



The impact of green finance, renewable energy, and economic growth on energy transition in African countries.

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of the requirements for the Degree of
Master of Commerce in Development Finance**

by

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***Building capacity to mobilize & align
F4D***



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DATE:

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To my family and friends, thank you for your love, prayers, and unwavering support. I am eternally grateful for your cheerleading and sacrifices that you have made during this journey. Most importantly thanks to my supervisor Dr Mundia Kabinga for your patience, guidance, and support during the very long journey. I have thought of giving up a few times, however, your encouraging words echoed to continue putting the efforts. Thank you for making time while you were away on your sabbatical research leave.

ABSTRACT

Energy transition demands radical and immediate action, requiring substantial mobilisation of green finance to advance progress towards limiting global warming to 1.5°C. The impact of green finance, renewable energy, and economic growth on carbon dioxide emissions has been assessed, however, limited to developed countries and China. The study poses the question whether green finance, renewable energy, and economic growth have an impact on carbon dioxide emissions in selected African countries. The study employed a panel PMG-ARDL approach, over the period 2000 – 2019. The findings indicate that in the long run, renewable energy has a negative impact on carbon dioxide emissions, whereas green finance and economic growth positively impact carbon dioxide emissions. Moreover, in the short run, green finance has a negative impact on carbon dioxide emissions, while renewable energy and economic growth indicate an insignificant impact on carbon dioxide emissions. Lack of access to green finance is the biggest obstacle to Africa's energy transition. The study suggests an improved leadership commitment; and environmental policy implementation to accelerate the energy transition.

Keywords: CO² emissions, energy transition, green finance, PMG-ARDL, renewable energy

ACRONYMS AND ABBREVIATIONS

ADF	Augmented Dickey Fuller
AMG	Augmented mean group.
ARDL	Autoregressive distributed lag
BRICS	Brazil, Russia, India, China, and South Africa
CADF	Cross-sectionally ADF
CCEMG	Common correlated effects mean group.
CD	Cross-section dependence
CIPS	Cross-sectionally augmented Im, Pesaran, and Shin
CO ²	Carbon dioxide
CPI	Climate Policy Initiative
DFE	Dynamic Fixed Effect
D-H	Dumitrescu-Hurlin
DOLS	Dynamic OLS
EKC	Environmental Kuznets Curve
EMT	Ecological Modernisation Theory
EP	Environmental Policy
EU	European Union
FMOLS	Fully modified OLS
GDP	Gross domestic product
GFIN	Green finance
GMM	General method of moments
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPS	Im, Pesaran, and Shin
IRENA	International Renewable Energy Agency
LLC	Levin-Lin-Chu

LM	Lagrange multiplier
Mtons	Million tonnes
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary least squares
PMG	Pooled mean group
PP	Phillips-Perron
QARDL	Quantile Autoregressive Distributed Lag
QQR	Quantile-on-Quantile Regression
REC	Renewable energy consumption
RMSE	Root mean square error
SSA	sub-Saharan Africa
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
UNFCCC	United Nations Framework Convention on Climate Change
UR	Urbanisation
US	United States
WB	World Bank

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CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 Introduction and background ¹

Carbon emission reduction rapidly gained global traction over the years, resulting in the prominence of energy transition from fossil fuels towards renewable energy sources. The combustion of fossil fuels for energy generation to meet energy demands leads to an adverse effect on environmental quality, rising the levels of carbon emissions (Gasimli et al., 2019). Economic growth is significantly linked to energy production and consumption (Acheampong, 2018; Li et al., 2021).

The study is anchored on Ecological Modernisation Theory (EMT); proposing that environmental degradation solution can be achieved through technological innovation, economic growth, legislative reforms and institutional reforms. Over the years, climate change and global warming mitigation strategies have been established to advocate for the decoupling of environmental quality from economic growth. The United Nations Framework Convention on Climate Change (UNFCCC) was introduced in 1992, as a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change.

The UNFCCC highlights that “such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.” The Kyoto Protocol Agreement and the 2015 Paris Agreement were additionally adopted, providing framework guidelines for climate change mitigation, adaptation, and finance to limit global warming below 1.5°C.

According to International Renewable Energy Agency (IRENA)’s World Energy Transitions Outlook (WETO), the path towards carbon emissions reduction requires radical, systemic, and managed energy transition from fossil fuels as the primary sources of energy production and consumption towards renewable energy sources (IRENA, 2022). Energy transition considers

¹ Many chapters in this thesis are drawn from earlier draft dissertation versions, assignments, and student papers I had previously submitted to UCT.

the social, economic, and environmental aspects of energy (Olave & Vargas-Payera, 2020). Cleveland and Morris (2015, p. iv), define the term ‘energy transition’ as a “change in the primary form of energy consumption of society, the transition from traditional energy sources such as wood to coal, followed by oil and gas towards clean energy sources such as solar, wind and biomass fuels.”

The energy systems’ reliance on fossil fuels remains undesirably high (IRENA, 2023). According to the IEA (2022b) report, in 2022, carbon dioxide (CO²) emissions from energy combustion grew by around 1.3% or 423 Mt. Electricity and heat generation accounted for the largest increase led by emissions from coal and oil. Developed and emerging countries are the world’s highest carbon emitters per capita; China, India, and the United States are the top emitters. African countries are the least emitter, accounting for less than 4% of global energy-related CO² emissions and less than 6% of global energy (IEA, 2022b). South Africa, Nigeria, Egypt, and Morocco are identified as the biggest fossil fuel consumers (Mutezo & Mulopo, 2021). Meanwhile, the rural remote sub-Saharan areas are facing basic energy security challenges, still dependent on wood and animal dung for energy consumption (Carbonnier & Grinevald, 2011; IEA, 2023). Nevertheless, African countries are expected to uniformly progress towards energy transition.

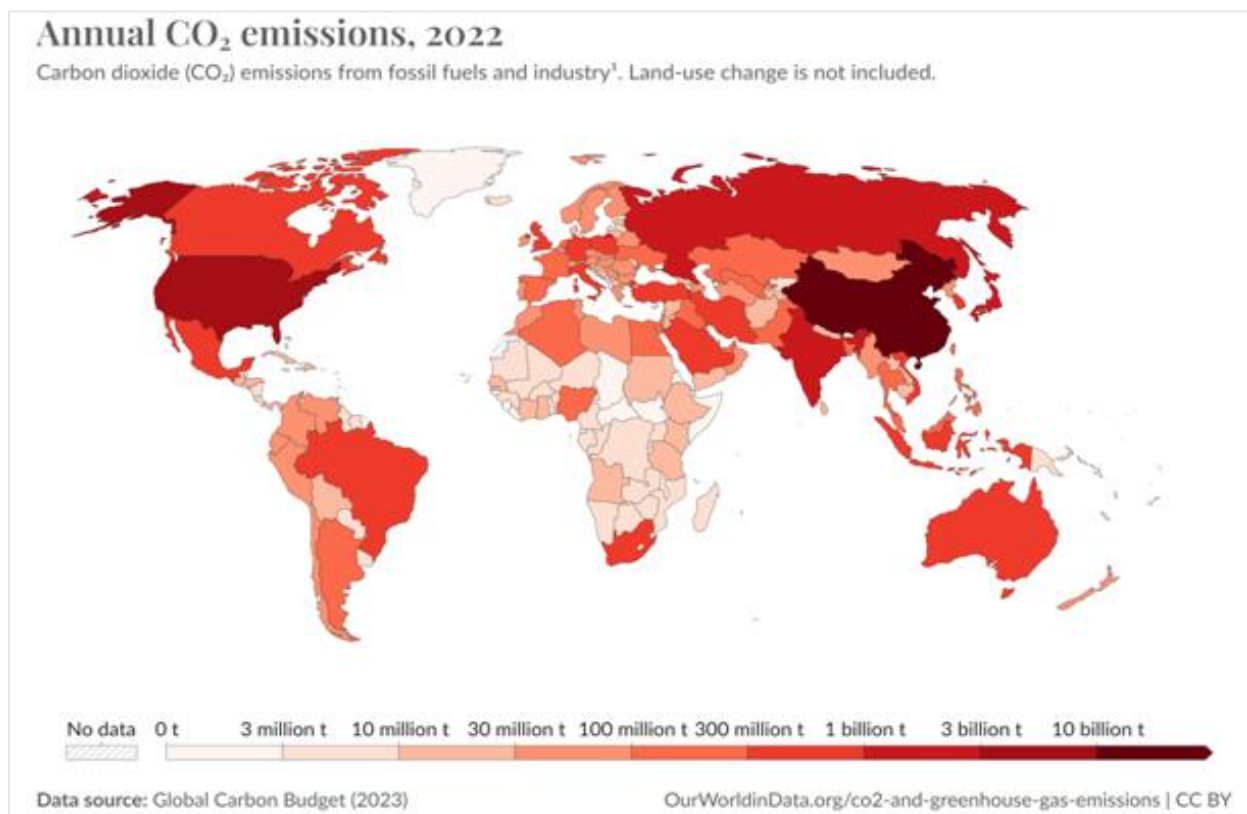


Figure 1: Annual CO² emissions
Source: Global Carbon Budget (2023)

The electricity utility business models are based on a conventional centralised system and thus require a significant disruptive technology transition for low-carbon technologies such as renewable energies (Arlota & Costa, 2021; Dong et al., 2020; IRENA, 2022). Renewable energy sources are widely accepted and adopted as an effective pathway for optimal energy transition from fossil fuels towards the mitigation of climate change (Apergis et al., 2018; Bhattacharya et al., 2017; Dong et al., 2020). Renewable energies have the potential to enable and accelerate energy transition while increasing energy security, achieving climate sustainability and contributing to the expansion of clean energy technologies, ultimately impacting the process of economic development and alleviating poverty (Kirikkaleli & Adebayo, 2021; Sinha & Shahbaz, 2018).

African continent is abundant with vast renewable energy resources, endowed with a wide landmass for the potential erection of wind turbines and harnesses the wind, rivers for hydropower, and all-year sunshine for solar power energy (Ackah & Kizys, 2015, da Silva et al., 2018). Thus, Africa has an opportunity to accelerate the progress towards energy transition by harnessing the available renewable resources. The study addresses the question of whether renewable energy has an impact on energy transition. However, renewable energy infrastructure is highly capital-intensive and requires substantial resource investments and financing.

The total project costs for wind, solar, and hydro energy are estimated to require more upfront capital costs than coal and gas projects (Shrimali et al., 2013). IRENA and CPI (2023) estimate that annual green finance of \$6.2 trillion is required until 2030 to progress towards energy transition, thereafter \$7.3 trillion until 2050. Yet over 80% of global renewable energy investment benefitted less than 50% of the global population in 2022. Green finance flow has been mobilised towards developed countries, further widening the financing gap in developing countries (IRENA & CPI, 2023).

Africa requires \$2.8 trillion between 2020-2030 to advance towards energy transitions, thus contributing to limiting warming to 1.5°C under the 2015 Paris Agreement (IRENA & CPI, 2023). Climate Policy Initiative (CPI), (2022) reports that the continent received less than 15% of global annual green finance, however, concentrated in 10 out of 54 countries (Figure 2). Green finance aims to reduce the levels of carbon emissions and mitigate environmental degradation by increasing investment and financing renewable energy project developments

(Dafermos & Nikolaidi, 2021; Dogan & Seker, 2016; Sun et.al 2023). Consequently, this study analyses the impact of green finance on energy transition for these countries.

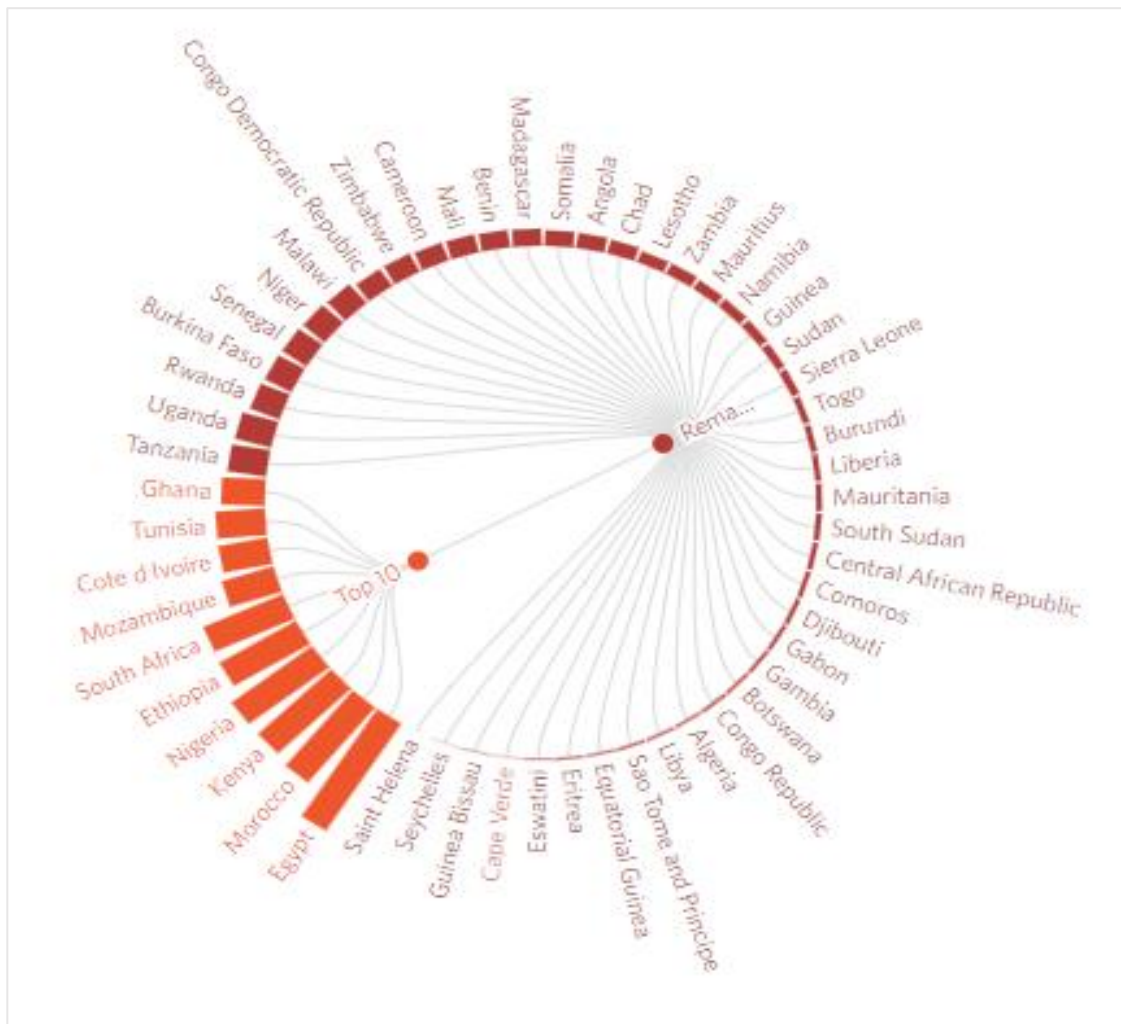


Figure 2: Top 10 green finance recipients in Africa
Source: IRENA and CPI (2023)

Despite the necessity and commitment to align investments with the goals outlined in the Paris Agreement, the bulk of energy investment continues to flow towards fossil fuels, causing the rise of global temperatures leading to climate change (IRENA & CPI, 2023). Therefore, it is necessary to redirect the mobilisation of energy investment from fossil fuels towards low-carbon renewable energies to achieve energy transition. Figure 3 below illustrates the investment comparison between renewable energy and fossil fuel.

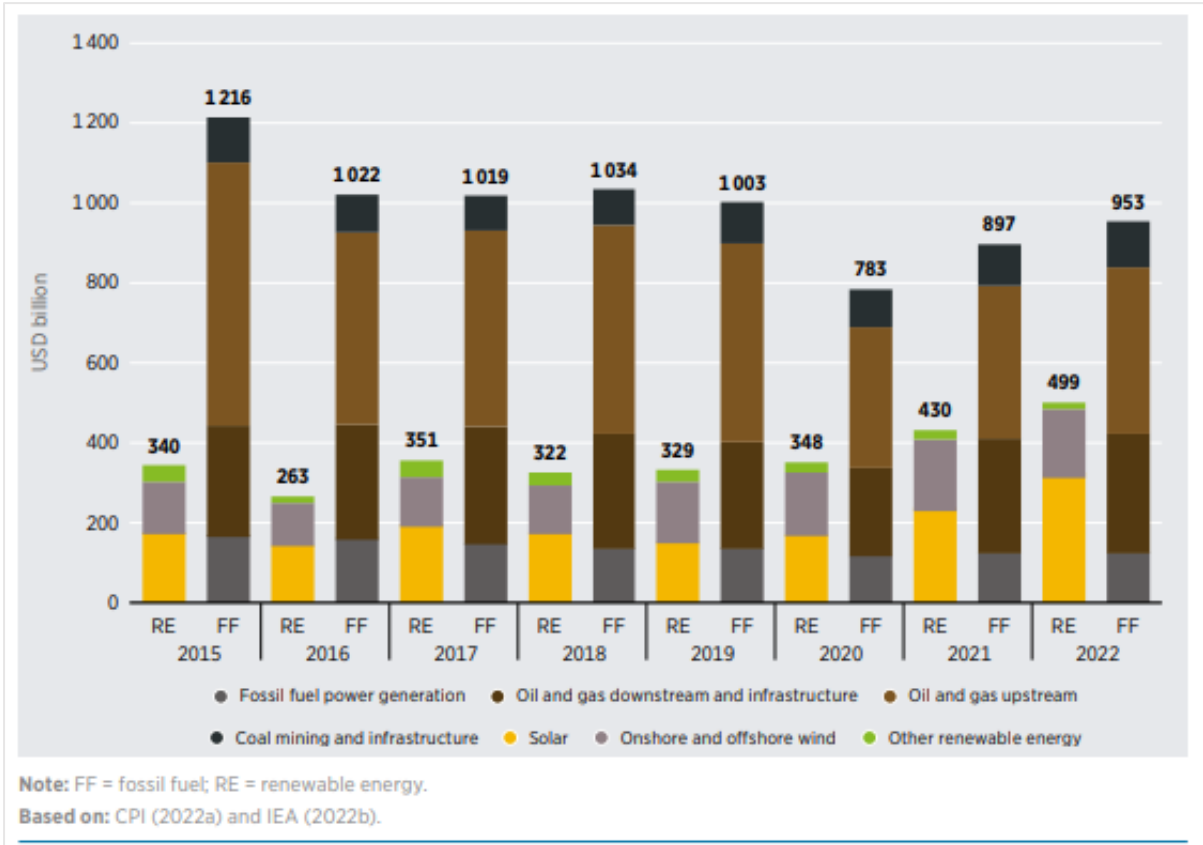


Figure 3: Renewable energy vs fossil fuels investment
Source: IRENA and CPI (2023, p.11)

Energy is key driver of economic growth, necessary for heating, lighting, and transport (Acheampong, 2018; Ozcan & Ozturk, 2019). Hence, the necessity to assess whether the path towards energy transition has an adverse impact on economic growth. African countries are continuously undergoing economic expansion and transformation, leading to rising energy demands in the continent, subsequently, increasing the levels of carbon emissions due to their dependency on fossil fuels.

The African population is expected to be one-fifth of the global population by 2030 and therefore is set to play an increasingly important role in the global energy transition (IEA, 2022a). IEA (2022b) states that 71% of global energy-related carbon emissions are due to urban areas, and this percentage is expected to increase as urbanisation increases. Recently, countries such as Botswana, Kenya and Senegal have increased their fossil fuel consumption, increasing CO² emissions (Espoir et al., 2023). Hence, this study analyses the impact of urbanisation on energy transition.

