

INTEGRATION OF RENEWABLE ENERGY ALTERNATIVES IN RESPONSE TO  
CLIMATE CHANGE: BARRIERS AND OPPORTUNITIES TO EFFECTIVE  
TRANSITIONING

By

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## **DECLARATION**

I Bertha Musonda do hereby declare that this dissertation represents my original work. It has not previously been submitted for a postgraduate degree or any award at the University of Zambia or any other institution. All work and materials from other sources have been acknowledged and references thereby provided.

May, 2025

Signature: .....

## CERTIFICATE OF APPROVAL

This dissertation by Bertha Musonda has been approved as fulfilment of the partial requirements for the award of a Master of Environmental and Natural Resources Management by the University of Zambia.

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## ABSTRACT

Renewable energy often referred to as clean energy, is an important energy source that comes from natural sources or processes that are constantly replenished such as solar, wind, geothermal and hydro-based energy. Zambia's installed energy capacity stands at 2,800 Megawatts (MW) of which 85 percent of that is hydro-based and increasingly vulnerable to climate change. In terms of policy, the Electricity Act of 2019 and Energy Regulation Act of 2019 are regulations meant to govern energy; however, they are inadequate to promote the exploitation of renewable energy sources because the two pieces of legislation are biased towards electricity generation and regulatory matters, respectively.

The purpose of this study was to develop an atlas of renewable energy alternatives and highlight the barriers and opportunities for effective transitioning, in response to climate change. Furthermore, the objectives included to develop an atlas of energy alternatives with a comparative advantage in different geographical regions of Zambia, to investigate the viability and barriers of integrating alternatives and to explore the opportunities for available energy sources. The Methodology involved key informant interviews, Participatory Geographic Information system, literature review of government reports, legislature, journal articles, books and any unpublished material on renewable energy and climate change in Zambia. The research design was qualitative and seven (07) key experts from the energy industry were purposively sampled because each answered a particular need for the research based on position, experience and knowledge.

Thematic analysis was employed to analyse the data and results revealed that renewable energy sources such as solar, geothermal are spread across the country. Further, barriers to the adoption of renewable energy alternatives are eminent and the development of methods that can overcome them appears to be constrained. Barriers such as Limited Infrastructure, Financial Constraints, Technical Capacity and Grid Integration continue to impede the process. The implications are that addressing these barriers and capitalizing on Opportunities associated with Abundant Renewable Resources, Policy and Regulatory framework, Job Creation and Economic Growth, significant progress can be made in transitioning to a more sustainable and climate-resilient energy system. The study recommends that ZESCO Ltd, the National Utility and Independent Power Producers should collaborate in investing in alternatives such as solar for power production country wide among others.

**Keywords:** *Adoption, Barriers, Climate Change, Renewable Energy, Integration, Viability*

## **DEDICATION**

This dissertation is dedicated to my beloved grandmother, Eugenia Mukela Situmbeko. You are a living testament to the power of wisdom that transcends textbooks and classrooms. Though you never went this far in your school in the traditional sense, your mind is as sharp as any scholar's. Your life is a story of learning through experience, observation, and a relentless curiosity that has always amazed me. You have taught me that intelligence isn't just about formal education, it's about the ability to see the world with clarity, to understand people, and to make decisions based on compassion and logic.

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## **ACRONYMS**

ERB	Energy Regulation Board
EIB	European Investment Bank
GHG	Greenhouse Gas
IEA	International Energy Agency
IDC	Industrial Development Corporation
IPPs	Independent Power Producers
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
MoE	Ministry of Energy
REA	Rural Electrification Authority
ZESCO	Zambia Electricity Supply Corporation

## CHAPTER ONE: INTRODUCTION

### 1. 0 INTRODUCTION

#### 1.1 Background

Climate change is already having an impact on many areas of the globe. If left unchecked, its long-term negative consequences will certainly be enormous, costing far more than averting them. The Intergovernmental Panel on Climate Change has emphasized the importance of taking immediate action to combat climate change, especially by transforming global energy consumption. They recommend an immediate, large-scale shift to renewable energy and energy efficiency given that the energy sector accounts for two-thirds of all greenhouse gas emissions.

The International Renewable Energy Agency (IRENA) has revealed new data demonstrating that renewable energy kept expanding and gaining speed amid global concerns. By the end of 2021, global renewable generation capacity amounted to 3 064 Gigawatt (GW), increasing the stock of renewable power by 9.1 per cent. Although hydropower accounted for the largest share of the global total renewable generation capacity with 1 230 GW, IRENA's Renewable Capacity Statistics of 2022 shows that solar and wind continued to dominate new generating capacity (IRA, 2022). A recent continental assessment by the IEA predicts a decrease in hydropower capacity factors of Mozambique, Zambia and Zimbabwe and this is expected to fall even further in future due to climate change. Since the temperatures keep rising Milliken et al (2021) suggest that transitioning to renewable energy sources, such as biofuels, can help counter this challenge. However, Singh et al. (2013) argue that mitigating climate risks will require integration of different renewable energy sources in power generation plans which is critical to sustain future demand. Zambia's energy sector continues to be hydropower dominant and the need to transition from this dominance is critical now more than ever in the face of climate change.

Zambia has 2,800 megawatts (MW) of installed electricity generation capacity, of which 85% is hydro based renewable energy (NEAS, 2023). National access to electricity averages 31% with 67% of the urban and 4% of the rural population having access to power (NEAS, 2023). The Government of the Republic of Zambia set a goal for universal electricity access for all Zambians by 2030 (NEAS, 2023). Energy has been identified as an important driving force behind economic development in Zambia and globally, and the government has declared its commitment to developing and maintaining energy infrastructure and services (IRP, 2022).

According to Moonga and Chileshe (2019), Zambia has been transitioning from a "brown economy" to a "green economy" for the past ten to fifteen years and the primary goal of such a transition is to eliminate trade-offs between increased economic growth and investment and improvements in environmental quality and social inclusion. Banda and Bass (2014) define green growth as "inclusive development that makes sustainable and equitable use of Zambia's natural resources while remaining within ecological constraints". This study therefore defines green growth as being transformed to become more ecologically friendly, inclusive, and productive to attain sustainable development. Modern renewable energy has been hailed as one of the prerequisites for fostering green growth and the achievement of sustainable development (Mudenda et al, 2018). Wang and Lo (2021) consider the development of renewable energy as a crucial tool for advancing sustainable development goals, as it could replace the highly polluted, dangerous, grey economy with an environmentally friendly, healthy, green economy. Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished. This study will consider renewable energy alternatives that are provided in the Zambia National Energy Policy of 2019 which include Solar, Wind, Geothermal, Small Hydro, Biomass and Waste to Energy. A historical dependence on hydropower generation hampered the growth of alternative renewable energy sources, but the 2015/2016 energy crisis forced the government to diversify the generation mix. Notwithstanding this step, Renewable Energy Solutions for Africa, bemoaned that in Zambia renewable energy sources (excluding hydro) covered less than 1% of the energy mix as of the year 2018 (ERB, 2020). By September of 2021 there was a slight increase to 2%. (IRP, 2022). In recent years, hydropower generation has been affected as a result of reduced rainfall activities in the country, which has contributed to low water levels in major reservoirs due to climate change. In 2020, the Energy Regulation Board reported that the country experienced a power deficit of up to 810 MW arising from reduced rainfall during the 2019/2020 rainfall season. In order to mitigate the effects of climate change on the energy sector, the Zambian Government committed to delivering affordable and clean energy through the implementation of a renewable energy investment plan to improve the energy mix available for the country (IRP, 2022). Zambia has significant alternative renewable energy resources, including, biomass, solar, wind and geothermal energy that can be exploited for both on-grid and off-grid systems. However, Hydro based renewable energy dominates the generation mix at 85% (ERB, 2023).

## **1.2 Problem statement**

Much of the renewable energy production in the energy sector is still biased towards hydro-electric power generation from which 85% of Zambia's energy is realised (NEP, 2019). Over dependence on hydropower which is susceptible to impacts of climate change makes Zambia's energy sector highly vulnerable.

The Zambian government acknowledged a significant electricity generation gap in February 2016 when the nation was faced with a deficit of 560-1000 MW in its energy supply. The El Niño-induced drought of the 2023–2024 season led to markedly reduced water levels in major reservoirs, notably Lake Kariba. This reduction severely impacted the Kariba North Bank power plant, limiting its generation to 214 MW out of an installed capacity of 1,080 MW. Consequently, Zambia faced a power deficit of approximately 1,360 MW as of July 31, 2024 (ERB, 2023). This is a wakeup call to diversification in the energy sector and it has led to the emerging of experimentation with renewable energy sources such as solar especially at a small scale. According to the Energy Regulation Board (2020), the country's reliance on hydropower puts it at risk owing to climatic changes, such as global warming contributing intermittent rainfall and drought.

Unfortunately, there is still a wide gap between hydro and alternative renewable energy sources integration i.e. energy mix diversification at national level, and the dependence on hydro based energy continues in spite of the talks on diversification of the energy mix, climate change challenges and the green economy transition. Renewable energy sources that exclude hydro covered less than 1% of the energy mix as of the year 2018 and by September of 2021 to date, there's been a slight increase to 2% (ERB, 2023). This entails that there is an identified problem of slow adoption which is possibly leading to a very slow transition to alternatives.

## **1.3 Aim**

To develop an atlas of renewable energy alternatives and highlight the barriers and opportunities for effective transitioning, in response to climate change

## **1.4 Objectives**

- i. To investigate the viability and barriers of integrating renewable energy alternatives
- ii. To explore the opportunities for available renewable energy sources
- iii. To generate an atlas of energy alternatives with comparative advantage in different geographical regions of Zambia

## **1.5 Research Questions**

- i. What is the potential for establishing different energy alternatives to hydropower in Zambia?
- ii. Which geographical regions have higher potential of energy alternatives?
- iii. Which renewable energy alternatives have a comparative advantage in different geographical regions of Zambia?
- iv. What is the viability of transitioning to various renewable alternative energy sources?
- v. What are the barriers and opportunities to integrating different energy alternatives in Zambia?

## **1.6 Rationale**

Climate change is a cross cutting issue that has spared no sector in terms of impacts whether at local, national or global levels. The impacts on the energy sector have been so significant leading to power deficits across the Southern African Region (IRP, 2022). Energy is one of the most important inputs for economic development (Zahid, 2008) and Zambia has been dependent on hydro based energy whose consistency has been negatively hampered by the effects of climate change hence the significance of this research.

This research will contribute to raising awareness to key actors in the energy sector such as the Ministry of Energy, ERB, ZESCO, IDC, REA, IPPs and different stakeholders such as the World Bank, EIB, KfW (The German Development Bank), etc. on the importance of integration of different energy mixes as a way of combating the impacts of climate change. It will further bring to the fore the barriers and opportunities to effective transitioning and expound on the possibility of how the energy sector can benefit from improving the efficiency of electricity generation through integration of renewable alternatives. This will help line ministries and institutions responsible for power generation to enhance the opportunities while minimising on the barriers to access of power among households.

Different studies have been undertaken on alternative renewable energy sources and their potential, but there's scarcity of knowledge on transitioning and possibly integration (Mudenda et al, 2028; Kaunda et al, 2012; Ibrahim et al, 2021) of alternatives and this study will enlighten the key electricity generation and transmission actors, stakeholders and consumers in the energy sector with important information that will contribute to the critical decision-making process on improving energy efficiency at national, local and household level. In addition, planning for power generation and transmission networks, investments in shared infrastructure,

advise on zoning, estimating the cost of power, and other policy-related activities all depend on such information. Commercial project developers will also make extensive use of it since reliable data can lower the resource risk expected by lenders and, consequently, the cost per unit of produced energy.

With regard to future studies, this research will serve as a possible reference tool to the process of more accurately expanding on information in renewable energy barriers and opportunities, and contribute to documenting knowledge which will be useful for reviewing, reinforcing, developing and implementing of policies for unleashing alternative renewable energy's potential and enhancing its efficiency across the country.

### **1.7 Organisation of the dissertation**

This study intends to address the dynamics of integration of renewable alternatives amidst Zambia's dependence on hydropower energy sources with a focus on identifying the barriers and opportunities to effective transitioning in response to climate change in Zambia. The dissertation is organised into six (6) chapters with chapter 2 making up the literature review and conceptual framework. Chapter 3 looks at the study area and chapter 4 captures the research methodology. Chapter 5 outlines the results and chapter 6 gives the discussion. The conclusion and recommendations are presented in chapter 7.

## CHAPTER TWO: LITERATURE REVIEW

### 2.0 INTRODUCTION

Renewable energy, often referred to as clean energy, is an important energy source that comes from natural sources or processes that are constantly replenished. This chapter discusses the status of renewable energy and the different types of renewable energy sources as well as rates of adoption. Climate change and renewable energy are key interlinked elements equally discussed. Key concepts linked to renewable energy specifically integration, transitioning, energy access and policy are also discussed.

### 2.1 Conceptual Definitions

- **Integration of Renewable Energy Alternatives**

In this research, the integration of renewable energy alternatives refers to the extent and manner in which sustainable energy sources (e.g., solar, wind, hydro) are incorporated into national and local energy systems. This concept is central to the study's objective of assessing how effectively such alternatives are being adopted as a response to climate change mitigation efforts.

- **Climate Change**

Climate change serves as the overarching global issue driving the need for energy system transformation (World Bank, 2024). Within this research, climate change is conceptualized as both a catalyst for action and a contextual backdrop against which renewable energy integration is measured. It underscores the urgency and necessity for transitioning to other renewable energy solutions.

- **Barriers**

The term barrier is used to identify and analyse the constraints that inhibit the integration of renewable energy alternatives. These may include economic limitations, policy and regulatory challenges, technological gaps, and socio-political resistance. Understanding these barriers supports the research objective of diagnosing critical obstacles to effective transitioning.

- **Opportunities**

Opportunities in this context refer to enabling factors or favourable conditions such as technological innovation, government incentives, international collaboration, or public support

that can accelerate the shift toward renewable energy alternatives. Exploring these opportunities aligns with the objective of identifying practical and strategic pathways to enhance integration efforts.

- **Effective Transitioning**

The concept of effective transitioning is framed as a process that is not only technically viable but also socially inclusive, economically sustainable, and environmentally sound. This research aims to evaluate what constitutes an effective energy transition and how various barriers and opportunities contribute to or hinder this outcome.

## **2.1 Renewable Energy and Climate Change**

Recent global and national discourses have mostly centred around energy and climate change. There is no path to protecting the climate without dramatically changing how we produce and use electricity (WWF, 2015).

Energy is at the heart of the climate challenge – and at the same time a key to the solution. A large chunk of the greenhouse gases that blanket the Earth and trap the sun’s heat are generated through energy production, by burning fossil fuels to generate electricity and heat. Fossil fuels, such as coal, oil and gas, are by far the largest contributor to global climate change, accounting for over 75 percent of global greenhouse gas emissions and nearly 90 percent of all carbon dioxide emissions (Milliken and Fisher 2021). The science is clear: to avoid the worst impacts of climate change, emissions need to be reduced by almost half by 2030 and reach net-zero by 2050 (UNCA, 2022). To achieve this, there is a need to stop relying on fossil fuels and transition to reliable, clean, accessible, and affordable alternative energy sources. The sun, wind, water, waste, and heat from the Earth are all abundant sources of renewable energy that replenish themselves naturally and emit little to no greenhouse gases or other air pollutants.

According to Singh (2013), Fossil fuels still account for more than 80 percent of global energy production, but cleaner sources of energy are gaining ground. About 20 percent of global electricity currently comes from renewable sources.

Renewable energy is on the rise across Africa, as several countries on the continent have already succeeded in taking necessary steps to scale-up renewables (FAO, 2020). The Government of the Republic of Zambia (GRZ) submitted its updated Nationally Determined Contribution (NDC) to the UNFCCC on 30th December 2020, highlighting renewable energy and energy efficiency as one of the three programmes through which the country is reducing its greenhouse gas emissions.

The solution to a healthy, liveable Earth today and for future generations is to hasten the transition to clean energy since renewable energy sources are more accessible and less expensive. Studies show that cheap electricity from renewable energy sources could provide 65 percent of the world's total electricity supply by 2030. It could decarbonize 90 percent of the power sector by 2050, massively cutting carbon emissions and helping to mitigate climate change (Singh, 2013).

## **2.2 The Status of Renewable Energy in Zambia**

Zambia's electricity generation mix is predominantly hydro, accounting for 85% of installed capacity (IRP, 2022). The Zambezi River is the major hydropower resource in southern Africa and Zambia's territory occupies a larger area of the river basin, at 41 per cent, than any of the other seven riparian nations.

One of the strategies under the Eighth National Development Plan (8NDP) is implementation of programmes focused on switching towards green and renewable energy sources, such as biogas, solar, and wind to enhance climate change mitigation. This is also in line with the Sustainable Development Goal No. 7 on Affordable and Clean Energy.

According to the Integrated Resource Plan (2022) Electricity supply in Zambia grew by 49.6% over a ten-year period (2005 to 2015), while consumption grew by 51.31% over the same period. The total installed generation capacity is 2,981.23 MW, of which over 80% comprises of hydropower, and the remaining capacity includes thermal units and renewable energy plants (IRP, 2022). A limited energy mix, heavy reliance on hydropower, and negligible contributions from biomass, solar, wind, geothermal, and other non-hydro sources to the total generation mix is among the key challenges in the energy sector.

Gorjian (2017) defines Renewable Energy as energy that is derived from natural sources that are replenished at a higher rate than they are consumed for example, sunlight and wind, are such sources that are constantly being replenished. According to the United Nations (2022), Generating renewable energy creates far lower emissions than burning fossil fuels, therefore, transitioning from fossil fuels, which currently account for the lion's share of emissions, to renewable energy is key to addressing the climate crisis.

According to the Integrated Resource Plan for the Power Sector in Zambia (2022), Zambia's electricity generation mix is predominantly hydro, accounting for 85 % of installed capacity. The remainder of the generation mix comprises of coal (10%), heavy fuel oil (3.7%), diesel (2.8%) and solar (3%) (IRP, 2022). Although the Government of Zambia considers alternative

renewable energy sources to be an important contributor to the national energy mix, their use has not been fully explored.

