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Creating Opportunities

DETERMINANTS OF RENEWABLE ENERGY DEPLOYMENT IN SELECTED SADC COUNTRIES

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Omphemetse Makabe

DEDICATION

This dissertation is dedicated to my late brother, Mompati Clifford Makabe. May your soul rest in peace.

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First and foremost, I thank God for granting me the strength to complete this dissertation. I am also grateful to my supervisor, Professor Andrew Maredza, and co-supervisor, Dr Rachel Nishimwe-Niyimbanira, for their guidance and encouragement, which were central to my dissertation. I also want to thank my colleagues at the University for their support and motivation.

ABSTRACT

The need to accelerate the use of Renewable Energy (RE) has seen a significant rise globally over the past few years, driven by its ability to achieve sustainable development and reduce climate change disasters caused by increased Green House Gases (GHGs). However, the Southern African Development Community (SADC) region remains heavily dependent on fossil fuel as a major energy source, posing a threat to energy security and sustainability (IRENA and AfDB,2022). Therefore, it is crucial to investigate the key factors influencing the deployment of RE. This study examines the environmental, macroeconomic and socioeconomic determinants in selected countries in the SADC region utilizing annual secondary data from 1990 to 2021.

The variables in this study included Carbon Dioxide (CO_2) emissions, financial development, Gross Domestic Product (GDP), regulation and policy dummy variable as well as the interaction term of financial development and GDP. The long-run and short-run relationship is investigated using the panel Auto Regressive Distributed Lag (ARDL) method and applying the Pooled Mean Group (PMG) estimate. In addition, the study tested the robustness of panel ARDL by applying the panel Fully Modified Ordinary Least Squares (FMOLS) and panel Dynamic Ordinary Least Squares (DOLS).

The empirical results reveal a significant positive relationship between GDP, regulation, and policy dummy variables and financial development, whereas financial development and CO_2 emissions showed a negative and significant relationship. However, the interaction effect of financial development and GDP showed an insignificant relationship. The study further found evidence that in the short run the empirical results differ in terms of the cross sections, where the results show a significant relationship between the variables in Angola, Botswana, Democratic Republic of Congo and Namibia however in Zambia and South Africa an insignificant relationship was observed with all the variables excluding the interaction term. The study concludes that all variables, including CO_2 emissions, financial development, GDP, regulation, and policy dummy variables, influence RE depending on the context.

Key Words: Renewable Energy, Southern African Development Community, Carbon Dioxide emissions, Nationally Determined Contributions, sustainable development, climate change

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RE	Renewable Energy
CO_2	Carbon Dioxide
CSP	Concentrated Solar Power
DOLS	Dynamic Ordinary Least Squares
DRC	Democratic Republic of Congo
EE	Energy Efficiency
EKC	Environmental Kuznet Curve
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GHG	Green House Gas
IPPs	Independent Power Producers
IRP	Integrated Resource Plan
NDCs	Nationally Determined Contributions
SADC	Southern African Development Community
SAPP	South African Power Pool
SSA	Sub-Saharan Africa
TPB	Theory of Planned Behaviour

CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 BACKGROUND OF THE STUDY

Over the past few years, the global community has seen an unprecedented upsurge in climate change events and global warming owing to high GHG. These developments have consequently underscored the urgent need for the implementation of actions to mitigate climate change, such as adopting clean and sustainable technologies for energy and electricity production and upholding international climate agreements. The SADC, a regional intergovernmental organization, has a role to play in this regard. A considerable amount of GHG emissions is attributable to energy - natural gas and the burning of coal and oil for electricity and heat, which accounts for 34 percent of total GHG emissions globally (IPCC, 2022). According to the IPCC (2022), developing countries are the most vulnerable to the effects of GHG and climate change events, which threaten their ability to achieve economic growth as well as the Sustainable Development Goals (SDG). SDG 7, which aims to ensure reliable, sustainable, affordable, clean energy for all, is one of the key SDG targets under threat.

The deployment of RE sources (such as hydro, solar photovoltaic, wind, and geothermal) offers an opportunity to reduce the impacts of global warming because it does not generate GHG and minimizes the use of fossil fuels (Tee et al., 2021). Notwithstanding, the SADC's energy system and electricity generation are dominated by the use of fossil fuels, with coal accounting for 57.1 percent, followed by biofuels and waste at 21.8 percent and oil at 14.8 (IRENA and AfDB, 2022). The remaining is supplied through natural gas, electricity, and heat, and nuclear and renewables account for 23.5 percent. In 2020, only 9.6 GW RE was generated (17 percent of total RE in Africa) in electricity generation (IRENA and AfDB, 2022). Countries such as Botswana and South Africa generate at least 70 percent of their power from coal.

Globally, there has been an upward trend in RE capacity, which reached almost 50 percent or 510 gigawatts (GW) in 2023 (IEA, 2023). However, SADC and the rest of Africa is falling behind in deploying large-scale RE, with only 20 percent of the electricity generated from RE and 2 percent investment in the past two decades (IEA, 2022). This has highlighted the role of RE in SADC to limit global warming to 1.5°C as agreed in the 2015 Paris Agreement - a legally binding international treaty to tackle climate change (IPCC, 2018).

Despite the high reliance on fossil fuel leads, the Southern African region continues to have some of the lowest electricity access rates in Africa. Evidently, fossil fuels have electricity failed to meet electricity demand, which is also indicated by rolling blackouts, which further damage "regional commerce" (Kamurai, 2022:8). This emphasises the importance of accelerating the use of energy sources that will provide sustainable and reliable electricity. RE technologies can play a role in increasing electricity access, and there is an urgency for alternative energy solutions to shift from fossil fuels. In the SADC, 8 out of the 16 SADC countries have at most 50 percent electricity access, however, countries including Malawi and the Democratic Republic of Congo (DRC) have less than 20 percent access (SADC,2016). The significance of RE is not only important in reducing the impact of climate change but also for future energy security and economic prosperity (Ohler and Fetters, 2014).

The Southern African region possesses significant potential from which renewable resources can be drawn; this includes vast solar, geothermal, hydro, and wind resource potential. Consequently, the region is gradually upscaling RE, as demonstrated by policy frameworks such as the Renewable Energy and Energy Efficiency Strategy and Action Plan (REEESAP) and the Regional Infrastructure Development Master Plan (RIDMP), among others. Furthermore, as part of international climate action, the SADC has committed to additional installed RE capacity in the Nationally Determined Contributions (NDCs) under the Paris Agreement.

While RE is appealing for electricity generation because of its contribution to sustainability development, economic prosperity and energy security in economies in the SADC, upscaling RE comes with vast challenges (Ohler and Fetters, 2014). These include governance strength, access to finance given the high cost of capital, and the lack of effective regulatory frameworks to promote RE and dependence on the fossil fuel industry. Therefore, for SADC to meet its people's needs, a greater understanding of the particular RE determinants is necessary to maximise economic and environmental benefits, address regional challenges, and accelerate the transition to a clean economy (Jamil et al., 2022).

Marques et al. (2010) reveal a few imperative factors that determine the use of RE, such as country-specific, political, macroeconomic, and socioeconomic factors. Unless the substantial factors that play a key role in RE adoption in influencing the evolving energy landscape are understood, the pursuit of the energy transition and the related economic opportunities will not be entirely realised (Asante et al., 2020). Against this background, there is a need to accelerate the pace of new RE capacity to reach the collective target, which serves as the basis for this study.

1.2 PROBLEM SATEMENT

The Intergovernmental Panel for Climate Change (IPCC) Global Warming 1.5°C report on Southern Africa is a climate change hotspot with high abnormal impacts, shown by the fact that the mean annual temperatures in SADC increased by between 1.04°C and 1.44°C (IPCC, 2018). This leads to the region's experiences of water scarcity, increased drying, warming, and extreme weather events, which affect the socioeconomic well-being of the region (Climate Diplomacy, 2024). These events are exacerbated by the SADC's high dependence on fossil fuels to produce energy, unlike the rest of Africa. The region accounts for the highest Carbon Dioxide (CO_2) emissions of 486 million tons in Africa (IRENA, 2021).

In the face of escalating risks of climate change owing to the contribution of fossil fuels, the transition to clean energy sources is, therefore, an urgent necessity to reduce climate change impacts and keep temperatures below the 1.5°C target of the Paris Agreement (Egli, 2020). Further to the risks that fossil fuels have on climate change, the dependence on the sources for energy production has failed to deliver access to reliable and affordable electricity, causing energy insecurity. Currently, eight out of the 16 SADC countries have less than 50 percent electricity access (Cabré et al., 2020).

In addition to the limited access to electricity of the Southern African population, the sector has been characterised by widespread electricity shortages in all but two countries (Angola and Botswana). At minimum, countries such as Zimbabwe, Malawi, Zambia, and South Africa have had more than 16 hours of power cuts and at least 6 hours (Mativier, 2023). This hampers the region's ability to achieve economic development since it is underpinned by energy and electricity. According to the World Economic Forum (2021), RE can be the most cost-effective and accelerated way to improve access.

Existing studies have examined RE determinants in various intergovernmental groups or individual countries. Evidence from previous studies (Yu and Gua, 2022; Kang et al., 2021; Ackah and Kizys, 2015) has shown that there are necessary factors that need to be understood and identified to realise the goal of increasing clean energy use and are yet to be studied in the Southern Africa region. Therefore, the limited available research on RE deployment is a reason for the discussions concerning the key determinants of RE development. The purpose of this study is to offer nuanced perspectives by focusing on the SADC region to promote RE.

1.3 RESEARCH QUESTIONS

i. What are the key determinants of RE production in selected SADC countries?

ii. What is the direction and magnitude of the relationship between RE production and its determinants in the short and long run?
iii. What are the differences in the effects of determinants of RE production across the selected countries?

1.4 AIM AND OBJECTIVES OF THE STUDY

The main purpose of this study is to assess the determinants of RE deployment in selected SADC countries and understand what factors promote RE production.

Objectives of the study:

i. To empirically identify the key determinants of RE production in selected SADC countries in the long and short run.
ii. To determine the direction and degree of the relationship between RE production and its determinants in the long run and short run.
iii. To investigate the differences in the effects of the determinants of RE production across the selected SADC countries in the short run.

1.5 HYPOTHESIS OF THE STUDY

The hypotheses for this study are formulated and stated below:

Hypothesis 1

H_0: The key determinants of RE have no statistically significant effect on RE production in the selected SADC countries.

H_1: The key determinants of RE have a statistically significant effect on RE production in the selected SADC countries.

Hypothesis 2

H_0: The relationship between RE production and its key determinants is not positive and significant both in the short run and long run.

H_2: The relationship between RE production and its key determinants is positive and significant both in the short run and long run.

Hypothesis 3

H_0: The effects of the determinants of RE production do not vary significantly across selected SADC countries.

H_3: The effects of the determinants of RE production vary significantly across selected SADC countries.

1.6 SIGNIFICANCE OF STUDY

As the world shifts to an energy mix that includes and scales up RE, it is essential to assess the ways to maximise the potential of RE use. Examining the determinants of RE will ensure that the study conducted will contribute to ongoing efforts to identify ways to accelerate RE production, reduce the occurrence of climate change events and honour international climate agreements.

The findings of this study will provide crucial insights to key stakeholders and policymakers regarding the determinants of RE. This information is vital for the government to develop appropriate national and regional strategies, policies, and regulatory frameworks that will create an environment that will benefit the sustainable growth and expansion of RE. Public authorities are grappling with setting up the system or providing incentives to encourage more renewable production. Moreover, additional contributions will be made to the existing vast body of literature that examines the determinants of RE and considers total RE as a dependent variable. No study has been conducted in the context of the SADC region, which was a strong driver for the topic.

1.7 ORGANISATION OF THE STUDY

Chapter 1 provides an introduction and background of the study. Chapter 2 discusses the RE in SADC and the selected countries by providing an overview of the sector. Chapter 3 provides an empirical and theoretical framework. Chapter 4 outlines the methodology and explanation of the tests that the study employs. Chapter 5 presents the outcomes of the in-depth analysis and interpretation of the results of the methods applied to examine RE and its potential determinants in the selected SADC countries. Lastly, chapter 6 provides the conclusion of the study and recommendations.

Chapter 2

OVERVIEW OF RENEWABLE ENERGY SECTOR IN THE SADC REGION

2.1 INTRODUCTION

Among all the regions in Africa, Southern Africa is commonly known for producing its energy largely from fossil fuels (IRENA and AfDB, 2022). However, over the years, this dependence has resulted in energy challenges such as an unreliable energy supply and inefficient electricity, including anthropogenic effects that result in climate change. For this reason, RE has received increased attention and is recognised as a solution for cleaner, sustainable, and reliable energy systems.

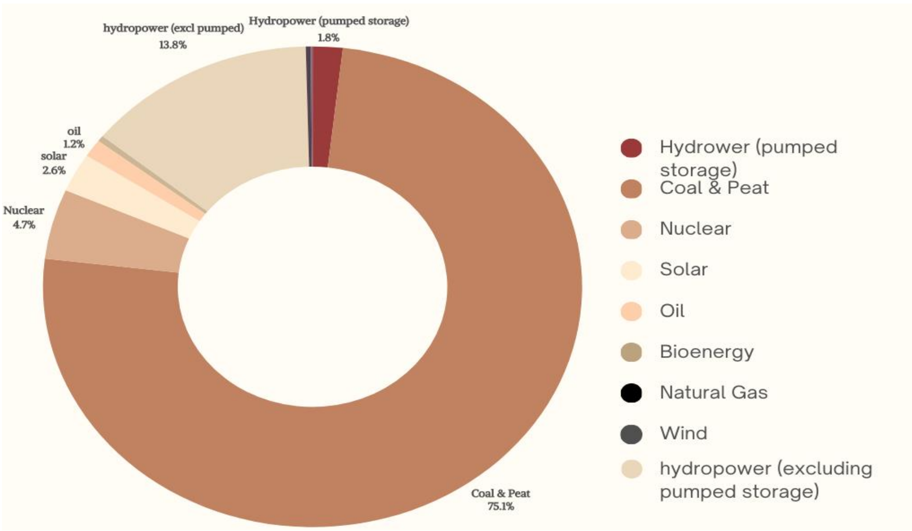
The SADC region is made up of 16 members, including Namibia, Botswana, Seychelles, Madagascar, Angola, Eswatini, Zimbabwe, the DRC,Malawi, Mozambique, Zambia, Lesotho, Botswana, South Africa, Mauritius and Tanzania. Nearly all the SADC countries have set RE targets for expanding clean energy sources. Therefore, significant efforts are being made to shift from fossil fuels.

This chapter reviews the RE sector in the SADC region and focuses on the six selected countries for the study. Following the introduction, section 2.2 outlines the RE sector across the SADC region then the investment flows of energy are highlighted in section 2.3, section 2.4 presents the SADC RE policies followed by section 2.5 which provides greater detail of the RE profile of each selected country of the study; Angola, Botswana, the DRC, South Africa, Namibia, Zambia and section 2.6 concludes the chapter.

2.2 RENEWABLE ENERGY SECTOR ACROSS THE SADC REGION

The energy market in SADC is one of the largest in Sub-Saharan Africa (SSA), and the landscape vastly differs from that of the rest of the African regions. This is because it is highly characterised by the use of fossil fuels, primarily coal, which continue to play a prominent role in energy supply, including generation (IRENA & AfDB, 2022). As shown in figure 2.1, SADC's primary energy supply accounts for 57 percent of coal, 21.8 percent from biofuels and waste and 14.8 percent of oil. The rest of the supply is made of gas (2.3%), electricity and heat (2.3%) and nuclear (1.6%)

Figure 2.1: Total Primary Energy Supply in Southern Africa by RE Source



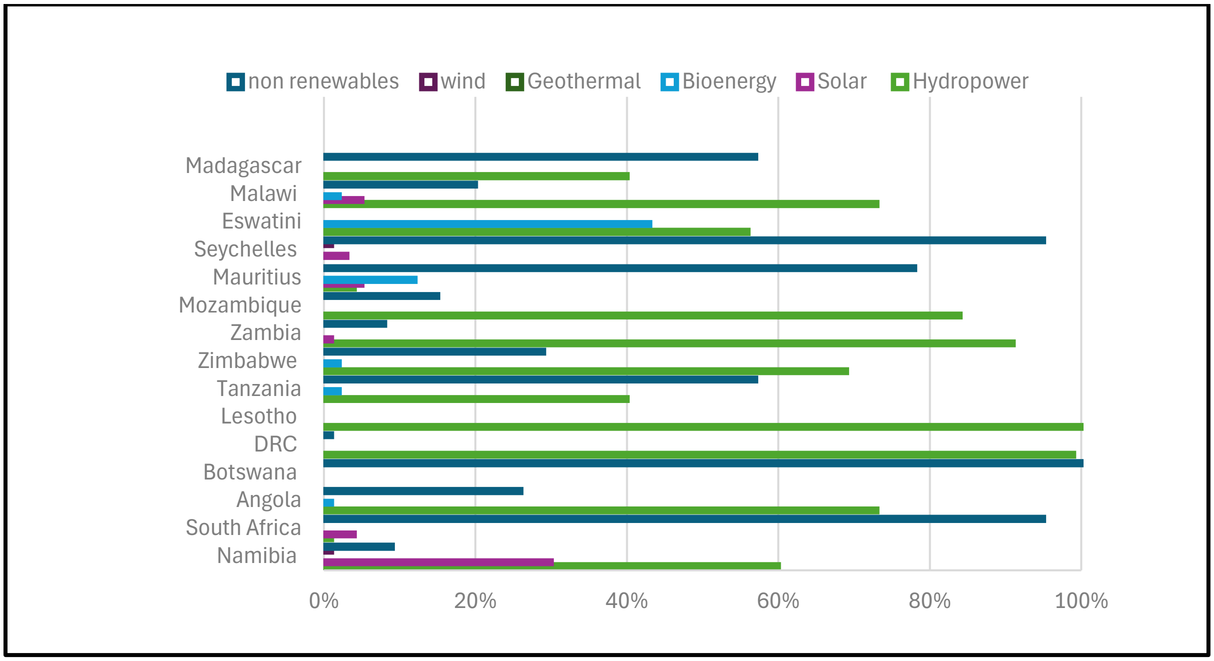
Source: IRENA and AfDB (2022)

In 2022, the SADC region generated a total of 273 terawatt hours (TWh), dominated by coal and peat. RE installed capacity of 51 TWh – about 42.588 TWh is accounted for by hydropower (pumped and excluding pumped storage), which continues to be the key source of RE. Solar energy is the second highest, with 7.098 TWh of installed capacity. SADC is the SSA region's largest installed solar capacity. The rest of the RE capacity is distributed among wind at 0.273 TWh and bioenergy at 1.092 TWh (IRENA and AfDB, 2022).

Notwithstanding the rates of energy generation, access to energy is still lagging in the region. One of the characteristics of SADC's energy landscape is low access to electricity. The average access across the region is 32 - 48 percent, which is equal to the weighted average for SSA (SADC, 2018). Over the past few years, the region has faced an energy supply crisis, which has been proven by insufficient and unreliable energy supply (SARDC, 2018). Renewable energy offers a significant opportunity to play a key role in tackling the challenges prevalent in the energy sector. However, despite the ample RE resources of SADC members, the RE market remains largely underdeveloped (Wits et al., 2022).

Figure 2.2 below presents the main RE sources in the SADC. Some of the SADC member states with the highest electricity generation from RE sources include Mozambique, Angola, Zambia, South Africa, and the DRC (IRENA,2023). By technology, hydropower dominates the current RE-installed capacity, total generation, and planned developments (Figure 2.2).

Figure 2.2: RE Sources in the SADC



Source: *IRENA (2023)*

In some SADC nations, such as Lesotho and DRC, hydropower is the only RE technology deployed, while Botswana is the only economy without hydropower capacity. Providentially, SADC is endowed with rich energy resources; therefore, these must be capitalised and leveraged to advance the RE agenda and further address the need for energy security (Bowa et al. 2021).

Arguably, SADC has the largest RE resources in Africa, abundant natural potential, and favourable geography; therefore, driving the increase in RE production is necessary. The abundant potential that can be harnessed in SADC includes solar photovoltaic 246 212 TWh/y, wind 171 739 TWh/y, hydro 415 TWh/y and biomass 96 TWh/y (KfW et al., 2021). While other types of resources are also plentiful, the region benefits from an abundance of solar radiation, with 2,500 hours of sunlight annually. In many parts of the SADC, hydropower is the major RE contributor. Regionally and globally, hydropower has been the most cost-effective form of renewable power generation (SARDC, 2018).

In contrast with solar resources, wind energy is unevenly distributed and mostly in coastal regions; consequently, installed capacity is lower than one percent (IRENA and AfDB, 2022). The SADC countries with significant wind potential include South Africa, Mauritius, Angola, Namibia, Mozambique, Lesotho, DRC, Tanzania, Seychelles, and Madagascar (SARDC, 2018).

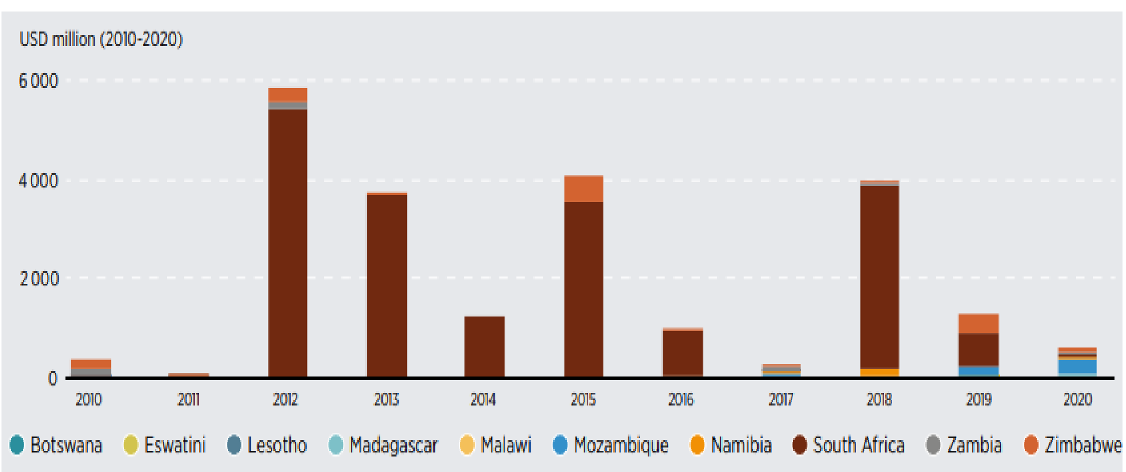
Biomass potential in SADC is based on agricultural waste; in 2017, only two power utilities contributed an aggregate of 52.5 megawatts (MW) in capacity (SADC, 2018). These are TANESCO (a state-owned electricity enterprise in Tanzania) with 10.5MW and Eskom (also a state-owned electricity entity in South Africa) with 42MW (SAPP, 2017). Compared to other RE sources, considerable geothermal potential has been minimal. An estimated 4,000 MW of electricity can be harnessed from geothermal sources located along the Rift Valley in Tanzania, Mozambique and Malawi (SARDC, 2018).

Despite the vast RE potential in SADC, the resources are inadequately exploited (IRENA and AfDB, 2022). However, RE can become a fundamental part of the region's structural economic transformation in the energy sector. The Southern African Power Pool (SAPP) – a cooperation of the national electricity companies of the SADC - have proven to be instrumental and a key resource in supporting SADC members' utilities to advance the integration of RE power supply by encouraging the participation of Independent Power Producers (SADC,2018).

2.3 SADC ENERGY INVESTMENT FLOWS

The RE landscape in the SADC region faces several barriers and obstacles, the most prominent of which is investment in energy infrastructure (SADC, 2018). Given the high initial costs of capital and the perceived investment risk, access to financial resources remains a barrier (SADC,2018). From 2010 to 2020, SADC attracted the highest cumulative share of RE investments in SSA; however, the scale of investment is considerably low in relation to the financial needs of the region (IRENA, 2024).

Figure 2.3: Annual RE Investment by Country



Source: IRENA (2024)

In 2022, almost 90 percent of this investment was in South Africa (Figure 2.3), and the rest flowed into Zimbabwe (7 percent), Zambia (2 percent), Mozambique (2 percent), and Namibia (1 percent). In terms of RE sources, investment was distributed as solar photovoltaic (PV) (36 percent), followed by wind energy (34 percent) and concentrated solar power (24 percent); other RE technologies only received marginal investment (IRENA, 2024).

2.4 SADC RENEWABLE ENERGY POLICIES

Efforts to scale up RE in SADC have been implemented through supportive policies and reforms for the continued expansion of the energy mix (Deloitte, 2023). According to Olanrele and Fuinhas (2022: 849), regarding the skills gap as well as the deficiency of technical knowledge, policy support has been relied on to scale up the uptake of renewables. One important policy is the NDCs, which are integral to the International Paris Agreement and have been ratified by all the SADC countries. The NDC is a policy that indicates a country's domestic climate commitments to the international community and includes RE contributions.

Table 2.1 below provides the scope of quantifiable (the target for all the NDCs is 2030) renewable targets of NDCs in the selected SADC countries for this study. The NDCs are categorised into two categories: unconditional and conditional. The unconditional NDCs are implemented regardless of assistance, whereas the conditional NDCs require technical, capacity-building and financial support from advanced nations to be fulfilled. Angola and South Africa are the only countries that have committed to unconditional NDCs, although Angola has some that are conditional, unlike South Africa.

Table 2.2: Quantified RE Contributions in NDCs from the Selected SADC Countries

	Quantified RE Contributions in NDC	
Country	**Unconditional NDCs**	**Conditional NDCs**
Angola	▪ 760 MW hydropower ▪ 100 MW wind	▪ US$ 11.34 billion of RE capacity by 2030 ▪ Hydropower - 6 540 ▪ Wind - 681 MW ▪ Biomass - 640 MW ▪ Solar - 438 MW ▪ Small hydropower - 192 MW ▪ 100 MW off-grid solar at an estimated cost of USD 150 million
Botswana	None	

Country	Unconditional NDCs	Conditional NDCs
DRC	None	▪ Hydropower – USD 2 billion ▪ Biomass – USD 240 million
Namibia	None	▪ Increase renewable electricity from 33 percent to 70 percent ▪ Biogas: 10 percent N2O emissions reduction by 2030
South Africa	▪ 5 243 MW / US$16 billion renewables ▪ 6 300 MW renewables	
Zambia	None	

Source: Muñoz (2020)

Among the key defining frameworks aimed at increasing RE's role in the region are the SADC Energy Protocol, the RE and Energy Efficiency Strategy and Action Plan (SADC, 2016), the Regional Energy Access Strategy and Action Plan (SADC, 2020), and the SADC Industrial Energy Efficiency Programme.

The SADC Energy Protocol (SADC 20), adopted in 1996, is the first main legal document and overarching institutional tool to encourage cooperation on energy development and harmonise policies that ensure energy sustainability, security, and reliability in the region (SADC, 1998). The Protocol was last reviewed in 2019 for alignment with the emerging needs of the countries. Below are details of the direct deployment policies targeting RE technologies; the policies include regulations and action plans of the SADC.

