Saharan African region lags other regions in electrification, emphasising the marginalisation of rural areas.

In providing context to the study, the section highlighted the importance of electricity in rural areas and its impact on economic and sustainable development. The literature identified the concepts and factors that hinder or drive rural electrification. According to the literature, the type of drivers and barriers in each area will influence the energy technology used in disseminating electricity. This section concludes by providing an overview of the factors and how different stakeholders view them.

The literature suggests that mobilisation of financial resources is a critical process in addressing the enigma of low access to electricity in rural areas. Energy access in rural electrification is complex and is constantly faced with essential barriers. These include high initial costs for electricity infrastructure and that citizenry in rural areas is predominantly impoverished, and affordability is a significant hurdle. It further highlights that the sub-Saharan region is endowed with natural resources and can leverage innovation systems to fully-fledged innovation (from R&D to full commercialisation) concerning renewable energy. The literature further acknowledges that innovative financing models are critical at each innovation stage and to the end-user to enhance rural electrification.

In light of the above, this research seeks to examine the innovative financing models in South Africa through the lens of the Adaptive Markets Hypothesis. AMH is a compatible theory of strategic investment in innovation and infrastructure that leads to energy system transformation, promoting sustainable energy innovation and spurring rural electrification. The study will further identify other innovative financing models based on the data from industry experts and stakeholders and make recommendations on appropriate strategies that will assist in improving the rate of rural electrification.

**Table 3: Consistency matrix: research questions and propositions**

| RQ # | Research Question | Prop | Statement of Proposition |
|---|---|---|---|
| 1 | What are the main drivers and barriers with respect to rural electrification in Eastern Cape, South Africa? | 1 | The drivers of rural electrification are policies, poverty mitigation; local initiative; local demand; affordability and environmental sustainability (Ahlborg & Hammar, 2014; C. Monyei et al., 2018; Morris, 2020). The barriers to rural electrification are rural infrastructure; technical system; weak organisations and institutions; finance and economy; local management; technology diffusion and adaptation (C Ketlogetswe et al., 2007; Mulder & Tembe, 2008; Peters et al., 2009b) |
| 2 | What financing models, whether innovative or traditional, have been deployed for the extension of rural electrification in Eastern Cape, South Africa? | 2 | The financial models or mechanisms for rural electrification are based on the source of funds classified as Public Financing, Private Financing and "Public-Private Partnerships" (Estache, 2006; Kouassi & Pineau, 2011; Mainali & Silveira, 2011). |
| 3 | How can innovative financing further promote | 3 | Innovative financing models can promote renewable energy |

| RQ # | Research Question | Prop | Statement of Proposition |
|---|---|---|---|
| | renewable energy technology innovation (that is beyond R&D) with respect to support rural electrification at the study site? | | technology innovation when used appropriately in the right socio-economic, environmental, and policy frameworks (Mazzucato & Semieniuk, 2018; Polzin et al., 2017; Vanadzina et al., 2019). |

# CHAPTER 3. RESEARCH METHODOLOGY

The chapter gives an outline of the research process followed in this study. Firstly, it provides an overview of the research approach and discusses the assumptions to qualify its appropriateness for this research. Next, the research method considered for this research is elaborated on as part of the research process, and the justification is given for the choice of the approach adopted. It further evaluates the chosen method citing the advantages and disadvantages of the design. Finally, the data collection methods give an outline of the defined population and sampling method. Elucidation of the features of the research instrument is then given to demonstrate consistency with the objectives of the research and its suitability for the collection of adequate data justified through the research questions.

Additionally, there is a detailed explanation of the techniques used to analyse the data gathered and a specific detailing of the population and sample and the particular sampling method used. Finally, the chapter concludes with a reflection on ethical considerations for the research and its validity and reliability and discusses how these requirements will be met in this study.

## 3.1 Research Setting

In this study, data will be collected in South Africa. The national power utility Eskom dominates the electricity sector in South Africa, and it generates, transmits, and distributes the majority of electricity in the country. However, South Africa houses the most significant number of Independent Power Producers (IPPs) market in Africa, which is estimated to contribute about 30 per cent of South Africa's future generation capacity. One hundred and thirty-seven municipal power companies that buy 40 per cent of electricity generated by Eskom intended to be supplied to the end-users have a nominal generation capacity. Currently, coal power generation is dominant. Nevertheless, this dominance is predicted to decrease as increased investments in nuclear power, gas and renewables are expected in South Africa, an essential partner of the South African Power Pool (SAPP), which imports and exports power from and to

neighbouring countries. Electrification in South Africa in urban and rural areas is comparatively very high for the region, varying from 85 to 90%.

Electrification has been predominantly through grid extension based on public finance and policy-driven since 1994 (democracy) to address the past socio-economic injustices and underserved or unmet electricity markets. The renewable energy revolution is global. This is evidenced by South Africa's renewable projects being financed by banks and private investors to a tune of R193 billion. This includes R53 billion sourced from abroad, which reflects a tremendously growing interest from the private sector. However, despite having atypical electrification rates compared to its counterparts and successes in both fossil-based and renewable electricity generation, more than 3 million people still lack electricity access in rural areas.

### 3.1.1 Population

The population for this study is comprised of industry experts or involved actors in rural electrification in South Africa. In the eastern part of South Africa is the province of the Eastern Cape. The province borders three regions of South Africa: KwaZulu-Natal and the Free State of Cape and Lesotho. There are mainly Black Africans in the province, with isiXhosa being the language most widely spoken. In all, the province with 6.99 million inhabitants is the third most populous province in the country. However, the region is mainly rural and one of the poorest provinces in the country. In addition, Buffalo City and Nelson Mandela Bay are the province's two metropolitan cities (StatsSA, 2016b).

South Africa has 11 provinces, with Gauteng with a population of 13.4 million being the most populous province. In the last few years, Black Africans represented over 45% of the population in all the provinces, other than Western Cape and Northern Cape. The populations distributed are relatively constant (StatsSA, 2016a).

South African households use electricity at a rate of 91.1 per cent. According to StatsSA (2016b), the provinces with the highest overall electricity usage when compared to other energy sources are the Western Cape (97.0%), Free State

(94.2%) and Limpopo (93.5%). By contrast, the Eastern Cape has the lowest percentage of households using electricity (86,8%) when compared to other provinces (StatsSA, 2016b).

## 3.2 Research approach

Qualitative research is a systematic research approach which is subjective and used to describe and give meaning to documented experiences of respondents (Williams, 2007). Employing qualitative research methods for data gathering and analysis has significantly increased in popularity over the past two decades (Strauss & Corbin, 2016). A qualitative approach seeks answers to questions that express how social experiences are created and given meaning (Denzin & Lincoln, 2008).

This study examines the innovative financing models for rural electrification in the Eastern Cape. The specific focus is also on how these financing models promote the deployment of renewable energy technologies in the study site. The qualitative approach and analysis were adopted to obtain the data. The qualitative methodology uses context, individual experience, and subjective interpretation; generalisability is not possible, nor is it a goal (Heppner et al., 1999).

The participants, primarily expert stakeholders with well-known and demonstrated expertise in rural electrification processes, were asked questions about the barriers and drivers of rural electrification. The researcher also explored questions about policy design and off-grid technologies. In addition, however, attention was paid to issues related to financing models, current and innovative, and how they can contribute to closing the gap in electricity access and promoting sustainable energy technologies.

## 3.3 Research Design

## 3.4 Research Design: Qualitative Methods

According to Lincoln and Denzin (2005) qualitative research is multifaceted research that involves an interpretative and a naturalistic approach to the study. Hence, it enables the researcher to comprehend more fully the phenomenon in question. This approach strengthens the perception and interpretation of meaning as well as the motives underlying human experience. The qualitative study relies on a humanistic or idealistic approach to consider a research issue; it gives voice to the respondents and permits participants to share their experiences (Pathak et al., 2013).