*Table 1: Renewable energy alternatives and their status according to International Renewable Energy Agency 2023 country profile for Zambia*

S/N	SOURCE	STATUS/LIMITATION validity and reliability of the data	Percentage contribution to electrification
<b>Renewable Energy</b>			
1.	Hydro	<p>Predominant energy source and main hydropower plants include Kariba North Bank (1,080MW), Kafue Gorge Lower (750MW), Victoria Falls (108), Lunsemfwa Hydro (56MW), and the Itzhi Tezhi (120MW) Hydro Power Stations.</p> <p>Small hydropower plants include the Chishimba Falls (6MW), Musonda Falls (5MW), Shiwangandu (1MW), Lunzua (14.8MW), and Lusiwasi Upper (15MW) Hydropower plants.</p> <p>The major factors that have impeded the development of small hydropower are economies of scale and long distances to load centres.</p>	85
2.	Solar	The low level of investment in solar energy electricity generation has been attributed to a number of factors, including high capital costs and insufficient regulatory frameworks for renewable energy systems, which have created investment uncertainty	3 to 5
3.	Wind	There is no power generation from wind energy at the moment because its development has been largely impeded by inadequate mechanisms to create an enabling environment and leverage private investment	0
4.	Geothermal	There has been inadequate exploitation of this resource for electricity due to the high costs of exploration	0
5.	Biomass	Its utilisation is considered unsustainable because the harvest exceeds re-growth of biomass contributing to climate change and negative health effects. The high dependence on wood fuel is due to low access and also unreliable electricity supply, high cost of efficient alternatives, inadequate enforcement of legislation and coordination among key sector institutions. Does not contribute to electricity energy mix however 70% is utilized for domestic activities such as heating and cooking	7 to 10
6.	Waste to Energy	Potential has been identified, however, there is lack of capacity for proper waste management	<1
<b>Non-Renewable</b>			

7.	Coal	There is one coal-fired plant, Maamba Collieries, which was commissioned in late 2016 and generates up to 300 MW of power	10
8.	heavy fuel oil	Sold by companies such as Total Energies Zambia, Puma, Mount Meru, etc and commonly used by mines, cement producers, in road construction and hotels. Mainly used in heaters, boilers, furnaces, kilns and power generators	3.7
8.	Diesel	Current diesel consumption hovers around 2 million litres with the main consumers being the mines. The country's supply level has remained fairly stable despite the challenges of the war in Ukraine	2.8

\*Renewable energy sources account for over 80 %. However, the difference in the percentage represents the non-renewables

### 2.2.1 Solar Energy

Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy. Solar technologies can deliver heat, cooling, natural lighting, electricity, and fuels for a host of applications. Solar technologies convert sunlight into electrical energy either through photovoltaic panels or through mirrors that concentrate solar radiation. Although not all countries are equally endowed with solar energy, a significant contribution to the energy mix from direct solar energy is possible for every country (Gorjian, 2017).

Zambia has an average solar irradiation of 5.5kWh/m<sup>2</sup>/day with approximately 3,000 sunshine hours annually providing good potential for photovoltaic and solar thermal applications (including electricity generation, solar home systems, solar water pumping and solar water heating). Solar power generation accounts for only 3 percent of the total installed generation capacity (NEP, 2019).

#### 2.2.1.1 Rate of adoption

In 2019 Zambia implemented the first Scaling Solar project by the IDC in close coordination with the Ministry of Energy. In March 2019, a joint French (Neon) – American (First Solar) consortium commissioned Zambia's first utility scale solar project, a 47.5 MW plant that is providing power directly into ZESCO's national grid. Italian firm Enel commissioned the second Scaling Solar project in May 2020, providing 26 MW of solar power to the grid (ITA, 2022).

In March of 2022 the Zambian government signed a deal with energy companies Total Eren and Chariot to build a 430MW solar and wind energy farm in Solwezi, which will power mining operations in the Kansanshi mine – Africa’s most productive copper mine – and the Sentinel copper mine (EITI, 2022).

Furthermore, three new solar photovoltaic plants are envisaged and this project is to be led by the state-owned Zambia Electricity Supply Corporation (ZESCO). The facilities will be built in Southern, Western and Luapula provinces, with a combined capacity of 500 MW (Takouleu, 2022).

At household level deployment has remained fairly low with most installations tilted towards social development projects such as health, education, institutional housing and water supply (Mudenda et al., 2018). According to the 2024 National Energy Access Survey, 8.9% of households in Zambia utilize solar energy. This reflects a significant increase from previous years, indicating growing adoption of solar technology. The surge in adoption is largely attributed to policy initiatives such as tax waivers and the removal of regulatory barriers, which have made solar installations more accessible to the population (NEAS 2023).

### **2.2.2 Wind Energy**

According to the National Energy Policy of 2019, the wind resource regime in Zambia has an average wind speed of 6 meters per second measured at eighty metres (80m) above the ground. The available wind resource is sufficient for electricity production, water pumping for household use and irrigation. However, there is no power generation from wind energy at the moment because its development has been largely impeded by inadequate mechanisms to create an enabling environment and leverage private investment. Resource mapping has been undertaken to identify suitable sites and some developers are currently undertaking feasibility studies on selected sites (NEP, 2019).

#### **2.2.2.1 Rate of adoption**

Currently, wind energy adoption in Zambia is extremely low, and it does not contribute significantly to the national energy mix. Zambia is yet to develop significant wind energy projects or infrastructure, and there are no large-scale wind farms operating in the country (Mutale et al, 2025)

### **2.2.3 Geothermal Energy**

Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems. Once at the surface, fluids of various temperatures can be used to generate electricity (Gorjian, 2017).

A study by Musonda and Sikazwe (2005) shows that Geothermal energy potential can also be considered relevant, with Zambia having more than 80 hot springs, of which 35 were rated highly in terms of surface temperature, low rate, and proximity to power lines, indicating ease of access and relative energy potential. To date, these springs have not yet been tapped for industrial or energy provision purposes. The Government of the Republic of Zambia does not have specific policy on geothermal energy; however, it does have policy on renewable energy as a whole.

#### **2.2.3.1 Rate of adoption**

Currently, there is only one small un-operational geothermal generation plant in Zambia (2 x 120kW), which was developed under an Italian Government initiative in 1987 and is located at the Kapisya hot springs. Recent estimates indicate that the plant can be upgraded to produce 2MW of electricity. Efforts are underway by ZESCO to revive and expand the plant, pending the construction of a 22 km access road by Government (Global Geothermal Alliance, 2022).

Zambia has about 80 hot and mineralized springs. Currently, only three geothermal sites (i.e., Bweengwa River, Kapisya and Chinyunyu, hot springs) have been identified as potential sites for geothermal resources. These sites possess the critical characteristics of sufficient heat, high volume of fluid and rock porosity for resource exploitation. However, the geothermal resource in Zambia still requires further elaboration and quantification (Mainza and Ziba, 2020).

### **2.2.4 Hydropower**

Hydropower harnesses the energy of water moving from higher to lower elevations. It can be generated from reservoirs and rivers. Reservoir hydropower plants rely on stored water in a reservoir, while run-of-river hydropower plants harness energy from the available flow of the river. Hydropower reservoirs often have multiple uses - providing drinking water, water for irrigation, flood and drought control, navigation services, as well as energy supply.

Hydropower currently is the largest source of renewable energy in the electricity sector. It relies on generally stable rainfall patterns, and can be negatively impacted by climate-induced droughts or changes to ecosystems which impact rainfall patterns (ERB, 2020).

Zambia's installed energy capacity stands at 2,800 Megawatts (MW) of which 85 percent of that is hydro-based and increasingly vulnerable to climate change. Zambia has heavily invested in hydro based renewable power over the years (ZDA, 2019) and main hydro power stations include Kariba North Bank Power Station, Kafue Gorge (1080 MW) Power Station, Kafue Gorge Lower (750MW) Power Station, Victoria Falls (108MW) Power Station, Lunsemfwa Hydro (56MW) Power Station, and the Itezhi Tezhi (120MW) Hydro Power Station.

Small Hydro Power stations include the Chishimba Falls (6MW), Musonda Falls (5MW), Shiwangandu (1MW), Lunzua (14.8MW), and Lusiwasi Upper (15MW) Hydropower stations. The contribution of small hydropower to the total installed electricity generation capacity is 1.5 percent (NEP, 2019). Government has recognized the important role small hydropower plays in rural electrification and the off-grid space where large hydropower and grid extension may not be economically and financially viable. The major factors that have impeded the development of small hydropower are economies of scale and long distances to load centres. However, many developers are undertaking feasibility studies for a greater number of sites located in many parts of the country (NEP, 2019).

#### **2.2.4.1 Implementation of hydropower projects**

Some of the upcoming hydropower projects include;

- The Batoka Gorge Hydro Electricity Scheme (BHES) 2.4GW hydroelectric project located across the boundary between Zambia and Zimbabwe, on the Zambezi River, approximately 54km downstream of the Victoria Waterfall.
- The Luapula 789MW Hydropower Project
- Lusiwasi Lower 86MW Hydropower project

#### **2.2.5 Biomass**

According to Energy Regulation Board of 2020, Biomass is the predominant source of energy in Zambia mainly used as a household fuel for cooking and heating making it account for more than 70 percent of total primary energy supply. The main forms and products of biomass based renewable energy include wood fuel (charcoal and firewood), biogas, pellets, briquettes, biofuels and gel fuel.

Wood fuel is the most widely used fuel for cooking. Its utilisation is considered unsustainable because the harvest exceeds re-growth of biomass contributing to climate change and negative health effects. The high dependence on wood fuel is due to low access and also unreliable electricity supply, high cost of efficient alternatives, inadequate enforcement of legislation and coordination among key sector institutions (NEP, 2019).

#### **2.2.5.1 Rate of adoption**

A study by Shane et al. (2015) demonstrated the presence of readily accessible biomass feedstock that has the ability to provide modern energy especially in rural areas. However, FAO (2020) submits that all energy subsectors would require considerable investment to ensure the identified bioenergy supply chains are established and function effectively. This would complement alternative energy integration efforts. The study by Shane et al ( 2015) also postulated that formulation of an integrative bioenergy policy, creation of a bioenergy resource database, conducting of research and development, creation of a bioenergy unit, engagement and involvement of all stakeholders, education and capacity building, feedstock value chain analysis, dissemination of information, creation of decentralized models, devolution of powers and financing models are very critical aspects if the bioenergy sector has to be sustainably adopted in Zambia.

#### **2.2.6 Waste to Energy (WTE)**

Waste to Energy (WTE) offers a way to turn the enormous volumes of waste into useful bioenergy, reducing the environmental problems associated with landfills and indiscriminate dumping of waste. Europe is currently the leading continent in utilising WTE technology, while first movers in Africa are following the trend. The first African WTE plant was built in Ethiopia in 2018 and construction plans are in place in Kenya and Ghana (Global Geothermal Alliance, 2022)

Zambia has potential to utilize waste to produce energy, electricity and other by-products. The forms of waste to be targeted may include but not limited to municipal solid waste, sewerage wastewater, agricultural crop residues, livestock manure or waste, wood chips or biomass and industrial waste. This potential has been identified and several private developers have expressed interest to undertake feasibility studies for Waste-To-Energy projects in Zambia (NEP, 2019).

A Study by Kombe (2019) revealed that major cities of Zambia such as Lusaka, Ndola, Kitwe and Livingstone have the potential to generate electricity from the annual municipal solid waste collected. The study found the average energy potentials for Lusaka, Ndola, Kitwe and

Livingstone to be 4.16TWh, 0.73TWh, 0.82TWh and 0.16TWh, respectively. The research findings revealed that this available resource of municipal solid waste can be used as an alternative energy source for electricity production.

#### **2.2.6.1 Rate of adoption**

The total amount of municipal solid waste from both legal and illegal landfills in Lusaka is currently at 1,260,000 tons per year (GGA, 2022). A complete WTE plant would be able to handle up to 45% of the waste from the landfills, i.e., 567,000 tons of waste annually. Insufficient solid waste management has emerged as a national priority in Zambia due to increasing health and environmental issues and decreasing quality of life due to rubbish in public spaces. Currently, only 40% of waste in Lusaka is collected and 6% is recycled. Due to growing urbanisation and informal settlements, establishing professional solutions to waste management is becoming a pressing and urgent issue (GGA, 2022). To address this, the Accelerated Growth for SMEs in Zambia undertook a feasibility study of developing a Waste to Energy Plant in the Lusaka District of Zambia in 2019.

The study showed that construction of a small dry waste plant in Lusaka was feasible, but with support to the development of a holistic waste management process from collection, sorting, logistics and delivery to a central depository site. The study further recommended that due to the limited electricity production capacity in the nation, electricity supply may be a profitable option for the WTE at pilot stage.

In terms of implementation of other WTE facilities, a number of projects are underway, for example, ALSET Zero Waste Zambia Limited (a private developer) is envisaged to construct four waste energy gasification power plants at a cost of US\$350 million in four districts in Lusaka, Southern and Northern provinces. The districts are Lusaka, Monze, Livingstone and Mpulungu respectively and the power plants will produce affordable electricity in the four districts (Mwendabai, 2022).

### **2.3 Barriers to alternative energy access in Zambia**

While hydropower continues to remain the mainstay of Zambian electricity supplies, renewable energy sources continue to have barriers to their successful adoption and deployment. The lack of information on possible renewable energy technologies is one of the barriers on the uptake of renewable energy technologies for modern power supply (Kaunda et al, 2012). Seetharaman et al (2019) categorised barriers to adoption of renewable energy into Social, Economic, Technical and Regulatory all of which have an influence on each other.

### **2.3.1 Social Barriers**

According to Goldsmith (2015), the transition from conventional resources to renewable energy has encountered public resistance and opposition. This is due to a lack of awareness of the benefits of renewable energy, disruption of seascape, and acquisition of land which could have been used for agriculture, tourism, etc. Seetharaman et al (2019) adds that Public awareness and information barriers, not in my backyard' (NIMBY) syndrome (Loss of other/alternative income from land used for renewable energy which would otherwise be used for agriculture and Lack of experienced professionals, skilled to install and operate renewable energy projects all constitute social barriers to deployment of renewable energy alternatives. For example, according to NIMBY syndrome, people do support renewable energy generally, but not in their own neighbourhood. In addition, underserved populations are a contributing factor. For example, currently Zambia stands at 50% access to electricity in urban areas and only 4% in rural areas entailing inadequate access.

### **2.3.2 Economic Barriers**

Raza et al (2015), submits that factors influencing economic and financial barriers include high initial capital, lack of financial institutes, lack of investors, competition from fossil fuels, and fewer subsidies compared to traditional fuel. These factors have further prevented renewable energy from becoming widespread as desired. Renewable energy projects require huge capital investment. Therefore, it is imperative to ensure that the renewable energy sub sector is guided by a robust investment plan and this could encourage private sector participation.

### **2.3.3 Technological barriers**

It has been reported by Zhao et al (2016) there are a number of legitimate technological barriers to the widespread deployment of renewable energy and these include limited availability of infrastructure, inefficient knowledge of operations and maintenance, insufficient research and development initiatives, and technical complexities like energy storage and unavailability of standards. Thus, Patwa et all (2019) agree that technological barriers have a significant influence on the deployment of renewable energy considering that sufficient research and development initiatives are key.

Insufficient data on the potential of renewable energy in Zambia, except for solar and wind energy is another factor. Geothermal could be a valuable renewable energy source to include

in Zambia's energy mix. However, geothermal is costly to develop compared to solar and wind energy (NEP, 2019).

#### **2.3.4 Regulatory Barriers**

Factors like lack of national policies, bureaucratic and administrative hurdles, inadequate incentives, impractical government targets, and lack of standards and certifications have prevented renewable energy from expanding dramatically as suggested by Stokes (2013). This is also affirmed by Mudenda et al (2018) as policy inadequacies are purported to affect successful adoption of clean energy technologies at household level.

#### **2.3.5 Underexploited renewable energy sector and heavy reliance on a service-challenged hydro-power utility**

Mudenda et al (2018) submits that the renewable energy sector remains under exploited owing to the aforementioned barriers. The National utility, Zambia Electricity Supply Corporation (ZESCO), the largest power producer supplies the majority of the power in the country and so far, it has experienced considerable difficulties in meeting the demands of the country's growing economy hence the service challenge.

Noteworthy is submissions of the Report on the Promotion of Renewable Energy Sources in Rural Areas in Zambia for the period 2015 to 2019, for the Fifth Session of the Twelfth National Assembly, which highlighted the following barriers to alternative energy access in Zambia;

- The lack of comprehensive data to ascertain the renewable energy potential, production and consumption has made it difficult to fully exploit the renewable energy potential of the country
- Spare parts for renewable energy technology being installed in rural areas cannot be sourced locally. Further, most beneficiaries of rural electrification technologies do not regard the equipment installed as their own property. As a result, the beneficiaries of these technologies abandon the equipment even for simple problems such as replacement of a bulb.
- Low literacy levels among the beneficiaries contributed to failure to understand the maintenance requirements of the equipment. Most beneficiaries of renewable energy technologies in rural areas are not fully aware of how to use and maintain the renewable energy equipment. As result of this limitation, most renewable energy technologies are prone to vandalism and damage

- Lack of research. Renewable Energy Technology keeps evolving, therefore, there is need for continued research. The report stressed the importance of adequate funding towards research.

#### **2.4 Rural and Urban population's access to energy/electricity in Zambia**

Zambia's energy resource potential includes bio-energy resources, hydro, solar, wind and geothermal power. In spite of its richness, the potential in power generation and supply is still not fully enhanced and balanced. The primary energy source for the majority of people is biomass (firewood and charcoal), which builds up 80% of supply. It is relied on to cover people's needs for cooking and heating, and accounts for over 70% of energy consumption (with 57% of urban populations and 97% in rural communities) (Sinkala, 2017).

Increasing access to energy is a key priority of the national development strategy and the government has set electrification targets at 90 % for urban areas and 51 % for rural zones by 2030. However, at the current pace, these targets are not expected to be achieved as the household electrification rates stand at approximately 67 per cent and 4.4 per cent for urban and rural areas, respectively (ERB, 2020).

#### **2.5 Climate and Non-Renewable Energy**

The World is shifting towards renewable energy sources; however, renewable energy's positive impacts cannot be appreciated without a mirror image of the negative impacts of non-renewable energy sources. Non-renewable energy sources such as fossil fuels, oils and coal cause serious, long-term, global climate impacts due to emission of greenhouse gases such as carbon dioxide. For example, chemically, coal is mostly carbon, which, when burned, reacts with oxygen in the air to produce carbon dioxide, a heat-trapping gas. When released into the atmosphere, carbon dioxide works like a blanket, warming the earth above normal limits (Milliken, 2021).

Coal is the second most important source of energy in Zambia accounting for 10% of the national energy mix behind hydro which is at 85% (IRP, 2022) but it is a 'dirty' fuel with negative climate impacts.

Clearly, non-renewable energy sources such as coal have significant negative impacts on climate and transitioning to renewable energy sources can help counter this challenge hence climate and renewable energy are at the heart of global discussions. In any discussion about climate change, renewable energy usually tops the list of changes the world can implement to stave off the worst effects of rising temperatures. That is because renewable energy sources

such as solar and wind do not emit carbon dioxide and other greenhouse gases that contribute to global warming (Nunez, 2019).

Many measures are being proposed at global, regional and national levels to in terms of mitigation and adaptation. Zambia's Integrated Resource Plan (2022), proposes several hard and soft measures that can be implemented to strengthen the overall climate resilience of hydropower installations considering that Zambia's electricity is mostly hydropower dependent accounting for 85% of the national energy mix. Some of the proposed measure include the development of resilience strategies, plans and regulations to promote the uptake of a diverse, climate-resilient energy mix, incentivise climate resilient sustainable development and regulate for enhanced resilience (IRP, 2022). However, in view of the articulated challenges, integration of renewable energy alternatives in response to climate change seems inevitable considering the fate of hydro based renewable sources.

From the literature reviewed, various studies have primarily focused on understanding and modeling renewable energy sources such as solar, geothermal and wind energy and the importance of their addition to Zambia's current energy mix. For example, a study by Mwanza et al, (2017) assessed the solar energy distribution and potential in Zambia of which nine provinces with different geographical and climatic regions that makes up Zambia were assessed. The study results indicated that Zambia has approximately 20,442TWh/year technical solar energy potential and receives 2109.97kWh/m<sup>2</sup> of solar energy per year with 4403.12hours of sunshine. Furthermore, the study established that the country has 186,121km<sup>2</sup> available and suitable land area for Renewable Energy Technology's implementations.