2.4.1. **Renewable Energy and Energy Efficiency Strategy and Action Plan**

The REEESAP, adopted in 2017 for the period 2016 - 2030, focuses on providing a framework for SADC countries to advance RE and energy efficiency (EE) strategies to mobilise funds (SACREEE, 2017). The objectives of the REEESAP include addressing the power sector's demand or supply gap, replacing inefficient, traditional energy sources and investing in RE and EE projects (SARDC, 2017). The policy targets are to boost RE in the region's electricity mix to 33% in 2020 and 39% in 2030 (SACREEE, 2017). SADC encourages member countries to domesticate and implement the actions in the REEESAP

Various strategic interventions and actions are proposed by the REEESAP, some of which include the following:

- Develop plans, strategies and policy frameworks to establish an enabling environment for RE investments.
- Strengthen SADC national institutions and agencies in the energy sector to adopt and implement EE/RE projects.
- Develop projects, technologies and transfer of expertise to meet demand targets
- Attract private sector participation in investments for EE and RE

2.4.2. **SADC Industrial Energy Efficiency Programme**

The SADC Industrial Energy Efficiency Programme (SIEEP) is a flagship project of the SADC that drives the Industrialisation Strategy and Roadmap (2015-2063), which recognizes energy as both a significant challenge and a vital driver for industrial competitiveness (SACREE, 2023). Additionally, the SIEEP contributes to the REEESAP in reference to the operationalisation by supporting the establishment of energy audits, the setting of minimum energy performance standards for EE equipment, and energy management systems, among others.

2.4.3. Regional Infrastructure Development Master Plan: Energy Sector Plan

The Energy Sector Plan (ESP), as part of the Regional Infrastructure Development Master Plan (RIDMP) - aims to define regional infrastructure needs and establish the conditions to facilitate the development of significant infrastructure in sectors, including energy, by 2027 (SADC, 2012). The key areas of consideration are the implementation of infrastructure projects, including but not limited to electricity generation plants and transmission lines.

Through the ESP, SADC intends to expand renewable energy capacity by 13,719 MW, 10,345 MW, and 8,243 MW in 2017, 2022, and 2027, respectively. This includes hydropower, followed by wind energy, solar PV, solar Concentrated Solar Power (CSP), biomass, and geothermal energies (SADC, 2012).

2.4.4 **Southern African Power Pool Plan**

The SADC SAPP Plan ("Pool Plan") was developed in 2017. Its objective is to identify regional transmission and generation investments that can provide an adequate electricity supply by 2040 (SAPP, 2017). The Pool Plan considers two different scenarios for the development of regional integration and power trade: realistic integration and high renewables.

Under the "high renewables" scenario, the Pool Plan anticipates that the region will need 157 Giga Watts installed generation capacity with 53 percent of RE (27 percent hydro and 26 percent of other renewables – solar, wind, and geothermal), 36 percent coal, 10 percent thermal and 1 percent nuclear (Muñoz et al., 2020). Whereas in the "realistic scenario" which considers individual country perspectives; the region reaches 130 GW installed capacity of 53 percent coal, 30 percent hydro, 12 percent thermal, and 5 percent other renewables and nuclear (IRENA, 2013b).

Currently, SADC produces an average rate of about 1.5 GW annually, leaving a gap of 1.3 GW per year from the region's plans to meet a 53% RE generation capacity target by 2040, as set out in 2017 by the SAPP (Munoz et al., 2020). The significant gap remains to reach the 2040 target.

2.5 ENERGY PROFILES OF SELECTED SADC COUNTRIES AND RENEWABLE ENERGY POLICIES

2.5.1 Introduction

Despite the continued use of non-RE sources such as waste, biofuel, and coal, SADC member countries aim to increase the deployment of RE in their energy mix. SADC member countries have committed to the increased use of substantial RE through established national energy plans and targets, including policies and frameworks over the next few decades.

Several other Member States already have RE in their energy systems, mainly in the power sector. Despite significant progress, technical and financial barriers still hamper the expansion of renewables (REN21, 2018). The next section outlines in greater detail the RE profile of each of the selected countries of study: Angola, Botswana, the DRC, South Africa, Namibia, and Zambia, as well as the key policies that encourage RE.

2.5.2 South Africa Renewable Energy Profile

In South Africa, a large percentage of energy needs are met domestically; the remaining requirements are made up of imports of oil and gas (IRENA, 2020). In 2023, coal dominated the energy supply, making up 75 percent of the primary energy supply, crude oil followed at 14 percent, Natural Gas at 3 percent, and Nuclear at 2 percent (Figure 2.4). The rest of the energy supply is made up of renewables, which contributed 6 percent during the same period (IRENA, 2024). The government has been advancing efforts focused on diversifying the energy mix with RE technologies (wind, hydro and solar PV) - making one of the top three largest economies in Africa with comprehensive RE investment plans (Cheruiyot et al.,2024).

Figure 2.4: South Africa Total Energy Supply 2023

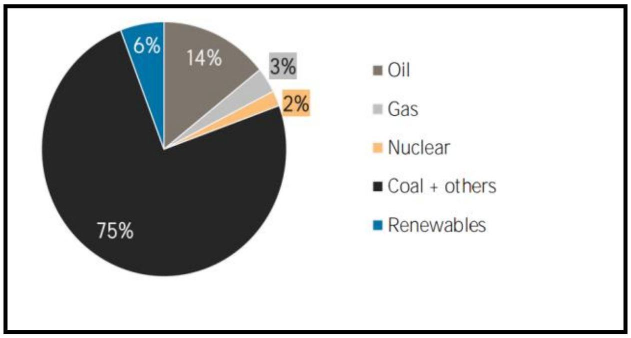
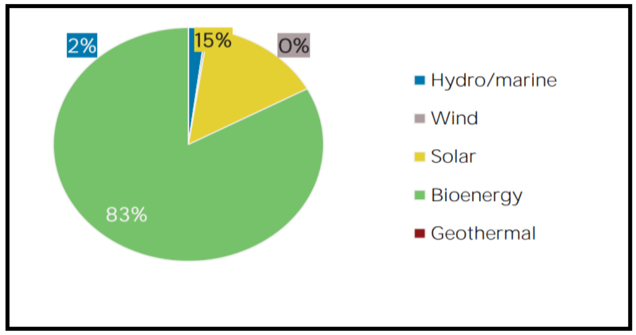


Figure 2.5: South Africa Total RE Supply 2023



Source: IRENA (2023)

In reference to electricity generation, RE accounts for 11 027GWh, which is 5 percent of the total electricity generation. In contrast, non-renewable sources (oil, coal, and gas) make up 95 percent of installed generation capacity combined. According to a report by Deloitte (2023), South Africa has been increasingly deploying RE to play a bigger role (although smaller in relative terms). It will remain on this trajectory to resolve the ongoing power crisis or intermittent power supply. Therefore, diversifying the energy mix, specifically expanding RE, is of utmost importance.

Due to its favourable geographical location, South Africa has immense and varied energy potential to generate RE from various technologies (Akimbami et al., 2021: 5080). It is the third global solar potential, granted from radiation between 4.5 and 6.5kWh/m2/day (Mutanga, 2023). On the other hand, high wind quality is expanding rapidly in numerous countries in Africa, most notably South Africa, which accounts for 41 percent of wind installed capacity in Africa (IEA,2019). According to a study by the Council for Scientific and Industrial Research (CSIR), the country can produce 6700GW of power through wind (Mutanga, 2023).

2.5.2.1 **Policies for Renewable Energy Adoption in South Africa**

South Africa has one of the most progressive energy policies among its peers in SSA, such as Nigeria and Egypt (Cheruiyot et al., 2024). Several policy frameworks have been implemented that opened the integration of RE into the energy mix in anticipation of reducing the reliance on coal. The next section briefly explains some of the energy policies that have transformed and evolved South Africa's energy landscape.

2.5.2.1.1. White Paper on Renewable Energy 2003

The White paper is central to RE in South Africa and presents a mandate to ensure the fair allocation of natural resources for RE promotion and implementation (DME, 2003). Further, it supplements the 1998 White Paper on Energy Policy. The policy includes a target planned for 2013 to generate 10,000 GWh of electricity from wind, biomass, solar and small-scale hydropower generation and non-electric technologies. Four key strategic areas have been addressed in the Paper, which include technology development, financial instruments, legal instruments, awareness raising, and capacity building as well as education.

2.5.2.1.2. Integrated Resource Plan 2019

The Integrated Resource Plan (IRP) 2019 supports the diversification of South Africa's energy mix by planning the procurement of the country's generation capacity up to 2030. Implementation of the IRP is based on the Electricity Regulations Act No. 4 of 2006 (Department of Energy, 2019). It is envisaged that by 2030, the changes in South Africa's energy mix will include the production of an additional 52.2 GW. Therefore, RE will increase to 9% (Scholtz et al., 2017). The policy is renewed every two years; as a result, the latest 2023 IRP has been released for public comment. The IRP (2019) RE targets make up 39.7 percent of RE capacity and are as follows,

- Wind - 17 742 MW
- Solar PV - 8 288 MW
- Hydropower – 4 600 MW
- CSP - 600 MW

2.5.2.1.3. National Energy Act 2008

The national act features RE regulations on diversification, addressing factors including the minimum contribution of RE to the national energy supply, and specifies the resources that can be used for RE (Nhamo and Ho, 2011). Amongst others, the act intends i) to ensure the availability of diverse energy resources in sustainable amounts and at cost-effective prices and ii) to increase generation and provide energy consumption and planning of RE (Presidency of the Republic of South Africa, 2008).

2.5.2.1.4. Renewable Energy Independent Power Producer Procurement Programme

The Renewable Energy Independent Power Producer Procurement Programme (REIPPP) was launched by the Department of Energy in 2011 to expand RE Supply through private sector procurement (Eberhard et al., 2014). Prior to this launch, the National Energy Regulator of South Africa introduced RE feed-in tariffs (REFITs). By 2030, the programme intends to install 20 400 MW of RE capacity, consisting of 45.7 percent from Wind and 19.1 percent from Solar photovoltaic (Department of Energy, 2019).

2.5.3 Botswana Renewable Energy Profile

Botswana's energy sector is characterised by the high use of conventional energy sources, which in turn has brought about several challenges. Unlike any other country in SADC, the country's coal generation capacity is 99.99 percent of electricity generation. Further, Botswana only generates 48 percent of its power, and the rest is sourced from 52 percent of imports SAPP, mainly from South Africa (AfDB and SEFA, 2021). This often results in a shortage of electricity, leading to the challenge of unreliable electricity in Botswana (BPC, 2020).

Figure 2.6: Botswana Total Energy Supply 2023

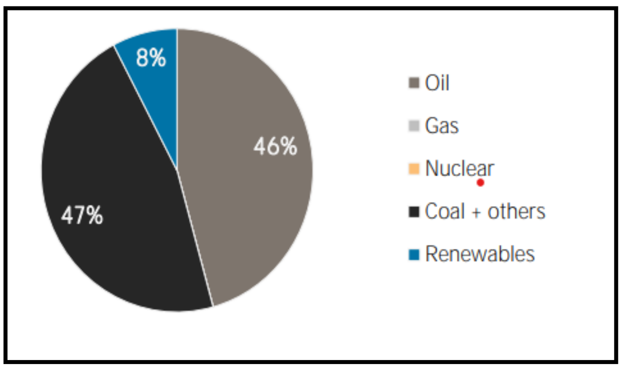
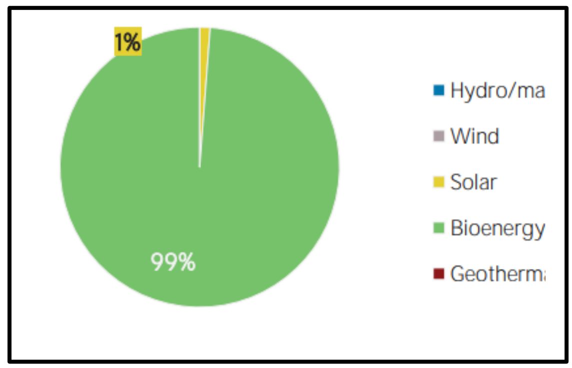


Figure 2.7: Botswana Total RE Supply 2023



Source: IRENA (2023)

Over the past few years, the government has recognised RE as one of the key factors that can drive electricity access or meet electricity demand at a lower cost. According to IRENA (2021), it is anticipated that by 2030, more than 18 percent of Botswana's power will be generated from renewables. However, the total energy supply is made up of 46 percent gas, 47 percent coal and 8 percent renewables, which is distributed between bioenergy at 99 percent and solar at 1 percent (Figure 2.6 and 2.7).

In terms of installed generation capacity, RE contributes insignificantly, with only 0.26 percent (6 GWh) and less than 0.1 percent from diesel out of an 890 MW installed generation (IRENA, 2023). Evidently, a large gap remains for Botswana to meet its RE targets set out in the policy frameworks. According to AfDB and SEFA (2021), some of the main challenges that impede RE generation include limited private sector participation, the absence of operational Independent Power Producers (IPPs), and the regulatory and policy environment at the early stages of development with slow progress on implementation.

Considerable energy potential in Botswana exists in the form of wind, solar and biomass, which evidently have not been harnessed. Botswana has solar energy potential throughout the country. Annually, the country receives an irradiation of 2,000 kWh/m²/annum (~5,5 kWh/m²/day) of global horizontal irradiation (GHI) on average (BERA, 2020). These irradiation levels are among the highest in the world today. The wind potential has not been explored; however, the country has an average wind speed higher than 7m/s and an annual energy production of 4.5 GWh/year (MMGE,2021).

In addition to the energy potential in solar and wind, Botswana has a massive biomass potential of 20 million tonnes per year, which has not yet been explored (DLA Piper, 2022). Unlike other SADC member states that have hydropower as the main source of electricity generation, the country's lack of perennial rivers has ruled out the potential for hydropower in Botswana (SEFA, 2016).

2.5.3.1. **Policies for Renewable Energy Adoption in Botswana**

Botswana's energy sector has been guided by the Botswana Energy Master Plan (BEMP) since 1985. The policy was last reviewed in 2002, leaving the sector without a guiding policy for about 15 years (MMGE, 2021). Therefore, other more recent policies were introduced to outline the government's intention to develop the energy sector and provide a framework for energy planning. In order to create an enabling environment, the Botswana Energy Regulatory Authority (BERA) was set up in 2017 (IRENA, 2021).

2.5.3.1.1. Integrated Resource Plan

The Integrated Resources Plan (IRP), launched in 2020 outlines a least-cost development plan for a period from 2020 to 2040 for energy demand and supply. Further, it announces expanding RE capacity in electricity generation mix with at least 15 percent renewable electricity by 2030, as compared to 1 percent recorded in 2020 (Government of Botswana, 2020a).

To meet the increasing demand, the Government of Botswana approved an installed capacity of 1 540 MW and thus plans implementation of energy projects by the year 2040 while decreasing the economy's carbon emissions. The total RE capacity to be implemented is as follows:

- Solar - 135 MW solar PV by 2022 (currently under procurement)
- CSP - 200 MW 2026 (procurement started in 2021)
- Wind - 50 MW by 2027 (procurement to start in 2024 after wind resource mapping is complete)

- Solar PV - 600 MW by 2040 (100 MW solar PV procurement to start in 2025) – the projects will be developed through private sector investment as IPP)
- Battery storage - 140 MW by 2040 (18 MW battery storage by 2032, procurement to start in 2029)

2.5.3.1.2. National Energy Policy

The goal of the National Energy Policy (NEP) is to improve energy security and access as well as provide a reliable and adequate energy supply to achieve a low-carbon economy (Government of Botswana, 2020b). The policy intends to act as a guide for Botswana's RE energy sector, particularly the expansion of RE sources into the energy mix.

The policy objectives include, among others, i) diversifying the national energy mix, ii) supporting the modernisation and expansion of energy infrastructure to meet the growing energy demand, and iii) minimising the effects of energy supply and consumption on the environment (Government of Botswana, 2020b).

2.5.4 Namibia Renewable Energy Profile

Generally, Namibia is severely reliant on imports from neighbouring countries, demonstrating nominal domestic supply for energy demand (NIPBD, 2021). In tandem, only 55.3 percent of the population has access to electricity despite its small population of about 3 million people (World Bank, 2024). While the total energy supply consists of 60 percent oil and significant coal use at 2 percent, RE contributes to 38 percent of the total electricity supply, including bioenergy, hydro, and solar (Figure 2.8). The country's energy demand (about 60 percent) is largely met by imports from South Africa, Zimbabwe and Zambia through the SAPP market (SAPP, 2019).

Figure 2.8: Namibia Total Energy Supply 2023

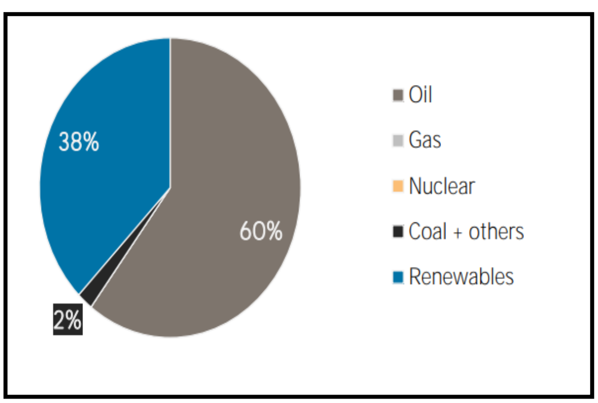
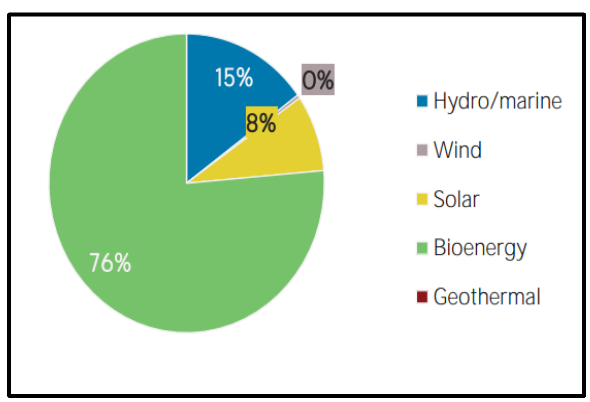


Figure 2.9: Namibia Total RE Supply 2023



Source: IRENA (2023)

It should be noted that while oil dominates electricity supply, the electricity generation is dominated by hydropower which has played a pivotal role in meeting Namibia's energy needs. RE contributes 1333 GW to electricity generation (out of 1470 GW of total generation capacity), and hydropower consists of 875 GWh; the rest is distributed to solar and wind with 427 GWh and 22 GWh, respectively (IEA, 2023). Namibia has a growing interest in renewables – the government has plans to expand power generation capacity by 60% from renewable energies (Business Scouts for Development, 2022).

Due to favourable conditions found on the south coast, Namibia possesses great wind energy potential among most countries in SADC, along with Botswana. The wind speed averages 6.2 – 8.5 meters coast with an annual electricity production potential of at least 2,800 MWh (IRENA, 2013). Further, an analysis by the Ministry of Mines & Energy (2022) shows that abundant biomass resources exist in the form of encroacher bush, and there is also high solar irradiation yearly of 2,200 - 2,400 kWh/m² of direct insolation. Despite the region presenting a high average heat flow, the geothermal potential is not exceptionally high and is only applicable in three locations, excluding Namibia (Business Scouts for Development, 2022).

2.5.4.1 **Policies for Renewable Energy Adoption in Namibia**

Namibia has seen some progress over the past years. Some regulations have been in place to accelerate the uptake of renewable electricity in some cases simply by establishing goals for RE and also introducing competitive bidding through IPP (Energy Regulation Board, 2020).

The first energy policy in Namibia was the White Paper on Energy Policy, which was assent in 1998 and served as a guideline for the energy sector for 20 years. The objective was to achieve energy security, investment, economic competitiveness, efficiency, and sustainability through improved access to energy sources, including RE (MME, 1998).

Considering the changing landscape of the Namibian economy, the government developed policies to encourage the energy sector's development. Among the latest key defining frameworks are the 2022 National Integrated Resource Plan (NIRP), the 2017 National Renewable Energy Policy, and the National Energy Policy adopted in 2017. The policies are outlined below.

2.5.4.1.1 National Integrated Resource Plan (NIRP)

The National Integrated Resource Plan (NIRP), adopted in 2016 and updated in 2022, provides a forecast of Namibia's future electricity demand (MME, 2022). The policy objective is to classify resources necessary to meet the country's electricity needs in a reliable and efficient way.

Therefore, the policy commitment envisages an RE generation capacity of 2,850 MW, including 650 MW of battery energy storage and supply by 2040. Ultimately, the NIRP is the policy custodian of the energy sector.

2.5.4.1.2 National Renewable Energy Policy

In 2017, Namibia adopted a central framework for RE, which is the National Renewable Energy Policy. The policy sought to facilitate access to sustainable, affordable, and clean energy for the whole population and make RE a tool for meeting all national development goals (MME,2017). The policy's objectives are to:

- Making RE a vehicle for expanded access to affordable electricity
- Creating an enabling environment for RE development
- Accelerating RE sector growth and enhancing value chains in the sector

RE electrification targets have been set at 49 percent to 70 percent renewable electricity by 2030, including solar PV and CSP, with 530 MW and 150 MW targets, respectively; wind at 349 MW, hydropower at 347 MW, and finally, 40 MW of biomass.

2.5.5 Angola Renewable Energy Profile

Angola is among the few SADC countries that are net energy exporters and the second-largest oil producer in Africa (Faria, 2021). According to Lima (2023), the RE sector is gaining ground annually, which shows an opportunity to contribute to Angola's diversification and security in the energy sector. This is demonstrated in Figure 2.9; RE energy supply encompasses 63 percent of the total supply capacity, including 28 percent of oil and 9 percent of Gas (IEA,2023).

Figure 2.10: Angola Total Energy Supply 2023

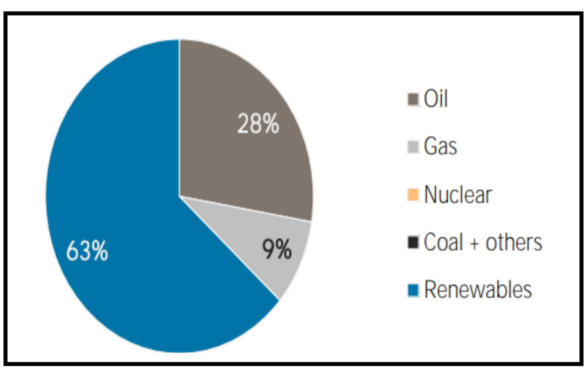
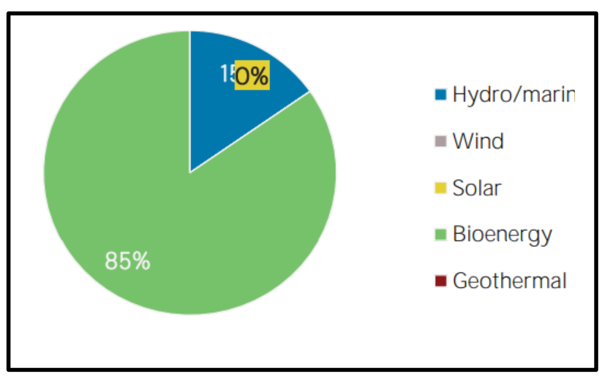


Figure 2.11: Angola Total RE Supply 2023



Source: IRENA (2023)

Notwithstanding that RE contributes the highest percentage of energy supply, the current electrification rates are approximately 43 percent (ALER, 2022). Angola's installed generation capacity is also largely based on RE, with 74 percent (14 004 GWh) of total generation, 73 percent accounted by hydropower, and only 26 percent (4996 GWh) for non-RE (IEA, 2023). Angola holds vast potential for RE production; the energy potential is estimated at 55 GW (MINEA,2015). However, the country continues to rely on hydropower as the only RE source, whereas the large potential for more capacity is yet to be exploited.

According to a report by the Ministry of Energy and Water (2015), Angola's water resources total 18.27 GW, in line with an average annual production of 72 TWh. Because wind capacity is particular to the region, Angola does not have a strong potential for wind energy; only 3.9 GW is viable to be exploited with a speed above 6.5 m/s (ALER, 2022). The Renewable Energy Atlas estimated a potential of up to 7.3 GW of generation from solar energy, which is the most uniformly distributed source, in bioenergy; Angola has resources that reach 170 MW capacity (MINEA and DGNER, 2017). Despite its potential, Angola's current RE-installed capacity is estimated at 3.5 GW, which is much lower than the set targets, which will be presented in the next section (USITA, 2024).

2.5.5.1. **Policies for Renewable Energy Adoption in Angola**

Over the past few years, Angola has progressively increased private sector participation by developing mechanisms to allow private companies in the energy sector, which is usually characterized by vast public dominance. The policy landscape has defined objectives in the electricity sector; some of the policies are explained below.

2.5.4.1.3 Angola Energia 2025

The Angola Energia 2025 was approved in 2008, the objective is to transform Angola into a modern country by promoting investment in various energy resources to meet demand. As part of the strategy, the Angolan government seeks to achieve 60% electricity access for the population by 2025 and renewables by 7.5 percent of installed capacity. Renewable energy will account for 70% of the nation's installed capacity (GOA, 2018). The RE targets are as follows:

- Large hydropower - 5000 MW
- Biomass - 500 MW
- Solar 100 MW
- Wind - 100 MW, small hydropower - 100 MW

2.5.4.1.4 General Electricity Act

The General Electricity Act was initially made official on the 31st of May 1996. In 2014, the act was revised and then approved in 2015 (GoA, 2015). The Act was intended to review the functions of the public sector institutions' generation, transmission, and distribution. Some of the key changes introduced incentives for investment in RE sources and ensured private sector participation by providing IPPs and Public-Private Partnerships (PPPs).

2.5.6 Democratic Republic of Congo Profile

Despite RE sources dominating the DRC electricity generation, access is only provided to just 19 percent of the 85 million population (Energy Capital and Power, 2022). The total energy supply of the DRC is composed of three main sources: oil, coal, and renewables (Bioenergy) (Figure 2.12). Oil is very important, accounting for 80% of the country's energy needs.

