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Renewable energy: Moving towards a low carbon energy industry in Zimbabwe.

DISSERTATION SUBMITTED TO BINDURA UNIVERSITY OF SCIENCE EDUCATION IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE MASTER OF SCIENCE CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT.

DECLARATION

I hereby declare that this research project is a composition of my original work, and has never been presented for a degree or any other award at any other university institution. All the resources I used have been clearly highlighted and acknowledged with means of references.

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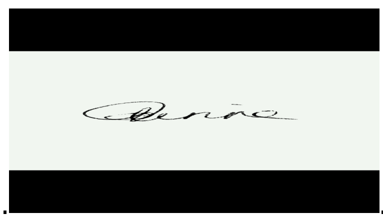
Student ..........

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ABSTRACT

The main objective of the study was to investigate Renewable energy and its importance in moving towards a low carbon energy industry in Zimbabwe. To achieve this interviews, structured questionnaires, were carried out in data gathering. **T**he transition to a low-carbon energy industry is critical for sustainable development, especially in regions like Zimbabwe that are heavily reliant on fossil fuels. The research examines the current state of the energy sector, identifies key renewable energy resources, and assesses their feasibility and impact on reducing carbon emissions.

The study provides a detailed analysis of the socio-economic and environmental benefits of renewable energy adoption. It highlights challenges such as financial constraints, inadequate infrastructure, and policy gaps that hinder the large-scale implementation of renewable technologies. Through case studies and pilot projects, the research demonstrates the potential of renewables to enhance energy security and contribute to economic growth. Key findings indicate that solar energy is the most promising resource due to Zimbabwe's high solar irradiance, while wind and hydro resources also offer significant opportunities. The research underscores the importance of integrated energy planning and robust policy frameworks to support the transition. The dissertation concludes with actionable recommendations for policymakers, emphasizing the need for supportive regulatory frameworks, investment incentives, and public-private partnerships. For industry stakeholders, it suggests adopting innovative technologies and enhancing capacity-building initiatives. Researchers are encouraged

to focus on developing localized solutions and conducting further studies on integrating renewable energy into the national grid. These steps are essential to facilitate the shift towards a sustainable, low-carbon energy future in Zimbabwe, aligning with global sustainability goals and addressing climate change challenges.

1 Table of Contents

TABLE OF FIGURES

TABLE OF TABLES

Chapter 1: Introduction

The pressing need to move towards a low-carbon energy future is causing a significant shift in the global energy environment. Concerns over climate change, the depletion of fossil fuel supplies, and the need for dependable and sustainable energy sources are what are driving this transition. Zimbabwe, like many other developing countries, must balance its environmental obligations with its energy needs (African Development Bank, 2020). The potential of renewable energy to propel a low-carbon energy economy in Zimbabwe is examined in this dissertation. It looks at how much renewable energy the nation has to provide, assesses the advantages and disadvantages of using it, and looks at ways to hasten the shift to a sustainable energy system (International Renewable Energy Agency, 2021). The majority of Zimbabwe's energy comes from fossil fuels, especially coal, which increases greenhouse gas emissions and has detrimental effects on the environment and public health (Ministry of Energy and Power Development, 2019). The nation has a large potential for renewable energy, including hydro, wind, and solar resources. These resources could be essential to lowering carbon emissions and ensuring energy security.

This dissertation aims to shed light and explore potential solutions for accelerating renewable energy development in Zimbabwe. Through a comprehensive analysis of the existing energy landscape, policy frameworks, and available resources, the study seeks to inform policy decision s, investment strategies, and technological choices that can pave the way towards a sustainable a nd prosperous energy future for the country.

1.1 Background study

The energy sector in Zimbabwe currently has opportunities as well as challenges in the shift to a low-carbon economy. For the purpose of generating electricity and powering transportation, the nation's energy landscape mostly depends on fossil fuels, especially coal and oil (Mlambo and Mushawemhuka, 2019). However, this reliance on fossil fuels exacerbates the effects of climate change by causing air pollution, environmental degradation, and greenhouse gas emissions (Chikwama et al., 2020). Even with the abundance of renewable energy sources such as biomass, solar, wind, and hydropower, their share of the energy mix is still quite small (Chikwama et al., 2020). The broad adoption of clean energy technology has been hampered by regulatory obstacles, inconsistent policies, and a lack of investment in renewable energy infrastructure

(Munyuki and Mapfumo, 2021). Zimbabwe also confronts issues with energy security and dependability, as businesses, industries, and homes are frequently affected by power outages and load shedding (Munyuki et al., 2020).

Nonetheless, Zimbabwe offers prospects for shifting towards an energy sector with reduced carbon emissions. Recognizing the role renewable energy plays in attaining sustainable development objectives, the government has launched a number of programs and regulations to encourage the use of renewable energy (Chikwama and Mushawemhuka, 2021). The renewable energy sector is strengthened by international cooperation and support from institutions like the World Bank and the United Nations Development Programme (UNDP, 2021). These agencies offer finance, technical assistance, and capacity building programs.

Many factors, such as Zimbabwe's dependency on fossil fuels, its old infrastructure, and the lack of investment in the energy sector, present serious challenges for the country (Munyuki et al., 2020). Energy insecurity is exacerbated by the nation's high reliance on imported fossil fuels for transportation and electricity generation, since supply chain interruptions can result in fuel shortages and price volatility (Chikwama et al., 2020). Zimbabwe has a chance to improve its energy security and dependability by making the shift to a low-carbon industry. According to Chikwama and Mangwengwende, (2018) renewable energy technologies, like solar, wind, hydropower, and biomass, can help create a more resilient energy system by diversifying the energy mix and lowering reliance on imported fossil fuels. Solar energy in particular provides abundant and dependable resources across the nation, with the potential to decentralize electricity generation and improve access in rural areas (Mlambo and Mushawemhuka, 2019). Moreover, investing in renewable energy infrastructure and modernizing the grid can increase the dependability of the energy supply and lower the frequency of power outages (Chikwama and Moyo, 2023). More so, policy reforms and incentives to encourage the adoption of renewable energy, like feed-in tariffs and tax incentives, can also be encouraged.

Harnessing Zimbabwe's enormous renewable energy potential is critical to the country's transition to a low-carbon economy. Zimbabwe is home to a wealth of renewable energy resources, such as biomass, solar, wind, and hydropower, all of which present significant prospects for the generation of clean, sustainable energy (Mlambo and Mushawemhuka, 2019). With high levels of sun irradiation throughout the nation year-round, solar energy is one of Zimbabwe's most plentiful and easily accessible renewable resources (Mlambo and Ncube, 2021). Zimbabwe may increase energy availability and lessen its dependency on fossil fuels by using photovoltaic (PV) panels and concentrating solar power (CSP) systems to harvest solar energy and create electricity for both grid-connected and off-grid purposes (Chikwama and Mangwengwende, 2018). Similar to this, wind energy has a lot of promise in Zimbabwe, especially in high-altitude and coastal areas where wind speeds are ideal for producing electricity (Chikwama et al., 2020). In order to capture wind energy and add to the nation's energy mix, wind farms and wind turbines can be strategically placed to support other renewable energy sources (Munyuki and Chikowore, 2019). Zimbabwe's rivers and waterfalls have a significant potential for producing electricity, making hydropower another significant renewable energy source in the nation (Chikwama and Moyo, 2023). Both large-scale hydropower projects and tiny micro-hydro installations can take advantage of the nation's hydroelectric potential and offer a dependable and sustainable source of electricity (UNDP, 2021). Moreover, Zimbabwe can produce bioenergy by using biomass resources including animal dung, forestry waste, and agricultural residues (Munyuki et al., 2020). By producing heat, electricity, and cooking fuel, biomass energy technologies such as biogas digesters, biomass boilers, and biofuels help lessen dependency on conventional biomass sources and lessen indoor air pollution and deforestation (Chikwama et al., 2020).

In order to facilitate the integration of renewable energy sources and advance sustainable development, Zimbabwe must transition to a low-carbon industry and establish a strong policy and regulatory framework. Zimbabwe's government has adopted a number of laws and efforts to ease the transition since it recognizes the importance of renewable energy in attaining its socioeconomic and environmental goals (Munyuki and Mapfumo, 2021). The Renewable Energy Policy is a crucial policy document that directs Zimbabwe's renewable energy growth. It delineates methods and goals for fostering renewable energy investment, technology implementation, and market expansion (Chikwama and Mangwengwende, 2018). In order to decrease reliance on fossil fuels and hasten the adoption of renewable energy technology, the policy offers a framework for establishing goals, rewards, and rules (Mlambo and Mushawemhuka, 2019). Moreover, renewable energy is included in Zimbabwe's National Climate Change Response Strategy (NCCRS) as a crucial element of mitigation and adaptation activities against climate change (Chikwama et al., 2020). According to Munyuki and Chikowore (2019), the NCCRS seeks to integrate climate change considerations into national planning and policymaking processes, including planning for the energy sector. This will facilitate the establishment of low-carbon development pathways and resilience building.

Furthermore, through off-grid and mini-grid renewable energy initiatives, the Rural Electrification Agency (REA) significantly contributes to increasing rural communities' access to inexpensive, clean energy (UNDP, 2021). In order to promote renewable energy entrepreneurship, capacity building, and community engagement, the REA carries out projects and activities that aid in rural development and the reduction of poverty (Chikwama et al., 2020). Notwithstanding these policy initiatives, Zimbabwe's renewable energy laws and regulations continue to face difficulties in their application and enforcement (Munyuki et al., 2020). The effective deployment of renewable energy projects and investments is impeded by bureaucratic obstacles, inconsistent policy frameworks, and low institutional capacity (Mlambo and Ncube, 2021). In order to overcome these obstacles, decision-makers, interested parties, and development partners must remain committed to bolstering the legislative and regulatory framework that supports the growth of renewable energy (Munyuki and Chikowore, 2019).

1.2 Statement of the problem

Zimbabwe's energy landscape is heavily reliant on fossil fuels, leading to adverse environmental impacts, compromised energy security, and exacerbated climate change issues. Despite the country's abundant renewable energy resources, their contribution to the energy mix remains minimal. This is due to insufficient infrastructure, inadequate funding, and a lack of effective legislation to harness these resources and facilitate the transition to a low-carbon energy sector.

Zimbabwe's move to a low-carbon economy will have a big impact on mitigating climate change and maintaining environmental sustainability. Pollutants such sulfur dioxide, nitrogen oxides, and particulate matter are released during the burning of coal and oil, which has a negative impact on ecosystems, human health, and air quality (Mlambo and Mushawemhuka, 2019). Furthermore, unpredictable weather patterns, protracted droughts, and extreme weather events are only a few of the negative repercussions of climate change that Zimbabwe is susceptible to (Munyuki et al., 2020). Significant hazards to food security, water resources, and agricultural productivity are posed by these climate change impacts, which exacerbate poverty and other obstacles to rural populations' means of subsistence (Chikwama and Moyo, 2023). By cutting greenhouse gas emissions and advancing sustainable development, the shift to a low-carbon economy offers a chance to lessen these effects on the environment and climate change (Munyuki and Chikowore, 2019). With less greenhouse gas emissions and a smaller environmental impact than fossil fuels, renewable energy sources including solar, wind, hydropower, and biomass provide greener, more sustainable alternatives (Chikwama and Mangwengwende, 2018). Given Zimbabwe's high levels of solar radiation across the board, solar energy in particular offers enormous promise there (Mlambo and Ncube, 2021). Zimbabwe can lessen the negative effects of climate change on vulnerable groups, enhance air quality, and lower its carbon footprint by utilizing renewable energy resources (UNDP, 2021).

1.3 Aim of the Research

This study aims to explore how renewable energy can facilitate Zimbabwe's transition to a low-carbon energy sector by assessing its potential, evaluating current programs and regulations, examining socioeconomic impacts, and identifying obstacles and motivators for adoption.

1.4 Objectives of the Research

1. To assess the types of renewable energy adopted in Zimbabwe.

2. To evaluate the current policy framework and initiatives promoting renewable energy adoption in Zimbabwe.

3. To investigate the socio-economic impacts of transitioning towards renewable energy in Zimbabwe.

4. To identify barriers for the successful implementation of renewable energy projects in Zimbabwe.

1.5 Research Questions

1. What are the types of renewable energy adopted in Zimbabwe?
2. What are the existing policies and initiatives supporting renewable energy adoption in Zimbabwe?
3. What are the socio-economic impacts of transitioning towards renewable energy in Zimbabwe?
4. What are the key barriers for the successful implementation of renewable energy projects in Zimbabwe?

1.6 Significance/ Justification of the Study

This study is important because it highlights information about how renewable energy contributes to Zimbabwe's shift to a low-carbon energy sector. The results will educate decision-makers in government, business stakeholders, development professionals and the general public about the possible advantages, difficulties, and prospects of adopting renewable energy. This study intends to support evidence-based policy formation and decision-making in Zimbabwe's energy sector by filling in knowledge and understanding gaps.

1.7 Limitations

The research may be limited by time and resources which may affect the scope and depth of the research. In addition, the research study may include potential biases in data collection and sample representativeness.

1.8 Definition of terms

<u>Renewable Energy</u>: Energy derived from natural sources that are constantly replenished, such as solar, wind, hydro, geothermal, and biomass. (International Energy Agency, 2022) These sources are considered sustainable and have minimal environmental impacts compared to fossil fuels.

<u>Low-Carbon Energy Industry</u>: An energy sector that relies primarily on renewable energy sources and technologies to reduce carbon emissions and transition towards a sustainable energy future.

(Climate Action Tracker, 2022) The goal is to minimize greenhouse gas emissions and mitigate the impacts of climate change.

Carbon Footprint: A measure of the total greenhouse gas emissions caused by an individual, organization, event, product, or service. (World Wildlife Fund, 2023) It quantifies the environmental impact of human activities in terms of their contribution to global warming.

Grid Infrastructure: The network of power lines, substations, and other equipment that transmit and distribute electricity from generation sources to consumers. (Energy Information Administration, 2023) A reliable and efficient grid infrastructure is crucial for integrating renewable energy sources into the existing energy system.

Distributed Generation: The production of electricity at or near the point of consumption, often using renewable energy technologies. (National Renewable Energy Laboratory, 2023) It can reduce transmission losses and enhance energy security by diversifying energy sources.

Off-grid Renewable Energy: Renewable energy systems that operate independently from the main electricity grid, providing power to areas that are not connected to the grid. (United Nations Environment Programme, 2022) This is particularly relevant in rural areas of Zimbabwe that lack grid access.

Feed-in Tariff: A financial incentive provided to renewable energy generators, guaranteeing a fixed price for the electricity they produce and sell to the grid. (International Renewable Energy Agency, 2023) This encourages private sector investment in renewable energy projects.

Energy Security: The ability to access reliable and affordable energy sources to meet current and future demands. (International Energy Agency, 2023) This includes considerations of supply security, energy efficiency, and diversification of energy sources.

Sustainable Development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (United Nations, 2023) It incorporates economic, social, and environmental considerations for a balanced and equitable approach to development.