Another study on "*the Status of Geothermal Exploration in Zambia*" was undertaken by Sinkala and Ziba in 2020. This study established that geothermal energy has not been exploited despite so many hot springs due to the high cost of production and a perception that they are of low temperature even without a comprehensive study. Another reason is the availability of less risky and low investment power generating options which are a low hanging fruit for power developers. The research also postulated that the failure of the Kapisya Geothermal Plant has affected future possible investment in the geothermal sector.

Furthermore, a program that consists of providing a validated mesoscale wind atlas for Zambia, including associated deliverables and wind energy development training courses was introduced in 2018 whose goal is to provide Zambian policy makers, stakeholders and independent power producers with accurate and valuable knowledge of the national wind

resource, including complementary tools, which can be of direct practical use, both for formulating energy policy and implementing wind projects.

Considerable progress has been on studies relating to diversification of energy from hydro based considering the impacts of climate change on this natural resource. Among such studies is the “*Review of Renewable Energy Technologies in Zambian Households: Capacities and Barriers Affecting Successful Deployment*” by Mudenda et al (2018). Research results showed that challenges to diversification of energy from hydro based are institutional in nature, and recommended for a baseline assessment to understand knowledge, perceptions, attitudes and drivers for renewable energy technology adoption.

## **2.6 Integration of Renewable Energy Alternatives**

Decentralization in the electricity sector is a major step in the spread of renewable energy sources that can reduce dependence on fossil fuels (Erdiwansyah, 2021). Alternative energy sources such as Hydropower, Wind power, solar power, Geothermal and Waste to Energy are technologies that can be integrated as the main sources of energy so that a balanced energy mix is achieved.

Globally, many countries aim to attain having renewable energy provide the majority of the energy supply. Countries, such as China, Germany, India, Brazil, and USA, have diversified into other forms of renewable and sustainable energy to meet their energy requirements (Ibrahim et al, 2021). For example, the German Government’s plans are that by 2050 at least 80 per cent of the power supply should come from renewable energy sources (Vonderlind, 2022). This shows the integration and transitioning potential of Germany.

A study by Ibrahim et al (2021) showed that countries such as Nigeria, Cameroon, Ghana and South Africa are among the leading African countries with an abundance of renewable energy resources, which have the potentials to improve their respective energy generation potentials; thereby, contributing to the socio-economic growth, promote industrialization, reduce global warming and create green jobs. The study further submits that despite the abundant renewable energy sources in these countries, they are yet to fully harness the potentials, therefore, resulting in their deficiencies in contributing to the electrical power generation per country. The bulk of the problems associated with renewable energy in African countries are: little interest and lopsided policy on renewable energy, enforcing existing policies, high renewable energy tariff, and lack of adequate infrastructure.

In order for renewable energy to gradually replace conventional energy sources, Ibrahim et al (2021) suggests that the different alternative sources must be continuously integrated into the power supply system. A thorough overhaul of the energy delivery system is necessary for this. However, one of the biggest obstacles to the reform of energy policies is ensuring a dependable, environmentally responsible, and economically efficient power supply.

In Zambia, there are five main electricity generation companies namely the state-owned Zambia Electricity Supply Corporation (ZESCO) Limited; Copperbelt Energy Corporation (CEC); North-Western Energy Corporation (NWECC); Lunsemfwa Hydro Power Company (LHPC); and Maamba Collieries Limited. ZESCO, as a vertically integrated parastatal and the country's largest electricity company, runs and operates power stations, transmission lines, and distribution networks, and is the only utility-scale off taker of independent power producers (IPPs).

ZESCO owns and operates over 90 % of the generation, transmission, and distribution assets in the country and supplies electricity to all grid-connected consumers, with the exception of some mining consumers in the Copperbelt Province, which are serviced by the Copperbelt Energy Corporation (CEC), a private company that purchases bulk power from ZESCO for onward supply to the mines (Zambia Power Sector Assessment Report, 2018).

A study by the Renewable Energy Solutions for Africa (2018) established that Successful integration of energy alternatives requires a stable and reliable set of rules governing the interaction of all the players (private and public persons) involved in electricity generation, transmission and distribution as well as a regulatory framework governing integration of alternatives.

At national level, Enel Foundation alongside RES4Africa, and with the technical expertise of a leading energy research firm CESI, embarked on an ambitious research project to define the optimal penetration of variable renewable energy sources in Zambia. In particular, the focus of the research was grid integration aiming to assess the optimal technical-economic amount of variable renewable energy sources, such as solar and wind, which can be integrated into the National Electric Network of Zambia ensuring system stability. At the time of conducting this study, this research is on-going. Further, in the search for alternatives to fossil fuel-based energy, FAO has been supporting the Zambian Government in developing and integrating sustainable bioenergy in the agriculture sectors since 2020.

## **2.7 Sustainable Integration and transition**

Renewable Energy Integration is a concept that focuses on incorporating renewable energy alternatives using a systems approach. A systems approach can be used to conduct integration development because it addresses technical, economic, regulatory, and institutional barriers. In addition to fully addressing operational issues, the integration also establishes viable business models for incorporating these technologies into capacity planning, grid operations, and demand-side management (Hossain and Mahmud, 2014).

The goal of renewable energy integration is to maximise and advance the energy capacity of the electric grid in order to reduce carbon emissions and emissions of other air pollutants through integrated use of renewable energy and other clean distributed generation and support achievement of renewable portfolio standards for renewable energy and energy efficiency.

Limitations of non-renewable energy sources such as fossil fuels include negative health issues, negative environmental impacts, and the possible depletion of fossil fuel resources such as coal, natural gas, and oil as well as low or poor rainfall which is responsible for the drop-in dam water levels (Milliken, 2021). Therefore, African nations must urgently diversify their energy mix and make decisions that benefit the masses that depend on it. This is also in line with the UN 2030 goal.

Studies show that the adverse effects of carbon dioxide emissions from fossil fuels may result in irreversible damage to the Earth and as we know it, this results in climate change (Milliken 2021). Integration of reliable, affordable, and clean energy, can play a crucial role in the conservation of the earth as maximum energy supply is attained. This is further in line with the Sustainable Development Goal seven (SDG-7) for the year 2030 target. The lack of access to electricity in the majority of developing nations, particularly in Africa, is a crucial argument in favour of renewable energy integration. For example, Nigeria continues to suffer consistently, inadequate energy supply, load shedding, and power outages for several decades owing to many factors among which include lack an integrated energy mix. Integration enhances enhance reliability, security, and resiliency of supply which counters the challenges faced in countries such as Nigeria.

Renewable energy is being considered as a critical driver of Africa's post-COVID-19 green recovery and economic prosperity. This point was also made by the UN Secretary-General Antonio Gutiérrez at the COP26 Roundtable on Clean Power Transition, under the theme 'Achieving a rapid shift to green, affordable and resilient power systems' (FAO, 2020).

The transition towards a renewable and sustainable energy system is currently the subject of much discussion throughout the world (Wang et al, 2018). The global transition toward sustainable energy systems is gaining speed, driven both by the continuing drop in renewable energy costs and improvements in performance, and expedited by globally agreed goals such as Sustainable Development Goal 7 and the Paris Agreement. This transition presents enormous opportunities to transform and modernise energy systems across the globe. Renewable Energy transition country Studies undertaken for Côte d'Ivoire, Ghana, South Africa, Morocco and Rwanda show that these and many African countries rich in renewable resources have much to gain from this transition, particularly in terms of a resilient and affordable low-carbon energy system development and universal access to electricity (IRENA, 2020).

According to Wang and Lo (2021), addressing the threat of anthropogenic climate change requires a fundamental transition from the incumbent fossil fuel energy system to renewable energy alternatives. Rather than completely shifting from one set of dominant energy resources to another, energy transition involves the phasing out of fossil fuels, while increasing renewable energy resources such as solar and wind, which used to occupy only a small share of the energy mix.

Dioha and Kumar (2020) submit that Sub-Saharan Africa (SSA) is the central point of global energy poverty, yet its portfolio of energy resources is more than enough to satisfy its overall energy requirements if they are well developed and evenly distributed and this can be achieved through formulation of policies that facilitate a renewable energy transition. The study emphasises that renewables-based energy transition promises to deliver vast socio-economic benefits to countries across Africa that are on a pathway to transitioning with Nigeria being a good example of being in a better position to improve energy access, create jobs and boost energy security once the transition is successfully achieved. Dioha and Kumar (2020) also add that for Nigeria to achieve a successful energy transition it needs to be informed by quantitative assessments which consider the role of technologies towards decarbonising the household sector and ensuring energy security.

The Renewable Energy for Africa (2018) recognised that a progressive transition from fossil fuels to Renewable Energy Alternatives can be achieved through several convergent socio-economic factors which include; availability of renewable energy alternatives resources worldwide, technology improvements, with the consequential drastic reduction of costs, such

that they are close to achieving competitiveness against other sources of power generation at global level and environmental and climate change concerns.

The theme report on Energy Transition: Towards the Achievement of SDG 7 and Net-Zero Emissions (2021) indicates that over the next decade, every aspect of national energy system will be affected by changes in climate. Ongoing developments in many countries including Zambia offer a promising outlook for the security, inclusiveness, and sustainability inherent in a transformed energy sector. However, the report emphasises that the transition needs to speed up significantly and broaden its scope to achieve SDG 7 and align with the goals of the Paris Agreement on climate change, while at the same time achieving implementation of the 2030 Agenda for Sustainable Development.

According to the United Nations Report (2021), the energy transition can thus no longer be limited to incremental steps. It must become a transformational effort, a system overhaul, based on the rapid upscaling and implementation of all available technologies at National and global level to innovate for the future. This is the right moment to reassess long-standing assumptions, perceived barriers, and default decisions. The emerging energy system must promote resilient economies and societies for a more inclusive and equitable world. Ambitious and targeted actions are needed now and throughout the coming decades to ensure the goals of SDG7 are fulfilled and a decarbonized energy system achieved by 2050 (UN, 2021).

At National Level, Zambia intends to conditionally reduce its greenhouse gas (GHG) emissions by at least 47% by 2030 with substantial international support and by 25% under the business-as-usual approach. At the same time, improving energy access remains a priority, as only 43% of the population has access to electricity (8NDP, 2022). To meet growing energy demand, the government has identified energy efficiency as a priority in the country's nationally determined contributions (NDCs) under the Paris Agreement. As per the 8<sup>th</sup> National Development Plan, strategies include plans to increase geothermal, wind and solar electricity generation by 2030 hence being on a pathway to alternatives transitioning.

Beyond the national domestic energy transition efforts, Zambia plays an important role in the global energy transition as a major exporter of copper, a mineral used for low-carbon technologies and electricity networks. As copper production increases, the country also faces increasing demand for energy needed to sustain copper mining activities. In this context multi-stakeholder dialogue has spurred debate on energy access, use and efficiency, and inform sustainable transition pathways and help monitor climate commitments (EITI, 2020).

## **2.8 Policies on Integration and energy transition in Zambia**

The 2008 National Energy Policy (NEP), still in effect, provides policy and implementation guidelines to increase access to modern energy in urban and rural areas, including from alternative and renewable energy sources. To support this, a renewable energy feed-in-tariff (REFiT) policy was drafted in 2015 to catalyse private sector investment in renewable-energy power generation (ERB, 2020).

### **2.8.1 Policy Inadequacies**

The Government had put in place the 2019 National Energy Policy which had an objective to increase exploitation of renewable energy in order to diversify the energy mix and facilitate promotion of renewable energy technologies. However, the Policy has emphasis on Grid-Connected Hydropower at the Expense of other Renewable Energy Technologies.

The *Electricity Act* and *Energy Regulation Act* are regulations meant to govern energy; however, they are inadequate to promote the exploitation of renewable energy sources because the two pieces of legislation are biased towards electricity generation and regulatory matters, respectively (ERB, 2020). Both the Electricity Act, No. 11 of 2019 and Energy Regulation Act, No. 12 of 2019, do not adequately provide for the effective exploitation and promotion of renewable energy sources in Zambia. The Electricity Act is heavily skewed towards electricity generation, while the Energy Regulation Act is more focused on regulatory matters. Stringent licensing requirements and regulatory processes can be burdensome for smaller-scale or community-based renewable energy projects. Additionally, the lack of clear incentives and guidelines for promoting renewable energy technologies and the potentially delayed and costly environmental impact assessments further slows down the adoption of clean energy (ERB, 2023).

Zambia further lacks enactment of specific legislation to govern the renewable energy sub sector. Ministry of Energy developed a Renewable Energy Strategic Plan which since expired in 2016, however, no new strategic plan had been developed after that. Therefore, the lack of a Strategic Plan has negatively impacted the development of renewable energies in Zambia as this plan is critical in providing a roadmap on how to effectively exploit and integrate renewable energies. The problem is further exacerbated by the lack of a legal and policy framework to govern the exploitation of renewable energy sources to boost economic development (Ministry of Energy, 2021).

Under most conditions, increasing the share of RET in the energy mix will require policies to stimulate changes in the energy system. Additional policies would be required to attract the necessary increases in investment in technologies and infrastructure (IPCC, 2012).

Zambia has a dedicated agency for rural electrification. Established in 2003 through Parliamentary Act 20, the Zambia Rural Electrification Authority (REA) is mandated to increase access to electricity to 51 percent by 2030 by providing infrastructure and appropriate technology to all rural areas. Although this is not in line with SDGs that call for universal access to electricity by 2030, Zambia requires an exponential effort to meet this target, with an access rate of less than 15 percent in 2017.<sup>4</sup> The REA advises on suitable policies, designs and implements the Rural Electrification Master Plan (REMP), and administers and mobilizes the Rural Electrification Fund (REF)— also founded through Parliamentary Act 20. The REF streamlines the previous bottom-up process of selecting and funding rural electrification projects. It is funded by a 3 percent levy charged by national utilities.

The establishment of the REA followed extensive changes to the energy sector between 2011 and 2016. As part of the liberalization process of the sector in the 1990s, the Zambian government created the Ministry of Energy and Water Development, later rationalized as the Ministry of Energy (MoE) in 2016. The Department of Energy (DoE) within the MoE is responsible for the development and implementation of energy policies, programs and projects, including the promotion and facilitation of renewable energy, energy efficiency, and electrification solutions.

An Energy Regulation Board (ERB) was another outcome of the liberalization process. The ERB was created in 1995, and operationalized in 1997, to monitor the reliability and quality of service provided by national and independent private providers. It is overseen by the MoE. In addition, an Office for Promoting Private Power Investment (OPPPI) was established in 1999 within the MoE to facilitate the growing involvement of the private sector in power project development in Zambia.

## **2.9 Geographical Information System (GIS) and Renewable Energy Alternatives**

Zambia's economy, which is mainly based on depleted resources, may not be sustained if technologies remain constant while energy demands increase substantially. The need to control human-induced atmospheric emissions of greenhouse gases requires development of other clean and renewable sources of energy as aforementioned. In recent years, Geographical Information System (GIS) has become a major tool used to identify and select the most suitable

sites for development of Renewable Energy Alternatives such as wind and solar. A recent GIS-Based Assessment of Solar Energy Harvesting Sites and Electricity Generation Potential in Zambia by Mwanza and Ulgen (2021) used a number of finer spatial resolution data for selection of potential solar sites and evaluation of technical electricity generation potential. The process of assessing this potential involved firstly excluding all the protected and restricted areas from the active surface area of the study area under consideration. A suitability map was produced and it showed that the larger PV electricity generation potential variability at district and provincial level is highly linked with the local geographical features and terrain which affect the availability of suitable areas and also local solar energy resource. On the other hand, Solar GIS, a technology company offering energy-related meteorological data, software and consultancy services to solar energy developed a high-resolution global database model in 2019 which includes solar resource and meteorological parameters, important for development and operation of solar power plants in Zambia. The output of the model calculation is aggregated data layers, in the data format that is compatible with Geographical Information Systems (GIS). This project is still ongoing. In 2018, the Zambia Energy Sector Management Assistance Programme under the World Bank was established with the aim to providing a validated mesoscale wind atlas for Zambia using GIS Technologies (World Bank 2018). A key conclusion from this study is that there is now an established network of state-of-the-art wind measurement masts in Zambia that can be used to support stakeholder wind analysis activities and future utility-scale wind development in-country.

Clearly GIS has been used to enhance the possible courses of action at local and national level in terms of renewable energy. Traditional GIS technologies have been used for local and regional planning in the past; however, their complex nature coupled with a requirement to involve key players (interest groups) in the planning process limits their uses (Aguilar et al. 2011). These key players are the stakeholders who are affected by the consequences of the planning decision. Thus, for the planning process to be effective, it is particularly important to involve different groups of stakeholders.

## **2.10 Conceptual framework**

The starting point of research is a fundamental comprehension of important theories or concepts and this research adopts a conceptual framework approach (Figure 1). A conceptual framework is essential for organizing and guiding the entire research process, ensuring that the study is theoretically grounded, methodologically sound, and logically coherent. It enhances

the clarity, rigor, and impact of the research by linking theory to practice, helping to structure the study in a systematic way (Bryman, 2012).

The integration of renewable energy alternatives involves multiple interrelated factors, however, the cause-and-effect relationship between climate change and renewable form the conceptual framework of this study. Furthermore, the conceptual framework helps clarify key variables such as barriers, opportunities, and concepts such as grid integration, energy storage or public-private partnerships, allowing the research to be organised around these focal points. The conceptual framework ensures that the research stays focused on identifying specific barriers while emphasizing the study of opportunities in the energy transition process.

The conceptual framework further provides theoretical foundation by connecting the research to existing theories and models in renewable energy integration and climate change mitigation, situating the study within the broader academic discussion. By referencing relevant theories, such as transition theory where necessary the conceptual framework allows the analysis of how renewable energy can be effectively integrated to address climate change.

The figure below provides a visual representation of the conceptual framework guiding this research on integration of renewable energy alternatives response to climate change with a focus on barriers and opportunities to effective transitioning. Climate Chang is presented as the contextual backdrop, with renewable energy alternatives at the centre. This is surrounded with the barriers and opportunities, connected to the outcomes at the bottom. Feedback arrows connect the outcomes back to the central theme, showing the cyclical nature of climate change adaptation.