Figure 2.12: DRC Total Energy Supply 2023

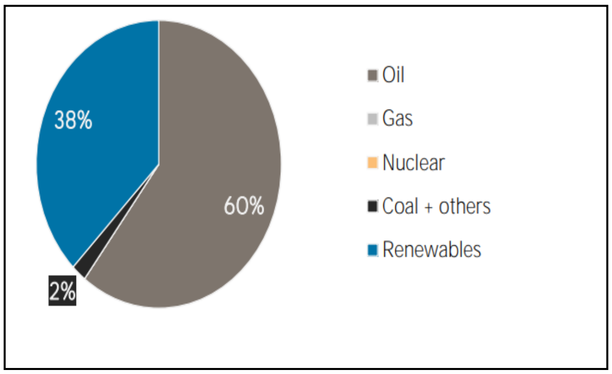
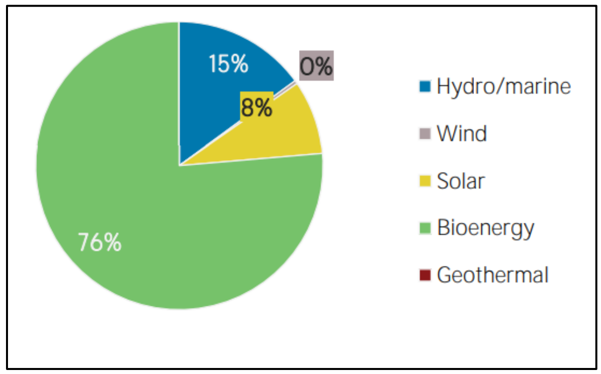


Figure 2.13: DRC Total RE Supply 2023



Source: IRENA (2023)

In the DRC, hydropower is currently nearly the only RE source in energy supply and electricity generation. In 2023, hydropower met 99 percent of the energy needs or installed RE generation capacity with 1775 MWh, while non-RE only contributed 1 percent (IRENA, 2023). The DRC has enough RE potential to be self-sufficient with sources beyond hydropower, which includes solar, wind, biomass, and geothermal; however, the lack of an enabling environment creates a barrier to production in the energy sector.

The DRC offers a significant solar energy potential of 70 GW at an average of 6kWh/m2/day; however, only 25GWh of that is currently operational; this is because of its high solar radiation. Meanwhile, wind energy has 15 GW potential that can be leveraged from wind speed with an average of 6-6.6m/s (Energy Capital and Power,2022). The Congo River, the second longest and deepest river in Africa after the Nile, possesses 100 MW of hydropower potential with 41,000

Cubic meters per second (IEA,2023). However, only 2.5 MW is exploited; therefore, three cascade hydropower stations are being considered in the DRC (IRENA, 2021b).

Even though the DRC is endowed with vast RE potential to diversify its energy mix and scale up the use of RE for additional energy supply capacity, the energy sector in the DRC has very negligible RE plans for development, noting the lack of policy and incentives to promote RE sources other than hydropower. Currently, there is no RE strategy or policy framework that can be found in DRC or even the energy sector, which is a result of limited institutional capacity. Nevertheless, an enabling policy - Law No. 14/011 of 17 June 2014 exists, which aims to liberalize the energy sector; the most recent sector development policy notes were issued in 2009.

2.5.7 Zambia Renewable Energy Profile

Zambia's energy resources include oil, renewables and coal. Renewables dominated the primary energy supply mix with a large share of 80 percent, followed by oil at 39 percent and coal at 6 percent (Figure 2.14). The 80 percent share for RE is distributed among bioenergy (85 percent) and hydro (15 percent). Other RE sources, including geothermal, wind and solar, have not been harnessed.

Figure 2.14: Zambia Total Energy Supply 2023

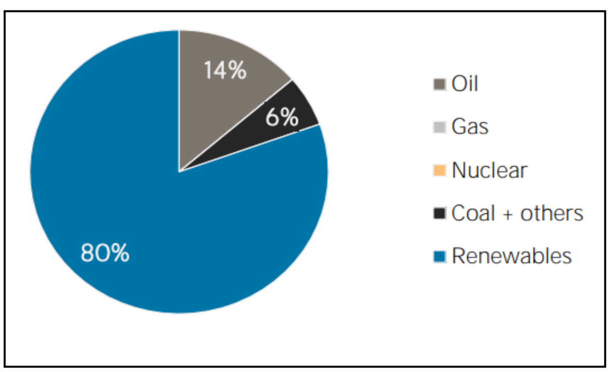
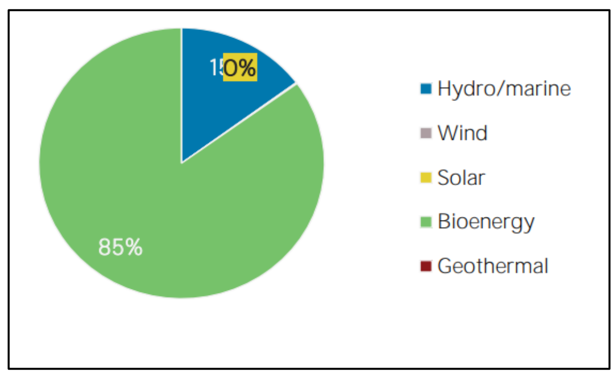


Figure 2.15: Zambia Total RE Supply 2023



Source: IRENA (2023)

Hydropower has been the main RE resource developed in Zambia to date (electricity is a major source of energy). This has been a cause for concern as droughts result in low reservoir levels, causing electricity deficits (Ruiters, 2018). At present, Zambia has 17725 GWh of installed electricity generation capacity, of which 92 percent (16075 GWh) is hydro-based and 1 percent is solar (IRENA, 2023).

The country's electrification rates are low, standing at nearly 27.9 percent; however, a large amount of hydro potential that can be harnessed remains standing at 5720 MW and 149 MW for large and small hydropower, respectively (IRENA, 2021b). Notwithstanding the generation capacity that hydropower provides to meet the electricity (contributing 92 percent) needs in Zambia, this increases the exposure to climate change events such as floods, causing inefficiencies in the energy sector (IRENA, 2013)

Zambia has ample RE resources for fuel and electricity production. Zambia is one of the SADC countries in which the energy sector is reliant on hydropower; 1700 MW of hydropower has been exploited in the country; however, more than 6000 MW potential in large-scale hydro can still be leveraged by the country, but only 1700 MW is currently being exploited (MoE,2022). Apart from hydropower, other potential RE sources include wind, biomass, solar and geothermal.

Zambia has a total biomass resource of 2.15 million as well as bioenergy potential and 498 MW (MEWD, 2008). Solar energy remains low in the energy sector despite its high potential among the highest in the world, with solar irradiance values up to 2,750 kWh/m2 (IRENA, 2013). In reference to wind resources, the potential is modest, and there is no utility-scale, but 150 – 300 MW of potential capacity has been identified (IRENA, 2021b). However, geothermal sources require elaboration and quantification.

2.5.7.1 **Policies for Renewable Energy Adoption in Zambia**

Zambia has implemented several regulatory reforms designed to promote private sector participation in the energy industry. Prior to 2020, the energy sector in Zambia was governed by the Energy Regulation Act, the Electricity Act, the Petroleum Act, and the Rural Electrification Act. However, the government recognised that the legislation had deficiencies, and thus, the National Energy Policy was developed to supplement these Acts.

2.5.7.1.1. National Energy Policy 2019

The overarching National Energy Policy (NEP) 2019 (MoE, 2020) objective is to promote conditions that enable an adequate and reliable supply of a diverse energy mix at a low social, environmental, and economic cost. The NEP underscores increasing the deployment of RE technologies by boosting private sector participation with the following objectives:

- Strengthen institutional capacity in the energy sector by decentralizing energy institutions, establishing an energy fund, and building facility capacity for the private sector.

- Strengthen the sectoral regulatory framework by strengthening the energy regulatory and establishing off-grid regulatory frameworks.
- Upscale the exploration of RE to diversify the energy mix by strengthening institutional capacity for RE research

2.5.7.1.2. Renewable Energy Strategy and Action Plan

The Renewable Energy Strategy and Action Plan was launched in 2022; it aims to scale up RE to increase access to energy services and improve energy security and sustainability (Ministry of Energy, 2022). The strategic objectives include, amongst others:

- To promote sustainable and inclusive socio-economic development by accelerating the deployment of RE
- To improve the national energy supply and expand access to modern energy services by decreasing reliance on traditional biomass
- To strengthen energy security by expanding supply options and diversifying the energy mix.

Accordingly, Zambia plans to add RE generation capacity on the grid, targets have been set for the 2030 timeline. These include 1383 MW of hydro, 130 MW of wind, 500 MW of solar and finally, 2.2 MW of geothermal.

2.6 CONCLUSION

The chapter critically reviews the energy sector at the regional and national levels and identifies factors related to the current deployment of RE. The SADC member states are heavily dependent on RE generation from water (hydro) and, to some extent, fossil fuels such as coal and oil. However, countries have been grappling with an energy crisis in the past years. Notable, there is a high interdependence on the supply of energy from the countries, particularly the dependence on South Africa from some of the selected countries. However, significant potential exists in wind, geothermal, and especially solar energy to accelerate the uptake and role of RE.

It is worth highlighting that most of the SADC member countries this study focuses on have deployed RE at moderate supply capacity and high generation capacity. Nonetheless, electricity access remains subdued in most countries besides South Africa; this becomes a necessary factor to scale up RE, including reducing the use of fossil fuels, for a sustainable, affordable, and reliable energy supply.

For scaling up RE deployment, increasing the share of electricity generation is the most common form of targeting. The targets generally focus on utilizing RE in the electricity sector and are exceptional in very few cases. Countries such as Botswana, Namibia, and South Africa have all identified specific targets for the RE share of electricity generation or consumption. However, others, such as Angola, Mozambique and Zambia, have identified capacity targets (MW) only. The DRC is the only country amongst the selected countries for the study that still lacks the necessary reforms and policies for increased RE. Whilst countries like South Africa and Namibia are currently advancing the deployment of RE, there is still slow progress to peripheral in SADC due to challenges such as high low infrastructure investment, slow implementation and weak reforms.

This chapter has discussed the major features of the SADC RE sector while trying to highlight the idiosyncratic characteristics of SADC in each of the selected countries that matter to the RE sector. The country's RE profiles and policies have revealed existing linkages between country-specific features that are predominant in the SADC region.

CHAPTER 3
THEORETICAL AND EMPIRICAL LITERATURE REVIEW

3.1 INTRODUCTION

Over the past years, there has been a significant shift in RE globally, and Africa is increasingly diversifying the energy mix to include renewables such as hydropower. Even with the various benefits brought about by the adoption of RE, such as the reduction in fossil fuels, the biggest challenge has been the slow uptake of energy sources, particularly from developing countries such as those in the SADC region (SADC, 2018). The purpose of this literature review is to gather theories on RE adoption and conduct an in-depth analysis of the determinants that influence RE deployment.

This chapter presents the theoretical framework and empirical literature on the determinants of RE. It is divided into four sections. Following this introduction, Section 3.2 presents the theoretical framework for RE determinants. Section 3.3 reviews previous empirical studies on the determinants of RE, and Section 3.4 concludes the chapter.

3.2 THEORETICAL FRAMEWORK

Although the determinants of RE have been an important subject, it has not received substantial attention in the theoretical literature. This section discusses the theories underpinning the study to explain the determinants of RE deployment. The theories include Schumpeter's Theory of Innovation, the Theory of Planned Behaviour, and the Environmental Kuznets Curve.

3.2.1 Schumpeter's Theory of Innovation

The theory of innovation is a concept developed by Schumpeter (1934) that explains that innovation contributes to change and creates new industries that enhance the efficiency of the economy by improving productivity. According to Sweezy (1943), Schumpeter explains innovation, explained as the process of "doing things differently" in an economy. One of the central arguments of this theory is that innovations are crucial for economic growth, as well as an entrepreneur is the central innovator identified as an agent of change.

Furthermore, Schumpeter's theory explains how industries peak and progressively decline to allow innovation to take place. The types of innovations that can take place in an economic system are identified below. These capture the ways in which entrepreneurs can drive change and economic progress.

Schumpeter highlights the following as the types of innovation:

1. Introduction of a new product or modification of an existing product
2. Application of new ways of production or sales not yet introduced
3. Opening a new industry
4. Developing a new supplier for raw materials
5. New industry structure

Building on the previously mentioned types of innovation, it is important to highlight that Schumpeter categorized the innovation process into four distinct dimensions: invention, innovation, diffusion, and imitation (Schumpeter,1934). The invention stage has a relatively minor effect, whereas the diffusion and imitation processes exert a far greater impact on the economic landscape. In addition to the dimensions of innovation explained, Schumpeter also believed that innovation is an essential driver of economic dynamics and central to explaining economic growth (Śledzik, 2013). Notwithstanding that, the macroeconomic effects of innovation are generally barely visible in the first 1- 3 years or longer (the invention and innovation phase); however, once the process shifts to diffusion and imitation, a greater impact on the state of an economy is observed.

Economic and technological conditions determine the development of these types of innovation; Schumpeter has pointed out that new uses and new production are dictated by capital, which is a driver of entrepreneurs' direction. Considering an economic system on the role of innovation, the theory further explains that credit mechanisms cannot be dissociated from entrepreneurial action. Therefore, innovations are intensified during certain periods and in certain sectors.

One of the central functions emphasised by Schumpeter is the concept of an agent of change and innovation, which is stressed as the role of entrepreneurs. The functions of entrepreneurs are not necessarily identified as individuals but as companies or corporations. An entrepreneur is explained as an endogenous economic agent to a decentralised economic system who ‘creatively destructs’ (Schumpeter, 1991).

Schumpeter’s theory is encapsulated in this concept of “creative destruction” which is caused by innovation; according to Schumpeter (1991) it is defined as the “process of industrial mutation, that incessantly revolutionises the economic structure from within, incessantly destroying the old one, incessantly creating a new one” (Upadhyay & Rawal,2018). Implies that innovation leads to disruptions of existing market or industry structures displaced by new ones, and more resources are getting deployed to the ‘new’ industries; this can cause a social upheaval. Accordingly, creative destruction ensures the long-run growth of an economy by destabilising the no-growth equilibrium that was the result of non-innovators. While Schumpeter has not examined the innovation theory in the energy sector, it can still provide a general understanding of RE technologies and innovation.

In the energy industry, an alternative RE-based system has emerged, focused on sustainable technologies. The shift to RE is noted as a stimulus or an incentive to innovation in the energy system in the SADC region that many new producers and users embrace – this is a disruptive innovation in that it substitutes for a dominant technological system (system for fossil fuels production). Therefore, the ‘non-innovative actors’ responsible for the production of fossil fuel energy will experience major challenges with the displacement, which are also likely to cause a spillover to those employed in the industry.

Nonetheless, the nature and extent of the disruption can be mitigated by promoting a diversified energy mix in the SADC region to include RE sources. Moreover, to enable the innovation of the RE sector, Schumpeter states that capital, credit mechanisms and certain economic conditions are required. In the main, Schumpeter provides a valuable framework to understand the transformative potential of RE technologies, the benefits of harnessing the innovation and the consequences that may occur.

Although policymakers encourage the use of such technologies (RE technologies), important strategies are in place to mitigate the impact of “creative destruction.” Finally, the potential of RE technologies to reduce carbon emissions and enhance economic progress aligns with Schumpeter's view that innovation drives economic transformation.

3.2.2 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) developed by Ajzen and Fishbein (1975) studies human intention and its impact on action. Behavioural intention, the main concept of the TPB, refers to the “motivational factors that influence behaviour” (Ajzen, 1991). According to Ajzen (1985), the stronger the intention to engage in a behaviour, the more likely it is to perform the behaviour. Historically, the theory has been used to predict as well as understand human behaviour concerning pro-environmental intention (Harland et al. (1999), East (1993)) and most recently energy related intentions, for instance, RE investments (Yee et al.,2022; Skordoulis et al., 2020; Ntanos et al., 2018).

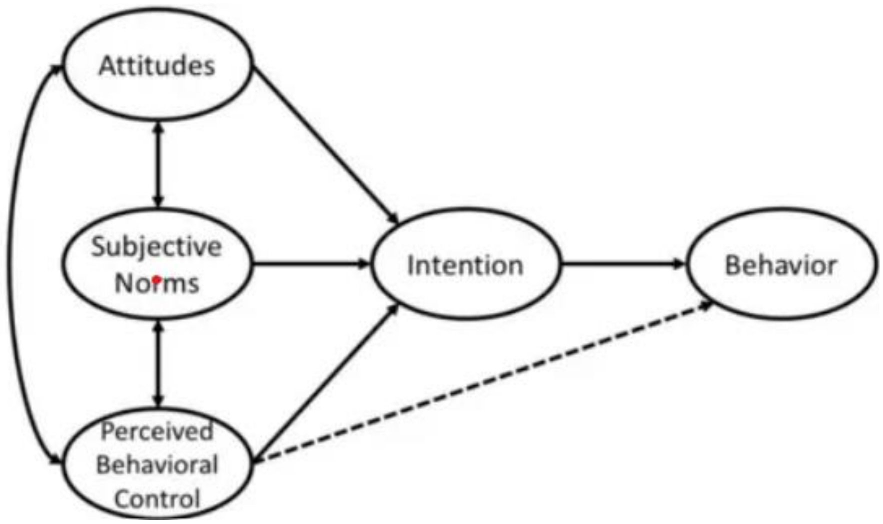
The behaviour and intention towards action are determined by three core components - attitude, subjective norms and perceived behavioural control. The three components are outlined below and explained in the context of RE generation as the intention:

- Attitude: Attitude (negative or positive perception) refers to the reasoning of an individual when assessing if a behaviour will result in favourable or unfavourable outcomes (Eagly and Chaiken, 1993). According to Qalati et al. (2022), a more positive attitude towards a behaviour will lead to an individual intention to perform the behaviour. Attitude toward RE can be influenced by the belief that RE can increase energy access and reduce energy cost and the understanding that RE will mitigate environmental problems by reducing CO_2 emissions (CO_2 is a proxy for environmental concern used in the study). Thus, the benefits of RE form a positive attitude, encouraging its adoption.
- Subjective norms refer to an individual's consideration to follow a behaviour from perceived social pressure to carry out a particular intention; this can impact the decision made (Qalati et al., 2022). According to Daiyabu (2022), stronger intention is demonstrated when more of their peers are involved in the behaviour; in the case of RE, this can be observed in discussions within intergovernmental organisations that have, for instance, led to the Paris Agreement. Because of their NDCs, countries are encouraged to generate more RE.
- Perceived behavioural control (control beliefs and self-efficacy), according to (Ajzen, 1991), refers to an individual's ability, ease or difficulty to carry out the behaviour of interest, which also has an important influence on an individual's intention. Perceived behaviour control can influence intention and behaviour and is divided into control beliefs and self-efficacy (Ajzen, 1985). Daiyabu (2022) argues that the factors that drive control include experience, information, and resources, all of which affect confidence in the intention or behaviour. In terms of RE behaviour control, it encompasses what impacts the ability to adopt RE technologies, financial abilities, technological advances, and economic development level. In this study, as perceived behavioural variables, two factors will be analysed: financial abilities through financial development and the generation level of RE.

While the key areas of the TPB have been attitude, perceived behavioural control, and subjective norms, the theory has been adopted and expanded for studying intention across various fields, leveraging the model's flexibility to integrate variables that offer deeper insights into intention

(Ajzen, 1991). This relationship between the three components and intention and behaviour is shown in the TPB model, Figure 3.1 below.

Figure 3.1: The Theory of Planned Behaviour Model



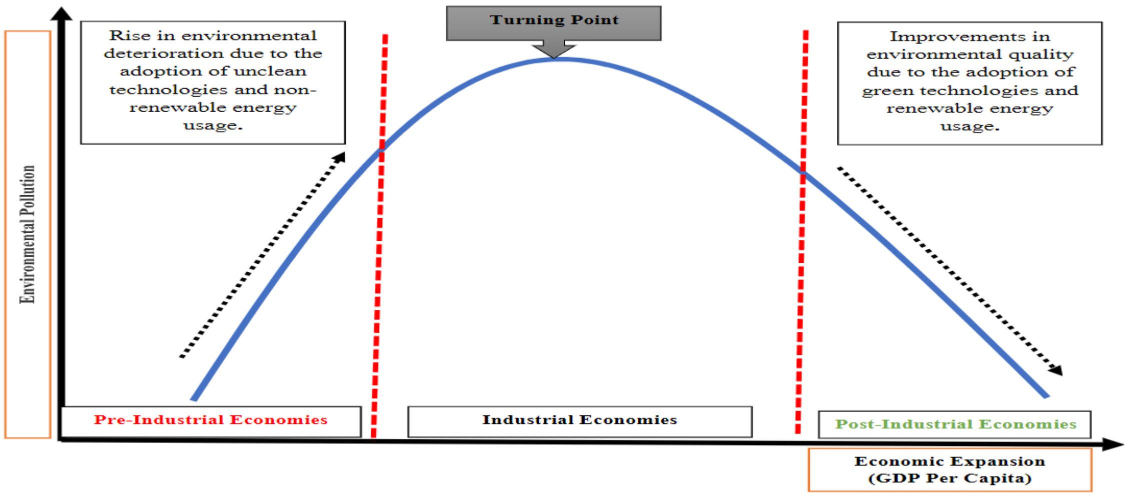
Source: Qalati (2022)

3.2.3 Environmental Kuznet Curve

In the early 1990s, Grossman and Krueger (1991) developed the environmental Kuznets theory, which emerged from Simon Kuznet's earlier work describing the relationship between income inequality and economic development. The Environmental Kuznets theory links and hypothesizes the relationship between economic growth and several measures of environmental quality using the Environmental Kuznets Curve (EKC) (Stern, 2003).

This relationship between environmental degradation and income per capita is defined and demonstrated using the EKC U-shaped curve. The EKC hypothesis explains the path of environmental pollution and income/economic growth over time, indicating that an economy prioritizes economic expansion over environmental quality (pollution increases simultaneously) in the early stages of economic growth; however, as the economies advance, so does concern in the environmental quality. The EKC U-shape demonstrates that as a society obtains high income per capita levels, clean resources must be deployed. In addition, it defines the pollution trajectory over time and income that results from economic development/ growth (Chukwuemeka, 2018). Figure 3.1 below demonstrates the inverse U-shaped graphical representation of the hypothesis. The dependent variable, environmental pollution, is represented through proxies such as various pollutants (air, soil production, water or land) or deforestation. The dependent variable is per capita income.

Figure 3.2: Environmental Kuznet Curve



Source: Prempe et al (2024)

In the early stage of economic growth (pre-industrial economies), the level of a country's pollution increases, and the environmental quality worsens as growth is prioritized over environmental quality, resulting in environmental degradation. This is also referred to as the scale effect. However, after the turning point, when the income level reaches a certain threshold, the environmental quality of the country improves (composite effect). Finally, when the economy expands subsequent to the turning point, the environmental degradation decreases (the later stages of growth in industrial economies). This is because as the country becomes wealthy, it prioritizes ecological concerns and is able to access clean technologies (such as RE technologies) for productive uses, which then leads to a sustained decline in pollution. Thus, achieving sustainable development in the process.

Although the argument of the EKC is founded on the relationship between economic growth and environmental degradation, empirical evidence of the consumption of RE and the economic growth hypothesis in the context of the EKC to measure environmental quality exists. Scholars such as Nabaweesi (2024) investigated the energy and environmental support nexus. Other authors who have conducted similar studies include Yao et al. (2019), Pablo-Romero and De Jesus (2016), Hundie and Daksa,2019), and Mahmood et al. (2021). This contributed to the emergence of the Energy Environmental Kuznets theory (EEKC).

Once substantial economic growth is achieved, countries plan to reduce CO_2 or GHG emissions by implementing regulations and policies, therefore adopting RE (Ahmed and Long, 2012). In the early stages of economic growth, an economy experiences increased energy consumption. Consequently, the RE-environmental Kuznets Curve (REKC) was founded from the EKC initially introduced by Yao et al. (2019) and shows evidence of a U-shaped relationship between income level and RE use.

The relationship stems from the concept that a negative relationship exists between economic growth and RE consumption in the early stages of development, where environmental degradation worsens. According to Gielen et al. (2019), throughout the early stages of development, the cost of RE sources, for instance, solar, exceeds that of fossil fuels. However, as economies expand and approach the turning point, the costs of RE sources begin to decrease. In addition, the government of a country may implement policies to reduce and avoid degradation. Therefore, countries begin consuming RE in the later stage of economic development

3.3 EMPIRICAL LITERATURE REVIEW

This section begins by discussing the empirical literature on the determinants and drivers of RE in emerging countries with growing RE adoption. It then follows the developed industrialized countries with existing RE infrastructure. The last subsection is devoted to examining the determinants of RE in resource-rich countries. The last section concludes the chapter.

3.3.1 RE Determinants in Emerging Economies with Accelerated RE Growth

In contrast to the advancement of RE in developed economies, emerging countries are grappling with increasing RE generation capacity due to several hindering factors and challenges. Despite existing challenges, several emerging economies have taken the initiative to invest more in RE sources to include them in their energy mix, which has yielded accelerated growth in RE.

Nasirov et al. (2015) assessed factors that shape the trajectory of RE adoption in Chile using a questionnaire survey and a series of semi-structured interviews with RE project developers. The results identified the significant barriers affecting RE sources deployment; the key barriers include limited access to project financing, long administrative processes of obtaining permits and grid connection constraints. Moreover, Nasirov et al. (2015) found that well-designed public funding financial support and increased access through multiple channels, streamlined administrative processes for permits, and government subsidies, including tax credits, can contribute to the long-term development of RE in Chile.

Muhammed and Tekbiyik-Ersoy (2020) assessed the effect of RE policies on RE adoption in the neighbouring South American Country Brazil, including countries China, as well as the United States of America (USA) and China using a simple linear regression analysis from 2000 to 2017. The results suggest that RE policies scale up RE-installed capacity in different proportions. For example, in Brazil, the proportion is significantly below the two China and the USA; wind policy increases the RE wind capacity by 0.689 GW. Economic instruments (such as direct investments, fiscal incentives, as well as market-based instruments) are more effective in advancing RE installed capacity in Brazil, whereas in China, the more influential policies are regulatory instruments. This view supports the global phenomenon that explains that the lack of RE-implemented policies is a barrier to RE deployment (REN21, 2018). Moreover, a positive and significant relationship exists between RE and patents in all countries in the study.

In their examination of the determinants of RE consumption, Salim and Rafiq (2012) conduct an examination of leading emerging countries of RE production, which include India, Indonesia, Philippines, Turkey, Brazil and China Salim and Rafiq (2012). The study utilized panel methods; Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Square (DOLS) and Auto Regressive Distributive Lag (ARDL) for the period 1980 to 2006. The result identifies income (GDP) and CO_2 emissions as the main drivers of RE in Indonesia, Brazil, China, and India, whereas in the case of Turkey and the Philippines, income is the only driver. Conversely, oil price has the least impact on RE consumption, this may be warranted by the fact that a number of these economies have oil price subsidies to avoid adverse economic effects. In particular, the FMOLS findings show that, a 1 percent rise in GDP results in 1.22 percent rise in RE consumption, whereas 1 percent rise in CO_2 emissions causes a 0.033 percent increase in RE.

A study by Saygin and Iskenderoglu (2021) used the Generalized Method of Moments (GMM) to conduct a study on 20 emerging countries covering the period 1990 – 2015. The 20 countries include the Philippines, Brazil, Malaysia, China, Poland, Egypt, Colombia, Greece, India, Korea, Peru, Hungary, Russia, Mexico, South Africa, Czech Republic, Thailand, Indonesia, Turkey and Chile. The results showed that when measured by stock market and banking variables, financial development has an insignificant effect on RE consumption; conversely, when it is measured employing stock market capitalization, it results in an increase in RE consumption.