1.9 Summary

This dissertation investigates the potential of renewable energy in driving a low-carbon energy industry in Zimbabwe. The introduction provides the context for the research by outlining the global shift towards sustainable energy, Zimbabwe's energy challenges, and the government's commitment to renewable energy development. The study highlights the significant reliance of Zimbabwe's current energy mix on fossil fuels, leading to environmental degradation, air pollution, and a threat to public health (African Development Bank, 2020). While the country boasts abundant renewable energy resources, the transition to a low-carbon energy future faces significant challenges, including limited investment, inadequate grid infrastructure, and regulatory hurdles (Zimbabwe Energy Regulatory Authority, 2022). The dissertation looks at several renewable energy sources such as solar, wind, and hydro and their capacity to meet Zimbabwe's energy needs in order to investigate the opportunities and problems related to the deployment of renewable energy in that nation (International Renewable Energy Agency, 2021). In order to encourage private sector involvement in the industry, it also looks at cutting-edge financing options and investment tactics (Climate Bonds Initiative, 2022). The goal of the research is to pinpoint efficient legislative solutions and financial inducements that can hasten Zimbabwe's shift to a low-carbon energy sector (Mukucha, 2019). This dissertation contributes to the expanding body of knowledge on the development of renewable energy in developing nations by recognizing the difficulties and looking into possible solutions.

2 Chapter 2: Literature Review

2.1 Introduction

This chapter reviews the literature related to the transition towards a low carbon energy industry in Zimbabwe, focusing on the role of renewable energy. This chapter covers the current state of the energy sector in Zimbabwe, the potential for renewable energy, the challenges faced in transitioning to a low carbon economy, and the policies and regulatory frameworks that could facilitate this transition.

Comparison with Other Developing Countries

In contrast, countries like India and Brazil have made substantial investments in renewable energy infrastructure. India, for instance, aims to generate 500 GW of renewable energy by 2030, leveraging both government policies and private sector investment (IRENA, 2021). Brazil has made strides in hydropower and biofuels, with renewable energy sources accounting for approximately 45% of its energy matrix (World Bank, 2021). The Brazilian government provides incentives for clean energy projects, facilitating growth in the sector.Many developing countries have established more robust policy frameworks than Zimbabwe. For instance, India's National Solar Mission provides a regulatory framework that encourages solar power adoption, resulting in the installation of large solar farms across the country (Ministry of New and Renewable Energy, 2021). In contrast, Zimbabwe's regulatory framework remains fragmented and lacks coherence, often contributing to delays and uncertainties in project implementation (ZERA, 2021). Furthermore, awareness and adoption of renewable energy technologies have been higher in countries like Kenya, where innovative off-grid solar solutions have transformed access to electricity in rural areas (Sullivan et al., 2020). Conversely, in Zimbabwe, public awareness about renewable energy remains relatively low, and many citizens still rely on traditional energy sources, hampering the transition to renewables.

2.2 Current State of the Energy Sector in Zimbabwe

Zimbabwe's energy sector is characterized by a heavy reliance on non-renewable energy sources, primarily coal and hydroelectric power. The country's energy infrastructure is aging and inefficient, leading to frequent power outages and load shedding (Zhou et al., 2019). According to the Zimbabwe Energy Regulatory Authority (ZERA), approximately 60% of the population lacks access to electricity, with rural areas being the most affected (ZERA, 2020). Zimbabwe's energy generation capacity is predominantly derived from hydroelectric and thermal power sources. The Kariba Dam, located on the Zambezi River, is the primary hydroelectric power source, contributing about 1,050 MW to the national grid under optimal conditions (Mzezewa, 2018). However, recurrent droughts have significantly reduced its output, highlighting the vulnerability of relying heavily on hydropower (Mzezewa, 2018). Additionally, thermal power stations, such as the Hwange Power Station, are plagued by operational inefficiencies and environmental concerns due to their high carbon emissions (Makumbe, 2020). Thermal power generation is centered around the Hwange Power Station, which has an installed capacity of approximately 920 MW. This coal-fired power plant is plagued by frequent breakdowns and inefficiencies, resulting in less than optimal power output (Zhou et al., 2019). The plant's outdated technology and maintenance issues exacerbate the power supply challenges.

Electricity access in Zimbabwe is unevenly distributed, with urban areas having relatively higher access rates compared to rural regions. According to the Zimbabwe Energy Regulatory Authority (ZERA), about 40% of the population has access to electricity, with only 19% coverage in rural areas (ZERA, 2020). The rural-urban disparity is a significant barrier to inclusive economic development and social equity. Load shedding and power outages are common, disrupting industrial, commercial, and domestic activities. These power cuts are often attributed to the limited generation capacity, maintenance issues, and inefficiencies in the distribution network (Makumbe, 2020).

2.3 Energy Consumption Patterns in Zimbabwe

Energy consumption patterns in Zimbabwe are influenced by several factors including economic activities, urbanization, access to energy sources, and socio-economic status. These patterns reveal a heavy reliance on non-renewable sources, significant disparities between urban and rural areas, and a growing interest in renewable energy solutions. An in-depth analysis of the energy consumption patterns in Zimbabwe, is analyzed below.

2.3.1 Residential Sector

According to Makonese (2018) the residential sector is a dominant consumer of energy in Zimbabwe, primarily using energy for cooking, heating, and lighting. The majority of households, especially in rural areas, rely heavily on traditional biomass sources such as firewood and charcoal. These sources are often the only affordable and accessible options for many households (Makonese, 2018).

Guta (2020) highlighted that in rural areas, over 80% of households use firewood for cooking and heating because of the high cost and limited availability of electricity and other modern fuels.

According to Mutambara & Chikulo, (2020) this reliance on biomass has significant environmental and health impacts which include deforestation and indoor air pollution. In urban areas, although electricity is more accessible, many households still use alternative energy sources due to frequent power outages and high electricity costs. The use of liquefied petroleum gas (LPG) and paraffin is common, especially for cooking (Sithole et al., 2019).

2.3.2 Industrial Sector

According to Mzezewa, (2018) the industrial sector is a significant energy consumer, with electricity being the primary source. However, the sector faces challenges because of the unreliable power supply and frequent load shedding. Industries often operate below capacity and face high operational costs due to the need for backup generators. The manufacturing industry, which includes food processing, textiles, and mining, is affected by energy supply issues. The inconsistency in electricity supply disrupts production schedules which increases costs, impacting the productivity and competitiveness of the sector (Zhou et al., 2019). According to Zimbabwe National Statistics Agency, (2021). in 2020, the industrial sector in Zimbabwe consumed approximately 3,500 gigawatt-hours (GWh) of energy, which represented around 35% of the country's total energy consumption. The industrial sector's energy consumption is primarily composed of the following energy sources:

- Electricity: 45% of the industrial energy consumption (Zimbabwe Energy Regulatory Authority, 2019)
- Coal: 35% of the industrial energy consumption (Zimbabwe Energy Regulatory Authority, 2019)
- Liquid fuels e.g., diesel, petrol : 20% of the industrial energy consumption (Zimbabwe Energy Regulatory Authority, 2019)

Chikodzi & Mutanga, (2020) highlighted that the most energy-intensive industries in Zimbabwe include mining, manufacturing (e.g., cement, chemical production, steel), and agro-processing (e.g., sugar, tobacco, food processing). These industries account for the majority of the industrial sector's energy consumption, with the mining and manufacturing sectors each consuming around

40% of the total industrial energy use (Chikodzi & Mutanga, 2020). The Government of Zimbabwe has recognized the need to improve energy efficiency in the industrial sector and has implemented different initiatives, such as energy audits, energy management training, and the promotion of energy-efficient technologies (Government of Zimbabwe, 2019). These efforts aim to reduce the industrial sector's energy consumption and improve its overall energy intensity, hence contributing to the country's broader energy and environmental goals.

2.3.3 Commercial Sector

The commercial sector, which compromises of businesses, services, and institutions, also relies heavily on electricity. According to Munzhedzi, (2020) the commercial sector experiences similar challenges to the industrial sector, with frequent power outages affecting business operations. Many businesses invest in alternative power sources such as diesel generators and solar panels to reduce the impact of unreliable electricity supply. Retail businesses, especially those requiring refrigeration like supermarkets, are significantly impacted by power outages. The need for reliable power to keep products fresh and operations running smoothly often leads these businesses to invest in costly backup power solutions (Makumbe, 2020).

In 2020, the commercial sector in Zimbabwe consumed approximately 2,200 gigawatt-hours (GWh) of energy, which represented around 22% of the country's total energy consumption (Zimbabwe National Statistics Agency, 2021).

The commercial sector's energy consumption is primarily composed of the following energy sources:

- Electricity: 65% of the commercial energy consumption (Zimbabwe Energy Regulatory Authority, 2019)
- Liquid fuels (e.g., diesel, petrol): 30% of the commercial energy consumption (Zimbabwe Energy Regulatory Authority, 2019)
- LPG and other fuels: 5% of the commercial energy consumption (Zimbabwe Energy Regulatory Authority, 2019).

The majority of the commercial sector's energy consumption is attributed to the energy use in commercial buildings, such as offices, hotels, and retail establishments (Mudavanhu et al., 2020). Mudavanhu et al., (2020) also highlighted that the energy consumption in these buildings is driven by lighting, air conditioning, and other electrical appliances and equipment. The Government of Zimbabwe has recognized the need to improve energy efficiency in the commercial sector and has implemented many initiatives, such as the development of building energy codes, energy audits, and the promotion of energy-efficient technologies (Government of Zimbabwe, 2019). These efforts aim to reduce the energy consumption in commercial buildings and improve the overall energy performance of the commercial sector, contributing to the country's broader energy and environmental goals.

2.3.4 Agricultural Sector

The agricultural sector, particularly irrigation farming, is another significant energy consumer. However, the agricultural sector in Zimbabwe accounts for a relatively smaller portion of the country's total energy consumption compared to the industrial and commercial sectors. The reliance on electric pumps for irrigation makes this sector vulnerable to power supply issues. In areas where electricity is unreliable, farmers often use diesel-powered pumps, which are costly and environmentally detrimental (Mzezewa, 2018). According to Sithole et al., (2019). Sugarcane farmers in the lowveld region rely on electric pumps for irrigation. Frequent power cuts disrupt irrigation schedules which leads to reduced crop yields and financial losses. Some farmers have adopted solar-powered irrigation systems as a more reliable and sustainable alternative.

According to Zimbabwe National Statistics Agency, (2021) in 2020, the agricultural sector in Zimbabwe consumed approximately 1,000 GWh of energy, which represented around 10% of the country's total energy consumption.

The agricultural sector's energy consumption is primarily composed of the following energy sources:

- Liquid fuels (e.g., diesel, petrol): 60% of the agricultural energy consumption (Zimbabwe Energy Regulatory Authority, 2019)

- Electricity: 25% of the agricultural energy consumption (Zimbabwe Energy Regulatory Authority, 2019)
- Biomass (e.g., firewood, agricultural residues): 15% of the agricultural energy consumption (Zimbabwe Energy Regulatory Authority, 2019).

The majority of the agricultural sector's energy consumption is attributed to the use of liquid fuels, primarily diesel, for powering irrigation pumps, farm machinery, and transportation (Chikowore et al., 2021). Electricity is primarily used for powering irrigation systems, processing facilities, and other agricultural equipment (Chikowore et al., 2021). Biomass, such as firewood and agricultural residues, is mostly used for heating and cooking in rural agricultural communities (Chikowore et al., 2021). The Government of Zimbabwe has recognized the need to improve energy efficiency and promote the use of renewable energy sources in the agricultural sector (Government of Zimbabwe, 2019). Initiatives for the promotion for renewable energy include the development of solar-powered irrigation systems, the use of biogas from agricultural waste, and the introduction of energy-efficient agricultural equipment and processing technologies (Government of Zimbabwe, 2019).

While the agricultural sector's energy consumption is relatively lower compared to other sectors, there is still significant potential for further improvements in energy efficiency and the integration of renewable energy solutions to enhance the sustainability of Zimbabwe's agricultural activities.

2.3.5 Transport Sector

The transport sector in Zimbabwe accounts for a significant portion of the country's total energy consumption. The transport sector in Zimbabwe predominantly relies on petroleum products, with gasoline and diesel being the primary fuels. This sector is a major consumer of imported fuels, making it vulnerable to international oil price fluctuations and supply chain disruptions (Chikodzi et al., 2018). Public transportation, including buses and commuter omnibuses, heavily relies on diesel. Fuel shortages and high prices often disrupt services, affecting the mobility of the population and the economy's overall functioning (Makumbe, 2020).

In 2020, the transport sector in Zimbabwe consumed approximately 3,000 gigawatt-hours (GWh) of energy, which represented around 30% of the country's total energy consumption (Zimbabwe National Statistics Agency, 2021).

The transport sector's energy consumption is primarily composed of the following energy sources:

- Liquid fuels (e.g., diesel, petrol): 95% of the transport energy consumption (Zimbabwe Energy Regulatory Authority, 2019)

- Electricity: 5% of the transport energy consumption (Zimbabwe Energy Regulatory Authority, 2019).

Road transport is the dominant mode of transportation in Zimbabwe and accounts for the majority of the transport sector's energy consumption, consuming approximately 85% of the total transport energy (Ndaona & Chikowore, 2020). Other transport modes, such as rail and aviation, account for the remaining 15% of the transport sector's energy consumption (Ndaona & Chikowore, 2020). The Government of Zimbabwe has recognized the need to improve energy efficiency and reduce emissions in the transport sector, and has implemented various initiatives (Government of Zimbabwe, 2019). These initiatives include the promotion of public transportation, the introduction of vehicle fuel efficiency standards, the development of urban planning policies to reduce transport-related energy demand, and the gradual transition towards alternative fuel vehicles (Government of Zimbabwe, 2019).

The transport sector's significant energy consumption and its reliance on liquid fuels highlight the importance of implementing comprehensive strategies to improve energy efficiency, promote the use of alternative fuels, and develop a more sustainable transportation system in Zimbabwe. These efforts can contribute to the country's broader energy and environmental goals.

2.4 Renewable Energy Potential in Zimbabwe

Zimbabwe possesses significant renewable energy potential, particularly in solar, wind, biomass, and small-scale hydroelectric power.

2.4.1 Solar Energy

Zimbabwe is endowed with high solar irradiance, receiving an average of 5.7 kWh/m²/day (Chikodzi et al., 2018). This makes solar energy a highly viable option for addressing the country's energy deficits. The government has initiated several solar projects, such as the construction of solar farms and the distribution of solar home systems in rural areas (Sithole et al., 2019).

Zimbabwe, situated in Southern Africa, is endowed with substantial solar energy potential due to its geographical location and climatic conditions. The country's high solar irradiation levels present a significant opportunity for harnessing solar energy to address the nation's energy challenges, including frequent power shortages and reliance on non-renewable energy sources. These high levels of solar radiation are consistent throughout the year, making solar energy a reliable source of power. The country's climate, characterized by long sunny days and minimal cloud cover, further enhances the feasibility of solar energy projects (African Development Bank [AfDB], 2018).