### 3.4.1 Key Informant Interviews

Qualitative data was collected through interviews with key respondents. The respondents were selected mainly for their knowledge and experience in rural electrification. The method of data collection that will be used that will also explain the context and background of the study as well as foster an understanding of innovative financing models for rural electrification in South Africa is the semi-structured interviews. These types of interviews are preferred because they are in-depth, offer flexibility, and allow respondents to be compared (Jamshed, 2014). However, unstructured interviews entail no specific format or predetermined questions; this increases the chances of deviating from the objective of this study which has specific outcomes (Bell et al., 2018). To mitigate the weakness of interviews on generalisability, this study will use the quantitative phase using a larger sample providing further validation of the interview findings (Johnson et al., 2007).

The semi-structured interviews utilised for data collection included an interview guide with a list of questions and research themes that should be covered during the interview process. They were not asked verbatim, but instead served as an aide-memoire, with interjections and clarifications during the interviews, as required.

Interviewing is a systematic qualitative research technique used to collect data from participants by asking questions and consistently documenting responses on issues relating to the subject being investigated (Jepsen & Rodwell, 2008). Brinkmann & Kvale (2018) regard interviews as an interchange of views between two or more people on a mutual topic of interest, suggesting that human interaction is central to the production of knowledge which may be elicited from research data. The semi-structured interview consists of a list of open-ended questions, which allows discussions to be centred around concepts, themes and beliefs in innovative financing models in the context of rural electrification and renewable energy technologies.

The medium by which interviews were conducted varied from one participant to another, depending on participants' preferences. Interviews were conducted face-to-face or telephonically. Interviews were also recorded for transcription and further analysis in later stages of the research using an electronic recording device. Research data took the form of written texts from transcribed interviews.

#### 3.3.1.1 Sample and sampling method

According to Burns and Grove (2003), a sample is taken from a study population often referred to as “the target population or accessible population”. Mamabolo (2006), along the same vein, explains that a sample is selected from a section of the population earmarked for participation in a research study. For this particular study, a sample shall consist of expert stakeholders who have known and proven experience in rural electrification processes. These include financiers or investors, development banks, officials at the regulator and Eskom utilities senior management, officials from the Ministry of Energy in South Africa, project developers or sponsors, civil society, and the local community.

**Table 4: Profile of respondents**

| Description of Respondents | Number to be Sampled |
|---|---|
| Department of Energy | 5 |
| Power Utility | 7 |
| Energy Regulator | 3 |
| Financiers / Investors | 10 |
| Academia | 5 |
| **Total** | **30** |

The criterion-based purposive sampling will be the appropriate sampling method. It includes identifying and selecting individuals or groups of people, particularly acquainted with or familiar with a topic of interest (Creswell & Clark, 2017). According to Patton (2005), in qualitative research, criterion-based purposive sampling is widely used to identify and select cases with rich information to make the most effective use of limited resources. Lastly, Bernard (2017) and Spradley (2016) note the benefits of this technique, including the availability and the willingness to engage and the possibility of articulate, expressive and reflective communication of experiences and opinions.

Khunou (2016) explains that criterion-based purposive sampling will allow the researcher to choose the best candidate to study and thereby “increase the likelihood of collecting profound, rich, and meaningful data for research purposes”. This is because probability sampling easily misses the appropriate persons needed to form a suitable sample. Furthermore, according to Leavy

(2014), the researcher can refine and adapt the sample using this sampling method, especially in new areas or locations where the researcher is unaware of whom to request to participate.

Krefting (1991) suggests that caution must be exercised in selecting interviewees to ensure that the sample is adequately representative of the targeted population; this is to allow findings to apply to a broader population. Accordingly, the stakeholder groupings for interviewees are as shown below:

#### 3.3.1.2 The research instrument

A semi-structured interview schedule will be used as the main instrument for the qualitative phase of this research because it can satisfy the objectives of this study. A semi-structured interview has a conversational and informal tone and allows participants to explore important issues. Furthermore, rather than a 'yes or no' answer, it allows for open responses in the participants' own words (Longhurst, 2003). Structured interviews may be difficult to elicit information due to their rigidity and lack of insight into the personal views of respondents. Also, unstructured interviews increase the possibility of deviating from concepts embedded in the research questions due to the free flow (Mathers et al., 2009).

The interview guide will be shared with all the participants before the meeting, and all interviews will be conducted as an open discussion. The guide will consist of questions derived from the literature review on the context of drivers and barriers to rural electrification and their associated factors.

The interview guide will include a list of open-ended questions centred on specific rural electrification themes. It will further allow respondents to provide a broader landscape of the study within innovative financing models, renewable energy and drivers and barriers to rural electrification.

The interview schedule will consist of 19 questions covering rural electrification themes in line with the Adaptive Market Hypothesis. The highlighted questions will focus on the supply side, which encompasses risk and reward, investments, policies, regulatory frameworks, and proposed strategies to spur rural electrification and adoption of new energy technologies.

The interview schedule that will be used is presented in Appendix A, with the covering letter to the potential respondents explaining what the research is about, what their rights are, and what will be done with the data collected from them.

### 3.4.2 Data analysis and interpretation

Data analysis is the systematic use of statistical or logical techniques to describe, illustrate, condense, collect, and evaluate data (Burns & Grove, 2003). Coffey and Atkinson (1996) state that qualitative data analysis should be conducted rigorously and carefully. The qualitative data analysis portion of this research study will identify similar themes within the responses and critically analyse them to achieve the research aims and objectives. In this study, a thematic analysis will be used to analyse the audio transcripts and interview scripts collected from the interviews. It is defined as identifying themes and patterns in qualitative data by Maguire and Delahunt (2017). In this study, Braun and Clarke's (2006) six-phase framework for doing a thematic analysis will be used, and the steps are shown in Table 5 below. The choice of this framework was based on the fact that it is not necessarily linear; one can move forward, backward, and between the steps as many times when dealing with complex data.

**Table 5: Braun and Clarke's Six-Phase Framework - Thematic Analysis**

| Step | Description |
|---|---|
| Step 1 | Become familiar with the data |
| Step 2 | Generate initial codes |
| Step 3 | Search for themes |
| Step 4 | Review themes |

| | |
|---|---|
| Step 5 | Define themes |
| Step 6 | Write-up |

## 3.5 Quantitative Method

Quantitative methodology is defined as explaining a phenomenon by collecting numerical data and analysing it using mathematically based methods (Muijs, 2010). The quantitative analysis will critically analyse and interpret data to find the rationale behind the main findings (Dudovskiy, 2019). This section of the report looks into the quantitative methodology used in this study which was mainly chosen for this research because of its ability to capture the views of a large number of stakeholders as well as for “its capability in the achievement of precise, reliable information and the enabling of a consistent and fairly cost-effective comparison of the responses of many people” (Khunou, 2016).

### 3.5.1 Data Analysis and Interpretation

Thematic analysis was primarily used to assess the data. It is a practical approach to determining people's views, opinions, knowledge, and experiences (Kiger & Varpio, 2020). It also helps to create values from a set of perspective data, such as interviews, transcripts, social media profiles, or various types of surveys. In order to find the answers to the qualitative research questions, data must be collected from the relevant participants and, after that, analysed. This analysis technique also has flexibility in interpreting data, even with large data sets, efficiently sorting them into broad themes (Clarke et al., 2015). The qualitative data analysis highlighted the themes, which guided interpreting, discussing, and concluding interviewee responses related to the research problem.

After every interview, the researcher converted the recordings into written texts. In the thematic analysis process, there are some critical factors to consider such as the distinction between inductive and deductive approaches. An inductive approach involves allowing the data to determine the themes. In contrast, a deductive approach collects data with preconceived themes directed at finding reflections based on existing theories of knowledge. In this study, deductive approach was used, and the most common six steps of analysis developed by Braun & Clarke in Table 4 above were followed.