Aloui et al. (2024) carried out a study to examine the drivers of RE use in Saudi Arabia, a heavily oil-dependent country, by applying a time-localized wavelet multiple regression correlation framework. By utilizing annual data for the period 1996 to 2022, the study found a significant and positive relationship between factors, including government effectiveness, economic complexity, economic growth and oil rents in the long run; nevertheless, the correlations are considerably low and insignificant in the short-term. In addition, the authors revealed that these factors promote RE dominated by government effectiveness and oil rents.

The study by Yadav et al. (2024) assessed the influence of financial development on RE consumption by employing the fixed effects panel data analysis and utilizing data covering the period 1995 to 2022. The study reveals a significant positive relationship between RE consumption and economic growth and the Consumer Price Index. However, an insignificant relationship was observed between RE consumption and domestic lending by financial institutions, implying that the variables have no considerable influence on RE. On the contrary, a negative relationship was observed between Foreign Direct Investment (FDI) and RE consumption; according to Yadav et al. (2024), this counterintuitive relationship could be the result of FDI causing technological advancements and reducing energy demand.

Mukhtarov et al. (2024) use the Vector Error Correction Model (VECM) and ARDL techniques to examine the influence of financial development on RE consumption in Turkey from 1980 to 2019. The results demonstrate that financial development has a positive impact on RE consumption; a 1 percent increase leads to a 0.21 percent rise in RE consumption. Conversely, when Gokceli (2023) conducted a similar study in Turkey using data from 1990 to 2020 and employing the Vector Autoregression (VAR) model, the finding indicated that financial development has no significant impact on RE adoption. In addition, financial institutions have a positive and significant effect on RE adoption, although the effect of financial markets is not statistically significant.

Table 3.1 below presents a summary of the reviewed empirical studies on RE Determinants in Emerging Economies with Accelerated RE Growth.

Table 3.1: Summary of Studies on RE Determinants in Emerging Economies with Accelerated RE Growth

Authors	Period	Country (s)	Methodology	Results
Nasirov et al. (2015)	2014	Chile	Questionnaire survey (semi-structured interviews)	RE sources deployment barriers: limited access to project financing, long administrative processes of obtaining permits and grid connection constraints

Authors	Period	Country (s)	Methodology	Results
Muhammed and Tekbiyik-Ersoy (2020)	2000-2017	Brazil, China, USA	Linear regression analyses	There is a positive and significant relationship between RE development and the total number of policies and patents in all countries.
Salin & Rafiq (2012)	1980 - 2006	India, Indonesia, Philippines, Turkey, Brazil and China	FMOLS and DOLS	Income and CO_2 emissions are the main drivers of RE in Indonesia, Brazil, China, and India, whereas income is the only driver in Turkey and the Philippines. The oil price has the least impact.
Aloui et al. (2024)	1996 - 2022	Saudi Arabia	Time-localized wavelet multiple regression correlation	Government and oil effectiveness are the most influential factors in promoting RE.
Yadav et al. (2024)	1995 - 2022	BRICS countries	Fixed effects panel data	A significant positive relationship between RE consumption and GDP, Domestic lending by financial institutions including CPI but a negative relationship with FDI
Mukhtarov et al. (2022)	1980 - 2019	Turkey	VECM and ARDL	Financial development has a positive on RE consumption
Gokceli (2023)	1990 - 2020	Turkey	VAR	Financial development and financial markets have an insignificant impact RE adoption, while financial institutions have a positive and significant effect

Authors	Period	Country (s)	Methodology	Results
Saygin and Iskenderoglu (2021)	1990 - 2015	Czech Republic, Malaysia, Brazil, China, Korea, Colombia, Egypt, Turkey, Hungary, India, Mexico, Chile, Peru, South Africa, Philippines, Poland, Greece, Russia, Thailand and Indonesia	GMM	Financial development has an insignificant effect on RE consumption and a positive impact on RE

3.3.2 RE Determinants in Industrialized Countries with Established RE Infrastructures

At the forefront of RE deployment are industrialized countries with high RE capacity. This is because of the substantial availability of financial resources. In addition, unlike developing economies, the industrial revolution that took place in advanced economies during the 19th century was developed through fossil fuel-powered energy production. Hence, these countries are the largest CO_2 emitters. As the largest carbon emitters, advanced economies have established RE industries, gradually and progressively advancing decarbonization efforts over the past years (IRENA, 2023).

In a study by Khan and Su (2023), the RE and technological innovation nexus was examined utilizing data from 2000 to 2021in Group of 10 (G10) countries (an intergovernmental group of industrialised economies), which include the Netherlands, Sweden, the UK, the USA, Switzerland, Japan, France, Canada, Belgium and Germany. By applying a panel bootstrap Granger approach, the result indicates that the relationship between RE and technological innovation varies between the countries. In the case of the Netherlands, Germany, Sweden, the USA, and the UK, RE and technological innovation show a significant positive relationship, implying that technological innovation is the key factor in RE development. Nevertheless, for France, Canada, Japan and France, there is no causality between the variables; therefore, other factors influence RE in these countries. Authors Su et al. (2022) and Zhao et al. (2021) argue that technological innovation is an essential element for RE because of the countries' innovative base and huge spending on research and development.

An in-depth study was conducted by Tu et al. (2022); the authors assessed the determinants of RE in 27 European Union (EU) countries using data covering the period of 2011 to 2020 and applying the random-effects Generalized Least Squares (GLS) regression. The findings showed a positive relationship between RE and variables, including economic freedom promotion, GDP (1 USD increase leads to 0.05 kWh increase in RE), political participation and employment in advanced technology manufacturing (one percent increase causes 0.37 percent increase in RE). However, the cost of business procedures had a negative correlation where a one unit increase decreased RE by 0.25 percent, including unemployment, was RE by 0.2 percent. Finally, democratic development and the level of corruption were observed to have an insignificant impact on RE. In another study of the EU, Papiez et al. (2018) identified the main factors of RE as the concentration of energy supply, GDP per capita, and the costs of energy consumption obtained from fossil fuels concerning GDP. Another important factor to consider is that countries importing fossil fuel sources tend to deploy RE to a larger extent.

The study by Derk (2023) investigates the influence of resource rents, institutional quality, and R&D on RE production, with a focus on how these relationships vary by income level. Using panel data analysis for 2005 to 2020 and a fixed-effects model, the findings reveal that the negative impact of resource rents on RE production diminishes as per capita income rises, turning positive in high-income countries. These results highlight the importance of the institutional capability of allocating resources to sustainable practices such as RE production. However, the study found evidence of an insignificant relationship between the effects of institutional quality and research and development (R&D). The study also showed that RE Production gets decreasingly negative as per capita income increases.

In a related study, Marinas et al. (2018) investigated the compatibility between economic growth and RE consumption in Central and Eastern European (CEE) countries from 1990 to 2014. Although the sample in the study contains some emerging economies, the selection was based on relatively homogenous social and economic development over a period of seven decades. The ARDL test was conducted, and it was concluded that a 1 percent increase in GDP leads to raises interest for RE sources, hence a higher growth rate of RE consumption by 0.32 percent. However, dynamics are independent in the case of Romania and Bulgaria.

Opoku et al. (2024) examined the determinants of RE consumption in 26 Organisation for Economic Co-operation and Development countries (OECD), an organization of the world's largest economies for the period 1974 to 2020. By applying the FMOLS and DOLS, the study analysed the effects of the variables on each energy source. The study finds that GDP and CO_2 emissions generally have positive effects; nonetheless, energy innovation R&D showed a negative effect on RE generation, although it is only statistically significant for gas and wind sources. Trade openness positively impacts RE generation, including solar and wind energies, whereas a negative effect was observed with hydro and nuclear energy generation. For FDI, there was a positive relationship between total RE generation and gas production, although the negative was for solar generation.

An important contribution was also made by Shahbaz et al. (2018), who analysed the determinants of RE consumption using non-linear ARDL in a Group of 7(G7) countries (the USA, Canada, Germany, Italy, France, Japan, and the United Kingdom) covering the period 1955 to 2015. The results show that in the US, France and Germany, higher income leads to more RE consumption symmetrically; this means that as income goes up, RE use goes up proportionally and steadily. The same results are observed for Canada and Japan; however, the effect is asymmetric. In the UK, higher income leads to less RE, but the effect is relatively weak and consistent (symmetric). Income has an insignificant impact on RE in Italy. CO_2 emissions show a symmetric positive effect on RE in Germany, Japan, Italy, the USA and France, but the impact is insignificant in the UK. Although in Canada, an increase in CO_2 emissions causes RE to increase, a decrease does not impact RE significantly. The impact of oil prices on RE is insignificant in Canada, Germany and Japan; however, there is a positive relationship between oil prices and RE consumption in the UK and France. An asymmetric impact on RE consumption for the US and Italy means that a decrease in oil prices results in a decrease in RE for the US and an increase in Italy.

Using time series data that covers the period 2000 to 2020, Hao et al. (2023) examined the factors affecting RE consumption in developed Asian countries - Korea, Japan, Singapore, Israel, China, and Hong Kong. The study employed the Panel VAR model as the method of estimation, which concluded that a 1 percent increase in the variables, including FDI inflows, electricity consumption and economic growth, results in an increase of 0.82 percent, 0.6 percent and 2.73 percent, respectively, in RE consumption. However, fossil fuels affect RE consumption negatively; a 1 percent increase results in a 0.26 percent decrease in RE.

To examine whether technological innovation drives RE, Khan et al. (2022) conducted a study utilizing data for the period 2000 to 2021 in Germany. The Bootstrap causality test was applied, and the study also accounted for the structural changes in some sub-samples. The findings show that technological innovation drives RE positively and negatively across the country. This implies that an increase in technology innovation spending development in RE will increase spending. Further, the results of causality showed that technological innovations significantly impact RE.

In a study of a sample of 29 developed countries, Shahzad et al. (2021) assessed the role of regulations and environmental taxes on RE generation. Employing the FMOLS model for data over the period 1994 to 2018, the study concluded that some of the factors that demonstrated a positive influence on RE generation include income level, urbanization, environment-related technologies and environmental regulation (the environmental policy stringency index was used as a proxy). Conversely, trade openness and bureaucratic qualities (such as decision-making) decrease RE generation. The authors further argue that innovative policies and regulations can help countries achieve SDG 7 - clean, affordable and modern energy.

Table 3.2 below presents a summary of the reviewed empirical studies on RE Determinants in Industrialized Countries with Established RE Infrastructures

Table 3.2: Summary of Studies on RE Determinants in Industrialized Countries with Established RE Infrastructures

Authors	Period	Country (s)	Methodology	Findings
Khan et al. (2022)	2000-2021	Germany	Bootstrap causality test	Technology innovations impact RE positively and negatively
Opoku et al. (2024)	1974 - 2020	26 OECD countries	Panel FMOLS and Panel DOLS	Energy innovation R&D has a negative effect on RE, GDP and CO_2 emissions have a positive effect; however, trade openness and FDI have both negative and positive effects.
Marinas et al. (2018)	1990 - 2014	10 CEE countries	Panel ARDL	GDP and RE consumption dynamics are independent in Romania and Bulgaria but in Hungary, Lithuania, Czech Republic and Slovenia an

Authors	Period	Country (s)	Methodology	Findings
				increase in RE consumption improves the economic growth.
Khan & Su (2023)	2000-2021	Netherlands, Sweden, the UK, the USA, Switzerland, Japan, France, Canada, Belgium and Germany	Panel bootstrap Granger causality	In the Netherlands, Germany, Sweden, the USA, and the UK, RE and technological innovation show a positive, significant relationship. In France, Canada, Japan, and France, there is no causality between the variables.
Tu et al. (2022)	2011-2020	EU countries	Random-effects GLS regression	Economic development, political participation, high employment, and economic freedom positively affect RE, whereas unemployment has a negative relationship. Democracy and the level of corruption index have no statistically significant impact on RE. Favourable geographical location drives RE.
Shahzad et al. (2021)	1994-2018	29 developed countries	Panel cointegration and panel regression analysis	Environmental regulations and GDP have a positive relationship with RE; bureaucratic attributes reduce RE generation

Authors	Period	Country (s)	Methodology	Findings
Shahbaz et al. (2018)	1955 - 2014	G7 countries	nonlinear ARDL	Higher income leads to more RE consumption in the US, France, Germany, Japan and Canada. CO_2 emissions have a positive effect on RE consumption in the US, Germany, Japan, France and Italy but are insignificant in the UK The impact of oil prices on RE is insignificant in Canada, Germany and Japan; however, there is a positive relationship between oil prices and RE consumption in the UK and France
Marinas et al. (2018)	1990 - 2014	10 CEE countries	Panel ARDL	GDP and RE consumption dynamics are independent in Romania and Bulgaria, but in Hungary, Lithuania, Czech Republic and Slovenia, an increase in RE consumption improves the economic growth.

3.3.3 RE Determinants in Natural Resource-Rich Developing Countries with High RE Potential

Countries in the Global South have a significant advantage due to their abundant renewable resources and favourable geographical locations. For many, the shift from fossil-fuel-based energy to renewable energy production presents challenges, as most renewable energy projects involve substantial initial costs, extended payback periods for returns on investment, and the need to contend with competitive technologies.

An interesting contribution was made by Awijen et al. (2022) regarding the relationship between RE deployment and governance quality through the adoption of Information and Communication

Technology (ICT) in the Middle East and North Africa (MENA) countries, including Egypt, Algeria, Iran, Morocco, Iraq, Jordan, Yemen, Lebanon and Tunisia. By using data covering the period 1984 to 2014, the study used the Panel Smooth Transition Model (PSTR) based on the results of the analysis, which shows that governance quality positively affects RE. Moreover, when innovation performance reaches a given threshold, it boosts the influence of governance quality on RE. For the analysis of RE, the study found that there is a positive correlation between RE and political stability, governance quality, economic growth, financial development, and environmental pollution. Still, RE negatively correlates with the country’s dependence on natural resources and FDI.

A further attempt to examine RE determinants was made by Tambari and Failler (2020). Using an unrestricted VAR model and data for the period 1990–2018, the study analysed the effect of RE investment in countries with energy concerns – Nigeria, Algeria, Egypt, Ethiopia, Angola and South Africa. Factors including changes in oil prices, GDP, interest rate and oil price volatility were considered. The results showed a positive relationship between interest rate and price shocks; however, it fluctuated negatively in response to GDP and oil price volatility (but became positive after the second period). A similar analysis was made by Ackah and Kizys (2015) using a sample of 12 oil-producing countries (Egypt, Angola, Cameroon, South Africa, Congo, Gabon, Tunisia, Ghana, Cote d'Ivoire, Algeria, Nigeria, the DRC and Sudan) based on data from 1985 to 2010. Through a random effect model, a fixed effects model, and a dynamic panel data model, the results indicate that key drivers of RE are real income per capita, carbon emissions per capita, energy resource depletion per capita, and energy prices.

Butler-Sloss et al. (2022) have described Africa as an RE superpower, with access to 39 per cent of RE potential for solar and wind. Ackah and Kizys (2015) investigated the drivers of RE demand in oil-producing African countries (Angola, South Africa, Congo, Ghana, the DRC, Gabon, Nigeria, Sudan, Cote d'Ivoire, Tunisia, Egypt and Cameroon,) using a fixed effect, a random effect, and a dynamic panel data model from 1985 to 2010. The results indicate that an increase in CO_2 emissions and energy resources increases RE deployment by 0.691 kilograms (kg) and by 0.00536 kg of oil equivalent per capita, respectively. Additionally, the results reveal that GDP has a positive effect on RE, and energy price has an inverse relation with RE demand. Factually, the countries in Africa are popular locations for the use of RE technology as a result of the low energy access in the continent.

Hoa et al. (2024) applied an ARDL to study factors that determine RE in the Association of Southeast Asian Nations (ASEAN), including Indonesia, the Philippines, Singapore, Thailand, Malaysia, and Vietnam, for the period 2000 to 2022. ASEAN has vigorous RE resource potential that creates opportunities for more ambitious development and investment (IEA,2023). The findings indicate that government policies (specifically tax incentives and subsidies) positively affect RE moderately, whereas technological innovation has a statistically significant positive impact on RE in the countries. The findings also show that public awareness plays a vital role. However, this role is less important than the other two variables.

In Pakistan, Iqbal et al. (2023) studied the asymmetric determinants of RE production utilising linear and nonlinear versions of the ARDL method for the period 1980 to 2019. The findings of the nonlinear ARDL show that environmental advancements, financial development, CO_2 emissions, GDP and FDI have some influence on RE production. Further, positive changes in GDP, environmental advancements, financial development, and CO_2 emissions show a positive and significant influence on RE production. However, FDI shows a negative relationship in the long run. However, negative changes have no significant effect on GDP; financial development and environment-related technologies increase RE production. In terms of the linear ARDL, GDP is the only variable that promotes RE production in the long run.

The analysis of RE done on African countries is limited at the regional and country levels. The study by Akintande et al. (2020) investigates RE in Africa's largest and most populated economies in Africa, including South Africa, Egypt, Nigeria, Ethiopia, and the DRC, spanning annual data from 1996 and 2016. The Bayesian Model Averaging (BMA) procedure was applied for the analysis, and the results indicated that the main determinants of RE consumption in the five countries include energy use, population growth, electric power consumption, urban population, and human capital. An increase in the factors identified will result in an increase in RE consumption.

On the other hand, Apergis and Payne (2014) assessed determinants of RE consumption in Costa Rica, Nicaragua, Guatemala, Honduras, Belize, Panama and El Salvador, using a VECM. The data was collected over the period 1980 to 2010 using the variables CO_2 emissions, real coal prices, and real oil prices. Each determinant had a positive impact on RE consumption in the long run. In addition, the study contends that post the 2002 period, there was a period of greater sensitivity of real GDP per capita to carbon emissions per capita.

Power pools have a substantial role in driving electricity generation and enhancing system reliability, particularly in the shift to cleaner energy. Aidoo (2024) examined the factors influencing RE in the 12 countries (Zambia, Lesotho, Angola, Eswatini, the DRC, Mozambique, South Africa, Malawi, Tanzania, Namibia, Botswana and Zimbabwe) in the SAPP using data from 1988 to 2018. Using the Panel ARDL, RE adoption was examined against the effect of explanatory variables, including GDP, labour, gross fixed capital formation, trade, and non-RE. The study found that coefficients of all explanatory variables have positive signs; however, gross fixed capital formation and non-RE have negative signs in the long run. Notwithstanding, each SAPP member state's explanatory variable impact on RE varied or was insignificant. Factors that increase RE include gross fixed capital formation (in seven SAPP countries), GDP (in Zambia, Angola, and Mozambique), labour (in DRC and Mozambique and Zambia), trade (in Angola and Tanzania and three other countries), non-RE (Botswana, the DRC, eSwatini and Zambia).

By focusing on SSA countries, Olouch et al. (2021) investigated factors that can promote RE consumption. The study considered 23 SSA countries during the period 1998 to 2014 using the panel ARDL. The study concluded that RE consumption positively correlates with the education index (in Gabon and Ethiopia, and a negative one in Botswana, Cameroon, Kenya, Malawi, Rwanda, Sudan, and Zambia), GDP, corruption (Gabon and Namibia) but corruption also correlates negatively for Cameroon, Malawi, and Congo Rep and Tanzania in the long run including CO_2 emissions per capita, and life expectancy index. In spite of the results of the study, only Gabon, Ethiopia and Kenya demonstrated trends that will result in a general rise in RE consumption. Further to the analysis of SSA, da Silva et al. (2018) applied the panel ARDL model using data from 1990–2014 to understand the main factors influencing it. The results indicated that economic development and increased energy use have a positive effect on RE, whereas other variables, including CO_2 emissions, population growth, price of fossil fuels, and imports, had a negative impact. In addition, the Kyoto Protocol either marginally contributed to promoting RE or decreased it.

Haifa Saadaoui and Nouri Chtourou (2023) conducted a study to investigate the impact of financial development, institutional quality, and economic growth on RE consumption on RE consumption by applying the symmetric and asymmetric ARDL during the period 1984 to 2017 in Tunisia. The findings showed that financial development negatively and significantly affects RE, while economic growth and institutional quality positively affect RE consumption.

While most research analysing the determinants of RE has focused on panel data, Kwakwa (2021) conducted an investigation in Ghana by employing regression and variance decomposition techniques using data from 1971 to 2014. The findings of the study indicated that industrialisation positively impacts RE consumption; however, negative influences were observed for income, price, and financial development in the long run; however, in the short run, financial development and industrialisation affect RE consumption. This type of investigation done on African countries is limited. Another study by Prempheh (2023) explored RE consumption in Ghana using data from 1994 to 2015 and employing the ARDL, VECM, canonical cointegration regression (CCR), FMOLS, and DOLS. The study found that financial development has a long-run positive effect on RE, although economic growth and energy costs have a negative effect.

Nabaweesi et al. (2023) investigated the REKC hypothesis in five selected East Africa Community (EAC) countries – Uganda, Burundi, Rwanda, Kenya and Tanzania for the period 1996 – 2019. The study also considered financial development in RE consumption. Employing the panel ARDL, the results confirm the U-shaped REKC hypothesis; moreover, financial growth and GDP per capita squared demonstrated a substantial positive impact on MREC, a 1 percent increase in financial development and GDP per capita increased RE consumption by 0.13 percent and 2.14 respectively. In the case of GDP per capita squared, urbanization, trade openness and FDI, a negative impact was observed. Thus, a 1 percent increase in the variables led to a 0,35 percent 0,63 percent, 0.34 percent and 0.06 percent increase, respectively.

Saibu and Omoju (2016) analysed the barriers to and drivers of RE adoption in the electricity sector in Nigeria by employing a VECM technique. The analysis covers data for the period 1981 to 2011; results from the estimation show that a long-run relationship exists between renewable electricity and GDP, financial development, trade openness and the share of fossil fuel in total energy consumption. In greater detail, the results suggest that being excessively focused on economic growth and the use of fossil fuels can weaken RE adoption; however, trade openness promotes it significantly, while financial development has no significant influence.

In South Africa, from 1990 to 2021, Ngcobo and De Wet (2024) employed the ARDL model to inspect if financial development and economic growth impact RE supply. The results showed that a 1 percent rise in financial development in the banking sector resulted in a 0.0284 percent increase in RE supply. In comparison, a 1 percent increase in financial development in the bond market sector resulted in a 0.0148 percent increase in RE supply. In addition, economic growth and load-shedding were found to have a positive impact on RE, while coal electricity supply was reported to have a negative effect on RE supply.

Another study focused on 69 Belt and Road initiative country regions, including sub-Saharan Africa, Europe, Central Asia, East Asia, South Asia, the Pacific, Latin America and the Caribbean, and the Middle East and North Africa (Khan et al., 2021). Using a standard error regression and dynamic Generalized Method of Moments (GMM) estimators, the study finds that the results are interesting and counterintuitive, indicating that economic growth, FDI and technological innovations have a negative influence on RE. However, financial developments showed a significant positive determinant in the RE sector. The authors further determined that FDI, economic growth and technological innovation contribute to energy use and CO_2 emissions.

Alhendawy et al. (2023) employed multiple machine learning algorithm methods, including Gradient Boosting, K-nearest neighbour, Support Vector Machine, Random Forest and Naïve Bayes, to identify the key determinants of RE production in Egypt. Utilising data from 2010 to 2022, the study found that RE adaptation, CO_2 emissions, RE technical innovation, and price of oil and energy imports do influence RE production – the combined impact of the variables is not higher than 1 percent. The variables that demonstrated an effect and indicated that RE production included GDP per capita growth, Governance indicators and Population growth, which had an impact of 13 percent, 10 percent and 60 percent, respectively.

Using an FMOLS approach, Dossou et al. (2024) conducted a panel study of 33 African countries over the period 2000-2020. The results found that governance quality (government effectiveness, control of corruption, political stability, rule of law, voice & accountability and regulatory quality) and financial development have a negative and statistically significant impact on RE consumption. The results also found that the interaction of financial development and governance quality is negative and significant. A governance quality threshold with regard to the negative effect of financial development on RE is negated at 0.825, 2.15, 2.86, 3.52, 3.36, and 0,1, respectively.

Lastly, employing the panel ARDL method, Asratie (2022) investigated the determinants of RE production from sources excluding hydroelectricity covering the period 1998 to 2019 in Eastern African countries, including Ethiopia, Tanzania, Kenya, Mauritius and Zimbabwe. The study found that electricity production from hydropower, oil, coal, and gas, as well as political instability, has a significant and negative impact on RE production. On the other hand, energy consumption per capita, GDP per capita growth, energy import and population growth have a significant and positive impact on RE electricity production from resources other than hydropower.

Table 3.3 below presents a summary of the reviewed empirical studies on RE Determinants in Natural Resource-Rich Developing Countries with High RE Potential.

Table 3.3: Summary of RE Determinants in Natural Resource-Rich Nations Developing Countries with High RE Potential

Authors	Period	Country (s)	Methodology	Findings
Tambari & Failler (2020)	1990-2018	Nigeria, Algeria and Egypt, Ethiopia, Angola and South Africa	VAR	There is a positive relationship between interest rate and price shocks; however, it fluctuated negatively in response to GDP and oil price volatility
Akintande et al (2020)	1996 - 2016	South Africa, Egypt, Nigeria, Ethiopia, and the DRC	BMA	A positive relationship between RE and energy use, population growth, electric power consumption, urban population, and human capital.
Hoa et al. (2024)	2000 - 2022	Indonesia, Philippines, Singapore, Thailand, Malaysia, and Vietnam	Panel ARDL	Government policies positively affect RE moderately, whereas technological innovation has a statistically significant positive impact on RE in the countries
Ackah & Kizys (2015)	1985 - 2010	Algeria, Angola, Cameroon, Congo, DRC, Cote d'Ivoire, Egypt, Gabon, Ghana, Nigeria, South Africa, Sudan and Tunisia	Random effect model, a fixed effects model and a dynamic panel data	The key drivers of RE identified were real income per capita, CO_2 emissions per capita, energy resource depletion per capita, as well as energy prices
Awijen et al. (2022)	1984 - 2014	Morocco, Tunisia, Algeria, Egypt, Iran,	PSTR	Governance quality positively affects RE

Authors	Period	Country (s)	Methodology	Findings
		Iraq, Jordan, Lebanon, and Yemen.		moreover, when innovation performance reaches a given threshold, it boosts the impact of governance quality on RE. RE and political stability, governance quality, economic growth, financial development, and environmental pollution have a positive relationship, but a negative relationship is observed with RE and the countries' dependence on natural resources and FDI
Ackah & Kizys (2015)	1985 - 2010	Angola, Tunisia Cameroon, DRC, South Africa, Cote d'Ivoire, Gabon, Congo, Ghana, Nigeria, Egypt, Sudan and Algeria	Random effect model, a fixed effects model and a dynamic panel data	The key drivers of RE identified were real income per capita, CO_2 emissions per capita, energy resource depletion per capita, as well as energy prices
Derk (2023)	2005 - 2020	Low, middle and high-income countries	Fixed-effects model	Resource rents have a negative impact on RE production as per capita income rises. Institutional quality and R&D have an insignificant effect on RE production.