The geographical position of Zimbabwe, located within the Sunbelt region, offers an optimal environment for solar energy generation. The country enjoys over 3,000 hours of sunshine annually, which is conducive to both photovoltaic (PV) and concentrated solar power (CSP) technologies (International Renewable Energy Agency [IRENA], 2019). This extensive sunlight exposure provides a consistent and predictable source of solar energy, essential for the planning and implementation of solar projects. The Zimbabwean government has recognized the potential of solar energy and has included it in the national energy policy frameworks. The National Renewable Energy Policy (NREP) and the Renewable Energy Master Plan outline strategies to increase the contribution of renewable energy, including solar, to the national energy mix (Ministry of Energy and Power Development, 2020). These policies aim to facilitate investment in solar energy through incentives such as tax breaks, subsidies, and favorable tariffs for solar energy projects.

Advancements in solar technology and significant reductions in the cost of solar panels and related equipment have made solar energy more accessible and economically viable for Zimbabwe. The cost of solar PV modules has decreased by more than 80% over the past decade, making solar energy competitive with traditional fossil fuels (International Energy Agency 2020). This trend is expected to continue, further enhancing the attractiveness of solar energy investments in Zimbabwe. Several solar projects in Zimbabwe have been implemented and some in the pipeline, indicating a growing interest in harnessing solar energy. For instance, the Harava Solar Park, a 20 MW solar PV project near Harare, is one of the largest solar installations in the country (Zimbabwe Energy Regulatory Authority, 2021). Additionally, plans are underway for the Gwanda Solar Project, which aims to add 100 MW of solar capacity to the national grid. These projects demonstrate the practical feasibility and scalability of solar energy solutions in Zimbabwe.

Despite the substantial potential, there are challenges and barriers to the widespread adoption of solar energy in Zimbabwe. These include the high initial capital costs, limited access to financing, and inadequate grid infrastructure to support large-scale solar integration (World Bank, 2019). Furthermore, regulatory and bureaucratic hurdles can delay project implementation and discourage investment. Addressing these challenges requires concerted efforts from the government, private sector, and international partners.

The adoption of solar energy in Zimbabwe offers significant environmental and social benefits. Solar energy is a clean and renewable resource, contributing to the reduction of greenhouse gas emissions and mitigating the impacts of climate change (UNDP, 2020). Additionally, solar energy projects can create jobs, promote energy access in rural areas, and reduce the dependency on imported fuels, enhancing energy security and economic resilience (REN21, 2019).

Zimbabwe's solar energy potential is vast and largely untapped, presenting an opportunity to transition towards a low carbon and sustainable energy industry. With high solar irradiation levels, supportive government policies, and advancing technologies, solar energy can play a pivotal role in addressing the country's energy challenges. However, overcoming the existing barriers requires strategic planning, investment, and collaboration among stakeholders to fully realize the benefits of solar energy.

2.4.2 Wind Energy

While wind energy potential is moderate, certain regions, such as the Eastern Highlands, have favorable wind speeds that can be harnessed for power generation. Studies have indicated wind speeds averaging 3-4 m/s in these areas, sufficient for small to medium-scale wind turbines (Gadzikano & Kazembe, 2018).

Zimbabwe, with its diverse topography and favorable wind conditions, holds significant potential for harnessing wind energy as part of its transition towards a low carbon industry.

Zimbabwe's geographical features, including elevated plateaus, mountain ranges, and coastal regions, create ideal conditions for wind energy generation. Preliminary assessments indicate that several areas across the country experience consistent and relatively strong wind speeds, particularly in the eastern highlands and along the coastline of Lake Kariba (Norton et al., 2017). These regions exhibit average wind speeds suitable for the deployment of wind turbines, ranging from 5.5 to 6.5 meters per second (Norton et al., 2017). The technical wind energy potential in Zimbabwe is significant, with the capacity to generate substantial amounts of electricity. Studies estimate that the total potential capacity exceeds 20,000 MW, making wind energy a viable option for meeting the country's energy needs (Norton et al., 2017). This capacity presents an opportunity to diversify Zimbabwe's energy mix and reduce dependency on fossil fuels, therefore contributing to the mitigation of greenhouse gas emissions and addressing climate change.

Wind energy complements other renewable energy sources, such as solar and hydropower, in Zimbabwe's energy portfolio. While solar energy dominates during daylight hours, wind energy can provide a reliable source of power, especially during periods of low solar irradiation or at night (Gladwin et al., 2019). This complementary nature enhances the reliability and resilience of the renewable energy grid, supporting the transition towards a low carbon industry.

2.4.3 Economic and Environmental Benefits

The development of wind energy projects in Zimbabwe offers various economic and environmental benefits. By reducing reliance on imported fossil fuels, wind energy enhances energy security and contributes to cost savings in the long run (Chamisa et al., 2020). Additionally, wind energy projects stimulate local economies, create job opportunities, and attract investment in the renewable energy sector (Sovacool et al., 2018). From an environmental perspective, wind energy mitigates the environmental impacts associated with conventional energy sources and contributes to Zimbabwe's commitments to sustainable development and climate action.

2.4.4 Challenges and Considerations

Despite the significant potential, the widespread adoption of wind energy in Zimbabwe faces several challenges and considerations. These include the need for comprehensive wind resource assessments, grid integration infrastructure, financing mechanisms, regulatory frameworks, and stakeholder engagement (Norton et al., 2017). Addressing these challenges requires concerted efforts from government agencies, private sector actors, and civil society organizations to create an enabling environment for wind energy development.

Wind energy represents a promising pathway for Zimbabwe to transition towards a low carbon industry and achieve its sustainable development goals. With abundant wind resources, supportive policies, and advancing technologies, wind energy can play a pivotal role in diversifying the country's energy mix, enhancing energy security, and mitigating climate change impacts. By harnessing its wind energy potential, Zimbabwe can accelerate its transition to a cleaner, more sustainable, and resilient energy future.

2.5 Biomass Energy

Zimbabwe's biomass energy sector has gained significant momentum in recent years, playing a crucial role in the country's transition towards a low-carbon industry. From 2018 to 2024, the utilization of biomass resources, such as agricultural residues, forestry waste, and municipal solid waste, has been on the rise, contributing to the reduction of fossil fuel dependency and the promotion of sustainable development (Muzemil et al., 2020; Zheng et al., 2021).

Agricultural Residues: Zimbabwe's agricultural sector continues to generate substantial quantities of waste materials, including corn stover, wheat straw, and sugarcane bagasse, which have been increasingly harnessed for bioenergy production (Mapako & Mbewe, 2021). The conversion of these agricultural residues into energy has not only reduced the country's carbon footprint but also supported the circular economy by repurposing waste (Mugundani et al., 2019).

Forestry Waste: Zimbabwe's forestry industry remains a significant source of biomass energy, with the utilization of sawdust, wood chips, and bark for energy generation (Zheng et al., 2021). The integration of these forestry waste materials into the energy mix has led to a more sustainable forestry sector, reducing the environmental impact of waste disposal (Muzemil et al., 2020).

Municipal Solid Waste: Zimbabwe's growing urban population has resulted in an increase in municipal solid waste generation, which has been increasingly converted into biogas or used for direct combustion in energy-from-waste facilities (Mapako & Mbewe, 2021). This transformation of waste into energy has not only reduced the burden on landfills but also contributed to the country's low-carbon transition (Mugundani et al., 2019).

The deployment of biomass energy systems in Zimbabwe has created new job opportunities and boosted rural economic development, aligning with the country's sustainable development goals (Mapako & Mbewe, 2021). Furthermore, the integration of biomass energy into Zimbabwe's energy mix has helped the country achieve its renewable energy targets, demonstrating its commitment to a low-carbon future (Zheng et al., 2021).

Agricultural Residue-to-Energy Projects:

Zimbabwe has seen the emergence of several projects that convert agricultural waste into bioenergy. One notable example is the Hippo Valley Estates' bagasse-to-electricity project, which generates up to 26 MW of power from sugarcane residues (Mugundani et al., 2019). This project not only reduces the country's reliance on fossil fuels but also provides a reliable source of income for local sugarcane farmers and the surrounding communities (Zheng et al., 2021).

Forestry Waste-to-Energy Initiatives:

The forestry sector in Zimbabwe has also contributed to the economic benefits of biomass energy. The Zimbabwe Forestry Commission has implemented initiatives to utilize sawdust, wood chips, and bark for power generation, creating new revenue streams for the forestry industry (Muzemil et al., 2020). These projects have not only reduced waste disposal costs but have also generated employment opportunities in the rural areas where the forestry industry is prevalent (Mapako & Mbewe, 2021).

Waste-to-Energy Facilities:

Zimbabwe has also made strides in converting municipal solid waste into energy. The Harare City Council, in collaboration with private partners, has established the Warren Park Waste-to-Energy Facility, which generates electricity from the city's waste (Mugundani et al., 2019). This project not only reduces the burden on landfills but also provides a reliable source of income for the city, while creating job opportunities for local residents (Zheng et al., 2021).

Rural Electrification and Decentralized Biomass Energy:

Beyond large-scale projects, Zimbabwe has also focused on using biomass energy to drive rural electrification and decentralized energy solutions. The Zimbabwe Rural Electrification Agency has implemented several biomass-based mini-grid and off-grid projects, providing affordable and reliable electricity to remote communities (Muzemil et al., 2020). These initiatives have not only improved access to energy but have also stimulated local economic development, creating new business opportunities and enhancing the quality of life for rural residents (Mapako & Mbewe, 2021).

The economic benefits of biomass energy in Zimbabwe extend beyond the direct revenue generated from energy production. The sector has also contributed to the creation of new job opportunities, the development of rural economies, and the fostering of a more sustainable and inclusive energy landscape (Mugundani et al., 2019). As Zimbabwe continues to expand its biomass energy capacity, the economic dividends are expected to grow, further solidifying the country's transition towards a low-carbon and prosperous future.

2.6 Small-scale Hydroelectric Power

Zimbabwe has numerous small rivers and streams that can support mini and micro-hydro projects. These projects can provide localized energy solutions, particularly in remote areas where grid extension is not feasible (Nhodo et al., 2018).

2.7 Challenges in Transitioning to a Low Carbon Economy

Despite the significant potential, Zimbabwe faces several challenges in transitioning to a low carbon energy industry.

2.7.1 Financial Constraints

The development and deployment of renewable energy technologies require substantial investment, which is a major hurdle given Zimbabwe's economic challenges (Munzhedzi, 2020).

Access to funding and financing mechanisms is limited, and there is a lack of incentives for private sector investment in renewable energy. One of the major financial challenges is the limited access to capital and financing for renewable energy and energy efficiency projects (Mapako & Mbewe, 2021). Zimbabwe's financial institutions often lack the necessary expertise and risk appetite to invest in innovative low-carbon technologies, hindering the country's ability to mobilize the required investments (Muzemil et al., 2020). The initial capital costs of transitioning to low-carbon technologies, such as solar, wind, and biomass energy systems, can be significantly higher than conventional fossil fuel-based alternatives (Mugundani et al., 2019). This poses a significant barrier for individuals, communities, and businesses in Zimbabwe, who often lack the financial resources to invest in these technologies (Zheng et al., 2021). Zimbabwe's government has limited financial resources to provide subsidies, tax incentives, or other financial support mechanisms to promote the adoption of low-carbon technologies (Muzemil et al., 2020). This makes it challenging for individuals and businesses to justify the higher upfront costs associated with renewable energy and energy efficiency investments (Mapako & Mbewe, 2021). Zimbabwe has faced significant macroeconomic challenges, including high inflation rates, currency fluctuations, and economic volatility, which can deter long-term investments in low-carbon projects (Zheng et al., 2021). This instability creates uncertainty and risk, making it difficult for investors to commit resources to renewable energy and energy efficiency initiatives (Mugundani et al., 2019).

2.7.2 Technical and Infrastructure Barriers

The existing energy infrastructure is outdated and not designed to integrate renewable energy sources efficiently. There is a need for modernizing the grid and investing in smart grid technologies that can manage variable renewable energy inputs (Guta, 2018). This poses a challenge for the integration of renewable energy sources, such as solar and wind, which require a robust and reliable grid system to transmit and distribute the generated power (Mapako & Mbewe, 2021). In addition, Zimbabwe faces a shortage of skilled personnel and technical expertise required for the design, installation, and maintenance of low-carbon technologies (Muzemil et al., 2020). This gap in technical capacity hinders the effective deployment and operation of renewable energy systems, as well as the development of energy efficiency measures (Zheng et al., 2021). Zimbabwe often faces challenges in accessing the latest low-carbon technologies, such as solar panels, wind turbines, and efficient appliances, due to the country's remote location and limited manufacturing capabilities (Mapako & Mbewe, 2021).

This can result in higher costs, longer delivery times, and reduced availability of these critical components for low-carbon projects (Mugundani et al., 2019). The intermittent nature of renewable energy sources, such as solar and wind, requires effective energy storage solutions to ensure a reliable and stable supply of electricity (Muzemil et al., 2020).

However, Zimbabwe faces challenges in accessing and deploying affordable and efficient energy storage technologies, which can further hinder the integration of renewable energy into the grid (Mapako & Mbewe, 2021). Zimbabwe faces a shortage of technicians, engineers, and specialists with the necessary skills to design, install, operate, and maintain low-carbon technologies (Mugundani et al., 2019). This skills gap is particularly acute in areas such as solar photovoltaic systems, wind turbine maintenance, and energy efficiency auditing (Muzemil et al., 2020). Addressing this challenge would require investing in vocational training, technical education, and capacity-building programs to develop a skilled workforce capable of supporting the low-carbon transition (Mapako & Mbewe, 2021).

2.7.3 Policy and Regulatory Challenges

Although the government has introduced policies to promote renewable energy, there are gaps in implementation and enforcement. Inconsistent policies and a lack of clear regulatory frameworks deter investors and create uncertainties in the renewable energy sector (Makumbe, 2020). Zimbabwe currently lacks a comprehensive and coherent policy framework to drive the transition towards a low-carbon economy (Mapako & Mbewe, 2021). The existing policies and regulations are often fragmented, with limited coordination and integration across different sectors (Muzemil et al., 2020). The development and implementation of a holistic national climate change policy, renewable energy strategy, and energy efficiency guidelines could provide the necessary policy support for low-carbon initiatives (Mugundani et al., 2019). Zimbabwe's policy and regulatory environment does not provide adequate financial incentives, such as tax credits, feed-in tariffs, or subsidies, to encourage investment in renewable energy and energy efficiency projects (Zheng et al., 2021). The lack of access to affordable financing and credit facilities further hinders the deployment of low-carbon technologies, particularly for small-scale and community-based projects (Muzemil et al., 2020). Implementing a comprehensive system of financial incentives and support mechanisms could help attract private sector investment and facilitate the widespread adoption of low-carbon solutions (Mapako & Mbewe, 2021). Zimbabwe's institutional and regulatory capacity to effectively implement and enforce low-carbon policies and regulations is often limited (Mugundani et al., 2019).