The main purpose of the study is to analyse the impact of energy transition on carbon emissions in African countries. The study highlights that progress towards energy transition is driven by

green finance and environmental policies for the acceleration of deployment of renewable energy infrastructure, thereby progressively decreasing dependency on fossil fuels to meet the energy demands arising from economic growth activities, and the growing population in African countries. This consequently leads to low carbon emissions levels, ultimately affecting energy transition, as illustrated in Figure 3.

A diagrammatic theoretical concept of the study is depicted in Figure 4 below.

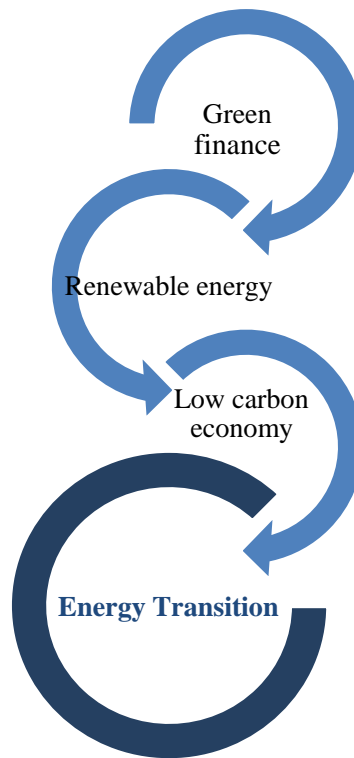


Figure 4: Theoretical concept of the study
Source: Author's own construct

The State of the Climate in Africa 2022 report indicates that in recent decades Africa has experienced severe accelerated weather- and climate-related hazards such as heavy rainfall, floods, tropical cyclones, droughts, heatwaves, wildfires, and sandstorms (World Meteorological Organization (WMO), 2023). The report further elaborates that according to the Emergency Event Database (EM-DAT), these events resulted in extreme impacts such as fatalities, population displacement, and over US\$ 8.5 billion in economic damages. Hence, the ubiquitous pledge to progress towards energy transition to accelerate carbon emission reductions (WMO, 2023). The path towards energy transition requires nothing short of global radical and immediate action, seeking an immense mobilisation of green finance and investment for a low-carbon economy in efforts to limit global warming to 1.5°C (IRENA, 2022).

1.2 Problem statement

Energy transition is relatively new concept in African countries compared to developed countries. Unsurprisingly, African countries lag in their progress towards energy transition due to the lack of access to green finance. Various studies widely discussed that green finance accelerates energy transition by funding the required renewable energy infrastructure development reducing dependency on fossil fuels, thereby effectively decreasing levels of carbon emission (Hailiang et al., 2023; Jiana & Afshan, 2023; Meo & Abd Karim 2022; Saeed & Karim, 2021; Udeagha & Ngepah, 2022). However, studies predominantly focused on developed countries and BRICS nations. There is limited literature analysing the progress of energy transition in the African context and consequently, there are no clear indications of whether green finance has an impact on energy transition. The continent received less than 15% of global green finance, however, concentrated in 10 out of 54 countries-Egypt, Morocco, Nigeria, Kenya, Ethiopia, South Africa, Mozambique, Cote d'Ivoire, Tunisia, and Ghana (CPI, 2022). This study aims to fill the literature gap by analysing the top 10 recipients of green finance to ascertain the impact on CO² emissions.

1.3 Research questions

The progress towards energy transition requires substantial initiatives to achieve carbon emission reduction. Therefore, this study seeks to answer the following questions:

- 1) Does green finance have significant impact on energy transition?
- 2) Does renewable energy have significant impact on energy transition?
- 3) Does economic growth, environmental policies, and urbanisation have significant impact on energy transition?

1.4 Research objectives

The study examines the impact of green finance, renewable energy, economic growth, environmental policies, and urbanisation on carbon emission, providing insight into the progress towards energy transition. The study seeks:

- 1) To analyse the impact of green finance on energy transition
- 2) To analyse the impact of renewable energy on energy transition
- 3) To analyse the impact of economic growth, environmental policies, and urbanisation on energy transition

1.5 Research scope

Renewable energy deployment is highly recommended to accelerate the progress towards energy transitions. The African region is abundant with renewable energy resources; however, Africa is heavily dependent on fossil fuels for energy generation (Maji et al., 2019; Sulaiman & Abdul-Rahim, 2020). Energy transition requires nothing short of global radical and immediate action for substantial resource mobilisation to contribute to global efforts to limit warming to 1.5°C. Green finance is a critical factor in accelerating the energy transition, effectively reducing the level of carbon emissions by up to 40% by the end of 2030 (UNFCCC, 2021).

Energy transition is driven by technological innovation advancement; thus, requiring massive green finance and investment to mobilise the required resources (Smil, 2016). IRENA and CPI (2023) report that the advancement of energy transitions requires an estimated \$2.8 trillion between 2020-2030 for renewable energy infrastructure in African countries. However, according to CPI (2022), 10 out of 54 African countries have received less than 15% of global green finance in 2019 and 2020. The recipient countries are South Africa, Nigeria, Egypt, Morocco, Kenya, Ethiopia, Ghana, Tunisia, Côte d'Ivoire, and Mozambique; thus, this study analyses the impact of green finance on energy transition for these countries over the period 2000-2019.

1.6 Research significance

Africa's literature on energy transition is analysed from environmental policies and climate change mitigation perspective, with limited analysis on green finance. Previous green finance literature was predominantly on developed countries context, thus, cannot be generalised for African countries and other developing countries. This study contributes to the extent of studies for African countries by Acheampong et al. (2021), Afriyie et al. (2023), Espoir et al. (2023), Farhani and Shahbaz (2014), Inglesi-Lotz and Dogan (2018), Jebli et al. (2015), Mutezo and Mulopo (2021), Nathaniel and Iheonu (2019) and Taghizadeh-Hesary et al. (2021).

However, previous studies only employed renewable energy, economic growth, and environmental policies as variables to measure CO² emissions reduction, consequently, processing towards energy transition. Although these variables are important to measure the process of energy transition, the exclusion of green finance does not encompass all critical aspects of energy transition. The implementation of energy transition requires extensive green finance, thus overlooking this could result in an incomplete analysis of the process in Africa.

It is reported that in 2019 and 2020, less than 15% of global green finance was mobilised to 10 out of 54 African countries to enable energy transition (CPI, 2022). This study provides meaningful insight and analyses the impact of green finance on the levels of carbon emission in African countries.

In addition, African countries' economies are heavily reliant on fossil fuels for energy generation, and it is crucial to evaluate and assess the impact on the economic growth on energy transition. Renewable energy has the potential to replace fossil fuels as the primary energy source, thus accelerating the energy transition. The study measures the impact of renewable energy on the progress of energy transition. Moreover, renewable energy infrastructure is capital intensive; the study highlights the required substantial green financing and investment for African countries to contribute towards the global climate targets and transition to a low-carbon economy.

Lastly, the study contributes to the empirical literature by applying the bounds test dynamic panel ARDL approach developed by Pesaran et al. (2001). The study aims to analyse the impact of green finance on CO² emissions in African countries, specifically analysing the short and long-run impact of the variables. Additionally, it investigates the short-run impact of green finance on CO² emissions for countries in the study panel. The study provides public and private institutions with a deeper insight into Africa's progress towards energy transition. Furthermore, it influences investors to mobilise financing across the continent to fast-track the path towards energy transition.

1.7 Limitations of the study

The main limitation of this study was data availability and accessibility for African countries, resulting in the exclusion of 44 African countries and private investors' green finance inflows from the study analysis. The study data selection was based on IRENA and CPI reports, indicating that green finance was concentrated in 10 out of 54 countries. Consequently, the study employed the convenience nonprobability sampling based on data availability. The study intended to analyse green finance from both public and private investors. The green finance data is available on the Bloomberg New Energy Finance (BNEF) database, however, due to cost implications to access the BNEF database, we resorted to using the free and easily accessible IRENA database. However, the IRENA database only has green finance flows from public investors, hence the study excludes green finance flows from private investors.

Lastly, the study aimed to analyse the impact of environmental policies and urbanisation on energy transition, however, the unit root test indicated that environmental policies and urbanisation are nonstationary times series, failing to meet the necessary regression model requirement. The usage of nonstationary variables in the regression model leads to spurious regression issues, resulting in the exclusion of environmental policy and urbanisation population in the analysis of energy transition.

1.8 Organisation of the study

The study is structured as follows:

Chapter 1: Introduction and background

This chapter introduces the study and commences by giving a brief background of the study. The research problem is stated, as well as the objectives of the research. The research questions formulated to achieve the set objectives are stated.

Chapter 2: Literature review of relevant literature

Chapter 2 reviews the literature that underpins the study. It outlines the key theoretical concepts and empirical literature contributing to green finance, renewable energy, economic growth, environmental policy, urbanisation, and energy transitions.

Chapter 3: Methodology employed in the study

This chapter describes the research methodology appropriate to outline research objectives while addressing the research questions and hypothesis. The study design, the population and the sample are outlined and the instrument used to collect the data and methods to ensure the validity and reliability of the instrument are also described.

Chapter 4: Discussion of findings

This chapter presents, discusses and analyses the data obtained from the statistics software STATA 17.

Chapter 5: Conclusion and recommendations

This chapter concludes the study. It provides a summary, and conclusions of the study based on the findings and analysis. The chapter also makes recommendations and suggests future research avenues.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter focuses on literature introducing and defining the main study concept, energy transition. The detailed theoretical framework is discussed, concluding with the empirical literature on energy transition. The chapter expands on the relationship between green finance, renewable energy, economic growth, environmental policies, urbanisation, and carbon emission in both developed and developing countries.

2.2 Theoretical framework

The study is based on the framework of Ecological Modernisation Theory (EMT) developed in the late 20th century by scholars Joseph Huber; Martin Janicke and Udo Simmonis. According to Huber (1985) ecological modernisation phase inevitably follows industrial breakthrough phase for period 1789 – 1848 and the construction of industrial society phase 1848 – 1980. The author states that economy and technology are the key drivers throughout phases, emphasising the urgent need to address the association of human activity and the environment quality (Mol and Spaargaren, 1992). Janicke (1895) and Simmonis (1989) established that the ecological modernisation requires macro-economic level structural change. Furthermore, elaborating that the resolution of environmental degradation starts at the national level, by examining the economic growth trajectories for the range of national economies associated with their basic resources' consumption (Mol and Spaargaren, 1992).

The concept of “ecological modernization” is outlined by Ali (2013) as the assumption that: *“1. environmental degradation is calculable most notably by combining the monetary units and discursive elements from different branches of natural and social sciences of which cost-benefit analysis of environment is one of the examples. 2. effective management of environmental problems is possible by collective action; if every individual, firm, and at the larger arena if every country participates, management of sustainable environment is possible. 3. Economic growth and the resolution of ecological problems can be reconciled...”*

The EMT advocates for energy transition from fossil fuel intensive industries towards eco-efficient industries, renewable energy technologies, environmental legislative reforms and institutional reforms, consequently leading to environmental quality without inhibiting economic growth process (Mol and Spaargaren, 1992). The transition towards green economy is recognised as an essential component of achieving an inclusive economy while tackling

inequalities such as poverty and social injustice affecting African countries (Smit & Musango, 2015).

Green Economy addresses the undervaluation of environmental quality and social costs for economic gains (Le Blanc, 2011). The concept was first introduced by Pearce, Markandya and Barbier in 1989 in response to the undervaluation of environmental and social costs in the current price system (Pearce et al., 1989). UNEP (2018) describes green economy as “...an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.”

The green economy concept is relatively new in African countries compared to the developed countries. The implementation of green economy in African countries refers to two interlinked developmental outcomes, firstly, economic growth resulting in job creation and livelihood improvements, and secondly, economic decarbonisation, shifting the economy towards cleaner industries and technologies (UNEP, 2018). The sub-Saharan region relies on biomass, collected from wood and animal dung for energy generation (Carbonnier & Grinevald, 2011). South Africa, Egypt and Morocco are at the forefront of green economy initiatives, strategies, and policies in Africa.

Green economy requires global framework and efforts with financial and investment commitment towards energy transition by shifting energy sector from fossil fuel generation to renewable energy sources (Khan et al., 2020). According to Smil et al. (2016), energy transition is defined as “the change in the composition (structure) of primary energy supply, the gradual shift from a specific pattern of energy provision to a new state of an energy system”.

The term energy transition is driven by technological innovation, dating back from the shift of the global agrarian economy to an industrial revolution requiring efficient energy sources (Smil, 2016). The first energy transition was the shift from biomass to an inclusion of coal, the second transition adopted a broader range of energy sources such as oil, gas, nuclear and hydropower. The recent energy transition includes renewable energy sources such as solar and wind in the energy model system (Kabeyi, & Olanrewaju, 2022).

The rising energy demands from increasing levels of industrialisation, expansion of economic development and rapid population growth leads to an increase of fossil fuel combustion for energy generation process, consequently emitting carbon dioxide (CO²) (Du et al., 2019;

Nathaniel & Iheonu 2019). CO² emissions contribute to rapid global warming and climate change (Manisalidis et al., 2020).

Renewable energies are widely accepted and adopted as an effective pathway for optimal energy transition from fossil fuels towards the mitigation of climate change (Apergis & Payne, 2018; Bhattacharya et al., 2017; Dong et al., 2020). According to IRENA (2020), renewable energy includes “bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity”.

The deployment of renewable energy sources to replace fossil fuels for energy generation is highly recommended for African countries (Maji et al., 2019; Sulaiman & Abdul-Rahim 2020). Africa is abundant with renewable energy resources, endowed with wide landmass for the potential erection of wind turbines to harness the wind, available river flows for hydropower and all-year sunshine for solar power (Ackah & Kizys, 2015; da Silva et al., 2018). IEA (2022a) states that “renewable energy offers prospects for economic growth, cost-effective technologies to expand energy access and quality of access, and industrial development along new value chains, with substantial, local job creation potential.”

In sub-Saharan Africa (SSA), over 775 million people are without access to energy, particularly the remote rural areas (IEA, 2023). Renewable energy is the best option for SSAs to leapfrog and escape the learning curve of energy security while simultaneously combating climate change (Oluoch et al., 2022). In the case of North Africa, an increase in renewable energy share is essential to improve energy security (Ainou et al., 2023).

Aliyu et al. (2017) reviewed Africa’s major renewable energy consumption leading countries being South Africa, Egypt and Nigeria. The authors found that the deployment of renewable energy sources requires appropriate technology, technical skills and expertise to harness the natural resources. Musah et al. (2020) confirmed that renewable energy consumption had a substantially negative impact on CO² emissions in West Africa. Ibrahim et al. (2021) found that renewable energy- generation can greatly reduce greenhouse gases in Nigeria, Cameroon, Ghana and South Africa. Hence, this study tests the hypothesis:

H1: Renewable energy has a significant impact on energy transition for selected African countries.

Africa requires long-term planning and financing commitment for energy transition, to implement the adoption of greener technologies initiatives and efficient regulations to harness the renewable energy potential (Tajudeen, 2015). Ibrahim et al. (2021) mentioned that the bulk of the challenges associated with renewable energy in African countries are lack of financing, poor policies advocating for renewable energy, high tariffs, and inadequate infrastructure. IEA (2023) opines that African countries are considered investment high-risk countries due to the ongoing debt crisis, policy uncertainties and implementation challenges.

Investment profiles for renewable energy projects vary from fossil fuel-based, the total project costs for wind, solar, and hydro energy require high upfront capital costs than coal and gas projects (Shrimali et al., 2013). Hence, investors expect compensation for higher risks. Ceres (2014) points out that investment returns from direct renewable energy infrastructure investment roughly meet the investors' required rate of return targets. Lack of access to green finance and investment is the biggest obstacle to renewable energy development in African countries.

The term green finance, also known as environmental/climate finance or sustainable finance, has various definitions, the concept has undergone an evolution process, explored from 1998 to 2000, then a stage of steady development from 2000 to 2005, and thereafter, a stage of rapid development from 2006 to 2012. In early studies, Salazar (1998) and Cowan (1999) clarify that green finance is differs from traditional finance, as it is a bridge between financial industry and environmental quality, whereas traditional finance overlooks environmental impact on financial and investment decisions.

Debrah et al. (2022) reviewed and examined 995 relevant publications and found that green finance is classified as green bond, green credit, carbon investment, green banking, and climate finance, further confirming that any form of finance to reduce CO² emissions, mitigate climate change and preserve natural resources is classified as green finance. Green finance refers to all financial tools specifically assigned towards renewable growth and environmental policies to facilitate and support green economic transition to reduce the increasing CO² emission (Chien et al., 2021; Li et al., 2021; Wang et al., 2019).

Various public and private financial institutions provide green finance—banks, investment and micro-credit firms and pension fund insurance. Ngwenya and Simatele (2020) observed the growth of the green finance in Africa's economic hubs such as Kenya, Nigeria, and South Africa. The author recommends that the expansion of the green finance market in these

countries. Additionally stating that the continent needs prioritise public-private partnerships, integrated policies, political will, and effective institutional frameworks. Michaelowa et al. (2021) examined Ethiopia, Madagascar, and South Africa; they suggest that green finance must interact with domestic policy instruments.

CPI (2022) reports that Africa requires green finance of \$2.8 trillion between 2020-2030 to invest in renewable energy infrastructure to contribute towards limiting global warming per the Paris Agreement. Nevertheless, the annual financing flows to Africa are reported to be around \$30 billion, however, concentrated in 10 out of 54 countries (CPI, 2022). African countries are equally expected to progress towards energy transition, effectively shifting from fossil fuels based to renewable energy sources. Hence, this study tests the hypothesis:

H2: Green finance has a significant impact on energy transition for selected African countries.

African countries' capability to progress towards energy transition has been debated, with studies advocating that countries focus on ensuring reliable energy access and economic growth rather than reduction of carbon emissions (Hanif & Gago-de-Santos, 2017; Kwakwa & Alhassan, 2018; Maduka et al., 2022; Twerefou et al., 2017; Udeagha & Ngepah, 2023). Developed countries are the world's highest carbon emitters per capita, whereas developing countries, particularly Africa, are the least global carbon emitters, accounting for less than 5% of global CO² (Climate Watch, 2023).

Considering that African economies rely heavily on fossil fuels such as oil, natural gas, and coal; the path towards energy transition requires managed adverse impact on livelihoods and economic growth. South Africa, Nigeria, Egypt, Morocco, and Algeria are referred to as Africa's biggest fossil fuel consumers (Mutezo & Mulopo, 2021). Recently, countries such as Botswana, Kenya and Senegal have increased their fossil fuel consumption, thus increasing carbon emissions (Espoir et al., 2023).

Abdallh and Abugamos (2017) found that in African regions, energy consumption and economic growth are the primary sources of CO² emissions. Therefore, the dissociation of country's economic development from environmental quality is a challenging task (Barbier, 2013). Bradlow and Humphrey (2016) posit that countries should "focus on sustainable infrastructure to establish a long-term foundation for environmentally and sustainable economic growth prosperity". Hence, this study tests the hypothesis:

H3: Economic growth has a significant impact on energy transition for selected African countries.

Global energy investment continues to flow towards fossil fuels technologies, hence the continuously rising levels of carbon emissions, leading the global community to enforce environmental policies to accelerate the progress towards energy transition for climate change mitigations (Sachs et al., 2019). Environmental policies provide a global framework and guidelines for effective carbon emissions reduction.

Environmental taxes are a form of environmental policies imposed as a cost-effective mechanism to reduce the levels of carbon emissions. Environmental taxes are classified as Pigouvian tax, defined by Polinsky and Shavell (1982) as “taxation used to control an externality-generating activity”. Moreover, environmental taxes are a form of additional revenue for the government while stimulating the innovation of environmental technologies (Guo & Wang, 2018).