Authors	Period	Country (s)	Methodology	Findings
Iqbal et al. (2023)	1980 - 2019.	Pakistan	Linear and nonlinear ARDL	Positive changes in GDP, environmental advancements, financial development, and CO_2 emissions have positive and significant influences on RE production; however, FDI shows a negative relationship. GDP has a positive influence on RE production using the linear ARDL
Aidoo (2024)	1988 - 2018	SAPP countries	Panel ARDL	GDP, labour force and trade have a positive impact on RE whereas gross capital formation and non-RE have a negative impact on RE.
Prempeh (2023)	1990 - 2019	Ghana	ARDL, VECM, CCR, FMOLS, and DOLS	Financial development drives RE however energy costs and economic growth have a negative effect
Olouch et al. (2021)	1998 - 2014	SSA countries	Panel ARDL	RE consumption positively correlates with the education index, GDP, corruption and negatively correlates with CO_2 emissions per capita

Authors	Period	Country (s)	Methodology	Findings
				and life expectancy index.
da Silva et al. (2018)	1990 - 2014	SSA countries	panel ARDL	Economic development and energy use have a positive effect on RE, whereas CO_2 emissions, population growth, price of fossil fuels, imports and Kyoto Protocol have a negative effect
Kwakwa (2021)	1971 - 2014	Ghana	Regression and variance decomposition techniques	Industrialisation positively impacts RE consumption; however negative influences were observed for income, price, and financial development
Prempeh (2023)	1990 - 2019	Ghana	ARDL, VECM, CCR, FMOLS, and DOLS	Financial development drives RE however, energy costs and economic growth have a negative effect
Apergis & Payne (2014)	1980 - 2010	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama	VECM	CO_2 emissions, real coal prices, and real oil prices had a positive impact on RE consumption
Saibu & Omoju (2016)	1981-2011	Nigeria	VECM	Economic growth can weaken RE adoption;

Authors	Period	Country (s)	Methodology	Findings
				however, trade openness promotes it significantly, and fossil fuels have a negative impact
Khan et al. (2021)	2000 - 2014	Belt and Road Initiative countries	Standard error regression and dynamic GMM estimators	Economic growth, FDI and technological innovations have a negative influence on RE. However, financial developments have shown a positive influence.
Da Silva et al. (2018)	1990 - 2014	Sub Saharan Africa	Panel ARDL	The results indicated that economic development increased RE development, whereas population.
Ngcobo & de Wet (2024)	1990 - 2021	South Africa	ARDL	Financial development and economic growth have a positive impact on RE.
Nabaweesi et al. (2023)	1996 - 2019	Burundi, Kenya, Rwanda, Tanzania, Uganda	Panel ARDL	Financial development positively and significantly affects RE consumption, whereas urbanization, FDI, and trade openness reduce it. Governance is insignificant.

Authors	Period	Country (s)	Methodology	Findings
Alhendawy et al. (2023)	2010 - 2022	Egypt	Machine learning methods - Gradient Boosting, K-nearest neighbor, Support Vector Machine, Random Forest and Naïve Bayes	GDP per capita growth, Population growth and Governance influence RE production. However, RE adaptation, CO_2 emissions, RE technical innovation, price of oil and energy imports have a negative impact.
Dossou at al. (2024)	2000-2020	Ethiopia, Algeria, Zimbabwe, Burkina, Faso Central African Congo, DRC, Lesotho, Cote d'Ivoire, Nigeria, Egypt, Gabon, Benin, Sao Tome, Ghana, Uganda Guinea, Kenya, Burundi, Madagascar, Tunisia, Malawi, Senegal, Mauritius, Morocco, Cameroon, Mozambique, Sudan, Rwanda, and Principe, Sierra	Panel FMOLS	The impact of governance quality and financial development have a negative and statistically significant effect on RE consumption. The interaction of Financial Development and governance quality was negative and significant.

Authors	Period	Country (s)	Methodology	Findings
		Leone, Zambia South Africa and Togo		
Saadaoui and Chtourou (2023)	1984 - 2017	Tunisia	Symmetric and asymmetric ARDL	Financial development negatively and significantly affects RE, and economic growth and institutional quality positively affect RE consumption.
Asratie (2022)	1998-2019	Ethiopia, Tanzania, Kenya, Mauritius and Zimbabwe	Panel ARDL	GDP per capita growth, energy consumption, population growth, and energy import have a significant and positive impact on RE (besides hydropower) electricity production and electricity production from hydropower, oil, coal and gas and political instability have a significant and negative impact

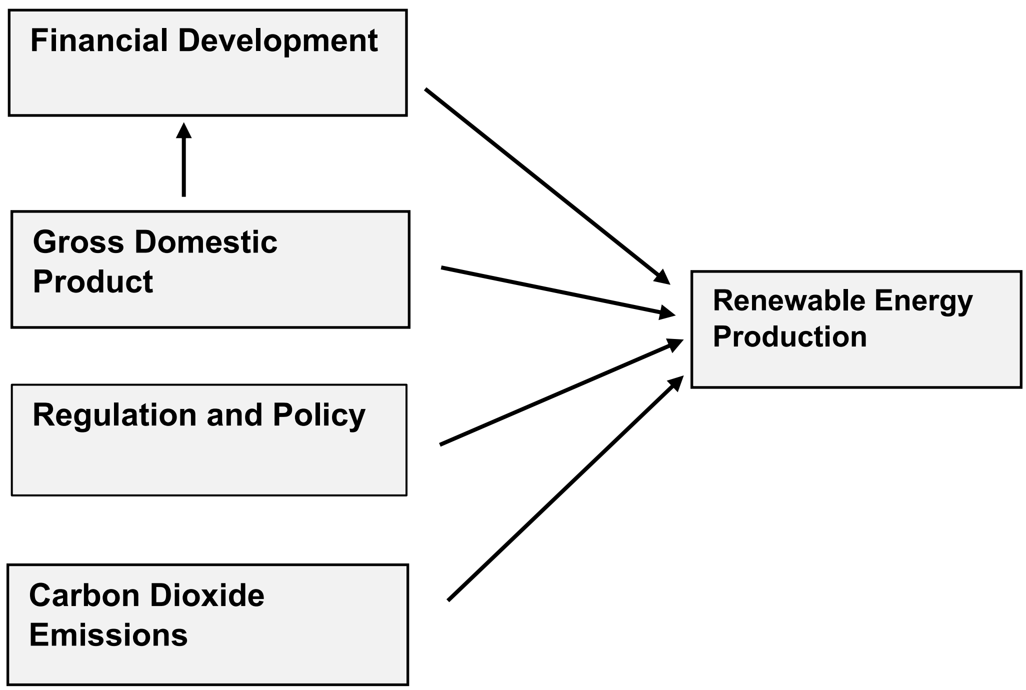
3.4 Conceptual framework

The deployment of RE is a critical component of sustainable development, particularly in regions like the SADC, where energy access and environmental sustainability remain significant challenges. To promote increased RE usage, it is necessary to investigate the key factors that influence its deployment. A vast body of literature has identified the main drivers of RE through the interplay of economic, socio-political and environmental factors, including government policies and technological advancements across various countries.

Building upon several key theoretical perspectives, Schumpeter's theory of innovation emphasizes the role of technological advancement (innovation) in economic development. Kumar (2020) argues that RE technologies contribute to energy security, economic growth, job creation, and poverty reduction, aligning with Schumpeter's view that innovation drives economic transformation.

Despite the potential, the promotion of RE faces various challenges. The Theory of Planned Behaviour highlights the importance of factors such as government policies, economic benefits, and environmental concerns in driving behavioural changes toward cleaner energy consumption. Barriers such as financial limitations also influence these behavioural shifts. These factors are central to understanding the challenges and opportunities for RE deployment in SADC countries (Nguyen et al., 2022; IRENA and AfDB, 2024; Claudy et al., 2013; Aidoo, 2024).

Figure 3.3: Conceptual framework



Source: own conceptualisation

The Environmental Kuznets Curve (EKC) suggests that as income levels rise and environmental concerns increase, there is a shift toward investing in cleaner energy sources. The EKC framework provides a foundation for understanding how economic growth in the SADC can lead to greater RE production, provided the right policies are in place.

Figure 3.3 above illustrates the relationships between the dependent and independent variables, providing an understanding of how to enhance RE development in the SADC region. The dependent variable is RE production, measured by generation from all sources. The independent variables include GDP, financial development, CO_2 emissions, and regulations and policies, which significantly impact the expansion of renewable energy. Higher economic growth and access to financial instruments can enhance investment in RE. Environmental concerns related to greenhouse gas emissions also contribute to the expansion of RE. Additionally, policy and institutional factors play a critical part in shaping RE deployment.

3.5 Conclusion

In this chapter, a compressive review of theoretical and empirical literature is presented on the determinants of RE. The reviewed theoretical framework includes Schumpeter's theory of Innovation, the Theory of Planned Behaviour and the EKC. The theories laid the foundation of the factors that determine the deployment of RE by providing a general view. The theoretical section began exploring the ‘channels’ through which RE is influenced, and it was observed that all the theories are compatible with the study. However, because it outlined the expected trend in RE adoption within developing countries such as those in the SADC region, the EKC has proven to be the most relevant to the study. The renewable EKC explains that RE tends to increase at a certain income level driven by the intention to improve environmental quality, thereby reducing CO_2 emissions.

Overall, when it comes to the determinants of deployment or adoption of RE, the theories recognize that economic conditions, access to financial capital, government policies, and environmental concerns could accelerate RE production. Against the theoretical framework, a comprehensive empirical review of the determinants of RE in various countries was undertaken. It is clear that in-depth studies identifying the determinants or drivers or determinants of RE for both developing and developed countries were conducted predominantly as panel studies categorized in regions or intergovernmental organizations (even country groupings). Literature that considers individual countries is limited; in addition, the focus is largely on developed and industrialised countries.

Notably, Southern African countries have not received sufficient attention, as the majority of the analysis focuses on Africa or SSA pooled together. Therefore, this created a gap in the literature, which this research aims to close with the application of an SADC panel study. Moreover, since only one previous study was conducted in the region, it is important to ascertain the precise behaviour of the variable’s values for SADC countries within this context.

From the literature conducted, it could be realised that few studies, specifically for Africa, do not investigate variables that cover all aspects of the determinants of RE deployment, including environmental, macroeconomic and socioeconomic indicators. This study will cover all the different aspects of the determinants. Most studies only apply macroeconomics variables such as oil prices, financial development, GDP and energy prices. Moreover, the extant of literature observes the multidimensional econometric models and estimation techniques.

Furthermore, most of the previous studies reviewed have a consensus on the determinants of RE in all the various countries, which are commonly CO_2 emissions, GDP, energy prices, R&D, energy prices, financial development, FDI, imports, exports and others. However, the results are mixed when it comes to other variables, such as technological innovation and carbon emissions, while the impact of policies is not extensively researched. The next chapter will outline the methodology employed in this study.

CHAPTER 4
RESEARCH METHODOLOGY

4.1 INTRODUCTION

The previous chapters have established that although Southern African countries' RE production has a large gap compared to the targets, there is great potential for RE that has not yet been harnessed, which can improve electricity access and achieve sustainable development. Most countries in the region are already implementing measures, strategies and policies to increase RE use; however, the uptake of clean energy technologies remains subdued. Studies reviewed in Chapter Three have shown evidence of RE determinants, which include CO_2 emissions, economic growth, technology, policies, trade openness and financial development, amongst others.

This chapter will explain how the objectives set in Chapter One (Introduction and Background of the Study) will be achieved and the application of the analysis from the literature review in Chapter Three, such as including some variables and adopting a model for the analysis. The objectives set out in chapter one include: i) To empirically identify the significant determinants of RE production in selected SADC countries in the long and short run. ii) To determine the direction and degree of the relationship between RE production and its determinants in the long run and short run iii) To investigate the differences in the effects of the determinants of RE production across the selected SADC countries.

The chapter presents the following sections: in section 5.2 the research design is explained, section 5.3 presents the model specification, followed by a definition of variables and expected signs of variables in 5.3, then data sourced are outlined in section 5.4, sections 5.5 and 5.6 discusses the unit root tests and the cointegration test respectively, in section 5.6 the estimation techniques and sensitivity or robustness check 5.7 granger causality, and 5.8 provides diagnostic test and section 5.9 concludes the study.

4.2 RESEARCH DESIGN

Quantitative research involves collecting numerical data and applying mathematical approaches to analyze a relationship between chosen variables. Whereas a qualitative approach applies non-numerical data such as surveys and interviews to analyze and interpret concepts (Creswell, 2003:153; Burns & Grove, 1993:777). A mixed approach involves both qualitative and quantitative methods.

This study follows a quantitative approach and correlational research design, applying econometrics techniques to analyze the determinants of RE in selected SADC countries. The advantage of this approach is that it helps minimize bias and subjectivity in the findings and determines the strength and direction of relationships between variables (Cresswell, 2003:154). Furthermore, panel data - a mixture of cross-sectional and time series data will be utilized is

4.3 DATA SOURCES AND SAMPLING

The study uses a panel estimation which is chosen for more reliable estimation and to control individual heterogeneity. More benefits of panel data include factors such as obtaining observation for the same variable in different cross sections, thus providing more informative data that can reveal more dynamic relationships. This study uses secondary time series annual panel data covering a 31-year period for each cross-section from 1990 to 2021 of six selected SADC countries and a total of 186 time series observations. The selection of the starting period was informed by the fact that although up to now Africa has fallen behind in RE production, a considerable rise in the consumption of RE sources has been gradual since 1990, particularly for solar and wind sources (Amoah et al., 2020: 4).

The selected SADC countries include South Africa, Botswana, Angola, Zambia, the DRC and Namibia. Countries including Angola, DRC, Namibia, and Zambia have a power sector base load supplied and generated primarily from RE, whereas in Botswana and South Africa, the base load is primarily supplied by coal generation. Accordingly, this examines the determinants in countries with varying degrees of RE, some of which are still transitioning to RE technologies. Only these countries were selected because other SADC countries have no data or inconsistent data on the variables for the years 1990 to 2021.

4.4 EMPIRICAL MODEL SPECIFICATION

The theoretical and empirical literature presented in Chapter 3 underscores the determinants of RE, which include but are not limited to economic growth, financial development, CO_2 emissions, oil prices, policies, trade, technological innovation, non-RE, and government effectiveness as key constructs that influence RE. Therefore, this study employs some of the variables to assess their influence in the selected SADC countries.

This study adopts a model employed by a study by Derk (2023) that investigated the determinants of RE through a panel study. The author proposed several variables as possible determinants of RE that cover developing and developed countries. The variables include GDP per capita, institutional quality, inflation, unemployment, resource rents, political spectrum, inflation, and RE production. Thus, RE production is expressed as a function of GDP per capita, institutional quality, inflation, unemployment, Research and Development and its interaction with GDP per capita, Political Spectrum, Inflation and Unemployment.

The function of RE production is expressed in the following equation

$$RE\ Production_{i,t} = \alpha_{i,t} + \beta_1 Resource\ Rents_{i,t} + \beta_2 Institutional\ Quality_{\ i,t} + \beta_3 GDP\ per\ Capita_{i,t} + \beta_4 Resource\ Rents_{i,t} * GDP\ per\ Capita_{i,t} + \beta_6 Inflation_{i,t} + \beta_7 Unemployment_{i,t} + \beta_8 Political\ Spectrum_{i,t} + \varepsilon_{i,t} \quad (4.1)$$

In this study, the equation in 4.1 is modified to include other variables or factors that are relevant to the study at hand. Therefore, in order to unveil the multifaceted determinants of RE, this study modified the above equation (4.1) to account for the role of the key constructs that influence RE - macroeconomic, environmental, and socio-political factors consistent with the studies of Lawal (2023) and Bamati and Raoofi (2020) focused on the power sector. The modified equation for the study utilizes Financial Development (FIN), CO_2 emissions, GDP per capita (GDP), regulation and policy as a dummy variable (R&P) including an interaction term between GDP per capita and financial development as a function of RE production. The equation excludes unemployment, inflation, and the political spectrum.

The relationship between policy and regulation and RE has not been widely researched in African countries or Southern Africa for panel studies. In particular, the study of Aidoo (2023) is the only study that attempted to examine the relationship using the Southern Africa by using SAPP. Furthermore, an interaction term between GDP per capita and financial development has not been investigated in developing countries. It should be noted that it was preferred that the innovations factor by proxy of patents or Research and Development expenditure be added to the model to serve as the technological factor affecting RE (it is anticipated that expansion in RE innovation will boost RE supply), however, it was not included owing to the limited and inconsistent availability of data for countries included in the study.

Based on the variables indicated above, the econometric model specification for this study is then expressed in 4.2 as follows:

$$RenG_{it} = \alpha_{it} + \beta_1 GDP_{it} + \beta_2 CO_{2\ it} + \beta_3 FIN_{it} + \beta_4\ R\&P\ (Dummy)_{it} + \beta_5 (GDP * FIN) + \varepsilon_{it}$$

(4.2)

Where i is cross-sectional units, t is the period, $\beta_1, \beta_2, \beta_3, \beta_4$ are the parameters to be estimated in this study, and ε_{it} is the error term. Where RenG denotes RE production, GDP is GDP per capita, representing economic growth. Nabaweesi (2023) highlighted CO_2 emissions, financial development and R&P as critical factors when evaluating environmental quality and concern, financial capacity and government incentives for adopting RE, respectively. GDP*FIN is an interaction term in which financial development enhances the effect of GDP on RE generation. The model variables, the corresponding unit of measurement and the sources are presented in Table 4.1 below.

Table 4.1: Variables Definitions, Measurement and Sources

Variable	Unit of Measurement	Source
Renewable Energy Production	The total RE generated in each country, including all sources such as solar, wind, bioenergy, hydropower, and geothermal in the power sector. The RE generation is measured by the units of Gigawatt hours (GWh).	International Energy Agency (IEA)
GDP per capita	GDP per capita represents the total gross value added within the borders of a country, adjusted by including product taxes and subtracting subsidies that are not part of the product's value, divided by mid-year population (World Bank, 2025). GDP measures the economic performance or economic growth of a country. The GDP per capita values are based on the constant price of the local currency of each country.	World Bank Group Data
Carbon Dioxide Emissions	Carbon dioxide is a type of GHG emitted primarily from burning fossil fuels produced during the consumption of liquid, gas fuels, and solid (i.e coal, oil and natural gas). It is measured using annual data of the unit of CO_2 emissions in kiloton (kt) in each country.	World Bank Group Data
Financial Development Index	The annual financial development index measures financial development and considers the development of financial markets and institutions in terms of their depth, access, and efficiency (IMF,2016). It is measured from 0, which indicates the lowest financial development, to 1, which indicates the highest financial development.	International Monetary Fund (IMF)

Regulations and Policies	Regulation and policy are treated as dummy variables that assume a value of 1 after the introduction of any policy instruments or regulation (tariffs, subsidies, guaranteed prices, tax, national plans and strategies) and 0 if policy or regulations have not been introduced in the energy sector to encourage and encourage the use of RE. The years of implementation of such were identified from the IEA policy database.	IEA
GDP*FIN	An interaction term occurs when two or more independent variables influence each other in affecting the dependent variable (Rajan and Zangales, 1998). The interaction term is computed by multiplying estimated GDP per capital (GDP) and financial development (FIN). GDP*FIN is the interaction term of GDP per capita and financial development.	N/A

As shown in Table 4.1 above, the annual data used in the study was obtained from multiple sources and reputable data outlets. The selected countries are shareholders of two of the three organizations: the World Bank Development Indicators, the IEA, and the IMF.

4.5 **DESCRIPTION OF VARIABLES**

The table below explains the study's dependent and independent variables, the rationale behind using them, and the expected signs.

Table 4.2: Description of Variables and Expected Signs

Variable	**Proxy & Symbol**	**Description**	**Expected Sign**
Renewable Energy Generation	Adoption of RE technologies in the power sector and RE production	RE is the dependent variable, represented by RE generation from sources including solar, wind, bioenergy, hydropower, and geothermal. Often, studies use RE consumption as a proxy	N/A

	(RENG)	for RE production; however, this study utilizes RE generation.	
GDP per capita	Economic Growth (GDP)	The relationship between GDP and RE is a well-researched variable in different regions. To capture the effect on RE, previous studies (Ndlovu 2020; Kim & Park, 2016; Bayomi, 2022) have shown that countries experiencing GDP growth have better prospects to access new technologies that are vital to the increase in RE uptake. Moreover, high income levels increase the capacity of private and public sectors to finance several projects, thereby increasing RE generation (Bamati and Raoofi, 2020).	+
Carbon Dioxide Emissions	Intensity of fossil fuel usage (CO_2)	The environmental concerns stemming from high CO_2 emissions tend to upscale the political pressure to advance sustainable technologies (Sadorsky, 2009). Especially since most countries are signatories of the Paris Agreement and are vulnerable to climate change effects caused by rising GHG emissions. Consequently, a positive relationship is expected, similar to the findings of Shahbaz et al. (2018), Ackah and Kizys (2015), However, some CO_2-emitting economies lobby for the continued use of fossil fuels because of the perceived risk associated with the losses in the carbon-emitting industries and other indirect losses, such as job losses (Da Silva, 2018). Hence, in addition to a positive sign, a negative sign is expected to be consistent with Olouch et al. (2021), Ackah and Kizys (2015), da Silva et al. (2018), and Marques et al. (2010).	+/-

Financial development	Financial development (FIN)	The financial development index measures financial development and considers the development of financial markets and institutions in terms of their access, depth, and efficiency (IMF,2016). An adequate financial landscape is necessary to ensure the availability of resources (investment and lending) for RE. Considering the initial high financial cost of RE production, financial development has been widely employed by Yadav (2024), Opoku et al. (2024), and Khan et al. (2021). Therefore, a country with developed financial development may result in the availability of funding required for RE capital.	+
Regulation and policies	Regulations and policy effectiveness (R&P)	Regulation and policies are treated as a dummy variable that takes a value of 1 after the introduction of any policy instruments. To account for the influence of a socio-political factor on RE. RE policies are usually the core action for the government to encourage RE generation. Hoa et al. (2024) and Muhammed and Tekbiyik-Ersoy (2020) employed policies in the study, which established that advanced RE policies result in high shares of renewable sources in the total energy supply.	+
GDP*FIN	Interaction term – GDP enhanced by financial development	Although most studies have researched the influence of GDP on RE and have provided evidence where in most cases a positive relationship is found. Authors such as Khan et al. (2021) and Shahbaz et al. (2021) have argued that this positive relationship is	+

		dependent on the level of GDP. Such that, much significant influence of GDP on RE may largely be seen in advanced economies. Thus, financial development is used to enhance the influence of GDP on RE, particularly as the selected countries are low- and middle-income countries.	

4.6 DESCRIPTIVE ANALYSIS

Before conducting a model estimation, it is essential to identify the behaviours of the key variables while also providing a summary of the relationship between them. This can be done by carrying out a descriptive analysis by employing a trend analysis. Descriptive statistics refers to a quantitative summary of both dependent and independent variables (Hassan, 2019). Moreover, the analysis provides information such as i) measures of central dependency, which includes mean, median and mode; ii) measures of dispersion – range, standard deviation, quartiles, percentiles, variance and deciles; and iii) measures of normality – kurtosis (which measures the degree of sharpness) and skewness (which measures the degree of symmetry).

4.7 PANEL UNIT ROOT TEST

Stationarity, or the unit root, is defined as a process wherein the variance and mean of a series remain unchanged over time (Asteriou and Hall, 2015). Harris and Sollis (2003) suggest that verifying the validity of estimation outcomes requires confirmation of the order of integration (stationarity) or testing for the existence of unit roots. This is because the presence of unit roots may lead to spurious regression results and incorrect conclusions in econometric modelling. In addition, testing the unit root constitutes the initial step in determining the existence of a long-term relationship.

Nonetheless, determining the maximum order of integration, stationarity, or unit root of variables among the regressors is also essential to determine the appropriate model that should be employed in the study (Yakubu,2015). Variables can be integrated into different orders of integration, order zero, one or two, also presented as I(0), I(1) or I(2), respectively. Usually, in an ordinary time series study, the Phillips Perron (PP) and Augmented Dickey-Fuller (ADF) tests are used to determine the unit root in the series. However, since panel data is used in this study, a mix of time series and cross-section data must inform the choice of unit root test employed, be appropriate and be able to combine time series and cross-section dimensions.

Over the years, there have been numerous panel unit root tests have been developed; these tests are mainly grouped into two categories. The first category consists of a group that assumes a common unit root process, for instance, Breitung (2001), Hadri (2000), and Levin, Lin and Chu (2002). The second category is of tests that assume individual unit roots, which include tests by Choi (2001), Im et al. (2003), and Maddala and Wu (1999). The tests are also known as first-generation unit root tests that assume cross-sectional independence across units.

Examining the presence of unit roots prior to estimating any regression is fundamental to determining the use of a panel ARDL approach; this is the estimation method that this study employs. Therefore, to identify the variables' order of integration and determine the statistical method to employ, the study applies first-generation unit root tests, which are also discussed. These include the Levin–Lin–Chu test (Levin et al., 2002) and Im-Pesaran and Shin (Im et al., 2003). The key limitation of the tests is their assumption of cross-sectional independence across units. When stationarity has been confirmed, cointegration tests are conducted to investigate the long-run relationship between variables.

4.7.1 Levin–Lin–Chu Unit Root Test

The Levin–Lin–Chu (LLC) is a test to determine if a time series variable follows a unit root process. The test was introduced by Levin et al. (2002) and assumes the same unit root process across the entire panel data set. The LLC is considered an extension of the ADF useful for panel data analysis, which allows the inclusion of more lags in the autoregressive process compared to the ADF test. Moreover, as Levin et al. (2002) noted, the LLC test is more appropriate for panels of moderate size; considering the size of the panel data in this study, the LLC test seems to be appropriate.

In panel data, individual-specific effects (cross-sectional dependence) and common time-series effects can usually exist. Therefore, as the first-generation unit root test, LLC considers these dependencies, making it robust for panel data analysis.