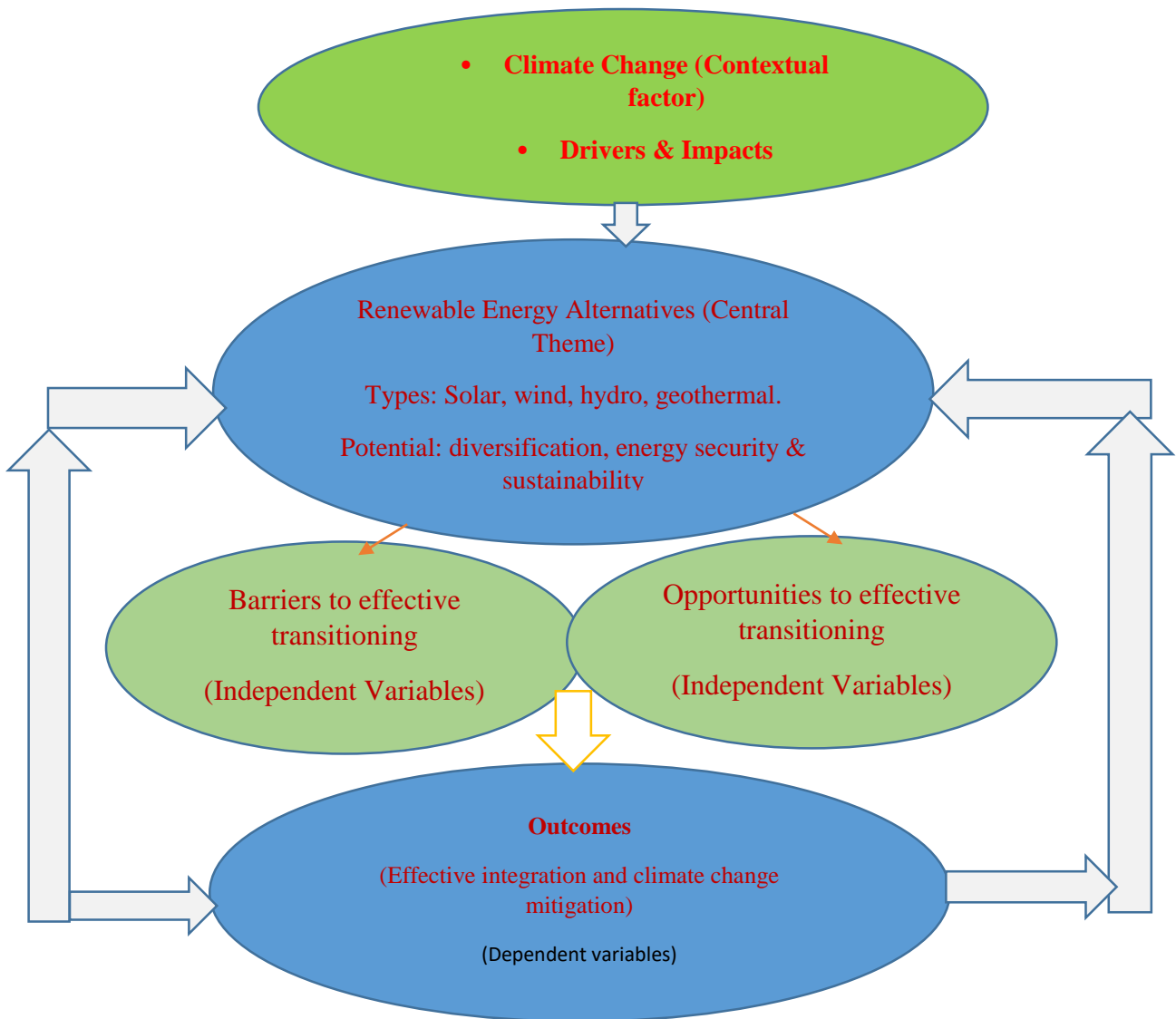


Figure 1: Conceptual Framework

## 2.11 Knowledge gap

In November 2018, Renewable Energy Solutions for Africa undertook studies on enhancing the renewable energy transition in Zambia which addressed and gave solutions related to electricity tariffs, market, costs, financial risks, managing environmental and social risks to achieve bankability for renewable projects in Africa, energy solutions to foster economic development, innovation and construction models for renewable energy and did not necessarily provide barriers and opportunities. Furthermore, a study by Mudenda et al (2018), looked at the Renewable Energy Technologies Capacities and Barriers Affecting Successful Deployment in Zambia with a particular focus on households and it postulates that barriers to successful adoption of clean energy technologies include underserved populations, policy inadequacies; underexploited renewable energy sector and heavy reliance on a service-challenged hydro-

power utility. The study found that most of the challenges are institutional in nature, and recommended for a baseline assessment to understand knowledge, perceptions, attitudes and drivers for renewable energy technology adoption among households.

Different studies undertaken on renewable energy give lean information on barriers and opportunities to effective transitioning at national and even local level (Mudenda et al, 2018; Kunda et al, 2012).

Renewable energy today has shifted to become a global focus because renewable energy can supply two-thirds of the total global energy demand, and contribute to the bulk of the greenhouse gas emissions reduction that is needed between now and 2050 for limiting average global surface temperature increase below 2 °C (Gielen et al, 2019). This has amplified the need for transitioning (Renewable Energy Solutions for Africa, 2018). Many African countries are also seeking to diversify their energy mix which leads to positive changes with regard to climate. However, the development of methods that can overcome barriers to transitioning and enhance opportunities appears to be constrained by the absence of empirical information on the integration of alternatives and their contribution.

Moreover, researchers have determined that renewable energy alternatives, climate change, transitioning, energy integration, and policy have a relationship with transformative effects and these factors may be interlinked (Table 2). But despite this, not many academic studies have focused on addressing the integration of renewable energy alternatives in response to climate change with a focus on barriers and opportunities to effective transitioning. This is another critical research gap.

Regardless of the different studies reviewed (Table 2) and many more studies being undertaken, there is still more need to focus on the integration and transitioning aspect with regard to Climate Change. This study therefore focuses on integration of three renewable energy alternatives namely Hydro, Solar and Wind energy.

Table 2: Selected related studies on renewable energy

Author (s)/year	Title	Objectives	Findings	Knowledge Gap
Ata, 2018	A Systematic Literature Review of the Economics of Renewable Energy	To overview economics of renewable energy with its drivers such as cost, learning curve, demand and supply	<ul style="list-style-type: none"> <li>Identified developing renewable energy sources which can play an important role especially in reducing dependence on imported energy products such as oil and gas and reduced emissions of greenhouse gasses.</li> <li>The huge potential of renewable energy sources is adequate to meet the world energy demand many times over.</li> <li>the adoption of a renewable energy policy is an important strategy for improving environmental factors and the substitution of fossil-based energy sources for electricity generation</li> <li>Renewable energy technologies can improve choice in energy supply markets contribute to long-term sustainable energy supplies</li> <li>renewable energy is the inevitable choice for sustainable economic growth.</li> </ul>	Renewable energy alternatives, climate change, transitioning, energy integration, and policy have a relationship with transformative effects and these factors may be interlinked but there is a critical research gap on this link. These reviewed studies so far have not focused on the critical link between renewable energy and climate change and yet in essence, renewable energy plays a key role in both reducing the causes of climate change and helping societies adapt to its impacts by promoting sustainability, energy security, and reducing environmental degradation.
Seetharaman, Krishna, Nitin., Patwa, Saravanan, and Gupta Y. (2019)	Breaking barriers in deployment of renewable energy	to find out the impacts of social, economic, technological and regulatory barriers in the deployment of renewable energy.	<ul style="list-style-type: none"> <li>social, technological and regulatory barriers have a strong influence on the deployment of renewable energy, while economic barriers significantly influence it indirectly</li> </ul>	
Kaunda, Cuthbert. Kimambo, and Torbjorn, (2012)	Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa	To discusses the small-scale hydropower in Sub-Saharan African region and its potential in alleviating electricity supply shortage especially in rural communities	<ul style="list-style-type: none"> <li>The SSA region has very low electricity access levels coupled with various challenges.</li> <li>Small hydropower technology is one of the promising decentralised power generation systems for rural electricity supply in the region.</li> <li>SSA has significant hydropower resources, but the level of installation is very low.</li> </ul>	

Author (s)/year	Title	Objectives	Findings	Knowledge Gap
			<ul style="list-style-type: none"> <li>Challenges hampering SHP technology development in the region include climate change, finance, and policy.</li> </ul>	
Ministry of Water Development-committee on energy, water development and tourism (2015)	Report on the Promotion of Renewable Energy Sources in Rural Areas in Zambia for the period 2015 to 2019, for the Fifth Session of the Twelfth National Assembly	To facilitate increased access to Renewable Energy Sources (RES) to targeted rural beneficiaries	<ul style="list-style-type: none"> <li>Lack of Specific Legislation and Regulatory Framework for Promotion of Renewable Energy Technologies, Lack of Strategic Plan, Policy Emphasis on Grid-Connected Hydropower at the Expense of other Renewable Technologies, lack of data on Resource Potential and Consumption of Renewable Energy Sources, Beneficiaries in rural areas not accessing energy from renewable sources</li> </ul>	
Mudenda, Makashini, Malama, and Abanda (2018)	Review of Renewable Energy Technologies in Zambian Households: Capacities and Barriers Affecting Successful Deployment	To review the requisite capacities of households for the adoption of renewable energy services and expounds on some of the barriers hampering renewable energy among households	<ul style="list-style-type: none"> <li>The study found that most of the challenges to deployment of renewable energy are institutional in nature, and recommended for a baseline assessment to understand knowledge, perceptions, attitudes and drivers for renewable energy technology adoption among households</li> </ul>	
Renewable Energy Solutions for Africa (2018)	Enhancing the Renewable Energy Transition in Zambia- Position papers	To highlight renewable energies initiatives and foster achievement of a sustainable energy future.	<ul style="list-style-type: none"> <li>Identification of non-economic barriers to transitioning such as regulatory uncertainty, market barriers, institutional and administrative, public acceptance and environmental barriers.</li> </ul>	

## CHAPTER THREE: DESCRIPTION OF THE STUDY AREA

### 3.0 INTRODUCTION

This Chapter highlights the characteristic features and basic facts about the study area so as to give a more focussed approach on Zambia.

#### 3.1 Location

Zambia is a large, landlocked, resource-rich country, with a sparse population, in the centre of Southern Africa and shares its border with eight countries (Angola, Botswana, the Democratic Republic of Congo, Malawi, Mozambique, Namibia, Tanzania, and Zimbabwe) that serve as an expanded market for its goods. It is situated on a high plateau with 10 provinces (Figure 2) and takes its name from the Zambezi River.



Figure 2: Zambia Provinces Map,

Source: Nations online

## **3.2 PHYSICAL ENVIRONMENT**

### **3.2.1 Topography**

Zambia covers an area of approximately 752,612 km<sup>2</sup> and 60% of it is covered by woodlands and forests. It consists for the most part of a high plateau, with an average height of between 1060 and 1363 meters above sea level and isolated mountain ridges that rise to more than 1,829 meters with an occasional peak above 2,134 meters on the eastern border, called Nyika Plateau (GRZ, 2020).

The country is subdivided into five physiographic regions, namely: The main northern plateau running the length of the Congo-Zambezi watershed from Central Zambia to Isoka in Muchinga province. These are part of the sources of the Zambezi and Congo River systems. The southern plateau stretching from Choma to Kalomo and lying between the Kafue flats to the north-west and the Zambezi Valley to the South. Its configuration is equally influenced by the Zambezi River and one of its major tributaries the Kafue River. The eastern plateau which covers most of Eastern and extreme northern part of Muchinga provinces. It also has a small intrusion of the Nyika plateau with its highly specialized Montane ecosystems. The highlands surrounding Lake Bangweulu and stretching from Kasama in Northern to Mansa in Luapula provinces. This system forms part of the drainage of the Congo River basin with other major lakes such as the Mweru and Mweru Wantipa and wetlands such as the Bangweulu wetlands. The Copperbelt and North-western highlands forming a low-lying ridge from Masaiti through Ndola to Solwezi and Kasempa. This ridge at its most northerly edge forms south and south-west physical divide between the Congo and Zambezi River basins (Mozambique-Zambia Interconnector EIS, 2022).

The rest of the Zambian land area is characterized by a number of low-lying areas categorized as flood plains, grasslands, valley depressions and wetlands. The most prominent river flow influenced grasslands are the Bangweulu, Barotse, Kafue flats and Busanga wetlands. The valley depressions are part of the extension of the Great Rift Valley and form the natural flow lines of the Zambezi River basin and are referred to as the Zambezi valley.

### **3.2.2 Climate**

Zambia experiences a predominantly sub-tropical climate characterised by three distinct seasons, namely a hot and dry season (mid-August to mid-November), a wet rainy season (mid-November to April) and a cool dry season (May to mid-August). Rainfall is strongly influenced

by the movement of the Inter-Tropical Convergence Zone (ITCZ) as well as the El Nino/Southern Oscillation (ENSO) phenomenon and varies from an annual average of 600 mm in the lower south up to 1300 mm in the upper north of the country (Mozambique - Zambia Interconnector EIS, 2022).

Average temperatures are moderated by the height of the plateau. Maxima vary from 15 - 27° C in the cool season with morning and evening temperatures as low as 6 - 10° C and occasional frost on calm nights in valleys and hollows which are sheltered from the wind. In the cool season, the prevailing winds, dry south easterlies, come from the southern hemisphere belt of high pressure. Invasions of cold air from the south-east bring cloudy to overcast conditions. During the hot season, maximum temperatures may range from 27 - 35°C (Figure 3). However, the mean annual temperature ranges between 18 - 20°C. The highest annual average temperature is 32 °C and the lowest temperature averages 4°C. Annual temperature variation is greatest at Livingstone, the most southerly town and least at Mbala, the town nearest the equator (World Bank 2021).

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### **3.2.4 Hydrology**

Zambia has two main river systems; the Zambezi and its tributaries - Kafue and Luangwa, which flows to the Indian Ocean; and the Chambeshi - Luapula River system (Figure 4), which is part of the Congo River basin. The Zambezi River basin is the fourth largest river basin in Africa, with an area of 1,390,000 km<sup>2</sup>. The Zambezi River rises in black marshy dambos in North-western Zambia, about 1,585 m asl. The 2,574-kilometre-long river then flows through eastern Angola, along the eastern border of Namibia and the northern border of Botswana, then along the border between Zambia and Zimbabwe to Mozambique, where it crosses that country

to empty into the Indian Ocean. The Zambezi River is the major hydropower resource in southern Africa and Zambia's territory occupies a larger area of the river basin, at 41 per cent, than any of the other seven riparian nations.

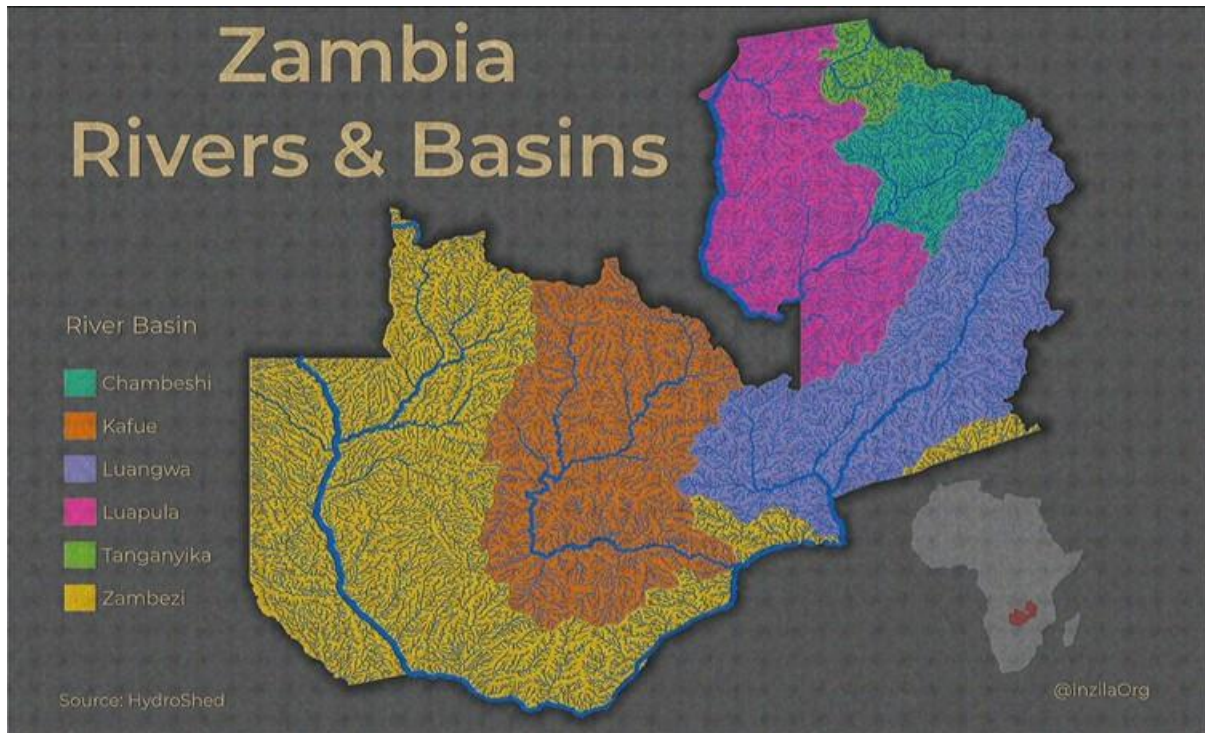


Figure 3: Zambia Rivers and Basins

Source-Hydroshed

### 3.2.5 Sunshine

Average annual hours of sunshine range from more than 3,000 in the southwest to less than 2,600 on the eastern border (Robert *et al*, 2022). Southern Zambia is one of the warmest regions in Zambia with an average daily high temperature of 31 degrees. It is yearlong warm or hot. The number of hours of sunshine refers to the time when the sun is actually visible. That is, without any obstruction of visibility by clouds, fog or mountains. With 11 hours per day, August is the sunniest month in the region of Southern Zambia. In December, the sun shines the shortest (World data, 2022).

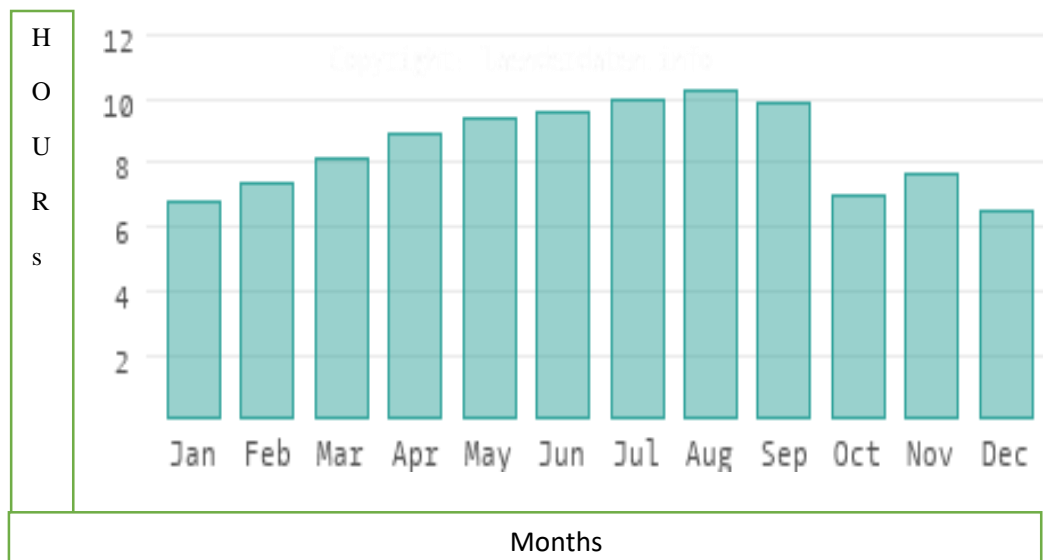


Figure 4: Average hours of Sunshine per day for different months in Zambia,

Source-World data 2022

### 3.2.6 Winds

Winds are predominantly easterly-south easterly, although in the rainy season winds blow from the northwest and north. Wind speeds are rarely strong enough to cause damage (World Bank, 2018). The windier part of the year lasts for 4.2 months, from July 13 to November 21, with average wind speeds of more than 9.6 miles per hour. The windiest month of the year in Lusaka, the capital city is October, with an average hourly wind speed of 12.4 miles per hour (World data, 2022).

In summary, Zambia's topography, climate, hydrology, and sunshine hours play a key role in determining the potential for renewable energy sources. The country's varied landscape, particularly its river systems like the Zambezi and Kafue Rivers, makes it highly suited for hydropower generation, with significant dams already in place. The tropical climate and abundance of sunshine across most regions, with up to 3,000 hours annually, make solar energy a highly viable option, especially in the dry season when skies are clearer. However, Zambia's wind patterns are generally weak, limiting the potential for large-scale wind energy projects, although localized areas with higher wind speeds may still have some wind energy potential. (World Bank, 2021).