Following the research design, data collection was conducted using a qualitative methodology, including the literature survey and interviews with expert stakeholders. The themes were also identified from the propositions extracted from the literature. Nineteen interviews were conducted with officials or experts from various electricity-related institutions like the Department of Energy, Eskom, NERSA, Commercial Banks, Development Banks and Academic Institutions.

The process of interview analysis was carried out manually in terms of familiarisation, coding, generating categories, reviewing themes, and defining and naming themes. After each interview and transcribing the conversation with the respondent, the electronic files were filed on the researcher's computer and backup systems as interview transcripts labelled using the respondent's name and the interview date. The coding and identification of themes were done by hand.

## 3.6 Procedure for Data Collection

First, permission from the University of the Witwatersrand’s Ethics Committee will be sought to conduct a study involving human participants to ensure respondents' ethical treatment and protection. When all the prospective participants are identified, a formal invitation to participate in the research or study will be sent via email or personal or formal community channels, detail the purpose of the research and how the data will be used. Additionally, the invitation will emphasise that participation will be purely voluntary, and they will be free to withdraw from participating at any time. Most importantly, to ensure the protection of the

participants, both parties will sign the consent form detailing all the relevant information regarding the study, and a pseudonym reference (Participant 1) will be assigned to each participant to conceal their identity. All quotes will be identified as such. During the investigation, the study will ensure that no physical, psychological, or social harm is caused to participants or anyone else in the study area (Kimmel, 2009).

The researcher will obtain formal permission from The Department of Statistics to access the secondary data in line with the study.

## 3.7 Limitations of the study

It is generally accepted that no study is flawless and inclusive in all aspects. These limitations are disclosed to reflect transparency, honesty, contemplate a complete understanding of the study and most importantly, to create opportunities for further research.

The small sample size used for the semi-structured interviews is one of the study's limitations. This is due to challenges experienced in determining the appropriate population size of rural electrification experts and stakeholders and also difficulties experienced in persuading experts with demanding schedules to participate in the study. The larger sample size is generally believed to be more representative and enhance the quality of the research findings.

Another limitation of this study will relate to the findings. The innovative financing models for rural electrification in the Eastern Cape are not lethargic but dynamic and reflect the country’s context. A change in the technology, policies, social, political and macroeconomic policies will impact the financing models. Therefore, these findings are not generalisable in a different context or at another point in the future of South Africa, although they may be transferable, where appropriate.

The other limitation will relate to the reliability of data provided by the experts during the interviews. Given that they are experts who meet the criteria to speak authoritatively on the rural electrification process, the researcher will take their views or opinions at face value without independent verification. This may result

in research findings being biased due to exaggeration or selective communication of information.

Another limitation was the non-availability of secondary data about existing financing models currently deployed in the Eastern Cape for rural electrification. The accountable institutions were unwilling to provide reports relating to financing models, and another challenge was that some institutions do not keep such data.

## 3.8 Validity and Reliability

These concepts are used to assess the quality of the research, particularly the findings that are to be used in practice. In addition, they outline the exactitude or integrity in which a study was conducted and ensure the credibility of findings as they demonstrate the accuracy of a method, technique or test used to measure something (Noble & Smith, 2015).

### 3.8.1 External validity (generalisability)

This research intends to have implications that extend beyond the analysis of financial models in rural areas. Some strategies are incorporated in the study, which plans to enhance external validity. Firstly, the setting of the research is not artificial; secondly, it consists of a representative sample - which are energy financiers and relevant stakeholders; and finally, It can be replicated with the possibility of demonstrating that the conclusions are valid and applicable in a variety of contexts and situations (Leedy & Ormrod, 2005). The extent to which conclusions are drawn can, at least, be transferable to other contexts.

### 3.8.2 Internal Validity

The internal validity of this research is the extent to which the design and the data will lead to accurate conclusions being drawn about the relationships within the data and the cause-and-effect (Leedy & Ormrod, 2005). This research will use triangulation, which relates to collecting data from multiple sources to converge and support the hypotheses identified in the conceptual framework.

### 3.8.3 Reliability

This research aims to produce stable and consistent results or conclusions based on the delimitations, design, and framework adopted. For example, the researcher will confine the sample to be studied to national data; this shows that the sample will be representative. Furthermore, the situation described in the research will be sufficiently rich in detail that readers will draw their conclusions from the data presented (Leedy & Ormrod, 2005). The reliability concept is based on the degree of consistency of the research instrument to produce the same results over time after multiple tests. (Kuder and Richardson,1937). The mixed methodology will enhance this strategy as different views will be collected from other groups.

### 3.8.4 Objectivity

The uncovered reality in this study's evidence or conclusions must remain uncontaminated by preconceptions or biases. The research design and instruments intend to mitigate against such by involving a relatively diverse group of respondents. According to Leedy and Ormrod (2005), other strategies that will be implemented are getting colleagues' opinions to verify the appropriateness of interpretations and validity for conclusions drawn from the data. Also, another strategy will be to get respondent validation. It entails providing the respondents or participants of the study conclusions to check if they agree with the outcomes and make sense.

## 3.9 Ethical considerations

In any research, the ethical implications of the study must be thoroughly investigated (Leedy & Ormrod, 2005). To this end, there is a need to adhere to the code of ethics, which focuses on the various issues, which among others, include: inflicting physical and mental harm to the participants, conducting covert or hidden research, the invasion of privacy, violation of anonymity and confidentiality, the use of deception and coercion, as well as plagiarism and fabrication or Invasion of data protection, infringement of anonymity,

confidentiality, the use of deceit and constraints as well as plagiarism, and the fabrication or disguise of results, physical and mental damage, covert or hidden research findings. Therefore, in addition to the consideration of the code as mentioned above of ethics during the study, the following additional code of ethics will be adhered to:

- The researcher will provide the respondents with an informed consent letter.
- Respect for privacy.
- Respondents will be notified about the nature of the study; their participation and any potential risks will be disclosed.
- Participation of respondents will be voluntary.
- The right of any participant not to answer any question.
- The right of respondents to withdraw anytime during the conduct of the research, and
- The right to access research findings by the participants.

This research acknowledges the levels of sensitivity of the information that will be required. The semi-structured interviews and questionnaire involving the respondents will demonstrate adherence to the code of ethics. The final process before commencing with the research will require obtaining consent from the University's Ethics Committee.

### 3.9.1 Researcher's ethical responsibility to research participants

Neuman (2007) maintains that the researcher has a responsibility to the respondents of ensuring that they are not harmed in any way during the conduct of the research study, where harm can be defined as "physical harm, psychological harm, legal harm and other harm" (Neuman, 2007). In this study, the researcher will ensure that there will be no harm inflicted on the respondents or participants in any form.

### 3.9.2 Researcher's ethical responsibility to the scientific community

According to Burns (2007), the researcher has critical ethical responsibilities to the scientific community. These include protecting the reputation of the scientific community, protecting the rights of the individual, and finally producing ethical research. In light of those as mentioned above, the researcher is cognisant that he belongs to the business and energy community and a broader community comprised of various areas of the discipline.

### 3.9.3 Informed Consent

Informed consent is a critical ethical principle of academic research because respondents have a right to be appraised of the research nature and its purpose and must, therefore, participate voluntarily (Burns, 2007). In this study, care will be taken to adhere to this principle; hence participants will be first directed to the informed consent statement that introduces the semi-structured interviews or read and explained to them.

## 3.10 Conclusion

Finally, the research methods and techniques to be applied in this research have been carefully selected and will be thoroughly implemented. It can, therefore, be concluded that despite the likelihood of challenges that might arise during the research, the findings will be sufficiently precise within an acceptable margin of error; hence they will be reliable and can be used to arrive at correct conclusions. Chapters 4 and 5 will discuss, in detail, the analysis and implementation of results.