Two main strands highlight the impact of environmental taxes on environmental quality. The first strand states that taxes on fossil fuels increase energy prices, thus leading to a fall in their demands, resulting in the reduction of CO² emission (Doğan et al., 2022). Additionally, environmental taxes encourage divestment from fossil fuels and direct investment towards renewable energy resources (Ulucak et al., 2020). Thus, arguing that imposing environmental taxes has a positive impact on environmental quality.

The second strand emphasises that environmental taxes may be counter-productive, resulting in an adverse impact on environmental quality. The time lag between environmental tax policies and the implementation gives fossil fuel suppliers an opportunity to accelerate their extractions, thus leading to the acceleration of environmental degradation (Wolde-Rufael & Mulat-Weldemeskel, 2021). Sinn (2015) termed this the “Green Paradox”, stating that environmental taxes lead to a rise in fossil fuel energy usage, thus, only steering fossil fuel demand instead of decreasing the demand.

Khan et al. (2020) state that countries should implement environmental policies, in efforts to minimise carbon emissions and reduce the reliance on fossil fuels, and progress towards the use of clean energies. Kayani et al. (2023) analysed the top 10 most polluted nations; the authors elaborated that stringent environmental policies should be implemented to reduce carbon emissions and attract FDI directed towards clean energy technologies. In their study,

Ibekilo et al. (2023) found that environmental regulations partially mitigate pollution in Africa through urbanisation and energy consumption channels. The authors suggest that African countries should tighten environmental regulatory policies for carbon emission reduction towards achieving carbon neutrality by 2050. Hence, the research hypothesis:

H4: Environmental policies have a significant impact on energy transition in selected African countries.

IEA (2022b) indicates that over 70% of global energy-related carbon emissions are due to urban areas, further urbanisation expansion is expected. Africa's energy demand is projected to significantly increase, driven by the expected rising urbanisation population (IEA, 2022a; Mutezo & Mulopo, 2021). African cities are the youngest rapidly growing cities in the world, which will have a profoundly significant impact on Africa's economic landscape in the forthcoming decades (African Development Bank, 2022).

Kayani et al. (2023) found that in developing countries urbanisation had positive and significant influence on carbon emissions. Erdoğan et al. (2022) confirm that urbanisation significantly poses threat to environmental sustainability. Considering that African energy generation is dependent on fossil fuels, an increase in the urbanisation population may result in rising levels of carbon emissions. Thus, the study tests the hypothesis:

H5: Urbanisation has a significant impact on energy transition in selected African countries.

2.3 Empirical evidence

Empirical literature analysing progress towards carbon emission reduction has become global phenomenon, however, predominantly in developed countries, limited in developing countries, particularly in African context. We present empirical literature analysing the relationship between green finance, renewable energy, environmental policies, urbanisation, economic growth, and energy transition, using various methodologies and over periods.

2.3.1 Impact of green finance on carbon emissions

Saeed and Karim (2021) examined the relationship between green finance and CO² in developed nations (Hong Kong, United States, Canada, Japan, Denmark, Norway, Sweden, United Kingdom, Switzerland, and New Zealand). Using the quantile-on-quantile regression (QQR), they confirmed that green finance negatively impacts CO² emissions. Furthermore, study confirms that green finance can be considered a financial approach towards reducing CO² emissions. These findings are expected for developed countries, over the years the nations have accelerated progress in reducing CO² emissions by mobilising green financing.

Similarly, Meo and Abd Karim (2022) analysed the top 10 economies, analysing the cointegration between green finance and CO² emissions. The study included Denmark, Canada, Japan, United States, Switzerland, Sweden, and United Kingdom, and used the QQR approach. The authors confirmed the negative impact of green finance on CO² emissions. The study further elaborated on the variation of correlation based on the green finance market and country-specific environmental regulations. These countries vary significantly from African countries, they have stable green finance market and environmental policies; these are new concepts in Africa.

Jian and Afshan (2023) investigated the role of green finance and green technologies in combating carbon emission in G10 economies over the years 2000 to 2018, using Cross-Sectional ARDL. The findings confirmed long- and short-run estimates for green finance and technologies promoting carbon neutrality. Additionally, endorsing the long-run validity of the Environmental Kuznets Curve (EKC) in G10 economies.

Jia (2023) assessed the impact of green finance on the decarbonisation of the top fossil fuel-reliant economies—China, Russian Federation, and United States of America. The study suggests green finance has not yet demonstrated tangible effect in these top fossil fuels-reliant countries. The author further mentions the involvement of relevant government agencies and

businesses in the green bond market may improve the impact of green finance on carbon emissions in the future.

Hailiang et al. (2023) explored BRICS economies, analysing the role of renewable energy and green finance in environmental quality from 2000 to 2018, using quantile regressions. The study showed that green finance and renewable energy consumption reduce carbon emissions in BRICS countries. Further pointing out that in these economies environmental quality is deteriorating due to the increasing usage of fossil fuel energy consumption. The BRICS countries are among the highest global emitters.

Udeagha and Ngepah (2023) examined the contribution of green finance and financial technology (fintech) in achieving carbon neutrality from 2000 to 2018 in the BRICS nations. The findings indicate that green finance, fintech, and energy innovation promote environmental sustainability. Similarly, Wei et al. (2024) examined the roles of Green Finance and Fintech on Environmental sustainability in BRICS countries, the study included Natural Resources and Green Growth using the novel MMQR technique. The results indicate that financial system technology streamlines the financial flows towards green projects, leading to environmental sustainability. The majority of African countries have poor financial system infrastructure, resulting in challenges for green finance mobilisation.

Chang et al. (2021) analysed the influence green finance has on climate change mitigation in China, applying the unit root test and panel co-integration technique. Green finance resulted in a significant drift in CO² emissions and climate change mitigation. The study indicated that green finance is the highest form of climate change control practices, indicating a CO² reduction of 27.1% and climate change mitigation by 31.3%. Similarly, Wang et al. (2019) examined the influence that green finance has on CO² emissions in China throughout 1998-2017 using the ARDL approach. The authors revealed that green finance significantly reduces the levels of CO² emissions.

Afshan et al. (2023) corroborated the findings; the authors evaluated the influence of green finance, eco-innovation, and environmental policy stringency on the ecological footprint in China. They employed the quantile autoregressive distributed lag (QARDL) approach for the period 2000 to 2017. The results demonstrated that there is a positive effect between eco-innovation, green finance, and environmental policy stringency with the ecological footprints. In their analysis, Li and Shao (2022) revealed that green finance is negatively and significantly

linked to carbon emissions per capita, resulting in carbon mitigation for the short and long term in China, using the ARDL-ECM for the period 2000 to 2019.

Lin et al. (2022) employed a dynamic spatial Durbin model, the study confirmed that green finance lowered CO² emissions in China for the period 2007 to 2018. Zhou and Xu (2022) found the positive impact of green finance on environmental quality relies on the economic development status of the region for the period 2010-2017 in China. Considering that African countries have lower-middle levels of economic development status, this suggests that green finance may result in a negative effect on environmental quality.

In the case of Vietnam as a developing country, Moslehpour et al. (2023) indicated a positive relationship between green finance and sustainable development for over years 1991 to 2020, using the Dynamic Auto-regressive Distributed Lags (DARDL) and the Bayesian Auto-regressive Distributed Lags (BARDL) model. Tran (2022) confirmed the cointegration between green finance and CO² emissions from 1986 to 2018 in Vietnam. African countries are similar to Vietnam, the study analyses how green finance reduces CO². However, in their study, Zhou and Xu (2022) employed the GMM approach to explore the effect of green finance on CO², the authors indicated a U-shape relationship for the period 2008 to 2020.

Taghizadeh-Hesary et al. (2021) examined the green bonds markets as the facilitator in supporting green finance for Asia and Pacific regions, using pooled OLS, and random effect generalised least square estimators. They found that green bonds have higher returns, however also present higher risks. This further, indicates that the banking sector leads 60% of the green bond market. The study indicates the significant role that the financial system plays in mobilising green finance. African countries have unstable financial systems, thus presenting challenges for investors to mobilise green finance across the continent.

Musango et al. (2014) found that green economy transition interventions lower fossil fuel dependency and reduce emissions in the case of South Africa. The authors further determined in the medium and longer terms, investments in low-carbon development and ecosystem services result in resilient economic growth. There is limited literature analysing green finance for African countries. Hence, this study hypothesis is:

H1: Green finance has a significant impact on energy transition in selected African countries.

2.3.2 Impact of renewable energy on carbon emissions

Literature analysing the impact of renewable energy on CO² emissions mostly reveals a negative relationship between the variables, for both developed and developing countries for different periods, using various methodologies.

Szetela et al. (2022) analysed the top countries dependent on natural resources for the years 2000 to 2015, using various methodologies, the Fixed Effects, OLS, and two-step GMM estimators. The authors confirmed the relationship between renewable energy and CO² emissions, demonstrating that a 1% increase in renewable energy consumption results in 1.25% decrease in CO² emissions. African countries are highly dependent on natural resources, and it is worth analysing whether renewable energy significantly decreases the levels of carbon emissions.

Dogan and Seker (2016) analysed top renewable energy countries using the FMOLS and the DOLS techniques. The study finds that increases in renewable energy consumption decrease carbon emissions, while increases in non-renewable energy consumption contribute to the level of emissions. Dimnwobi et al. (2022) corroborated the results in the case of Nigeria, they found the long-run relationship between financial development and renewable energy in Nigeria, using the ARDL approach for the period 1981 to 2019. The study findings indicate that financial development results in a significant positive effect on renewable energy consumption.

Huang et al. (2021) analysed major renewable energy-consuming countries for the period 2000 to 2015 employing the two-step GMM. The findings reveal that renewable energy negatively impacts CO² emissions and further indicates 1% rise in renewable energy results in 0.5% fall in CO² emissions levels. Shafiei and Salim (2014) confirmed that renewable energy consumption decreases CO² emissions while non-renewable energy consumption increases CO² emissions, using the STIRPAT model for the period 1980 to 2011 for OECD countries. Mendonça et al. (2020) assessed 50 major economies for drivers of CO² emissions over the years 1990 to 2015, confirming that renewable energy was among the drivers decreasing the levels of CO² emissions. These economies have advanced their renewable energy development and consumption, the study confirmed the achieved objective to reduce the levels of CO² emissions.

Nguyen and Kakinaka (2019) examined 107 countries for the period 1990-2013 and revealed a country's income level has an impact on renewable energy's influence on CO² emissions.

Moreover, the authors suggest that low-income countries indicate positive relationship between renewable energy and CO² emissions, while high-income countries revealed negative relationship between renewable energy and CO² emissions. On the contrary, Dong et al. (2020) assessed 120 countries for the period 1995 to 2015 and revealed for all income levels, renewable energy negatively impacts CO² emissions, however, insignificantly impacts carbon emissions. The study implies that regardless of country's income level, renewable energy reduces CO² emissions.

Majewski et al. (2022), using two-step GMM regression, investigated 94 middle-income countries for the period 2000 to 2015 and found an adverse relationship between renewable energy and CO² emissions, further indicating 1% rise in renewable energy output leads to 0.18% decrease in CO² emissions. However, Maslyuk and Dharmaratna (2013) analysed Asia's 11 middle-income countries. They found that renewables generation surprisingly resulted in the rise of CO² emissions over the years 1980-2010, employing the structural vector auto-regression (SVAR).

China is among the world's highest carbon emitters. The country increased its renewable energy development and infrastructure for carbon emission reduction, resulting in extensive literature exploring the nexus between renewable energy and CO² emissions in comparison to other emerging economies. Chen et al. (2019) confirmed the negative short and long-run relationship in China when analysing green energy deployment influence on carbon emissions for the period 1980-2014 using the ARDL approach.

Similarly, Ameer et al. (2022) employed the ARDL approach and confirmed that in the long run, renewable energy consumption significantly decreases environmental pollution. In their study, Sun et al. (2023) found that a 1% increase in renewable energy consumption may result in CO² emission reduction by 0.103%. They used the STIRPAT theory and system GMM for the period 2010 to 2021 in China. Liu et al. (2023) corroborated the results using the STIRPAT approach in China.

Few authors have focused on developing countries, particularly African countries. The analysis is often within the multi-variate and broader SSA context. South Africa leads in energy transition literature, albeit within the BRICS context. Wolde-Rufael and Mulat-Weldemeskel (2020) found that renewable energy consumption negatively impacts CO² emissions, using the panel PMG estimator for the years 1993-2014. Similarly, analysing the BRICS countries, using

the AMG estimator, Dong et al. (2020) revealed that 1% increase in renewable energy will reduce CO² emissions by 0.2601%.

Hu et al. (2018) showed renewable energy consumption increases influence carbon reduction for 25 major developing countries over the period 1996-2012. The findings suggest that developing countries should increase their renewable energy consumption for low carbon transition. However, Akram et al. (2020) found mixed results in 66 developing countries over the years 1990-2014 using the panel OLS and fixed effect; they found that renewable energy decreases carbon emissions in certain countries while having no impact in other countries.

Apergis et al. (2018) revealed a feedback hypothesis examining the link between renewable energy consumption and CO² emissions for the SSA region during the period 1995 to 2011. Furthermore, the authors indicated short-run two-way causality relationship between CO² emissions and renewable energy consumption. Meanwhile, there is one-way long-run elasticity, thus suggesting that renewable energy consumption reduces CO² emissions.

Acheampong et al. (2021) confirmed that renewable energy reduced carbon emissions in the case of 46 SSA countries for the years 1980 to 2015, using fixed and random-effects estimation approaches. Inglesi-Lotz and Dogan (2018) modelled 10 sub-Saharan African countries for the period 1980-2011 and revealed long-run relationship between renewable energy and CO² emissions. In their study, Farhani and Shahbaz (2014) revealed feedback hypothesis for 10 MENA countries for the years 1980-2009. Our current study similarly includes the North African countries of Egypt, Morocco, and Tunisia.

Tran (2022) examined Vietnam for the period 1986 to 2018, using Granger causality and ECM and the findings revealed unidirectional causality. Additionally, the author further conducted the Granger causality test, revealing unidirectional causality from renewable energy consumption and green investment towards CO² emission. The study variables are similar to our current study variables and analyse the existence of cointegration. Although based on one country and a longer time period, these results are comparable to our study of individual countries.

Brini (2021) found that in the long run, a rise in renewable energy consumption mitigates climate change for the years 1980 to 2014. The study further indicates renewable energy can effectively improve the levels of greenhouse gas emissions. Aydođan and Vardar (2020) confirmed a negative link between CO² and renewable energy consumption. Oluoch et al.

(2022) used the panel (ARDL) to analyse 23 SSA countries during the years 1998 to 2014. The study findings indicate that in the long run, renewable energy consumption has significant and negative relationship with CO² emissions.

Nathaniel and Iheonu (2019) assessed selected 19 African countries using the AMG estimator; they found renewable energy insignificantly inhibits CO² emissions for the period 1990 to 2014. Additionally, when analysing the country-specific, energy sources' impact on CO², emissions differ per magnitude and significance level. Furthermore, the study confirmed one-way causality flow towards CO² emissions from renewable energy. However, Jebli et al. (2015) found renewable energy negatively related to CO² emissions, though insignificant impact for 24 SSA countries for the period 1980 to 2010.

Maji and Abdul-Rahim (2019) examined the impact of renewable energy consumption on environmental quality in Nigeria for the period of 1989-2019, using the OLS approach. The authors found that results are dependent on sectors, they found that the agricultural sector, manufacturing and construction sector, and oil sector have unfavourable impacts on environmental quality. Meanwhile, the transportation sector, residential buildings, and commercial and public services sectors have favourable impacts on environmental quality.

Iorember et al. (2020) found that renewable energy consumption improves environmental quality by decreasing CO² emission in both the long run and short run in Nigeria in the period 1990 to 2016, using ARDL and VECM Granger causality tests. Kwakwa and Alhassan (2018) examined Ghana over the period 1971-2013 using the Fully Modified OLS. The authors confirmed that renewable energy consumption reduces the levels of carbon emission, whereas fossil fuel consumption expectedly increases CO² emission.

In the case of North Africa, Farhani and Shahbaz (2014) used the panel (FMOLS) and (DOLS) to investigate the causal relationship between renewable and non-renewable electricity consumption, output, and CO² emissions for 10 Middle East and North Africa (MENA) countries for 1980-2009. The findings indicate that renewable and non-renewable electricity consumption adds to CO² emissions. Ibrahiem (2015) analyses the relationship between renewable energy consumption, foreign direct investment, and economic growth in Egypt; using the ARDL bound testing approach for the years 1980 to 2011. The study findings show positive long-run relationship exists among the variables in the study.

Literature suggests that renewable energy has an impact on carbon emissions nevertheless varies depending on the development status of a country. Although in the case of developing countries renewable energy has an impact on carbon emissions, it is insignificant compared to the impact that renewable energy has on carbon emissions in developed countries. Hence, this study analyses whether renewable energy consumption decreases the levels of carbon emissions. The study proposes hypothesis:

H2: Renewable energy has a significant impact on energy transition in selected African countries.

2.3.3 Impact of economic growth on carbon emissions

Empirical evidence confirms that CO² emissions and economic growth are significantly linked, studies predominantly indicated a positive relationship (Acheampong, 2018; Alaganthiran & Anaba, 2022; Al-Mulali et al., 2015; Li et al., 2021; Sarkodie & Adams, 2018; Twerefou et al., 2017; Wang et al., 2022).

Jebli et al. (2015) indicate that in the long-run estimates, the inverted U-shaped EKC hypothesis is verified for a sample of 25 OECD countries over the period 1980-2010. Hanif (2018) examined the impact of economic growth on environmental degradation in SSA developing economies, using the system GMM model and EKC. The study revealed an inverted U-shape, furthermore, confirming that in middle- and low-income economies there is an existence of EKC.

Twerefou et al. (2017) confirmed EKC exists between economic growth and environmental quality degradation for the period 1990-2013 for the case of SSA countries. Farhani and Shahbaz (2014) found that GDP exhibits an inverted U-shaped relationship with CO² emissions, thus validating the EKC hypothesis for 10 Middle East and North Africa (MENA) countries from 1980 to 2009. Cowan et al. (2014) examined BRICS countries, revealing, in the case of South Africa, one-way causality from GDP to CO² emissions for the period 1990-2010. However, when Ali et al. (2022) examined the existence of the EKC in BRICS, they found non-existence of EKC in South Africa.

Espoir et al. (2023) examined the effects of economic growth, urbanisation, renewable energy consumption, and good governance on CO² emissions across 47 African countries for the period 1996-2019. They applied the PMG-ARDL approach and Dumitrescu-Hurlin causality test. The authors validated the EKC hypothesis that, in the long run, 1% rise in GDP increases

CO² emissions by 0.61%. However, in the short run, the authors found that economic growth has an insignificant impact on CO² emissions.

Kwakwa and Alhassan (2018) examined Ghana over the period 1971-2013, and employing the Fully Modified OLS, they confirmed the existence of the EKC hypothesis. In the case of Nigeria, Maduka et al. (2022) found no evidence of the EKC hypothesis, using the ARDL and quartile regression technique. The authors indicated that in the short run and long run, they found the N-shaped relationship between CO² emissions and economic growth. Considering that Nigeria's economy heavily relies on fossil fuels, this suggests that economic growth has an adverse impact on environmental quality.

Ren et al. (2021) analysed 26 European Union countries and found that in the short-run and long-run economic growth expansion results in rising carbon emissions. Jebli et al. (2015) investigated the causal relationships between per capita CO² emissions, GDP, renewable and non-renewable energy consumption, and international trade for a panel of 25 OECD countries over the period 1980-2010 using FMOLS and DOLS. Similarly, Shafiei and Salim (2014) explored OECD countries for the period 1980 to 2011, using the STIRPAT model. The empirical results confirmed renewable energy consumption decreases CO² emissions, whereas non-renewable energy consumption increases CO² emissions in developed nations.