While Zambia's hydropower is vital to its energy mix, the potential for geothermal energy is limited due to the lack of significant geothermal resources. The country's climate and topography, however, offer substantial opportunities for solar power generation, especially in areas with consistent sunlight. Overall, Zambia's geographic and climatic conditions favour

solar and hydropower energy development, while wind and geothermal resources are less prominent. This understanding helps inform energy planning by directing resources and investments to the most appropriate regions for each renewable energy source (World Bank, 2021).

### **3.3 Socio Economic Environment**

#### **3.3.1 Population**

According to the 2022 census of population and housing, Zambia's population as of 8th September 2022 was 19,610,769. The male population was 9,603,056 and the female population was 10,007,713. The population more than quadrupled from 4,056,955 in 1969 to 19,610,769 in 2022.

#### **3.3.2 Employment**

The LCMS (2015) results indicate that 43 percent of the population aged 12 years or older were in paid employment while 27 percent were Full-Time Students and 6.3 percent were Unpaid Family Workers. The unemployed made-up 9.2 percent of the working-age population.

#### **3.3.3 Economic Activities**

Zambia's economy is predominantly driven by mining, particularly copper extraction, which constitutes approximately 70% of the nation's export earnings and about 15% of its Gross Domestic Product (GDP). Despite this substantial economic contribution, the mining sector accounts for only 2.4% of total employment, highlighting its capital-intensive nature. The industrial sector, encompassing mining, construction, and manufacturing, contributes around 35.3% to Zambia's GDP and provides employment to about 10% of the workforce (ILO 2022).

The COVID-19 crisis exacerbated Zambia's fragile macroeconomic situation in 2020. The economy contracted by 1.2 percent, reflecting the impact of lockdown measures and external shocks due to the pandemic. Poverty is estimated to have increased by just over 1 percentage point to 59.7 percent (World Bank, 2022). According to the World Bank World Development Indicators (2022), Zambia's national average monthly household income was ZMW 1,801 (ZMW 810 for households in rural areas and ZMW 3,152 for households in urban areas) (World bank, 2022).

### **3.4 Reason(S) For the Choice of the Study Area**

The Zambia Renewable Energy Financing Framework cites the Indaba Agricultural Policy Research Institute (IAPRI) (2016) stating that for most developing countries in Sub-Saharan Africa (SSA), electricity generation is hydro based, with only Botswana, South Africa, Tanzania, and Angola producing significant amounts of power using other sources. As such, power shortages are usually associated with droughts and erratic rainfall patterns. Despite the rapidly growing electricity demand by various consumers, there have been limited investments in expanding electricity generation capacity, with little effort made to replace the aging electricity infrastructure. What is also clear is that there is very little diversity in the energy generation mix, with only Angola, Zimbabwe, and Tanzania generating significant amounts of power from other generation sources than hydro (IAPRI, 2016).

In view of the aforementioned, it is clear that without adaptation, the societal consequences of this general drying trend, with more frequent intense rainfall events, could be profound. The energy sector is very much threatened by this expected trend.

## **CHAPTER FOUR: METHODOLOGY**

### **4.0 INTRODUCTION**

The methodology for the study is presented in this chapter. The elements are philosophical position, research design, the sample size and the research tools. It also outlines the methods that were used to acquire the data and how it was analysed in order to find the answers to the research questions.

### **4.1 Philosophical Assumptions**

Research philosophy refers to a system of beliefs and assumptions about the development of knowledge. A research philosophy serves as a compass that guides the procedures and methodologies used in the study. It includes how the researcher views the world and how information about it can be gathered and verified (Saunders et al, 2009). For this research, the principal focus is to unveil the barriers and opportunities in effectively transitioning to renewable energy alternatives. In congruent with study's objectives, the constructivist approach was adopted. This is the view that the understanding of climate change and renewable energy is constructed through human experiences and social contexts. This would imply that perceptions of barriers and opportunities are shaped by cultural, social, and individual factors. Epistemologically, the Interpretivist philosophy was adopted. According to interpretivism, reality is neither stable or distinct, but rather formed based on people's experiences, perceptions, and cultural settings (Bryman, 2016). In this research interpretivism is the belief that knowledge is gained through understanding subjective experiences and the meanings individuals or groups attach to the process of integrating renewable energy. This would support qualitative methods to explore different perspectives and experiences. Axiologically this research embraces the assumption that research can be conducted objectively without letting personal values or biases influence the outcomes, focusing on a more neutral analysis of barriers and opportunities.

### **4.2 Research Approaches**

This study employed a qualitative method approach in achieving the intended outcome. In line with the objective to generate an atlas of energy alternatives with comparative advantage in different geographical regions of Zambia, differences in methodology (such as the relative value of qualitative information), methods and tools, ways of representing space, appropriate spatial scale, time and other inputs, were all included in an epistemological and methodological

application of standard GIS (Orban-Ferauge et al., 2011). Further, qualitative studies stress the depth and diversity of participants' viewpoints.

### **4.3 Research Design**

Research design is the overall plan for connecting the conceptual research problems to the pertinent and achievable empirical research. It is an inquiry which provides specific direction for procedures in research (Creswell & Creswell 2018). The study applied exploratory research. Exploratory research focuses on investigating what is happening, asking questions, seeking new insights, assessing phenomena in a new light, as well generating ideas and hypothesis for future research (Robson, 2002). Therefore, exploratory research necessitated implementation of Participatory Geographical Information System (PGIS) in the generation of an atlas of energy alternatives with comparative advantage in different geographical regions of Zambia. PGIS was used to integrate key expert's perspectives, geographic information data, exploratory tools and structured discussion in order to use and maximize the knowledge, expertise, and experience of multiple stakeholders.

### **4.4 Population and Sample Size**

The sampling approach used under non-probability was homogenous purposive sampling. A homogenous purposive sample is one that is selected based on the knowledge of a population and the purpose of the study. In this case homogenous purposive sampling procedure was used to select key players in the renewable energy sector who included Energy Regulation Board (ERB), Zambia Electricity Supply Corporation (ZESCO), Ministry of Energy (MoE), Rural Electrification Authority (REA) and Two Independent Power Producers (IPPs). In addition, Zambia Meteorological Department (ZMD) formed part of the sample population as they were key in the generation of an atlas of energy alternatives. This brought the sample size to a total of Seven (7) representatives. These were purposively sampled because they are key experts in the industry and each answered a particular need for the research based on position and knowledge of the phenomena under study. In this research study, the researcher selected one representative from each of the above stated institutions as they were specifically targeted.

### **4.5 Data Collection Instruments**

Primary data was collected from key informant interviews using an interview guide and a questionnaire. Flick (2006) submits that the purpose of an interview in research "is to reveal existing knowledge in a way that can be expressed in the form of answers and so become

accessible to interpretation. Interview guides were used as data collection Instruments. Furthermore, a questionnaire was also used. The questionnaire was carefully structured using the five-point Likert Scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire consisted of three sections. The first section particularised barriers to renewable energy integration. The second section covered opportunities for effective transitioning and in the third section respondents were asked to state their general perception of renewable energy integration. The questions were formulated from the research questions provided in section 1.5. The research questions addressed the research objectives by breaking them down into specific, manageable queries that formed the interview guides.

#### **4.5.1 Key Informant Interviews**

The purpose of key informant interviews is to collect information from a wide range of stakeholders including community leaders, professionals, or residents who have first-hand knowledge about the topic of discussion (Zohrabi 2013). Key informant interviews were conducted with representatives as highlighted in section 4.4. These were purposively identified as the necessary ones to the needs of the study i.e., representatives in renewable energy, climate data, survey and GIS software from the institutions. In Summary Primary and Secondary data that meets the objective to generate an atlas of energy alternatives with comparative advantage in different geographical regions of Zambia was collected as outlined in the table below:

Table 3: Primary and Secondary Data sources

<b>RENEWABLE ENERGY RESOURCE</b>	<b>DATA COLLECTED</b>	<b>SOURCE</b>
<b>Phase 1: Key Informant interviews</b>		
Solar	Sunlight data, location, latitude, Climate system	Zambia Metrological Department (ZMD)
Wind	Topography, Land cover, Infrastructure, Climate data	ZMD, ZESCO, REA
Geothermal	Geological, hydrological, hot spring/thermal data and GPS coordinates for identified sites	ZESCO, REA
Hydro	Slopes and flow data, GPS coordinates for potential sites	ZESCO, Independent Power Producers (IPPs), REA, Industrial Development Corporation (IDC)
<b>Phase 2: other data sources</b>		
Solar	Available sunlight hours, intensity	SASSCAL <a href="http://www.sasscalweathernet.org/">http://www.sasscalweathernet.org/</a> Global Solar Atlas <a href="https://globalsolaratlas.info/map">https://globalsolaratlas.info/map</a> , publications and other web-based sources
Wind	Wind speed and Direction	Global Wind Atlas <a href="https://globalwindatlas.info/en">https://globalwindatlas.info/en</a> , journal publications and other web-based sources
Geothermal	Remote sensing data from satellites	Local institutions such as Ministry of Energy, ERB, ZESCO, internet sources, etc
Hydro	Identified hydropower watersheds and rivers	Web based sources, Local institutions such as ERB, ZESCO, etc

Steps in mapping of Solar, Wind, Geothermal and Hydro energy resources and assessment of viability of integration

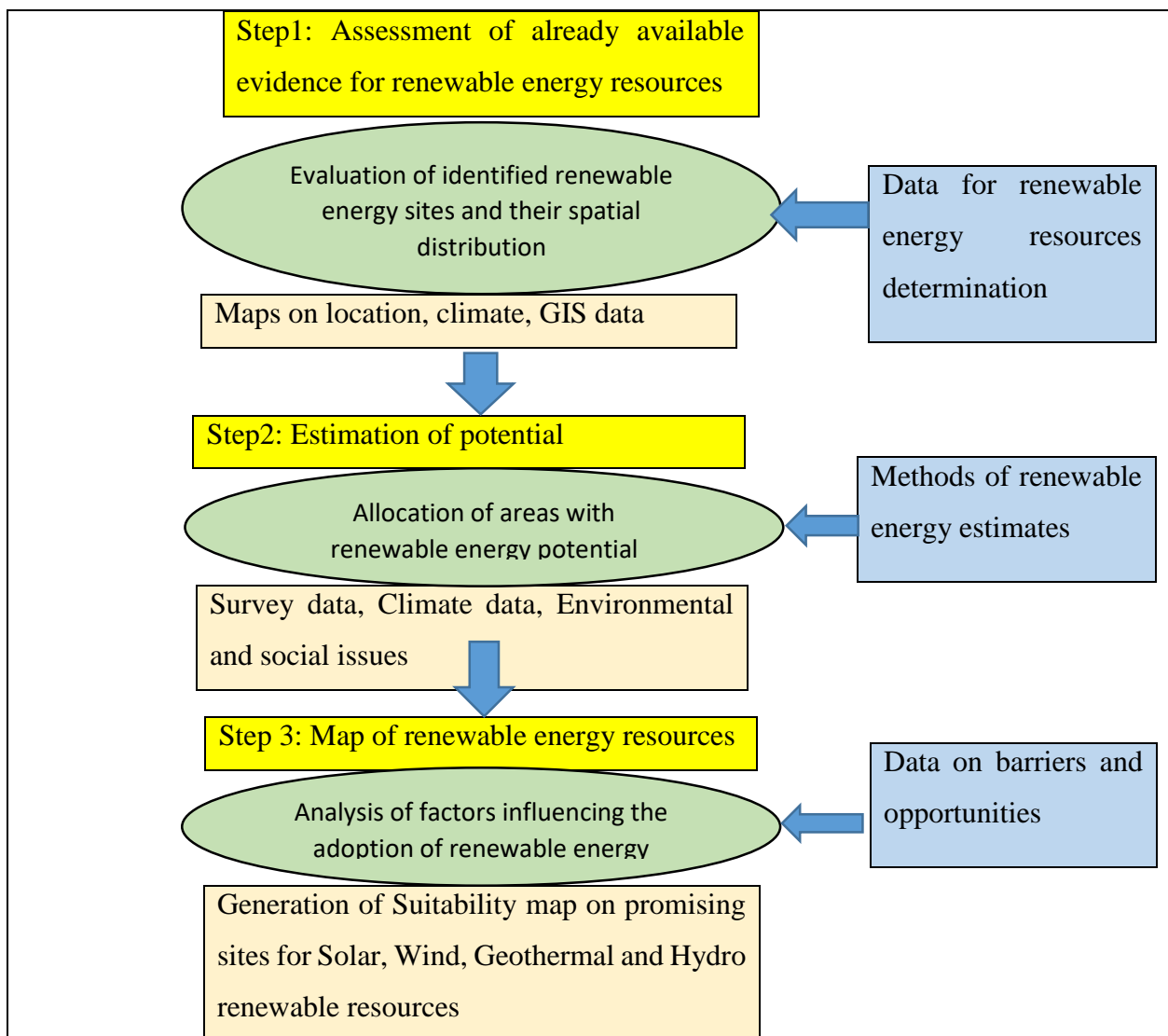


Figure 5: Structure of mapping of Solar, Wind, Geothermal and Hydro energy resources and assessment of viability of integration

#### 4.6 Data collection Procedure

The following was undertaken in the collection of data for this research.

Step 1: Data was collected in form of reviewing existing literature on the subject matter, visiting websites highlighted in Table 3 and any other in the area of interest, furthermore, books, maps, articles, policy documents as well as unpublished data were reviewed.

Step 2: Primary data was collected through in-depth key informant interviews through the following process;

- Development of in-depth interview guides
- Identification of purposive respondents and contacts
- Contacting and securing appointments with respondents
- Holding face to face interviews
- Recording and storing of data collected during interviews by note taking and audio recording.

#### **4.6.1 Development of the Energy Atlas Map**

A Participatory Mapping approach was undertaken in the generation of an atlas Map for renewable energy alternative. The key informants indicated potential sites on a map of Zambia printed on A3 paper, based on their expert knowledge. Cochrane & Corbett (2018) acquiesce that Participatory mapping is a mapmaking process that strives to make visible the relationship between a place and local groups through the use of cartography. They further submit that Participatory maps provide a unique visual representation of what a community perceives as their place and identify features of significance within it – both physical and sociocultural. Participatory mapping employs a range of tools. These include sketch mapping, transect mapping, and participatory three-dimensional modelling. More recently, participatory mapping initiatives have begun to use geographic information technologies including Global Positioning Systems (GPS), aerial photos and remote-sensed images (from satellites), geographic information systems (GIS), and the geospatial web (Johnson, 2017).

In this study, Participatory mapping acknowledges the inherent importance of creating an atmosphere where participants are given the opportunity to voice their opinions. Hence the key informants indicated in section 4.3 were engaged in sketch mapping as a participatory mapping tool which involved drawing features and explaining areas of interest on a map.

According to Elwakil et al, (2015) Geographical Information Systems (GIS) are defined as an organised collection of computers hardware, software, geographical data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information. This software was utilized in the analysis and interpretation of participatory GIS data for this study. Information from the sketch map was digitized so that it could be analysed and interrogated using computer GIS software, resulting in the generation of a renewable energy atlas map.

#### **4.6.2 Investigating the viability of integrating different energy alternatives**

In addition to interviews, a survey was conducted on key informants using a Likert scale in answering the second objective i.e., investigating the viability of integrating different energy alternatives. The Likert scale was used to support the explanation of the themes derived from the thematic analysis. As highlighted earlier, Thematic analysis approach provides the opportunity to group data into codes, summarise the codes into categories, and tabulate the data to calculate the frequency of identified concepts hence the use of a Likert scale (Appendix 2).

In its final form, the Likert scale is a five (or seven) point scale that is used to allow an individual to express how much they agree or disagree with a particular statement. The Likert scale (typically) provides five answers to a statement or question that allows respondents to indicate their positive-to-negative strength of agreement or strength of feeling regarding the question or statement (Jamieson, 2004). Likert scales results were used to provide context and support for the thematic analysis.

Jamieson (2004) submits that the response categories in the Likert scales have a rank order but the intervals between values cannot be presumed equal. Participants provided their opinions or attitudes on the integration of different energy alternatives.

#### **4.7 Data Analysis**

Data collected which was mainly qualitative in nature was analysed by thematic techniques based on data transcription, organisation and interpretation as well as validation. This formed the basis for generation of an Atlas Energy map and assessment of viability of integration of the renewable energy alternatives

Thematic Analysis Method was employed in analysing data that was collected through key informant interviews and Likert Scale survey. Data was transcribed and analysed through the following process;

- Codes based on the research objectives and research questions were generated and these included keywords
- The codes were then categorised and organised into themes and further sub-themes which emerged through the coding process
- Data was interpreted by identifying any reoccurring themes throughout and highlighting any similarities and differences in the data

- The final stage involved data verification, i.e., checking validity of understanding by rechecking the transcripts and codes again, thus allowing the researcher to verify or modify data already arrived at previously (Sarantakos, 1998)

#### **4.8 Testing for Validity and Reliability**

Qualitative data follows a set format to ensure its quality. In this study, testing for validity and reliability was done using credibility, transferability, dependability, conformability, and trustworthiness which are Guba's (1981) Four reliable procedures suitable for all qualitative studies. The meaning of these four criteria as approaches to research consistency is explained in depth with regard to this study. Korstjens and Moser (2018) contemplate the concept of "credibility" in relation to qualitative research. The goal of credibility is to give a detailed explanation of the research procedure, including the methods used to gather and evaluate the data (Bengtsson, 2016). In qualitative research, this is a crucial stage because it fosters "confidence in the truth of the research findings (Korstjens& Moser, 2018). Put another way, expressing and interpreting the participants' initial opinions in the most open, accurate, and understandable manner is what it means to be credible. Dladla (2017) says that "making the research findings believable" is what credibility is all about. Cope (2014) finds that the credibility in a qualitative study is maintained when researcher displays engagement, methods of observation, and audit trails. There are many strategies that can be used to achieve credibility in qualitative research. These strategies include triangulation, member checking, peer examination and interview technique (Korstjens& Moser, 2018).

Triangulation, which refers to the utilization of numerous data collection techniques, was applied in this study. These techniques included key informant interviews and Likert scale questionnaire. The technique of comparing data gathered from multiple sources in order to explore the extent to which findings can be verified is known as triangulation (Houghton et al., 2013) and one of its goals is data confirmation. The use of several data collection methods as encouraged by one who have proposed that qualitative interviews, for example, can be paired with document analysis or other data collection approaches.

Credibility was also improved through member checks. Since the participant and the researcher may have different perspectives on and interpretations of the same data, member check is about gathering participant comments to improve the data (Korstjens & Moser, 2018). Stated differently, member check is the procedure whereby research participants are asked to verify that the work that has been completed accurately reflects what they (participants) have said.

Additionally, data quality was guaranteed by contextualizing the results with findings from other studies that brought fresh information to the body of knowledge and ensured transferability.