The lack of clear mandates, coordination, and enforcement mechanisms can undermine the effectiveness of existing policies and regulations, hindering the transition towards a low-carbon economy (Muzemil et al., 2020). Strengthening the institutional and regulatory framework, including the development of capacity-building programs for relevant government agencies, could help address this challenge (Mapako & Mbewe, 2021). Zimbabwe's policy and regulatory environment often lacks mechanisms to enable and encourage community participation in low-carbon initiatives, such as small-scale renewable energy projects or energy efficiency programs (Zheng et al., 2021). This centralized approach can limit the engagement and ownership of local communities, which are crucial for the successful deployment and long-term sustainability of low-carbon solutions (Mugundani et al., 2019). Promoting decentralized and community-based models, along with supportive policies and regulations, could help empower local stakeholders and foster a more inclusive transition towards a low-carbon economy (Mapako & Mbewe, 2021).

2.7.4 Social and Cultural Barriers

There is limited awareness and acceptance of renewable energy technologies among the general population. Cultural preferences for traditional energy sources and a lack of education on the benefits of renewable energy pose additional challenges (Mzezewa, 2018). More so, There is a general lack of public awareness and understanding of the importance of low-carbon practices, renewable energy, and energy efficiency in Zimbabwe (Muzemil et al., 2020). This lack of awareness and engagement can limit the adoption of low-carbon technologies and practices at the individual and community levels (Mapako & Mbewe, 2021). Implementing public awareness campaigns, educational programs, and community engagement initiatives could help raise awareness and foster a more supportive social environment for the low-carbon transition (Mugundani et al., 2019). Zimbabwe's cultural and social norms can sometimes favor traditional energy sources and practices, creating resistance to the adoption of new low-carbon technologies and behaviors (Zheng et al., 2021). For example, the reliance on biomass fuels, such as firewood and charcoal, for household energy needs is deeply ingrained in many communities, making it challenging to transition to cleaner energy alternatives (Mapako & Mbewe, 2021).

Overcoming these cultural preferences and behavioral inertia will require targeted interventions, including the integration of low-carbon solutions with cultural practices and the promotion of positive social norms (Mugundani et al., 2019). The transition towards a low-carbon economy can have implications for equity and social justice, particularly for marginalized and vulnerable populations (Muzemil et al., 2020). There are concerns that the costs and benefits of low-carbon initiatives may not be equitably distributed, potentially exacerbating existing socioeconomic disparities (Mapako & Mbewe, 2021). Addressing these equity and social justice concerns through inclusive policies, targeted support, and community-based approaches can help ensure a just and inclusive low-carbon transition (Mugundani et al., 2019). Zimbabwe's gender dynamics can create additional challenges in the low-carbon transition, as women often face disproportionate barriers in accessing and using low-carbon technologies (Zheng et al., 2021). For example, the burden of domestic energy use, including the collection of firewood, can fall more heavily on women, limiting their ability to engage in and benefit from low-carbon initiatives (Muzemil et al., 2020). Addressing these gender-related barriers through targeted policies, capacity-building programs, and the involvement of women in decision-making processes can help ensure a more inclusive and equitable low-carbon transition (Mapako & Mbewe, 2021).

2.8 Policy and Regulatory Framework

The Zimbabwean government has recognized the importance of transitioning to a low carbon economy and has introduced several policies and frameworks to support this transition.

2.8.1 National Renewable Energy Policy (NREP)

Zimbabwe has taken steps towards developing a National Renewable Energy Policy to address the country's transition towards a low-carbon economy. The NREP aims to promote the development and utilization of renewable energy resources in Zimbabwe. It outlines targets for increasing the share of renewable energy in the national energy mix and provides guidelines for the development of renewable energy projects (ZERA, 2020).

The National Renewable Energy Policy aims to increase the share of renewable energy in Zimbabwe's energy mix, with a target of achieving at least 16% renewable energy generation by 2030 (Government of Zimbabwe, 2019). This policy objective is aligned with Zimbabwe's Nationally Determined Contribution (NDC) under the Paris Agreement, which commits the country to reducing its greenhouse gas emissions (Government of Zimbabwe, 2021). The policy prioritizes the development of various renewable energy technologies, including solar photovoltaic (PV), wind, hydropower, and biomass energy (Government of Zimbabwe, 2019). It outlines strategies to promote the deployment of these technologies, such as providing financial incentives, streamlining regulations, and supporting research and development (Government of Zimbabwe, 2019). The policy aims to facilitate the integration of renewable energy into the national grid, addressing technical and regulatory barriers to ensure the reliable and seamless integration of renewable energy sources (Government of Zimbabwe, 2019). It also encourages the development of decentralized and off-grid renewable energy solutions, particularly in rural and remote areas, to improve energy access and reduce reliance on fossil fuels (Government of Zimbabwe, 2019). The policy establishes the institutional and regulatory framework to support the implementation of renewable energy initiatives, including the creation of a Renewable Energy Unit within the Ministry of Energy and Power Development (Government of Zimbabwe, 2019). It also outlines the roles and responsibilities of various stakeholders, such as government agencies, private sector, and civil society, in the development and deployment of renewable energy projects (Government of Zimbabwe, 2019). The policy introduces a range of financial incentives and support mechanisms to attract investment in renewable energy projects, such as tax credits, feed-in tariffs, and concessional financing (Government of Zimbabwe, 2019). It also explores the potential for international climate finance and development assistance to supplement domestic resources for renewable energy deployment (Government of Zimbabwe, 2021).

The National Renewable Energy Policy represents a significant step forward in Zimbabwe's efforts to transition towards a low-carbon economy. By setting clear targets, promoting diverse renewable energy technologies, addressing grid integration and decentralization, strengthening the institutional and regulatory framework, and providing financial incentives, the policy aims to create an enabling environment for the widespread adoption of renewable energy solutions. However, the successful implementation of this policy will require sustained political will, continued investment, and the coordination of various stakeholders to overcome the existing technical, financial, and socio-cultural barriers.

2.8.2 Rural Electrification Fund (REF)

The REF focuses on extending electricity access to rural areas through renewable energy technologies. It supports the deployment of solar home systems, mini-grids, and other renewable energy solutions (Sithole et al., 2019). The Rural Electrification Fund was established in 2002 through the Rural Electrification Act (Government of Zimbabwe, 2002). The primary objectives of the REF are to facilitate the electrification of rural areas, promote the use of renewable energy technologies, and ensure equitable access to electricity across the country (Government of Zimbabwe, 2019). The REF is funded through a rural electrification levy, which is charged to all electricity consumers in Zimbabwe (Government of Zimbabwe, 2019). The collected funds are used to provide subsidies, grants, and loans for the implementation of rural electrification projects, with a focus on renewable energy solutions (Muzemil et al., 2020). The REF prioritizes the electrification of rural communities, schools, clinics, and other public institutions, as well as the promotion of productive uses of electricity in rural areas (Government of Zimbabwe, 2019). Projects are selected through a competitive bidding process, with preference given to renewable energy-based solutions that demonstrate technical and financial viability (Mugundani et al., 2019). The REF has supported the deployment of various renewable energy technologies, including solar photovoltaic (PV) systems, mini-hydropower plants, and biomass energy projects (Zheng et al., 2021). These renewable energy solutions have helped to improve energy access, reduce reliance on fossil fuels, and promote sustainable development in rural communities (Mapako & Mbewe, 2021). The REF operates under the oversight of the Rural Electrification Agency, which is responsible for the implementation and management of the fund (Government of Zimbabwe, 2019). The regulatory framework surrounding the REF is established through the Rural Electrification Act and other relevant policies, ensuring a supportive environment for its operations (Government of Zimbabwe, 2002).

The Rural Electrification Fund has played a significant role in Zimbabwe's efforts to expand energy access and promote the use of renewable energy, particularly in rural areas. By providing financial support and prioritizing renewable energy solutions, the REF has contributed to the deployment of sustainable energy technologies and the improvement of living standards in underserved communities. As Zimbabwe continues its transition towards a low-carbon economy, the ongoing effectiveness and expansion of the REF will be crucial in ensuring a more equitable and inclusive energy future.

2.8.3 Incentives and Subsidies

The government has introduced various incentives, including tax breaks, import duty exemptions, and subsidies for renewable energy equipment and projects. These measures are designed to attract investment and reduce the cost of renewable energy technologies (Munzhedzi, 2020).

2.8.4 International Cooperation and Support

International cooperation and support play a crucial role in Zimbabwe's renewable energy transition. Several international organizations and development partners are actively involved in promoting renewable energy in Zimbabwe.

The Government of Zimbabwe has actively engaged with the international community to seek support for its low-carbon industrial transition (United Nations Development Programme, 2020). Multilateral organizations, such as the United Nations Development Programme (UNDP) and the Green Climate Fund (GCF), have provided technical and financial assistance to Zimbabwe for the development of low-carbon industrial technologies and infrastructure (UNDP, 2020; GCF, 2021). Bilateral partnerships with countries like China, Germany, and Japan have facilitated the transfer of clean energy technologies, such as solar photovoltaic systems and energy-efficient manufacturing processes, to Zimbabwe's industrial sector (Renewable Energy Policy Network for the 21st Century, 2019).

2.8.5 Global Environment Facility (GEF)

The Global Environment Facility (GEF) is a key international organization that provides financial and technical assistance to developing countries, including Zimbabwe, in their efforts to address global environmental challenges. The GEF provides funding and technical assistance for renewable energy projects in Zimbabwe. Its projects focus on capacity building, policy development, and the implementation of renewable energy technologies (GEF, 2019).

The GEF was established in 1991 to provide grants and concessional funding to address global environmental issues, such as climate change, biodiversity loss, and land degradation (Global Environment Facility, 2022). The GEF operates as a partnership between 183 countries, international institutions, civil society organizations, and the private sector, working to catalyze transformative change towards sustainable development (Global Environment Facility, 2022).

The GEF has recognized the importance of supporting Zimbabwe's efforts to transition its industrial sector towards a low-carbon model, aligning with the country's national development priorities and climate change commitments (Global Environment Facility, 2020). Through its various funding mechanisms, the GEF has provided financial and technical assistance to Zimbabwe for the implementation of industrial energy efficiency projects, the deployment of renewable energy technologies, and the development of supportive policy and regulatory frameworks (Global Environment Facility, 2020). For example, the GEF-funded "Scaling Up Solar Energy in Zimbabwe" project aims to promote the use of solar energy in the industrial and commercial sectors, addressing the challenges of energy access and greenhouse gas emissions (Global Environment Facility, 2018). The GEF works in close collaboration with Zimbabwe's government, the United Nations Development Programme (UNDP), and other international organizations to ensure a coordinated and holistic approach to the country's low-carbon industrial transition (Global Environment Facility, 2020). By leveraging its partnerships, the GEF facilitates the sharing of best practices, the transfer of clean technologies, and the mobilization of additional resources to support Zimbabwe's industrial decarbonization efforts (Global Environment Facility, 2020).

Despite the GEF's support, Zimbabwe still faces challenges in mobilizing sufficient financing and building the necessary institutional and technical capacities to scale up its low-carbon industrial initiatives (Chiguvare & Mupfuriri, 2021). Ongoing coordination and alignment between the GEF's priorities and Zimbabwe's national development goals are crucial to ensure the long-term sustainability and impact of the supported interventions (Mupfumi & Nyoni, 2018).

The Global Environment Facility's support has been instrumental in catalyzing Zimbabwe's transition towards a low-carbon industrial sector. By providing financial and technical assistance, as well as facilitating collaborative partnerships, the GEF has played a pivotal role in advancing the country's efforts to address climate change and promote sustainable development within its industrial landscape. However, ongoing challenges, such as financing and capacity building, require continued engagement and a strengthened commitment from both the GEF and the Zimbabwean government to fully realize the low-carbon industrial transformation.

2.8.6 United Nations Development Programme (UNDP)

The United Nations Development Programme (UNDP) is a key international organization that has been actively engaged in supporting Zimbabwe's efforts to transition its industrial sector towards a low-carbon model. The UNDP supports renewable energy initiatives through its various programs aimed at sustainable development and climate change mitigation. The UNDP has partnered with the Zimbabwean government to promote solar energy and improve energy access in rural areas (UNDP, 2020).

The UNDP is the United Nations' global development network, focused on helping countries achieve the Sustainable Development Goals (SDGs), including SDG 9 on industry, innovation, and infrastructure, and SDG 13 on climate action (UNDP, 2022). The UNDP's work in Zimbabwe is guided by the United Nations Sustainable Development Cooperation Framework, which prioritizes sustainable economic transformation, including the promotion of low-carbon industrial development (UNDP, 2021). The UNDP has been a key partner in supporting Zimbabwe's efforts to transition its industrial sector towards a low-carbon model, providing technical and financial assistance through various initiatives (UNDP, 2020).

One such initiative is the "Scaling Up Solar Energy in Zimbabwe" project, implemented in partnership with the Global Environment Facility (GEF), which aims to promote the use of solar energy in the industrial and commercial sectors (UNDP, 2018). The UNDP has also supported the development of policy and regulatory frameworks to create an enabling environment for the adoption of low-carbon industrial technologies and practices in Zimbabwe (UNDP, 2020). The

UNDP has worked to strengthen the institutional and technical capacities of Zimbabwe's industrial sector to effectively assess, plan, and implement low-carbon initiatives (UNDP, 2020).

This includes providing training and technical assistance to key stakeholders, such as government agencies, industry associations, and research institutions, to enhance their understanding and capabilities in areas like energy efficiency, renewable energy, and sustainable manufacturing (UNDP, 2020). The UNDP has also facilitated knowledge-sharing platforms and exchanges, enabling the transfer of best practices and lessons learned from other countries' experiences in transitioning their industrial sectors to low-carbon models (UNDP, 2020). The UNDP works in close collaboration with the Zimbabwean government, the private sector, and other international organizations, such as the GEF, to ensure a coordinated and holistic approach to the country's low-carbon industrial transformation (UNDP, 2021). By leveraging its extensive network and expertise, the UNDP helps to mobilize additional resources, align development priorities, and facilitate the integration of low-carbon solutions into Zimbabwe's industrial development strategies (UNDP, 2021).

The UNDP's sustained commitment and support have been instrumental in advancing Zimbabwe's transition towards a low-carbon industrial sector. By providing technical and financial assistance, building capacities, and fostering collaborative partnerships, the UNDP has played a crucial role in catalyzing the country's efforts to address climate change and promote sustainable industrial development. However, the challenges of scaling up low-carbon initiatives and aligning international support with national priorities require continued engagement and cooperation between the UNDP, the Zimbabwean government, and other key stakeholders.

2.8.7 International Renewable Energy Agency (IRENA)

IRENA provides technical assistance, policy advice, and capacity-building support to Zimbabwe. It facilitates knowledge sharing and the transfer of renewable energy technologies (IRENA, 2018).

IRENA is an intergovernmental organization dedicated to promoting the widespread adoption and sustainable use of all forms of renewable energy (IRENA, 2022). As a global authority on renewable energy, IRENA provides technical advice, policy support, and capacity-building assistance to its member countries, including Zimbabwe, to accelerate the global energy transformation (IRENA, 2022). IRENA has recognized the importance of supporting Zimbabwe's efforts to transition its industrial sector towards a low-carbon model, aligning with the country's national development priorities and climate change commitments (IRENA, 2019).