Menyah and Wolde-Rufael (2010) examined South Africa, they found that short and long-run equilibrium relationships exist for economic growth and CO² emission, and unidirectional causality using the ADRL bound cointegration testing approach for the period 1965-2006. This suggests that in the case of South Africa, economic growth is highly linked to energy consumption. Samour et al. (2022) affirmed that economic growth positively impacts CO² emissions. The authors found connection between energy, economic growth, banking sector development and CO² emissions in South Africa for the period 1986-2017, using the ARDL approach. It confirmed that energy consumption negatively affects CO² emissions in South Africa.

However, analysing BRICS members, Sebri and Ben-Salha (2014) found bidirectional interaction between economic growth and renewable energy consumption using VECM. In the case of South Africa, the authors found a positive relationship between economic growth and renewable energy consumption, although statistically insignificant. Odusanya et al. (2016) explored the case of Nigeria for the period 1971-2014, using the co-integration approach, they found a relationship between economic growth and energy consumption. The results are

unsurprising—that Nigeria’s economic growth is dependent on fossil fuels; it is amongst the top global oil exporters.

Alaganthiran and Anaba (2022) examined 20 selected SSA countries for the period 2000 to 2020, using the pooled OLS, FEM and REM. They found that 1% increase in economic growth increases the CO² emission level by 0.02%, confirming that SSA countries' economic growth has an adverse impact on environmental quality. Adedoyin et al. (2020) confirmed that economic output has a significant impact on CO² emissions in 12 selected SSA using the PMG ARDL for the period 1980-2014. Similarly, this study tests the hypothesis:

H3: Economic growth increases the levels of carbon emissions in selected African countries.

Odhiambo (2017) indicated a relationship between economic growth and CO² emissions in the short run and long run for 10 SSA countries. Employing the Granger-causality approach for the period 1986 to 2013, the author found a unidirectional causality relationship between economic growth to CO² emissions. However, Zaidi and Ferhi (2019) found a bidirectional causal relationship for SSA using a dynamic GMM estimator, although for a different time series (2000-2012). Similarly, Omri et al. (2015) found evidence for a bidirectional causality relationship between economic growth and CO² emissions for the period 1990-2011 for MENA Countries.

Esso and Keho (2016) examined the long-run and causal relationships among energy consumption, CO² emissions and economic growth for 12 selected SSA countries. They applied the cointegration and Granger causality test for the period 1971-2010 and found mixed results across countries. The bidirectional causality between economic growth and CO² emissions is found in the short run for Nigeria, while the long run indicates that economic growth leads to CO² emissions in Benin, Cote d’Ivoire, Nigeria, Senegal, South Africa, and Togo.

Afriyie et al. (2023) found a significant and negative relationship between economic growth and CO² emissions for 37 SSA countries for the period 1995 and 2017, using the PMG-ARDL and the Dumitrescu-Hurlin causality test. Musah et al. (2020) found that economic growth has a significant positive effect on CO² emissions in the case of the West Africa region. However, Acheampong (2018) found no significant causality relationship between economic growth and

CO² emissions for SSA countries. The author examined 116 countries between 1990 and 2014 using the panel vector autoregression (PVAR) and system GMM.

2.3.4 Impact of environmental policy on carbon emissions

Empirical literature on the role of environmental policies in reducing the levels of carbon emissions has been conducted mainly on developed and emerging countries (Bashir et al., 2021).

Bashir et al. (2021) analysed the influence of environmental taxes on CO² emissions during 1995-2015 for OECD economies, applying the GMM and quantile regression models. The result indicated that environmental taxes negatively influence CO² emissions. Ahmad and Satrovic (2023) examined 10 OECD countries and found that environmental regulations play a significant role in improving environmental quality. Similarly, Wolde-Rufael and Mulat-Weldemeskel (2021) explored 20 European countries for the period 1995 to 2012. They found that environmental taxes are associated with lower CO² emissions.

Zaghdoudi and Maktouf (2017) confirm that a nonlinear relationship exists between taxes and CO² emissions. In addition, the study indicated that environmental taxes reduce CO² emissions below the 2.67% threshold, and then they raise carbon emission emissions. Al Shammre et al. (2023) confirm that when a certain threshold level is achieved, environmental tax effectively reduces CO² emissions in 34 OECD countries, stating that the energy tax threshold level is 1.991%.

Doğan et al. (2022) employed the Pedroni cointegration test and fully modified ordinary least squares (FMOLS) technique in G7 economies. The study found environmental taxes reduce CO² emissions and further elaborated that when strict environmental regulations are implemented, businesses shift to greener technologies. Sarpong et al. (2023) analysed the effects of environmental taxes on CO² emissions in E7 nations over the years 2000-2020. Employing Driscoll-Kraay and quantile-on-quantile techniques, the results confirmed that environmental taxes reduce CO² emissions.

Using CS-ARDL and CS-ARDL for the period 1995 to 2018, Tao et al. (2021) evaluated seven emerging economies and found that environmental taxes have a significant influence on CO² emission reduction. Chien et al. (2021) corroborated the findings, using the AMG, the CS-ARDL and Common Correlated Effects Mean Group estimators. The authors confirmed the impact of environmental taxes on CO² emissions for seven emerging countries for the period

1995 to 2018. Wolde-Rufael and Mulat-Weldemeskel (2021) included South Africa in the evaluation of seven emerging countries for the period 1994 to 2015 using the AMG, FMOLS and causality analyses. The authors declared that environmental taxes negatively influence carbon emissions. Moreover, they suggested that stringent environmental policy improves environmental quality, further stating that South Africa has the lowest environmental policy stringency index.

Adekunle (2021) investigated the role of governance and good institutions in the search for environmental sustainability for 53 African countries for the period 1996-2017, using the dynamic system GMM estimator. The study findings suggest a positive relationship between law and regulatory quality and environmental sustainability. Environmental laws and policies are relatively new in African countries, thus the implementation of environmental policies in African countries is lagging in comparison to the developed countries. The study proposes hypothesis

H4: Environmental policies have a significant impact on energy transition in selected African countries.

2.3.5 Impact of urbanisation on carbon emissions

Few studies investigated the relationship between urbanisation and CO² emissions, predominantly in multi-country studies for both developed and developing countries (Cole & Neumayer, 2004; Ehrhardt-Martinez et al., 2002; Poumanyvong & Kaneko, 2010; Saidi & Mbarek, 2017; York et al., 2003).

Afriyie et al. (2023) empirically examined the impact of urbanisation, economic growth, energy consumption, and industrialisation on carbon emissions for 37 SSA countries between the period 1995 and 2017, using the PMG-ARDL technique and the Dumitrescu-Hurlin causality test. They confirmed no significant impact of urbanisation on carbon emissions in both the long run and short run. However, Ibekilo et al. (2023) employed the AMG method and CCEMG in 33 African countries for the period between 1996 and 2020 and found that urbanisation increased environmental pollution.

Adedoyin et al. (2020) confirmed that urbanisation has a significant impact on CO² emissions for 12 selected sub-Saharan African using the PMG ARDL for the period spanning 1980-2014. Musah et al. (2020) examined the relationship between urbanisation and carbon emissions in West Africa. Using the cointegration test, they affirmed that in the long run, urbanisation had

a significantly positive influence on CO² emissions. Salahuddin et al. (2019) examined the effects of urbanisation and globalisation on CO₂ emissions in South Africa for the period 1980-2017, using the ARDL approach. The findings indicate that in the short run and long run, urbanisation causes CO² emissions. Additionally, the causality test shows a bidirectional link between urbanisation and CO² emissions.

Abdallah and Abugamos (2017) examined the impacts of urbanisation on carbon emissions for a panel of 20 countries in the MENA region over the period 1980-2014, using the STIRPAT framework. The authors found little evidence supporting an inverted-U-shaped relationship between urbanisation and carbon emissions. Shafiei and Salim (2014) support the existence of an EKC between urbanisation and CO² emissions, implying that at higher levels of urbanisation, the environmental impact decreases.

In an earlier study, Ehrhardt-Martinez et al. (2002) found an inverted U-shaped relationship between urbanisation and CO² emissions, arguing that the relationship between urbanisation and CO² emissions may vary from country to country, thus dependent on the country's development. Analysing emerging economies, Sadorsky (2009) confirmed that urbanisation has an insignificant impact on CO² emissions. Poumanyvong and Kaneko (2010) analysed 99 countries, and categorised countries per income levels (low-, middle- and high-income) over the years 1975-2005. The authors found a positive relationship exists for all income groups, however, more prominently in the middle-income group. African countries are predominantly low-income level, thus tend to have less impact on CO² emissions.

Luqman et al. (2023) examined 91 cities and found that urban CO² emissions are increasing in all cities, however, the dominant contributors differ per development level of these cities. The study cluster analysis of factors indicates that developing countries were dominated by cities with rapid area and per capita CO² emissions increases, meanwhile developed countries' cities indicate a slow area and per capita growth. Similar to other developing countries, African countries have clusters of cities with concentrated populations.

Kayani et al. (2023) explored the top 10 polluted countries for the period 2000-2019 and found that the cities' expansion is harmful to nature and ecological footprints. Furthermore, the author shows that in developing countries, urbanisation had a positive and significant effect on CO² emissions. However, Martínez-Zarzoso and Maruotti (2011) found an inverted U-shaped relationship between urbanisation and CO² emissions for developing countries over the years 1975-2003.

Martínez-Zarzoso et al. (2007) examined the impact of urbanisation on carbon emissions for European Union member countries for the period 1975-1999, the results confirmed that urbanisation increases CO² emission. The authors further stated that the effect of population change on CO² emissions should be considered for future discussions of climate change policies within the EU. Using the panel bootstrap Granger causality test, Khan et al. (2020) reveal a causal relationship between urbanisation and carbon emission in newly industrialised countries. The result shows that urbanisation has a significant impact on carbon emissions.

York et al. (2003) examined 137 countries, indicating an increase in urbanisation population leads to an increased CO² emission. Similarly, for a panel of 86 countries, Cole and Neumayer (2004), examining the relationship between urbanisations, found that urbanisation positively impacts an increase in CO² emissions. Africa has the fastest-growing urbanisation population, expected to rise to an estimated 60% by 2050. Thus, energy demands are expected to increase. The continent heavily relies on fossil fuels; hence, the study tests whether urbanisations increase carbon emission in selected African countries.

2.4. Summary of the literature review

The empirical evidence predominantly found that green finance, renewable energy, and environmental policies have significant and negative impacts on carbon emissions, while economic growth and urbanisation positively impact carbon emissions. The studies employed various models such as AMG estimation, OLS, fixed and random-effects estimation approaches, GMM estimators, ARDL models and spatial modelling analysis. Empirical literature conducted in a multivariate panel of countries included common variables such as financial development, trade openness, population and non-renewable energy consumption, fossil fuels consumption, tourism sector and population (Chang et al., 2021; Dong et al., 2020; Huang et al., 2021; Lin et al. 2022; Majewski et al., 2022; Nathaniel & Iheonu, 2019; Saeed & Karim, 2021; Samour et al., 2022; Szetela et al., 2022; Zhou & Xu, 2022).

Developed and BRICS countries are at the forefront of the empirical literature and these economies are the highest global emitters. Developed countries are the world's highest per capita carbon emitters, however, also leading the global financing and investment contribution towards the reduction of carbon emissions levels. Empirical literature illustrates green finance decreases the levels of carbon emissions in developed countries and China (Dafermos & Nikolaidi, 2021; Dogan & Seker, 2016; Sun, 2023). Meanwhile, there is limited literature

analysing developing countries, particularly African countries, hence the study addresses this question: *Does green finance have a significant impact on energy transition?*

The impact of renewable energy on carbon emissions varies slightly, depending on the development status of a country. The impact on carbon emissions in developing countries, specifically SSA countries, is insignificant compared to the developed and emerging countries (Akram et al., 2020; Apergis et al., 2018; Brini, 2021; Farhani & Shahbaz, 2014; Hua et al., 2016; Inglesi-Lotz & Dogan, 2018; Jebli et al., 2015; Brini, 2021; Nathaniel & Iheonu, 2019). Thus, the study question is: *Does renewable energy consumption increase or decrease the levels of carbon emission in African countries?*

The literature verified the existence of EKC hypothesis in the case of OECD, BRICS, SSA countries, particularly South Africa, Nigeria, and Ghana (Ali et al., 2022; Hanif, 2018; Jebli et al., 2015; Kwakwa & Alhassan, 2018; Maduka et al., 2022; Twerefou et al., 2017; Udeagha & Ngepah, 2023). This implies that economic growth and carbon emissions increase lead to environmental degradation. However, the trend reverses at some level of per capita income, resulting in high-income levels after which economic growth leads to environmental quality improvement (Stern, 2019).

Studies have linked a relationship between renewable energy consumption and economic growth, emphasising that the developmental status of a country has an impact on the variable relationship. Suggesting that in high-income level countries, renewable energy consumption exhibits no influence on economic growth, whereas, in low- and middle-income countries, renewable energy consumption can promote economic growth (Destek & Aslan; 2017; Narayan & Doytch, 2017; Xie et al., 2020). African countries are mostly low-income level; however, this study panel included the high-income countries in the continent. These countries rely heavily on fossil fuels for economic growth; hence the study answers the question: Does economic growth increase or decrease the levels of carbon emissions?

The literature confirmed that environmental policies influence the levels of CO² emissions. In developed countries, environmental taxes are associated with lower CO² emissions, further emphasising that emerging and developing countries require strict environmental policies and regulations (Adekunle, 2021; Doğan et al., 2022; Wolde-Rufael & Mulat-Weldemeskel, 2021). The literature found that urbanisation has a positive relationship with CO² emissions, suggesting that the relationship is dependent on the country's development (Ehrhardt-Martinez et al., 2002; Kayani et al., 2023; Khan et al., 2020).

2.4.1 Hypothesis Summary

The literature indicated limited analysis based on developing countries, particularly African countries. The study contributes to Africa's empirical literature by analysing the impact of green finance, renewable energy, economic growth, environmental policies, and urbanisation on carbon emission, hence the study hypotheses are outlined as:

H1: Green finance has a significant impact on energy transition in selected African countries.

H2: Renewable energy has a significant impact on energy transition in selected African countries.

H3: Economic growth increases the levels of carbon emissions in selected African countries.

H4: Environmental policies have a significant impact on energy transition in selected African countries.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research methodology appropriate to outline research objectives while addressing the research questions and hypothesis. The study design, the population and the sample are outlined and the instrument used to collect the data and methods to ensure the validity and reliability of the instrument are also described.

The study design followed a quantitative approach. The quantitative approach was an appropriate methodology for extensive insight into the overarching objective of the study: to analyse the relationship between green finance, economic growth, renewable energy, environmental policies, urbanisation, and energy transition. The quantitative approach analyses the relationship and causality among econometric variables (Ott & Longnecker, 2015).

3.2 Model and variable specification

The study applied the panel autoregressive distributed lag (ARDL) model by Pesaran et al. (2001). Similar to Afriyie et al. (2023) and Espoir et al. (2023), these studies analysed the impact of economic growth, urbanisation, good governance and renewable energy on CO² emissions in African countries. Our study included green finance and environmental policies. The analytical framework was expressed as follows:

$$CO^2_{it} = f(GFIN_{it}, REC_{it}, GDP_{it}, EP_{it}, UR_{it}) \quad (1)$$

where, CO², GFIN, REC, GDP, EP, and UR represented CO² emissions, green finance, renewable energy, economic growth, environmental policy, and urbanisation respectively. The term (i) denotes the cross-sectional dependence (1...2, ... 3.... N. African countries), whereas the term (t) shows the period 2000 to 2019 of the study. From the above Equation (1), the regression analysis is as follows:

$$CO^2_{it} = \alpha_0 + \alpha_1 GFIN_{it} + \alpha_2 REC_{it} + \alpha_3 GDP_{it} + \alpha_4 ENVR_{it} + \alpha_5 EP_{it} + \alpha_6 UP_{it} + \varepsilon_{it} \quad (2)$$

Where α_0 is the constant term and $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ and α_5 are the coefficients for the relationship between dependent and independent variables, while ε represents the error term. The variables were transformed to logarithmic form to minimise the outliers of time series and ensure that estimated results were interpreted efficiently. Therefore, the econometric model in log linear was as follows:

$$\ln CO^2_{it} = \alpha_0 + \alpha_1 \ln GFIN_{it} + \alpha_2 \ln REC_{it} + \alpha_3 \ln GDP_{it} + \alpha_4 \ln ENVR_{it} + \alpha_5 \ln EP_{it} + \alpha_6 \ln UP_{it} + \varepsilon_{it} \quad (3)$$

The equations above (1)-(3) addressed the following study sub-questions: *Does green finance, renewable energy consumption, economic growth, environmental policies, and urbanisation increase or decrease the levels of carbon emissions?*

Table 1: Definitions of variables and data sources

Variable	Definition	Measurement	Sign	Source
Dependent variable:				
CO ²	Carbon dioxide emissions	Metric tons		IRENA
Independent variables:				
GFIN	Green finance	Annual \$000	-	IRENA
REC	Renewable energy consumption	Annual kWh	-	World Bank
GDP	GDP	Annual \$000	+	World Bank
ERT	Environmental sustainability rate	1- 6	-	World Bank
UP	Urbanisation population	Annual 000	+	World Bank

Source: Author

3.2.1 Dependent variable

Carbon emissions

The study's dependent variable is the CO² emissions. According to Climate Watch (2023), CO² emissions are defined as “...emissions stemming from the burning of fossil fuels for energy production and the manufacturing of cement...”. The combustion of fossil fuels for energy generation is the highest emitter, therefore energy-related carbon emissions is a proxy for energy transition. CO² emissions are measured in metric tons and collected from the IRENA database.

3.2.2 Independent variables

Renewable energy

Renewable energy consumption (REC) is the proxy for renewable energy sources. It is defined as the ratio between the gross consumption of energy from renewable sources and the total (primary) gross energy consumption calculated for a calendar year, thus calculated as the sum of the gross consumption of energy from renewable sources. Renewable energy consumption (REC) was measured in millions of kilowatt hours, collected from the World Bank database.

Green finance

Green finance is defined as “the financing of investments that provide environmental benefits in the broader context of environmentally sustainable development” (Woodward, 2009, p.

176). Green finance refers to financial and investment flows towards the implementation of renewable energy infrastructure that benefits the environment and society. In this study green financial and investment flows from public investors were proxy of green finance (GFin), measured in millions of dollars, collected from the IRENA database.

Economic growth

Economic growth is described as an increase in the economic activities of one period compared to a previous period. Generally, economic growth is measured in terms of gross domestic product (GDP) which measures the total production of an economy. GDP is a proxy for economic growth. The database was collected from the World Bank in millions of dollars.

Urbanisation

Urbanisation is described as a migration from rural areas to urban areas seeking economic opportunities. Urbanisation is expected to rapidly increase between 2000 and 2030, thus, resulting in increased energy demands. Africa's energy consumption is dependent on fossil fuels, thus an increase in urbanisation rate may lead to an increase in carbon emissions level, hence, urbanisation is selected as a study variable. The urbanisation population size is proxy for urbanization and previously used the same proxy to investigate the impact of urbanisation on CO² emissions (Adedoyin et al., 2020; Afriyie et al., 2023; Majewski et al., 2022).

Environmental policies

Environmental policies are initiated to mitigate global climate change and control the adverse effects of CO² emissions. The environmental sustainability rate is proxy to assess the countries' adoption of environmental policies and taxes to progress towards energy transition. The environmental sustainability rate is measured on a rate from low to high (1-6), and the database was collected from the World Bank.