Reliability was achieved by undertaking Member Checks or Expert Views to make research tools dependable. Conformability was achieved through the use of "Bracketing" or "Epoch," which took participant information and reported it verbatim (Guba and Lincoln, 1994). "A single and most critical technique for establishing credibility" was considered to be member verification (Guba and Lincoln, 1989). Member check was accomplished by presenting all of the results to the interested individuals at the conclusion. As a result, participants were able to evaluate the results critically and offer feedback, and they confirmed that the results accurately reflected their opinions, emotions, and experiences. However, in order to guarantee reliability, it is imperative to underscore the significance of triangulation in this particular situation in order to mitigate the impact of investigator bias. Therefore, the qualitative researchers think about member verification, triangulation, careful transcribing, methodical planning, and coding to ensure the rigor and reliability.

Participatory mapping approach was employed as it does not cause unwarranted harm to stakeholders hence use of this approach for validation of the Energy Atlas data as well as the process.

#### **4.9 Ethical Considerations**

Ethical approval and clearance were obtained from the National and applied Sciences Research Ethics Committee (NASREC) (Appendix 6). The study ensured that participants' consent was obtained. Participants received information about the study's goals and their part in the investigation. The respondents were also given the assurance that their responses would be treated with the highest confidentiality, privacy, and anonymity throughout the research.

To protect the participants' anonymity, the researcher gave a symbol to each one. Assigning symbols to participants was critical for the clarity and specificity of the source data. Symbols used in presenting and interpreting outcomes serve two purposes: concealing participant identities and presenting study conclusions. This ensures confidentiality. Symbols aid in data analysis by allowing researchers to easily discover recurring themes. The Key informants were symbolised as KI and had numbers 1 to 7, and the year was also included. For example, KI 6, 2023. Data collected from the research that is subject to privacy constraints was kept in a secure location that only authorised people can access e.g., the Supervisor or the Researcher.

## CHAPTER FIVE: RESULTS

### 5.0 INTRODUCTION

This chapter presents results obtained in line with the specific objectives of the study and research questions as follows: (1) What is the potential for establishing different energy alternatives to hydropower in Zambia? (2) Which geographical regions have higher potential of energy alternatives (3) Which renewable energy alternatives have a comparative advantage in different geographical regions of Zambia? (4) What is the viability of transitioning to various renewable alternative energy sources? (5) What are the barriers and opportunities to integrating different energy alternatives in Zambia?

#### 5. 1. Potential for different energy alternatives to hydropower in Zambia

Key informants interviewed stated that alternative energy sources in Zambia are important and have been found to be viable. One key informant said that:

*“There is no need to continue to be dependent on hydro. Green energy is very commercially viable and good for environmental sustainability” (KI 4, 2023)*

Another Key Informant had this to say:

*“Due to the erratic rain pattern, other forms of renewable energy have the ability to make a positive contribution to the national energy mix” (KI6, 2023)*

Zambia has abundant Renewable Energy resources including solar, wind, Geothermal and hydro (Table 4) which if well explored can help diversify the energy mix and reduce dependence on fossil fuels.

Table 4: Identified renewable energy sources and rating of their potential of establishing them in Zambia

Renewable energy source	Average Key informant Score (1-10, with 1 being completely low and 10 being highest)	Explanation of the score
Solar	7	Easy to develop but does not provide baseload unless coupled with an energy storage system like utility battery
Hydro	8	It can be capital intensive and has high environmental cost but can provide baseload even if it is susceptible to climate changes
Geothermal	6	Limited to geographical area, capital intensive and has high costs with fairly high environmental costs. Long lead time to deploy because the exploration is more like mining
Wind	7	Similar as Solar, but not available when wind is not there

(Source: Field data, 2024)

Research results show that Geothermal and Wind have an average key informant score of 6 and 7, respectively, (Table 4) implying that while promising, it currently has the lowest viability due to high costs and uncertain resource potential, warranting further exploration and pilot projects before large-scale deployment.

## 5.2 Geographical regions with higher potential for renewable energy alternatives

An atlas energy map of alternatives was generated using GIS software (Figure 8) as follows;



Forty-five (45) sites with untapped potential for Solar, Hydro, Wind and Geothermal were identified on the atlas energy map. For solar energy, it was based on available data on the strength and duration of sunlight throughout the year in the given areas. Wind energy included looking at available data on wind patterns and velocity. Similarly, for hydropower, and geothermal energy.

Twelve (12) sites had hydropower potential twenty (20) sites had solar power and the remaining comprised of Geothermal with three (3) sites and ten (10) sites for Wind energy. The results on the map show that Lundazi, Kasama, Nakonde, Isoka, Serenje, Chongwe, Kabwe, Mumbwa, Sesheke, Senanga, Mongu, Limulunga, Shangombo have higher potential for Solar energy. Chama district displays potential for all the four forms of renewable energy alternatives (Figure 8) hence has greatest potential for development, entailing that there's opportunity to prioritize investments in this district. Based on the Energy Atlas map (Figure 8) results reveal that Geothermal potential seems to be in districts that lie along the escarpment. A summary of sites with renewable energy potential is outlined in Table 5.

*Table 5: Summary of renewable energy sites*

S/N	Renewable Energy Alternative	No. of sites	Percentage	Geographical Location (Districts)
1.	Solar	20	44%	Lundazi, Kasama, Nakonde, Isoka, Serenje, Chongwe, Kabwe, Mumbwa, Sesheke, Senanga, Mongu, Limulunga, Shangombo
2.	Hydro	12	27%	Nchelenge, Chiengi Kaputa, Nsama, Mwense, Mansa, Sioma, Senanga, Chavuma, Mwinilunga
3.	Wind	10	22%	Chipangali, Chadiza, Mansa, Mpika, Chitambo, Serenje, Chisamba, Choma, Mwinilunga
4.	Geothermal	3	7%	Rufunsa, Chama
	<b>TOTAL</b>	<b>45</b>		

### **5.3 Renewable energy alternatives that have a comparative advantage in different geographical regions of Zambia**

#### **5.3.1 Solar Energy**

Solar energy potential analysis was based on factors such as sunlight intensity, duration, geographic location, and land use. Districts such as Lundazi, Kasama, Nakonde, Isoka, Serenje, Chongwe, Kabwe, Mumbwa, Sesheke, Senanga, Mongu, Limulunga and Shangombo have particularly good solar resources as they generally experience high levels of sunlight

throughout the year. According to the Key informants Lundazi District is very sunny with a sunlight level of 700-peak watts' hour Sq. which are optimal for solar energy exploitations.

Solar was identified to have high comparative advantage with 44% coverage followed by hydro with 27% (Table 2).

One of the key informants stated that:

*“We can just say that sunlight is literary everywhere in the country” (KII,2023)*

Study results show that the effectiveness of solar energy systems depends on the amount of sunlight they receive, typically measured in peak sunlight hours. According a Key informant, Zambia lies within the Sun Belt and the required and optimal sunlight hours for efficient solar energy production requires at least 4-5 hours of direct sunlight per day to be viable. This amount of sunlight can provide enough energy to make solar installations practical and worthwhile. Furthermore, solar energy systems benefit from 5-7 peak sunlight hours per day. This range maximizes the energy output and efficiency of solar panels.

In addition, Zambia is blessed with abundant sunlight, receiving an average of 6-8 peak sunlight hours per day across various regions. This shows the opportunity for solar energy projects. The Key Informant stated that specific districts might have slight variations, but generally, the country is well-suited for solar energy production.

A key informant also submitted that:

*“Identifying and assessing these potential sites requires comprehensive studies considering technical, environmental, and social factors. Factors such as land availability, environmental impact, proximity to existing infrastructure, and community engagement should be considered when planning and implementing renewable energy projects.” (KI 3, 2023)*

### **5.3.2 Wind Energy**

Results revealed that districts where wind energy could be possible include Chipangali, Chadiza, Mansa, Mpika, Chitambo, Serenje, Chisamba, Choma and Mwinilunga. Furthermore, Mansa district has potential for wind energy due to its relatively open terrain hence it could be worth investigating. Some areas such as Chadiza have more open landscapes and less vegetation, hence they might have modest wind energy potential and could be explored for wind energy projects.

It was revealed that Mpika district has open terrain and a higher elevation and therefore might experience more favorable wind conditions. While Southern Province is better known for its solar potential, there may still be pockets with moderate wind resources, particularly in districts with more varied terrain such as Choma.

### 5.3.3 Hydro Energy

Results show that districts with potential for hydro energy include Nchelenge, Chiengi Kaputa, Nsama, Mwense, Mansa, Sioma, Senanga, Chavuma and Mwinilunga. Chavuma District for instance, is located along the Zambezi River and has potential for hydroelectric power generation, particularly with smaller-scale projects or run-of-the-river installations.

According to the Key informants, districts such as Mansa located in Luapula Province which is known for its numerous rivers and water bodies, including the Luapula River and Lake Bangweulu has potential for hydroelectric power generation, either through large-scale dams or smaller run-of-the-river projects.

Districts in Northern Province, including Kasama and Mbala, are situated along rivers such as the Luapula and Chambeshi Rivers, which offer potential for hydroelectric power generation (Figure 8).

### 5.3.4 Geothermal Energy

According to research findings (Table 6), Zambia's potential for geothermal energy is relatively unexplored compared to other renewable energy sources like hydro and solar. However, there are areas where geothermal potential may exist and the ones identified in this study include Rufunsa and Chama.

*Table 6: Renewable energy alternatives that have a comparative advantage in different geographical regions of Zambia*

Site	Comparative in different geographical regions of Zambia				Total	Percentage Potential (%)
	Geothermal	Solar	Hydro	Wind		
Chama	✓	✓	✓	✓	4	100
Lundazi	✗	✗	✗	✗	0	0
Chadiza	✗	✗	✗	✓	1	25
Chipangali	✗	✗	✗	✓	1	25
Nchelenge	✗	✗	✓	✗	1	25
Chiengi	✗	✗	✓	✗	1	25
Kaputa	✗	✗	✓	✗	1	25
Nsama	✗	✗	✓	✗	1	25
Mwense	✗	✗	✓	✗	1	25
Mansa	✗	✓	✓	✓	3	75

Kasama	X	✓	X	X	1	25
Nakonde	X	✓	X	X	1	25
Isoka	X	✓	X	X	1	25
Mpika	X	X	X	✓	1	25
Chitambo	X	X	X	✓	1	25
Lavushimanda	✓	X	X	X	1	25
Serenje	X	✓	X	✓	2	50
Rufunsa	✓	✓	X	X	2	50
Chongwe	X	✓	X	X	1	25
Chisamba	X	X	X	✓	1	25
Kabwe	X	✓	X	X	1	25
Choma	X	X	X	✓	1	25
Mumbwa	X	✓	X	X	1	25
Sesheke	X	✓	X	X	1	25
Sioma	X	X	✓	X	1	25
Senanga	X	✓	✓	X	2	50
Mongu	X	✓	X	X	1	25
Limulunga	X	✓	X	X	1	25
Shangombo	X	✓	X	X	1	25
Chavuma	X	X	✓	X	1	25
Mwinilunga	X	X	✓	✓	2	50

(Source: field data 2024)

#### 5.4 Viability of transitioning to renewable energy alternative sources

As outlined in the Table, results show that transitioning to renewable energy sources such as solar is highly viable and hence presents an opportunity. The country's renewable energy potential, especially in solar and hydropower is significant. The viability of transitioning is presented in Tables 7:

Table 7: Key informants' analysis of viability of transitioning to renewable energy alternative sources

Renewable Energy Source	Resource Potential	Initial cost	Infrastructure Needs	Environmental Impact	Viability Rating (Low, Medium, High)
Solar	High	Medium	Moderate	Low	High
Hydropower	High	High	High (dams, grid integration)	Medium (ecosystem impact, displacement)	High
Wind	Moderate	High	Moderate	Low	Medium
Geothermal	Low to moderate	High	High (exploration, drilling)	Low	Low to medium

All the key informants shared the view that Zambia has abundant sunlight, with significant opportunities for rural electrification and large-scale solar projects. Despite high initial costs, solar energy is economically and technically feasible with increasing investment and government support hence the high viability rating. The key informant from ZESCO for instance, stated that the corporation has embarked on a drive to harness renewable energy sources such as Solar aimed at increasing access to electricity, improving power supply, quality and security throughout the country. Further, the key informants observed that wind energy has moderate viability due to insufficient wind resources while Geothermal energy has low to moderate viability with significant potential, but requires high investment and technical capacity. Hydropower on the other hand was observed to have high viability, but dependent on climate conditions and environmental management.

The study revealed that transitioning to renewable energy alternatives in Zambia would involve significant investment, a clear policy framework, and widespread public and private sector collaboration. It would not only involve a change in how energy is produced but also how it is distributed, consumed, and integrated into the wider economic and environmental context.

Table 8 gives is a detailed analysis based on various factors such as potential, opportunities and challenges as submitted by the Key informants.

Table 8: Significant renewable energy opportunity and challenges according to Key informants

Energy Source	Potential	Current Status	Opportunities	Challenges
Solar	Abundant sunshine (3,000 hours/year) - Vast land area for large-scale installations	Slow uptake, though projects like Bangweulu Solar Plant (47.5 MW) by Neon Limited-IPP exist	Rural electrification through off-grid solar - Reducing reliance on hydropower - Job creation in installation and maintenance	High upfront costs - Need for battery storage for energy continuity
Wind	Low wind potential overall - Pockets of higher wind speed in districts such as Chipangali, Chadiza, Mansa, Mpika, Chitambo, Serenje, Chisamba, Choma and Mwinilunga	No significant wind projects operational	Small-scale wind turbines for localized energy needs	Generally low wind speeds - Large-scale wind farms may not be viable without advancements
Geothermal	Places near the Rift Valley such as Rufunsa show geothermal potential	Still in exploration phase, no major developments	Stable, continuous baseload energy - Long-term low operating costs	High exploration and development costs - Lack of technical expertise
Hydro	Abundant resources from the Zambezi River and tributaries - Potential for small and large-scale projects	Contributes 85% of Zambia's electricity - Vulnerable to droughts	Expansion of small-scale hydropower - International partnerships and investments for infrastructure upgrades	Vulnerability to climate change (droughts) - Environmental impact on ecosystems and communities

(source: field data 2024)

### 5.5 Barriers to Renewable Energy Integration in Zambia

A questionnaire was formulated by the use of a 5-point Likert scale to collect information on the participant's perspectives on transitioning to renewable energy alternatives as well as their expectations of the viability of that being achieved. The questionnaire covered barriers to renewable energy integration and opportunities for effective transitioning.

The results show that several factors hinder renewable energy alternatives integration and these are as follows:

**a) Lack of supportive government policies**

Most respondents believe that the lack of supportive policies is a barrier to the integration of renewable energy alternatives, with the majority of these strongly agreeing with the statement (Figure 9). This suggests that the perception of inadequate supportive policies as a barrier is relatively strong. The presence of a ‘neutral’ and a ‘disagree’ response indicated variation in opinion, but it was limited.

Overall, the results suggest a consensus that supportive policies are important for the integration of renewable energy alternatives, with most respondents perceiving the lack of such policies in Zambia as a significant barrier.

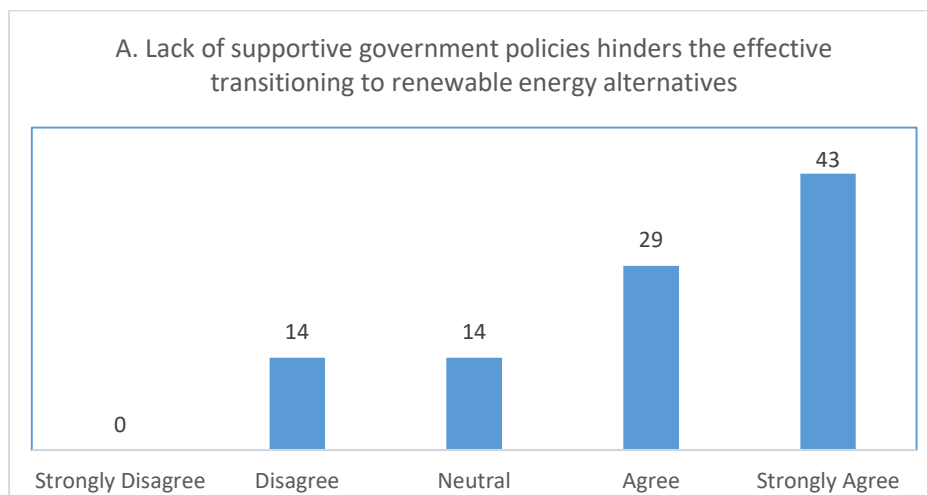


Figure 7: Lack of supportive policies

A Key Informant had this to say:

*“Lack of political will, poor policies and regulations, lack of incentives especially for investors, unsustainable tariffs are among the main barriers” (KI 4, 2023)*

Another Key Informant had this to say

*“Legal and regulatory frameworks do not provide open access to the grid. ZESCO still has a strong say whether you connect to the grid or not. Lack of a clear procurement mechanism for renewables and for partnership projects in general. Also, MoUs signed at national level such as agreements with China are huge capacities which if achieved, those involved at local level such as green energy are not going to see any of those projects as all the capacity would have been taken up already hence a lack of a clear and consistent procurement mechanism is a challenge. There are also bankability issues, i.e., ZESCO still owes the IPPs and other suppliers quite a bit of money and that raises a concern for financiers who look at ZESCO’s balance sheet and its ability to meet its obligations” (KI 7, 2023)*

## b) Financial Constraints

Results (Figure 10) show that financial considerations and access to funding affect the integration of renewable energy projects especially for Independent Power Producers. All respondents agree that financial constraints pose significant barriers to integrating renewable energy alternatives with the majority strongly agreeing. This implies that Governments and private entities may lack access to affordable financing or credit to invest in renewable projects. High interest rates or limited availability of long-term loans were stated to inhibit the financial feasibility of renewable energy development especially to the IPPs. However, this shows that there's opportunity for creation of innovative financing mechanisms to support the growth of renewable energy alternatives.

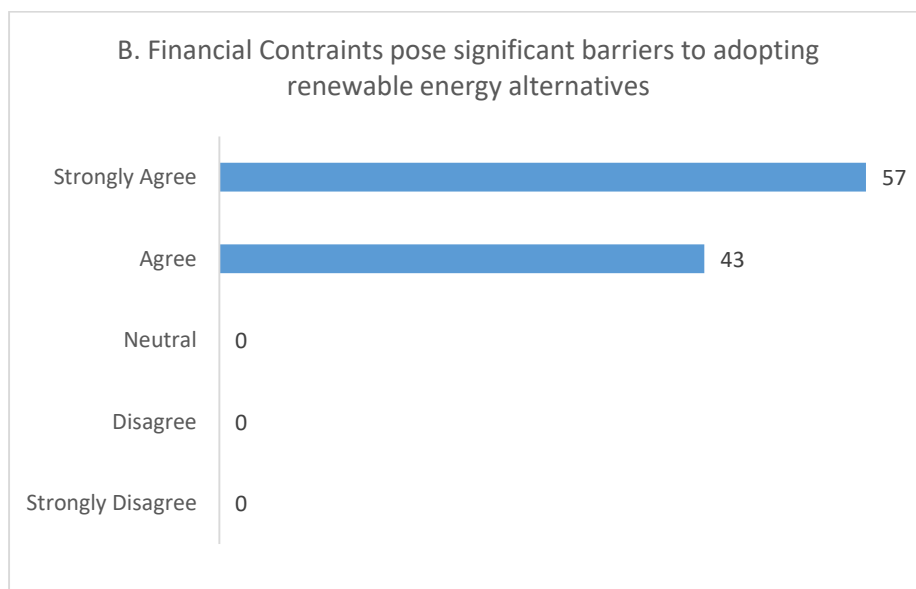


Figure 8: Financial constraints

- A key informant said that “Bigger projects would require huge funding and there’s limited capacity in the local markets to fund such projects. You will then need to look outside.” (KI 7, 2023)

According to the key informants, international organizations and climate funds that support renewable energy in developing nations such as Zambia (e.g., the Green Climate Fund) do exist, however, the process of accessing these funds can be complex, bureaucratic, and time-consuming. In addition, countries may lack the technical expertise or institutional capacity to prepare and submit successful funding proposals.