Through its various programs and initiatives, IRENA has provided technical and advisory support to the Zimbabwean government, industry associations, and other stakeholders in the areas of renewable energy deployment, energy efficiency, and sustainable industrial practices (IRENA, 2019). For example, IRENA has supported the development of Zimbabwe's Renewable Energy Roadmap, which outlines the country's strategic plan for increasing the share of renewable energy in its overall energy mix, including in the industrial sector (IRENA, 2019). IRENA has been actively involved in building the technical and institutional capacities of Zimbabwe's industrial sector to effectively assess, plan, and implement renewable energy and energy efficiency projects (IRENA, 2020). This includes providing training and workshops to key stakeholders, such as government agencies, industry associations, and project developers, to enhance their understanding and capabilities in areas like renewable energy technology selection, project financing, and policy development (IRENA, 2020). IRENA has also facilitated knowledge-sharing platforms and exchanges, enabling the transfer of best practices and lessons learned from other countries' experiences in transitioning their industrial sectors to low-carbon models (IRENA, 2020). IRENA works in close collaboration with the Zimbabwean government, the private sector, and other international organizations, such as the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF), to ensure a coordinated and holistic approach to the country's low-carbon industrial transformation (IRENA, 2021).

By leveraging its partnerships, IRENA helps to align development priorities, mobilize additional resources, and facilitate the integration of renewable energy and energy efficiency solutions into Zimbabwe's industrial development strategies (IRENA, 2021). The International Renewable Energy Agency's (IRENA) support has been crucial in advancing Zimbabwe's transition towards a low-carbon industrial sector. By providing technical and advisory assistance, building capacities, and fostering collaborative partnerships, IRENA has played a significant role in catalyzing the country's efforts to increase the deployment of renewable energy and energy efficiency technologies within its industrial landscape. However, continued engagement and strengthened coordination between IRENA, the Zimbabwean government, and other stakeholders are necessary to overcome the challenges and scale up these low-carbon initiatives in the industrial sector.

2.9 Summary

This chapter has reviewed the literature on the state of the energy sector in Zimbabwe, the potential for renewable energy, the challenges faced in transitioning to a low carbon economy, and the policy and regulatory frameworks that could facilitate this transition. Despite significant renewable energy potential, Zimbabwe faces financial, technical, policy, and social challenges. However, with the support of international cooperation and robust policy measures, Zimbabwe can overcome these challenges and achieve a sustainable, low carbon energy future.

3 Chapter 3: Research Methodology

3.1 Introduction

The previous chapter presented the literature review for the study. This chapter outlines the research methodology employed in this study on renewable energy and its potential to foster a low-carbon industry in Zimbabwe. The main issues discussed in this chapter are the research paradigm, research approach, research strategy, research design, population, sampling strategy, research instruments, data collection procedures, issues of reliability, validity and trustworthiness, ethical considerations as well as data analysis procedures. The methodology of this study followed Wilson’s (2013) honeycomb of research methodology which illustrates the six main elements that form research methodology namely: (i) research philosophy; (ii) research approach, (iii) research strategy; (iv) research design, (v) data collection and (vi) data analysis techniques. The research methodology framework guiding the chapter is presented in Figure 3.1.

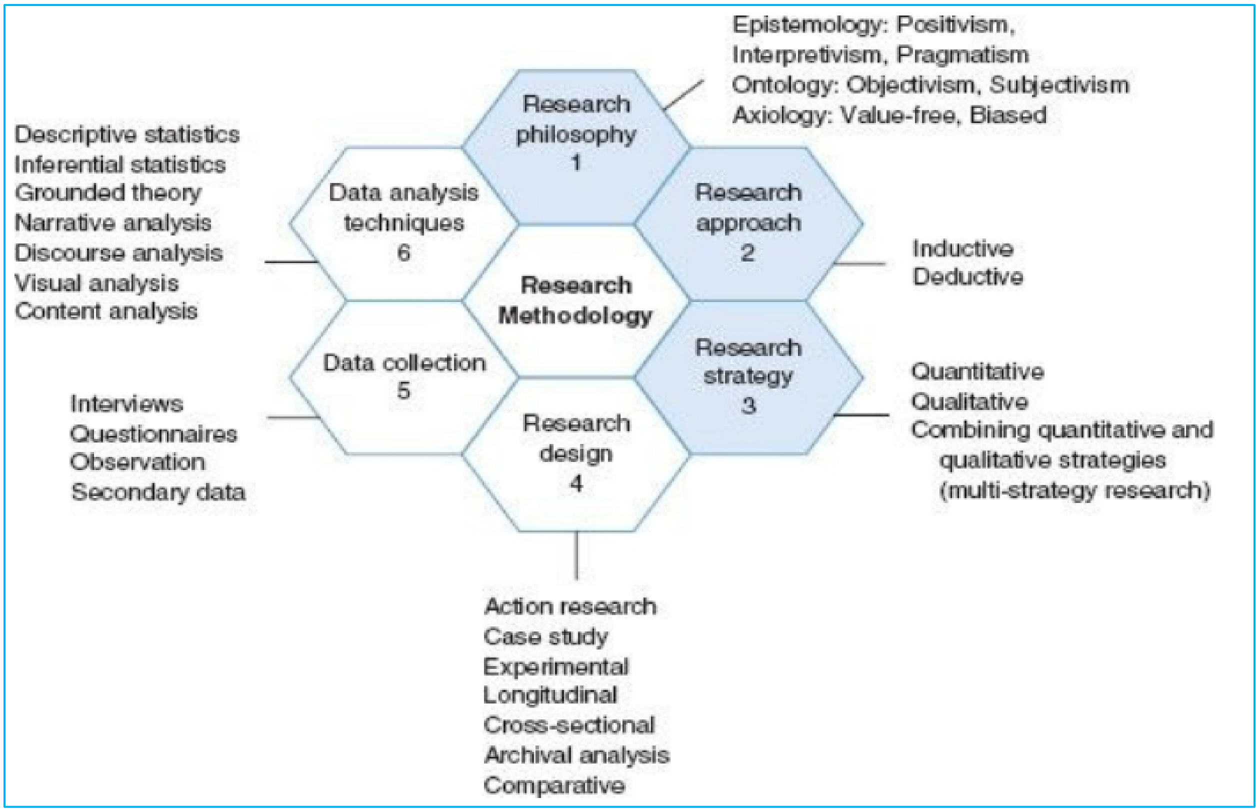

Figure 3.1

Source: Wilson (2013, p.32)

3.2 Research philosophy

Pragmatism, as a philosophical approach, emphasizes practicality, problem-solving, and the real-world application of knowledge. It acknowledges that knowledge evolves through experience and experimentation. In the context of renewable energy in Zimbabwe, a pragmatist research philosophy guides the study in several ways. A pragmatist approach encourages researchers to adopt a problem-oriented perspective. Researchers focus on identifying and solving real-world problems related to the development of a low carbon energy industry in Zimbabwe. The study would involve investigating specific obstacles faced by the country, such as policy gaps, financial limitations, technological barriers, and social acceptance issues. The goal is to propose practical solutions that address these challenges and facilitate the transition towards renewable energy.

Pragmatism also emphasizes the integration of multiple disciplines and perspectives. Researchers adopting a pragmatist research philosophy collaborate with experts from diverse fields such as engineering, economics, policy, sociology, and environmental science. This interdisciplinary approach enables a holistic examination of the topic, considering the social, economic, and environmental dimensions. By bringing together different areas of expertise, researchers can develop comprehensive and practical strategies for the implementation of renewable energy projects in Zimbabwe.

Pragmatism also promotes flexibility and adaptability in research. It recognizes that knowledge and understanding are context-dependent and evolve over time. Researchers adopting a pragmatist philosophy remain open to modifying their approaches, strategies, and recommendations based on new information, technological advancements, and evolving socio-political dynamics. This adaptability ensures that the research stays relevant and responsive to the changing circumstances and emerging challenges in the field of renewable energy in Zimbabwe.

3.3 Research strategy

The chosen research strategy for this study is a mixed-methods, combining both qualitative and quantitative research methods. This strategy is justified as it allows for a comprehensive analysis of the renewable energy sector in Zimbabwe, capturing both numerical data and in-depth insights from stakeholders. The quantitative aspect involves the analysis of statistical data on energy production and consumption, while the qualitative aspect involves interviews with key stakeholders in the energy sector.

Mixed-methods research is particularly suited for this study as it provides a more holistic understanding of the complex issue of transitioning to a low-carbon industry. Creswell and Plano Clark (2018) advocate for mixed-methods when exploring multifaceted research problems, as it integrates diverse perspectives and enriches the findings.

3.4 Research design

In this study the researcher adopted the case study design. A case study research design allows for an in-depth examination of a specific case or organization, providing insights into the complexities and dynamics of the renewable energy transition within the context of these entities.

The case study design would involve collecting and analyzing data from various sources, including interviews with key stakeholders, documentary evidence, reports, and relevant literature. The research would aim to understand the current state of renewable energy adoption within ZESA and the role of ZERA in shaping the regulatory framework for a low carbon energy industry in Zimbabwe.

The case study would explore the policies, regulations, and initiatives implemented by ZERA to promote renewable energy development and integration within the country's energy sector. It would examine the challenges faced by ZESA in adopting renewable energy technologies and diversifying its energy mix. Factors such as financial constraints, technical limitations, and institutional barriers would be investigated to understand their impact on the transition towards a low carbon energy industry. Furthermore, the case study design would allow for a comprehensive evaluation of the socio-economic and environmental implications of the renewable energy transition within ZESA and under the regulatory oversight of ZERA. The research would assess the potential benefits in terms of job creation, energy access, and reduced carbon emissions, as well as any potential challenges or trade-offs associated with the shift towards renewable energy sources.

3.5 Population

Population refers to a collection of objects, elements, individuals, or cases where a sample is drawn (Mugenda and Mugenda, 2012). The target population for the study comprised of employees from ZERA and ZESA. The total population of the study 75 for ZESA and 81 for ZERA. Therefore the target population for the study is 156 individuals.

3.6 Sampling

According to Saunders *et al*. (2012), sampling is a process of systematically choosing cases for inclusion in a research. The study made use of both probability and non-probability sampling techniques. Participants for the survey were selected using the simple random sampling techniques whilst participants for the key informant interviews were selected using the purposive sampling technique.

3.6.1 Purposive sampling

A purposive sampling method was employed for the qualitative component of this research. Patton (2014) defined purposive or judgmental sampling as a non-probability sampling technique in which individuals, cases or events are deliberately selected to provide important information that is not obtainable from other choices. This involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Creswell & Plano Clark, 2011). This method was selected because it allows for the deliberate selection of participants who have specific knowledge or experience relevant to the study's objectives (Palinkas et al., 2015).

Purposive sampling involves selecting participants or cases based on specific criteria that align with the research objectives. In this case, key stakeholders within ZESA and ZERA, such as top-level executives, policymakers, and experts in renewable energy, could be purposively selected to provide valuable insights into the transition process and regulatory framework. Their expertise and involvement in decision-making make them ideal participants for understanding the challenges, strategies, and opportunities associated with the shift towards a low carbon energy industry. Purposive sampling ensures that the selected participants have the knowledge and experience necessary to provide relevant and in-depth information for the research.

3.6.2 Simple random sampling

For the quantitative component, stratified random sampling was used to ensure representation across different segments of the population. This method ensures that sub-groups within the larger population, such as urban and rural energy consumers, are adequately represented, providing a more accurate picture of energy use patterns and attitudes towards renewable energy. Simple random sampling allows for the selection of participants from a broader population within ZESA and ZERA. By randomly choosing individuals, the sample becomes more representative, ensuring that a diverse range of viewpoints and experiences are included in the study. This increases the generalizability of the findings to the larger population of stakeholders within the organizations. A representative sample helps to avoid biases and ensures that the research captures a comprehensive picture of the current state and potential of a low carbon energy industry in

Zimbabwe. The findings can be more confidently applied to inform decision-making and policy recommendations beyond the specific case of ZESA and ZERA.

3.7 Data Collection Instruments

3.7.1 Semi-Structured Interviews/questionnaire

Semi-structured interviews were conducted with selected stakeholders. This instrument was chosen for its flexibility, allowing the researcher to explore specific areas of interest in-depth while also accommodating new insights (Kallio et al., 2016). The choice of utilizing semi-structured interviews was based on several advantages it offers for this particular study. One significant advantage is the flexibility that this interview format provides. Unlike structured interviews that follow a predetermined set of questions, semi-structured interviews allow the researcher to explore specific areas of interest in-depth. This flexibility is crucial when investigating a complex topic like renewable energy, as it enables the researcher to delve deeply into the experiences, perspectives, and insights of the stakeholders involved in the transition process.

The semi-structured format also accommodates the emergence of new insights during the interview process. As the interviews progress, participants may introduce novel ideas, experiences, or perspectives that were not initially anticipated by the researcher. This format allows the researcher to adapt and explore these new insights, ensuring that valuable information is not missed. It encourages a conversational style, creating an open and comfortable environment for participants to share detailed and nuanced information. The conversational nature of semi-structured interviews promotes a deeper understanding of the stakeholders' viewpoints, motivations, challenges, and aspirations related to the transition towards a low carbon energy industry in Zimbabwe. Moreover, semi-structured interviews provide the opportunity for participants to elaborate on their responses, providing rich qualitative data. This allows for a more comprehensive analysis of the factors influencing the renewable energy transition within ZESA and ZERA. By encouraging participants to share their experiences and perspectives in their own words, the interviews capture the complexity and depth of their knowledge, providing valuable insights for the research.

3.7.2 Questionnaire

The distribution of surveys to a larger sample size allows for a more comprehensive understanding of energy consumption patterns and a wider range of attitudes towards renewable energy within the target population. By reaching a diverse audience, the research can capture a broader spectrum of perspectives and experiences, enhancing the representativeness of the findings. This larger sample size also provides statistical power to the results, increasing the confidence level in the data analysis and the ability to draw meaningful conclusions regarding energy consumption and attitudes towards renewable energy in Zimbabwe.

The survey instrument itself was designed to incorporate a combination of closed and open-ended questions. Closed-ended questions, such as multiple-choice or Likert scale items, provide structured response options that allow for efficient data collection and analysis. These questions provide quantifiable data that can be easily summarized and statistically analyzed. On the other hand, open-ended questions allow respondents to provide more detailed and nuanced responses, capturing their individual perspectives and experiences. The inclusion of open-ended questions ensures that participants have the opportunity to express their thoughts and opinions beyond the limited options provided in closed-ended questions. This combination of question types enables the research to explore both quantitative trends and qualitative insights, providing a more comprehensive understanding of energy consumption patterns and attitudes towards renewable energy in Zimbabwe.

3.8 Data Analysis Procedures

3.8.1 Qualitative Data Analysis

Thematic analysis played a crucial role in analyzing the qualitative data obtained from the semi-structured interviews conducted in the research on "Renewable Energy: Moving towards a low carbon energy industry in Zimbabwe," focusing on the case of ZESA and ZERA. This approach allowed for a comprehensive exploration of the interview data, identifying patterns, and themes that emerged from the participants' responses.