3.2.3 Model estimate framework

The study applied the panel (ARDL) model. The approach was suitable for empirical analyses on the impact of green finance, renewable energy, economic growth, environmental policies, and urbanisation on carbon emissions. The ARDL approach was selected for the study due to several advantages. Firstly, the approach provides flexibility; the variables are used regardless of integrated order, whether they are at I (0) or integrated of order I (1), however, not exceeding order I (1). Secondly, the ARDL deals with endogenous and exogenous variables in the regression by providing valid t-statistics with unbiased long-run estimates. Moreover, the

approach can simultaneously assess the time series' and provide insights into short-run and long-run relationships. It provides efficient cointegration in comparison to other cointegration tests such as Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990).

However, the conventional ARDL model does not support panel data analysis, thus Pesaran et al. (1999) developed three alternative method estimators, mean group (MG), pooled mean group (PMG) and dynamic fixed effects (DFE) estimators. According to Demetriades and Law (2006), the three models consider the dynamic adjustment process for the long-run equilibrium and the heterogeneity. The mean group MG model provides the averages of the long-run parameters for the individual countries, thus, resolving the heterogeneity bias in dynamic panels (Pesaran et al., 1999), while the PMG estimator analyses both the long and short-run between variables and investigates the heterogeneous bias across countries. Moreover, the estimator allows for short-run coefficient intercepts, while adjusting speed to the long-run equilibrium. The error variances were heterogeneous for each country while restricting the long-run slope coefficients to be homogeneous across countries (Pesaran et al., 1999).

Similarly, DFE estimates the long and short run between variables, however, limits the coefficient of the co-integrating vector by equalising across countries in the long run (Rafindadi & Yosuf, 2013). Further restricting the adjustment speed of the coefficient and the short-run coefficient to be equal across panels while allowing for the panel-specific intercepts. According to Rafindadi and Yosuf (2013), due to the endogeneity between the error term and the lagged dependent variable, the DFE models are subject to biases. The model estimator is dependent on the Hausman test results, which were based on the null hypothesis of homogeneity. The null hypothesis was rejected if the p-value < 0.05 ; if the null hypothesis could not be rejected, then the study applied the PMG estimator.

Our study was a heterogeneous panel, large T (19), small N (10), thus approaches such as GMM and PVAR, SDEM, FE and REM were not appropriate for analysis. This approach has been extensively used in the literature to model the relationship between variables by authors such as Afriyie et al. (2023), Chien et al. (2021), Espoir et al. (2023), Samour et al. (2022), Tao et al. (2021), and Wolde-Rufael and Mulat-Weldemeskel (2021) and was therefore appropriate to address the study's overarching question of whether there was a long-run and short-run relationship between green finance, renewable energy, economic growth, environmental policies, urbanisation, and energy transition for selected African countries. The long-run and short-run model estimates are shown below:

$$CO^2_{it} = \alpha_1 + \sum_{j=1}^p \varphi_{ij} CO^2_{it-j} + \sum_{j=0}^q \beta_{ij} X_{it-j} + \varepsilon_{it} \quad (4)$$

The study hypothesis is:

H0: $\beta_{ij} = 0$ for all i and j

The alternative hypothesis is:

H1: $\beta_{ij} \neq 0$ for some i and j

We estimated the following for our study variables:

$$CO^2_{it} = \alpha_1 + \sum_{j=1}^p \varphi_{ij} CO^2_{it-j} + \sum_{j=0}^q \beta_{1ij} GFIN_{it-j} + \sum_{j=0}^q \beta_{2ij} REC_{it-j} + \sum_{j=0}^q \beta_{3ij} GDP_{it-j} + \sum_{j=0}^q \beta_{4ij} EP_{it-j} + \sum_{j=0}^q \beta_{5ij} UR_{it-j} + \varepsilon_{it} \quad (5)$$

Where i, t, and j denote cross-sectional units, time series, and optimal lags. X_{it} represents the independent variables, $\Delta GFIN$, ΔREC , ΔGDP , ΔEP , and ΔUP , representing green finance, renewable energy, economic growth, environmental policy, and urbanisation respectively. The formula above was re-parameterised as an error correction model in equation (6) below, where δ_i represents panel speed of adjustment coefficient; ϕ_i refers to the vector of long-term, while β_{ij} and φ_{ij} refers to the short-term dynamic coefficients and $(CO^2_{it-1} - \phi_i X_{it})$ refers to the error correction term (ECT) and p-1 and q-1 denote the optimal lag orders:

$$CO^2_{it} = \alpha_1 + \delta_i (CO^2_{it-1} - \phi_i X_{it}) + \sum_{j=1}^{p-1} \varphi_{ij} CO^2_{t-j} + \sum_{j=0}^{q-1} \beta_{ij} X_{it-j} + \varepsilon_{it} \quad (6)$$

3.2.4 Data collection

The study analysed the impact of green finance on energy transition using a secondary annual time series for the period 2000-2019. The annual data was selected over the quarterly and monthly due to data availability in Africa. Similarly, the panel countries were selected based on availability. These countries are the top recipients of green finance in Africa—South Africa, Nigeria, Egypt, Morocco, Kenya, Ethiopia, Ghana, Tunisia, Côte d'Ivoire, and Mozambique. The convenience nonprobability sampling based on data availability and accessibility was employed to select a panel of 10 African countries (Lyons & Doueck, 2010). The study observations of 190 ($N = 10 \times T = 19$) included variables of carbon emissions, green finance, renewable energy, economic growth, environmental policy, and urbanisation. The secondary data sets were collected from the World Bank and IRENA and retrieved from an online database.

3.3 Data analysis

The relevant pre-test analyses were conducted prior to conducting a meaningful regression model to evaluate the validity and robustness of the study results. The study data had numerous units of measurement and magnitudes, and the data was transformed to logarithmic form to normalise and stabilise the variances to ensure estimates and results are interpreted efficiently. The study data was processed and analysed using the statistics software STATA 17. Firstly, descriptive statistics were conducted to provide data summary in a meaningful, clear, and concise basis to gain insight into the data patterns, trends, and distributions. Thereafter, a correlation test to indicate the multicollinearity amongst independent variables resulted in the exclusion of correlated independent variables from our model to ensure reliable statistical inferences.

Secondly, the 1st and 2nd generation unit root test LLC, IPS and MW, Pesaran's CADF and CIPS test were conducted to confirm the stationary level of the variables at the order of integration I (1), with lag of 1. The variables with unit root test did not meet the requirement of non-stationary series and hence were excluded from the model. Thirdly, the study applied the Lagrange multiplier (LM) test, developed by Breusch and Pagan (1980) confirming the heteroscedasticity of slope coefficients in the panel data. Furthermore, it confirmed the existence of cross-sectional dependencies. Lastly, the Hausman test was applied to select an appropriate model estimator to analyse the dynamic impact of our study variables among pooled mean group (PMG) and dynamic fixed effects (DFE) procedures developed by Pesaran et al. (1999). Additionally, the Random-effects and Fixed-effects regression were conducted, verifying the robustness and corroborating the study results.

3.4 Research Philosophy

The study rooted in positivism research philosophy, relying on the hypothetico-deductive method seeking to verify the impact and relationship between dependent variable – carbon emissions and independent variables – green finance, renewable energy, economic growth, environmental policies, and urbanisation. The research data is collected to test hypotheses outlined in Chapter 2; and answer research questions in Chapter 1. The study ensures objective data analysis by using standardized instruments, procedures outline in the section and statistical software STATA.

3.5 Research Methodology delimitation and limitations

The study only used the public green finance due to cost implications to access the private green finance. The data range and frequency were selected based on the availability of green finance database in African countries. The 10 African countries were selected as the panel countries based on the availability of green financing and investment in these countries. Thus, resulting in heterogeneous panel study, narrowing panel (ARDL) model as the appropriate approach for the study data analysis.

CHAPTER 4: DISCUSSION OF FINDINGS

4.1 Introduction

This chapter presents the study findings processed and analysed from the statistics software STATA 17. The study analyses the impact and relationship between green finance, renewable energy, environmental rate, urban population, and carbon emissions for selected 10 African countries from 2000 to 2019. Firstly, the variables are transformed into logarithmic form to ensure an efficient model estimation and interpretation. Secondly, the correlation test, cross-sectional dependence test, unit root test and cointegration test were conducted prior to ensure the validity and reliability of our model. Thereafter, the Hausman test indicated that the PMG estimator is most efficient for analysing the study panel model.

4.2 Descriptive statistics

The descriptive statistics were conducted to analyse the data summary seen in Table 2, illustrating the panel variables mean, mode median, standard deviation, minimum and maximum for the 200 study observations. The dependent variable summary shows a mean of 3.5 and standard deviation of the variable 1.4, with the minimum and maximum values of 1.0 and 6.1. GFin has a minimum value of 0, with a standard deviation of 2.3 and a mean of 3.0.

Table 2: Descriptive statistics

Variables	Mean	Std. dev.	Min	Max	Obs
lnCO ²	3.5470	1.4516	1.0986	6.1800	200
lnGfin	3.0151	2.3344	0	8.5569	200
lnREC	3.5245	1.0332	1.6094	4.5643	200
lnGDP	24.7772	1.2072	22.3293	27.0762	200
Envr	1.655	1.8609	0	4	200
lnUP	16.6145	0.7438	15.4584	18.5569	200

Source: Author

4.3 Correlation test

The correlation test is conducted to examine and determine the multicollinearity amongst the study variables. The correlation results in Table 3 indicate that independent variables, urbanisation and GDP; REC and Envr are positively and significantly correlated, implying that multicollinearity exists among these independent variables. The possible reason is that urban population is responsible for the majority of countries 'GDP. Table 3 indicates that GDP and urbanisation are significantly correlated with the dependent variable carbon emissions at 0.90 and 0.86 respectively. Renewable energy sources reduce CO², thus contributing to

environmental sustainability, consequently resulting in the independent variables positive correlation. The inclusion of the highly correlated independent variables in our model may lead to spurious outcomes and unreliable statistical inferences; thus, environmental sustainability and Urbanisation are excluded from study. Furthermore, REC has a negative relationship with CO² and GDP. Thus, implying that an increase in REC results in a reduction of CO² and GDP.

Table 3: Correlation test results

	ln CO²	lnGDP	Envr	lnUP	lnGfin	lnREC
lnCO ²	1.0000					
lnGDP	0.9087	1.0000				
Envr	-0.3541	-0.0932	1.0000			
lnUP	0.8697	0.8688	-0.0192	1.0000		
lnGfin	0.2501	0.3645	0.1315	0.2726	1.0000	
lnREC	-0.6272	-0.5223	0.6758	-0.2954	-0.2344	1.0000

Source: Author

4.4 Cross-sectional dependence

The study applied the Lagrange multiplier (LM) test, developed by Breusch and Pagan (1980), to determine the presence of heteroscedasticity of slope coefficients in the panel data. The results of Table A1 in Appendix A indicate the p-value of the statistic to be 0.0001 (<0.01) using a random and fixed effects model. Thus, we reject the null hypothesis of no cross-sectional dependency at a 1% level of significance, indicating the presence of cross-sectional dependencies. The study panel time series indicates the presence of cross-sectional dependency; hence we employ robust panel data ARDL methods for cross-sectional correlations and heterogeneity.

4.5 Unit root test

The three-1st generation unit root tests were conducted to determine the stationary or nonstationary variables, using the Levin-Lin-Chu (LLC) test, Im-Pesaran-Shin (IPS) test, and Maddala and Wu (MW) test proposed by Levin et al. (2002), Im et al. (2003), Breitung (2002) and Hadri (2000). The unit root test findings in Table C1 in Appendix C illustrate Gfin, and GDP are stationary at their levels per IPS, LLC and MW tests, while other variables are non-stationary at their levels. The results further indicate that the CO², REC and Gfin, and GDP are stationary at order of integration I (1), per IPS, LLC and MW test, therefore unit root hypothesis

can be rejected at a significance level of 1%. However, environmental rate and urbanisation are nonstationary, we fail to reject the hypotheses. These variables are excluded from the model as they do not meet the necessary requirements of stationary series. The usage of nonstationary variables in the regression model will result in spurious findings.

Furthermore, the second-generation Cross-sectionally Augmented Im-Pesaran-Shin (CIPS) panel unit root and Cross-sectional Augmented Dicky-Fuller (CADF) panel unit root test were conducted to confirm the unit root results as heterogeneity and cross-sectional dependencies are present in the panel series. The result indicates that our variables CO_2 , REC, GFin and GDP are stationary at first difference (see Table C2 in Appendix C). The results corroborate and confirm the first-generation test results for LLC, IPS and MW unit root tests. The panel times series data meets the requirement of stationary to further conduct the panel cointegration test.

4.6 Cointegration test

The cointegration test is conducted using panel Pedroni and Kao tests to determine the long-run linear relationship between the dependent and the independent variables. The panel unit root tests in Tables C1 and C2 in Appendix C confirmed the variable stationarity in their first differences $I(1)$, further confirming that no variable is differenced at $I(2)$ order. The results in Table B1 in Appendix B indicate that the PP t , and the ADF t Pedroni test statistics reject the null hypothesis of no cointegration and therefore favour the alternative hypothesis that CO_2 , GDP, GFin, and REC are cointegrated.

Similarly, Kao test results indicate that modified DF t , the DF t , and the ADF t test statistics reject the null hypothesis of no cointegration, therefore, confirming cointegration among CO_2 , GDP, GFin, and REC. The results in Table B1 in Appendix B indicate that the null hypothesis of no cointegration is rejected, and the statistic value is greater than the upper bound, $I(1)$ at the 0.05 critical value; thus, there is the presence of a long-run relationship among the study variables (Pesaran et al., 2001). The cointegration among the variables is further tested and confirmed in the panel ARDL model.

4.7 Hausman test

The Hausman test is applied to select an appropriate model estimator to analyse the dynamic impact of our study variables. We conducted pooled mean group (PMG) and dynamic fixed effects (DFE) procedures developed by Pesaran et al. (1999). The results in Table C3 in Appendix C present the results of the short- and long-run relationship between GDP, REC and

CO² for both PMG and DFE techniques. The PMG estimator indicates that REC, GFin and GDP are significant at level 1% and 5%, while the DFE model indicates that only REC is significant at level 5%, indicating that GFin and GDP are statistically insignificant. Furthermore, the Hausman test results indicate a probability of 0.9949, therefore the null hypothesis is rejected. The p-value <0.05; we fail to reject the null hypothesis of homogeneity restrictions in the long run among the variables, therefore, confirming that the PMG estimator is efficient to analyse our panel model.

4.8 Panel ARDL Model

The PMG estimator is applied to estimate the study model to analyse the dynamic impact of the variables for selected African countries. The PMG estimator affirms the homogeneity of the long-run coefficients for all the countries in the panel while allowing the short-run parameters to differ per country in the panel. Table 4 shows the PMG long run and short run for selected African countries. The results confirm that in the long-run and short-run, there is a relationship between the dependent variable and independent variables. Therefore, we can reject the null hypothesis in favour of the alternative hypothesis. Importantly, the results address the overarching study question of whether a long-run and short-run relationship exists between energy transition, green finance, and renewable energy for the selected African countries.

Table 4: Panel ARDL PMG model

Variable	PMG	
Long-run estimates	Coefficient	p-value
LnGDP	0.3103	0.000***
LnGfin	0.0200	0.011**
LnREC	-0.8339	0.000***
Short-run estimates		
ECT	-0.2232	0.075*
LnREC	-0.6159	0.106
LnGfin	-0.0048	0.045*
LnGDP	-0.0059	0.781
Cons	-0.3789	0.085

Source: Authors

Note: The significance level 1%, 5% and 10% indicated ***, **, *

4.8.1 Short-run error correction model (ECM)

The short-run impact of green finance, renewable energy and economic growth on Africa's CO² emissions is conducted using the Error Correction Term (ECT) based on the PMG estimator. The ECT is the speed adjustment coefficient in case of disequilibrium in the dynamic

model. Table 6 indicates that the ECT of CO² emissions has the expected negative sign; and is statistically significant at a level of 10%. Therefore, confirming the existing co-integration between green finance, renewable energy economic growth and CO² emissions. The model demonstrates the short-run coefficient indicates the ECT of -0.2232, indicating the low speed of adjustment following disequilibrium from the long-run; the CO² emissions converge towards long-run equilibrium at around 22.32% yearly.

The short-run estimate in Table 6 indicates negative coefficients for all the independent variables. The results suggest that in the short run, green finance, renewable energy, and economic growth have a negative relationship with carbon emissions for the selected African countries during the period 2000-2019. Green finance has a negative and significant impact on CO² in the selected African countries for the period 2000-2019, in the short run an increase in green finance reduces the CO² emissions levels by 0.045%. Therefore, we can reject the null hypothesis and accept the alternative hypothesis, *H1: "Green finance has a significant impact on energy transition"*.

Moreover, the results confirm that green finance decreases the levels of carbon emissions, thus addressing the study sub-question *"Does green finance increase or decrease the levels of carbon emissions?"* An increase in green finance and investment towards African countries leads to the development and implementation of green projects. When green and clean projects are increased in the market, alternatives to fossil fuels are available for energy consumption, resulting in the reduction of fossil fuel consumption, consequently reducing the levels of CO² emissions. The findings support Jian and Afshan (2023), Meo and Abd Karim (2022).

Renewable energy is statistically insignificant, suggesting that in the short run, renewable energy does not have a significant impact on the levels of CO² emissions. The reason may be that renewable energy development in African countries has not reached a significant level as an alternative to fossil fuel consumption to meet the energy demands, thus is not yet sufficient to effect CO² emission reduction in the short run. Consequently, we fail to reject the null hypothesis, *"Renewable energy has no significant impact on energy transition"*. The results support the findings of Dong et al. (2020), Jebli et al. (2015) and Nathaniel and Iheonu (2019); however, contradict the findings of Brini (2021) and Apergis et al. (2018).

In the case of economic growth, the findings indicate statistically insignificant, thus, suggesting that in the short run, economic growth does not have a significant impact on the levels of CO² emissions. Thus, we fail to reject the null hypothesis, *"Economic growth has no significant*

impact on energy transition". The increase in the production of goods and services in an economy demands extensive energy consumption. African economies rely heavily on fossil fuels for energy generation, thus the increase in economic growth leads to an increasing fossil fuel consumption. However, African countries are in the early stages of economic development, consequently not consuming substantial energy. Hence, in the short run economic growth has no impact on CO² emissions in African countries. The results support Acheampong (2018) however, contradictory to the findings of Adedoyin et al. (2020), Musah et al. (2020) and Odhiambo (2017).

4.8.2 Panel long-run estimates

The long-run estimates in Table 6 indicate that REC, GFin, and GDP are statistically significant at 1% and 5% levels. The results show that the variables have a significant impact on the levels of CO² for the selected African countries during the period 2000-2019. In the long run, green finance has a positive coefficient at a significant level of 5%, thus indicating that green finance has a significant and positive impact on the levels of CO² emissions. An increase in green finance flows leads to an increase in the levels of CO² emissions by 0.02%. Hence, we reject the null hypothesis, and accept the alternative hypothesis, *H1: "Green finance has a significant impact on energy transition"*.

Furthermore, the results indicate that green finance increases the levels of carbon emissions, addressing the study question, *"Does green finance increase or decrease the levels of carbon emissions?"*. The possible reason for the results may be that green businesses utilise green finance inflows on economic activities such as equipment, goods and services for the implementation of green projects, resulting in the enhancement of economic consumption and expenditure. Considering that African economies rely heavily on fossil fuels, the increase in economic activities leads to an increase in fossil fuel consumption, consequently increasing the level of CO² emissions.

The green project development is capital intensive, requiring substantial resources and financing. However, the green finance development level in Africa is less advanced than in developed countries. The result indicates that the average green finance is approximated at \$3 million, while the minimum is approximated at \$0 million. Therefore, green finance has not yet reached the required threshold level to have a negative impact on the levels of CO² emissions in African countries. Furthermore, the study green finance data only include financing flows from public institutions, thus the inclusion of private finance inflows may

result in a negative impact on CO² emissions. The results contradict the findings of Meo and Abd Karim (2022), Saeed and Karim (2021) and Zhou and Xu (2022).