### c) Technical Challenges

Results (Figure 11) show that technical challenges such as intermittency, grid infrastructure, grid flexibility, inverter technology, transmission congestion and storage impede the efficient utilisation of renewable energy and this has impact on grid stability and reliability and majority of the respondents agree. Affirmatively a Key informant from REA had this to say:

*“The variable forms of renewable energy like solar and wind can be a source of grid instability if technical limits are not adhered to” (KI 2, 2023)*

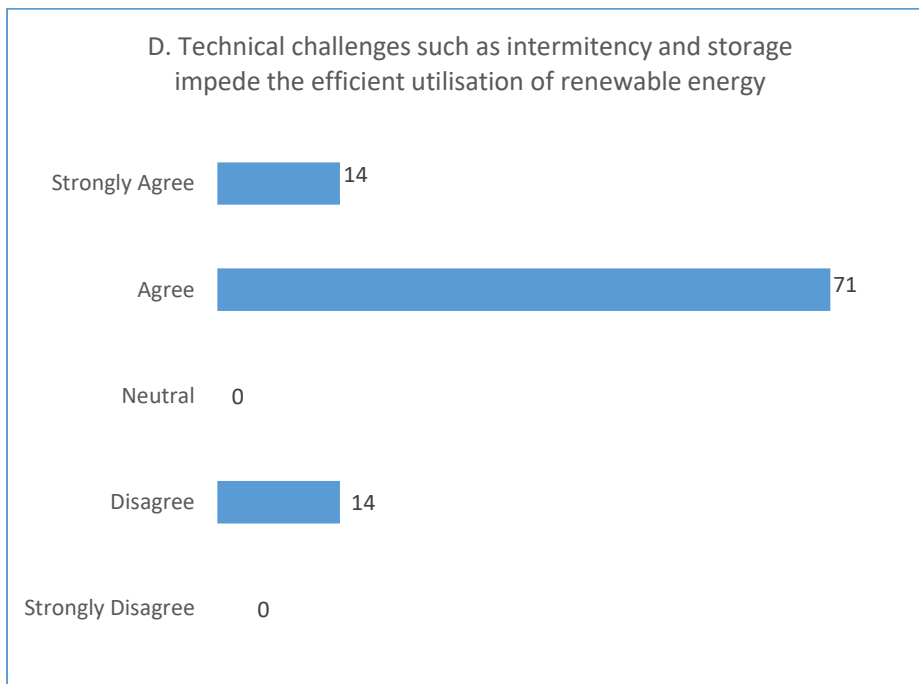


Figure 9: Technical challenges

The Respondents illustrated that since solar energy is generated only during daylight hours, energy storage systems (like batteries) are crucial for providing power during non-sunny periods. However, current battery technologies can be expensive and have limited storage capacity and this affirms that storage would impede the efficient utilisation of renewable energy.

### d) Uncertainty about the long-term viability and return on investment.

Study results (Figure 12) reveal that the upfront cost of investing in renewable energy alternatives can be daunting for investors with limited resources, and this can discourage investments as renewable energy projects often require a long payback period before investors can recover their capital, which can be unattractive compared to shorter-term, higher-return

investments. And to this, majority of the respondents agree, with some strongly agreeing while others disagreeing but to affirm the disposition of the majority a key informant had this to say:

*“Tax incentives should be considered for RET projects improved financial performance and recovery since the tariffs are low” (KI 5, 2023)*

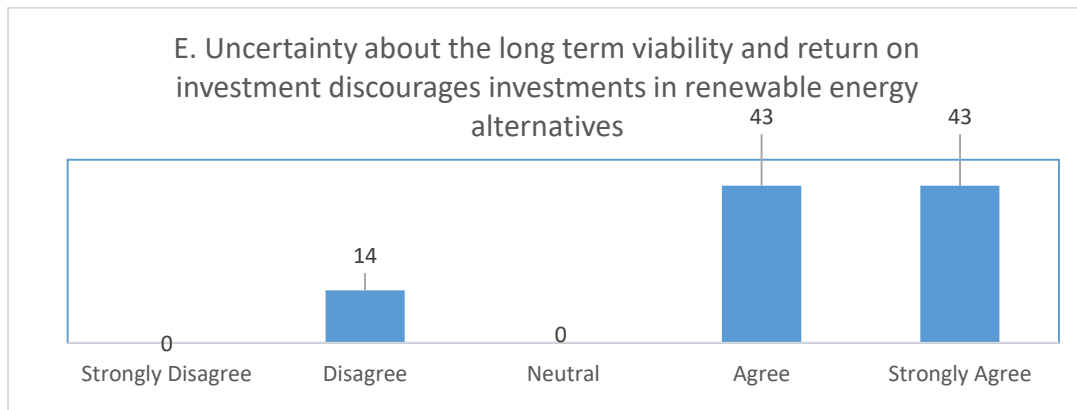


Figure 10: Uncertainty

The respondents gave an instance that while solar and wind projects may take years to deliver significant financial returns, traditional energy projects such as coal may offer quicker profits hence private investors would opt to invest in traditional energy projects as opposed to renewable energy projects. This would explain why financial constraints rank highest followed by uncertainty and lack of supportive government policies (Figure 13).

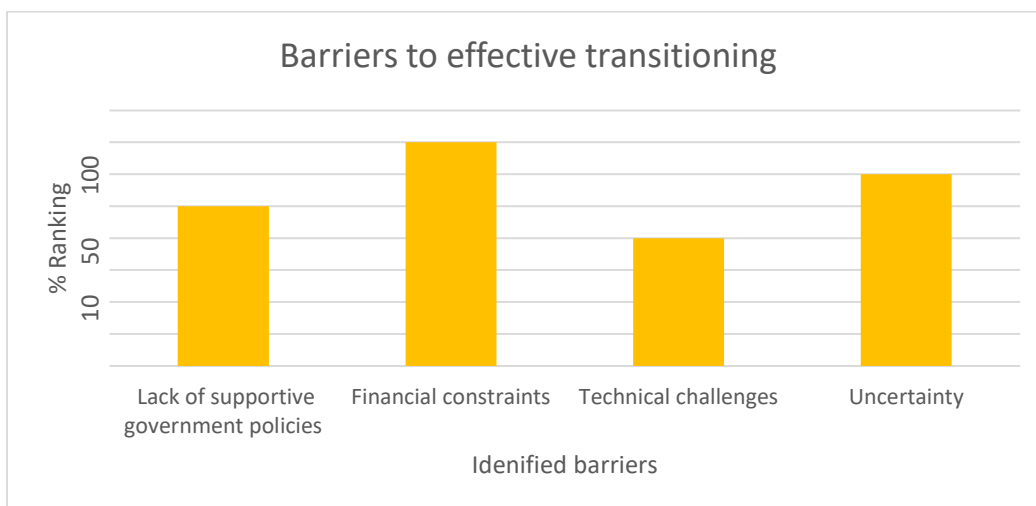


Figure 11: Barriers to effective transitioning

## 5.6 Opportunities for Effective Transitioning

Opportunities identified from the key informant interviews included but not limited to the following:

- The role of Government subsidies and incentives;
- Collaborative efforts and partnerships;
- Technological advancements in renewable energy solutions; and
- Innovative efforts in renewable energy technologies e.g., advanced storage batteries

It was observed that the above factors which were generated as themes, together can create a robust ecosystem for the large-scale adoption of renewable energy alternatives. And a key informant stated about collaborative efforts and partnerships that:

*“IPPs and more partnerships can help bring about stability in the sector and there are a lot of opportunities there because these ensure that the entities created are profitable and efficiently managed” (KI 3, 2023)*

Table 9: Opportunities for transitioning

Theme	Opportunities for Transitioning to Renewable Energy
Government Subsidies and Incentives	<ul style="list-style-type: none"> <li>● Increased adoption: Lower financial barriers for businesses and consumers to switch to renewable energy.</li> <li>● Investment in innovation: Encourages R&amp;D for advanced technologies.</li> <li>● Long-term growth: Attracts sustainable, long-term investments in the clean energy market.</li> </ul>
Collaborative efforts and partnerships	<ul style="list-style-type: none"> <li>● Shared expertise: Combines knowledge and technology across sectors</li> <li>● Joint investment: Allows for larger, more ambitious renewable energy projects</li> <li>● Scalability: Enables broader deployment of renewable energy projects across regions.</li> </ul>
Technological advancements in renewable energy solutions	<ul style="list-style-type: none"> <li>● Efficiency improvements: Increases energy generation efficiency, reducing costs.</li> <li>● Decarbonization: New technologies, like carbon capture, reduce emissions.</li> <li>● Adaptation and resilience: Tailors renewable energy solutions to local climates and grid conditions.</li> </ul>
Innovative efforts in renewable energy technologies	<ul style="list-style-type: none"> <li>● Grid stability: Advanced storage balances energy supply and demand.</li> <li>● Increased renewable integration: Greater reliability of renewable energy, reducing fossil fuel dependency.</li> <li>● Cost reduction: Lower costs for energy storage make renewables more affordable.</li> </ul>

The key informants further submitted it that government incentives catalyse the market hence ranks the highest on opportunities to effective transitioning (Figure 14) partnerships and collaboration follow on the rank as they provide scale and shared expertise. Technological advancements and innovations like energy storage come in to ensure that renewable energy becomes a reliable and cost-effective solution.



Figure 12: Opportunities to effective transitioning

### 5.7 Benefits of Renewable Energy Integration

Integrating hydropower, solar, wind, and geothermal energy into Zambia’s energy mix is a viable and strategic option for enhancing the country's energy security and sustainability as each source brings unique benefits as summarized in the table below:

Table 10: Benefits of integrating renewable energy alternatives

Energy Source	Benefit
Hydropower	Offers reliable baseload power though vulnerable to climate change
Solar	abundant and ideal for daytime generation
Wind	Can provide power during off-peak solar hours
Geothermal	can offer consistent energy

(Source: field data 2024)

The study further established that developing renewable energy projects for the identified sites involves collaborations between the government, private sector, and international organizations. However, critical factors and processes to facilitate the exploration and utilization of these potential sites must be considered and these are presented in the table below:

Table 11: Factors and processes to facilitate renewable energy integration

Factor/process	Significance	Relevance
<b>Planning</b>	<ul style="list-style-type: none"> <li>- Crucial for successful integration</li> <li>- Assessing current energy needs</li> <li>- Essential for developing a road map for integration</li> </ul>	<ul style="list-style-type: none"> <li>- Strategic for transitioning</li> </ul>
<b>Technological Advancements</b>	<ul style="list-style-type: none"> <li>-Investigating technological landscape</li> <li>-Analysing feasibility and scalability of renewable energy solutions</li> </ul>	<ul style="list-style-type: none"> <li>-Identifying areas where innovation could address the barriers</li> </ul>
<b>Commercial Viability</b>	<ul style="list-style-type: none"> <li>-Examining commercial challenges helps identify barriers such as high initial costs and uncertainties in returns on investment.</li> </ul>	<ul style="list-style-type: none"> <li>-Assessing the current economic conditions, investment climate, and financial mechanisms</li> </ul>
<b>Synergizing Collaborations</b>	<ul style="list-style-type: none"> <li>-Collaboration among stakeholders is essential for a smooth transition</li> </ul>	<ul style="list-style-type: none"> <li>-Investigating existing collaborations</li> <li>-identifying successful models and potential areas for improvement</li> <li>-Assess how well stakeholders work together towards renewable energy integration.</li> </ul>
<b>Addressing Gaps in Political Will and Regulatory Frameworks</b>	<ul style="list-style-type: none"> <li>-Political will and regulatory frameworks dictate the direction and pace of the transition.</li> </ul>	<ul style="list-style-type: none"> <li>-Identifying gaps or obstacles and propose recommendations to enhance governance for sustainable energy transition.</li> </ul>
<b>Renewable Energy Optimization</b>	<ul style="list-style-type: none"> <li>-Maximising the efficiency and output of renewable energy systems</li> </ul>	<ul style="list-style-type: none"> <li>- Investigate current practices in renewable energy optimization</li> </ul>

(Source: field data 2024)

## **CHAPTER SIX: DISCUSSION OF RESEARCH FINDINGS**

### **6.0 INTRODUCTION**

This chapter discusses the study's findings in relation to the study's objectives, which include renewable energy alternatives with comparative advantage in different geographical regions of Zambia and the viability of integrating different energy alternatives. The findings are then related to the study's theoretical framework.

#### **6.1 Renewable energy alternatives that have a comparative advantage in different geographical regions of Zambia**

The study established that Zambia has vast renewable energy resources particularly in hydro, Solar, wind and geothermal. For instance, various research shows the eastern part of the country lies on the western edge of the East African Rift System, a tectonic zone known for geothermal activity (Musonda and Sikazwe, 2005; Mainza and Ziba, 2020) and a study by Avtar and Kumar (2016) affirms that best suitable sites for commercial production of geothermal energy are high-temperature (>180°C) hydrothermal systems located near active plate tectonic boundaries (i.e., convergence zones, subduction zones, transform faulting), or at crustal and mantle hot spot anomalies. This explains why Kenya is the African leader for operational geothermal power plants, with its geothermal power production totalling more than 40% of the country's total electricity production, according to a study by Elbarbary et al (2022) as beneath Kenya, the African tectonic plate splits in two. That cleave creates hydrothermal vents, ripe for harnessing geothermal energy, hence countries like Kenya, Ethiopia, and Tanzania, are advanced in geothermal energy production. It was found that Chama, Lavushimanda and Rufunsa have potential geothermal resources though largely under-explored.

The study established that Nchelenge, Chiengi Kaputa, Nsama, Mwense, Mansa, Sioma, Senanga, Chavuma and Mwinilunga districts have higher potential for hydro while Chipangali, Chadiza, Mansa, Mpika, Chitambo, Serenje, Chisamba, Choma, Mwinilunga have higher potential for wind. This aligns with a study by Mwanza et al (2017) who suggests that estimates measured at height of 10meters indicates these parts of the country have the wind speed average of 3m/s, compared to other parts of the country as well as abundant water resources making them suitable for hydro and wind power production.

Furthermore, the findings of a study by Bimenyimana et al (2024) show that, on average, Africa exhibits a moderate level of wind suitability, with an estimated average of around 37.27% of its land area moderately suitable for wind energy technology installation, covering thousands of square kilometres, however, each nation exhibits its unique pattern as can be observed for Zambia.

The study further established that the country has a significant potential of solar energy for both power production and solar energy technologies because it is situated at the latitude of 8 to 18 degrees south of the equator and longitude 22 to 34 degrees east of prime meridian with an average sunshine of about 6-8hours per day and high monthly average solar radiation incident rate of 5.5kWh/m<sup>2</sup>/day throughout the year, this is according to weather results by Meteorological Department of Zambia for the last five years (ERB, 2023). It is clear that Zambia receives abundant sunlight throughout the year in many places, making it an ideal location for solar power generation. This explains why the IPPs interviewed are mainly involved in Solar projects for now.

## **6.2 Integration of Renewable Energy Alternatives**

The integration of renewable energy alternatives in response to climate change is guided by a conceptual framework that emphasizes policy coherence, technological advancement, financial mobilization, and societal engagement. Effective transitioning involves aligning energy systems with climate mitigation goals through strategic planning across governance, infrastructure, and economic sectors. However, several barriers hinder progress, including inconsistent regulatory frameworks, high initial investment costs, technological limitations (e.g., energy storage and grid integration), and entrenched fossil fuel interests (IRENA, 2021; IPCC, 2022). Societal resistance, especially due to misinformation or lack of awareness, further complicates adoption, particularly in developing regions with limited institutional and technical capacity.

Despite these challenges, significant opportunities exist to accelerate the renewable energy transition. Innovations in energy storage, smart grid systems, and clean technology are reducing costs and improving efficiency. Global climate agreements and green financing instruments—such as carbon pricing and climate funds—support the scaling of renewable infrastructure (UNEP, 2023). Moreover, decentralized energy systems and community-based initiatives enhance energy access and foster local ownership, especially in remote or underserved areas (REN21, 2022). The shift toward renewables not only addresses climate goals but also

contributes to job creation, economic diversification, and social equity, making an integrated and inclusive approach essential for long-term sustainability.

An examination of the possibility of combining different renewable sources, focusing on their strengths, challenges, and how they might complement one another is as follows:

### **6.2.1 Hydropower**

Zambia is already heavily dependent on hydropower, which accounts for about 85% of its electricity generation. Major hydropower plants include the Kariba Dam, Kafue Gorge, and Itezhi-Tezhi. Despite the negative impact of climate change the country still has abundant water resources and rivers suitable for hydropower generation and RES4Africa (2019) affirm that hydro power plants can continue to operate to maximise renewable energy integration and economic benefits thereof. An article by Zimba (2024) discusses the impact of severe droughts on Lake Kariba, Zambia's primary hydropower source, and underscores the need for diversifying the energy mix to enhance resilience.

#### **6.2.1.1 Challenges**

As seen recently, Zambia's hydropower plants are vulnerable to droughts and changing rainfall patterns due to climate change, which has caused power shortages. Furthermore, the country's reliance on a few large-scale dams means that fluctuations in water levels can have a major impact on energy generation.

#### **6.2.1.2 Integration Potential**

Hydropower provides a baseload energy supply, which means it can be used as a stable foundation for the grid. When integrated with solar, wind and geothermal which are intermittent sources, hydropower can fill in the gaps when solar and wind for instance energy are not available. The government of the Republic of Zambia recognises the importance of diversifying its energy sources in order to improve energy security and resilience. To lessen dependency on hydropower, the 2019 National Energy Policy promotes integration of alternative renewable energy sources such as solar, wind and geothermal.

### **6.2.2 Solar Energy**

Zambia has high solar potential, with solar radiation levels of around 2,000–2,300 kWh/m<sup>2</sup> per year, making it one of the best locations for solar energy in the region. Solar power plants, like

the Bangweulu and Ngonye solar farms, have already been developed under the Scaling Solar Program by the World Bank.

### **6.2.2.1 Challenges**

Solar energy is only available during the day, and its generation fluctuates depending on weather conditions. To make solar energy more viable for 24-hour use, battery storage or integration with other power sources is essential.

### **6.2.2.2 Integration Potential**

Solar energy is an ideal partner to hydropower because it generates electricity during the day, when demand is typically higher. This can reduce the load on hydropower plants during dry seasons. Integrating solar with hydropower also allows Zambia to reduce reliance on dams such as the Kariba and use solar energy for rural electrification via off-grid solutions. Integrating solar energy requires significant investments in grid infrastructure to manage intermittency and ensure stability. The government is focusing on modernizing the national grid, enhancing transmission and distribution networks, and implementing energy storage solutions to accommodate the influx of this renewable energy source. The Energy Efficiency Strategy and Action Plan (2022) outlines measures to improve grid efficiency and reduce energy losses. Furthermore, a study by Walusa (2022) analysed the technical and financial aspects of key on-grid solar PV power plants in Zambia, offering insights into their performance and lessons learned for future solar energy entrepreneurs. The study submits that solar PV technology is the cheapest source of energy, environmentally friendly and financially viable to the government.