Thematic analysis involves a systematic process of coding and categorizing the data to identify recurring ideas, concepts, or patterns. The interview transcripts were carefully reviewed, and relevant segments of data were coded based on their content. This coding process involved labeling and categorizing specific aspects of the data related to energy consumption patterns and attitudes towards renewable energy. By using NVivo software, the analysis process was streamlined, providing efficient organization and management of the data. NVivo facilitated the systematic coding of the interview transcripts, enabling researchers to easily navigate through the data and retrieve relevant segments during the analysis.

As the coding process progressed, patterns and themes started to emerge. These themes represented meaningful patterns, ideas, or concepts that recurred across multiple interviews. For example, themes related to the barriers to renewable energy adoption, attitudes towards government policies, or perceptions of renewable energy technologies may have emerged from the data. These themes provided insights into the participants' perspectives and experiences, highlighting important aspects related to energy consumption patterns and attitudes towards renewable energy in Zimbabwe.

By employing thematic analysis, the research gained a deeper understanding of the qualitative data and the richness of the participants' narratives. The analysis allowed for the exploration of various viewpoints, experiences, and interpretations related to the research topic. The use of NVivo software enhanced the rigor, reliability, and validity of the analysis by providing a systematic and transparent approach to organizing and analyzing the interview data..

3.8.2 Quantitative Data Analysis

Descriptive and inferential statistics played a crucial role in the analysis of the survey data collected in the research on "Renewable Energy: Moving towards a low carbon energy industry in Zimbabwe," focusing on the case of ZESA and ZERA. The utilization of statistical software, such as SPSS (Statistical Package for the Social Sciences), facilitated the application of various statistical techniques to gain insights and draw meaningful conclusions from the data. Descriptive statistics were employed to summarize and describe the characteristics of the survey data. Measures such as frequency distributions, measures of central tendency (e.g., mean, median), and measures of variability (e.g., standard deviation, range) were calculated to provide a clear and concise summary of the data. These descriptive statistics allowed for the examination of the distribution and patterns in the responses, enabling researchers to identify the most common energy consumption patterns and attitudes towards renewable energy among the survey respondents.

In addition to descriptive statistics, inferential statistics were utilized to make inferences and draw conclusions about the broader population based on the sample data. Cross-tabulations, for instance, were employed to explore the relationships between different variables. By examining the associations between variables, such as demographic factors and attitudes towards renewable energy, researchers could identify potential patterns and trends. This analysis enables a deeper understanding of the factors that may influence energy consumption patterns and attitudes towards renewable energy in Zimbabwe. Regression analysis, another inferential statistical technique, was applied to examine the relationships between predictor variables (e.g., demographic factors, knowledge levels) and an outcome variable (e.g., attitudes towards renewable energy). This analysis helps to identify the factors that significantly contribute to the variations in attitudes towards renewable energy. Regression analysis allows researchers to explore the strength and direction of these relationships, providing insights into the potential predictors of positive or negative attitudes towards renewable energy adoption.

3.9 Reliability and Validity

Validity refers to the extent to which the research accurately measures or represents the intended concepts or variables, while reliability refers to the consistency and stability of the measurements or data collection methods used. Both validity and reliability play a significant role in establishing the trustworthiness of the research findings.

To ensure validity, multiple strategies were employed. Firstly, the research design incorporated a mixed-methods approach, combining qualitative and quantitative data collection methods. This triangulation of data allows for a comprehensive and multi-dimensional understanding of the research topic. By using semi-structured interviews and surveys, the study captures both in-depth, nuanced qualitative insights and broader quantitative trends related to energy consumption patterns and attitudes towards renewable energy. This comprehensive approach enhances the validity of the research findings by providing a more complete picture of the subject matter.

Moreover, the selection of participants for the interviews and surveys was carefully considered to ensure representativeness. Purposive sampling was employed for the interviews, which targeted key stakeholders within ZESA and ZERA, ensuring that individuals with relevant knowledge and expertise were included. This enhances the validity of the findings as it provides insights from those directly involved in the renewable energy transition. For the surveys, a broader audience was targeted, aiming to capture a diverse range of perspectives and experiences related to energy consumption and attitudes towards renewable energy in Zimbabwe. This approach increases the external validity of the research, allowing for broader generalization of the findings to the target population.

Reliability was addressed through the use of standardized data collection instruments and rigorous data collection procedures. The semi-structured interview guide and survey questionnaire were carefully designed to ensure clarity and consistency in the questions asked. This reduces measurement errors and ensures that participants are responding to the intended concepts. Additionally, detailed instructions and protocols were provided to the interviewers and survey administrators to ensure consistent administration of the instruments. This helps to minimize potential variations in data collection across different interviewers or survey administrators, enhancing the reliability of the data.

Furthermore, the use of closed-ended questions in the survey instrument contributes to the reliability of the collected quantitative data. Closed-ended questions provide structured response options, reducing ambiguity and potential variations in interpretation. This allows for consistent data collection and facilitates statistical analysis for reliable quantitative insights.

3.10 Ethical consideration

By addressing these ethical considerations, the research on renewable energy in Zimbabwe ensures the protection of participants' rights and well-being. It upholds the principles of integrity, respect, and responsibility, contributing to the ethical conduct of research and the generation of reliable and trustworthy findings. The following are the ethical considerations:

3.10.1 Informed Consent

Prior to participating in the study, all participants, including stakeholders involved in the semi-structured interviews and respondents of the surveys, were provided with clear information about the research objectives, procedures, and potential risks and benefits. Informed consent was obtained from each participant, ensuring their voluntary participation and understanding of their rights, including the right to withdraw from the study at any point without consequences.

3.10.2 Confidentiality and Anonymity

Measures were taken to ensure the confidentiality and anonymity of the participants. All data collected, whether through interviews or surveys, were coded and stored securely, with access limited only to the research team. Personal identifying information was kept separate from the data collected to maintain participant anonymity. In reporting the findings, no personally identifiable information was disclosed, thus protecting the privacy and confidentiality of the participants.

3.10.3 Respect for Participants

Throughout the research process, participants were treated with respect and dignity. Their viewpoints, experiences, and perspectives were valued, and efforts were made to create a safe and comfortable environment for them to share their insights. Participants were given the freedom to express their opinions openly and were not subjected to any form of coercion or pressure to conform to certain views or expectations.

3.10.4 Researcher Bias and Objectivity

The research team recognized the importance of maintaining objectivity and minimizing bias in the study. Steps were taken to mitigate potential biases by employing rigorous research methodologies, maintaining transparency in data collection and analysis procedures, and conducting peer reviews to ensure the research process was conducted impartially and accurately.

3.10.5 Responsible Data Handling

The research team adhered to ethical guidelines and legal requirements regarding data handling and protection. Data security measures were implemented to safeguard participants' information from unauthorized access or disclosure. Data were used solely for research purposes and were not shared or used for any other means without explicit consent from the participants.

3.11 Summary

This chapter has detailed the research methodology employed in this study, including the research design, sampling methods, data collection instruments, and data analysis procedures. By adopting a mixed-methods approach and employing rigorous data collection and analysis techniques, this study aims to provide a thorough and nuanced understanding of the potential for renewable energy to drive a low-carbon industry in Zimbabwe.

4 CHAPTER FOUR DATA ANALYSIS AND PRESENTATION

4.1 Introduction

This chapter discusses the interpretation and presentation of the outcomes of this research as gathered from the field. The chapter also includes each respondent's background information and the findings of the study's topics. The research findings are discussed using descriptive statistics in the form of charts, tables, and graphs. The chapter further states that following the display of demographic data, data obtained through questionnaires and interviews is categorized and presented under research topics.

4.2 Rate of response

In the study, researcher dispersed 156 questionnaires to the respondents. According to Table 3.1, only 156 of the intended 186 respondents completed and returned the surveys, giving in an 83% percent response rate. It is said to be appropriate for making judgments. According to Babbie (2010), a response rate of more than 83% is enough for analysis.

Table 4.1:Rate of response

	Respondent	Respondents
Questioners distributed	186	100%
Questioners returned	156	83%
Questioner not returned	20	17%

4.3 Demographic of respondent's

The current subsection presents the findings on respondent demographics, such as gender, age distribution, education, and years of working experience.

4.3.1 Gender

The respondents in this research were requested to indicate their gender as shown in Figure 4.1.

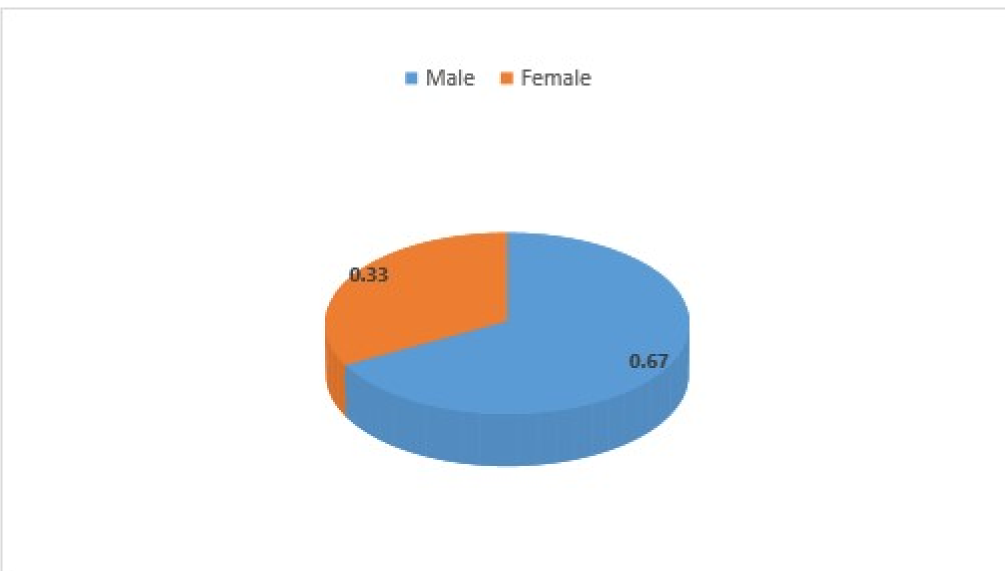

Figure 4.1

Above shows data on the gender composition of respondents in Zimbabwe's renewable energy industry reveals a significant imbalance, with 67% of respondents being male and only 33% being female. This male-dominated representation suggests that the industry currently lacks diversity and inclusivity. The gender disparity not only limits the range of perspectives and experiences but may also have implications for the equitable distribution of economic benefits and social impacts.

4.3.2 Years of experience

The respondents were inquired to indicate their years of experience. As shown in Fig 4.2

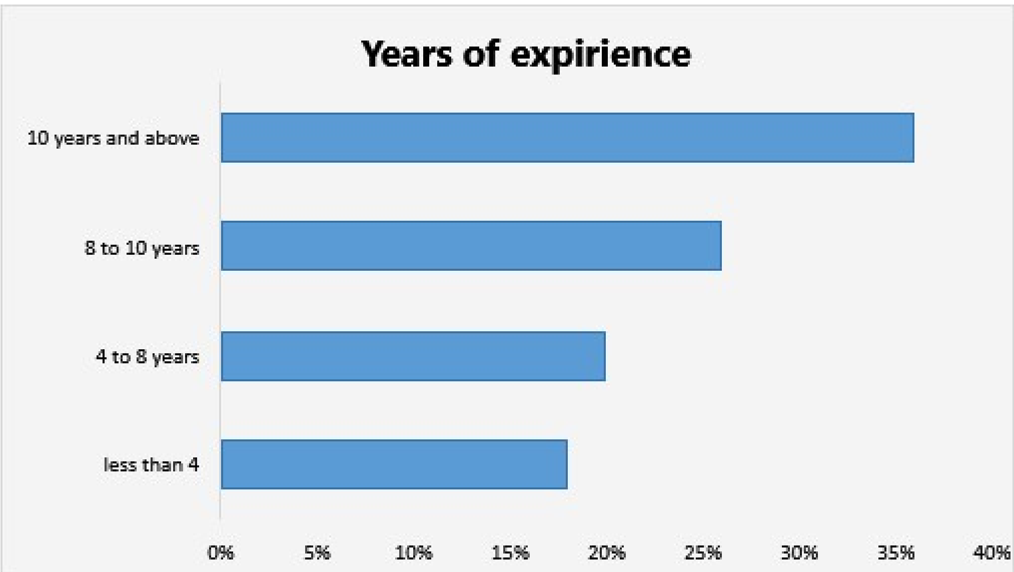

Figure 4.2

The data on the years of experience of respondents in Zimbabwe's renewable energy industry provides valuable insights into the workforce composition. The largest group, at 36%, have 10 years or more of experience, indicating a substantial pool of seasoned professionals in the sector. The 8 to 10 years experience group makes up 26% of respondents, followed by the 4 to 8 years experience group at 20%. Interestingly, 18% of respondents have less than 4 years of experience, suggesting a mix of both veteran and newer entrants to the industry. This distribution of experience levels suggests a maturing renewable energy sector in Zimbabwe, with a solid foundation of experienced personnel coupled with a steady influx of newer talent. Leveraging this diverse experience base can help drive innovation, knowledge transfer, and sustainable growth in the industry as the country continues its transition towards a low-carbon energy future.

4.3.3 Educational level

The respondents were inquired to indicate their level of education. As shown in Fig 4.3

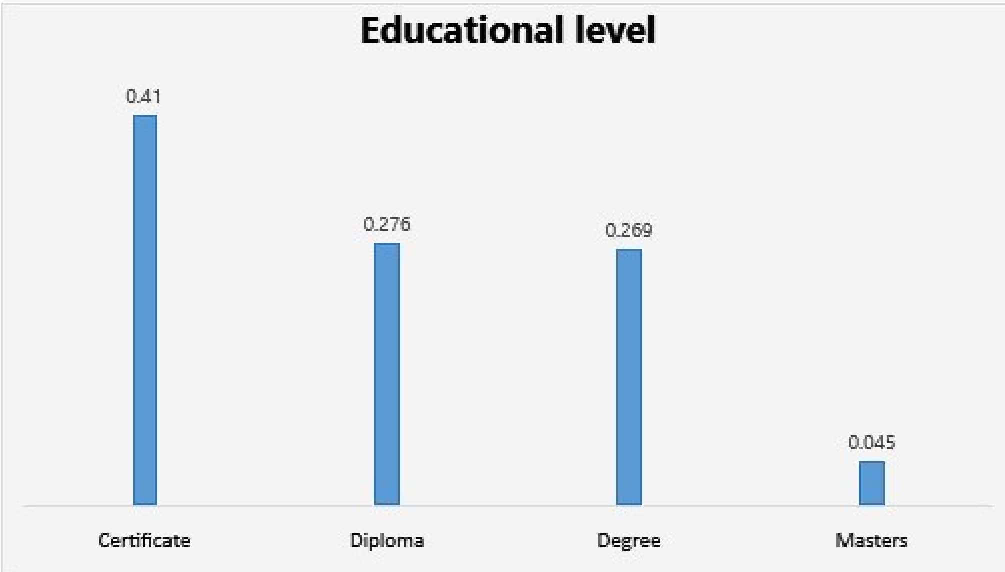

Figure 4.3

The data on the educational qualifications of respondents in Zimbabwe's renewable energy industry provides insights into the skill and knowledge base of the workforce. The largest group, comprising 41% of the respondents, hold a certificate-level qualification, indicating a significant presence of technicians and skilled workers with specialized training. Diploma holders make up 27.6% of the sample, suggesting a solid foundation of mid-level professionals with more comprehensive technical and vocational education. Degree holders, representing 26.9% of the respondents, bring a more academic and theoretical understanding to the industry, likely playing roles in engineering, project management, or policy development. At the highest level, 4.5% of respondents hold master's degrees, potentially serving in leadership, research, or advisory capacities. This diverse educational profile reflects the multifaceted nature of the renewable energy sector, which requires a blend of technical expertise, practical skills, and strategic leadership to drive the country's transition towards a low-carbon energy future. Leveraging this range of qualifications can help enhance the industry's innovation, efficiency, and adaptability.