The long-run relationship between renewable energy and CO² emission indicates a negative coefficient of 0.83 at a significant level of 1%, suggesting that an increase in renewable energy significantly decreases the level of CO² emission by 0.83% in the long run. Therefore, we have sufficient evidence to reject the null hypothesis in favour of the alternative hypothesis, *“Renewable energy has a significant impact on energy transition”*. Additionally, the results address the research question *“Does renewable energy have a significant impact on energy transition?”* and the sub-question *“Does renewable energy consumption increase or decrease the levels of carbon emission?”*

Renewable energy sources incorporation in energy policies provides access to alternatives to fossil fuel sources for energy generation to meet rising energy demands. The accessibility and availability of renewable energy stimulate the energy transition from fossil fuel consumption towards renewable energy consumption; thus, results decreasing the levels of CO² emissions. The continuous rise in renewable energy gradually increases the dependence of African countries on renewable energy to improve and support energy security solutions, which can significantly diminish the level of CO² emissions. The result is consistent with Acheampong et al. (2021), Akram et al. (2020), Brini (2021) and Dogan and Seker (2016) for several economies.

Economic growth shows a positive coefficient, at a significant level 1%, indicating that GDP has a positive impact on CO² emissions; the rise in GDP leads to an increase of CO² emissions levels by 0.30%. Therefore, we have evidence to reject the null hypothesis, and accept the alternative hypothesis, H3: *“Economic growth has a significant impact on energy transition”*. Additionally, the results answer the research question: *“Economic growth increases the levels of carbon emission?”* The study results accord with the results of Alaganthiran and Anaba (2022), Ezzo and Keho (2016) and Musah et al. (2020).

The relationship between economic growth and CO² emissions is emphasised on the notion that the economies' production of goods and services is associated with substantial energy consumption; consequently, leading to significant CO² emissions. African economies are dependent on fossil fuels for energy generation; considering that fossil fuels are the highest CO² emitters, the rise in fossil fuel consumption results in an increase in levels of CO²

emissions. The study results confirm that economic growth in African countries has an adverse impact on environmental quality by increasing the levels of CO² emissions.

4.8.3 Countries' short-run estimates

The PMG estimator analyses the long and short-run coefficients intercept and assumes homogeneous long-run coefficients across the panel. However, the error variances are heterogeneous for each country in the panel. The short-run coefficients intercept for individual countries' results are indicated in Table 5. African countries vary in economic developmental stages and energy policies; hence, the results differ across the selected countries. The majority of panel countries show the expected error correction term with the acceptable range between -2 and 0. The ECT for Cote d'Ivoire, Ghana, Kenya, South Africa and Tunisia are statistically significant, confirming adjustment coefficient in case of disequilibrium from the long run, while Ethiopia, Egypt, Morocco, Nigeria and Mozambique indicate statistically insignificant error correction terms.

Table 5: Short-run estimates per country

c_id	1 Cote d'Ivoire		2 Ethiopia		3 Ghana		4 Egypt		5 Kenya	
Variable	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
ECT	-1.1625	0.000***	-0.0552	0.645	-0.2486	0.096*	0.1149	0.125	-0.5112	0.003***
lnREC	-1.2606	0.000***	-2.2322	0.159	-0.7190	0.160	-0.2033	0.015**	-0.8743	0.170
lnGfin	-0.0179	0.011**	-0.0001	0.949	-0.0040	0.653	-0.0086	0.580	-0.0086	0.101
lnGDP	0.01857	0.933	-0.0980	0.262	0.1182	0.331	-0.0387	0.538	-0.1094	0.513
Cons	-2.0267	0.073	0.0011	0.993	-0.4228	0.226	0.1962	0.162	-0.6977	0.206
c_id	6 Morocco		7 Nigeria		8 Mozambique		9 S. Africa		10 Tunisia	
Variable	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
ECT	0.0046	0.957	-0.0057	0.871	-0.0372	0.626	0.1189	0.011**	-0.4497	0.010**
lnREC	0.0946	0.248	-2.6414	0.000***	1.4020	0.400	0.1704	0.097*	0.1048	0.481
lnGfin	0.0061	0.091*	-0.0034	0.338	-0.01672	0.346	-0.0025	0.508	-0.00304	0.404
lnGDP	0.0210	0.878	-0.03628	0.544	0.00390	0.897	0.0390	0.482	0.02244	0.835
Cons	0.0497	0.772	0.0048	0.861	0.0222	0.878	0.0679	0.527	-0.9844	0.078

Source: Author

Note: The significance level 1%, 5% and 10% indicated ***, **, *

Renewable energy shows a negative coefficient and significance level of 1% and 5%, in the case of Côte d'Ivoire, Egypt and Nigeria. The results suggest that renewable energy has a negative impact on CO² emissions in these countries. This affirms that a 1% increase in renewable energy reduces CO² emissions by 0.20% in Egypt and 0.26% in Côte d'Ivoire and significantly reduces CO² emissions by 2.06% in Nigeria in the short run. The possible reason for Nigeria's significant impact is that its economic development advanced compared to other

African countries, thus environmental degradation is the focus, hence the increase in environmental-friendly renewable energy technology. We have sufficient evidence to reject the null hypothesis and accept the alternative hypothesis that “*Renewable energy has a significant impact on energy transition*” for Côte d'Ivoire, Egypt, and Nigeria. The findings accord with the findings of Szetela et al. (2022) who found that for the top countries dependent on natural resources, an increase in renewable energy results in a 1.25% decrease in CO² emissions.

Renewable energy has a positive relationship with CO² emissions at a significance level of 10% in South Africa, implying that an increase in renewable energy increases the levels of CO² emissions by 0.17%. The possible reason could be that energy infrastructure in South Africa exists, however, primarily for fossil fuel sources, therefore the extensive consumption of renewable energy is not feasible as economic activities are still reliant on fossil fuel energy consumption. The results address the research question, “*Does renewable energy increase or decrease the levels of carbon emissions?*” This result supports the findings of Nguyen and Kakinaka (2019) for low- and middle-income countries.

Furthermore, the results confirm that renewable energy has an insignificant impact on the levels of CO² emissions in Ethiopia, Ghana, Tunisia, Morocco, Kenya and Mozambique over the period 2000-2019. The development of renewable energy projects requires substantial funding for advanced technology, these countries cannot afford the implementation and the promotion of renewable energy. Therefore, we failed to reject the null hypotheses for these countries in the short run.

The findings confirmed that green finance did not have a significant impact on CO² emission in South Africa, Nigeria, Egypt, Kenya, Ethiopia, Ghana, Tunisia, and Mozambique during the period 2000-2019. Therefore, we cannot reject the null hypothesis for these countries, additionally addressing the study question, “*Does green finance increase or decrease the levels of carbon emissions?*”

Green finance illustrates a negative coefficient and significance level of 5%, suggesting that in Côte d'Ivoire, a 1% increase in green finance flow leads to a 0.017% reduction in the levels of CO² emissions. Renewable energy shares 31% of the energy mix in Cote d'Ivoire; suggesting the increase of green financing and investment inflow, resulting in the reduction of fossil fuel dependency, thus leading to CO² emissions reduction (IEA, 2022b). Therefore, we have

sufficient evidence to reject the null hypothesis for the alternative hypothesis, “*Green finance has a significant impact on energy transition*”.

However, green finance has a positive relationship with CO² emission at a significance level of 10% for the case of Morocco. This suggests that an increase in green finance slightly increases the levels of CO² emission by 0.06% in the short run over the period 2000-2019. Ainou et al. (2023) suggest that an increase in green finance and investment is required to influence the CO² emission reduction. Morocco is progressively advancing green financing and investment to increase the deployment of renewable energy. However, the results imply that the mobilised green finance expended on activities that increase fossil fuels, therefore did not yet affect CO² emission reduction.

In the case of economic growth, the findings indicate statistically insignificant CO² emissions for all the countries. The findings confirm that the rise in economic growth does not have a significant impact on the levels of carbon emission in these countries in the short run. Economic activities in these countries are not sufficient to impact the level of carbon emissions. Thus, we fail to reject the null hypothesis, “*Economic growth has no significant impact on energy transition*” for our panel countries during the period 2000-2019. The results do not align with the findings of Espoir et al. (2023), Hanif (2018), Kwakwa and Alhassan (2018), Maduka et al. (2022), and Twerefou et al. (2017).

The results indicate that renewable energy, green finance, and economic growth are statistically insignificant in Ethiopia, Ghana, Kenya, Mozambique, and Tunisia, therefore, there is no impact on the variables in these countries in the short run. Thus, we fail to reject the null hypothesis that there is no significant relationship between renewable energy, green finance, economic growth and CO² emissions in these countries. We conclude that there is an insignificant impact on the levels of carbon emissions.

4.9 Robustness regressions

The robustness test of the study results is conducted using the Random-effects and Fixed-effects regression model. The empirical results reported in Table 6 indicate that the impact between renewable energy, green finance, economic growth, and CO² emission are consistent for both random-effects and fixed-effects models. Additionally, the models are statistically significant at a 1% significance level. Thus, we can reject the null hypothesis in favour of the

alternative hypothesis, that there is a relationship between independent variables and the dependent variable.

Table 6: Panel random and fixed effects regression

Variable	Random effect		Fixed effect	
	Coefficient	p-value	Coefficient	p-value
lnGDP	0.3028	0.000***	0.2747	0.000***
lnGfin	0.0019	0.778	0.0058	0.358
lnREC	-0.5942	0.000***	-0.5805	0.000***
Cons	-1.8694	0.033	-1.2330	0.168

Source: Author

Note: The significance level 1%, 5% and 10% indicated ***, **, *

The random effect model results indicate that GDP has a positive coefficient, at a significant level of 1%. The findings suggest that there is a positive relationship between GDP and CO². Moreover, a rise in economic growth leads to an increase in CO² emission levels by 0.27% for these selected countries. Similarly, the fixed effect results indicate that economic growth has a 0.30% impact on CO² emission level. Therefore, we have sufficient evidence to reject the null hypothesis in favour of the alternative hypothesis, “*Economic growth has a significant impact on energy transition*”. The results confirm that the long-run coefficients estimated and modelled by the PMG-ARDL approach are robust.

The results indicate that renewable energy has a negative and significant level of 1% on CO² emission in both RE and FE models. Moreover, the results suggest that an increase in the REC decreases the levels of CO² emission by over 0.58%. There is sufficient evidence to reject the null hypothesis, so the results addressed the study question, “*Does renewable energy have a significant impact on energy transition?*” The findings indicate that the renewable energy long-run coefficients estimated and modelled by the PMG-ARDL approach are robust.

Green finance has a positive relationship with CO² emission, however an insignificant impact on both RE and FE models. Therefore, we fail to reject the null hypothesis, “*Green finance has no significant impact on energy transition*”. The findings indicate that green finance has a positive relationship in the long run, however, it is insignificant as estimated and modelled by the PMG-ARDL method.

4.10 Chapter Conclusion

The correlation test indicated that urbanisation and GDP; REC and Envr are highly correlated, thus implying multicollinearity among the independent variables. This resulted in environmental sustainability and urbanisation exclude from the study model as it may lead to unreliable statistical inferences and spurious study findings. The cross-sectional correlations and heterogeneity are detected in the panel time series, confirming the robust panel data ARDL methodology. The first and second-generation unit root tests confirmed that the panel times series data are stationary at first difference. Furthermore, the cointegration was confirmed among CO², GDP, GFin, and REC.

The panel ARDL model is confirmed as the efficient analysis of the panel model, processed and analysed with the statistics software STATA 17. The panel ARDL model confirmed that there is long-run and short-run relationship between energy transition and green finance, renewable energy and economic growth for the selected African countries. The model demonstrates the low speed of adjustment of 22.32% to converge towards long-run equilibrium from to the short-run.

The study findings indicate that in the short run green finance has a negative and significant impact on CO² emissions. However, in the long run, green finance has a positive impact on CO² emissions for the panel countries. The individual countries' analysis, indicate that only in Côte d'Ivoire and Morocco green finance has a significant impact on CO² emissions. Côte d'Ivoire shows a negative relationship, while Morocco shows slightly positive relationship between green finance and CO² emissions. Green finance confirmed no significant impact on CO² emission in South Africa, Nigeria, Egypt, Kenya, Ethiopia, Ghana, Tunisia, and Mozambique for the study period.

The finding confirmed that renewable energy consumption reduces CO² emissions in the long run and short run for panel countries. The individual study countries' analysis indicates that in Egypt, Nigeria, Côte d'Ivoire, and South Africa renewable energy has a significant impact on CO² emissions. The analysis further confirmed that renewable energy reduces the levels of carbon emissions only in Egypt, Nigeria, and Côte d'Ivoire. Unexpectedly, renewable energy increases CO² emissions in South Africa for period 2000-2019. Moreover, the results confirmed that over the period 2000-2019, renewable energy insignificantly impacts CO² emissions in Ethiopia, Ghana, Tunisia, Morocco, Kenya and Mozambique.

Economic growth has a positive relationship with CO² emissions, resulting in an increase in the levels of CO² emissions in the long run. However, in the short run economic growth has an insignificant impact CO² emission for selected African countries. In the case individual countries analysis, the study finding indicate that economic growth has an insignificant impact CO² emission for all the panel countries. Thus, confirming that the increase of economic growth in the panel countries has an insignificant impact on the levels of carbon emission over the period 2000 – 2019.

The study indicates that for the period 2000 – 2019, green finance, renewable energy and economic growth has an insignificant impact on CO² emissions in Ethiopia, Ghana, Kenya, Mozambique, and Tunisia. In these countries, the green finance, renewable energy and economic growth has no impact on the levels of CO² emissions in the short run. Thus, confirming that independent variables have an insignificant impact on the dependent variable in these countries.

African countries rely on fossil fuels the economic growth process, considering that the economic development activities are low energy intensive, therefore less likely to increase the level of CO² emissions. The development of renewable energy in African countries is not reached the threshold level that can cause the reduction of CO² emission. This consequently implies that green finance flows for the development of renewable energy projects have also not reached the required level to negatively impact the levels of CO² emissions in these African countries.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary, and conclusions of the study based on findings and analysis. The chapter also makes recommendations based on the research findings and suggests future research avenues.

5.2 Discussion

The path towards energy transition has become prominent to mitigate the rapid environmental degradation resulting in climate change. The long-term global energy system transformation is critical to low-carbon economy. Climate change mitigations call for acceleration of energy transition process for rapid CO² emission reduction, thus requiring radical, systemic, and managed energy transition from fossil fuels as the primary source of energy generation. Energy transition requires substantial green financing to impact the reduction of CO² emissions.

The study findings, however, unexpectedly indicated that green finance had a positive relationship with carbon emissions in the long run, suggesting that green finance increases the levels of CO² emissions. The results are contrary to the core objective of green finance and investment, advocating for the advancement of energy transition, and delaying the transition process for the selected African countries in the long run. Additionally, the findings are contrary to Jian and Afshan (2023), Li and Shao (2022), Meo and Abd Karim (2022), Saeed and Karim (2021), Udeagha and Ngepah (2023) found that green finance negatively impacts CO² emissions predominantly in developed countries, BRICS countries and China. These countries are the highest global emitters, mobilising green finance to accelerate their efforts in reducing CO² emissions.

There is limited literature analysing the relationship between green finance and carbon emission in the case of developing countries, particularly in African countries. In the case of individual countries' analysis, the results indicate that green finance has a significant impact on CO² emissions only in Côte d'Ivoire and Morocco. Côte d'Ivoire shows a negative relationship, suggesting that an increase in green finance leads to the reduction of CO² emissions, while in Morocco, green finance slightly increases the levels of CO² emissions, countering the objective of green finance.

Renewable energy presents a viable energy security solution while simultaneously reducing the dependence on fossil fuels, resulting in an accelerated process towards energy transition

(Kirikkaleli & Adebayo, 2020; Sinha & Shahbaz, 2018). The study findings confirmed that renewable energy has a significant impact on the levels of CO² emissions in the long run, thus indicating that renewable energy reduces CO² emissions. The results are consistent with the findings of Acheampong et al. (2021), Apergis et al. (2018) and Oluoch et al. (2022), who found that renewable energy reduces CO² emissions in African countries.

Similarly, Oluoch et al. (2022) employed a panel (ARDL) examining 23 SSA countries for the period 1998 to 2014. In the short run, the results further indicate that renewable energy has an insignificant impact on the levels of CO² emissions in African countries. The findings support Nathaniel and Iheonu's (2019) analysis of 19 African countries for the period 1990 to 2014. Jebli et al. (2015) found that renewable energy insignificantly reduces CO² emissions in SSA countries. These results contradict the findings of Apergis et al. (2018) who found a short-run two-way causal relationship for the SSA region during the period 1995 to 2011.

The individual study countries' analysis confirms that renewable energy has a significant impact on CO² emissions in Egypt, Nigeria, Côte d'Ivoire, and South Africa, which are Africa's top countries dependent on fossil fuels. Renewable energy reduces the levels of carbon emissions in Egypt, Nigeria, and Côte d'Ivoire, while increasing CO² emissions in South Africa. The finding supports the finding of Akram et al. (2020) who found mixed results when analysing 66 developing countries over the period 1990-2014, using the panel OLS and fixed effect.

The results confirm the findings of Iorember et al. (2020) in the case of Nigeria. The authors found that renewable energy consumption improves environmental quality by significantly decreasing CO² emissions in both the long run and short run. Nigeria indicates a significant impact of 2%, which is the highest reduction that renewable energy has on CO² emission across all countries. Surprisingly in the case of South Africa, renewable energy has a positive relationship with carbon emissions, suggesting that renewable energy consumption increases the levels of CO² emissions. This is contrary to the objective of renewable energy development and deployment. South Africa is the continent's highest carbon emitter, hence the increased renewable energy share in the energy mix system for CO² emission reduction.

Energy is key to economic growth. It is essential to meet energy requirements for basic economic development activities, primarily transportation, heating, and lighting. African economies rely heavily on fossil fuels for energy consumption. The study findings indicate that in the long run, the rise in economic growth leads to an increase in the levels of CO² emissions.

The findings support Alaganthiran and Anaba (2022), Espoir et al. (2023) and Musah et al. (2020), confirming the long-run GDP increase of CO² emissions in African countries. However, this is contradictory to Acheampong (2018), they found an insignificant causality relationship between economic growth and CO² emissions for SSA countries.

In the case of short-run analysis, economic growth has an insignificant impact on CO² emissions for selected African countries. The results support Espoir et al. (2023) who found that in the short run, economic growth has no significant impact on emissions in SSA countries. Majewski et al. (2022) indicate that economic growth has an insignificant impact on the levels of CO² emissions in middle- and low-income countries. The study analysis includes our study panel countries, except for Ethiopia and Mozambique.

The results indicate that green finance, renewable energy and economic growth have no significant impact on CO² emissions in the case of Ethiopia, Ghana, Kenya, Mozambique, and Tunisia. This suggests that in these countries, the increase or decrease in renewable energy consumption, green finance and economic growth are insignificant to the levels of CO² emissions. Suggesting that green finance flow, renewable energy consumption and economic growth activities are insufficient to have an impact on the level of carbon emission in these countries.

5.3 Conclusions

Africa is the least carbon emission emitter, accounting for less than 4% of global energy-related CO² emissions (IEA, 2022b). The rural remote SSA areas face basic energy access, highly dependent on wood and animal dung for energy consumption (IEA, 2022a). However, these countries are equally expected to transition energy systems from fossil fuels towards cleaner energy sources in efforts to accelerate CO² emission reduction per the Paris Agreement. The continent is abundant with vast natural resources, both fossil fuels and renewable energy resources. However, the focus has been on fossil fuel deployment, resulting in less progress in advancing renewable energy development.