### **6.2.3 Wind Energy**

Zambia has moderate wind energy potential, particularly in districts like Chipangali, Chadiza, Mansa, Mpika, Chitambo, Serenje, Chisamba, Choma and Mwinilunga where wind speeds average between 6–7 m/s at 100 meters height. However, wind energy development is still in its infancy, with no large-scale wind farms in operation.

#### **6.2.3.1 Challenges**

There is still insufficient wind resource mapping and assessment in Zambia, making large-scale wind farm development uncertain. Wind energy, like solar, is an intermittent resource that depends on weather conditions, so its output can vary significantly.

### **6.2.3.2 Integration Potential**

Wind energy can complement both solar and hydropower by generating power during different periods. For example, wind speeds are often higher at night or during off-peak solar hours, making it a good partner for solar energy. When integrated with hydropower, wind can also help reduce reliance on dams during dry periods, contributing to the stability of the grid. Current Zambian policies focus largely on hydropower and solar. There would be a need for policy reforms or enhancements to specifically encourage the development of wind energy. This would involve setting national targets for wind capacity and integrating wind into Zambia's overall renewable energy strategy.

### **6.2.4 Geothermal Energy**

Zambia's geothermal potential is limited but concentrated near the East African Rift System. Some over 80 hot springs have been identified historically and few indicate moderate geothermal activity, but no large-scale geothermal power plants have been developed. A 2018 country report offers an updated overview of geothermal energy prospects in Zambia, discussing ongoing projects and future development plans. It highlights the country's efforts to diversify its energy sources through geothermal energy.

#### **6.2.4.1 Challenges**

Geothermal energy requires significant investment in exploration and drilling to assess resource viability. Zambia's geothermal potential is underexplored, and it is unclear whether large-scale projects can be developed.

#### **6.2.4.2 Integration Potential**

If explored further, geothermal energy could provide a consistent and reliable baseload power supply, much like hydropower, but without the same vulnerability to droughts. Geothermal could complement solar and wind energy by providing power during periods when these sources are not available, helping to smooth out fluctuations. Zambia's current National Energy Policy focuses primarily on hydropower and solar energy. Integrating geothermal will require an expansion of the policy focus to include these newer, less utilized technologies, promoting them as strategic priorities.

### **6.3 Benefits of an Integrated Energy Mix**

By integrating hydropower, solar, wind, and geothermal energy, Zambia can reduce its reliance on hydro energy source and enhance its overall energy security. For example, hydropower can

be vulnerable to drought, but combining it with solar, wind, and geothermal helps balance supply during shortages or weather-related disruptions. Integrating these diverse sources can make Zambia's electricity grid more stable. Solar and wind can provide power during the day and windy periods, while hydropower and geothermal provide a stable, round-the-clock power supply. Currently, Zambia has an energy deficit of 1,360 Megawatts compelling consumers to turn to diesel generators during periods of intense load management. Integrating more solar, wind, and geothermal energy would reduce the need for fossil fuels and contribute to Zambia's climate goals. With international support for renewable energy development (Muhango and Mwanza, 2023) the cost of solar and wind technologies has dropped significantly. Integrating these sources with hydropower and geothermal could result in a cost-effective energy mix in the long term, reducing Zambia's dependence on fuel imports and increasing energy access. This resonates with a study by Muhango and Mwanza (2023) who postulates that successful diversification of renewable energy requires policy directives that accentuate and dedicate resources towards the exploration and implementation of alternative renewable sources such as solar, wind, and geothermal technologies.

Zambia's policy framework is evolving to support the integration of various renewable energy sources. This involves diversifying the energy mix, establishing supportive policies and regulations, providing financial incentives, upgrading infrastructure, and building technical capacity to ensure a sustainable and resilient energy future. And the following key considerations are identified as main themes:

**a) Policy and Regulatory Framework**

To facilitate the integration of diverse renewable energy sources, Zambia has developed specific policies and regulatory frameworks. The Renewable Energy Strategy and Action Plan (RESAP) outlines targets and strategies for renewable energy development, aiming to add 500 MW of renewable capacity by 2030, with a focus on solar and small-scale hydro projects. Additionally, the Energy Regulation Act No. 12 of 2019 provides a legal basis for regulating the energy sector, including provisions for licensing and promoting renewable energy investments.

**b) The role of Government subsidies and incentives**

Government subsidies or incentives are very essential in promoting the integration of renewable energy especially among independent power producers. The Key informants all submit and agree that Tax incentives for instance should be considered for Renewable Energy projects to improve financial performance since the tariffs are low. They further added that the land acquisition process should also be made easier for Renewable Energy projects.

### **c) Collaborative efforts and partnerships**

Partnerships among stakeholders such as government agencies, utility companies, or technology providers play a key role in facilitating renewable energy integration. Hence, collaboration is essential for a smooth transition. The study also established that the Government needs IPPs without which it cannot manage to meet all the energy requirements of the nation. IPPs help bring about stability in the sector because they ensure that the entities created are profitable and efficiently managed for instance the partnership between Enel Green Energy and ZESCO Limited.

### **d) Technological advancements in renewable energy solutions**

Emerging or cutting-edge renewable energy technologies such as advanced batteries and storage systems show significant promise for the future of renewable energy and a lot of research is being undertaken in this area. These technological advancements have potential impact on the energy landscape leading to successful integration of renewable energy. The integration of variable renewable energy sources necessitates upgrades to the existing grid infrastructure to manage intermittency and ensure stability. This includes investments in energy storage solutions and advanced grid management systems. ZESCO's strategic plans for instance, reflect a commitment to enhancing infrastructure to accommodate renewable energy.

### **d) Innovative efforts in renewable energy technologies**

There is need for innovative strategies such as integrating alternatives which include wind, solar, geothermal and hydropower in order to optimise generation. This is key in balancing energy supply and demand. Furthermore, sectors or industries that have the greatest potential to leverage renewable energy alternatives effectively such as transportation, agriculture and manufacturing can foster renewable energy integration e.g., there is an emergence of solar powered vehicles in the transport sector. Moreover, initiatives and projects promoting renewable energy development in Zambia often involve collaborations between the government, private sector, and international organizations. Policies and regulations that support investment in renewable energy can further facilitate the exploration and utilization of these potential sites.

Like Zambia, many African countries face several challenges in integrating renewable energy, including outdated grid infrastructure, reliance on fossil fuels like coal, and financial constraints limiting investment in renewable projects. Many nations also struggle with the intermittency of renewable sources like solar and wind, requiring energy storage solutions that

are often expensive or underdeveloped. Additionally, political resistance, especially from the coal industry, and limited technical capacity hinder progress. Countries like South Africa and Mozambique face further difficulties with climate-induced variations in hydropower generation, while smaller nations like Lesotho and Eswatini struggle with limited resources and grid capacity (RES, 2023). Despite these hurdles, there is significant potential for renewable energy, but overcoming these challenges requires coordinated efforts in policy, investment, and infrastructure development.

## **CHAPTER SEVEN: CONCLUSION AND RECOMMENDATION**

### **7.0 OVERVIEW**

This chapter marks the conclusion of the study which involved a qualitative approach, extensive literature review and content thematic analysis, enabling an in-depth exploration of the research addressing the study objectives. Transitioning to renewable energy alternatives reduces dependence on fossil fuels, mitigates the impacts of climate change and promotes economic growth

### **7.1 Conclusion**

There are abundant alternative energy sources spread across the country with Geothermal potential which has not been utilised. The research has brought to the fore the barriers and opportunities to effective transitioning and has expounded on the possibility of how the energy sector can benefit from improving the efficiency of electricity generation through integration of renewable alternatives.

The integration of renewable energy alternatives represents both a significant opportunity and a set of complex challenges. On the one hand, renewable energy technologies such as solar, wind, hydro, and geothermal offer the potential to significantly reduce carbon emissions, mitigate the impacts of climate change, and foster sustainable development. However, the transition to a cleaner energy system is hindered by multiple barriers. These include inadequate policy frameworks, limited access to financing, technological limitations in energy storage and integration and lack of collaboration among stakeholders.

Despite these obstacles, there are promising opportunities. Technological advancements, declining costs of renewable energy, increased governmental support through subsidies and incentives, have ability to drive the transition. Collaborative efforts among stakeholders are essential in overcoming these barriers. Ultimately, a successful transition to more renewable energy alternatives will require concerted efforts across multiple sectors, integrating policy reforms, technological innovation, and public engagement.

### **7.2 Recommendations**

As Zambia navigates the transition to alternatives other than hydro, the findings of this study provide essential insights to help guide the way forward and presents recommendations that not only highlight the obstacles, but also show the pathways to realize a much-needed energy mix and they are as follows:

- ZESCO Ltd, the National Utility and Independent Power Producers should collaborate in investing in solar energy for power production country wide.
- The Government of the Republic of Zambia, should prioritise Investments in Chama district as part of implementing the renewable energy strategies set out in the 8NDP as it displays potential for different sources of renewable energy.
- The Government should further address the identified barriers as follow:
  - ❖ Strengthen policy and Regulatory framework: Governments should implement and strengthen policies that encourage renewable energy adoption, such as subsidies, tax incentives, and renewable energy targets. Clear and stable regulations can provide confidence for investors and developers in renewable energy projects. The government should have a clear procurement mechanism for renewables that is consistent, predictable and managed by a unit as that is what attracts developers
  - ❖ Enhance financing mechanisms and investments: Governments and international organizations should create more robust financial mechanisms, such as green bonds, public-private partnerships, and carbon pricing strategies, to increase investments in renewable energy. These mechanisms should also support small-scale renewable projects such as small hydro power projects.

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## **9.0 APPENDICES: DATA COLLECTION INSTRUMENTS**

### **Appendix 1: Key Informant interview guide**

I am Bertha Musonda, this study is a requirement for the award of Master of Science in Environmental and Natural Resources Management at University of Zambia. Thus, the purpose of this process is to investigate the Integration of Renewable Energy Alternatives in Response to Climate Change in Zambia with a focus on Barriers and Opportunities to Effective Transitioning. All information will be confidentially treated.

Title: Integration of Renewable Energy Alternatives: Barriers and Opportunities - IPP

Introduction: Thank you for agreeing to participate in this interview regarding the integration of renewable energy alternatives and the challenges and opportunities faced by independent power producers. Your expertise and insights as a key informant in this field are highly valuable in understanding the current landscape of renewable energy integration. The objective of this interview is to gather your thoughts, experiences, and suggestions related to the barriers and opportunities for independent power producers in adopting and integrating renewable energy sources into their operations.

Please note that your responses will be treated with confidentiality, and all data collected will be used solely for research purposes.

Background and Experience:

- a. Can you provide a brief overview of your organization and its involvement in the power production sector?
- b. How long has your organization been operating, and what is the primary focus of your power generation activities?

Current Renewable Energy Integration:

- a. How has your organization incorporated renewable energy sources into its energy generation portfolio, if at all?
- b. What types of renewable energy technologies have you explored or implemented?
- c. What are the main drivers behind your organization's interest in renewable energy integration?

Barriers to Renewable Energy Integration:

- a. In your experience, what are the main barriers or challenges faced by independent power producers in adopting and integrating renewable energy alternatives?
- b. Are there any specific regulatory or policy-related hurdles that hinder the expansion of renewable energy in your region?
- c. How do financial considerations and access to funding affect the integration of renewable energy projects for independent power producers?

#### Grid Integration and Infrastructure:

- a. How do you perceive the impact of renewable energy sources on grid stability and reliability?
- b. Have there been any technical challenges in integrating renewable energy into the existing power grid? If so, how were they addressed?
- c. What opportunities do you see for improving grid infrastructure to accommodate larger shares of renewable energy?

#### Market Dynamics and Competitiveness:

- a. How do renewable energy sources compare with conventional energy sources concerning cost and competitiveness in your region?
- b. Have you observed any shifts in the market demand for renewable energy solutions in recent years?

#### Policy and Regulatory Support:

- a. What kind of policy support or incentives do you believe would be most effective in promoting the integration of renewable energy among independent power producers?
- b. Are there any existing policies that have proven to be particularly beneficial or problematic for your organization's renewable energy projects?

#### Opportunities and Future Outlook:

- a. What potential opportunities do you foresee for independent power producers in expanding their renewable energy footprint?
- b. How do you think the energy landscape will evolve in the next 5-10 years concerning renewable energy integration?

Technology Advancements:

a. Have there been any notable advancements in renewable energy technologies that have positively influenced your organization's approach to integration?

Collaboration and Partnerships:

a. How important is collaboration with other stakeholders, such as government agencies, utility companies, or technology providers, in facilitating renewable energy integration?

Key Takeaways:

a. Based on your experiences, what are the key takeaways or lessons learned for other independent power producers looking to venture into renewable energy integration?

Conclusion: Thank you for your valuable insights and time. Your contributions will play a crucial role in our research on renewable energy integration. If there are any additional points or thoughts you would like to share, please feel free to do so. Your participation in this interview is greatly appreciated, and we look forward to analysing the data to gain a better understanding of the barriers and opportunities in the integration of renewable energy alternatives for independent power producers.

**Appendix 2: Likert Scale questionnaire**

To investigate the viability of integrating different renewable energy alternatives

STATEMENT	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree
<b>Section 1: Barriers to Renewable Energy Integration</b>					
1. The lack of supportive government policies hinders the effective transitioning to renewable energy.					
2. Financial constraints pose significant barriers to adopting renewable energy alternatives.					
3. Inadequate grid infrastructure limits the seamless integration of renewable energy sources.					
4. Technical challenges, such as intermittency and storage, impede the efficient utilization of renewable energy.					

5. Limited access to skilled workforce and expertise inhibits the successful implementation of renewable energy projects.					
6. Public resistance or lack of acceptance of renewable energy technologies complicates their integration.					
7. Uncertainty about the long-term viability and return on investment discourages investments in renewable energy.					
<b>Section 2: Opportunities for Effective Transitioning</b>					
8. Government incentives and subsidies play a crucial role in facilitating the successful transitioning to renewable energy sources.					

9. Collaborative efforts and partnerships between various stakeholders can enhance the integration of renewable energy.					
10. Technological advancements in renewable energy solutions create new opportunities for power producers.					
11. Market demand for clean and sustainable energy fosters favourable conditions for renewable energy integration.					
12. Innovations in energy storage technologies present significant opportunities for effective transitioning to renewable energy.					
13. Flexibility and adaptability in power generation practices can help power					

producers embrace renewable energy sources.					
14. Access to reliable data and information supports informed decision-making during the transition to renewable energy.					



**Appendix 4: Work plan and Budget**  
**Activity Budget 2023-2024**

Research Activity	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Budget (ZMW)
Develop research proposal												-
Literature review												-
Development of instruments for data collection												-
Pilot study												2,000
Data collection												6,000
Data Analysis												1,500
Development of first draft												500
Write up of final draft												-
Submission of dissertation												-
<b>Total</b>												<b>10,000</b>

## Appendix 5: Ethical Clearance Approval



# THE UNIVERSITY OF ZAMBIA

## DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

Great East Road Campus | P.O. Box 32379 | Lusaka 10101 | Tel: +260-290 258/291 777  
Fax: (+260) 211 290 258/253 952 | Email: director.drgs@unza.zm | Website: www.unza.zm /directorates/drgs

### APPROVAL OF STUDY

**IORG No. 0005376**  
**NASREC- IRB No. 00006465**

4<sup>th</sup> August, 2023

**REF NO. NASREC-2023- JUN - 012**

Ms. Bertha Musonda,  
The University of Zambia  
School of Natural Sciences,  
P.O. Box 32379  
**LUSAKA**

Dear Ms. Musonda,

**RE: "INTEGRATION OF RENEWABLE ENERGY OF ALTERNATIVES IN RESPONSE TO CLIMATE CHANGE IN ZAMBIA. BARRIERS AND OPPORTUNITIES TO EFFECTIVE TRANSITIONING"**

Reference is made to your protocol dated as captioned above. NASREC resolved to approve this study and your participation as Principal Investigator for a period of one year.

REVIEW TYPE	ORDINARY REVIEW	APPROVAL NO. NASREC-2023—JUN- 012
Approval and Expiry Date	Approval Date: 4 <sup>th</sup> August , 2023	Expiry Date: 3 <sup>rd</sup> August, 2024
Protocol Version and Date	Version - Nil.	3 <sup>rd</sup> August, 2024
Information Sheet, Consent Forms and Dates	<ul style="list-style-type: none"><li>English.</li></ul>	To be provided
Consent form ID and Date	<ul style="list-style-type: none"><li>Version - Nil</li></ul>	To be provided
Recruitment Materials	<ul style="list-style-type: none"><li>Nil</li></ul>	Nil
Other Study Documents	<ul style="list-style-type: none"><li>Interview Guide.</li></ul>	

Specific conditions will apply to this approval;

*Towards Improving Service and Excellence in High Education Beyond Fifty Years*

As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

**Conditions of Approval**

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to NASREC within 5 days.
- All protocol modifications must be approved by NASREC prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to NASREC within 5 working days.
- All recruitment materials must be approved by NASREC prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. NASREC will only approve a study for a period of 12 months.
- It is the responsibility of the PI to renew his/her ethics approval through a renewal application to NASREC.
- Where the PI desires to extend the study after expiry of the study period, documents for study extension must be received by NASREC at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Documents received within 30 days after expiry will be labelled "late submissions" and will incur a penalty fee of K500.00. No study shall be renewed whose documents are submitted for renewal 30 days after expiry of the certificate.
- Every 6 (six) months a progress report form supplied by The University of Zambia Natural and Applied Sciences Research Ethics Committee as an IRB must be filled in and submitted to us. There is a penalty of K500.00 for failure to submit the report.
- When closing a project, the PI is responsible for notifying, in writing or using the Research Ethics and Management Online (REMO), both NASREC
- and the National Health Research Authority (NHRA) when ethics certification is no longer required for a project.
- In order to close an approved study, a Closing Report must be submitted in writing or through the REMO system. A Closing Report should be filed when data collection has ended and the study team will no longer be using human participants or animals or secondary data or have any direct or indirect contact with the research participants or animals for the study.
- Filing a closing report (rather than just letting your approval lapse) is important as it assists NASREC in efficiently tracking and reporting on projects. Note that some funding agencies and sponsors require a notice of closure from the IRB which had approved the study and can only be generated after the Closing Report has been filed.
- A reprint of this letter shall be done at a fee.
- All protocol modifications must be approved by NASREC by way of an application for an

amendment prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address or methodology and methods. Many modifications entail minimal risk adjustments to a protocol and/or consent form and can be made on an Expedited basis (via the IRB Chair). Some examples are: format changes, correcting spelling errors, adding key personnel, minor changes to questionnaires, recruiting and changes, and so forth. Other, more substantive changes, especially those that may alter the risk-benefit ratio, may require Full Board review. In all cases, except where noted above regarding subject safety, any changes to any protocol document or procedure must first be approved by NASREC before they can be implemented.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

On behalf of NASREC, we would like to wish you all the success as you carry out your study.

Yours faithfully,



*Dr. M. Kaonda*

**VICE - CHAIRPERSON**

**THE UNIVERSITY OF ZAMBIA NATURAL AND APPLIED SCIENCES RESEARCH  
ETHICS COMMITTEE - IRB**

cc: Director, Directorate of Research and Graduate Studies  
Assistant Director (Research), Directorate of Research and Graduate Studies  
Assistant Registrar (Research), Directorate of Research and Graduate Studies