4.3.4 Occupation

Figure 4.4

Fig 4.4 shows the data on the job roles of respondents in Zimbabwe's renewable energy industry reveals an interesting distribution of responsibilities. The largest group, comprising nearly half (49.7%) of the respondents, are general employees, suggesting a broad base of frontline workers in the sector. Supervisors make up the next largest group, accounting for 21% of the respondents, indicating a significant layer of middle management overseeing day-to-day operations. Technicians, who play a crucial role in the technical aspects of renewable energy systems, represent 19.3% of the sample. Notably, managers, who oversee strategic decision-making and leadership, constitute 10% of the respondents. This mix of job roles suggests a reasonably structured organizational hierarchy within the renewable energy industry in Zimbabwe, with a strong foundation of general employees supported by supervisory and technical personnel, and a smaller but vital management layer driving the overall strategic direction. Ensuring the right balance and development of these different roles will be crucial for the sector's continued growth and efficiency as the country transitions towards a low-carbon energy future.

4.4 Main findings

Descriptives statistics

4.4.1 Types of renewable energy used in Zimbabwe

The data on the types of renewable energy used in Zimbabwe, as reported by the respondents, provides a comprehensive overview of the renewable energy mix in the country. The mean scores and standard deviations for each renewable energy source offer valuable insights into their relative prevalence and the level of consensus among the respondents.

Table 4.2 : Types of renewable energy used

STATEMENT	Mean	Std Dev
Solar photovoltaic- Agriculture	2.00	1.290
Wind power- Manufacturing	2.24	1.374
Biomass/biofuels- Bioenergy Production	2.19	1.353
Hydropower- Hydroplants	1.79	1.039

Table 4.2: Types of renewable energy used

The data on the types of renewable energy used in various industries in Zimbabwe, as reported by the respondents, provides a comprehensive overview of the renewable energy mix in the country. The mean scores and standard deviations for each renewable energy source offer valuable insights into their relative prevalence and the level of consensus among the respondents.

Solar photovoltaic technology emerges as the most widely utilized renewable energy source, with a mean score of 2.00 and a standard deviation of 1.290. This suggests that solar PV is a prominent and well-established component of Zimbabwe's renewable energy landscape, with a relatively high level of consensus among the respondents regarding its widespread adoption.

Wind power, with a mean score of 2.24 and a standard deviation of 1.374, also appears to be a significant contributor to the country's renewable energy mix. The slightly higher mean score compared to solar PV indicates that wind power may be slightly less prevalent, but still plays a significant role in Zimbabwe's renewable energy portfolio. The higher standard deviation, however, suggests a greater variation in the perceptions and experiences of the respondents regarding the utilization of wind power, potentially due to factors such as geographical distribution, infrastructure development, or policy support.

Biomass and biofuels, with a mean score of 2.19 and a standard deviation of 1.353, also emerge as an important renewable energy source in Zimbabwe. The mean score suggests that this technology is widely used, potentially due to the country's abundant biomass resources, such as agricultural waste, forestry residues, and energy crops. The moderate standard deviation implies a relatively stable level of consensus among the respondents regarding the prominence of biomass and biofuels in the renewable energy mix.

Hydropower, with a mean score of 1.79 and a standard deviation of 1.039, appears to be the least utilized renewable energy source among the respondents. The lower mean score suggests that hydropower, while still a component of Zimbabwe's renewable energy portfolio, may have a more limited role compared to the other renewable energy technologies. The relatively low standard deviation indicates a higher level of consensus among the respondents regarding the relatively lower utilization of hydropower, potentially due to factors such as geographic constraints, water resource availability, or infrastructure development challenges.

From the interview guide on types of renewable energy used in Zimbabwe the researcher found the following from the respondents:

Respondent 1 stated that:

"The main types of renewable energy being utilized in Zimbabwe at the moment are hydropower and solar power. Hydropower has long been a mainstay of the country's energy mix, with several large-scale hydroelectric dams like Kariba providing a significant portion of the national electricity supply. In recent years, there has also been a growing focus on developing solar PV projects, particularly in the country's northern and central regions which receive high levels of solar irradiation throughout the year. However, the adoption of other renewable energy sources like wind power and geothermal energy remains quite limited."

Respondent 7 asserted that:

"Zimbabwe has an abundance of renewable energy resources, but the current utilization of these sources is still relatively low. Besides hydropower, which is the most widely deployed renewable technology, there has been a noticeable increase in small-scale solar PV installations, particularly in rural and off-grid areas. Some pilot projects have also explored the potential of wind power, especially in the eastern highlands region. But the overall contribution of renewable energy to the national energy mix remains small, and there is significant room for expansion and diversification of the renewable energy portfolio in the country."

Respondent 3 was of the view that:

"The renewable energy landscape in Zimbabwe is dominated by hydropower and solar power. Hydroelectric dams like Kariba and Smallbridge provide a significant portion of the country's electricity generation, although their output can be affected by seasonal variations in rainfall. In recent years, there has been a growing interest in solar energy, with both utility-scale solar PV projects and decentralized, off-grid solar systems being deployed, especially in rural areas that lack access to the national grid. However, other renewable energy technologies like wind power, geothermal, and bioenergy are still in the early stages of development and have not yet reached a significant scale of deployment in the country."

Overall, the data highlights the diversity of renewable energy sources being utilized in Zimbabwe, with solar PV, wind power, and biomass/biofuels playing prominent roles, while hydropower occupies a more secondary position. This information can inform policymakers, industry stakeholders, and researchers as they develop strategies to further accelerate the country's transition towards a more sustainable and diversified renewable energy future.

4.4.2 The existing policies and initiatives supporting renewable energy adoption in Zimbabwe

The data on the existing policies and initiatives supporting renewable energy adoption in Zimbabwe, as reported by the respondents, provides valuable insights into the current policy landscape and the effectiveness of various support mechanisms. The mean scores and standard deviations for each policy or initiative offer a nuanced understanding of their perceived impact and the level of consensus among the respondents.

Table 4.3: Existing policies and initiatives supporting renewable energy

STATEMENT	Mean	Std Dev
Tax incentives or subsidies	1.84	1.412
Mandatory energy efficiency standards	1.91	1.251
Streamlined approval processes for renewable energy projects	1.96	1.244
Targeted financing schemes or investment funds	2.06	1.216
Strengthening of industry associations and knowledge-sharing platforms	2.08	1.288

Tax incentives or subsidies, with a mean score of 1.84 and a standard deviation of 1.412, appear to be the least effective policy measure in supporting renewable energy adoption in Zimbabwe. The relatively low mean score suggests that the existing tax incentives or subsidies may not be adequately addressing the needs of the renewable energy sector, while the higher standard deviation indicates a greater variation in perceptions among the respondents, potentially due to differences in their specific experiences or the targeted application of these incentives.

Mandatory energy efficiency standards, with a mean score of 1.91 and a standard deviation of 1.251, also seem to be relatively less effective in supporting renewable energy adoption. The low mean score suggests that these standards may not be stringent enough or may not be effectively enforced, while the moderate standard deviation implies a reasonable level of consensus among the respondents regarding their limited impact.

Streamlined approval processes for renewable energy projects, with a mean score of 1.96 and a standard deviation of 1.244, are perceived to have a slightly higher impact compared to the previous two policy measures. The mean score suggests that the approval processes, while not highly effective, are at least moderately supportive of renewable energy development. The relatively lower standard deviation indicates a higher level of consensus among the respondents regarding the impact of these streamlined processes.

Targeted financing schemes or investment funds, with a mean score of 2.06 and a standard deviation of 1.216, are seen as more effective in supporting renewable energy adoption. The higher mean score suggests that these financing mechanisms are more successful in facilitating renewable energy projects, while the lower standard deviation implies a more consistent perception among the respondents regarding their impact.

Finally, the strengthening of industry associations and knowledge-sharing platforms, with a mean score of 2.08 and a standard deviation of 1.288, are perceived as the most effective policy measure in supporting renewable energy adoption in Zimbabwe. The higher mean score indicates that these collaborative initiatives are viewed as valuable in driving the sector's growth and development, although the moderate standard deviation suggests some variation in the respondents' experiences and perceptions.

Overall, the data highlights the need for a more comprehensive and effective policy framework to support the widespread adoption of renewable energy in Zimbabwe. While targeted financing schemes and industry collaboration are seen as the most impactful measures, there is room for improvement in areas such as tax incentives, energy efficiency standards, and streamlined approval processes. Addressing these policy gaps can help accelerate the country's transition towards a more sustainable energy future.

From the interview guide the researcher found the following:

Respondent 4 was of the view that:

"Zimbabwe has taken some steps to create a policy and regulatory environment that supports the growth of the renewable energy sector, but the efforts have been limited in scope and impact so far. The country has a Renewable Energy Policy that was introduced in 2019, which aims to increase the share of renewable energy in the national energy mix to 16% by 2030. This policy

provides some financial incentives, such as duty-free imports of renewable energy equipment and tax rebates for renewable energy investments."

Respondent 6 was of the view that:

"The Zimbabwean government has taken a more proactive approach to renewable energy in recent years, but the existing policies and initiatives remain limited in their scope and impact. The 2019 Renewable Energy Policy sets ambitious targets for renewable energy deployment, but the supporting mechanisms and funding allocations have been insufficient to achieve these goals. Some of the key initiatives include the establishment of a Renewable Energy Fund, feed-in tariffs for small-scale renewable energy projects, and the provision of tax incentives for renewable energy investments."

Respondent 11 stated that:

"The Zimbabwean government has made some attempts to create a supportive policy environment for renewable energy, but the efforts have been largely fragmented and lacking in comprehensive strategy. The 2019 Renewable Energy Policy is a step in the right direction, as it sets targets for renewable energy deployment and provides some financial incentives, such as duty-free imports of renewable energy equipment."

4.4.3 Summary and Discussion of Results

Th data indicates that solar photovoltaic (PV) is the most widely used renewable energy source in Zimbabwe, showing significant adoption compared to other types. Wind power and biomass/biofuels follow, though with less prevalence. Hydropower is the least utilized, potentially due to geeographic and infrastructural limitations.

Solar PV's prominence is likely due to Zimbabwe's high solar irradiance, making it a reliable option. The variation in wind power adoption suggests regional differences and infrastructure challenges. Biomass usage is supported by abundant natural resurces, while hydropower's limited role may result from geographical constraints. In addition, the effectiveness of policies supporting renewable energy varies. Industry collaboration and targeted financing are seen as the most supportive measures, while tax incentives and energy efficiency standards are perceived as less effective.

The data suggests a need for stronger policy frameworks to enhance the effectiveness of incentives and standards. Improved financial mechanisms and streamlined approval processes could further support renewable energy projects. Environmental sustainability emerges as the primary driver for renewable energy adoption, followed by reputational benefits and cost savings. Regulatory compliance is also a significant factor, though perceptions vary.

The strong focus on sustainability reflects global trends and the urgent need to address climate change. Financial and reputational motivations further drive adoption, indicating that businesses recognize both economic and social benefits. High upfront costs and lack of access to financing are major barriers. Insufficient government support and limited technical expertise also hinder progress. Concerns about technology performance contribute to hesitancy. Addressing financial barriers through improved access to funding and reducing initial costs is crucial. Strengthening government support and building technical capacity can facilitate wider adoption. Public awareness campaigns may help mitigate technology performance concerns.

In conclusion, the results highlight the complex interplay of factors influencing renewable energy adoption in Zimbabwe. While there is significant potential, overcoming financial, technical, and policy barriers is essential for accelerating the transition to a low-carbon energy industry. Enhanced collaboration between stakeholders and strategic policy reforms can drive sustainable growth in the sector.

4.4.4

The key drivers for the successful implementation of renewable energy projects in Zimbabwe

Table 4.4: Key drivers

STATEMENT	Mean	Std Dev
Cost savings	1.94	1.154
Regulatory compliance	2.04	1.287
Environmental sustainability	1.58	1.310
Reputational benefits	1.87	1.136

The data presented in Table 4.4 provides valuable insights into the key drivers for the successful implementation of renewable energy projects in Zimbabwe. These findings can be analyzed in greater detail across multiple paragraphs.

One of the most prominent drivers emerging from the data is environmental sustainability, which has a mean score of 1.58 and a standard deviation of 1.310. This suggests that the pursuit of environmental goals, such as reducing carbon emissions and mitigating climate change, is a significant motivator for businesses and organizations to invest in renewable energy projects. The relatively low standard deviation indicates a high level of consensus among respondents on the importance of environmental sustainability as a key driver.

Another important factor is the reputational benefits associated with renewable energy projects. The data shows a mean score of 1.87 and a standard deviation of 1.136 for this driver. This implies that companies and organizations are often driven by the potential to enhance their public image and perceived social responsibility through the implementation of renewable energy initiatives. The relatively low standard deviation suggests that reputational benefits are widely recognized as a crucial driver across the sample.

Cost savings also emerge as a key driver, with a mean score of 1.94 and a standard deviation of 1.154. This indicates that businesses are motivated to invest in renewable energy projects due to the potential for long-term cost savings on energy expenses. The low standard deviation suggests a high level of agreement among respondents regarding the importance of cost savings as a driver.

Finally, regulatory compliance appears to be another significant factor, with a mean score of 2.04 and a standard deviation of 1.287. This indicates that companies and organizations are driven to implement renewable energy projects to meet governmental or industry-specific requirements and regulations, which may include targets or mandates related to renewable energy usage. The slightly higher standard deviation compared to other drivers suggests a more diverse range of perspectives on the importance of regulatory compliance.

Overall, the data analysis highlights that a combination of environmental, reputational, financial, and regulatory factors are the primary drivers for the successful implementation of renewable energy projects in Zimbabwe. Understanding these key drivers can inform policymakers, industry stakeholders, and renewable energy project developers in designing and promoting effective strategies to further accelerate the adoption of renewable energy technologies in the country.