The LLC unit root is based on the equation shown below:

$$\Delta y_{i,t} = \theta_i + \rho_i \sum_{j=1}^{p} \alpha_j \, \Delta y_{i,t-j} + \beta X_{i,t} + \epsilon_{i,t} \qquad (4.3)$$

Wherein Δy_{it} is the deterministic component, ϵ_{it} is the stationary process, i symbolize the cross section and t the period. The LLC tests the null hypothesis of $\rho_i = \rho = 0$ and alternative hypothesis $\rho_i = \rho < 0$ are illustrated below based on the following t-statistic:

$$t_{\varphi} = \frac{\hat{\rho}}{se\,(\hat{\rho})} \tag{4.4}$$

H_0 : all series in the panel contain unit root and variables are non-stationary

H_1: all series do not contain unit roots and variables are stationary

The LLC test has a few notable limits. One of the key limitations is that autoregressive parameters are considered identical across the panel (Barbier, 2005), are shown below:

$$H_0: p_1 = p_2 = \cdots = p_N = p = 0$$

$$H_1: p_1 = p_2 = \cdots = p_N = p < 0 \tag{4.5}$$

This limitation is overcome by the Im Pesaran and Shin unit root test, which does not assume identical first-order correlation under the alternative. The second limitation is that the LLC test is dependent on the assumption of independence across individual cross-sections; therefore, it is not applicable if cross-sectional dependence (CSD) is present.

4.7.2 Im-Pesaran and Shin (IPS)

The Im-Pesaran and Shin (2003) test is another widely used unit root test for panel data, aiming to enhance efficiency and reliability and provide more accurate inference. This is shown by the test's ability to observe each cross-section unit in the panel rather than pooling the data, which is different from the LLC test, especially when dealing with cross-sectional dependence and heterogeneity. In addition, the IPS test is more open to having different-order autoregressive coefficients, thus resolving the autocorrelation issue (Barbieri, 2006). The IPS is robust against various forms of heterogeneity and dependence commonly found in panel data analysis.

Considering the test with an individual cross-sectional, Augmented Dickey-Fuller regression proceeds as follows:

$$\Delta y_{i,t} = \rho y_{i,t-1} + \sum_{p=1}^{j} \theta_i \, \Delta y_{i,t-1} + \beta X_{i,t} + \epsilon_{i,t} \tag{4.6}$$

Where i = 1,2 ,..., N , t = 1,2 ,...,T

The null hypothesis is as follows:

H_0 : ρ_i = 0 for all i

And the alternative hypothesis:

H_1 : ρ_i = 0, for i = 1, 2,……,N1 or ρ_i = 0 for i = N + 1,N + 2,…..,N (4.7)

With $0 < N_1 \leq N$

The null is the same as that of the LLC test, which indicates that all series in the panel have a unit root or are non-stationary. Whereas the alternative hypothesis is that all series in the panel are stationary or do not contain a unit root.

It is also imperative to highlight that the IPS test assumes that T is the same for all cross-sections (Im et al., 2003). Therefore, a balanced panel in the computation of the t-test statistic is needed, which is specified as the average of the individual ADF t-statistic.

The IPS t-statistic is computed as follows:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^{N} t_{iT} \quad (4.8)$$

The IPS assumes that t_{iT} are $i.i.d$ and also have finite variance and mean.

4.8 CROSS-SECTIONAL DEPENDENCE

It is crucial to examine CSD before estimating the model when making use of panel data where a number of observations exist for individual cross-sections. According to Hoyos and Sarafidis (2006), the effect of CSD in panel data is severe because if found in data and ignored, it can reduce the efficiency of estimates such that the panel least-squares estimator could provide small benefits with single-equation ordinary least squares (OLS).

CSD is defined as the estimated residuals on cross-sections that rely on each other. Economically, financially and socially, economies can be integrated due to spillovers and externalities; therefore, accounting for CSD in panel data is crucial to eliminate biased estimation results and incorrect inferences about the stationarity of the variables, thus inefficient empirical estimation (Qiu-Hua et al., 2016). Nevertheless, there are estimation models that assume no correlation among the cross-sectional units.

When applying a framework or test for CSD, the size of the time series of the panel (T) relative to the cross-section is considered (N). When N is larger than T, a seemingly unrelated regression (SUR) method is applied to model the CSD; alternatively, when T is larger than N, the SUR will not be possible. An SUR system encompasses multiple individual relationships that have correlated disturbances (Zellner, 1962). There are a number of methods which can be utilized for a CSD test; these tests include Breusch and Pagan's (1980) Lagrange multiplier (LM) test, Pesaran (2004) scaled LM test, and Pesaran (2004) CSD test.

The study uses the Breusch and Pagan (1980) LM statistic CSD test suggested by Breusch and Pagan (1980) for detecting CSD. The test is the best choice for the study considering that the data contains a small number of cross-section units from the panel observations. In this study, N = 6 and T = 186 (or 31 for each variable). The test is based on the following LM statistic:

$$CD_{lm} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{p}_{ij}^2 \tag{4.9}$$

$$\hat{P}_{i,j} = \hat{P}_{j,i} = \frac{\sum_{t=1}^{T} \hat{e}_{it}\hat{e}_{jt}}{(\sum_{t=1}^{T} \hat{e}_{j,t}^2)^{\frac{1}{2}} (\sum_{t=1}^{T} e_{j,t}^2)^{\frac{1}{2}}} \tag{4.10}$$

where $\hat{p}_{ij}$ denotes a sample estimate of the pair-wise correlation of the residuals and e_{it} is the OLS estimate of u_{it}. LM is asymptotically distributed as x^2 while $N\ (N-1)/2$ degrees of freedom.

The following are the null and alternative hypotheses;

H_0: No cross-section dependence

H_1: There is cross-section dependence.

4.9 PANEL COINTEGRATION TEST

Subsequent to verifying the order of integration, as explained in subsection 4.7.1, the study uses cointegration tests to determine evidence of long-run cointegration amongst RE generation and the independent variables. The cointegration of the variables suggests movement, so the short-term disturbances are adjusted in the long run. Similar to general time series data cointegration, the prerequisite of panel data cointegration is that the data must be stationary.

Various tests have been designed to determine the cointegration within panel data studies (Maddala and Wu, 1999; Levin et al., 2002; Kao, 1997; Kao, 1999; McCoskey and Kao, 1998; Pedroni, 1999). To confirm the presence of cointegration, this study will conduct two tests: the Pedroni (1999, 2004) and Kao (1999) panel cointegration tests. These tests assume one cointegrating vector and are based on residual analysis.

4.9.1 Pedroni Cointegration Test

The Pedroni panel cointegration assumes heterogenous intercepts across individual cross-sections of the panel and permits trend coefficients. Pedroni (1999) proposes seven tests to determine whether variables are cointegrated in the panel data models. The Pedroni test has two categories: within and between dimensions.

The within dimension under residual-based Lagrange multiplier (LM) tests entails averaging the test statistics in the time series within cross-sections (Mahembe, 2014). These test statistics include PP statistics, rho-statistics, v-statistics and ADF-statistics. Nonetheless, the between dimension entails an average in such a manner that limiting distributions hinge on piecewise numerator and denominator terms (Baltagi, 2008:295). The between dimension includes PP-statistics, rho-statistics and ADF statistics. All seven statistics - the between and within dimensions these statistics are considered in the study in order to be able to compare them to choose whether there is an existence of cointegration.

The heterogeneous panel cointegration test proposed the following residual based on the variables:

$$y_{i,t} = x_{i,t} + \beta_{i,t} + z_{i,t}\tau_i + \varepsilon_{i,t} \quad (4.11)$$

$$\varepsilon_{i,t} = \emptyset_i \varepsilon_{i,t-1} + \omega_{i,t} \quad (4.12)$$

Where for i=1, 2 .., N for each unit in the panel, t=1, 2…, T. Where y represents the fixed effect and z signifies the slope coefficient authorized to change across individual units.

4.9.2 Kao Cointegration Test

Similar to the Pedroni test, the Kao test is residual-based. However, the cross-sections are specified as homogenous regression parameters, which further assume a common cointegrating vector (Kao, 1997). The test is specified by applying the Dickey-Fuller and ADF type tests.

According to Kao (1999), the cointegration test can be used to model:

$$\hat{u}_i = eu_{i,t-1} + v_{i,t} \quad (4.13)$$

Where $\hat{u}_{it}$ is the estimated residuals from the model, both tests have the same null hypothesis that there is no cointegration (where the residuals will be I(1)), against the alternative that cointegration exists. The Kao and Pedroni tests necessitate that the covariates are not integrated amongst themselves.

4.10 Selection of Optimal Lags

Prior to estimating the equation, it is appropriate and important to determine and select the optimal lag length. This is crucial since the presence of standard error terms is necessary (Shrestha & Bhatta, 2018). To conduct this procedure of selecting the optimal lag order, the VAR model is used (Chandio, Jiang & Rehman, 2019). In this study, the model order selection criteria used include those such as the Schwartz Bayesian criterion (SBC) and the Akaike information criterion (AIC). Subsequent to the selection of the appropriate lag order, the panel ARDL is estimated.

4.11 Panel Autoregressive Distributed Lag (ARDL)

This study uses the panel ADRL model, which was first developed by Peresan and Shin (1999) and later modified by Peresan et al. (2001). The model is used to quantify the direction as well as the strength of the relationship between the variables. One of the key favourable factors of the ARDL model is that although variables should not be I(2), they can be employed when variables have a mixed order of integration of either I(0) and I(1).

In addition, employing the panel ARDL model to test regression includes lagged variables for both the independent and dependent variables. These can be applied with different optimal lags and provide unbiased estimates of the long and short-run relationships (Pesaran et al., 1999). Therefore, robust and consistent results between variables for both periods (short and long run) were produced. Some more advantages of the ARDL model are that it can provide reliable estimates on 'small' sample periods. According to Pesaran and Shin (1998), the long-run parameters are consistent, although the short-run parameters are square of t consistent - even when a sample size exists.

According to Asghar et al. (2015), the general form for the panel ARDL model can be computed as follows:

$$Y_{i,t} = \sum_{j=1}^{p} \beta_{i,j}\, Y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij}\, X_{i,t-j} + \mu_t + \varepsilon_{i,t} \tag{4.14}$$

Where number of cross section units i = 1,2,3…,N and t= 1,2, 3,….T, $X_{i,t-j}$ is a vector of regressors, βij is a scalar,δ_{ij} are coefficient vectors, and μi is a group of specific effects. The error term (ε_{it}) is the first (stationarity) of the variables.

The study specifies the relationship between RE and macroeconomic variables in a panel ARDL form as:

$$\Delta REs_{i,t} = \beta_0 + \sum_{i-t}^{p} \beta_1 \Delta REs_{t-1} \sum_{i-t}^{p} \beta_2 \Delta GDP_{t-1} + \sum_{i-t}^{p} \beta_3 \Delta CO2_{t-1} + \sum_{i-t}^{p} \beta_4 \Delta FIN_{t-1} + \delta_1 GDP_{t-i} + \delta_2 CO2_{t-1} + \delta_3 FIN_{t-1} + \delta_4 R\&P_{t-1} + \delta_5 R\&P_{t-1} + \varepsilon_{i,t} \quad (4.15)$$

Where β_0 represents the constant, and Δ denotes the first difference operator in the model and p the optimal lags by some information criterion. The short-run coefficients are shown by $\beta_1 - \beta_6$ whereas the long-run coefficients are shown by $\delta_1 - \delta_5$ coefficients. Further, p represents the lags of the dependent variable and independent variables and ε_{it} is the error term, which is assumed to be white noise and varies across countries and times. Provided that cointegration is established, the error correction term for equation (4.15) is written as:

$$\Delta REs_{i,t} = \beta_0 + \sum_{i-t}^{p} \beta_1 \Delta REs_{t-1} + \sum_{i-t}^{p} \beta_2 \Delta GDP_{t-1} + \sum_{i-t}^{p} \beta_3 \Delta CO_{2_{t-1}} + \sum_{i-t}^{p} \beta_4 \Delta FIN_{t-1} + \sum_{i-t}^{p} \beta_5 \Delta R\&P_{t-1} + \sum_{i-t}^{p} \beta_6 \Delta GDP * FIN_{t-1} + q_i ect_{i,t-1} + \mu_{i,t} + \varepsilon_{i,t}$$
(4.16)

The error correction term for each cross-section is defined as $ect_{i,t-1} = REs_{i,t-1} - \vartheta_{0i} - \vartheta_{1i} GDP_{i,t-1} - \vartheta_{2i} CO_{2_{i,t-1}} - \vartheta_{3i} FIN_{i,t-1} - \vartheta_{4i} R\&P_{i,t-1}$

The error correction term (ECT) captures the short-term speed of adjustments of the variables toward the long-term equilibrium relationship identified by the cointegration (Sisimogang, et al., 2016). For long-run equilibrium to be established between RE and the explanatory variables, the coefficient of the error term is anticipated to be negative and statistically significant.

4.11.1 Pooled Mean Group Estimator

The panel ARDL model in equation (4.6) is estimated employing the pooled mean group (PMG), while other existing estimators exist, such as the mean group (MG) developed by Pesaran and Smith (1995) or the dynamic fixed effects (DFE) estimator. Each of these estimators can justify heterogeneity in the relationship among variables and is of long-run equilibrium computed by the maximum likelihood.

Pesaran et al. (1999) developed the PMG, which entails averaging and pooling. The estimator also allows variation in cross-sections of short-run coefficients and error variances; however, in the long run, coefficients are confined to being homogenous. Generally, the long-run coefficients are expected to be homogenous as a result of the effects of technology influencing each country, economic shocks, income levels, and so on. However, the reasons for the heterogeneity assumption in short-run coefficients and error variances are likely less compelling.

The PMG estimator offers the advantage of capturing short-run dynamics, which can be evaluated for each cross-section while considering the number of time series observations within each cross-section. Moreover, the PMG is also appropriate when applied to ‘small samples’, that is, when T and N are small (Peseran et al, 1999).

The specification of the ARDL model on equation 4.14 can also be characterized as a VECM framework shown below:

$$\Delta Y_{i,t} = \alpha_i\left(Y_{i,t-1} - \delta X_{i,t-1}\right) + \sum_{j=1}^{p-1} \delta_{i,j}\, \Delta Y_{i,t-j} + \sum_{j=1}^{q-1} \acute{\beta}_{ij}\, \Delta X_{i,t-j} + \mu_i + \varepsilon_{i,t} \tag{4.17}$$

Where σ_i and α_i are the long-run and the equilibrium (error) correction parameters, respectively. One of the limitations of the PMG is that the elements of σ are common throughout the countries; therefore:

$$\Delta Y_{i,t} = \alpha_i\left(Y_{i,t-1} - \sigma X_{i,t-1}\right) + \sum_{j=1}^{p-1} \delta_{i,j}\, \Delta Y_{i,t-j} + \mu_i + \varepsilon_{i,t} \tag{4.18}$$

In the panel ARDL framework, a PMG or Means Group estimator is usually applied following a Hausman test, which assists in deciding which estimator should be used. However, this study applies the PMG directly; according to Pesaran and Shin (1999), the PMG estimator is preferable as it makes provision for short run variance coefficients by country. In addition to the aforementioned fact, the direct use of the PMG is also applicable when there is justification of homogeneity across the cross section or countries (Peresan et al., 1999). A long-run association between the variables in the study is assumed because of the energy dependencies amongst the countries, infrastructure deficits or gaps including in energy infrastructure and climate risks associated with the use of fossil fuel.

4.12 SENSITIVITY ANALYSIS

Sensitivity analysis is conducted to assess the robustness and reliability of the primary methodology, providing insights amidst a range of plausible and varying assumptions (Morris et al., 2014). The study presents a sensitivity analysis to explore whether the choice of the panel ARDL model alters the findings across different methodologies, provides robust outcomes of the cointegration analysis, and a more nuanced interpretation of how RE determinants impact your outcomes.

The approach employs the panel FMOLS developed by Pedroni (2000), and the panel DOLS estimation method developed by Kao and Chiang (2000). The two methodologies vary from the panel ARDL approach in numerous ways.

4.12.1 Panel Fully Modified Ordinary Least Square

The FMOLS was developed by Phillips and Hansen (1990) and was modified from the traditional OLS to directly estimate the cointegration. When employed, the panel FMOLS resolves the issues associated with simultaneous bias and non-stationary variables, including serial correlation and endogeneity (Pedroni, 2001a). Furthermore, the panel FMOLS resolves the issues in relation to non-stationary variables and simultaneous bias (Pedroni, 2000). Panel FMOLS eliminates the weak second-order bias from the dependent variables (Phillip and Hansen, 1990).

Prior to constructing the panel FMOLS, the study demonstrates the unmodified OLS cointegrated panel equation below:

$$Y_{i,t} = \alpha_i + x'_{i,t}\beta + \mu_i \tag{4.11}$$

Where the dependent $Y_{i,t}$ are a matrix of the dimension of 1×1. β is the vector parameter slope k×1 μ_{it} are the stationary error terms and $x_{i,t}$ represent the k×1 of all i I(1).

$$x_{i,t} = x_{i,t-1} + \varepsilon_{i,t} \tag{4.12}$$

Where the ε_{it}; μ_{it} disturbance terms are stationary with covariance matrix Ω_i . The cointegration assumption between Y_{it} and x_{it} will be satisfied by the constant estimator β. The nuisance of parameters relies on the restrictive distribution of the OLS estimator

The constructed panel FMOLS is shown on the model below:

$$\hat{\beta}_{FM} = [\textstyle\sum_{i=1}^{N}(\sum_{t=1}^{T}(x_{i,t} + \bar{x}_i)^2)^{-1} \left(\sum_{t=1}^{T}(x_{i,t} - \bar{x}_i)\mu_{i,t}^{*} - T_{\hat{Y}_i}\right) \tag{4.13}$$

Where; $\mu_{i,t}^{*} = \left(\mu_{i,t} - \bar{\mu}_i\right) - \frac{\widehat{\Omega}2l_i}{\bar{\widehat{\Omega}}22_i}\Delta x_{i,t}$

Adopted from Mutambirwa (2022)

4.12.2 Panel Dynamic Ordinary Least Squares

The panel DOLS is a parametric estimator that uses leads as well as lag values whether the variables are integrated of order I(0), I(1), or I(2) or co-integration exits (Pedroni, 2000). The panel DOLS was established by Kao and Chiang (1999) to address and consider the inefficiencies and inconsistencies in Ordinary Least Squares (OLS). The model has also proven to have less bias with better finite-sample properties than panel FMOLS. Nonetheless, similar to the FMOLS, DOLS is appropriate for removing problems such as autocorrelation and endogeneity (Amarawickrama and Hunt, 2008).

The panel DOLS model is an extension of the simple OLS regression model which is appropriate for dealing with individual time series shown in the equation below:

$y_{i,t} = \alpha_i + \beta_i x_{i,t} + \mu_{i,t}$

The extended panel DOLS regression is defined as follows:

$$y_{i,t} = \alpha_i + \beta_i x_{i,t} + \sum_{j=-p}^{p} \Upsilon_{i,j}\, \Delta x_{i,t-j} + \mu^{*}_{i,t}$$

Where; i = 1,2,3,…,N is the number of units in the panel, t =1,2,3…,T is the number of periods, p = 1,2,3…,P is the number of flags and leads in the DOLS regression, $x_{i,t}$ is the vector of the explanatory variable, and β_i is the slope coefficient. Therefore, the estimated coefficient of DOLS is given by

$$\hat{\beta}_{GM} = [N^{-1} \textstyle\sum_{i=1}^{N} (\sum_{t=1}^{T} (\mathcal{Z}_{i,t} + \mathcal{Z}'_{i,t})^{2})^{-1} \left(\sum_{t=1}^{T} (\mathcal{Z}_{i,t} - \tilde{\mu}_{i,t}\right)] \qquad (4.9)$$

Where, $z_{i,t}$ is the vector of independent variables and $z_{i,t}$ = $(\bar{p}_i, \Delta p_{i,t-K}, \ldots\ldots \Delta p_{i,t+K})$ and $\tilde{\mu}_{i,t}$ = $(\mu_{i,t} - \bar{\mu}_i)$.

4.13 PANEL GRANGER CAUSALITY WALD TEST

The Granger causality is the easiest technique for causality; panel causality tests are applied to determine whether a variable can predict another - relationship between variables (Granger, 1987). Therefore, based on this study it will be used to investigate the presence of a long-run causality between RE and variables (Granger, 1969). This study aims to determine the factors influencing RE deployment.; hence, testing for causality is relevant to achieve this objective.

A number of studies exist to test for causality including VER, VAR, Sim, and Granger Causality. Granger (1969) developed a technique to assist in deciding the causality amongst the variables. A vital assumption of this test is that it assumes data to be stationary. The null hypothesis is no Granger causality or that X does not Granger-cause Y.

4.14 DIAGNOSTIC TEST - NORMALITY

Testing for Normality is important in regression analysis as it identifies whether the classical linear regression of residuals being normally distributed is not violated (with zero mean and constant variance). Multiple tests exist that can test for normality, these include histogram of residuals normal probability curve, Jarque Bera and Anderson Darling tests. Therefore, this study utilizes the Jarque-Bera test developed by Jargue and Bera (1980) to detect normality. The Jarque-Bera test determines that the skewness and kurtosis in the data sampled corresponded to that of a normal distribution.

The Jarque Bera test statistic is shown below as:

$$JB_{statistics} = \frac{N}{6}SK + \frac{N}{24}K \tag{4.10}$$

Where K denotes the number of predictor variables, N denotes the number of observations, and S represents the skewedness of the sample's distribution.

The null hypothesis of the test states that the data follows a normal distribution, whereas the alternative hypothesis indicates that the data does not follow a normal distribution. If the P-value is less than the level of significance (usually 0.05), the null hypothesis is rejected.

4.15 CONCLUSION

The purpose of this chapter was to discuss the research methodology for the study, which includes the econometric methods applied in the study as well as data. The chapter presented the estimated model from which an analysis will be conducted, data and methods to be employed in the study, all suitable for panel data. This study also describes and applies descriptive and statistical tests conducted on the variables, panel unit root tests, and CSD. The chapter continued with a discourse on the estimation technique of panel ARDL employed in the study and explained the sensitivity test or robustness test based on panel FMOLS and DOLS. This study further applies the Granger causality test to test for causality between RE and independent variables. Finally, a normality test was applied for a diagnostic test. In the next chapter, the EViews 12 software is utilised to run the specified model and perform various tests discussed in this chapter.

CHAPTER 5
EMPIRICAL ANALYSIS AND RESULTS

5.1 INTRODUCTION

This chapter presents the findings obtained using the EViews 12 software and provides an analysis to the overall objective of the study; to examine the determinants of RE in the selected SADC countries. The chapter is divided into eight sections. Section 5.2 presents the trend or descriptive statistics of the data. Section 5.3 presents the unit root tests, followed by 5.4, which presents cross-sectional dependence, and then the cointegration tests in section 5.5. Section 5.6. presents the empirical results from the estimation model using the panel ARDL approach; thereafter, the results of the FMOLS and the DOLS are presented for robustness check in section 5.7. Finally, Granger Causality and a diagnostic test before proceeding to conclude the chapter in section 5.8.

5.2 DESCRIPTIVE ANALYSIS

Table 5.1: Descriptive Statistics in the Selected SADC Economies

	RenG	**R&P**	**GDP**	**FIN**	**CO_2**
Mean	5898.224	0.421	3412.883	0.211	5748.870
Median	5956	1.000	3189.109	0.170	3028.400
Standard Deviation	4475.200	0.495	2384.224	0.139	6594.511
Minimum	1.0000	0.000	0.160	0.01	1117.90
Maximum	21793	1.000	8737.041	0.590	31648.90
Skewness	0.539	0.316	0.037	1.019	2.233
Jacque-Bera	9.335	32.080	9.770	34.657	294.517
Probability	0.009	0.000	0.007	0.000	0.000
Observations	192	192	192	192	192

Source: *Author's computation using EViews 12 Software*

As shown in the descriptive statistics in Table 5.1 above, the average value of RenG is 5898 with a maximum value of 21793 and a minimum value of 1 R&P has a mean value of 0.421, a maximum value of 1 and a minimum value of 0. GDP per capita growth has a mean value of 3413, a maximum value of 8737 and a minimum value of 0.160. Lastly, FIN has a mean value of 0.211, a maximum value of 0.590, and a minimum value of 0.01. According to Svirydzenka (2016), most of the empirical literature uses measures such as domestic credit to private creditors to denote financial depth. However, in the FIN variable, multiple indices are used that account for the multidimensional process of financial development. CO_2 emissions have a mean value of 5748, a maximum value of 31648, and a minimum value of 1117.

When comparing the skewness, the distribution of all of the variables is positively skewed to the left. Furthermore, it can be observed that the median and the mean variables are almost close, which suggests low variability and symmetry. The Jacque-Bera (JB) test reveals the normal distribution of the variables used in this study; the JB probability value is less than 0.05 per cent significance level, which implies that the null hypothesis of normal distribution is rejected. Therefore, the variables used in this study are not normally distributed, suggesting the transformation of variables as logarithmic, which will be applied in the next sections. The next subsection will test the series for unit root or determine the order of integration.

5.3 PANEL UNIT ROOT TEST RESULTS

As outlined in chapter four, the study applies the LLC (Levin et al., 2002) and IPS (Im et al., 2003) panel unit root test to determine the stationarity and ensure that the variables are not integrated of order two (I (2)) or higher, considering the estimation approach indicated in chapter four. Testing for unit root is essential to avoid inaccurate regressions and non-stationary data. The results of the unit root tests are presented in Table 5.2.

Table 5.2: Results of the Panel Unit root Tests

	Levin, Lin, and Chu (LLC) test			**Im, Pesaran and Shin (IPS) test**		
Variable	Level	1^{st} difference	Order of integration	Level	1^{st} difference	Order of integration
LRenG	0.999	0.000***	I (1)	1.000	0.000***	I (1)
LR&P	0.720	0.000***	I (1)	0.962	0.000***	I (1)
LGDP	0.377	0.000***	I (1)	0.888	0.000***	I (1)
LFIN	0.002***	-	I (0)	0.030**	-	I (0)
LCO_2	0.005***	-	I (0)	0.178	0.000***	I (1)

*Note: *** and ** represent 1 percent and 5 percent and levels of significance, respectively.*
***Source:** Author's computation using EViews 12 Software*

Levin, Lin and Chu, (2002) and Im Perasan and Shin (2003), panel unit root test are used to test for stationarity in the series, as outlined in chapter four. Table 5.2 shows LLC and IPS panel unit root results for the selected SADC economies, all the tests were performed under the assumptions of trend and intercept. The null hypothesis is that there is a unit root, if the probability value is less than the 1 or 5 percent level of significance, then the null hypothesis is rejected, concluding that the variable is stationary.

The results of the LLC test reveal that based on the respective probability values – LFIN and LCO_2 are stationary at the level or integrated of I(0) at 1 percent whereas LRenG, R&P and LGDP are only stationary at the first difference, therefore, I(1) also at 1 percent significance level, overall the null hypothesis fails to be rejected, concluding that there is no unit root at level for LFIN and LCO_2 and at the first difference for LRenG, R&P and LGDP.

Notwithstanding, the results of the IPS show similar results where all the variables are stationary at first difference or I(1) at 1 percent significance level except LFIN which is stationary at level therefore I(0) at 5 percent level of significance, thus the null hypothesis is also fails to be rejected concluding that there is no unit root. Given these results have variables integrated of mixed order I(0) and I(1), then the study will proceed to perform the panel ARDL estimation approach to determine the long run relationship co-integration test between RE production and its potential determinants.