# CHAPTER 4. PRESENTATION AND ANALYSIS OF RESULTS

## 4.1 Introduction

This Chapter has the objective of presenting, analysing and interpreting the findings of the study. The statistical results are presented in terms of the description of the participants and descriptive statistics.

This chapter is divided into five sections. Section 4.2 presents findings on the description of respondents and reports rate. Section 4.3 presents findings and discussion on drivers and barriers to rural electrification in the Eastern Cape. Section 4.4 presents findings and discussion on traditional and innovative financing models currently deployed in the Eastern Cape and suitable financing models to spur rural electrification. Section 4.5 presents findings and discussion on how innovative financing models can be leveraged in promoting renewable energy technologies and how off-grid technologies can spur rural electrification in the Eastern Cape.

## 4.2 Description of participants

Details regarding the participants in these interviews are hidden, as they are confidential and could lead to privacy concerns. Therefore, as agreed in the consent form (Appendix 1), the participants will remain anonymous and assigned pseudonyms (Respondent A, Respondent B, etc.). The target population for this study was experts in fields related to rural electrification, including academia, engineers, bankers, energy regulators, and government officials.

Interviews enhance the opportunity for flexibility thanks to their semi-structured format and also allow adequate responses to the derived research questions (Creswell, 2013). A pilot test of the interview questions was conducted before the final interview process. It was also ensured that all the respondents who participated in the interviews clearly understood the meaning of each interview question.

Although a relatively small sample size, the interviews can be considered significant since all interviewees are high-level, experienced professionals and experts who shared practical information about the subject under study. Therefore, the comments and information provided by the interviewees help to shed light on a credible picture of rural electrification technologies and financing models. Furthermore, sufficient time was given to the interviewees to express their thoughts and perspectives. The interview questionnaire is attached in Appendix A.

### 4.2.1 Response rate

**The sample consisted of thirty expert stakeholders, defined as people with known and demonstrable experience and expertise in rural electrification processes. These included financiers or investors, development banks, officials at the regulator, Eskom senior management personnel, officials from the Ministry of Mineral Resources and Energy in South Africa and project developers or sponsors, shown in Table 6. The response rate results are also shown in the same table to indicate the data collection exercise success rate.**

**Table 6: Categories and sizes of target population/sample**

| Description of Respondents | Number Sampled | Respondents | Response rate |
|---|---|---|---|
| Department of Energy | 5 | 2 | 40% |
| Power Utility | 7 | 3 | 43% |
| Energy Regulator | 3 | 1 | 33% |

| | | | |
|---|---|---|---|
| Financiers / Investors | 10 | 5 | 50% |
| Academia | 5 | 3 | 60% |
| **Total** | **30** | **14** | **47%** |

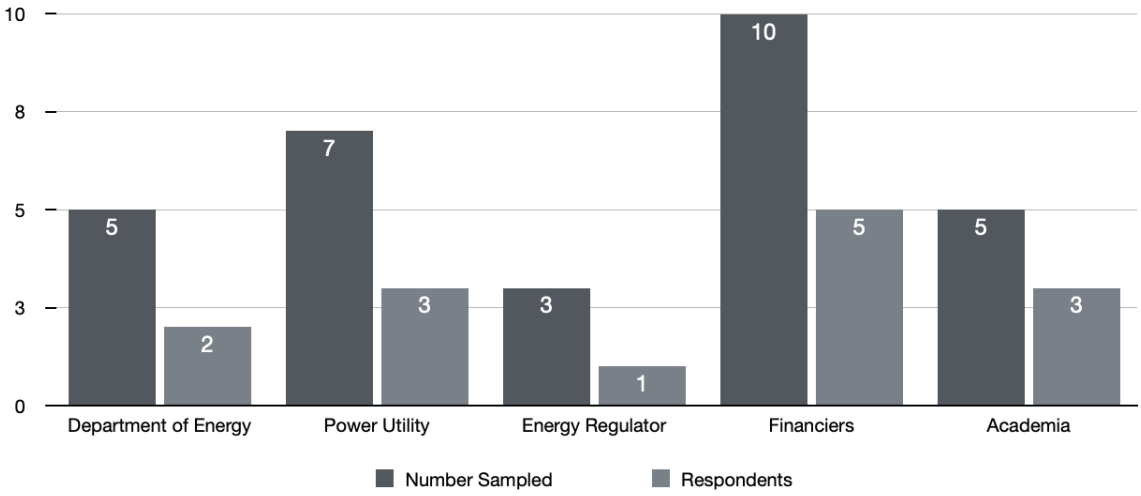



**Figure 3: Categories and sizes of target population/sample**

Saunders et al. (2009) note that a census approach includes data collection for all possible population members. Table 6 and Figure 4 show that out of the 30 participants sampled, the researcher managed to interview 14 respondents from various sectors and all sectors were covered. As a result, the sample size of thirty respondents and overall response rate of 47% is adequate for the study, allowing the researcher to conclude innovative financing models for rural electrification in South Africa's Eastern Cape Province.

## 4.3 Findings and Discussion pertaining to Proposition 1

Based on the scholarly literature, the first proposition states that the drivers of rural electrification are policies, poverty mitigation, local initiative, local demand, affordability, and environmental stability. On the other hand, the barriers to rural electrification are rural infrastructure, technical systems, weak organisations and

institutions, finance and economy, local management, technology diffusion and adaptation.

### 4.3.1 Analysis of the respondents' perceptions of the drivers of rural electrification

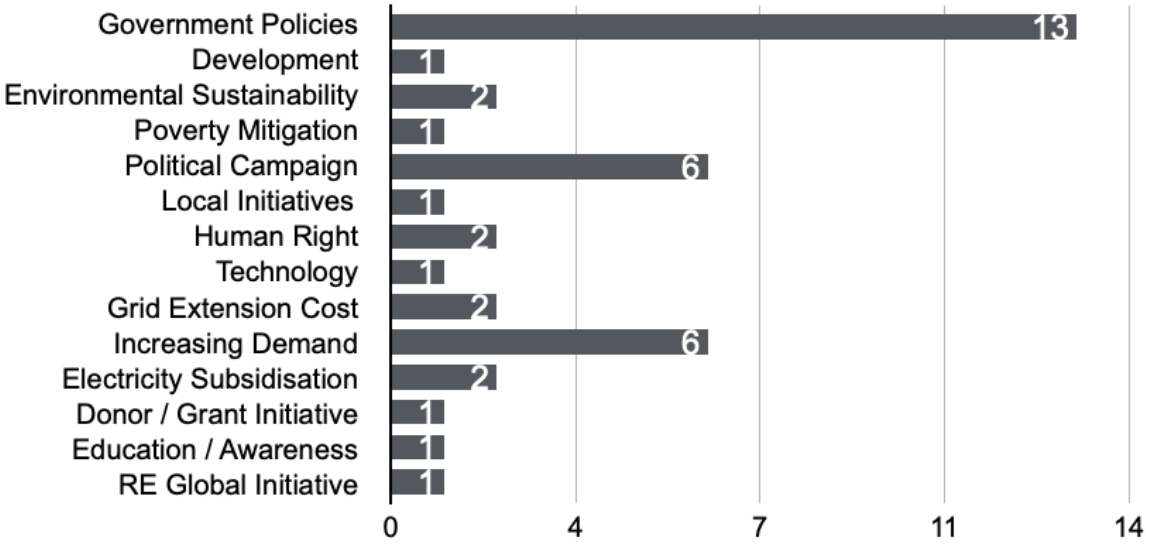



**Figure 4: Identified drivers of rural electrification extracted from the interview**

- The numbers reflect the number of interviews wherein the respondent referred to a particular driver (s).