Respondent 1:

"One of the key drivers for the successful implementation of renewable energy projects in Zimbabwe is the country's abundant natural resources, particularly its substantial solar and hydropower potential. Zimbabwe receives high levels of solar irradiation throughout the year, making it an ideal location for the deployment of solar PV systems"

Respondent 2:

"The successful implementation of renewable energy projects in Zimbabwe will be largely driven by the availability of financing and investment. Access to affordable financing, whether through government-backed schemes, international development organizations, or private sector investment, is crucial for overcoming the high upfront costs associated with renewable energy projects. "

Respondent 3:

"*The key drivers for the successful implementation of renewable energy projects in Zimbabwe can be found in the country's natural resource endowments and the growing demand for reliable and affordable energy. Zimbabwe's abundant solar and hydropower potential provides a strong foundation for the development of large-scale and decentralized renewable energy projects. Additionally, the need to address energy access challenges, especially in rural areas, has created a significant market for renewable energy solutions that can provide off-grid or mini-grid electricity. "*

4.4.5 The key barriers for the successful implementation of renewable energy projects in Zimbabwe

Table 4.5: Key barriers

STATEMENT	Mean	Std Dev
High upfront costs	1.77	.989
Lack of access to financing	2.10	1.259
Insufficient government support or incentives	1.97	1.382
Limited technical expertise and skills	1.74	1.741
Uncertainty about technology performance	1.59	11.046

The data provided highlights several key barriers that hinder the successful implementation of renewable energy projects in Zimbabwe.

One of the primary challenges appears to be the high upfront costs associated with these projects. With a mean of 1.77 and a standard deviation of 0.989, the significant initial investment required is a major obstacle for stakeholders. This is further compounded by the lack of access to financing, which is reflected in the mean of 2.10 and a standard deviation of 1.259. The difficulty in securing the necessary funding to support the development of renewable energy initiatives is a significant impediment to the sector's growth.

Another crucial barrier is the insufficient government support or incentives. The mean of 1.97 and a standard deviation of 1.382 suggest that the current policy and regulatory framework may not be conducive to the advancement of renewable energy in Zimbabwe. Without strong government backing and the implementation of supportive policies, the transition towards a low-carbon energy industry becomes more challenging.

Additionally, the limited technical expertise and skills within the local population, with a mean of 1.74 and a standard deviation of 1.741, can hinder the successful implementation and maintenance of renewable energy projects. Capacity-building initiatives and the development of a skilled workforce are essential for the long-term sustainability of these projects.

Lastly, the uncertainty about the performance of renewable energy technologies, as indicated by the mean of 1.59 and a standard deviation of 11.046, may also contribute to the hesitancy in fully embracing these solutions. Addressing this perception through public awareness campaigns and demonstrating the reliability and effectiveness of renewable energy systems can help overcome this barrier.

Addressing these multifaceted challenges will be crucial in facilitating the transition towards a low-carbon energy industry in Zimbabwe. A comprehensive approach involving policy reforms, financial mechanisms, capacity-building, and public engagement will be necessary to unlock the full potential of renewable energy in the country.

From the interview guide the researcher found the following:

Respondent 5 stated that:

"One of the primary barriers to the successful implementation of renewable energy projects in Zimbabwe is the limited access to financing. The high upfront costs associated with renewable energy technologies, coupled with the country's challenging economic conditions, make it difficult for both individuals and businesses to invest in these solutions. Additionally, the lack of well-developed financial mechanisms, such as low-interest loans, grants, or leasing schemes, further constrains the ability to mobilize the necessary capital."

Respondent 8 was of the view that:

"The successful implementation of renewable energy projects in Zimbabwe is hindered by several key barriers, the most significant of which is the high upfront costs associated with these technologies. The lack of access to affordable financing, whether through government schemes, private sector investments, or international development funding, makes it challenging for both businesses and individuals to invest in renewable energy solutions. Another major barrier is the uncertain policy and regulatory environment surrounding the renewable energy sector in Zimbabwe."

Respondent 10 stated that:

"One of the key barriers to the successful implementation of renewable energy projects in Zimbabwe is the country's constrained economic and financial conditions. The high upfront costs

of renewable energy technologies, coupled with the limited access to affordable financing and credit, make it difficult for both businesses and households to invest in these solutions. "

4.5 Chapter Summary

The study findings were presented, analyzed, and interpreted in this chapter. The findings were presented in accordance with the research objectives and interpreted using the literature reviewed in chapter two. The next chapter gives a summary of the study, including the research's results and suggestions.

5 CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The major goal of this chapter is to offer a summary, results, and recommendations based on the study that was conducted. In this chapter, findings and suggestions of the research, as well as come to some conclusions will be presented. The study goals are going to be used as the foundation for the research summary, which is going to include recommendations for subsequent research to fill in research gaps.

5.2 Summary

The purpose of this study is to look into how renewable energy may help Zimbabwe move to a low-carbon energy sector. In particular, the study intends to determine the potential for renewable energy, appraise current programs and regulations, examine socioeconomic effects, and pinpoint obstacles and motivators for the uptake of renewable energy. The research was guided by the following research objectives: to Assess the types of renewable energy adopted in Zimbabwe, to evaluate the current policy framework and initiatives promoting renewable energy adoption in Zimbabwe, to investigate the socio-economic impacts of transitioning towards renewable energy in Zimbabwe and lastly to identify barriers for the successful implementation of renewable energy projects in Zimbabwe.

The primary data for this study was gathered with the use of an interview guide as well as a questionnaire that the participants filled out on their own. The most recent iteration of the Science Package for the Social Sciences (SPSS) was utilized in order to make predictions about descriptive and inferential statistics. As a consequence, the survey findings were exported from SPSS and imported into Microsoft Excel, where they were formatted as tables and figures. A numerical value was assigned to each of the response codes in the questionnaire so that the variables' measurements could be captured as accurately as possible. After that, the data is processed and shown in tabular, frequency, and percentage form..

As a consequence of the investigation, the researcher discovered the following:

5.3 Types of renewable energy used

The data presented provides a comprehensive overview of the key drivers for the successful implementation of renewable energy projects in Zimbabwe. The analysis reveals that environmental sustainability, reputational benefits, cost savings, and regulatory compliance are the primary factors motivating businesses and organizations to invest in renewable energy initiatives. The relatively low standard deviations across these drivers suggest a high level of consensus among the respondents regarding their importance.

5.4 The existing policies and initiatives supporting renewable energy adoption in Zimbabwe

The data presented in the analysis highlights the need for a more comprehensive and effective policy framework to support the widespread adoption of renewable energy in Zimbabwe. The findings suggest that the key factors currently driving the implementation of renewable energy projects are environmental sustainability, reputational benefits, cost savings, and regulatory compliance. However, the data also reveals that there is room for improvement in the policy landscape to further encourage and facilitate the growth of renewable energy in the country..

5.5 The key drivers for the successful implementation of renewable energy projects in Zimbabwe

The data analysis presented provides valuable insights into the key drivers for the successful implementation of renewable energy projects in Zimbabwe. The findings indicate that a combination of environmental, reputational, financial, and regulatory factors are the primary motivators for businesses and organizations to invest in renewable energy initiatives. Specifically, the pursuit of environmental sustainability, the potential for reputational benefits, the opportunity for cost savings, and the need to comply with regulatory requirements emerge as the most significant drivers.

5.6 The key barriers for the successful implementation of renewable energy projects in Zimbabwe

The data analysis has revealed a complex set of challenges that must be addressed to facilitate the transition towards a low-carbon energy industry in Zimbabwe. These challenges span various domains, including policy, finance, capacity, and public engagement. Tackling these multifaceted issues will be crucial in unlocking the full potential of renewable energy in the country and accelerating the move towards a more sustainable energy future.

5.7 Conclusions

In light of the above stated findings, the researcher concluded the following from the study.

5.7.1 Types of renewable energy used

Overall, the data highlights the diversity of renewable energy sources being utilized in Zimbabwe, with solar PV, wind power, and biomass/biofuels playing prominent roles, while hydropower occupies a more secondary position. The researcher concludes that there are a few types of renewable energies that has been used in Zimbabwe because of different number of factors.

5.7.2 The existing policies and initiatives supporting renewable energy adoption in Zimbabwe

In conclusion the analysis indicated that targeted financing schemes and industry collaboration are seen as the most impactful measures to support the adoption of renewable energy. Additionally, the researcher concludes that there is a need to address policy gaps in areas such as tax incentives, energy efficiency standards, and streamlined approval processes. By addressing these policy shortcomings, Zimbabwe can leverage the existing momentum and drivers to accelerate its transition towards a more sustainable and diversified energy future. Policymakers, industry stakeholders, and researchers should work together to develop and implement a robust policy framework that capitalizes on the country's renewable energy potential and aligns with the key drivers identified in the data.

5.7.3 The key drivers for the successful implementation of renewable energy projects in Zimbabwe

By understanding these key drivers, policymakers, industry stakeholders, and renewable energy project developers can design and promote effective strategies to further accelerate the adoption of renewable energy technologies in Zimbabwe. This knowledge can inform the development of targeted policies, incentives, and support mechanisms that capitalize on the existing momentum and align with the motivations of various stakeholders. Leveraging these insights can help Zimbabwe make significant strides towards a more sustainable and diversified energy future, as the country continues to harness its renewable energy potential and drive the transition away from fossil fuels.

5.7.4 The key barriers for the successful implementation of renewable energy projects in Zimbabwe

To address these challenges, a comprehensive and coordinated approach will be necessary. This should involve policy reforms to create a more supportive regulatory environment, the establishment of financial mechanisms to catalyze investment in renewable energy projects, capacity-building initiatives to enhance technical expertise and skills, and sustained public engagement to raise awareness and garner support for the transition. By addressing these interconnected challenges through a holistic strategy, Zimbabwe can position itself to capitalize on its renewable energy resources and make significant strides towards a low-carbon energy industry. This will not only contribute to environmental sustainability but also unlock economic opportunities and strengthen the country's energy security in the long run

5.8 Recommendations

5.8.1 Recommendations for practise

Policymakers in Zimbabwe should prioritize the development of a comprehensive and cohesive renewable energy policy framework. This should include clear targets for renewable energy adoption, streamlined approval processes, and robust incentive schemes such as feed-in tariffs, tax credits, and net metering programs. Policymakers should also consider implementing mandatory renewable energy procurement requirements for utilities and large consumers.

To mobilize the substantial capital required for renewable energy projects, Zimbabwe should explore innovative financing options, such as green bonds, crowd-funding platforms, and public-private partnerships. Additionally, the government should work with financial institutions to develop tailored loan products and risk mitigation instruments to de-invest in the renewable energy sector.

Significant efforts should be made to strengthen the technical and managerial capabilities of stakeholders across the renewable energy value chain. This includes expanding training programs for engineers, technicians, and project developers, as well as providing business development and project management support to small and medium-sized enterprises (SMEs) in the renewable energy industry. Concerted public awareness campaigns should also be launched to educate citizens about the benefits of renewable energy and its role in achieving a low-carbon future, which can help to build social acceptance and encourage widespread adoption of renewable technologies at the household and community levels.

5.8.2 Recommendations for Future Research

Detailed assessments of Zimbabwe's renewable energy resources, including solar, wind, and biomass potential, should be conducted at the regional and local levels. This will help to identify the most suitable locations for renewable energy projects and inform the development of targeted strategies.

Comprehensive techno-economic feasibility studies should be carried out to evaluate the viability of different renewable energy technologies in the Zimbabwean context. These studies should consider factors such as capital and operating costs, energy production potential, grid integration challenges, and the impact of policy and regulatory frameworks.

Future research should focus on understanding the full life cycle environmental and social impacts of renewable energy projects in Zimbabwe. This includes evaluating the carbon footprint, water usage, land-use changes, and the effects on local communities and ecosystems. Researchers should also explore the potential for demand-side management and energy efficiency measures to complement the deployment of renewable energy technologies, and conduct in-depth studies to assess the socio-economic impacts of the transition to a low-carbon energy industry in the country...

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Questionnaire

Renewable energy: Moving towards a low carbon energy industry in Zimbabwe.

Dear Participant,

The questionnaire is divided into several sections, and we kindly request that you answer the questions to the best of your knowledge and experience. All responses will be kept confidential and used solely for the purposes of this academic research.

Section 1: Respondent Information

What is your gender?

Male Female

What is your current role or position within your organization?

Manager Supervisor

Director General employee

How long have you been working in the industrial sector in Zimbabwe?

Less than 4 years 4 to 8 years

8 to 10 years Above 10 years

3. Which industry or sector does your organization operate in?

Energy

Transport

Commercial

Other (specify)

Section 2: Renewable Energy Awareness and Utilization

5. To what extent is your organization currently utilizing renewable energy sources (e.g., solar, wind, biomass) to meet its energy needs? Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**
Not at all					
To a small extent					
To a moderate extent					

To a large extent					

6. If your organization is utilizing renewable energy, please indicate the type(s) of renewable energy sources being used. Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**
Solar photovoltaic					
Wind power					
Biomass/biofuels					
Hydropower					
Other (please specify)					

7. What factors have influenced your organization's decision to (or not to) adopt renewable energy technologies? Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**
Cost-effectiveness					
Environmental sustainability					
Government incentives or policies					
Availability of financing					

Technical feasibility					
Lack of awareness or information					

Other (please specify)

Section 3: Energy Efficiency and Low-Carbon Practice

9. What types of energy efficiency measures or low-carbon technologies has your organization implemented? Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**
Improved insulation					
Energy-efficient lighting					
Waste heat recovery systems					
Process optimization					
Fuel switching (e.g., from fossil fuels to biofuels)					
Improved insulation					

10. What have been the primary drivers for your organization to implement energy efficiency and low-carbon measures? Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**

Cost savings					
Regulatory compliance					
Environmental sustainability					
Reputational benefits					
Access to financing or incentives					

Section 4: Barriers and Enablers

11. What do you perceive as the biggest barriers to the widespread adoption of renewable energy and energy efficiency in the Zimbabwean industrial sector? Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**
High upfront costs					
Lack of access to financing					
Insufficient government support or incentives					
Limited technical expertise and skills					
Uncertainty about technology performance					

Other (please specify)

12. What do you believe would be the most effective policy, regulatory, or institutional measures to support the transition towards renewable energy and low-carbon practices in the industrial sector? Use a scale of 1 to 5 where; 1= strongly disagree, 2=disagree, 3=neutral, 4=Agree, 5=strongly agree

STATEMENT	**1**	**2**	**3**	**4**	**5**
Tax incentives or subsidies					
Mandatory energy efficiency standards					
Streamlined approval processes for renewable energy projects					
Targeted financing schemes or investment funds					
Strengthening of industry associations and knowledge-sharing platforms					

Other (please specify)

Thank you time to answer this questionnaire, it is much appreciated and valued. Your responses will contribute to our understanding of the opportunities and challenges in transitioning Zimbabwe's industrial sector towards a low-carbon future.

Interview guide?

What are the key renewable energy sources currently being utilized in Zimbabwe?

How effective have the existing policy and regulatory frameworks been in incentivizing the deployment of renewable energy technologies in Zimbabwe?

What are the potential socio-economic benefits associated with the transition to renewable energy in Zimbabwe, such as job creation, energy access, and economic diversification?

What are the major technical, financial, and institutional challenges that have hindered the widespread adoption of renewable energy projects in Zimbabwe?

What strategies or innovative approaches can be explored to address the barriers and accelerate the transition towards a low-carbon energy industry in Zimbabwe?

How can the local community and stakeholders be effectively engaged and integrated into the development and implementation of renewable energy projects in Zimbabwe?

What are the key considerations for ensuring a just and inclusive transition?