Green finance and investments are necessary to advance the deployment of renewable energy towards the progress of energy transition. Africa's green finance inflows remain very low, accounting for around 3% of global green finance, largely mobilised in high-income countries, consequently, low-income countries are left behind process of energy transition. In recent years, a marginal increase in green finance has been mobilised from developed countries to

Africa, however, still failing to meet the required targets set by both donor and recipient governments (IEA, 2022a).

The role of renewable energy ought to be prioritised and promoted to improve the expansion of renewable energy sources in African countries' energy policies. The study confirms that renewable energy development has the potential to achieve the goal of CO² emission reduction in African countries. However, Sinha and Shahbaz (2018) caution against the rapid shift towards renewable energy consumption due to the lack of financial and technological capacity, particularly in low-income countries, as it may result in slow economic development progress. Moreover, renewable energy may have an adverse impact on economic growth as it is insufficient to meet the energy demands for economic development. Hence, for many low-income economies, energy transition is a challenging and slow process (Inglesi-Lotz & Dogan, 2018).

African economies are heavily dependent on fossil fuel resources and the oil and coal industries are enormous sources of income for various African countries. The top African economic hubs, Nigeria and South Africa are amongst the highest global exporters of oil and coal, thereby boosting the continent's economic growth. The study concludes that the rise in economic growth leads to an increase in the levels of CO² emissions, implying that economic growth has an adverse impact on the progress of the energy transition. This suggests that the energy system shift from fossil fuels towards renewable energy has an impact on economic growth. However, when analysing individual countries, economic growth shows no significant impact on CO² emissions. It is essential that energy transition is well designed to consider the nuances and diversity of African countries in terms of economic development stages, financial capability, energy structures, policies and governance.

5.4 Policy recommendations

The study employed the PMG-ARDL model estimate to analyse the impact of green finance, renewable energy, and economic growth on carbon emissions for 10 African countries over the period 2000-2019. The analysis indicated unanimous consensus on the impact of green finance, renewable energy, and economic growth on CO² emission reduction between the short run and the long run. Empirical findings provide various government stakeholders, policymakers and researchers with the following recommendations:

Leadership obligation and commitment are required for the mobilisation of resources towards all African countries to accelerate energy transition while improving energy security (Khan et al., 2020). Therefore, it is imperative that African governments and policymakers embark on initiatives of energy transition that have minimal adverse impacts on economic growth. Renewable energy development and deployment is a critical initiative to provide clean energy solutions to meet energy demand, gradually reducing the level of dependency on fossil fuels. Africa has abundant sunshine all year, providing a reliable energy source, moreover solar has proven to be cost-efficient.

Renewable energy development infrastructure is capital-intensive and lack of access to green finance is one of the major obstacles to renewable energy development, particularly in African countries. Governments, multilateral organisations and DFIs should increase the mobilisation of grant support, particularly to low-income countries and additionally, extend their mandate to households and small businesses by providing credit access for renewable energy development and infrastructure for energy consumption.

African governments must provide financial relief in the form of a tax rebate system to both households and businesses to encourage renewable energy development. South African government has implemented the tax incentive system for households and businesses with installed renewable energy sources; and can thus provide policy guidance and implementation to other African countries. This will reduce financial exclusion and attract green finance, particularly in countries with unstable financial system infrastructure, mainly low-income countries.

Renewable energy development requires specialised skills and expertise, however, the continent has a lack of skilled labour in the renewable energy sector. Developed countries have made significant advancements in the renewable energy sector, and thus have sufficient skills and expertise gained over the years. African governments should form an official partnership programme with developed countries to transfer skills and provide training to African businesses.

Africa requires long-term planning and financing commitment for the adoption of greener technology initiatives and efficient regulations to harness renewable energy potential (Tajudeen, 2015). Developed and major emerging countries are the highest global emitters, hence developed countries need to assist African countries to acquire the necessary clean energy technologies for optimisation of the abundant renewable energy sources. The

mobilisation of green finance and investment in the African energy sector is beneficial for global climate change mitigation.

Environmental policies and energy transition initiatives should be easily accessible to guide households and businesses to actively improve their contribution towards climate change mitigation. Investment in environmental advertising is essential to reach the population, increase environmental degradation awareness and drive environmentally friendly consumerism. Environmental advertising is defined as “*a specific type of communication designed towards promoting social, economic and environmental benefits of products to form a responsible values and behavior of consumers*” (Chekima, 2019).

5.5 Avenues for future research

Energy transition is a relatively new concept in Africa, hence there is limited empirical literature and data availability on the topic. Unsurprisingly, African countries have been left behind, however, carbon emission reduction is a global phenomenon requiring participation from all quarters. Hence, it is essential that future researchers contribute and advance the analysis of energy transition empirical literature specific to African countries, using various approaches and techniques in the following analysis:

Firstly, further analysis of green finance's impact on CO² emissions, with the inclusion of financing flows from both private and public investors. Our study only analysed public green finance due to data accessibility, thus the analysis of green finance was limited to public finance's impact on achieving the objective of a low-carbon economy in Africa. Secondly, compressive analysis is critical to address the economic diversities and nuances of each African country. The study panel indicated economic growth has no significant impact on CO² emissions, further analysis is required as our study panel countries are Africa's top economies and heavily reliant on fossil fuels for energy generation.

Lastly, researchers should venture into the analysis of environmental policies on energy transition in Africa. Environmental policies have been adopted and enforced to provide a global framework and guidelines for effective reduction of CO² emissions. Our study excludes environmental policy analysis due failure of meeting the necessary nonstationary requirements of the regression model. Literature indicates that African countries should tighten environmental regulatory policies to address the levels of CO² emission towards achieving carbon neutrality by 2050 (Ibekilo et al., 2023).

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APPENDICES

APPENDIX A: CROSS-SECTIONAL DEPENDENCE TEST

Table A1: Cross-sectional dependence

Breusch and Pagan Lagrangian multiplier test for random effects

	Var	SD = sqrt (Var)
lnCO ²	2.107372	1.451679
e	.0261253	.1616331
u	.1287295	.358789

Test: Var(u) = 0

chibar2(01) = 363.72

Prob > chibar2 = 0.0000

Fixed-effects model:

Frees' test of cross-sectional independence = 1.270

Friedman's test of cross-sectional independence = 28.726, Pr = 0.0007

Pesaran's test of cross-sectional independence = 2.465, Pr = 0.0137

Source: Author's calculation using Stata 17

APPENDIX B: COINTEGRATION TEST

Table B1: Cointegration Test

Tests	Pedroni test		Kao test	
	Statistics	p-value	Statistics	p-value
Modified Phillips-Perron t	0.5629	0.2868		
Phillips-Perron t	-3.1162	0.0009***		
Modified Dickey-Fuller t			2.2614	0.0119*
Dickey-Fuller t			2.5127	0.0060*
Augmented Dickey-Fuller t	-2.8385	0.0023**	2.9934	0.0014**
Unadjusted modified Dickey-Fuller t			0.3269	0.3719
Unadjusted Dickey-Fuller t			0.1088	0.4567

Source: Author's calculation using Stata 17

Note: The significance level is determined by 1%, 5% and 10% indicated through ***, **, *

Based on lag 1 selection

APPENDIX C: UNIT ROOT TEST

Table C1: Unit root test-1st generation

IPS						
	I (0)			I (1)		
Variable	Statistics	p value	Meaning	Statistics	p value	Meaning
lnCO ²	1.8619	0.9687	Non-stationary	-6.0811	0.0000***	Stationary
lnGfin	-1.6978	0.0448*	Stationary**	-10.3837	0.0000***	Stationary
lnREC	1.0807	0.8601	Non-stationary	-5.6478	0.0000***	Stationary
lnGDP	-1.3446	0.0894*	Non-stationary	-4.8597	0.0000***	Stationary
Envr	""	-	-	""	-	-
lnUP	3.1576	0.9992	Non-stationary	0.7705	0.7795	Non-stationary

LLC						
	I (0)			I (1)		
Variable	Statistics	p value	Meaning	Statistics	p value	Meaning
lnCO ²	-0.1113	0.1332	Non-stationary	-5.6775	0.0000***	Stationary
lnGfin	-2.7425	0.0030**	Stationary **	-9.1541	0.0000***	Stationary
lnREC	-1.6363	0.0509	Stationary*	-5.7504	0.0000***	Stationary
lnGDP	-4.2109	0.0000***	Stationary***	-5.5519	0.0000***	Stationary
Envr	-1.4501	0.0735*	Stationary*	-1.2304	0.1093	Non-stationary
lnUP	-1.9525	0.0254**	Stationary**	1.2997	0.9031	Non-stationary

MW

Variable	I (0)			I (1)		
	Statistics	p value	Meaning	Statistics	p value	Meaning
lnCO ²	2.9552	0.9984	Non-stationary	-3.0748	0.0011***	Stationary
lnGfin	-1.3946	0.0816*	Stationary*	-4.4152	0.0000***	Stationary
lnREC	1.2734	0.8986	Non-stationary	-4.4159	0.0000***	Stationary
lnGDP	1.8789	0.9699	Non-stationary	-4.1755	0.0000***	Stationary
Envr	0.5414	0.7059	Non-stationary	-5.4419	0.0000***	Stationary
lnUP	-4.1515	0.0000**	Stationary***	0.8215	0.7943	Non-stationary

Source: Author's calculation using Stata 17

Note: The significance level is determined by 1%, 5% and 10% indicated through ***, **, *

Based on lag 1 selection"

"" Insufficient number of time periods to compute W-t-bar

Table C2: Unit root test-2nd generation

Variables	Pesaran's CADF test		Meaning
	Statistics	p-value	Meaning
lnCO ²	-4.455	0.000***	Stationary
lnGfin	-5.715	0.000***	Stationary
lnGDP	-6.604	0.000***	Stationary
lnREC	-3.569	0.000***	Stationary

Variables	CIPS Test		Meaning
lnCO ²	CIPS = -4.600		Stationary
lnGfin	CIPS = -4.066		Stationary
lnGDP	CIPS = -2.429		Stationary
lnREC	CIPS = -2.518		Stationary
Critical values	10%	5%	1%
	-2.21	-2.34	-2.6

Source: Author's calculation using Stata 17

Note: The significance level is determined by 1%, 5% and 10% indicated through ***, **, *

Based on lag 1 selection

Table C3: Hausman Tests (PMG and DFE)

Variable	PMG		DFE		Difference	Std. err
	Coefficient	p-value	Coefficient	p-value		
Long-run estimates						
lnGDP	0.3103	0.000***	0.3993	0.030**	-0.08900	1.17312
lnGfin	0.0200	0.011**	0.0422	0.427	-0.02227	0.31388
lnREC	-0.8339	0.000***	0.4526	0.590	-1.28662	5.10877
Short-run estimates					Chi 2(3):	0.07
lnREC	-0.6159	0.106	-0.1183	0.169	Prob:	0.9949
lnGfin	-0.0048	0.045**	-0.0023	0.415		
lnGDP	-0.0059	0.781	0.0589	0.201		

Source: Author's calculation using Stata 17

Note: The significance level 1%, 5% and 10% indicated through ***, **, *

APPENDIX D: RAW DATA FROM STATA 17

Descriptive statistics

3 . xtsum lngdp		rec	lnup	gfin1	lngfin	lnco2	lnrec
Variable		Mean	Std. dev.	Min	Max	Observations	
lngdp	overall	24.77722	1.207207	22.32927	27.07622	N =	200
	between		1.110915	23.12878	26.42714	n =	10
	within		.583995	23.182	26.03354	T =	20
rec	overall	50.85	34.54234	5	96	N =	200
	between		36.03282	5.95	93.05	n =	10
	within		4.332824	38.9	68.9	T =	20
lnup	overall	16.61451	.7438683	15.45844	18.45994	N =	200
	between		.7529703	15.79482	18.03135	n =	10
	within		.2012664	16.15525	17.07871	T =	20
gfin1	overall	183.285	535.8892	1	5203	N =	200
	between		134.1658	29.75	383	n =	10
	within		520.4761	198.715	5003.285	T =	20
lngfin	overall	3.015152	2.33441	0	8.556991	N =	200
	between		1.037061	1.336286	4.311637	n =	10
	within		2.115812	1.296485	9.096826	T =	20
lnco2	overall	3.547052	1.451679	1.098612	6.180017	N =	200
	between		1.499802	1.711864	6.059422	n =	10
	within		.269692	2.933801	4.320095	T =	20
lnrec	overall	3.5245	1.033286	1.609438	4.564348	N =	200
	between		1.077706	1.768282	4.532913	n =	10
	within		.1308496	3.210242	4.043151	T =	20

Panel Unit root test:

```
41 . xtcips lnco2, maxlags(2) bglags(2)
```

Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for lnco2
Deterministics chosen: constant

Dynamics: lags criterion decision General to Particular based on F joint test

H0 (homogeneous non-stationary): $\beta_i = 0$ for all i

CIPS = -2.471 N,T = (10,20)

	10%	5%	1%
Critical values at	-2.21	-2.34	-2.6

```
42 . xtcips d.lnco2, maxlags(2) bglags(2)
```

Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.lnco2
Deterministics chosen: constant

Dynamics: lags criterion decision General to Particular based on F joint test

H0 (homogeneous non-stationary): $\beta_i = 0$ for all i

CIPS = -4.496 N,T = (10,19)

	10%	5%	1%
Critical values at	-2.21	-2.34	-2.6

```
43 . xtcips d.lnco2, maxlags(2) bglags(2)
```

Pesaran Panel Unit Root Test with cross-sectional and first difference mean included for D.lnco2
Deterministics chosen: constant

Dynamics: lags criterion decision General to Particular based on F joint test

H0 (homogeneous non-stationary): $\beta_i = 0$ for all i

CIPS = -4.496 N,T = (10,19)

	10%	5%	1%
Critical values at	-2.21	-2.34	-2.6

```

66 . pescadf d.lngdp, lags(2)

Pesaran's CADF test for D.lngdp
Cross-sectional average in first period extracted and extreme t-values truncated
Deterministics chosen: constant

t-bar test, N,T = (10,19)      Obs = 160
Augmented by 2 lags (average)

      t-bar   cv10    cv5    cv1  Z[t-bar]  P-value
      -2.156  -2.218   -2.340  -2.600  -1.369    0.095

67 . pescadf d.lngdp, lags(1)

Pesaran's CADF test for D.lngdp
Cross-sectional average in first period extracted and extreme t-values truncated
Deterministics chosen: constant

t-bar test, N,T = (10,19)      Obs = 170
Augmented by 1 lags (average)

      t-bar   cv10    cv5    cv1  Z[t-bar]  P-value
      -3.081  -2.218   -2.340  -2.600  -6.664    0.000

68 . pescadf d.lngfin, lags(1)

Pesaran's CADF test for D.lngfin
Cross-sectional average in first period extracted and extreme t-values truncated
Deterministics chosen: constant

t-bar test, N,T = (10,19)      Obs = 170
Augmented by 1 lags (average)

      t-bar   cv10    cv5    cv1  Z[t-bar]  P-value
      -3.592  -2.218   -2.340  -2.600  -5.715    0.000

69 . pescadf d.lnco2, lags(1)

Pesaran's CADF test for D.lnco2
Cross-sectional average in first period extracted and extreme t-values truncated
Deterministics chosen: constant

t-bar test, N,T = (10,19)      Obs = 170
Augmented by 1 lags (average)

      t-bar   cv10    cv5    cv1  Z[t-bar]  P-value
      -3.181  -2.218   -2.340  -2.600  -4.455    0.000

70 . pescadf d.lnrec, lags(1)

Pesaran's CADF test for D.lnrec
Cross-sectional average in first period extracted and extreme t-values truncated
Deterministics chosen: constant

t-bar test, N,T = (10,19)      Obs = 170
Augmented by 1 lags (average)

      t-bar   cv10    cv5    cv1  Z[t-bar]  P-value
      -2.961  -2.218   -2.340  -2.600  -3.595    0.000

```

Cross-sectional dependence test

16 . xtglm lnco2 lngdp envr lnup lngfin lnrec

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares
Panels: homoskedastic
Correlation: no autocorrelation

Estimated covariances = 1 Number of obs = 200
Estimated autocorrelations = 0 Number of groups = 10
Estimated coefficients = 6 Time periods = 20
Wald chi2(5) = 3262.48
Log likelihood = -72.68835 Prob > chi2 = 0.0000

	lnco2	Coefficient	Std. err.	z	P> z	[95% conf. interval]
lngdp		.5276682	.0547275	9.64	0.000	.4264843 .6349121
envr		-.1668754	.0214654	-7.77	0.000	-.2089468 -.1248804
lnup		.891055	.0744786	11.96	0.000	.7450796 1.03703
lngfin		-.0223413	.0120232	-1.86	0.063	-.0459865 .0012238
lnrec		-.1784167	.0474161	-3.76	0.000	-.2713329 -.0854885
_cons		-.23.35919	.737595	-31.67	0.000	-.24.80485 -.21.91353

17 . xttest2

Correlation matrix of residuals:

	_e1	_e2	_e3	_e4	_e5	_e6	_e7	_e8	_e9
_e1	.4609881								
_e2	.0947815	1.384385							
_e3	.2188249	.4565821	.3358124						
_e4	-.1654896	.772736	.3773213	.868081					
_e5	.1662583	.4561351	.2257681	.1891644	.4866885				
_e6	-.0569754	.3183431	.0938451	.2673293	.0187957	.1922572			
_e7	-.0247321	1.053884	.3756717	.8969595	.2249565	.4262666	1.782		
_e8	-.3766027	-1.143242	-.2151396	-1.024143	-.3748082	-.4084097	-1.439238	2.493074	
_e9	-.1266777	.4316338	.1422219	.4213816	.0038818	.2444055	.8996497	-.5996475	.6934922
_e10	.0029744	.1551188	.1196296	.1981216	.0226417	.102868	.4163227	-.4186319	.2919783

	_e1	_e2	_e3	_e4	_e5	_e6	_e7	_e8	_e9	_e10
e1	1.0000									
_e2	0.1272	1.0000								
_e3	0.5941	0.6696	1.0000							
_e4	-0.2885	0.7049	0.3284	1.0000						
_e5	0.3764	0.5557	0.5584	0.2910	1.0000					
_e6	-0.2052	0.6171	0.3693	0.6544	0.0353	1.0000				
_e7	-0.0293	0.6718	0.4856	0.7212	0.2416	0.7283	1.0000			
_e8	0.3767	-0.6154	-0.2351	-0.6962	-0.3395	-0.5899	-0.6828	1.0000		
_e9	-0.2482	0.4405	0.2947	0.5431	0.0867	0.6693	0.8093	-0.7683	1.0000	
_e10	0.0114	0.3204	0.4992	0.4959	0.0789	0.5782	0.7580	-0.6320	0.8521	1.0000

Breusch-Pagan LM test of independence: chi2(45) = 241.332, Pr = 0.0000
Based on 20 complete observations over panel units

31 . xtreg lnco2 lngdp lngfin lnrec, fe

Fixed-effects (within) regression Number of obs = 200
Group variable: c_id Number of groups = 10

R-squared: Obs per group:
 Within = 0.6625 min = 20
 Between = 0.6827 avg = 20.0
 Overall = 0.6771 max = 20

corr(u_i, Xb) = 0.4127 F(3,187) = 122.34
Prob > F = 0.0000

	lnco2	Coefficient	Std. err.	t	P> t	[95% conf. interval]
lngdp		.2747985	.0262365	10.48	0.000	.2230447 .3265362
lngfin		.0058312	.0063294	0.92	0.358	-.0066549 .0183174
lnrec		-.5885284	.1065731	-5.45	0.000	-.7987685 -.3782883
_cons		-.1.233082	.8985428	-1.38	0.168	-.2.989864 .5237994
sigma u		.93482268				
sigma_e		.16163315				
rho		.97097252	(fraction of variance due to u_i)			

F test that all u_i=0: F(9, 187) = 216.17 Prob > F = 0.0000

32 . xtcsd, pesaran

Pesaran's test of cross sectional independence = 2.465, Pr = 0.0137

33 . xtcsd, friedman

Friedman's test of cross sectional independence = 28.726, Pr = 0.0007

34 . xtcsd, frees

Frees' test of cross sectional independence = 1.270

-----|

Critical values from Frees' Q distribution

alpha = 0.10 : 0.1294

alpha = 0.05 : 0.1695

alpha = 0.01 : 0.2468

35 . xttest0

last estimates not xtreg, re

r(381);

36 . xtreg lnco2 lngdp lngfin lnrec, re

Random-effects GLS regression

Number of obs = 200

Group variable: c_id

Number of groups = 10

R-squared:

Obs per group:

Within = 0.6617

min = 20

Between = 0.6972

avg = 20.0

Overall = 0.6584

max = 20

corr(u_i, X) = 0 (assumed)

Wald chi2(3) = 370.24

Prob > chi2 = 0.0000

	lnco2	Coefficient	Std. err.	z	P> z	[95% conf. interval]
	lngdp	.3028944	.0278966	10.86	0.000	.2482299 .3575589
	lngfin	.0019825	.0070398	0.28	0.778	-.0118153 .0157802
	lnrec	-.5942266	.0891499	-6.67	0.000	-.7689572 -.4194559
	_cons	-1.869457	.8771187	-2.13	0.033	-3.588578 -.1503355
	sigma_u	.35878898				
	sigma_e	.16163315				
	rho	.03129181	(fraction of variance due to u_i)			

37 . xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

lnco2[c_id,t] = Xb + u[c_id] + e[c_id,t]

Estimated results:

	Var	SD = sqrt(Var)
lnco2	2.107372	1.451679
e	.0261253	.1616331
u	.1287295	.358789

Test: Var(u) = 0

chibar2(01) = 363.72

Prob > chibar2 = 0.0000

Hausman Test

```
15 . hausman pmg dfe,sigmamore
```

	Coefficients		(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
	(b) pmg	(B) dfe		
lngdp	.310307	.39931	-.089003	1.173192
lngfin	.020008	.0422872	-.0222791	.3138804
lnrec	-.8339651	.4526547	-1.28662	5.108776

b = Consistent under H0 and Ha; obtained from xtpmg.
 B = Inconsistent under Ha, efficient under H0; obtained from xtpmg.