5.4 CROSS-SECTIONAL DEPENDENCE TEST RESULTS

Testing for CD is important; if unaccounted for, it can potentially lead to omitted variable bias or residuals being correlated across units (Juergen, 2019). Because the data in the study shows T is large relative to N. The technique Breusch and Pagan (1980) LM developed by Breusch and Pagan (1980 is the test proposed to test for cross-sectional dependence in this study.

Table 5.3: Cross-Sectional Dependence Test Results

Residual Cross-Section Dependence Test			
Test	**Statistic**	**d.f**	**Probability**
Breusch-Pagan LM	22.130	15	0.104
Pesaran scaled LM	1.302		0.1930
Pesaran CD	-1.114		0.2653

Source*: Author's computation using EViews 12 Software*

The results in Table 5.3 show the outcomes of the CSD test, including Pesaran (2004), Breusch and Pagan (1980) LM, and Pesaran scaled LM. The Breusch and Pagan (1980) LM observed shows a probability value of 0.104. Since the value is more than a significance level of 0.05, the null hypothesis of no cross-section dependence (correlation) in residuals fails to be rejected, meaning there is no cross-sectional dependence on the estimated residuals.

5.5 PANEL COINTEGRATION TEST RESULTS

Based on the preliminary results of unit root tests, which showed that variables are integrated at order one, the cointegration test is conducted to determine the long-run relationship among the variables of interest before the panel ARDL is estimated. As a result, the panel Pedroni (2004) and Kao (1999) cointegration tests were conducted. Both tests have the same null and alternative hypothesis:

H_0 : There is no cointegration

H_1 : There is cointegration

5.5.1 Pedroni Cointegration Test

The results of the Pedroni tests are presented in the table below; results are divided into two categories - within and between groups. The results of the cointegration tests are presented in Table 5.4

Table 5.4: Pedroni Residual Cointegration Test Results

Method		**t-statistic**	**Probability value**
Within Group	panel v-statistic	0.641	0.030**
	panel rho-statistic	0.024	0.902
	panel pp-statistics	-2.341	0.007***
	panel ADF- statistic	-1.792	0.011**
Between Group	panel rho-statistic	1.814	0.987
	panel pp-statistic	-0.068	0.000***
	panel ADF- statistic	0.351	0.012**

*Note: *** and ** represent 1 percent and 5 percent levels of significance, respectively.*

***Source:** Author's computation using EViews 12 Software*

On the results shown in Table 5.4, the within-group test shows that the v-statistic and pp-statistic and ADF-statistic are 0.030, 0.007 and 0.011, respectively 5 percent and 1 percent levels of significance, Therefore, under this category, the null hypothesis is rejected, it can be concluded that there is cointegration between the variables. On the other hand, rho-statistics showed a probability value of 0.902, which is above all the levels of significance. Therefore, under rho, the conclusion suggests that the null hypothesis fails to be rejected and concludes that there is no cointegration between the variables.

The results of the between dimension, which has three test statistics, indicate that the null hypothesis is rejected when observing the probability values of pp-statistic and ADF-statistic, which are 0.000 and 0.012, at the 1 percent and 5 percent level of significance, respectively. This concludes that there is cointegration between the variables using the between-group test statistic.

In order to determine cointegration for the overall Pedroni test, the conclusion was drawn from all seven tests, including both the within and between dimensions. Three out of four within-group tests proved cointegration exists, whereas two of the 3 is in the between-groups also proved that cointegration exists. This concludes that there is cointegration and a long-run relationship between the independent and dependent variables. The Kao test is further applied to determine the existence of a long relationship between the variables.

5.5.2 Kao Cointegration Test

In addition to the Pedroni test, the Kao (1999) panel cointegration test was also conducted for robustness. The Kao test follows a similar approach to the Pedroni test; however, it identifies homogenous coefficients and cross-section-specific intercepts. Table 5.4 shows Kao cointegration test on RE and its potential determinants

Table 5.5: Kao Cointegration Test Results

Method		t-statistic	Probability value
Kao Test	ADF Statistic	0.048	0.384
	Residual variance	0.044	

Source: *Author's computation using EViews 12 Software*

The results, as shown in Table 5.5, conclude that at the 10 percent level of significance, the null hypothesis of no cointegration fails to be rejected since the probability value is 0.384, which is more than the level of significance. Therefore, this demonstrates that there is no long-run relationship between the independent variable (LRENG) and independent variables (R&P, LGDP, LFIN, LCO_2).

Nonetheless, the Pedroni results are given precedence because the test is robust in examining different dimensions of a cointegration test with a variety of test statistics. The study proceeds with the estimation of the Panel ARDL to calculate both the long-run and short-run coefficients for this study.

5.6 PANEL ARDL ESTIMATION RESULTS

5.6.1 Selection of Optimal Lag

Prior to further tests and estimation, the next appropriate step is choosing the appropriate lag length. This is critical to determining the lags where the short and long estimates are optimal. Hence, the results are presented in Table 5.6. The VAR lag order selection criterion is applied to find the optimal lag length.

Table 5.6: Optimal Lag Selection Results

Lag	LogL	LR	FPE	AIC	SIC	HQ
0	-2721.276	N/A	27983224	31.336	31.427	31.373
1	-987.316	3328.335	0.082	11.693	12.238	11.914
2	-918.595	**128.753***	**0.050***	**11.191***	**12.189***	**11.596***

Note: * represents the lag order selected by the criterion.
Source: *Author's computation using EViews 12 Software*

Table 5.6 summarises the results of the test of optimal lag length (with two lags), using different criteria used where LogL is loglikelihood, LR is Likelihood Ratio, FPE is Final Prediction Error, AIC denotes Akaike Information Criterion, SIC is the Schwarz Information Criterion, and finally HQ is Hannan Quinn information critirion. The lag of the AIC is selected as suitable for the study, and the lag of two was chosen as the appropriate lag length in the model specifications. Having chosen the appropriate lag length, the panel ARDL can be estimated.

5.6.2 Panel ARDL results

The results in section 5.3 confirmed that variables integrated of mixed order I(0) and I(1) are applicable for performing the panel ARDL estimation approach to determine the long-run relationship co-integration test between RE generation and its potential determinants. The results of the long- and short-run estimations are shown in the tables below.

Table 5.7: Long run Panel ARDL Estimation

Long-term coefficient				
Variable	**Coefficient**	**Std. error**	**t-statistics**	**Prob.**
LGDP	0.499	0.128	3.893	0.000***
LFIN	-0.968	0.494	-1.959	0.052**
LCO_2	-0.687	0.130	-5.283	0.000***
R&P	0.203	0.000	5.544	0.000***
LGDP*LFIN	-0.000	0.037	-1.2768	0.097

*Note: *** and ** represent 1 percent and 5 percent levels of significance, respectively.*
Source: *Author's computation using EViews 12 Software*

Table 5.7 presents the long-run results of the panel ARDL model using the PMG estimation. The results show that a long-term positive relationship exists between RE generation and GDP per capita at 1 percent level of significance. The coefficient of GDP per capita is 0.499, therefore, 1 percent increase in GDP increases RE generation by 0.499 percent. This is consistent with the prior expectation and empirical findings of various studies, including Yadav et al. (2024), Shahzad et al. (2021), Alhendawy et al. (2023) and Omoju (2016), which also show a positive and influential relationship between the two variables.

The result of the GDP and RE relationship also proves that increased economic growth raises environmental concerns, thus resulting in governments deploying clean technologies, in this case, RE technologies, as argued by Yadav et al. (2024) and the REKC theory explained in chapter 3. According to Alhendawy et al. (2023), further reasons attributed to the positive effect of GDP on RE generation include firstly the ability of growth to enable infrastructure development, including RE generation and secondly, more resources (investment) by the government can be allocated RE technologies including the implementation of incentives to encourage RE.

The measure of financial sector development (LFIN) shows a negative relationship, where a 1 percent increase in financial sector development causes a 0.968 decrease in RE generation at a 5 percent significance level. The results are in contradiction with the prior expectations and studies, including Awijen et al. (2022), Ngcobo and De Wet (2024) and Prempeh (2023); this highlights the complexities of the financial development in energy sector financing. Commonly (theoretically), financial development boosts RE generation through access to financial capital. While the negative coefficient of FIN contradicts the literature mentioned above, it is consistent with implications from studies such as Sharma and Paramati (2021) and Toyo et al. (2024) but deviates from theories such as the theory of planned behaviour. However, these findings may stem from the limited availability of financial resources, even when financial development takes place, that could be allocated to conventional energy as RE is a high-risk industry, whether this includes real or perceived risks that lead to high borrowing costs. Even when resources are allocated to clean technologies, not all RE sources benefit from financial development; it may benefit solar PV more than biomass and geothermal energy (Dossou et al., 2024). In addition, according to Gbohoui (2023), generally, the interest rates charged by international investors in SSA counties, which includes those from SADC, are “disproportionately larger than justified by their sovereign ratings”.

The findings also show that CO_2 emissions have a long-term negative influence on RE generation, demonstrated by a -0.687 coefficient. CO_2 emissions is statistically significant at a 1 percent significance level, and a 1 percent increase in CO_2 emissions causes a 0.687 decrease in RE generation. This is in line with the a priori expectations, supported by research with the same conclusion, including Olouch et al. (2021), Ackah & Kizys (2015), da Silva et al. (2018) and Marques et al. (2010). However, most studies (Apergis & Payne (2014); Opoku et al. (2024); Shahbaz et al. (2018)) have indicated that an increase in CO_2 emissions leads countries to seek to mitigate the harmful effects (particularly in Africa, where countries are vulnerable to climate change) caused by GHG emissions especially considering their NDCs and the Paris Agreement.

However, there are concerns regarding the ‘creative destruction’ of the fossil fuel industries explained by Schumpeter’s theory of innovation, which can result in social injustices such as job losses in the industry and other spillover effects. This reduces the political will for the use of RE technologies and can, therefore, result in countries lobbying for the continued use of fossil fuels. Apergis et al. (2018) also suggested that a majority of SSA countries may not have achieved the required level of industrialization or GDP per capita that allows for reduced carbon emission levels.

RE regulation and policies (R&P) results revealed that the coefficient at 5 percent level of significance, a country that has implemented regulations and policies in the RE sector generates more RE by 0.203 percent at 1 percent level of significance. Therefore, regulations and policies are crucial for RE and countries with regulation and policies are more likely to have increased uptake of RE. The positive and significant results coincide with the findings of Hoa et al. (2024), Shahzad et al. (2021) and Muhammed and Tekbiyik-Ersoy (2020) and underscore the argument by IRENA (2023) that suggest that introducing policies is essential and the foundation to support the direct use of renewables including emerging industrialisation.

Lastly, to investigate the relationship determinants of RE further, the joint effect of GDP per capita and financial development on RE generation was examined, and how it differs when GDP per capita changes. However, the interaction of financial development with GDP per Capita had a negative coefficient of -0.000 and was insignificant at 5 percent significance. GDP per capita does not appear to change the effect in a statistically significant way. No studies have conducted an analysis of the impact of GDP per capita on financial development.

Table 5.8: Short-term Panel ARDL Estimation

Short-term coefficient				
Variable	**Coefficient**	**Std. error**	**t-statistics**	**Prob.**
COINTEQ01	-0.089	0.060	-1.497	0.137
D (LRENG (-1))	-0.168	0.079	-2.137	0.035
D (LGDP)	0.497	0.203	2.441	0.529
D (LGDP (-1))	0.645	0.805	0,801	0.425
D (R&P)	0.110	0.110	1.003	0.318
D (R&P (-1))	0,043	0.068	0.632	0.529
D (LFIN)	0.211	0.141	1.499	0.139
D (LFIN (-1))	0.086	0.265	0.326	0.745
D (LCO_2)	-0.495	0.141	-3.520	0.001***
D (LCO_2 (-1))	-0.608	0.702	-0.867	0.388
D (LFIN*LGDP)	0.346	0.346	0.999	0.320
D (LFIN*LGDP (-1))	0.853	0.853	0.999	0.3198
C	0.485	0.569	-0.852	0.396

*Note: *** represents a 1 percent level of significance.*
***Source:** Author's computation using EViews 12 Software*

Table 5.8 displays the short-term result of the panel ARDL, which shows some interesting observations. The value of ECT (which represents the speed of adjustment) indicated negative -0.089; however, the probability value shows that it is insignificant. These results could confirm cointegration and suggest that the convergence speed of equilibrium is – 2.7 percent annually, however, the ECT value is insignificant. The short-term dynamic model indicates a number of explanatory variables; GDP per capita, financial development, regulation and policy and the interaction of GDP per capita and financial development that all have an insignificant relationship with RE generation in both a zero and one lag period. The GDP per capita results show an insignificant relationship with RE generation. According to Alhendawy et al. (2023), the relationship between GDP per capita and RE depends on the level of economic growth; therefore, in developed countries, GDP is more likely to increase RE generation than in low- or middle-income countries. Financial development also showed an insignificant relationship with RE generation; these findings coincide with those of Saadaoui (2022) and Saygin and Iskenderoglu (2022). Similarly, the results for regulation and policy and the interaction term of GDP and financial development also demonstrate an insignificant relationship.

The probable explanations for the insignificant results in short run mainly include i) the implementation process of policies and regulations takes time to demonstrate impact on RE production, and more weak institutional capacity could result in weak implementation of policies (Muhammed and Tekbiyik-Ersoy, 2020) ii) despite financial development, the availability of capital for renewable energy projects might still be limited due to risk perceptions (Gbohoui et al., 2023) and iii) Derk (2023) indicated the impacted of GDP on RE is reliant on the level of GDP.

However, at a zero-lag period, the results of CO_2 emissions show a negative relationship where 1 percent increase in CO_2 emissions results in a 0.495 percent decrease in RE. These results are similar to the long-run results, which were supported by Olouch et al. (2021), Ackah and Kizys (2015), Apergis and Payne (2014).

Overall, the long-term and short-run results also show the applicability of the empirical evidence derived from Hypothesis 1 and Hypothesis 2, which are being tested in the study. Hypothesis 1 states that the determinants of RE have a statistically significant effect on RE production. In addition, Hypothesis 2 states that the relationship between RE and its determinants is positive and statistically significant.

Hypothesis 1 is accepted, and the long-run results show a statistically significant effect on RE. However, in the short run, the findings have mainly demonstrated an insignificant relationship with RE besides CO_2, which found a negative relationship. Conversely, Hypothesis 2 is not accepted since the results of the factors or variables that increase or drive RE production vary such that while some variables drive RE (GDP, regulation and policy), others, such as CO_2 emissions and financial development, decrease RE. This is shown particularly in the long run where there's evidence of a significant relationship, unlike the short run.

5.6.3. Cross-sectional short run Panel Auto Regression Distributed for the Six Selected Countries

Table 5.9: Short-term Cross-section Coefficient for Individual countries – Panel ARDL

Variables		LGDP	LFIN	LCO_2	R&P	GDP*FIN
Country	**Lags**					
Angola	0	0.032 (0.188)	0.207 (0.002) ***	-0.439 (0.001) ***	0.042 (0.023) **	-0.0002 (0.000) ***
	1	0.062 (0.064) *	0.312 (0.001) ***	-0.336 (0.007) ***	0.217 (0.000) ***	0.0001 (0.000) ***
Botswana	0	0.158 (0.699)	-0.986 (0.098) *	0.254 (0.003) ***	0.016 (0.405)	9.410 (0.000) ***
	1	1.155 (0.086) *	1.159 (0.062) *	1.291 (0.000) ***	-0.083 (0.012) *	-0.001 (0.000) ***
DRC	0	0.438 (0.000) ***	0.080 (0.000) ***	-0.223 (0.000) ***	0.079 (0.000) ***	-0.001 (0.000) ***
	1	0.230 (0.003) ***	0.064 (0.001) ***	-0.027 (0.009) ***	-0.119 (0.001) ***	-0.000 (0.000) ***
Namibia	0	0.196 (0.002) ***	1.381 (0.001) ***	0.574 (0.002) ***	-0.166 (0.000) ***	-0.001 (0.000) ***
	1	0.150 (0.011) **	0.617 (0.003) ***	0.136 (0.015) **	-0.153 (0.000) ***	-0.000 (0.000) ***
South Africa	0	-0.559 (0.829)	1.046 (0.869)	0.071 (0.744)	0.695 (0.367)	0.000 (0.000) ***
	1	-2.366 (0.7001)	1.139 (0.869)	0.215 (0.257)	-0.096 (0.709)	0.001 (0.000) ***

Zambia	0	-0.559 (0.830)	1.046 (0.869)	0.071 (0.744)	0.695 (0.367)	0.000 (0.000) ***
	1	-2.366 (0.700)	1.139 (0.839	0.215 (0.247)	-0.096 (0.709)	0.001 (0.000) ***

Note: ***, ** and * represent 1%, 5% and 10% levels of significance respectively.
Source: *Author's computation using EViews 12 Software*

In the short run, **Zambia and South Africa** mostly show insignificant relationships with RE generation at zero and one lagged period, the variables include LGDP, LCO_2, LFIN and R&P. The results between the two countries coincide despite the differences in income status (**South Africa** is an upper middle income and **Zambia** is lower middle income), the scale of RE generation and CO_2 emissions. This suggests a weak cross-sectional effect between the variables. The findings are supported by Saygin and Iskenderoglu (2022). The only variable that exhibited significance was the interaction term of GDP and FIN; although this variable demonstrated significance, the coefficient does not demonstrate a considerable effect this signifies that a 1 percent increase in financial development increases the effect of GDP on RE generation by 0.001 percent but only during a one-year lag period at 1 percent level of significance.

On the other hand, **Namibia and DRC** exhibit consistently significant relationships, indicating more robust relationships between the independent and dependent variables in the two countries. In the case of the DRC, a 1 percent increase in LGDP and LFIN showed a 0.438 and 0.080 increase in RE generation, respectively at 1 percent level of significance. A positive relation was also observed in the variables one period lag. The results for CO_2 emissions how a negative relation where 1 percent increase in CO_2 emissions leads to a 0.223 percent increase in RE. These results are surprising, considering that RE sources already dominate the DRC energy sector.

Namibia exhibits a positive relationship between GDP, financial development and CO_2 emissions. These variables increase RE generation by 0.196, 1.381 and 0.574, respectively, at a 1 percent significance level. The relationship is positive even during the one-year lag period. However, regulation and policy, as well as the interaction term of GDP and financial development, had a negative relationship with RE generation such that it reduced it by 0.166 and 0.001 percent.

Furthermore, in **Botswana**, the CO_2 emissions and the interaction term of GDP and financial development results proved to affect RE generation positively, and both were statistically significant at a 5 percent level of significance. Therefore, 1 percent increase in CO_2 emissions will increase RE by 0.254 percent and the effect of financial on GDP results in increased RE by 9.410 percent. Nevertheless, financial development has a negative relation with RE, wherein 1 percent increase in financial development results in a 0.986 percent decrease in RE. The relationship between GDP per capita and regulation and policy is insignificant, although this is only the case for a zero lag period.

Angola also observed insignificance in the GDP per capita results, and all the other variables showed a significant relationship. For instance, financial development, as well as regulation and policy showed a positive and significant relationship; 1 percent increase in the two variables results in a 0.207 percent and 0.042 percent increase in RE generation, respectively. Nevertheless, a 1 percent increase in CO_2 emissions and the joint effect of GDP and financial development causes a 0.439 percent and 0.0002 percent decrease in RE generation at 1 percent level of significance.

Overall, the findings show that GDP per capita, financial development, CO_2 emissions and regulation and policies are critical in determining the scale of RE generation deployed. The results also demonstrated that although in the majority of the countries, there is a significant relationship, whether that relationship is positive or negative, and some similarities, the results are typically highly context-dependent. For instance, while the results for financial development were generally positive, the effectiveness varies, and Botswana (the country with the lowest RE generation) is the only country that exhibited a negative relationship. Conversely, regulation and policies were mostly favourable and showed a positive relationship with RE. Considering that this is the basis for encouraging the uptake of RE, there are occasional negative effects that reflect possible implementation issues. As a result of the varying results of the effect of the variables in RE production, Hypothesis 3 is accepted.

5.7 SENSITIVITY ANALYSIS RESULTS

A sensitivity analysis is applied to examine whether the choice of methodology affects the main findings. The study uses the panel FMOLS and panel DOLS to conduct the analysis. The results are presented in Table 5.10 presents for both techniques.

Table 5.10: Results for Panel FMOLS and DOLS

	Panel FMOLS		Panel DOLS	
variables	**Coefficient**	**Probability**	**Coefficient**	**Probability**
LGDP	-0.394	0.014	0.100	0.614
LFIN	-2.929	0.000	0.302	0.158
LCO_2	0.405	0.038	0.140	0.603
R&P	0.047	0.963	-0.034	0.823
LGDP *LFIN	0.001	0.040	-0.001	0.000

Source: *Author's computation using EViews 12 Software*

The results show that when both the panel FMOLS and DOLS are applied. The findings of the DOLS are mostly insignificant among the variables except the interactive term; however, this is different in the case of FMOLS. This implies that the explanatory variables have no influence on RE generation. The FMOLS show that GDP per capita and financial development have a negative long run effect on RE generation. According to the results 1 percent increase in GDP per capita and financial development will cause a 0.394 percent and 2.929 percent decrease RE generation, respectively. The relation is also significant at 5 percent. For the LGDP results, studies such as Kilinc-Ata (2016) found that income has a positive effect on RE for developed countries, but not for developing countries, which includes those selected for the study. For the variable of financial development, this outcome is inconsistent with the findings of Prempeh (2023), Yadav et al., 2024, Mukhtarov et al. but aligned with those of Sharma and Paramati (2021) and Toyo et al. (2024).

The results of CO_2 emissions using both methods show a positive but insignificant relationship aligned with Panel ARDL results. By implication a 1 percent increase CO_2 emissions results in a 0.4041 percent and 0.4061 in RE generation in both FMOLS and DOLS. This is in line with the a priori expectations, supported by research with the same conclusion: Opoku et al. (2024), Ackah & Kizys (2015), Apergis & Payne (2014), as well as Shahbaz et al. (2018). In addition, these results support the argument that a continuous increase in CO_2 emissions drives the expansion of RE because of environmental concerns related to climate change, and countries seek to mitigate the harmful effects caused by GHG emissions.

In examining the role of regulations and policies (R&P) in RE generation, the results of the panel FMOLS show that when countries have relevant RE sector regulations and policies in place, RE generations increase by 0.0731 percent, however insignificant. These are expected because of the evident role of policies and regulations in boosting RE development. However, the results of the DOLS models show conflicting results wherein the presence of regulations and policies reduces RE generation by -0.6901 and is insignificant. This uncovers a counterintuitive, even uncommon relationship; according to Aguirre and Ibikunle (2014), potential reasons for this outcome are two-fold - failure in policy design or uncertainty and the likelihood of discontinuity.

For the joint effect of GDP per capita and financial development on RE generation, the variable shows a positive coefficient of -0.001 for the FMOLS. The negative coefficient suggests that the effect of financial development on RE generation decreases with GDP per capita at the 5 percent level of significance. However, DOLS results show that the effect of financial development on RE generation increases by 0.008 percent with GDP per capita but is not significant.

For robustness, both panel FMOLS and panel DOLS results indicated that some empirical findings contradicted panel ARDL findings. The results explain a significant portion of the variation in RE generation. Overall, the panel ARDL results are adopted since it is the primary technique. In addition, the technique is superior to panel FMOLS and panel DOLS as it separates long-run and short-run estimates.

5.8 GRANGER CAUSALITY RESULTS

The result in Table 5.11 presents the result of the panel granger causality of RE and the selected variables while holding each variable as dependent on others. For most of the variables across, the null hypothesis of Granger causality could not be rejected because the probability value of each variable is greater than 10% level of significance. This implies that there is no causality running from each of the variables in all the selected SADC countries. Therefore, the variables do not have predictive power over RE generation and the rest of each of the variables and vice versa.

H_0 = xt does not cause yt

H_1 = xt does cause yt

Table 5.11: Causality test between renewable energy and selected economic variables

Pairwise Granger causality test					
Variable	LRenG	LGDP	LFIN	LCO_2	R&P
LRenG		0.8076	0.7893	0.6183	0.9892
LGDP	0.6769		0.9990	0.9284	0.94820

LFIN	0.7782	0.7732		0.9908	0.8758
LCO_2	0.0080*	0.3036	0.7937		0.6288
R&P	0.1285	0.4099	0.6262	0.2854	

Source*: Author's computation using EViews 12 Software*

The results further suggest that there is a one-way causality between RE generation (RenG) and CO_2 emissions, running from LCO_2 to LRenG at a 10 percent significance level without corresponding feedback. Countries that emit CO_2 emissions often, especially when the Paris Agreement has been ratified, employ clean technologies to reduce GHG emissions and reduce the use of fossil fuels. The country's vulnerabilities to climate change events, such as those in the SADC region and NDCs, also tend to influence an increased use of clean energy. These findings suggest that as a result of high CO_2 emissions, countries begin to become concerned with the environmental impacts and adopt cleaner energies (Olouch et al. (2021); Ackah & Kizys (2015); Apergis & Payne (2014); Marques et al. (2010).

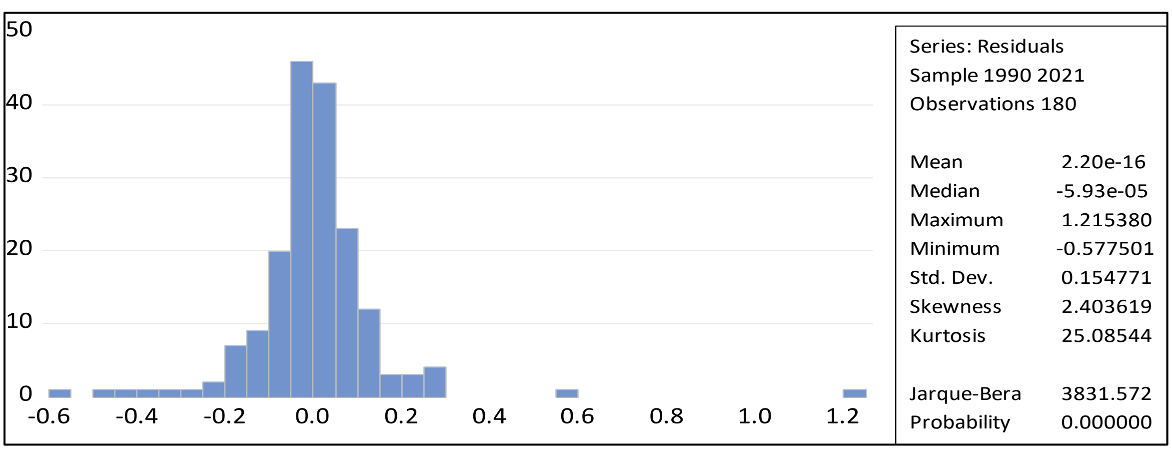
5.9 DIAGNOSTIC TEST RESULTS

The study carried out a normality test to ascertain whether the error terms are normally distributed and establish the performance of the model. Table 6.10 below presents the result of the Jargue-Bera normality test for the model.