**Percentages on the analysis of respondents' perceptions of the drivers of rural electrification in Eastern Cape, South Africa.**

**Table 7: The drivers of rural electrification**

| Parameter: Drivers of rural electrification in the Eastern Cape, South Africa | Government Policy | Private Policy | Unclear | Both |
|---|---|---|---|---|
| Drivers of rural electrification. | 85.71% | 0% | 7.14% | 7.14% |

This section provides an overview of the number of respondents who referred to or indicated a particular theme as a driver of rural electrification, as shown in Figure 5 and Table 7. In this case, 13 out of 14 respondents mentioned government policy as a significant driver, consisting of 86% of the participants. There was a unanimous agreement amongst respondents that in the Eastern Cape, the dominant driver for rural electrification is government policies through the INEP leveraging its implementing agencies: municipalities, Eskom, and non-grid service providers. Other significant drivers are political campaigns and increasing demand, which 6 out of 14 (43%) of the respondents mentioned. In commenting about the role of government policies in rural electrification, Respondent L, an official at First National Bank stated that:

*"Since the dawn of democracy, the new government crafted the INEP to address the inequalities that existed during apartheid and access to energy was critical. This was done through strong policies; South Africa is atypical to most of its counterparts in sub-Saharan Africa with extremely high rates of electrification."*

### 4.3.2 Analysis of the respondents' perceptions on the barriers to rural electrification

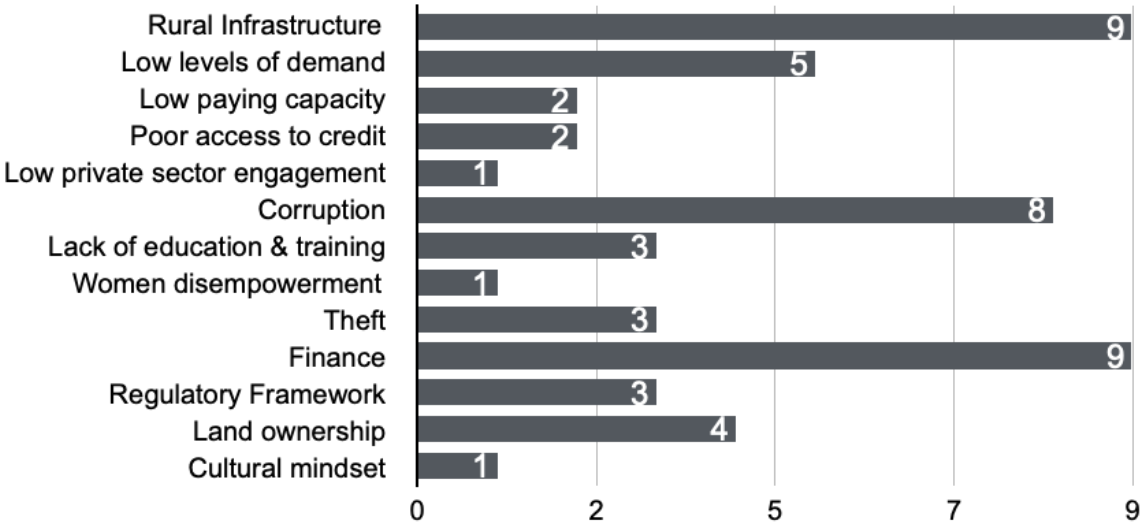



**Figure 5: Identified barriers to rural electrification extracted from interviews**

- The figures show the number of interviews with the respondents mentioning the barrier (s).

**Percentages on the analysis of respondents' perceptions on the barriers to rural electrification in Eastern Cape, South Africa**

**Table 8: The barriers to rural electrification**

| Barriers to rural electrification in the Eastern Cape, South Africa | Location | Corruption | Both |
|---|---|---|---|
| Barriers | 71.42% | 28.57% | 0% |

This section provides an overview of the number of respondents who referred to or indicated a particular theme as a barrier to rural electrification, as shown in

Figure 6 and Table 8. Nine out of fourteen respondents highlighted two dominant barriers: rural infrastructure and finance, 63% of the sampled population. Corruption was recorded as the second-highest barrier mentioned by 8 out of 14 participants (57%)

Interestingly, three barriers stood out, showing a spread of contributing factors to low electrification rates compared to the drivers. First, many respondents cited rural infrastructure and finance as the most significant factors impeding rural electrification, followed by corruption. Regrettably, however, the reality is that the levels of government funding have not translated into actual electrification projects as observed by Respondent A, an official at the Department of Mineral Resources and Energy:

*“Another concerning issue is that whenever we find malfeasance or corruption, or irregularities in the municipality, we cannot do anything; we do not have authority over the municipality level processes, even for the funds we channel to them.”*

As noted above, government policies are still vital in spurring rural electrification and creating an enabling environment for other private players with innovative solutions to participate. On the other hand, there are impeding factors that must be addressed which include rural infrastructure, financing, and corruption.

## 4.4 Findings and Discussion pertaining to Proposition 2

### 4.4.1 Analysis of respondents' perceptions on financing models that can be deployed to spur rural electrification

**Table 9: Financing models**

| Traditional or Innovative financing models that can be deployed to spur rural electrification. | Public | Private | Public-Private Partnership |
|---|---|---|---|
| | 13 | 0 | 1 |
| | 92,86% | 0% | 7,14% |

**Percentages on the analysis of respondents' perceptions on innovative financing models to be used to spur rural electrification, considering the costly electricity supply and low ability to pay in rural areas**

**Table 10: Innovative financing models and rural electrification**

| Innovative financing models that can be used to spur rural electrification, considering the costly electricity supply and low ability to pay in rural areas | Agree | Disagree | No idea |
|---|---|---|---|
| Percentages on the analysis | 85.71% | 0% | 14.29% |

The current traditional or financing models that have been deployed for rural electrification in the Eastern Cape could not be identified or established due to a lack of verified secondary data (lack statistical precision) and the unwillingness of authorities or institutions to provide data. However, there was a broad consensus amongst respondents that public finance is the most ideal and effective model fitting the profile for the rural populace, where many are characterised as indigent. There is currently no appetite for private sector participation, as shown in Table 9, with no respondent choosing private finance and public finance getting 13 out of 14 (92.86%). Respondent M, an energy expert in Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) expressed the following view:

*"The private sector is motivated by the bottom line, usually can invest in projects where there are minimum returns of at least 12%. At the moment, that is not possible in the rural areas."*

Furthermore, innovative financing models will undoubtedly play an imperative role in promoting rural electrification, given the complexity of the rural infrastructure and type of customer in the rural Eastern Cape. The majority 12 out of 14 (85.71%) respondents, as shown in Table 10, argue that financing models must be tailor-made to suit the conditions of the identified area.

## 4.5 Findings and Discussion pertaining to Proposition 3

### 4.5.1 Analysis of respondents' perceptions on how innovative financing can be used to promote renewable energy technologies innovation in rural areas

**Table 11: Innovative financing and renewable energy technologies**

| Can innovative financing be used to promote renewable energy technologies innovation in rural areas? | Agree | Disagree | Not sure |
|---|---|---|---|
| Percentages on the analysis | 64.29% | 0% | 35.71% |

The general sentiment amongst respondents is that innovative financing can be leveraged to promote renewable energy technologies in rural areas, with more than nine (64%) of the respondents agreeing and five (35%) not sure, as shown in the table above. The energy expert at GIZ further stated that:

*"They have not fully utilised the off-grid options, and support is needed in finance, enabling regulatory framework, policies and awareness."*

### 4.5.2 Analysis of respondents' perceptions on regulation / licensing in promoting rural electrification

**Table 12: Regulation / licensing for rural electrification**

| Does effective regulation and licensing represent a barrier to rural electrification? | Agree | Disagree | Unclear |
|---|---|---|---|
| Percentage response | 50% | 35.71% | 14.29% |

There were conflicting views on the role of regulation and its impact on rural electrification; this is shown by the spread amongst respondents in the table above. However, most respondents agree that strong regulation will spur progress in rural electrification. In contrast, a significant number of respondents cites the inefficiencies of the current regulatory framework, which does not cater for off-grid electrification.