Test of H0: Difference in coefficients not systematic

chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
 = 0.07
 Prob > chi2 = 0.9949

PMG Model

```

5 . xtset c_id year

Panel variable: c_id (strongly balanced)
Time variable: year, 2000 to 2019
Delta: 1 unit

6 . xtpmg d.lnco2 d.lnrec d.lnfin d.lngdp, lr(1.lnco2      lngdp      lnfin      lnrec)

Iteration 0: log likelihood = 316.2291 (not concave)
Iteration 1: log likelihood = 321.23498
Iteration 2: log likelihood = 322.10923
Iteration 3: log likelihood = 322.12986
Iteration 4: log likelihood = 322.12989
Iteration 5: log likelihood = 322.12989

Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Variable (i): c_id      Number of obs   =    190
Time Variable (t): year      Number of groups =    10
                               Obs per group: min =    19
                               avg   =    19.0
                               max   =    19

                               Log Likelihood   = 322.1291

```

	D.lnco2	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
__ec							
lngdp		.310307	.0292232	10.62	0.000	.2530306	.3675835
lnfin		.020008	.0078345	2.55	0.011	.0046527	.0353634
lnrec		-.8339651	.1274132	-6.55	0.000	-1.08369	-.5842399
SR							
ec		-.2232056	.1251962	-1.78	0.075	-.4685857	.0221745
lnrec	D1.	-.6159089	.3814195	-1.61	0.106	-1.363477	.1316596
lnfin	D1.	-.0048552	.002421	-2.01	0.045	-.0096602	-.0001102
lngdp	D1.	-.0059246	.021314	-0.28	0.781	-.0476993	.0358501
_cons		-.3789534	.2199034	-1.72	0.085	-.8099563	.0520494

```
22 . xtmg d.lnco2 d.lnrec d.lngfin d.lngdp, lr(l.lnco2 lngdp lngfin lnrec) replace pmg full
```

```
Iteration 0: log likelihood = 316.2291 (not concave)
Iteration 1: log likelihood = 321.23498
Iteration 2: log likelihood = 322.10923
Iteration 3: log likelihood = 322.12966
Iteration 4: log likelihood = 322.12969
Iteration 5: log likelihood = 322.12969
```

Pooled Mean Group Regression
(Estimate results saved as PMG)

```
Panel Variable (i): c_id      Number of obs   =    190
Time Variable (t): year      Number of groups =    10
                               Obs per group: min =    19
                               avg   =   19.0
                               max   =    19
```

Log Likelihood = 322.1291

D.lnco2	Coefficient	Std. err.	z	P> z	[95% conf. interval]	
__ec						
lngdp	.310307	.0292232	10.62	0.000	.2530366	.3675835
lngfin	.020008	.0078345	2.55	0.011	.0046527	.0353634
lnrec	-.8339651	.1274132	-6.55	0.000	-1.08369	-.5842399
c_id_1						
__ec						
lnrec						
D1.	-1.260637	.3609529	-3.49	0.000	-1.968092	-.5531822
lngfin						
D1.	-.0179657	.0071032	-2.53	0.011	-.0318877	-.0040437
lngdp						
D1.	.0185587	.2206772	0.08	0.933	-.4139607	.4510781
__cons	-2.026653	1.131273	-1.79	0.073	-4.243906	.1906006
c_id_2						
ec						
lnrec						
D1.	-2.232255	1.584949	-1.41	0.159	-5.338698	.8741877
lngfin						
D1.	.0001828	.0028336	0.06	0.949	-.0053711	.0057366
lngdp						
D1.	-.0980965	.0874872	-1.12	0.262	-.2695603	.0733752

Cote d'Ivoire

Ethiopia

Ghana	c_id_3						
	__ec	-.2486588	.1493764	-1.66	0.896	-.5414312	.8441136
	Inrec D1.	-.7198146	.5114373	-1.41	0.168	-1.721413	.2833842
	Ingfin D1.	-.0848761	.0898789	-0.45	0.653	-.0218783	.8137182
	Ingdp D1.	.118281	.1217516	0.97	0.331	-.1283478	.3569897
	_cons	-.4228215	.3498947	-1.21	0.226	-1.187835	.2613916
Egypt, Arab Rep.	c_id_4						
	ec	.1149182	.0749863	1.53	0.125	-.0318955	.2617319
	Inrec D1.	-.2833835	.0839438	-2.42	0.815	-.3679182	-.8388568
	Ingfin D1.	.0816364	.0829538	0.55	0.588	-.0841529	.8874257
	Ingdp D1.	-.0387637	.86295	-0.62	0.538	-.1621434	.8846161
	_cons	.196286	.148381	1.48	0.162	-.0786988	.4712789
Kenya	c_id_5						
	__ec	-.5112712	.1698397	-3.01	0.883	-.8441589	-.1783915
	Inrec D1.	-.8743392	.6374181	-1.37	0.178	-2.12364	.3749615
	Ingfin D1.	-.0888687	.0852954	-1.64	0.181	-.0198659	.8816918
	Ingdp D1.	-.1894252	.1671848	-0.65	0.513	-.4371815	.2182511
	_cons	-.6977123	.5519116	-1.26	0.286	-1.779439	.3848144
Morocco	c_id_6						
	__ec	.0846866	.0873886	0.05	0.957	-.1664351	.1758884
	Inrec D1.	.0946917	.0819766	1.16	0.248	-.0659794	.2553629
	Ingfin D1.	.08617	.0836519	1.09	0.891	-.0889876	.8133277
	Ingdp D1.	.0218124	.137183	0.15	0.878	-.2477844	.2897293
	_cons	.6487381	.1712785	0.29	0.772	-.2859695	.3854297
Nigeria	c_id_7						
	ec	-.0857886	.0356995	-0.16	0.871	-.0757583	.8641811
	Inrec D1.	-2.641489	.4822257	-5.48	0.888	-3.586554	-1.696264
	Ingfin D1.	-.0834998	.0836491	-0.96	0.338	-.0186519	.8836523
	Ingdp D1.	-.0362852	.0597478	-0.61	0.544	-.1533888	.8888184
	_cons	.0848584	.0278297	0.17	0.861	-.0496888	.8594837

Mozambique	c_id_8						
	__ec	-.0372867	.0764546	-0.49	0.626	-.1871349	.1125616
	lnrec						
	D1.	1.402032	1.665392	0.84	0.400	-1.862076	4.666139
	lnqfin						
	D1.	-.016721	.0177352	0.94	0.346	-.0514015	.0180394
lnqdp							
D1.	.003986	.2426525	0.02	0.987	-.4716042	.4795762	
_cons	.0222013	.1444929	0.15	0.878	-.2609995	.3054021	
South Africa	c_id_9						
	ec	.1189064	.0470225	2.53	0.011	.026744	.2110688
	lnrec						
	D1.	.1704221	.1028068	1.66	0.097	-.0310756	.3719198
	lnqfin						
	D1.	-.0025494	.0038547	-0.66	0.508	-.0101045	.0050057
lnqdp							
D1.	.0390582	.055582	0.70	0.482	-.0698805	.147997	
_cons	.0679496	.1073167	0.63	0.527	-.1423072	.2782865	
Tunisia	c_id_10						
	__ec	-.4497451	.1744762	-2.58	0.010	-.7917122	-.1077781
	lnrec						
	D1.	.1048041	.148886	0.70	0.481	-.187007	.3966152
	lnqfin						
	D1.	-.0030421	.0036432	-0.84	0.404	-.0101026	.0040984
lnqdp							
D1.	.0224279	.1073634	0.21	0.835	-.1880004	.2328563	
_cons	-.9844771	.55859	-1.76	0.078	-2.079293	.1103392	

APPENDIX E: SUMMARY OF EMPIRICAL LITERATURE

Authors	Regions	Period	Methodology	Results (impacts on CO2 emissions)				
				Renewable energy	Green finance	Economic growth	Urbanisation	Environmental policies
Saeed and Karim (2021)	Hong Kong, USA, Canada, Japan, Denmark, Norway, Sweden, UK, Switzerland,& New Zealand	2008 - 2019	QQR		Negative impact			
Meo and Abd Karim (2022)	Denmark, Canada, Japan, USA , Switzerland, Sweden, and UK,	2008 - 2019	QQR approach		Negative impact			
Jian and Afshan (2023)	G10 economies	2000 - 2018	Cross-Sectional ARDL.		Negative impact			
Jia (2023)	China, Russian Federation, and United States of America				Negative impact			
Hailiang et al. (2023)	BRICS economies	2000 - 2018	quantile regressions	Negative impact	Negative impact			
Udeagha and Ngepah (2023)	BRICS nations	2000 - 2018	AMG method		Negative impact			
Wei et al. (2024)	BRICS countries		MMQR technique		Negative impact			
Wang et al. (2019)	China	1998 - 2017	ARDL approach		Negative impact			
Afshan et al. (2023)	China	2000 - 2017	QARDL approach		Negative impact			
Li and Shao (2022)	China	2000 - 2019	ARDL-ECM		Negative impact			
Lin et al. (2022)	China	2007 - 2018	Dynamic spatial Durbin model,		Negative impact			
Moslehpour et al. (2023)	Vietnam	1991 - 2020	DARDL and the BARDL model		Positive impact			
Zhou and Xu (2022)	Vietnam	2008 - 2020	GMM approach		No impact	Positive impact	Positive impact	
Szetela et al. (2022)	top countries dependent on natural resources	2000 - 2015	Fixed Effects, OLS, and two-step GMM estimators.	Negative impact				
Dogan and Seker (2016)	top renewable energy countries		FMOLS and the DOLS techniques	Negative impact				
Dimnwobi et al. (2022)	Nigeria	1981 - 2019	ARDL approach	Negative impact				
Huang et al. (2021)	major renewable energy-consuming countries	2000 - 2015	two-step GMM.	Negative impact				
Shafiei and Salim (2014)	OECD countries	1980 - 2011	STIRPAT model	Negative impact				
Mendonça et al. (2020)	50 major economies	1990 - 2015	hierarchical regression modeling	Negative impact				
Nguyen and Kakinaka (2019)	107 countries	1990 - 2013	Panel cointegration analysis	Negative impact				
Dong et al. (2020)	120 countries - All income levels	1995 - 2015	Cross-sectional dependence and slope heterogeneity	Negative impact				
Majewski et al. (2022),	94 middle-income countries	2000 - 2015	two-step GMM regression	Negative impact				
Maslyuk and Dharmaratna (2013)	Asia's 11 middle-income countries	1980 - 2010	SVAR	Positive impact				
Chen et al. (2019)	China	1980 - 2014	ARDL approach	Negative impact				
Sun et al. (2023)	China	2010 - 2021	STIRPAT theory and system GMM	Negative impact				

Wolde-Rufael and Mulat-Weldemeskel (2020)	BRICS countries	1993 - 2014	panel PMG estimator	Negative impact			
Hu et al. (2018)	25 major developing countries	1996 - 2012	FMOLS and DOLS	Negative impact			
Akram et al. (2020)	66 developing countries	1990 - 2014	OLS and fixed-effect	Negative impact			
Apergis et al. (2018)	SSA region	1995 - 2011	Granger causality	Negative impact			
Acheampong et al. (2021)	46 SSA countries	1980 - 2015	fixed and random-effects estimation approaches	Negative impact			
Inglesi-Lotz and Dogan (2018)	10 sub-Saharan African countries	1980 - 2011	Panel estimation techniques	Negative impact			
Farhani and Shahbaz (2014)	10 MENA countries	1980 - 2009	FMOLS and DOLS	Negative impact			
Oluoch et al. (2022)	23 SSA countries	1998 - 2014	panel (ARDL)	Negative impact			
Nathaniel and Iheonu (2019)	19 African countries	1990 - 2014	AMG estimator	Negative impact			
Jebli et al. (2015)	24 SSA countries	1980 - 2010	Granger causality	Negative impact			
Maji and Abdul-Rahim (2019)	15 West African countries	1995 - 2014	DOLS	Negative impact			
Iorember et al. (2020)	Nigeria	1990 - 2016	ARDL and VECM Granger causality tests	Negative impact			
Kwakwa and Alhassan (2018)	Ghana	1971 - 2013	Fully Modified OLS	Negative impact			
Farhani and Shahbaz (2014)	10 (MENA)	1980 - 2009	FMOLS and DOLS	Negative impact			
Ibrahiem (2015)	Egypt	1980 - 2011	ARDL bound testing approach	positive impact			
Jebli et al. (2015)	25 OECD countries	1980 - 2010	FMOLS and DOLS	Negative impact			
Shafiei and Salim (2014)	OECD countries	1980 - 2011	STIRPAT model	Negative impact			
Espoir et al. (2023)	47 African countries	1996 - 2019	PMG-ARDL approach and Dumitrescu-Hurlin causality test			Positive impact	
Kwakwa and Alhassan (2018)	Ghana	1971 - 2013	Fully Modified OLS			Positive impact	
Maduka et al. (2022)	Nigeria		ARDL and quartile regression technique			Positive impact	
Ren et al. (2021)	26 European Union countries	1990 – 2015	fixed-effects dynamic spatial Durbin error model			Positive impact	
Menyah and Wolde-Rufael (2010)	South Africa	1965 - 2006	ADRL bound cointegration testing approach			Positive impact	
Samour et al. (2022)	South Africa	1986 - 2017	ARDL estimations	Negative impact		Positive impact	
Sebri and Ben-Salha (2014)	BRICS members	1971 – 2010	ARDL bounds testing	Positive impact		Positive impact	
Oduanya et al. (2016)	Nigeria	1971 - 2014	co-integration approach			Positive impact	
Alaganthiran and Anaba (2022)	20 selected SSA countries	2000 - 2020	pooled OLS, FEM and REM			Positive impact	
Adedoyin et al. (2020)	12 selected SSA	1980 - 2014	PMG-ARDL			Positive impact	
Odhiambo (2017)	10 SSA countries	1986 - 2013	Granger-causality approach			Positive impact	
Zaidi and Ferhi (2019)	SSA	2000 - 2012	dynamic GMM estimator			Positive impact	
Omri et al. (2015)	MENA Countries.	1990 - 2011	GMM			Positive impact	

Esso and Kebo (2016)	12 selected SSA countries	1971 - 2010	cointegration and Granger causality test			Positive impact	
Afriyie et al. (2023)	37 SSA countries	1995 - 2017	PMG-ARDL and the Dumitrescu-Hurlin			Negative impact	
Musah et al. (2020)	West Africa region	1990 - 2018.	CCEMG and the DCCEMG estimators			Positive impact	
Acheampong (2018)	116 countries	1990 - 2014	PVAR and system GMM.			No impact	
Bashir et al. (2021)	OECD economies	1995 - 2015	GMM and quantile regression models				Negative impact
Ahmad and Satrovic (2023)	10 OECD countries	1995 - 2020	Method of Moments Quantile Regression				Negative impact
Wolde-Rufael and Mulat-Weldemeskel (2021)	7 emerging economies	1994-2015	AMG				Negative impact
Zaghdoudi and Maktouf (2017)	OECD countries	1994-2014	PSTR model				Positive & Negative impact
Al Shammre et al. (2023)	34 OECD countries	995 - 2019	dynamic panel threshold regression				Negative impact
Doğan et al. (2022)	G7 economies		Pedroni cointegration test and FMOLS technique				Negative impact
Sarpong et al. (2023)	E7 nations	2000-2020	Driscoll-Kraay and quantile-on-quantile techniques				Negative impact
Tao et al. (2021)	7 emerging economies	1995 - 2018	CS-ARDL and CS-ARDL				Negative impact
Chien et al. (2021)	7 emerging countries	1995 - 2018	AMG, the CS-ARDL and CCEMG				Negative impact
Wolde-Rufael and Mulat-Weldemeskel (2021)	7 emerging countries	1994 - 2015	AMG, FMOLS and causality analyses				Negative impact
Adekunle (2021)	53 African countries	1996-2017	dynamic system GMM estimator				Negative impact
Afriyie et al. (2023)	37 SSA countries	1995 - 2017	PMG-ARDL technique and the Dumitrescu-Hurlin causality test				No impact
Ibekilo et al. (2023)	33 African countries	1996 - 2020	AMG method and CCEMG				Positive impact
Adedoyin et al. (2020)	12 selected SSA	1980-2014	PMG ARDL				Positive impact
Musah et al. (2020)	West Africa		cointegration test				Positive impact
Salahuddin et al. (2019)	South Africa	1980-2017	ARDL approach				Positive impact
Abdallh and Abugamos (2017)	20 countries - MENA region	1980-2014	STIRPAT framework				Positive impact
Shafiei and Salim (2014)	OECD countries.	1980 - 2011	STIRPAT model				Positive impact
Ehrhardt-Martinez et al. (2002)	Less developed countries	1980-1995	OLS				Positive impact
Sadorsky (2009)	G7 countries	1980 - 2005	FMOLS				Positive impact
Poumanyong and Kaneko (2010)	99 countries	1975-2005	STIRPAT model				Positive impact
Luqman et al. (2023)	91 cities	2000-2018	Cluster analysis				Positive impact
Kayani et al. (2023)	top 10 polluted countries	2000-2019	FM-OLS				Positive impact

Martínez-Zarzoso and Maruotti (2011)	developing countries	1975-2003	STIRPAT model				Positive impact	
Khan et al. (2020)	newly industrialised countries	1980 - 2018	panel bootstrap Granger causality test				Positive impact	