H_0 = The residuals are normally distributed

H_1 = The residuals are not normally distributed

Figure 5.1: Residuals Diagnostic Test Results - Normality



Source: *Author's computation using EViews 12 Software*

The Jarque-Bera results, as shown in Figure 6.1, reveal that RE generation and the explanatory variable show a probability value of 0.0000, which is less than the 5 percent significance level. This implies that the null hypothesis of the normal distribution fails to be rejected, and therefore, the residuals are not normally distributed. However, Pesaran et al. (2004) argue that the validity of estimating an ARDL model does not require the assumption of normality. Further, according to Frain (2007:3-15), non-normality is natural when sample sizes are large; this is because they are not inherent to an "α-stable" distribution. For that reason, the estimated results of panel ARDL still hold.

5.10 CONCLUSION

Chapter five examined the effect of the variables on RE generation in the six selected SADC countries from 1990 to 2021. Descriptive analyses were presented at the beginning of the chapter, which continued to test for unit root tests by employing the IPS and LLC tests, which confirmed the order of integration and non-stationarity. The Pedroni and Kao panel cointegration test was applied, and a long-run relationship was confirmed.

The study also tested for cross-sectional dependence among the variables, and the results revealed that no dependencies exist. Fortunately, the ARDL accounts for cross-sectional heterogeneity. By following the model proposed by Derk (2023), the analysis considered variables, including GDP per capita, CO_2 emissions, financial development and regulation, and policy.

Most of the findings of the long-run panel ARDL model confirmed most of the expected signs (positive or negative), including CO_2 emissions, GDP per capita, and regulation and policy, which have a positive impact on RE generation or RE production, which is the proxy. However, financial development indicated a negative significant influence on RE generation in contrast to theory and the expected sign. Interestingly, the interaction term of GDP and financial development, though significant, showed a very marginal effect on RE generation. Nevertheless, these findings substantiate that empirically, there is evidence of long-run equilibrium between RE generation, GDP per capita, financial development, CO_2 emissions and regulation and policy. The empirical literature has also provided evidence of such relationships and holds important implications for policies to boost the uptake of RE sources and understanding of the influences of RE. The panel ARDL short-run estimate results contradicted the long-term estimation, with all the variables showing an insignificant relationship except CO_2 emissions.

The short-term cross-section coefficient for the individual countries Angola, Botswana, DRC, Namibia, South Africa and Zambia was also estimated. The results for South Africa and Zambia showed an insignificant relationship between RE generation and all the explanatory variables, excluding the joint effect of GDP and financial development. The results of the rest of the countries showed a dynamic relationship (negative or positive) and were significant in Angola, DRC, and Namibia, although in Botswana and Angola, GDP exhibited an insignificant relationship with RE generation. Generally, the results differed according to specific country contexts, although there was some consistency.

Further, the results accepted Hypothesis 1 as the long-run results show a statistically significant effect of the key determinants on RE. Conversely, Hypothesis 2 is not accepted since the results of the factors or variables that increase or drive RE production vary such that while some variables drive RE, others reduce RE production. As a result of the varying results of the effect of the variables in RE production, Hypothesis 3 is also accepted.

Apart from a panel ARDL analysis, this study also applied the panel FMOLS and panel DOLS to test for robustness and sensitivity of the choice of methodology to the main findings. Including the techniques provides confidence in the validity and reliability of the findings. The results of the panel DOLS and panel FMOLS and results showed that GDP and financial development all positively contributed to RE generation in selected SADC countries in the long run. Furthermore, for R&P, panel FMOLS showed a positively significant relationship but a negatively insignificant relationship for panel DOLS. On the other hand, CO_2 emissions showed a positively significant relationship for panel FMOLS and a negatively significant relationship. The normality test confirms the reliability and unbiasedness of the model. Granger causality results revealed that there is no causality between most variables in the study.

CHAPTER 6
CONCLUSION AND POLICY IMPLICATIONS

6.1 INTRODUCTION

This chapter summarizes the findings of the analysis in the study, draws a conclusion, and suggests policy recommendations that can be explored. The chapter is divided into four sections: firstly, the summary of the study is presented, and secondly, a conclusion is drawn from the analysis. Following that, policy recommendations based on the results are suggested, including areas for further stand. Finally, the chapter provides the limitations of the study. opportunities for further research.

6.2 SUMMARY OF THE STUDY AND RESULTS

RE adoption has become critical for climate change mitigation, including energy access, affordability, and sustainable development – all of which are important for the SADC region. Given the importance of RE, identifying the determinants is important to give direction in what boosts the uptake. The study aimed to investigate the factors influencing RE; based on this objective, macroeconomic, environmental, and socioeconomic variables were considered. These variables include CO_2 emissions, GDP, regulation, policy, and financial development, which were identified in previous studies as factors that influence RE in different regions and countries.

The analysis utilized the Pedroni and Kao Cointegration tests to assess the existence of a long-term relationship between RE and its determinants. The results of the Pedroni test indicated that cointegration exists between dependent and independent variables.

Further, the study employed the Panel ARDL using data from 1990 to 2021, a significant period for RE deployment. The long-run results indicate that there is a positive relationship between RE generation and GDP, regulation and policy. However, a negative relationship was observed between financial development, CO_2 emissions and the joint effect of GDP and financial development. Most of these results confirm the prior expectations. Contrary to the long-term results, the short-term results show insignificant relationships between all the variables, although CO_2 emissions showed a significant negative relationship.

In attempting to reach the specific objectives, the individual short-run cross-section was analysed. The results revealed some of the commonalities and differences in the influence of the determinants on RE generation depending on each country. Financial development, CO_2 emissions, GDP per capita, and the joint effect of GDP per capita and financial development were all confirmed to impact RE generation.

In addition to the panel ARDL, the panel DOLS and panel FMOLS analysis were performed to determine whether the results were sensitive to the model applied and for robustness. In the case of panel FMOLS the results proved that there is a positive relationship between RE generation and, regulation and policy, CO_2 emissions, but a negative relationship with financial development and GDP per capita. Notwithstanding, the panel DOLS also showed an insignificant relationship between the variables.

In reference to the hypotheses of the study, the results accepted Hypothesis 1 as the long-run results show a statistically significant effect on RE. Conversely, Hypothesis 2 is not accepted since the results of the factors or variables that increase or drive RE production vary, such that some variables drive RE. As a result of the varying results of the effect of the variables in RE production, Hypothesis 3 is also accepted.

6.3 **POLICY RECOMMENDATIONS**

This research makes a contribution to policymaking by examining the major determinants of RE on different fronts, including technical, financial, advocacy, regulatory and policy. Firstly, all recommendations are made recognizing that it is crucial that RE be included to diversify the energy mix for a carbon-neutral power sector along with other sources of energy in the power system. This is particularly important for countries where the power system is dominated by the use of fossil fuels, these include Botswana and South Africa. The policy recommendations are as follows:

i. The results in Chapter 5 found that regulation and policy positively and significantly influence RE generation in the long run and in several of the individual short-run coefficients. Demonstrating and proving that an effective policy environment is paramount and foundational for encouraging the RE generation and, to a certain extent, consumption. This gives rise to the need for the SADC countries to strengthen efforts to establish effective and rigorous RE policies to unprecedented levels. While most countries have some kind of policy and strategy for the RE sector, most have not been updated for years, meaning the policies are no longer in line with the current needs. Through developing and updating policy frameworks, regulations, instruments, and incentives, governments can create an enabling environment that shapes the RE market and energy system design, including encouraging RE investments even at a large scale. This policy development must be aided by stronger national institutions with clear RE production targets and strategies enhanced through technical assistance and capacity building to reinforce governance structures and create effective implementation.

ii. Surprisingly, the results in the study found that financial development, negatively and significantly influence RE, which is uncommon is most studies. This may be due to the high-risk perception associated with Africa resulting in high-risk premiums. The cost of accessing capital becomes high from global investors despite financial development. Energy affordability, access, and sustainability go hand in hand. The government should; with the assistance of development institutions or multilateral development banks - develop innovative frameworks and financial tools to promote low-cost solutions and de-risk projects (using credit enhancements, guarantees, risk sharing or mitigation, and blended finance mechanisms) - by transferring investment risks to public actors, such as development banks. Further, financial instruments should be established in projects spread across the various RE sources (hydropower, solar, wind geothermal, and biomass) while taking into account the cost of RE production.

iii. One of the key considerations when countries transition to clean energy is the effect this will have on the fossil fuel industry. The negative influence of CO_2 emissions to RE generation found in the study demonstrates this concern. Because of the creative destruction to the fossil fuel industry that can be caused by increased use in RE technologies, social injustices such as job losses and other indirect effects that could potentially decrease GDP, it is important to find remedies to avoid such issues. Localising industrial value chains for manufacturing components for renewable technologies will limit the impact of the RE industry. Particularly because generally, Africa is raw materials which are necessary for RE products such as lithium, manganese and cobalt.

iv. Enhance and deepen collaboration between countries (in and out of the region), other development partners, the private sector, and international financial institutions to build and advance partnerships and share best practices and knowledge in the RE sector. Through the SADC region, countries should drive and invest more in regional integration and the removal of investment barriers between countries to develop cross-border energy projects.

6.4 LIMITATIONS OF THE STUDY

Data availability has emerged as a significant challenge in African research; this study is no exception. Hence, some variables have been omitted from the estimation because of a lack of data or inconsistent availability. It was preferred that patents or Research and Development expenditures be added to serve as the technological factor affecting RE production. Another limitation is that the empirical research conducted on the determinants of RE in individual SADC countries is restricted, this dilutes the empirical work.

6.5 AREAS FOR FURTHER RESEARCH

Although this study applied a dummy for aggregate regulation and policy which has proved to be significant further analysis should examine the determinants using disaggregated policy instruments to gain knowledge of which policies contribute significantly. Further, there is limited research on individual countries generally and those, particularly in the region where most of the selected countries for the study are from, SADC. Therefore, studies on individual countries can be conducted in that regard.

Another important consideration is that hydropower remains a major contributor to the energy system in most of the selected SADC countries, suggesting that research examining the determinants for different energy sources (biomass, solar, wind, geothermal).

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APPENDICES

Appendix 1: Cross Dependence Tests

Residual Cross-Section Dependence Test
Null hypothesis: No cross-section dependence (correlation) in weighted residuals
Equation: Untitled
Periods included: 32
Cross-sections included: 6
Total panel observations: 192
Note: non-zero cross-section means detected in data
Cross-section means were removed during computation of correlations

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	22.13047	15	0.1044
Pesaran scaled LM	1.301839		0.1930
Pesaran CD	-1.113890		0.2653

Appendix 2: Pedroni cointegration test

Pedroni Residual Cointegration Test
Series: LREN_G LGDP LFIN LCO2 R_P__DUMMY_ GDP_FIN
Date: 11/12/24 Time: 22:32
Sample: 1990 2021
Included observations: 192
Cross-sections included: 6
Null Hypothesis: No cointegration
Trend assumption: Deterministic intercept and trend
User-specified lag length: 1
Newey-West automatic bandwidth selection and Bartlett kernel

Alternative hypothesis: common AR coefs. (within-dimension)

	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	2.093554	0.0181	1.866616	0.0310
Panel rho-Statistic	0.745412	0.7720	1.295825	0.9025
Panel PP-Statistic	-1.755786	0.0396	-2.423528	0.0077
Panel ADF-Statistic	-1.359354	0.0870	-2.258754	0.0119

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	2.227211	0.9870
Group PP-Statistic	-3.472103	0.0003
Group ADF-Statistic	-2.250357	0.0122

Appendix 3: Kao cointegration

Kao Residual Cointegration Test
Series: LREN_G LGDP LFIN LCO2 R_P__DUMMY_ GDP_FIN
Date: 11/12/24 Time: 22:34
Sample: 1990 2021
Included observations: 192
Null Hypothesis: No cointegration
Trend assumption: No deterministic trend
User-specified lag length: 1
Newey-West automatic bandwidth selection and Bartlett kernel

	t-Statistic	Prob.
ADF	0.294015	0.3844
Residual variance	0.048114	
HAC variance	0.043867	

Appendix 4: Selection of optimal lags

VAR Lag Order Selection Criteria
Endogenous variables: LRENG__GWH_ LGDP_PER_CAPITA01 LFIN LCO2 RE...
Exogenous variables: C
Date: 11/04/24 Time: 23:08
Sample: 1990 2021
Included observations: 174

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2721.276	NA	27983224	31.33650	31.42728	31.37333
1	-987.3163	3348.335	0.082417	11.69329	12.23796	11.91424
2	-918.5953	128.7532*	0.049897*	11.19075*	12.18930*	11.59582*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Appendix 4: Panel ARDL

Dependent Variable: D(LREN_G)
Method: ARDL
Date: 11/12/24 Time: 15:49
Sample: 1992 2021
Included observations: 180
Dependent lags: 2 (Fixed)
Dynamic regressors (2 lags, fixed): R_P__DUMMY_ LGDP LFIN LCO2 GDP_FIN
Fixed regressors: C

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
		Long Run Equation		
R_P__DUMMY_	0.089211	0.315780	0.282511	0.7781
LGDP	-3.615227	0.759253	-4.761560	0.0000
LFIN	-3.666385	0.809558	-4.528873	0.0000
LCO2	2.778817	0.341596	8.134817	0.0000
GDP_FIN	0.002626	0.000438	5.990944	0.0000
		Short Run Equation		
COINTEQ01	-0.089492	0.059792	-1.496723	0.1374
D(LREN_G(-1))	-0.167744	0.078500	-2.136867	0.0348
D(R_P__DUMMY_)	0.110280	0.109937	1.003120	0.3180
D(R_P__DUMMY_(-1))	0.042888	0.067888	0.631750	0.5289
D(LGDP)	0.496647	0.203496	2.440579	0.0163
D(LGDP(-1))	0.644573	0.804758	0.800953	0.4249
D(LFIN)	0.210739	0.140609	1.498765	0.1368
D(LFIN(-1))	0.086312	0.264516	0.326302	0.7448
D(LCO2)	-0.495592	0.140779	-3.520361	0.0006
D(LCO2(-1))	-0.608149	0.701654	-0.866735	0.3880
D(GDP_FIN)	0.134332	0.134695	0.997309	0.3208
D(GDP_FIN(-1))	0.822844	0.823066	0.999731	0.3197
C	-0.484889	0.569296	-0.851734	0.3962

Root MSE	0.171184	Mean dependent var	0.048688
S.D. dependent var	0.218708	S.E. of regression	0.227196
Akaike info criterion	-0.861209	Sum squared resid	5.626344
Schwarz criterion	0.546979	Log likelihood	165.6761
Hannan-Quinn criter.	-0.290883		

*Note: p-values and any subsequent tests do not account for model selection.

Appendix 5: Short run coefficients Individual countries

Angola

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	-0.054417	0.004322	-12.58936	0.0011
D(LREN_G(-1))	-0.257936	0.024793	-10.40351	0.0019
D(LGDP)	0.031624	0.018627	1.697784	0.1881
D(LGDP(-1))	0.062182	0.021681	2.868029	0.0642
D(LFIN)	0.206502	0.018942	10.90184	0.0017
D(LFIN(-1))	0.310698	0.020834	14.91321	0.0007
D(LCO2)	-0.438742	0.036551	-12.00348	0.0012
D(LCO2(-1))	-0.335662	0.050043	-6.707470	0.0068
D(GDP_FIN)	-0.000194	1.60E-07	-1212.653	0.0000
D(GDP_FIN(-1))	-0.000112	2.07E-07	-537.7123	0.0000
D(R_P__DUMMY_)	0.042102	0.009839	4.279240	0.0234
D(R_P__DUMMY_(-1))	0.216699	0.009210	23.52760	0.0002
C	0.564968	0.285314	1.980161	0.1420
@TREND	0.003987	2.89E-05	137.7421	0.0000

Botswana

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	-0.023354	0.002985	-7.824924	0.0043
D(LREN_G(-1))	-0.277560	0.015153	-18.31751	0.0004
D(LGDP)	0.158165	0.370842	0.426502	0.6985
D(LGDP(-1))	1.154934	0.457305	2.525522	0.0858
D(LFIN)	-0.985842	0.414652	-2.377516	0.0978
D(LFIN(-1))	1.158704	0.397089	2.917992	0.0616
D(LCO2)	0.254398	0.028327	8.980653	0.0029
D(LCO2(-1))	1.289641	0.032081	40.19892	0.0000
D(GDP_FIN)	9.41E-05	1.29E-07	727.5308	0.0000
D(GDP_FIN(-1))	-0.000912	1.59E-07	-5721.735	0.0000
D(R_P__DUMMY_)	0.015813	0.016343	0.967550	0.4046
D(R_P__DUMMY_(-1))	-0.082737	0.014959	-5.530928	0.0116
C	-0.121843	0.006393	-19.05827	0.0003
@TREND	0.011524	3.62E-05	318.0376	0.0000

DRC

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	0.072747	0.002097	34.69533	0.0001
D(LREN_G(-1))	-0.024443	0.030506	-0.801240	0.4816
D(LGDP)	0.438135	0.020720	21.14513	0.0002
D(LGDP(-1))	0.229572	0.025393	9.040665	0.0029
D(LFIN)	0.080089	0.002797	28.62928	0.0001
D(LFIN(-1))	0.063799	0.004092	15.59110	0.0006
D(LCO2)	-0.223440	0.009294	-24.04259	0.0002
D(LCO2(-1))	-0.027336	0.004580	-5.969084	0.0094
D(GDP_FIN)	-0.000924	1.16E-07	-7976.806	0.0000
D(GDP_FIN(-1))	-0.000350	2.36E-07	-1482.070	0.0000
D(R_P__DUMMY_)	0.078942	0.004223	18.69385	0.0003
D(R_P__DUMMY_(-1))	-0.118597	0.007272	-16.30924	0.0005
C	-0.522750	0.161276	-3.241342	0.0478
@TREND	0.002830	2.50E-06	1132.732	0.0000

Namibia

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	-0.908736	0.048838	-18.60700	0.0003
D(LREN_G(-1))	-0.066256	0.024647	-2.688214	0.0745
D(LGDP)	0.195735	0.019293	10.14563	0.0020
D(LGDP(-1))	0.149935	0.026476	5.663090	0.0109
D(LFIN)	1.380653	0.093400	14.78211	0.0007
D(LFIN(-1))	0.616640	0.069420	8.882673	0.0030
D(LCO2)	0.573939	0.038955	14.73325	0.0007
D(LCO2(-1))	0.136052	0.026626	5.109651	0.0145
D(GDP_FIN)	-0.000697	4.41E-08	-15819.69	0.0000
D(GDP_FIN(-1))	-0.000485	7.13E-08	-6807.746	0.0000
D(R_P__DUMMY_)	-0.165870	0.002412	-68.76765	0.0000
D(R_P__DUMMY_(-1))	-0.153498	0.002715	-56.53623	0.0000
C	7.043784	6.384831	1.103206	0.3505
@TREND	0.049992	9.91E-05	504.2817	0.0000

South Africa

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	-0.716039	0.039594	-18.08475	0.0004
D(LREN_G(-1))	0.141253	0.032705	4.319010	0.0229
D(LGDP)	-0.559231	2.382725	-0.234702	0.8295
D(LGDP(-1))	-2.366128	5.580410	-0.424006	0.7001
D(LFIN)	1.046003	5.835327	0.179254	0.8692
D(LFIN(-1))	1.139434	5.153084	0.221117	0.8392
D(LCO2)	0.070625	0.197068	0.358380	0.7438
D(LCO2(-1))	0.215389	0.149997	1.435957	0.2465
D(GDP_FIN)	0.000224	2.94E-07	763.2126	0.0000
D(GDP_FIN(-1))	0.000546	5.23E-07	1044.856	0.0000
D(R_P__DUMMY_)	0.695259	0.655325	1.060939	0.3666
D(R_P__DUMMY_(-1))	-0.095918	0.233584	-0.410635	0.7089
C	5.389271	3.454954	1.559867	0.2167
@TREND	0.087292	0.000865	100.9257	0.0000

Zambia

Variable	Coefficient	Std. Error	t-Statistic	Prob. *
COINTEQ01	-0.259125	0.012706	-20.39389	0.0003
D(LREN_G(-1))	-0.303597	0.026012	-11.67161	0.0014
D(LGDP)	0.660786	0.261732	2.524667	0.0858
D(LGDP(-1))	2.406729	75.35311	0.031939	0.9765
D(LFIN)	-0.031746	0.147787	-0.214808	0.8437
D(LFIN(-1))	-0.144667	0.182523	-0.792598	0.4859
D(LCO2)	-0.571945	0.114867	-4.979190	0.0156
D(LCO2(-1))	-2.567042	73.09540	-0.035119	0.9742
D(GDP_FIN)	2.075271	89.27048	0.023247	0.9829
D(GDP_FIN(-1))	5.116598	103.3059	0.049529	0.9636
D(R_P__DUMMY_)	-0.097848	0.010571	-9.256566	0.0027
D(R_P__DUMMY_(-1))	-0.088603	0.007731	-11.46121	0.0014
C	3.378113	2.478060	1.363208	0.2661
@TREND	0.014049	5.28E-05	266.3231	0.0000

Appendix 6: FMOLS and DOLS

FMOLS

Dependent Variable: LREN_G
Method: Panel Fully Modified Least Squares (FMOLS)
Date: 11/12/24 Time: 22:36
Sample (adjusted): 1991 2021
Periods included: 31
Cross-sections included: 6
Total panel (balanced) observations: 186
Panel method: Pooled estimation
Coefficient covariance computed using default method
Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDP	-0.393630	0.159401	-2.469433	0.0145
LFIN	-2.929321	0.734288	-3.989333	0.0001
LCO2	0.405552	0.194282	2.087440	0.0382
R_P__DUMMY_	0.047395	1.034662	0.045807	0.9635
GDP_FIN	0.001427	0.000690	2.068457	0.0400

R-squared	0.191442	Mean dependent var	7.293142
Adjusted R-squared	0.173574	S.D. dependent var	3.172934
S.E. of regression	2.884450	Sum squared resid	1505.929
Long-run variance	30.10670		

DOLS

Dependent Variable: LREN_G
Method: Panel Dynamic Least Squares (DOLS)
Date: 11/12/24 Time: 22:39
Sample (adjusted): 1992 2020
Periods included: 29
Cross-sections included: 6
Total panel (balanced) observations: 174
Panel method: Pooled estimation
Cointegrating equation deterministics: C @TREND
Fixed leads and lags specification (lead=1, lag=1)
Coefficient covariance computed using default method
Long-run variance (Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDP	0.099823	0.197189	0.506231	0.6144
LFIN	0.302277	0.211874	1.426684	0.1583
LCO2	0.139878	0.267880	0.522165	0.6033
R_P__DUMMY_	0.033856	0.150723	0.224622	0.8230
GDP_FIN	-0.000953	0.000206	-4.626262	0.0000

R-squared	0.997533	Mean dependent var	7.273040
Adjusted R-squared	0.993629	S.D. dependent var	3.174919
S.E. of regression	0.253422	Sum squared resid	4.302932
Long-run variance	0.025084		

Appendix 8: Granger Causality

Pairwise Granger Causality Tests
Date: 11/06/24 Time: 16:30
Sample: 1990 2021
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
LGDP1 does not Granger Cause LRENG	180	0.39262	0.6759
LRENG does not Granger Cause LGDP1		0.21389	0.8076
LCO2__KT does not Granger Cause LRENG	180	4.96643	0.0080
LRENG does not Granger Cause LCO2__KT		0.48217	0.6183
LFIN does not Granger Cause LRENG	180	0.25119	0.7782
LRENG does not Granger Cause LFIN		0.23698	0.7893
R_P__DUMMY_ does not Granger Cause LRENG	180	2.07616	0.1285
LRENG does not Granger Cause R_P__DUMMY_		0.01085	0.9892
LCO2__KT does not Granger Cause LGDP1	180	1.20006	0.3036
LGDP1 does not Granger Cause LCO2__KT		0.07431	0.9284
LFIN does not Granger Cause LGDP1	180	0.25761	0.7732
LGDP1 does not Granger Cause LFIN		0.00102	0.9990
R_P__DUMMY_ does not Granger Cause LGDP1	180	0.89650	0.4099
LGDP1 does not Granger Cause R_P__DUMMY_		0.05319	0.9482
LFIN does not Granger Cause LCO2__KT	180	0.00920	0.9908
LCO2__KT does not Granger Cause LFIN		0.23142	0.7937
R_P__DUMMY_ does not Granger Cause LCO2__KT	180	1.26295	0.2854
LCO2__KT does not Granger Cause R_P__DUMMY_		0.46523	0.6288
R_P__DUMMY_ does not Granger Cause LFIN	180	0.46936	0.6262
LFIN does not Granger Cause R_P__DUMMY_		0.13271	0.8758

Dependent Variable: LRENG
Method: Panel Fully Modified Least Squares (FMOLS)
Date: 11/06/24 Time: 07:16
Sample (adjusted): 1991 2021
Periods included: 31
Cross-sections included: 6
Total panel (balanced) observations: 186
Panel method: Pooled estimation
Coefficient covariance computed using default method
Long-run covariance estimates (Bartlett kernel, Newey-West fixed bandwidth)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDP1	-0.387805	0.159143	-2.436835	0.0158
LFIN	-2.938739	0.745746	-3.940670	0.0001
R_P__DUMMY_	0.073193	1.036000	0.070650	0.9438
GDP_FIN	0.001395	0.000692	2.016332	0.0452
LCO2__KT	0.404174	0.195862	2.063567	0.0405

R-squared	0.191266	Mean dependent var	7.293142
Adjusted R-squared	0.173394	S.D. dependent var	3.172934
S.E. of regression	2.884764	Sum squared resid	1506.257
Long-run variance	30.11420		

Dependent Variable: LRENG
Method: Panel Dynamic Least Squares (DOLS)
Date: 11/06/24 Time: 07:24
Sample (adjusted): 1992 2020
Periods included: 29
Cross-sections included: 6
Total panel (balanced) observations: 174
Panel method: Pooled estimation
Fixed leads and lags specification (lead=1, lag=1)
Coefficient covariance computed using default method
Long-run variance (Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDP1	0.001066	0.467826	0.002278	0.9982
LFIN	-1.877233	0.747103	-2.512684	0.0140
R_P__DUMMY_	-0.621837	0.900964	-0.690191	0.4921
GDP_FIN	0.000897	0.000618	1.452324	0.1504
LCO2__KT	0.406122	0.333473	1.217857	0.2269

R-squared	0.813718	Mean dependent var	7.273040
Adjusted R-squared	0.592066	S.D. dependent var	3.174919
S.E. of regression	2.027811	Sum squared resid	324.8493
Long-run variance	3.513879		