Two out of Fourteen (14%) respondents cited that they were unclear because of the complexity of regulation which is supposed to balance the interests of both the customer and the licensee, as noted by Respondent B, an official at NERSA.

Respondent I, a professor at the University of the Witwatersrand stated that South Africa is still using an old regulatory Act drafted in a market with centralised power stations with big economies of scale (a cheaper way to make electricity). The regulatory policies are struggling to meet the rapid technological advancement in the energy industry.

### 4.5.3 Analysis of respondents' perceptions on the importance of off-grid technologies in rural electrification

**Table 13: The importance of off-grid technologies in rural electrification**

| Are off-grid technologies important for rural electrification? | Agree | Disagree | Unclear |
|---|---|---|---|
| Percentage response | 78.57% | 14.29% | 7.14% |

The overwhelming majority of the respondents highlighted the importance of off-grid technologies as alternatives to address the barriers that impede universal electrification. The energy expert at GIZ, Respondent M, stated the following:

*"Off-grid technologies are vital to meeting universal electrification goals in rural areas as long as an enabling environment is created, and there is support from all stakeholders."*

Other respondents disagreed on the effectiveness or impact of off-grid technologies since some people consider them inferior compared to grid connection. In addition, some view them as temporary measures while waiting for grid connection, as cited by Respondent I, a professor at Wits.

## 4.6 Summary of the findings

The respondents identified 14 drivers and 13 barriers to rural electrification. Government policy stood out as the most potent driver mentioned by 93 per cent of the respondents. In contrast, rural infrastructure, finance, and corruption are the significant barriers to rural electrification in the Eastern Cape. There was a broad consensus amongst the respondents that the ideal financing model for rural electrification is public finance. In addition, most respondents agreed that innovative financing models could promote renewable energy technologies, that regulation can positively impact rural electrification, and, lastly, many respondents pointed out that off-grid technologies could help close the gap to achieve universal electrification.

# CHAPTER 5. DISCUSSION

## 5.1 Introduction

The chapter discusses the findings within the literature review that was undertaken to examine the innovative financing models for rural electrification in the Eastern Cape, South Africa. This chapter is divided into five sections. Section 5.2 provides the demographic profile of respondents. Section 5.3 discusses findings pertaining to Proposition 1, Section 5.4 discusses findings pertaining to Proposition 2, Section 5.5 discusses findings pertaining to proposition 3, and Section 5.6 presents the conclusion on the findings

## 5.2 Demographic profile of respondents

**Table 14: The role of respondents in the organisation**

| Parameter | The Frequency | Percentage |
|---|---|---|
| Engineers | 3 | 21.4% |
| Students | 2 | 14.3% |
| Professors | 1 | 7.1% |
| Deputy Directors | 3 | 21.4% |
| Unspecific | 5 | 35.7% |
| **Total** | **14** | **100%** |

As shown in Table 4.2, most experts, 9 out of 14 (64.3%) play a significant role in their organisations, and only 5 out of 14 (35.7%) of the total number of respondents have an unspecific parameter.

## 5.3 Discussion pertaining to Proposition 1

### 5.3.1 Drivers of rural electrification

According to interviews, the main driver for rural electrification is government policies. This is not surprising as the local government plays a central role in the provision of electricity (Ledger, 2021), and governments of most countries have made electricity access a priority (Morris, 2020), leveraging policy in grid extension or deploying off-grid technologies (Ahlborg & Hammar, 2014). Political campaigns are also significant drivers in the Eastern Cape, reflecting their vital role in determining which areas may gain access to energy. According to Ahlborg and Hammar (2014), the political priorities usually have ambitions of rural development. The high demand is another substantial driver, whereas factors like poverty mitigation, environmental sustainability and affordability are less influential than the impact they have in South Asian countries (C. Monyei et al., 2018; Rahman et al., 2013).

### 5.3.2 Barriers to rural electrification

Despite the high electrification rates in South Africa, which is atypical compared to its counterparts in sub-Saharan Africa, the Eastern Cape region still lags other provinces. The three significant barriers identified are rural infrastructure, finance, and corruption. According to Kyriakarakos et al. (2020), grid extension in rural areas is not cost-effective due to high initial costs, especially in sparse communities. Most of the rural populace in the Eastern Cape are indigent with willingness and ability to pay; therefore, the roll-out of electricity has been adversely impacted by poverty and low household affordability from a financial sustainability perspective (Kankam & Boon, 2009). Finally, corruption increases

the inequality of resource allocation or distribution (Rahman et al., 2013); it is one of the most vital factors impeding rural electrification in the Eastern Cape.

Other impactful barriers like theft, regulatory framework and land ownership cannot be overlooked in rural electrification strategies. The case of rural infrastructure and finance as significant barriers to rural electrification is universally well established. However, though not unique to the Eastern Cape in South Africa, corruption has contributed to significantly halting or hindering progress from achieving universal electrification. This is primarily due to poor procurement processes, lack of governance, unethical leadership, and oversight.

## 5.4 Discussion pertaining to Proposition 2

### 5.4.1 Traditional and innovative financing models

The financing models for rural electrification can be classified as private, public and public-private partnerships (Kouassi & Pineau, 2011). The currently deployed financing models for rural electrification in the Eastern Cape could not be established due to a lack of verified secondary data and the unwillingness of authorities to avail reports. This is not a unique case in South Africa, as the Department of Mineral Resources and Energy has flagged energy availability data as a critical risk (DMRE, 2020). There is a lack of consistent, transparent energy data sets for planning, which leads to poor decision-making and increased risk. This is also prevalent with the energy regulator (NERSA), where licences are not regularly updated. According to (Pauser et al., 2015), the lack of suitable end-user financing mechanisms is cited as a financial impediment to rural electrification due to the unavailability of energy data or information.

Public finance was overwhelmingly cited by the respondents as the most suitable model to spur rural electrification in the Eastern Cape; this view is supported by Twesigye (2019). The choice for private finance and public-private partnerships ranged between 0 to 7.14 per cent as it is difficult to justify a competitive rate of return that motivates a business case for the involvement of the private sector in the electrification of rural areas since investors respond to trade-offs between risk

and reward. The private sector is attracted to industries where the government plays a dominant or critical role in some mini-grid projects in the Eastern Cape (Raymond Muhlaba Municipality). Kouassi and Pineau (2011) point out that most public-private partnership schemes were due to a need to attract the participation of the private sector in electrification.

In the Eastern Cape, respondents cited that only the public financing model will be effective. This position is supported by Ajakaiye and Ncube (2010) and (Twesigye, 2019) who argue that rural electrification is structurally unprofitable and is indispensable to economic and social development; it has never been the product of a purely commercial strategy.

## 5.5 Discussion pertaining to Proposition 3

### 5.5.1 Innovative financing and renewable energy technologies

South Africa is widely regarded as the best candidate for making greater use of its abundant natural resources, such as sun and wind (Azimoh et al., 2017), and the Eastern Cape dominates in wind power. The majority of the respondents (64.29%) agree that innovation in financing models could significantly impact promoting the uptake of renewable energy technologies. Therefore, public finance will not be adequate to spur rural electrification as the sole financing model since rural electrification is not practicable without significant funding from sources other than the rural customers' actual ‘rural revenue base'. This is supported by Soumonni et al. (2016), who suggest that focusing on end-user financing could be instrumental. It increases the viability of financing mechanisms to make off-grid or renewable energy technologies affordable in rural areas.

### 5.5.2 The importance of off-grid technologies in rural electrification

The off-grid system consists of various approaches that conduct rural electrification competitively and effectively: mini-grids, micro-grids and stand-alone systems (Gebrehiwot et al., 2019). The overwhelming majority (78.57%) of the respondents highlighted the importance of off-grid technologies as

alternatives to address the barriers that impede universal electrification. According to Scharfetter and Van Dijk (2017), the challenge for rural electrification is providing electricity to areas with low population densities.; the Eastern Cape region is characterised as having the most sparsely located communities with unfriendly terrain. The unpredictability or flaws of traditional rural electrification programs have led to demand in other countries such as Nepal, Bangladesh and India, for alternative solutions (Shukla & Bairiganjan, 2011). Interestingly, in the Eastern Cape, the adoption of off-grid technologies is very low. The populace views such alternatives as inferior or only temporary with the ultimate goal of on-grid connection.

### 5.5.3 Relevance for Theoretical Framework:

Behavioural finance focuses on the cognition of individuals and organisations with bounded rationality. Marechal & Lazaric (2010), Pollit & Shaorshadze (2013) and Bergek et al., (2013) highlighted three critical elements of the theory; namely, actors seek satisfactory rather than optimal solutions; uneven implementation of energy decisions and focus on non-financial investors. This is demonstrated by significant drivers highlighted by the respondents, including government policies, political campaigns, and customer demand. This approach is primarily driven by political influence. It is not sustainable since it leverages grid extension with high initial and maintenance costs and revenue as the target market consists of the indigent population in rural areas. Through public finance, progress has been made in rural electrification. However, as highlighted in this theory, the public financing approach has limitations in that it does not typically consider systemic changes in the energy industry. For instance, the approach does not cater for financing optimal solutions like renewable energy technology innovations, which can also be cost-effective. Some changes to be considered include the environmental impact, which requires transitioning from fossil energy sources to renewable and carbon-free innovative energy solutions.

In the Efficient Market Hypothesis (EMH), investors are driven by profit opportunities; and when they recognise attractive investments, they quickly

allocate capital to exploit them (Soufian et al., 2014). The investment and electrification rates in rural areas remain abysmal since they are not considered attractive by rational investors (Polzin et al., 2017). The literature demonstrates this and the feedback from the respondents in that they agree that public finance (or the government) is the main or, in some instances, the only investor in rural electrification projects. The respondents highlighted finance and corruption as some of the primary critical barriers to rural electrification related to finance, in line with this hypothesis. Therefore, the current financing model in the Eastern Cape is not driven by market efficiency. Public financing of grid extension with high start-up costs leads to economic, political, and financial arrangements susceptible to high interference and, ultimately, corruption. The EMH has limitations because it focuses on maximising profit by leveraging market efficiency. It does not consider other critical non-financial aspects imperative for developing innovative renewable energy technologies.

Behavioural finance and EMH can be used to help determine appropriate energy financing mechanisms, but each has limitations for successful financing of innovative renewable energy technologies. However, the two approaches can be combined to create a co-evolutionary approach to socio-technical systems called the Adaptive Market Hypothesis (AMH). They give an overview of how innovations such as technologies for renewable energy proliferate through complex physical and social systems, (Foxon, 2011), which are relevant for rural areas in the Eastern Cape. Grubb et al., (2014) argue that this domain is concerned with the challenges of strategic investment in innovation and infrastructure that can transform energy systems. AMH can also be aimed at stimulating investment in renewable energy in rural areas and tackling underinvestment in innovation in the market. Therefore, this approach is used in this study to address the limitations highlighted in the dimensions of behavioural finance and EMH. Most respondents agreed that innovative financing models (which are consistent with AMH) could promote renewable energy technologies. However, the respondents further alluded to the notion that an ideal financing model must also cater to changes such as regulation. Lo (2012) highlights that

AMH is rooted in the principles of variation, retention, choice, and stability of economic systems. This innovative financing model is adaptive and can cater to changes such as new governments, policies, societal preferences, and technological innovation. These are some critical barriers and drivers highlighted by the respondents, making it an ideal framework for identifying and combining innovative financing models for renewable energy technologies in rural areas.

## 5.6 Conclusion

The dominant driver of rural electrification in the Eastern Cape is government policy. The general sentiment amongst respondents is that technological and financial innovation can be successful if backed by government policies. Rural infrastructure, finance and corruption stood out as the most significant factors impeding rural electrification in the study area. The existing financing models deployed in the region could not be precisely established due to limitations in accessing data. However, the overwhelming majority of respondents cited public finance as the most suitable model to achieve universal electricity access in the Eastern Cape. The respondents unanimously agreed that innovative financing models could promote renewable energy technology innovation and given the ideal regulatory, policy, environmental, and socio-economic framework focusing on end-users. As a result, off-grid technologies could assume a leading role in reaching the universal electrification goal.

| RQ # | Research Question | Answer |
|---|---|---|
| 1 | What are the main drivers and barriers with respect to rural electrification in South Africa? | The dominant drivers of rural electrification are government policies, political campaigns and increasing demand. The significant |

| RQ # | Research Question | Answer |
|---|---|---|
| | | barriers to rural electrification are rural infrastructure, finance, and corruption. |
| 2 | What financing models, whether innovative or traditional, have been deployed for the extension of rural electrification in South Africa? | The currently deployed financing models could not be established due to a lack of secondary data. However, Public Financing is preferred as the ideal financing model compared to Private Financing and “Public-Private Partnerships” models. |
| 3 | How can innovative financing further promote renewable energy technology innovation (i.e., beyond R&D) in order to support rural electrification at the study site? | Innovative financing models can promote renewable energy technology when used appropriately in the right socio-economic, environmental and policy frameworks. However, most notably, the focus must be on end-user financing. |

# CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Introduction

This chapter presents the research findings for this study, integrates them into the propositions, and answers each research question. Finally, the highlighted conclusions are presented as cohesive, coherent synopses of the research objectives, the literature reviewed and findings on innovative financing models for rural electrification in the Eastern Cape.

The contribution to knowledge in innovative financing models for rural electrification will be detailed using the consistency matrix. Recommendations of innovative financing models that can spur rural electrification in the Eastern Cape will be presented to all the stakeholders. The chapter will conclude by making suggestions for future research considerations.

## 6.2 Conclusions regarding research question 1

While electricity may not be sufficient to spur development on its own, it is a highly sought-after commodity that plays a vital role in people's lives, especially in rural areas. The functions of national and local actors in planning and implementation are strongly related to the drivers and barriers. Essentially, this research has established an element of similarity in the drivers of rural electrification, especially in South Africa and the SADC region at large. For example, government policies are the main driver in the Eastern Cape; and the same level of driver dominance is found in countries like Tanzania and Mozambique. Other significant drivers are political campaigns and increasing demand, and there are other drivers like local initiatives and environmental sustainability.

The barriers are frequently interconnected, and therefore it is hard to isolate the impact of one specific barrier. This was evidenced by three dominant barriers of rural electrification in the Eastern Cape: rural infrastructure, finance, and corruption. It is interesting to see corruption ranking high amongst the common

factors that impede the rural electrification or deployment of new technologies. This is a barrier that the literature did not highlight as a major constraint.

The research has also revealed that drivers and barriers to rural electrification could be similar, but they vary in each area's degree of impact. Additionally, the understanding of prevailing drivers and barriers globally, including other provinces in South Africa, may not be transferable to the context of the Eastern Cape.

## 6.3 Conclusions regarding research question 2

Finance is at the centre of any entrepreneurial opportunity and developmental initiative. In electricity or energy finance, the financing mechanisms have been classified as private, public, and public-private partnership financing models. The research aimed to answer the research question about existing financing models in the Eastern Cape using secondary data. However, there is no available secondary data specific to the financing models used in the Eastern Cape and authorities (Department of Mineral Resources and Energy, Eskom, NERSA, and Municipalities) are not willing to provide reports on rural electrification projects. This presents an opportunity for further study to add to the body of knowledge regarding the existing financing models in the Eastern Cape if the researcher can gain access to such restricted documents.

However, most respondents highlighted public finance as a suitable financing model for rural electrification. Most of them disputed the possible participation of the private sector in rural electrification since it is impossible to justify a business case for rate of return on investments and given that investors are motivated by the trade-off between risk and reward. These findings are contrary to some literature that argues that changes in technology will present a platform for private sector involvement. The respondents say that the rural populace in Eastern Cape and other regions is primarily indigent and has a low ability and willingness to pay. Only 1 out of 13 (7.14 per cent) respondents advocated for public-private partnership, which is feasible when the government takes a leading role through public funding. The position of many experts is that rural electrification is

indispensable for socio-economic development; it is not necessarily meant to be commercially viable on its own.

## 6.4 Conclusions regarding research question 3

Low carbon innovation (adoption of renewable energy technologies) is impeded by finance, which is considered one of the most salient barriers to spur rural electrification. The research revealed that innovative financing can promote renewable energy technology, that a good regulatory framework can play a pivotal role in enhancing electrification in rural areas. Lastly, off-grid technologies could be the best alternative to achieve universal electrification goals. The research findings highlight that suitable innovative financing models must focus on the end-user, and there must be an element of community involvement.

In addition, the private sector is primarily motivated to finance electrification projects based on profitability. Therefore, it does not finance small to medium scale projects for rural electrification due to the risk of offering risk to poor households (low willingness and ability to pay). In contrast, the public sector is not motivated by profits obtainable since the focus is mostly on development and service provision. As a result, the public sector does not offer finance at the micro level but finances large projects like grid extension. Based on the research findings, this presents a unique and complex case in the Eastern Cape. Therefore, government policies must drive rural electrification using innovative financing models for renewable energy technologies (off-grid) through public finance.

This case is different from most of those found in the literature because traditionally, it is the private sector that is adaptable to create innovative financing models. For example, the ability to adapt is seen in Small Scale Embedded Generation (SSEG), such as rooftop solar, where all the major banks have designed financing models for institutions. However, the findings reveal no incentive for the private sector to participate in rural electrification; therefore, the government needs to create innovative financing models or an enabling environment.

| RQ # | Research Question | Proposition | Answer | Contribution to knowledge |
|---|---|---|---|---|
| 1 | What are the main drivers and barriers with respect to rural electrification in South Africa? | The drivers of rural electrification are policies, poverty mitigation; local initiative; local demand; affordability and environmental sustainability. Conversely, the barriers to rural electrification are rural infrastructure, weak organisations and institutions; technical systems; finance and economy, local management, technology diffusion and adaptation. | The dominant drivers of rural electrification are government policies, political campaigns and increasing demand. The significant barriers to rural electrification are rural infrastructure, finance, and corruption. | The rural electrification drivers and barriers cannot be generalisable but may be transferred from one context to another, as long as the uniqueness of each place, province, country or region is fully taken into account. |
| 2 | What financing models, whether innovative or traditional, have been deployed for the extension of | The financial models or mechanisms for rural electrification are based on the source of funds | The currently deployed financing models could not be | The Eastern Cape region does not have readily available data |

| RQ # | Research Question | Proposition | Answer | Contribution to knowledge |
|---|---|---|---|---|
| | rural electrification in South Africa? | classified as Public Financing, Private Financing and "Public-Private Partnerships". | established due to a lack of secondary data. However, Public Financing is preferred as the ideal financing model compared to Private Financing and "Public-Private Partnerships" models. | or records for rural electrification financing models. As a result, public finance is the only financing model that can effectively spur rural electrification. |
| 3 | How can innovative financing further promote renewable energy technology innovation (i.e., beyond R&D) in order to support rural electrification at the study site? | Innovative financing models can promote renewable energy technology when used appropriately in the right socio-economic, environmental and policy frameworks. | Innovative financing models can promote renewable energy technology when used appropriately in the right | The Eastern Cape presents a unique and complex case where government policies must drive rural electrification |

| RQ # | Research Question | Proposition | Answer | Contribution to knowledge |
|---|---|---|---|---|
| | | | socio-economic, environmental and policy frameworks. But, most importantly, the focus must be on end-user financing. | using innovative financing models for renewable energy technologies (off-grid) through public finance. |

## 6.5 Recommendations

The following recommendations can improve rural electrification in the Eastern Cape when implemented, based on the conclusions of this study.

**Government**

The study showed that government policy plays a significant role in rural electrification in the Eastern Cape. As a result, it is suggested that the government consider expanding related development programs (inclusion in policy formulation, training on energy projects, funding of community-based energy projects). This will increase the levels of participation by the public in the Eastern Cape, resulting in an increase in the level of economic development of the nation at large. However, the suitability of financial models or mechanisms is mainly dependent on policy structure.

The findings further reveal that public finance is the dominant financing model suitable for spurring rural electrification in the rural Eastern Cape. Therefore, the government needs to develop innovative and adaptive financing models that will promote renewable energy technologies and increase the uptake of off-grid solutions.

Some government policies should aim to support and integrate communities into the development and renewable energy technology innovation. In addition, communities must be equipped with innovation and technical skills to improve the contribution on or diffusion of renewable energy technology innovation.

**Private Sector**

The private sector, especially banks and financial institutions, are very adaptive and have had time to gauge the South African energy transition risks and opportunities. The average standard Eskom tariffs have risen by almost 300 per cent since 2007. Combined with the continued risk of load shedding, this cost has forced businesses to transition to SSEG to meet their energy needs. The banks have been quick to provide innovative financing models to meet the needs of these customers. The private sector must consider micro-financing mechanisms that meet the rural customer profile focusing on the end-user. This can be coupled with development in partnership with the government or local community. Furthermore, the private sector can play a pivotal role in financing renewable energy innovation in collaboration with research institutions.

**NERSA**

The energy regulator must create a regulatory framework that will be ideal for enhancing rural electrification. The current lack of regulation for off-grid technologies increases uncertainty which hinders new entrants into the market. Therefore, to increase activity level, the regulatory framework governing rural electrification must be monitored and revised. Also, the regulatory framework must consistently catch up with technological advancement in the energy industry. The licenses must be regularly updated to keep accurate records of all rural electrification projects.

**Municipalities**

The local government plays a pivotal role in determining whether households can access affordable energy. The findings in the study also reveal that most of the rural populace are not registered as indigents to qualify for Free Basic Electricity (FBE). The municipalities need to create awareness. Furthermore, the FBE is based on a free monthly allocation of 50kWh to qualifying households. This has proven insufficient based on the findings and literature, revealing that the bare minimum requirement is 250kWh which increases to 420kWh during winter. Most rural areas do not buy electricity once the Free Basic Electricity (FBE) provision is exhausted; they resort to traditional forms of energy like wood, gas, biomass and kerosine. The municipalities need to evaluate the cost of additional FBE provision versus the cost externalities (environmental, health, agricultural and tourism) where traditional energy sources are used.

**Rural Communities**

These sectors are generally characterised as lacking consumer demand density and consisting of low-income groups. These sectors struggle to attract private investors due to poor market incentives (Xu et al., 2016). Due to inaccessibility to affordable energy, local communities can leverage economies of scale and venture into partnerships with municipalities, government, the private sector, and donors to develop community-owned off-grid solutions.

## 6.6 Suggestions for further research

The research findings have shown that developing innovative financing models for rural electrification in the Eastern Cape needs to be explored. A thorough inquiry is warranted in these respects and would benefit the province most.

Future research opportunities exist to:

a. Examine the innovative financing models for rural electrification in other provinces or other countries. As demonstrated by the research, the findings depend on the context and cannot be generalised, although some insights may be transferable.

b. Further research on existing financing models in the Eastern Cape and investigating the number of rural electrification projects financed are required. This will help identify the dominant and effective financing models and lay the foundation for creating innovative financing models that can spur rural electrification.
c. Research on how policies can drive rural electrification using innovative financing models for renewable energy technologies (off-grid) through public finance.
d. Investigate mechanisms to catalyse rural electrification investment projects.
e. Investigate the use of non-conventional financing models like crowdfunding and Pay-As-You-Go and assess their suitability for the South African market.

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